Fundamental Chemistry

for **O Level**

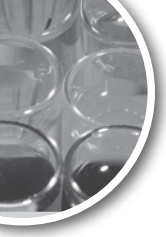
Teaching Guide

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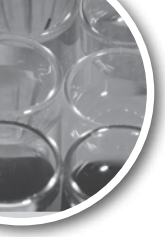
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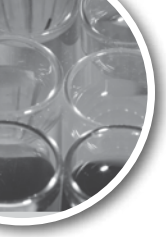
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Introduction to Fundamental Chemistry for O Level Teaching Guide

This Teaching Guide has been written for teachers preparing students for the O Level Chemistry exam and complements the material presented in the student's book, *Fundamental Chemistry for Cambridge O Level*.

This Guide contains a number of resources which will enable the teacher to deliver the course more easily and effectively:

Suggested demonstrations The demonstrations suggested in this Guide can be carried out by teachers before explaining a topic. These 20 demonstrations involve presenting material and conducting classroom activities to stimulate students' interest in a new topic. Clear instructions have been provided to guide teachers in conducting the demonstrations effectively.

Suggested investigations The investigations suggested in this Guide can be assigned to students after a certain topic has been discussed in class. These 15 investigations would help students to conduct research and design investigations independently outside the classroom to explore the topic covered in class. The instructions in the Guide offer sufficient flexibility to enable students to devise their own strategy without prescribing a particular method.

Suggested practical exercises This series of exercises provides guidance for practical work which might be used to support the content in the student's book. Each of the 25 exercises includes a list of materials and apparatus to be used, and step-by-step instructions on the collection of valid data. Materials and apparatus are chosen to be simple and readily available in most centres delivering this subject. Exercises are quantitative wherever possible, and each of them includes appropriate assessment opportunities.

Alternative-to-practical exercises Alternative-to-practical exercises have been included in this Guide to provide practice to students appearing for the ATP exam. Effort has been taken to develop a questioning strategy and style that would enable students to prepare themselves for the final examinations. These 10 exercises cover most of the important topics from the curriculum and can be administered to students at the end of the relevant topics from the student's book rather than towards the end of the course.

Worksheets The worksheets included in this Guide have been developed to facilitate the teacher in providing reinforcement material to students after a topic has been covered in class. All of the 25 worksheets may be assigned either to be completed in class or as homework.

Assessment sheets The 25 assessment sheets provided in this Guide can be used to test students' comprehension after a topic has been completed in class. The assessment questions have been designed to enable students to grasp the questioning style they are likely to come across in their examinations.

Identifying cations

This demonstration might be conducted in the classroom to support discussion on ion identification.

Aim

To demonstrate the properties of NH_4^+, Ca^{2+}, and Cu^{2+} ions

Equipment

- platinum wire
- test tubes
- test tube holders
- beaker
- china dish
- red litmus paper

Chemicals

- salt samples containing ammonium (NH_4^+), calcium (Ca^{2+}), and copper (Cu^{2+}) ions
- 10 cm^3 concentrated hydrochloric acid
- 20 cm^3 sodium hydroxide solution
- 20 cm^3 ammonia solution

Preparation

1 Prepare the salt samples.

2 Clean the tip of platinum wire by burning it in a flame before use.

3 The flame of the Bunsen burner should be non-luminous.

Method

1 Take the ammonium salt sample in a china dish and add some sodium hydroxide solution.

2 Heat the solution gently over a flame. A gas is given off.

3 Test the gas with litmus paper. The paper turns red.

4 Explain that this is evidence of the gas being ammonia and the salt containing ammonium ions.

5 Take the salt sample containing calcium ions in a china dish and add a few drops of concentrated hydrochloric acid.

6 Dip the end of the platinum wire in the paste and burn it over a non-luminous flame. A brick-red flame is observed. Explain that this is evidence of the salt containing Ca^{2+} ions.

7 Take some quantity of the salt containing calcium ions in a test tube and add some sodium hydroxide solution to it. A white precipitate is formed that is insoluble in excess sodium hydroxide solution. Explain that this is evidence of the salt containing Ca^{2+} ions.

8 Repeat steps 5 and 6 with the salt containing Cu^{2+} ions. A bluish-green flame is observed. Explain that this is evidence of the salt containing Cu^{2+} ions. Repeat step 7 with the salt containing Cu^{2+} ions. A pale blue gelatinous precipitate is formed that is insoluble in excess sodium hydroxide solution. This confirms that the salt contains Cu^{2+} ions.

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9 Take some quantity of the salt containing Cu^{2+} ions in a test tube and add some ammonia solution to it. A pale blue precipitate forms a deep blue solution in excess ammonia solution. Explain that this confirms Cu^{2+} ions in the salt.

Explanation

Cations, e.g. Na^{+}, Ca^{2+}, Cu^{2+}, Zn^{2+}, Fe^{2+}, etc are metallic radicals. Metallic salts produce metallic radicals when reacted with concentrated hydrochloric acid. These metallic radicals when reacted with sodium hydroxide solution a little at a time and then to excess, produce precipitates of peculiar colours as seen above.

Question for classroom discussion

1 Name some more metallic radicals and check the colour of the precipitate they form when reacted with sodium hydroxide and ammonia solution, respectively.

Identifying anions

This demonstration might be conducted in the classroom to support discussion on ion identification.

Aim

To demonstrate the properties of Cl^{-}, Br^{-} and I^{-} ions

Equipment

- test tubes
- beaker
- test tube holders
- delivery tube
- cork
- dropper

Chemicals

- Salt samples of sodium chloride, sodium bromide, and sodium iodide
- Reagents: nitric acid, freshly prepared silver nitrate solution, ammonia solution, manganese dioxide, and sulfuric acid

Method

1 Identify the three salt samples before the students.

2 Prepare solutions of the salts in distilled water and pour them into test tubes. (Remember to use a clean spatula before taking a sample each time.)

3 Add some MnO_2 and a few drops of sulfuric acid in the test tube containing sodium chloride solution. A colourless gas with a pungent smell is evolved. Explain that this is chlorine gas and Cl^{-} may be present.

4 Confirm this by adding 5 drops of silver nitrate solution to the salt solution. A white precipitate is formed that dissolves upon adding a few drops of ammonia solution.

5 Similarly, add some MnO_2 and a few drops of sulfuric acid in the test tube containing sodium bromide solution. A reddish-brown gas is evolved. Explain that this is bromine gas and Br^- may be present.

6 Confirm this by adding 5 drops of silver nitrate solution to the salt solution. A pale yellow precipitate is sparingly soluble upon adding a few drops of ammonia solution.

7 Add some MnO_2 and a few drops of sulfuric acid in the test tube containing sodium iodide solution. Purple vapours are given off. Explain that these are iodide vapours and I^- may be present.

8 Confirm this by adding 5 drops of silver nitrate solution to the salt solution. A yellow precipitate remains insoluble upon passing ammonia gas over it.

Results

- Chloride salts give off pungent and colourless chlorine gas when reacted with MnO_2 and sulfuric acid.
- Bromide salts give off reddish-brown bromine gas when reacted with MnO_2 and sulfuric acid.
- Iodide salts give off purple iodide vapours when reacted with MnO_2 and sulfuric acid.

Explanation

Halogens belong to Group 7 of the Periodic Table. They are reactive non-metals. Halides (ionic compounds of halogens, e.g. sodium chloride, potassium bromide, etc.) react with sulfuric acid in the presence of a catalyst resulting in coloured gases being evolved. These gases react with metals readily forming ions with a single charge (F^-, Cl^-, Br^-, and I^- respectively). They exist in gaseous form as diatomic molecules.

Halogens possess different physical properties but their chemical properties are similar. They react with silver nitrate solution to form halides (silver chloride, silver bromide, and silver iodide).

Sodium iodide forms a pale yellow precipitate which is sparingly soluble or insoluble in ammonia solution and hence can be identified.

Question for classroom discussion

1 How might knowledge of these properties be useful to a chemist?

Bond breaking and bond formation

This demonstration might be conducted in the classroom to support discussion on covalent bonding

Aim

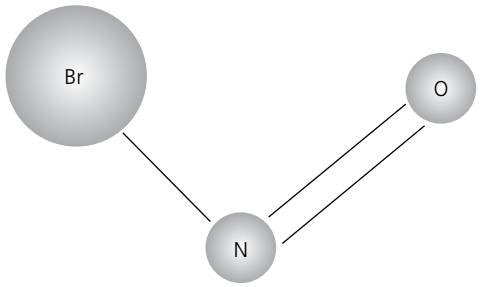
To demonstrate the chemical reaction between two molecules of bromine nitroxide (BrNO)

Equipment

- models of two BrNO molecules
- charts to show the chemical equation and energy profile diagram for the reaction

Preparation of collision model

1 Using beads of three different colours and sizes and copper wire make two models of BrNO molecules as shown below:



2 Refer to the Periodic Table where necessary. You could use wire of a different colour to represent the weaker covalent Br-N bond.

Method

1 Display the model and the chart explaining the reactants and the products.

2 Introduce the terms *collision*, *activation energy*, and *reversible reaction*.

3 Explain what happens when two molecules of BrNO collide:

(a) Molecules react upon colliding with one another.

$2BrNO\ (g) \longrightarrow 2NO\ (g) + Br_2\ (g)$

(b) The Br-N bond in the two reactant molecules must be broken to form a new Br-Br bond in the product. (Do this by snapping the wire representing the Br-N bond in the two models and joining the two bromine atoms together with another piece of wire.)

(c) State that the reaction is thus complete.

(d) Identify the two molecules of nitrous oxide (NO) and one molecule of bromine (Br-Br) formed as products.

Explanation

Point to the energy profile diagram and begin discussion on enthalpy changes during bond breaking and bond making. Explain that bond breaking is an endothermic reaction that requires energy whereas bond making is an exothermic process as it releases energy. The overall enthalpy change during a reaction depends on whether more energy is absorbed than released. Help students to interpret the energy profile diagram for the reaction in terms of enthalpy change.

Questions for classroom discussion

1 What happens when molecules of the reactant collide?

2 What does the hump on the energy profile diagram indicate?

3 Which has the lower energy level—the reactant side or the product side?

4 Although the above reaction is a reversible reaction, it is more favourable on the product side. Why?

Stoichiometric calculation for percentage composition

This demonstration might be conducted in the classroom to support discussion on stoichiometric calculation.

Aim

To calculate the percentage composition of sulfuric acid

Chemicals

- sulfuric acid

Background knowledge

- The percentage composition of a pure compound is always fixed.
- Knowing the formula of a substance, you can calculate the % composition by mass by the following formula:

  percentage of component element = A_r of the element / M_r of the compound × 100

Method

1 Explain the following solution by writing it on the board:

The formula of sulfuric acid is H_2SO_4.

M_r of sulfuric acid = 2 x 1+ 32 + (4 x 16) = 98

Constituent elements of H_2SO_4 are hydrogen, sulfur, and oxygen.

Percentage of component element = A_r of the element / M_r of the compound x 100

Therefore,

% of hydrogen = 2 / 98 x 100 = 2.04%

% of sulfur = 32 / 98 x 100 = 32.65%

% of oxygen = 64/98 x 100 = 65.31%

To verify, 2.04 + 32.65 + 65.31 = 100

Question for group discussion

1 Calculate the percentage composition of calcium carbonate $CaCO_3$.

Stoichiometric calculation for volume of a gas

This demonstration might be conducted in the classroom to support discussion on stoichiometric calculation.

Aim

- To demonstrate the concept of a mole
- To calculate the volume of gas evolved at room temperature and pressure for the following problem:

  50 g marble chips are dissolved in excess of hydrochloric acid. Calculate the amount of carbon dioxide gas evolved. Also calculate the number of molecules of CO_2 formed.

Equipment

- Woulf's bottle
- cork
- delivery tube
- thistle funnel
- gas jar

Chemicals

- marble chips
- hydrochloric acid

Background knowledge

- One mole is the amount of substance which contains Avogadro's number of particles (6.02×10^{23}).
- One mole of a pure substance is obtained by weighing out the relative atomic mass (A_r) or the relative molecular mass (M_r) of the substance in grams. So A_r and M_r differ in mass but contain the same number of atoms or molecules.
- The volume of 1 mole of gas at r.t.p. is 24 cm^3.

Method

1 Weigh 50 g marble chips and place them in a Woulf's bottle. Pour hydrochloric acid in the bottle through a thistle funnel and note the gas evolving through the delivery tube. You may collect the gas in a gas jar to test its properties.

2 Write an equation to show the reaction between calcium carbonate and hydrochloric acid and balance it so that mass of the reactants is equal to the mass of the products:

$CaCO_3\ (s) + 2HCl\ (aq) \longrightarrow CaCl_2\ (aq) + H_2O + CO_2\ (g)$

3 Explain that the students are not going to actually measure the volume of the gas produced, but calculate it using the concept of moles.

4 Calculate the molecular weight of the reactants and products taking part in the reaction:

Mass of one mole of $CaCO_3$ (M_r) = 40+12 + (3 x 16) = 100 g

Mass of one mole of CO_2 (M_r) = 12 + (2 x 16) = 44 g

5 Write the equation in terms of moles:

1 mole (100 g) of $CaCO_3$ produces 1 mole (44 g) of CO_2 gas.

So, 0.5 moles (50 g) of $CaCO_3$ produces 0.5 moles (22 g) of CO_2 gas.

6 Explain that the molar volume of carbon dioxide gas evolved according to the equation is 24.0 cm^3.

So, 0.5 moles of CO_2 gas at r.t.p. have a volume of 12 cm^3.

7 Calculate the number of carbon dioxide molecules as under:

No. of molecules in 0.5 moles of carbon dioxide produced = $6.02 \times 10^{23} \times 0.5$

Question for group discussion

1 Discuss the concept of moles and identify some practical applications.

Redox reactions

This demonstration might be conducted in the classroom to support discussion on electrolysis and redox reactions.

Aim

To demonstrate that electrolysis is an oxidation-reduction reaction

Equipment

- electrolytic cell
- molten lead bromide solution as electrolyte
- graphite rods as electrodes

Method

1 Set up the apparatus as shown on page 104 of the textbook.

2 Refresh students' memories by explaining the following:

- Electrolysis is the breaking down of a compound into its components by electricity.
- An electrolytic cell is composed of an electrolyte (solution of an ionic compound) and two electrodes (positive and negative) connected to the terminals of a battery.
- Usually inert carbon or graphite rods are used as the electrodes but other metallic rods may also be used depending upon the type of reaction.
- The electrodes attract oppositely charged ions whereby the redox reaction takes place.

3 Identify the power source, electrodes, and electrolyte (molten lead bromide solution).

4 Connect the anode to the positive end and cathode to the negative end of the battery. This completes the circuit and the current starts flowing.

5 Ask students to observe the following:

- Movement of ions in the form of tiny scintillations
- Lead collecting at the cathode and eventually dropping off
- Reddish-brown gas bubbling off at the anode

6 Write down the following equations on the board and provide explanations:

At anode:

$2Br^-(l) \longrightarrow Br_2(g) + 1e^-$ (Oxidation is loss of electrons.)

Explain that the bromide ion loses an electron at the anode and becomes neutral to form a bromine atom. Two atoms combine to form a molecule and reddish-brown bromine gas is liberated at the anode.

At cathode:

Pb^{2+} (*l*) + $2e^{-} \longrightarrow$ Pb (*l*) (Reduction is gain of electrons.)

Explain that the lead ions accept two electrons each at the cathode and become lead atoms to be deposited on the cathode which appears thicker after a while.

7 Conclude that electrolysis is a redox reaction.

Questions for group discussion

1 What do you understand by 'OILRIG'?

2 Two spoons need to be electroplated with silver and copper, respectively. Suggest an electrolyte and electrode for each.

3 Draw two diagrams of electrolytic cell arrangement to show:

(a) an object plated with silver

(b) an object to be plated with copper

Refining copper by electrolysis

This demonstration might be conducted in the classroom to support discussion on refining of copper by electrolysis.

Aim

To demonstrate the refining of copper by the electrolytic method

Equipment

- electrolytic cell
- copper sulfate as electrolyte

Method

1 Set up the electrolytic cell for obtaining pure copper from a copper anode. (It is advisable if some background knowledge of copper extraction is provided to students before this demonstration).

2 Identify the copper sulfate solution as the electrolyte, the strip made of impure copper as the anode, and the pure copper strip as the cathode.

3 Connect the two strips to the power source and help students to observe the changes taking place.

4 Write down the following equations on the board to illustrate the reactions taking place:

At anode

Cu - $2e^{-}$ $\longrightarrow$ Cu^{2+} (*aq*)

(Impure copper)

At cathode

Cu^{2+} + $2e^{-}$ $\longrightarrow$ Cu *(s)*

(pure copper)

5 Explain that the metallic copper ions lose two electrons each at the anode and dissolve in solution as copper ions. These copper ions are attracted to the cathode where they become deposited as copper by accepting two electrons.

6 Explain that the cathode becomes thicker with the passage of electricity whereas the anode gets thinner and is replaced when required.

Questions for classroom discussion

1 Can you electroplate an iron spoon with copper? How?

2 Discuss some uses of copper.

Enthalpy change in exothermic reactions

This demonstration might be conducted in the classroom to support discussion on enthalpy change in exothermic reactions.

Aim

To demonstrate the conversion of anhydrous copper sulfate to blue vitriol as a chemical reaction that involves the release of energy in the form of heat

Equipment

- copper sulfate (anhydrous)
- flask
- cork with two holes
- thistle funnel
- thermometer
- water

Method

1 Take two spatula of anhydrous copper sulfate powder in a dry flask.

2 Fit a two-holed cork in it.

3 Pass a clean thistle funnel through one hole and insert a thermometer through the other.

4 Note the initial temperature of the reactant and mark it as t_1°C in an observation table.

5 Add 50 cm^3 distilled water through the thistle funnel and wait for some time.

6 Note the change in colour and the rise in temperature of the solution. Mark it as t_2°C.

7 Calculate the difference between the two readings (t_2-t_1). This gives the rise in temperature.

Explanation

Heat is evolved during some chemical reactions, indicating a release of energy to the surroundings. The amount of heat evolved can be determined by measuring the heat content of the reactants and products.

Questions for classroom discussion

1 Ask students if they can say what type of reaction dissolution of copper sulfate is by looking at the difference in temperature.

2 Conversion of anhydrous copper sulfate to blue vitriol is a reversible process. Ask students to write the reversible reaction in the form of an equation and explain what type of reaction it is.

Burning of coal as an exothermic reaction

This demonstration might be conducted in the classroom to support discussion on enthalpy change in exothermic reactions.

Aim

To demonstrate the burning of coal as an exothermic reaction that involves the release of heat energy

Equipment

- coal
- sand bath
- thermometer
- tongs
- thermometer

Method

1 Prepare a sand bath and note the initial temperature of the sand bath and the piece of coal. Mark it as t_1°C.

2 Place a piece of burning coal on the sand for a few minutes.

3 Carbon dioxide gas is produced as the carbon reacts with oxygen in the atmosphere. Test for this gas by bringing a glowing splint near it. The gas does not support combustion.

4 Note the temperature of the sand. Mark it as t_2°C. Explain that the increase in temperature is because the sand has absorbed the heat produced by the exothermic reaction.

5 Calculate the difference between the two readings (t_2–t_1). This gives the rise in temperature.

Explanation

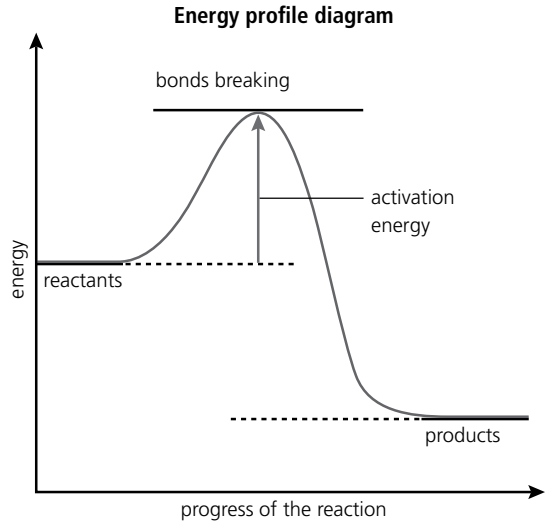
Heat is evolved during some chemical reactions indicating a release of energy to the surroundings. The amount of heat evolved can be determined by measuring the heat content of the reactants and products.

Fuels like coal and methane gas when burnt in excess of air produce large amounts of heat accompanied by production of carbon dioxide.

Enthalpy (energy) change (ΔH) = E_1–E_2

where E_1= energy in, E_2= energy out

It is interesting to note that exothermic reactions also need some heat to start.



Question for classroom discussion

1 Ask students if they can identify some exothermic reactions in their environment. Ask them to suggest how the heat produced by these reactions might be used productively.

Decomposition of carbonates, nitrates, and hydroxides as endothermic reactions

This demonstration might be conducted in the classroom to support discussion on enthalpy change in endothermic reactions.

Aim

To demonstrate the decomposition of carbonates, nitrates, and hydroxides as chemical reactions that involve the intake of energy in the form of heat

Equipment

- calcium carbonate
- lead nitrate
- copper hydroxide
- test tube
- Bunsen burner
- glowing splint
- thermometer
- spatula

Method

1 Place some calcium carbonate in a test tube and note its temperature.

2 Heat it gently over a Bunsen burner. The compound undergoes decomposition into calcium oxide.

3 Carbon dioxide gas is evolved which can be tested with a glowing splint. It does not support combustion and the splint fails to burn.

$CaCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$

4 Do the same test with lead nitrate and copper hydroxide. Write equations for both the reactions.

$2Pb(NO_3)_2\ (s) \longrightarrow 2PbO\ (s) + 4NO_2\ (g) + O_2\ (g)$

$Cu(OH)_2\ (s) \longrightarrow CuO_2\ (s) + H_2\ (g)$

Explanation

Compounds containing carbonates, nitrates, and hydroxides of metals possess larger molecules and breaking the chemical bonds between them requires a large amount of energy. This energy is provided by heating them. As a result, carbonates evolve carbon dioxide and nitrates give off oxides of nitrogen on decomposition. Most hydroxides are basic in nature and break into metallic positive ions and hydroxide (OH^-) ions.

Question for classroom discussion

1 Why is the energy content of the reactants in these reactions less than the energy content of the products?

Endothermic reaction between citric acid and baking soda

This demonstration might be conducted in the classroom to support discussion on enthalpy change in endothermic reactions.

Aim

To demonstrate the reaction between citric acid and baking soda as an endothermic reaction that involves the intake of energy in the form of heat

Equipment

- transparent plastic bag
- thermometer
- citric soda powder
- baking soda
- water
- stirrer

Method

1 Mix equal amounts of citric soda powder and baking soda in a transparent plastic bag and record the temperature of the mixture.

2 Add water to the mixture and stir it well. A chemical reaction takes place and the temperature goes down. Students can experience this by touching the plastic bag to feel it becoming cooler.

3 Use the thermometer to measure the temperature and record it.

4 Compare the change in temperature.

Explanation

The citric soda and baking soda participate in an endothermic reaction that requires energy to be provided before it can begin. This intake of energy from the surroundings is observed as a drop in temperature. Less energy is given out during the reaction than required to get it started, unlike an exothermic reaction that gives out energy greater during the reaction than the activation energy required to get the reaction to begin.

Question for classroom discussion

1 Why is the energy content of the reactants in these reactions less than the energy content of the products?

Redox reactions as oxygen/hydrogen gain/loss reactions

This demonstration might be conducted in the classroom to support discussion on redox reactions.

Aim

To demonstrate redox reactions as oxygen/hydrogen gain/loss reactions

Equipment

- tongs
- china dish
- test tubes
- test tube holder
- glowing splint
- burner

Chemicals

- magnesium ribbon
- sulfur powder
- copper oxide

Method

1 Hold a magnesium strip over a flame with a pair of tongs and ask students to observe a bright white flame and magnesium oxide being formed.

2 Write the following equation on the board:

$2Mg\,(s) + O_2\,(g) \longrightarrow 2MgO\,(s)$

3 Explain that oxidation has resulted in a gain of oxygen by magnesium to produce magnesium oxide.

4 Pass steam over the sulfur powder. It is reduced to hydrogen sulfide and oxygen gas is produced.

5 Test for the gas with a glowing splint.

6 Write the following equation on the board:

$2S\,(s) + 2H_2O\,(g) \longrightarrow 2H_2S\,(s) + O_2\,(g)$

7 Explain that reduction has resulted in a gain of hydrogen by sulfur and the release of oxygen gas.

8 Pass hydrogen gas over heated copper oxide. Water is produced as a result.

9 Write the following equation on the board:

$2CuO\,(s) + H_2\,(g) \longrightarrow 2Cu\,(s) + H_2O\,(g)$

10 Explain that copper(II) oxide has reduced to copper. Hydrogen acts as a reducing agent.

Warning

Make sure students are kept at a safe distance from where you are performing the demonstration. Magnesium burns violently!

Question for group discussion

1 Discuss how the term *redox* explains the type of reaction.

Making insoluble salt by precipitation

This demonstration might be conducted in the classroom to support discussion on salt preparation.

Aim

To prepare insoluble salts by precipitation

Equipment

- three beakers, 500 cm^3
- glass rod
- filter paper
- funnel
- china dish

Chemicals

- barium chloride
- magnesium sulfate

Method

1 Prepare a solution of barium chloride in distilled water.

2 Prepare a solution of magnesium sulfate in distilled water.

3 Mix the two solutions in a beaker. A chemical reaction takes place forming soluble magnesium chloride and white precipitate of barium sulfate.

$BaCl_2\,(aq) + MgSO_4\,(aq) \longrightarrow BaSO_4\,(s) + MgCl_2\,(aq)$

4 Place a folded piece of filter paper in the funnel and filter the mixture through it. Barium and sulfate ions get trapped in the filter paper.

5 Transfer the residue to a china dish and leave it to dry to obtain barium sulfate.

Explanation

All salts of sodium, potassium, and ammonia are soluble in water. All chlorides are also soluble excepting silver and lead chloride. Most metal sulfates are soluble excepting sulfates of calcium, barium, and lead. Of carbonates, only those of sodium, potassium, and ammonium are soluble.

All insoluble salts, e.g. barium sulfate, can be prepared and precipitated as long as the positive and negative ions of the salt are in the solution.

$Ba^{2+}\,(aq) + SO_4^{2-}\,(aq) \longrightarrow BaSO_4\,(s)$

Question for group discussion

1 Discuss uses of some insoluble coloured compounds as pigments.

Salt preparation by filtration and crystallization

This demonstration might be conducted in the classroom to support discussion on salt preparation.

Aim

To prepare crystals of copper sulfate by filtration and crystallization

Equipment

- beaker
- glass rod
- china dish
- filter funnel
- filter paper
- spatula

Chemicals

- copper(II) oxide
- dilute sulfuric acid
- distilled water

Method

1. Add some copper(II) oxide to 20 cm^3 dilute sulfuric acid and heat it. The oxide of copper dissolves.
2. Add more copper(II) oxide and heat. Continue until a saturated solution is obtained and excess of oxide is seen settling down at the bottom.
3. Take a filter paper and fold it three times to make a cup and place it inside the funnel.
4. Filter the copper sulfate solution by pouring it into the funnel. The copper sulfate solution comes out as filtrate while the excess of oxide remains in the filter paper.
5. Transfer the filtrate into a china dish and heat it to evaporate excess water. Leave it to cool.
6. Blue crystals of copper sulfate can be seen as the solution cools.
7. Alternatively, suspend a glass rod into the filtrate and leave it overnight. Blue copper sulfate crystals appear on the glass rod as the solution cools.

Explanation

Copper sulfate is prepared by the action of dilute sulfuric acid on copper(II) oxide.

$CuO\ (s) + H_2SO_4\ (aq) \longrightarrow CuSO_4\ (aq) + H_2O$

The penta hydrate copper sulfate (blue vitriol) loses four molecules of water of crystallization on heating at about 100°C and forms anhydrous copper sulfate salt at about 300°C. The reaction is reversible and anhydrous salt readily picks up water molecules from the atmosphere upon cooling.

$CuSO_4\ (aq) + 5H_2O \longrightarrow CuSO_4.5H_2O$ (crystals of copper sulfate salt)

This provides a convenient test to detect the presence of water of crystallization in blue vitriol.

Question for group activity

1. Sodium chloride can be prepared by the action of hydrochloric acid on sodium hydroxide. Suggest a simple method to prepare the salt crystals and write an equation for the reaction.

Displacement reactions for non-metals

This demonstration might be conducted in the classroom to support discussion on displacement reactions of Group VII elements.

Aim

To demonstrate the properties of Group VII elements in displacement reactions with solutions of other halide ions

Equipment

- test tubes
- test tube holders
- cork
- delivery tube
- gas jar

Chemicals

- potassium bromide
- chlorine gas

Method

1 Take 10 cm^3 potassium bromide solution in a large test tube and allow freshly prepared chlorine gas to pass through it.

2 Note the change in colour of the solution and any precipitate formed.

3 Explain that chlorine atoms are reduced to form negative chloride ions by accepting one electron each whereas bromine ions are oxidized to form neutral bromine atoms. Two bromine atoms combine to form a bromine molecule and hence liquid bromine is obtained.

4 Write the following equations on the board to illustrate the chemical reactions:

$Cl_2\,(g) + 2KBr\,(aq) \longrightarrow 2KCl\,(aq) + Br_2\,(l)$

$Cl_2\,(g) + 2e^- \longrightarrow 2Cl^-\,(aq)$

$2Br^-\,(aq) \longrightarrow Br_2\,(l)$

Warning

Make sure students are kept at a safe distance from where you are performing the demonstration. Chlorine is a poisonous gas!

Questions for group discussion

1 Write the overall equation to show the redox reaction.

2 Define oxidation number.

3 Name some oxidizing and reducing agents? Explain their working in terms of electron transfer.

The reactivity series of metals

This demonstration might be conducted in the classroom to support discussion on the reactivity series of metals.

Aim

To demonstrate the order of reactivity of magnesium, iron, zinc, and copper

Equipment

- four large test tubes with test tube holders
- measuring cylinder, 25cm^3
- spatula
- thermometer

Chemicals

- powdered magnesium
- iron filings
- hydrochloric acid (reagent)
- copper turnings
- powdered zinc

Preparation

Prepare an observation table as under:

Metal used	Rise in temperature / °C	Precipitate formed	Change in colour of solution	Nature of gas evolved
Magnesium				
Iron				
Zinc				
Copper				

Method

1 Pour 10 cm^3 hydrochloric acid in a test tube and measure its temperature. Mark it as t_1°C.

2 Add some powdered magnesium into the test tube. A vigorous reaction takes place and a gas is given off.

3 Quickly note down the highest temperature reached as t_2°C.

4 Calculate the difference (t_2–t_1) as the rise in temperature.

5 Also observe and record any precipitate formation, colour change, etc.

6 Explain that magnesium reacts vigorously with dilute hydrochloric acid to evolve hydrogen gas and produce magnesium chloride which is soluble in aqueous solution.

$Mg\ (s) + HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g)$

7 Repeat steps 1 and 2 with iron filings, powdered zinc, and copper turnings in separate test tubes and note the changes in temperature.

8 Observe other changes such as gas or precipitate formation, colour change, etc.

9 Compare the change in temperature for the four samples.

10 Explain that magnesium reacts more readily with hydrochloric acid to form its respective chloride and produce hydrogen gas. Iron and zinc react slowly whereas copper is the least reactive.

Questions for group activity

1 Write balanced equations for the chemical reactions taken place between hydrochloric acid and the four metals.

2 Using the rise in temperature recorded, arrange the metals in the order of reactivity. Check if it matches with the standard reactivity series.

3 Suggest a method to verify the properties of the gas evolved in the above reactions.

Extraction of aluminium by electrolysis

This demonstration might be conducted in the classroom to support discussion on extraction of aluminium by electrolysis.

Aim

To demonstrate the extraction of aluminium by electrolytic reduction

Equipment

- model of an electrolytic cell including carbon anodes and electrodes
- photographs of aluminium ores, e.g. bauxite and cryolite

Method

1 Display the model of the electrolytic cell and help students to identify the carbon rods as anodes and the carbon lining of the tank as the cathode. Point out to the power source and the drain pipe used for drawing away molten aluminium.

2 Display the photographs of bauxite and cryolite. Explain that bauxite is found nearer to the surface in the Earth's crust and is easier to obtain. The ore is then taken to the factory where it is cleaned of most impurities and converted to white alumina (Al_2O_3).

3 Explain that the melting point of aluminium is 2045°C which is very expensive to reach. Hence, the ore is mixed with sodium fluoride or cryolite. The mixture of alumina and cryolite has a much lower melting point and hence the electrolysis can be performed at a cheaper rate.

4 Explain that on passing electric current, the electrolyte consisting of alumina and molten cryolite dissociates into Al^{3+} ions and O^{2-} ions. The cations are then reduced at the cathode whereas the anions are oxidized at the anode.

5 On the board, write down the following chemical reactions that takes place within the cell:

$2Al_2O_3 \longrightarrow 4Al^{3+}(l) + 3O^{2-}(l)$ (in solution)

At the cathode

The aluminium ions gain electrons.

$4Al^{3+}(l) + 12e^- \longrightarrow 4Al(l)$ (reduction)

At the anode

The oxygen ions lose electrons. The oxygen gas reacts with the carbon anode to produce carbon dioxide gas which bubbles off.

$6O^{2-}(l) \longrightarrow 3O_2(g) + 12e^-$ (oxidation)

$C(s) + O_2(g) \longrightarrow CO_2(g)$ (oxidation of carbon)

6 Explain that aluminium is very reactive but it reacts with oxygen in the air forming a thin film of aluminium oxide that prevents further reaction.

Question for classroom discussion

1 Why are aluminum products more commonly used for outdoor purposes than iron or copper products?

Formation of ethanol

This demonstration might be conducted in the classroom to support discussion on the formation of ethanol.

Aim

To demonstrate the formation of ethanol by the fermentation of glucose

Equipment

- conical flask
- delivery tube
- test tube
- cork

Chemicals

- glucose solution
- ethanol
- propanol (antifreeze)
- lacquer (solvent used in making perfumes)

Method

1 Write down the formulae of the first four members of the family of alcohols and display the products they are used in before the students:

Alkane series	**Formula**	**General uses**
Methyl alcohol	CH_3OH	solvent, methylated spirits
Ethanol	C_2H_5OH	solvent, fuel, alcoholic drinks
Propanol	C_3H_7OH	solvent, aerosol, antifreeze
Butanol	C_4H_9OH	lacquer, solvent, perfumes

2 Take some glucose solution in a conical flask and make it airtight using a cork.

3 Pass a delivery tube through the cork and allow the other end to enter a test tube containing water.

4 Add some yeast to the conical flask.

5 The reaction takes place at 18–20°C and bubbles of carbon dioxide gas can be seen appearing in the test tube with the formation of ethyl alcohol.

6 Write the following reaction on the board:

$$C_6H_{12}O_6\,(s) \xrightarrow{\text{(yeast)}} 2C_2H_5OH\,(aq) + 2CO_2\,(g) + \text{energy}$$

7 Explain that a functional group is that part of an organic molecule that largely dictates how the molecule will react. Saturated alkanes containing at least one hydroxyl group (–OH) are classified as alcohols. The general formula for the series is $C_nH_{2n+1}OH$.

8 Explain that yeast is a living cell and needs energy to survive and work as a catalyst. It works best at a mild temperature of 18–20°C and is denatured at high temperatures (above 20°C) after which the reaction stops. Ethanol is then separated from the solution by fractional distillation.

9 Identify the contents of the conical flask as ethanol or ethyl alcohol.

Questions for group discussion

1 Ethanol is also prepared by the hydration of ethene (C_2H_4). Write an equation to show the reaction.

2 Write an equation to show oxidation of ethanol. Could it be used as a car fuel?

3 Discuss major uses of alcohols.

Carboxylic acids

This demonstration might be conducted in the classroom to support discussion on carboxylic acids and the formation of ethanoic acid.

Aim

To introduce carboxylic acids and demonstrate the production of ethanoic acid by the oxidation of ethanol by acidified potassium dichromate(VI)

Equipment

- bottle of vinegar
- ethanol
- beakers
- potassium dichromate solution

Method

1 Explain that carboxylic acids are an important homologous series of organic compounds with the functional group $–CO_2H$.

2 Display the bottle of vinegar and explain that vinegar is mainly a solution of ethanoic acid (CH_3COOH).

3 Warm some ethanol with acidified potassium dichromate(VI) solution (oxidizing agent). Ethanoic acid is formed as a result of the reaction.

4 Explain that this is a common way of identifying drunk drivers.

5 Write and explain the following equation on the board:

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

Questions for group discussion

1 Discuss the properties of organic acids.

2 Write the names and formulae for the first four members of the homologous series of organic acids.

3 Benzoic acid is an organic compound with a typical ring structure. Its formula is C_6H_5COOH. Can you draw its structural formula?

Condensation polymerization

This demonstration might be conducted in the classroom to support discussion on making nylon and its uses.

Aim

To prepare nylon by condensation polymerization

Equipment

- two beakers, 25 cm^3
- tweezers
- glass rod

Chemicals

- Solution A: 1 g 1-6 diaminohexane dissolved in 10cm^3 sodium hydroxide
- Solution B: 1 cm^3 hexane 1-6 dioyl chloride dissolved in 10 cm^3 tetrachloromethane

Method

1 Pour solution B into a beaker.

2 Carefully pour solution A over solution B taking care to avoid mixing the two solutions.

3 Using a pair of tweezers, pull out the nylon film that forms on the interface of the two solutions.

4 Carefully pull this film upwards out of the beaker and wind it round the glass rod to form a 'nylon rope'.

5 Explain that nylon is manufactured from two monomers, i.e. 1-6 diaminohexane, which has two NH_3 groups on both ends of the molecule, and hexane 1-6 dioyl chloride having one (-COCl) group on each end.

6 Further explain that when the two monomers are allowed to interact, they join readily eliminating a water molecule and forming a polymer called nylon. The link between the two monomer molecules is called an amide linkage (–CO–NH).

7 Continue with step 4 to remove the nylon until the rope breaks.

Questions for group activity

1 Name some uses of nylon.

2 Ethane (C_2H_2), propene ($CH_2CH{=}CH_2$), and chloroethane ($CHCl{=}CH_2$) are three monomers. Write three equations to show each of them forming a polymer:

(a) polythene from ethane

(b) polypropene from propene

(c) polychloroethene from chloroethene

Investigating pure and impure substances

Matter can be classified as pure and impure substances. Elements and compounds are pure substances and are composed of only one type of atom (except isotopes) or molecule, respectively. Compounds cannot be separated into their components by physical methods. New compounds are formed after a chemical reaction. Mixtures are impure substances and can be separated into their constituents by physical methods.

Ask the students to design and carry out an activity to investigate various methods of separating pure and impure substances into their constituents.

Get your students started by thinking on the following:

- What are pure and impure substances?
- Name some physical methods used to check the purity of a substance.
- What is chromatography? How does it help to identify colours present in a solution?
- What method might be used to separate a solute from its solution?
- How would you separate iron filings from a mixture of sand and filings? Sugar from its solution?
- What happens to a substance when it undergoes a chemical change?

Help students to identify the equipment they might need:

- mixture of iron filings, sand, and salt
- sugar solution
- Bunsen burner, tripod, and gauze
- flask
- funnel
- clip
- copper sulfate solution
- fruit juice, ink
- beaker
- filter paper
- chromatography paper
- bar magnet

Help students to plan out their investigation by suggesting the following steps:

1 Students might separate the iron filings by running a bar magnet over the mixture, sand by filtering a suspension in water of the remaining mixture, and salt by evaporating the filtrate.

2 They might separate copper sulfate crystals from solution by crystallization.

3 They might separate the components of ink or fruit juice by placing a drop of each on chromatography paper and standing it in a beaker containing just enough water to enable water to run up the filter paper without damaging the stains.

Note:

Students should be able to select appropriate purification techniques for the mixtures or compounds they work on, e.g. evaporation for separating a solute from its solution, chromatography for separating pigments, filtration for separating a solid from a liquid, crystallization to remove a solute from its solution, etc. They should be able to explain the rationale behind selecting a particular technique and describe how the purification is carried out.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of pure and impure substances, and purification techniques
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded
- a conclusion about the effectiveness of various purification techniques
- how the students might have performed the investigation better

Investigating the relationship between molecular structure and melting point

The chemical properties of a substance are determined by its molecular structure. Melting point is one such property. The amount of energy required to overcome the intermolecular forces of attraction depends on how the molecules are arranged. The molecular structure of a substance, e.g. chocolate can change when it is first melted and then solidified.

Ask the students to design and carry out an activity to investigate the effect of molecular structure on the melting point of chocolate.

Get your students started by thinking on the following:

- What is the difference between crystalline and amorphous solids?
- What happens when a substance melts?
- Name some factors that affect the melting point of a substance such as chocolate.
- How would you investigate the effect of molecular structure on the melting point of chocolate?

Help students to identify the equipment they might need:

- two identical chocolate bars
- beaker
- Bunsen burner, tripod, and gauze
- test tubes
- thermometer

Help students to plan out their investigation by suggesting the following steps:

1 Students might place one chocolate bar at room temperature and place the other to melt in the sun. Once the bar has melted, they might place it in the refrigerator to solidify it.

2 They might break up the two bars into small pieces and place them in two separate test tubes.

3 The test tubes might be placed in a beaker of water and warmed over a Bunsen burner. A thermometer might be placed in each test tube and the time taken for the chocolate samples to start melting be recorded.

4 The procedure might be repeated for multiple samples.

Note:

The chocolate stored at room temperature will have a higher melting point than the chocolate that has been melted and then solidified. Students should be able to reason that the arrangement of molecules in the chocolate has changed upon meting and then solidifying, and as a result the melting point

has changed. They should conclude that any difference in the way molecules are held together in a substance causes a change in the amount of energy required to break that arrangement.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of molecular arrangement and melting point
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded
- a conclusion about the effect of molecular arrangement in solids and their melting point
- how the students might have performed the investigation better

Investigating the percentage composition of a common substance

The percentage of a substance in a compound can be determined by the following formula:

% of substance = mass of substance (g) / mass of compound (g) x 100

Ask the students to design and carry out an activity to investigate the percentage of water by mass in popcorn kernel.

Get your students started by thinking on the following:

- What makes popcorn kernels go 'pop'?
- What formula would you use to calculate the percentage of water in popcorn?

Help students to identify the equipment they might need:

- microwave oven or burner
- popcorn kernels
- balance

Help students to plan out their investigation by suggesting the following steps:

1 Students might determine the mass of a sample of popcorn kernels using a balance.
2 They might then warm the kernels in an oven or over a burner to make popcorn.
3 The mass of the water in the kernels might be calculated by the following formula:
mass of water / g = mass of kernels / g – mass of popped corn / g
4 They might calculate the composition of water by mass in popcorn by the following formula:
% of water in popcorn = mass of water (g) / mass of popcorn kernels (g) x 100

Note:

Students should be able to determine the mass of the kernels and popped corn by using a balance effectively. They should apply the formulae for calculating the mass of water and the percentage of

water by mass in the popcorn. They should be prepared to carry out more complex experiments for determine percentage composition of elements in more complex compounds.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of the methods used to determine percentage composition
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded
- a conclusion about the percentage of water by mass in popcorn
- how the students might have performed the investigation better

Investigating substances for electrical conductivity

Substances that allow electric current to pass through are called conductors. Metals are usually conductors because they possess free electrons in their structure that carry charge through the substance. Solutions of ionic compounds also act as conductors and are called electrolytes. Insulators do not possess free electrons and do not allow electric current to flow as a result.

Ask the students to design and carry out an activity to investigate various substances for electrical conductivity.

Get your students started by thinking on the following:

- Name some materials that allow electricity to pass through and some that do not.
- Think of some other properties that these materials share.
- How would you test whether a material is a conductor or an insulator?

Help students to identify the equipment they might need:

- an assortment of substances to be investigated, e.g. aluminium, sodium chloride crystals, sodium chloride solution, copper sulfate (in solution and as crystals), wax, sugar solution, tap water, ethanol, citric acid solution, etc.
- bulb
- copper sulfate solution
- beaker
- connecting wires
- power source
- ammeter
- electrodes

Help students to plan out their investigation by suggesting the following steps:

1 Students might set up a simple electrical circuit by connecting the bulb and ammeter to the power source, leaving a gap where the substances to be investigated might be inserted one by one.

2 Students might insert the solid substances in the gap to complete the circuit and observe if the bulb lights up and the ammeter shows a reading, thus indicating that the substance is a conductor.

3 To investigate liquids two electrodes connected to an ammeter and the power source might be dipped into each liquid and the effect on the bulb and ammeter noted. Care must be taken to wipe the electrodes well before testing a new liquid.

Note:

Students should be able to identify the various solid and liquid substances as conductors or insulators, and as good or bad electrolytes. They should be able to draw similarities between the good conductors/ electrolytes, for instance, most are metals or solutions of ionic compounds, etc.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of conductors, insulators, and electrolytes
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in the form of a table
- a conclusion about the properties of good and bad conductors
- how the students might have performed the investigation better

Investigating the effect of a change in the concentration of reactants on the rate of a chemical reaction

When metals, e.g. magnesium, react with dilute hydrochloric acid, the reaction is accompanied by effervescence liberating hydrogen gas. The effervescence becomes less vigorous with the passage of time.

$Mg\,(s) + HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g)$

The rate of the reaction can be increased by increasing the concentration of the magnesium or hydrochloric acid.

Ask the students to design and carry out an activity to investigate the effect of changing the concentration of one of the reactants, i.e. hydrochloric acid or magnesium, on the rate of the reaction.

Get your students started by thinking on the following:

- What would be the reactants for the reaction? What would be the products?
- How would you change the concentration of the hydrochloric acid available?
- How would you measure the rate of the reaction?

Help students to identify the equipment they might need:

- magnesium ribbon
- distilled water
- measuring cylinder
- scissors
- concentrated hydrochloric acid
- test tubes and holder
- ruler
- stopwatch

Help students to plan out their investigation by suggesting the following steps:

1 Students might cut out different lengths of the magnesium ribbon and react them with the same volume and concentration of hydrochloric acid.

2 They might calculate the variation in the rate of reaction by using the formula:

rate of reaction = length of ribbon (cm) / time for effervescence (s)

3 Students might then vary the concentration of hydrochloric acid by adding distilled water and carry out the reaction with the same length of magnesium ribbon.

4 They might calculate the rate of reaction at the different concentration levels using the formula in step 2.

5 Students might plot graphs to illustrate graphically the effect of increasing or decreasing the concentration of a reactant on the rate of the reaction.

Note:

Students should be able to carry out the reaction by varying the concentration of a reactant at least five times and plot the results on a graph. They should conclude that increasing the concentration of one reactant while keeping the concentration of the other unchanged results in an increase in the rate of reaction as the product is formed more rapidly.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of the variables affecting the rate of a chemical reaction
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in the form of a table and a graph
- a conclusion about the relationship between the concentration of a reactant and the rate of reaction
- how the students might have performed the investigation better

Investigating the pH values of various substances

Acidic substances give hydrogen ions in solution. Stronger acids display this property to a greater extent than weak acids. On the other hand, basic substances give off hydroxyl ions in solution, with stronger bases displaying this property to a greater extent. The strength of acids and bases can be compared with the values on a pH scale and using the colour change brought about by Universal Indicator solution.

Ask the students to design and carry out an activity to investigate the pH values of various substances.

Get your students started by thinking on the following:

- What are acids? Bases?
- What is a Universal Indicator? How does it help to determine the strength of acids and bases?
- What is a pH scale? How are values arranged on such a scale?

Help students to identify the equipment they might need:

- an assortment of various substances to be investigated for pH, including vinegar, lemon juice, tap water, bicarbonate of soda, toothpaste, liquid detergent, milk of magnesia, ammonia solution, etc.
- Universal Indicator solution
- spatula
- pipette
- pH chart
- test tube
- distilled water

Help students to plan out their investigation by suggesting the following steps:

1 Students might take small samples of the substance to be tested in a test tube.

2 They might add some distilled water to the test tube to dissolve the substance.

3 Students might add a few drops of Universal Indicator solution in the test tube and note the colour change.

4 Students might add a few drops of Universal Indicator solution in the test tube and compare the colour change observed with the pH chart.

Note:

Students should be able to assign an approximate pH range for the substances based on the colour change observed. Substances with pH values of 0 to 6.5 or colour changes to red, orange, or yellow will be termed acidic while those with pH values above 7 or colour changes to green, blue, or purple will be basic.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of acids and bases along with the use of Universal Indicator solution and the pH scale
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in a table
- a conclusion about the properties of acidic and basic substances
- how the students might have performed the investigation better

Investigating natural indicators

An indicator is usually a weak organic acid or base that dissociates into ions in water. The colour of the indicator depends on the extent to which the ions dissociate and the molecules present. Indicators can also be prepared from naturally occurring substances.

Ask the students to design and carry out an activity to investigate indicators prepared from naturally occurring substances.

Get your students started by thinking on the following:

- What is an indicator?
- How does an indicator help to identify a substance as acid or base?
- How might an indicator be prepared from naturally occurring substances?

Help students to identify the equipment they might need:

- mortar and pestle
- various acidic and basic substances
- brightly coloured natural substances to be used as indicators, e.g. hibiscus, beetroot, turmeric, etc.
- ethanol

Help students to plan out their investigation by suggesting the following steps:

1 Students might grind each of the natural substances in a little ethanol with a mortar and pestle to prepare their natural indicators.

2 They might filter out the different indicators separately and experiment upon them with various known acid and base samples.

3 All the colour changes observed might be recorded for future reference.

Note:

Students should be able to prepare sufficient samples of the natural indicators. Care must be taken to clean the mortar and pestle properly before grinding a new substance. The change in colour can be verified by repeated tests and a colour chart prepared.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of indicators
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in a table and chart
- a conclusion about the effectiveness and reliability of natural indicators
- how the students might have performed the investigation better

Investigating the industrial production of ammonia by the Haber process

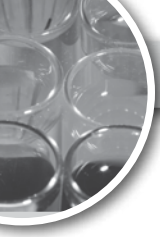
Liquid ammonia is prepared in industry by fractional distillation of air. Nitrogen and hydrogen gases are taken in the ratio of 1:3 by volume. The chemical reaction between the two gases is shown below:

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$ +heat

It is a reversible reaction and produces a large amount of heat.

The mixture of the two gases is passed over a bed of catalyst at 500°C and 250 atm pressure. The ammonia thus obtained is liquefied by cooling. Only 10% yield is obtained by this process. However, since ammonia gas is highly soluble in water, it is recycled repeatedly to increase the final yield.

Ask the students to design and carry out an activity to investigate the production of ammonia in industry and prepare a model of the Haber process.



INVESTIGATIONS

Get your students started by thinking on the following:

- What is the ratio of the two gases needed for the reaction? Why is this ratio suitable?
- How is ammonia gas prepared in the laboratory?
- Air is a mixture of a number of gases. Does nitrogen gas combine with other gases at r.t.p. If not, why?
- What is meant by fractional distillation of air?
- What is the best catalyst used during the Haber process.

Help students to identify the equipment they might need:

- cardboard or other material to make a model of the Haber process
- knowledge about the production of ammonia gas by the Haber process

Help students to plan out their investigation by suggesting the following steps:

1 Students might identify the most suitable raw materials and catalyst used in the Haber process.

2 They might draw up a diagram before developing appropriate models to identify the stages of the Haber process.

3 They might use labels to identify the temperature and pressure levels maintained at various stages.

4 They might rehearse demonstrating and explaining their model before their friends prior to presenting it before the class.

Note:

Students should be able to construct a model that clearly illustrates the raw materials used, temperature and pressure ranges, and products obtained at each stage. They should explain where the reverse reaction takes place in the process. They should also explain the rationale behind using the specific temperature and pressure levels throughout the process and describe the release of heat energy during the process.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of fractional distillation of air and the Haber process, including chemical equations
- how the model was designed
- a conclusion about the effectiveness of the model
- how the students might have performed the investigation better

Investigating trends in the Periodic Table

The modern Periodic Law states that the properties of the elements are a periodic function of their atomic number.

In the Periodic Table, elements are arranged in the order of increasing proton number. The vertical columns called groups are numbered from 1 to 7. The horizontal rows called periods are also numbered from 1 to 7. Between Groups 2 and 3 is a collection of elements that show similar behavior. They are mostly metals in which bonds between the atoms are very strong. They possess high melting points and show variable valency. Rare earth elements and artificial elements classified as Lanthanides and Actinides lie in Period VI.

Ask the students to design and carry out an activity to investigate trends in the Periodic Table.

Get your students started by thinking on the following:

- What are atoms composed of?
- What is proton number? Nucleon number?
- What does the electronic configuration atom show?
- What are valence electrons?
- Why noble gases like helium, argon, and neon are called inert gases?

Help students to identify the equipment they might need:

- copy of the Periodic Table

Help students to plan out their investigation by suggesting the following steps:

1 Students might study how atomic number and mass number change down groups and across periods.

2 They might then study the trend of valence electrons, especially in Periods 1 and 2.

3 Next, they might study the electronic configuration of the first four elements of a group.

4 They might identify the positions of metals and non-metals in the Periodic Table.

5 Students might explore trends in the Group VII and Group VIII elements.

6 They might note down the interesting features about transition elements.

Note:

Students should be able to locate an element on the Periodic Table and state its atomic number and atomic mass. They should also be able to identify and describe major trends in the Periodic Table, e.g. increase in atomic number towards the right across a period, the same number of valence electrons down a period, a change from metal towards non-metals across a period, and so on.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a description of the Periodic Table and major trends in the groups and periods
- how the students might have performed the investigation better

Investigating the extraction of iron

The blast furnace is a 30-metre tall chimney-like structure which is used to extract iron from its ore. The charge is a mixture of haematite ore, calcium carbonate, and coke, which is loaded from the top. Various reactions take place at different temperatures to yield useful by-products. The furnace is provided with several outlets that allow the molten iron, slag, and waste (hot gases) to come out separately.

Ask the students to design and carry out an activity to investigate the extraction of iron and prepare a model of the blast furnace.

Get your students started by thinking on the following:

- How is iron obtained from its ore?
- What raw materials are used in the process? What are the products?
- What stages are included in the process?
- Is it possible to recycle the blast of hot gases coming out from the blast furnace? Is it cost effective?
- What environmental conditions need to be created in the blast furnace?

Help students to identify the equipment they might need:

- cardboard or other material to make a model of the blast furnace
- knowledge about the iron extraction process

Help students to plan out their investigation by suggesting the following steps:

1 Students might identify the most suitable ore used in the extraction of iron.
2 They should develop appropriate models to identify the stages through which the ore passes and the by-products obtained.
3 They might use labels to identify the ranges of temperatures at the top, middle, and bottom of the furnace.
4 They might rehearse demonstrating and explaining their model before their friends prior to presenting it before to the class.

Note:

Students should be able to construct a model that clearly illustrates the raw materials used, temperature range, and products obtained at each stage. They should use appropriate materials to represent the raw materials and products of the reaction. The model should be clearly labelled and attractive.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of the iron extraction process
- how the model was designed
- a conclusion about the effectiveness of the model
- how the students might have performed the investigation better

Investigating fertilizers as a source of water pollution

Water is a universal solvent and dissolves many substances. Fertilizers are also absorbed by plant roots once they have been dissolved in soil water. However, this property of water also becomes a source of pollution because fertilizers absorbed easily into soil water can be leached into nearby water bodies causing eutrophication. The solubility of a substance in water also increases with temperature.

Ask the students to design and carry out an activity to investigate the solubility of fertilizers in water.

Get your students started by thinking on the following:

- What is a fertilizer and how does it make nutrients available to the plant?
- Name some common fertilizers available.
- What factors affect the solubility of fertilizer in water?
- How can fertilizers become a source of water pollution?

Help students to identify the equipment they might need:

- samples of commonly available fertilizers, e.g. ammonium nitrate, potassium sulfate, etc.
- beaker
- measuring cylinder
- thermometer
- Bunsen burner, tripod, and gauze
- spatula
- water
- stand, boss, and clamp
- stirrer
- balance

Help students to plan out their investigation by suggesting the following steps:

1 Students might take out equal volumes of water in two beakers and put in equal masses of the same fertilizer in them, stirring with a glass rod to dissolve the fertilizer.

2 They might continue to do so until no more fertilizer dissolves and begins to settle at the bottom of the beaker.

3 The water in one of the beaker might be heated with a Bunsen burner and more fertilizer added to dissolve it.

4 Students might also investigate dissolving other substances in water in the same manner to compare whether fertilizers dissolve more readily in water compared to other substances.

Note:

Students should be able to determine that fertilizers are absorbed readily in water compared with other substances. This makes it easier for plants to obtain the nutrients present in fertilizers by absorbing them in solution from the soil. They should be able to describe environmental problems that this might cause and discuss ways of dealing with them.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of fertilizers, their chemical composition, and the chemical properties

- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in a table
- a conclusion about the solubility of fertilizers in water and its implications
- how the students might have performed the investigation better

Investigating commonly used oils and fats for saturation

Fats and oils are macromolecules that are manufactured by plants when fatty acids and glycerol are combined:

$3(RCOOH) + (HOCH_2\text{-}HOCH\text{-}HOCH_2) \longrightarrow RCOOCH_2\text{-}RCOOCH\text{-}RCOOCH_2$

fatty acid glycerol 1 macromolecule of fat

This is a condensation reaction with the elimination of a water molecule. The macromolecules of oils have more than one C=C bond. As a result, they are found in liquid form. The oils are hydrogenated to form fats.

To test whether they are saturated, different fats and oils can be dissolved in a solvent and then tested with bromine water. The decolourization of bromine water is evidence of the fat or oil being unsaturated.

Ask the students to design and carry out an activity to investigate commonly used oils and fats for saturation.

Get your students started by thinking on the following:

- Name some common fats and oils used in everyday life.
- What is a suitable solvent for oils and fats? Is it available in the laboratory?
- What are the safety measures to be considered?
- How does bromine water help to confirm whether a fat is unsaturated?

Help students to identify the equipment they might need:

- cooking oil
- butter
- test tubes
- lard
- bromine water
- stoppers
- margarine
- 1.1.1 trichloroethane
- test tube holders

Help students to plan out their investigation by suggesting the following steps:

1 Students might select various types of oils and fats from around the house to investigate for saturation.

2 They might select 1.1.1 trichloroethane as a suitable solvent for dissolving the oils and fats.

3 They might take out the dissolved fats and oils in separate test tubes and test them by adding bromine water and observing the change of colour. The colour of the bromine water remains unchanged in solutions of saturated fats but become colourless in solutions of unsaturated fats.

Note:

Students should be able to select appropriate types and quantities of oils and fats for investigating. They should be able to prepare solutions using 1.1.1 trichloroethane and shaking properly. They should be able to determine which type of oils and fats, i.e. animal or vegetable are saturated or unsaturated in general.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of saturated and unsaturated fats and oils
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in a table
- a conclusion about the difference between various types of fats and oils with regard to saturation
- how the students might have performed the investigation better

Investigating how addition polymerization works

Alkenes are unsaturated hydrocarbons. They contain at least one double bond and hence undergo addition reaction. Simple molecules like hydrogen, hydrogen chloride, and bromine water can be added to them.

Examples of alkenes are ethene, propene, butene, and so on. Structurally they are written as follows:

$H_2C=CH_2$	ethene
$H_2C=CH–CH_3$	propene
$H_2C=CH–CH_2–CH_3$	butene
$H_2C=CH–CH_2–CH_2–CH_3$	pentene
$H_2C=CH–CH_2–CH_2–CH_2–CH_3$	hexene

Ask the students to design and carry out an activity to investigate addition polymerization in alkenes.

Get your students started by thinking on the following:

- What are alkenes? How are they structurally different from alkanes?
- What is addition polymerization? Why do alkenes undergo addition polymerization whereas alkanes do not?
- Which alkene might be suitable for investigating for addition polymerization?
- How might you test whether a liquid is an alkane or an alkene?

Help students to identify the equipment they might need:

- liquid alkene, e.g. hexene
- liquid alkane, e.g. hexane
- bromine water
- test tubes
- dropper
- corks
- test tube holder

Help students to plan out their investigation by suggesting the following steps:

1 Students might select liquid hexane and hexane as the substances to be tested for addition polymerization.

2 They might take out equal quantities of hexane and hexene in separate test tubes.

3 Students might use a dropper to drop equal quantities of orange or brown bromine water into both the test tubes.

4 The bromine water remains unchanged in the test tube containing hexane but turns colourless in the test tube containing hexene as the hexene forms a new compound with the bromine atoms. This indicates that addition polymerization has taken place.

Note:

Students should be able to observe the colour change and interpret it as a result of addition polymerization taking place between the hexene molecule and bromine atoms.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of addition polymerization
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded, including chemical equations
- a conclusion about the mechanism and products of the reaction
- how the students might have performed the investigation better

Investigating the efficiency of hydrocarbons as fuels

Hydrocarbons can be oxidized to release large amounts of energy. This makes them useful as fuels. Most of the fossil fuels commonly used, e.g. oil, coal, and natural gas are hydrocarbons. More efficient fuels release greater amounts of energy upon combustion.

Ask the students to design and carry out an activity to investigate the efficiency of two hydrocarbon compounds as fuels.

Get your students started by thinking on the following:

- What are hydrocarbons? Why are they used as fuels?
- Name some hydrocarbon compounds commonly used around the house.
- Why are some fuels better than others? How might this be measured and compared?

Help students to identify the equipment they might need:

- ethanol
- spirit burner
- thermometer
- measuring cylinder, 100 cm^3
- nail polish remover (propanone)
- copper can
- stand, boss, and clamp
- balance

Help students to plan out their investigation by suggesting the following steps:

1 Students might measure out 100 cm^3 into the copper can and note the initial temperature.

2 They might then fill the spirit burner with ethanol and determine its mass using a balance.

3 They might then light the burner and heat the water in the copper can so that the temperature of the water rises by 40°C.

4 They might immediately note the mass of the burner after the temperature rise and calculate the difference in mass.

5 The water in the can might then be disposed of and the procedure repeated using nail polish remover instead of ethanol.

6 Students might then determine the mass of fuel burnt to bring about the same rise in temperature. This might be used to determine which fuel provides more heat energy per gram.

Note:

Students should be able to measure out exact and equal amounts of water and fuels. Care must also be taken when handling ethanol and nail polish remover because they are flammable. The findings should be tabulated clearly so that the possibility of error in calculations is minimized.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of energy release from the burning of fuels
- how the apparatus was set up (including diagrams)
- a log of the activities conducted and the observations recorded in the form of a table
- a conclusion about the relative effectiveness of ethanol and propanone as a fuel
- how the students might have performed the investigation better

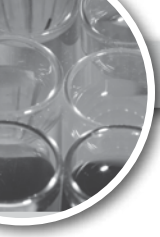
Investigating the formation of esters

When ethanoic acid is allowed to react with an acidified alcohol, e.g. propanol, a sweet smell of pears is produced. It indicates that a chemical reaction has taken place and a new compound known as ester (propyl ethanoate) has been formed.

Ask the students to design and carry out an activity to investigate ester formation.

Get your students started by thinking on the following:

- What is the formula of ethanoic acid?
- What is the functional group of organic acids?
- Propan-1-ol is an alcohol. Why?
- Can you acidify a solution using a few drops of sulfuric acid? How?
- What causes the sweet smell while painting your room and mixing dyes?
- Most organic compounds are flammable. What precautionary measures do you need to take while heating them?



Help students to identify the equipment they might need:

- carboxylic acid
- alcohol
- concentrated sulfuric acid
- Bunsen burner
- wire gauze
- beaker
- tongs
- test tube
- boiling chip
- watch glass
- thermometer
- flask
- pipettes
- balance
- safety goggles

Help students to plan out their investigation by suggesting the following steps:

1 Students must select exact quantities of the carboxylic acid and alcohol to produce an ester.

2 They must determine the right quantity of concentrated sulfuric acid to be added as a catalyst.

3 Students must use a water bath to heat the reactants while taking care to prevent alcohol fumes catching fire.

4 Students should observe the sweet smell being produced as the ester is formed.

Note:

It is very important that students take all precautionary measures while performing this activity. They should wear safety goggles at all times and handle the chemicals with care to avoid risk of fire.

Check the students' plans and suggest improvements.

Let the students carry out their investigations.

Ask the students to prepare a write-up on the following:

- the purpose of the investigation
- a brief description of ester formation from the reaction of carboxylic acids and alcohols with chemical equations
- how the apparatus was set up (including diagrams and safety precautions)
- a log of the activities conducted and the observations recorded
- a conclusion about the type of ester produced
- how the students might have performed the investigation better

Name:

Separating salt and sand

Aim

To separate a mixture of salt and obtaining both as separate solids

You need:

- a mixture of salt and sand
- distilled water
- 100 cm^3 beaker
- 50 cm^3 measuring cylinder
- 100 cm^3 two conical flasks
- filter funnel
- filter paper
- glass rod
- spatula
- evaporating basin
- Bunsen burner and heat-resistant mat
- tripod and gauze
- safety glasses

Introduction

Salt is soluble in water, but sand is insoluble. So you can dissolve the salt from a mixture of salt and sand, then filter the mixture to obtain the sand. You get the salt back by evaporating the water from the filtrate (the liquid from filtering). Salt dissolves faster in hot water than cold.

Preparation

1 Set the filter funnel into the conical flask.

2 Fold a piece of filter paper to fit inside the funnel.

Procedure

1 Put five spatula measures of the salt-and-sand mixture into the beaker. Add 50 cm^3 of distilled water.

2 Place the beaker on the tripod and gauze. Heat gently, while stirring with a glass rod.

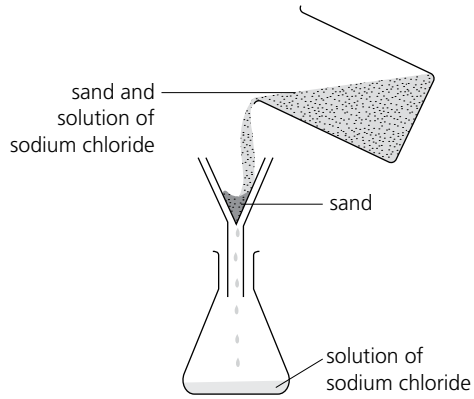
3 When the water is about to boil, turn off the Bunsen burner. Continue stirring for 1 minute. Then leave the beaker to cool.

4 When the beaker is cool enough to handle safely, filter the mixture, collecting the filtrate in a conical flask.

5 Remove the filter funnel, and place it in the other conical flask.

6 To obtain clean dry sand

- Rinse the sand with distilled water.
- Place the open filter paper and sand on a paper towel, and leave it to dry.



7 To obtain salt crystals

- Pour the filtrate into the evaporating basin and heat it until the water has evaporated. TAKE CARE: Turn the Bunsen burner down to avoid 'spitting'.
- Using a spatula, scrape the salt from the basin and place it on a piece of filter paper.

Observations

Describe the appearance of the mixture, and the two solids you obtained.

Questions

1 What is the chemical name for salt?

2 Salt often contains impurities such as magnesium sulfate. Will these be removed in the separation above? Explain your answer.

3 How will the melting point of impure salt compare with that of the compound you named in **1**?

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Name: .....

Purification of acetanilide by crystallization

Aim

To learn purification of a substance by crystallization

You need:

- 100 g acetanilide
- 200 cm^3 water
- acetone
- ethanol
- petroleum ether
- four test tubes, 100 cm^3
- Buchner funnel
- graduated conical flasks, 25 cm^3
- hot plate
- utility clamps
- pipette
- stoppers
- filter paper
- filter funnel
- microspatula
- sand bath

Introduction

When a solid is dissolved in a liquid it forms a solution. On heating the solution some of the solvent is evaporated. If the heated solution is allowed to cool, some of the dissolved solid forms pure crystals. This process of reappearance of the solid is called crystallization. Crystallization is used to purify substances especially when impurities in the substance are also soluble in solution. Pure silicon can be obtained from silica by crystallization for manufacturing microchips for the electronics industry.

Procedure

1 Arrange the apparatus as shown in the figure on the next page.

2 Take four 100 cm^3 test tubes and label them with solvents used: water, acetone, ethanol, and petroleum ether.

3 Put 100 g acetanilide in each test tube.

4 Use a microspatula to break any lumps present in the acetanilide sample.

5 Pour 5 cm^3 of labelled solvent in each test tube.

6 Thoroughly stir the contents of the test tubes with a glass rod.

7 Carefully observe each test tube and record if the acetanilide is soluble or insoluble at room temperature.

8 Separate the test tubes in which acetanilide remains undissolved.

9 Using a sand bath, heat the mixture to the boiling point while stirring the contents. Record the temperature at which acetanilide gets completely dissolved.

10 Allow the heated test tube containing the solvent to cool down slowly to room temperature.

11 Fill a 250 cm^3 beaker with equal amounts of water and ice for making an ice-bath.

12 Place the test tubes in the ice-bath for 5 minutes.

13 Observe the formation of crystals in the test tubes.

14 Record your observations and identify a suitable solvent for obtaining acetanilide crystals.

Extension work

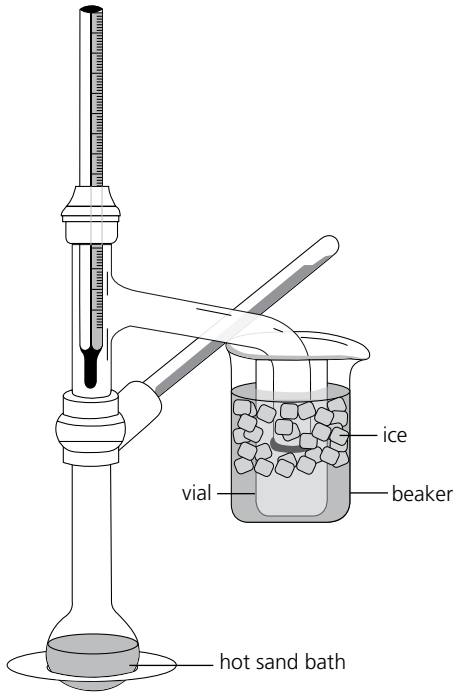
You can calculate the percentage recovery of the pure compound from the given formula:

% recovery = mass of crystallized compound obtained / mass of impure compound used x 100

Find the percentage recovery of pure acetanilide in each of the four test tubes.

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Name:



Questions

1 Explain why a Bunsen burner is not suitable for heating organic compounds like acetanilide.

2 You might have observed that crystallization does not occur completely in all samples. Write down three reasons that might cause improper crystallization.

3 Describe a method for securing maximum recovery of a pure product from an impure sample.

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Name:

Distilling cola

Aim

To separate the solvent from a solution, and identify the solvent.

You need:

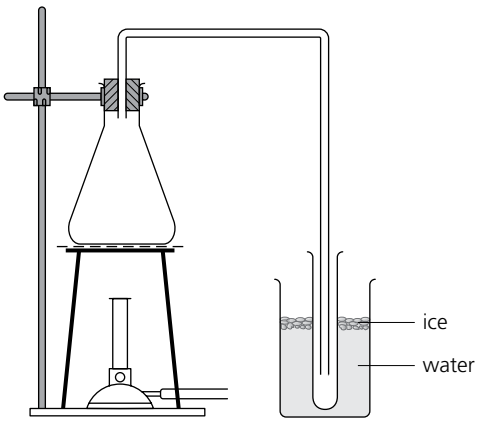
- cola
- ice
- anhydrous copper(II) sulfate, a white solid *(harmful)*
- beaker, 100 cm^3
- measuring cylinder, 25 cm^3
- conical flask, 100 cm^3
- spatula
- anti-bumping granules
- delivery tube with bung for flask
- retort stand, clamp, and boss
- Bunsen burner and heat-resistant mat
- tripod and gauze
- safety glasses
- test tube

Introduction

Cola is a solution. It contains a mixture of solutes, including carbon dioxide gas. The solvent can be separated from it by distillation and collected.

Preparation

Set up the apparatus as shown here:



Procedure

1 Remove the conical flask from the apparatus.

2 Pour 20 cm^3 of cola into the flask. Shake it to get rid of the bubbles of carbon dioxide.

3 Add 5 anti-bumping granules to the cola.

4 Reattach the conical flask to the apparatus.

5 Heat the conical flask gently.

6 Stop heating when the test tube is half-full of liquid.

7 Remove the test tube and add some anhydrous copper(II) sulfate to it using a spatula.

Observations

1 What do you observe in the flask and delivery tube during heating?

2 Describe the appearance of:

(a) the cola

(b) the liquid in the test tube

(c) the liquid left in the conical flask

3 What change do you observe when you add anhydrous copper(II) sulfate in step 7?

Questions

1 Where in the apparatus do these take place?

(a) evaporation

(b) condensation

2 Why is ice added to the beaker?

3 Explain the observation in 3 above.

4 If the liquid in the test tube is pure, what will its boiling point be?

5 Heating will drive off any remaining carbon dioxide from the cola. It cannot be collected using the apparatus on the left. Why not?

6

(a) What is the test for carbon dioxide?

(b) See if you can suggest a way to modify the apparatus so that the experiment includes a test for carbon dioxide.

7 See if you can name one other solute that the liquid in the flask might contain.

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Name:

Distillation of $KMnO_4$ solution

Aim

To separate water from a $KMnO_4$ solution by distillation

You need:

- potassium permanganate ($KMnO_4$) crystals
- flask, 100 cm^3
- Bunsen burner
- one-holed rubber stopper
- delivery tube
- test tube
- thermometer

Introduction

When a solid is dissolved in a liquid it forms a solution. The solute and solvent can be separated by a process called distillation. Upon heating a solution of potassium permanganate, water vapours are given off which can be changed to water upon condensation. Potassium permanganate crystals are left behind.

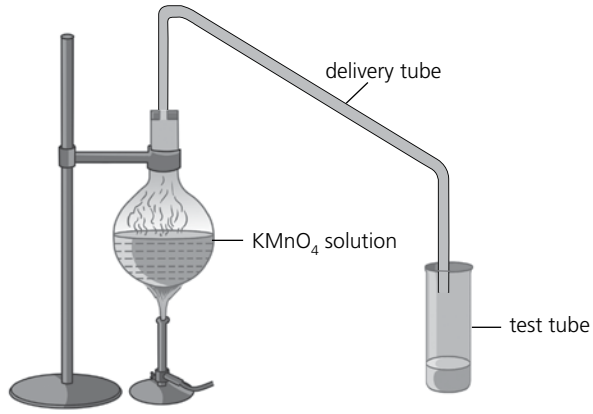
Procedure

1 Take out 30 cm^3 $KMnO_4$ solution in a flask.

2 By inserting the short end of the glass tubing in a one-holed rubber stopper, set a simple distillation apparatus as it is shown in the figure.

3 Heat the solution so that water vapours are carried through the delivery tube into the test tube.

4 Note down the difference between the colour of the distillate and the $KMnO_4$ solution.



Questions

1 What does the colour difference indicate?

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Name:

Separating the colours in ink

Aim

To separate the dyes in ink, using chromatography

You need:

- black ink
- 100 cm^3 beaker
- 25 cm^3 measuring cylinder
- capillary tube or dropper
- chromatography paper
- paper clip
- pencil and ruler
- safety glasses

Introduction

Black ink is a mixture of dyes of different colours. Chromatography can be used to separate the dyes.

Procedure

1 Using a ruler, draw a straight pencil line across the chromatography paper, about 2 cm from the bottom.

2 Drop two spots of ink on the pencil line, using a capillary tube or dropper. Let them dry. Then place another drop on one of the spots, and let it dry. (This is in case the dyes from the single drop do not show up clearly.)

3 Pour some water into the beaker. (Not enough to reach the ink spots—see the diagram below.)

4 Straighten a paper clip. Rest it across the top of the beaker. Then fold the top of the chromatography paper over. Hang the paper from the wire so that it dips into the water, as shown here.

5 The water moves up the paper. Remove the paper when the water is about 2 cm from the fold. Mark where it has reached, with a pencil line.

6 Let the paper dry. (You could wave it about to help it dry faster.) Then measure the distance between the two pencil lines.

7 Measure the distance each colour has travelled, from the lower pencil line to the centre of the colour. Record your results.

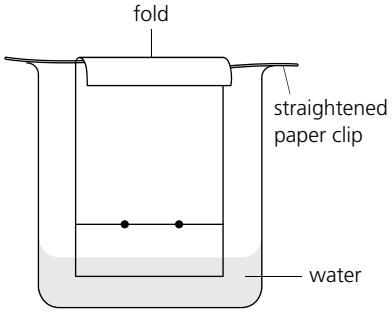
Analysis

1 How many different dyes does the ink appear to contain, and what colours are they?

2 Of the dyes that separate, which colour of dye:

(a) moves furthest up the paper?

(b) is the most soluble in water?



Extension questions

1 Choose one of the dyes. Calculate how far it would have travelled if the water had reached the fold in the paper. (You will need to make one further measurement.)

2 Scientists often work with very tiny samples of compounds. See if you can suggest a way to obtain tiny samples of the separate dyes from the chromatography paper.

Further work

Use chromatography to compare inks. (Put spots of them side by side on chromatography paper.) Do any appear to contain the same dyes?

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Name:

Testing for anions

Aim

To practice carrying out the tests for anions

You need:

- 1 M solutions of these five potassium salts: chloride, iodide, carbonate, sulfate, nitrate *(irritants)*
- 1 M dilute nitric acid *(corrosive)*
- 1 M dilute hydrochloric acid *(corrosive)*
- 1 M sodium hydroxide solution *(corrosive)*
- five test tubes and a test tube rack
- Bunsen burner and heat-resistant mat
- 0.05 M silver nitrate solution (*harmful*)
- 1 M barium nitrate solution (*harmful*)
- small piece of aluminium foil
- test tube holder
- graduated dropping pipettes
- limewater (*harmful*)
- red litmus paper
- boiling tube
- safety glasses

Introduction

Anions are negative ions. The carbonate ion is identified by the release of carbon dioxide. The other anions in the tests below are identified by precipitates that form.

IMPORTANT

Use a CLEAN dropping pipette for each different solution you use.

Preparation

Prepare a larger copy of this table in which to record your observations.

Solution	Compound in solution	Anion present (name and formula)	Test	Observation during test
1	potassium chloride		A	
2	potassium iodide		A	
3	potassium carbonate		B	
4	potassium sulfate		C	
5	potassium nitrate		D	

Test A: for the chloride and iodide ions

1 Take about 3 cm^3 of solution 1 in one test tube, and about 3 cm^3 of solution 2 in another.

2 To each, add a few drops of nitric acid, and about 1 cm^3 of silver nitrate solution.

3 Observe and record the colour of the precipitate.

Test B: for the carbonate ion

1 Take about 3 cm^3 of solution 3 in a test tube. Add about 3 cm^3 of dilute hydrochloric acid.

2 Using a dropper, collect some of the gas that is released, and bubble it through a test tube containing limewater.

Test C: for the sulfate ion

1 Take about 3 cm^3 of solution 4 in a test tube. Add a few drops of nitric acid and about 1 cm^3 of barium nitrate solution.

2 Observe and note the colour of the precipitate.

Test D: for the nitrate ion

1 Take about 3 cm^3 of solution 5 in a boiling tube.

2 Add about 3 cm^3 of sodium hydroxide solution, and one piece of aluminium foil.

3 Using a test tube holder, heat the boiling tube carefully until the solution starts to boil. (Make sure the tube is pointed away from you, and keep your safety glasses on.)

4 Test the gas that forms with red litmus paper.

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Name: .....

Testing for cations

Aim

To practice carrying out the tests for cations

You need:

- aqueous solutions (0.2 M) of these seven chlorides: aluminium, ammonium, calcium, copper(II), iron(II), iron(III), zinc *(irritants)*
- 2 M sodium hydroxide solution *(corrosive)*
- six test tubes and a test tube rack
- Bunsen burner and heat-resistant mat
- 2 M ammonia solution *(corrosive)*
- test tube holder
- graduated dropping pipettes
- red litmus paper
- boiling tube
- safety glasses

Introduction

Cations are positive ions. The metal cations in the tests below are identified by the precipitates they form when sodium hydroxide and ammonia solutions are added. The ammonium ion is identified by the release of ammonia gas.

IMPORTANT

Use a CLEAN dropping pipette for each different solution you use.

Preparation

1 Prepare a larger copy of this table in which to record your observations.

Solution	Compound in solution	Cation present (name and formula)	Observation on adding a solution of …	
			Sodium hydroxide	Ammonia
1	aluminium chloride			
2	calcium chloride			
3	copper(II) chloride			
4	iron(II) chloride			
5	iron(III) chloride			
6	zinc chloride			
7	ammonium chloride			

Test A: for the metal cations

1 Take about 3 cm^3 of solution 1 in a test tube.

2 Add a few drops of sodium hydroxide solution. Record the colour of the precipitate.

3 Continue to add sodium hydroxide until no further change occurs. If the precipitate redissolves in excess sodium hydroxide, record this observation.

4 Repeat steps 1–3 using ammonia solution in place of sodium hydroxide.

5 Repeat steps 1–4 for solutions 2–6, in turn.

Test B: for the ammonium ion

1 Take about 3 cm^3 of the ammonium chloride solution in the boiling tube. Add about 3 cm^3 of sodium hydroxide solution.

2 Using a test tube holder, heat the boiling tube carefully until the solution starts to boil. (Make sure the tube is pointed away from you and keep your safety glasses on.)

3 Test the gas that forms with red litmus paper.

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Name:

Changing the quantity of a reactant

Aim

To investigate how changing the amount of a reactant affects the volume of a gas produced

You need:

- 2M dilute hydrochloric acid *(corrosive)*
- 15 cm magnesium ribbon *(flammable)*
- sandpaper
- ruler
- scissors
- boiling tube
- two measuring cylinders, 10 cm^3 and 50 cm^3
- trough for water
- delivery tube and bung
- two retort stands, with clamps and bosses
- graph paper
- safety glasses

Introduction

In a reaction, the amount of product depends on the amounts of reactants used. If the product is a gas, its volume also depends on the amounts of reactants used. If it is an insoluble gas, you can collect it in a measuring cylinder over water, and measure its volume.

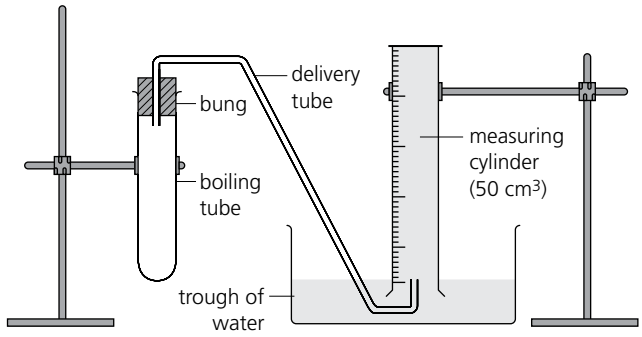
Preparation

1 Prepare a table of results, as started here. In the first column, fill in these values for the length of ribbon: 2.0, 2.5, 3.0, 3.5, and 4.0 cm.

2 Clean the magnesium ribbon with sandpaper. Then cut it into the five lengths given in **1**.

3 Set up the apparatus as on the right. Note that the measuring cylinder is full of water. The gas will bubble up into it, displacing water. (This is called downward displacement.)

Length of magnesium ribbon / cm	Volume of gas collected / cm^3
2.0	



Procedure

1 Carefully remove the bung, and pour 10 cm^3 of dilute hydrochloric acid into the boiling tube. (The hydrochloric acid will be in excess.)

2 Drop a piece of magnesium into the acid, and quickly replace the bung.

3 When the reaction is complete, measure the volume of gas collected, and record your results. Then empty the boiling tube.

4 Repeat steps 1–3 for the other four pieces of magnesium.

Analysis

1 Plot a graph of the gas volume produced against the length of magnesium ribbon used.

2 Write down any conclusions you can draw from your results.

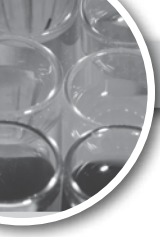
Questions

1 Write a balanced equation for the reaction that takes place in the boiling tube.

2 What test could you carry out to confirm the identity of the gas?

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PRACTICAL

Name:

The composition of magnesium oxide

Aim

To find the percentages of magnesium and oxygen in magnesium oxide (MgO)

You need:

- 20 cm magnesium ribbon *(flammable)*
- balance
- crucible with lid
- tongs
- sandpaper
- tripod
- pipe-clay triangle
- Bunsen burner
- heat-resistant mat

Introduction

When magnesium burns in air, there is only one product—magnesium oxide. The increase in mass from magnesium to its oxide tells you the mass of oxygen gained. From this you can work out the empirical formula of magnesium oxide. The empirical formula is the ratio in which magnesium and oxygen atoms have combined.

Preparation

1 Prepare a table for your results, like this one:

mass of empty crucible + lid	g
mass of crucible, lid + magnesium	g
mass of crucible, lid + magnesium oxide	g

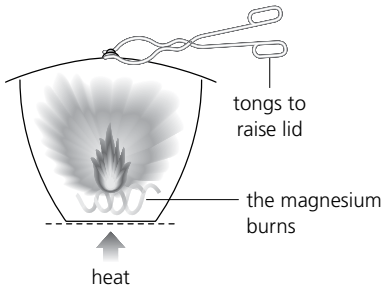
2 Clean the magnesium ribbon with sandpaper, and coil it tightly.

Procedure

1 Weigh the crucible and lid. Then add the magnesium, replace the lid, and weigh again. Record the masses in your table.

2 Place the crucible on the pipe-clay triangle on the tripod. Heat until the base of the crucible is red-hot.

3 Using the tongs, lift the lid very briefly to let air in. Try to prevent any smoke from escaping.



4 Repeat step 3 until all the magnesium has burnt to magnesium oxide.

5 Continue heating with the lid off for about a minute, to make sure all the magnesium has reacted. Then let the crucible cool.

6 Weigh the crucible, lid, and magnesium oxide. Record the result in your table.

Analysis

1 Find the mass of:
   (a) magnesium used
   (b) magnesium oxide formed
   (c) oxygen added

2 Using your answers for 1, calculate the % of magnesium and oxygen in magnesium oxide.

3 The *actual* % composition of magnesium oxide is 60% magnesium, 40% oxygen.
Comment on any differences between these values and the values you obtained in 2.

4 What is likely to be the main source of error in this experiment?

Questions

1 Using your answers for 1 above, calculate the number of moles of magnesium atoms and oxygen atoms that combined in your experiment. (A_r: Mg = 24, O = 16)

2 Now work out the ratio of magnesium atoms to oxygen atoms in the magnesium oxide you produced.

3 How does your answer for 2 compare with the *actual* ratio (1:1)?

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Name:

Electrolysis of water

Aim

To learn about decomposition of substances by electrolysis

You need:

- 500 cm^3 tap water
- 100 cm^3 hydrochloric acid (HCl)
- electrolytic cell containing carbon electrodes
- two test tubes
- two connecting wires with crocodile clips
- 6 V battery
- stand, boss, and clamp
- splints
- measuring cylinder, 10 cm^3

Introduction

When electric current is passed through an electrolyte, chemical decomposition takes place. This process is known as electrolysis. Electrolysis is applied widely in industry for extraction of metals from their ores, e.g. aluminium. Other applications include purification of metals like copper and gold.

Preparation

Pure water is a bad conductor of electricity. To make water an electrolyte dilute it with 20 cm^3 HCl.

Procedure

1 Arrange the apparatus as shown in the figure.

2 Clamp the electrolytic cell in the stand.

3 Fill the electrolytic cell with a dilute solution of water about half the height of the cell.

4 Fill the two test tubes up to the brim with the electrolyte.

5 Place a finger on top of one of the test tubes. Turn over the test tube and place it over an electrode. Repeat the same action with the other test tube.

6 Connect the electrolytic cell to the battery using connecting wires.

7 Lift up the test tubes while keeping them in the electrolyte water solution ensuring that the test tubes do not come into contact with the bottom of the cell, which will prevent the flow of current from the electrodes.

8 All electrolytes are ionic in nature, as they are composed of positively and negatively charged ions. On passing electric current through the electrolyte, the ions in the electrolyte travel towards oppositely charged electrodes. Since oxygen is a non-metal and forms negatively charged ions called anions it will move towards the positive cathode. The hydrogen ions are positively charged and therefore move towards the negative anode.

9 Continue the electrolysis until the test tube at the cathode is filled with the gas.

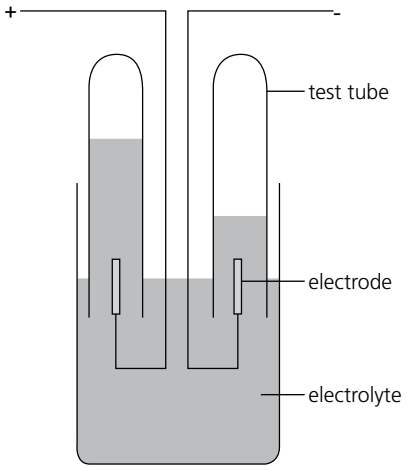
10 Test the gas collected at the cathode using a lighted splint. The glowing splint verifies that the gas collected is hydrogen.

11 Test the gas collected at the anode with the glowing splint. Verify if it is oxygen.

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Name:



Questions

1 Perform electrolysis with a solution of sodium chloride and find the nature of the gas collected at the anode and the cathode.

2 Increase the concentration of the electrolyte by adding more acid and find the effect of concentration on electrolysis and the nature of the gas produced.

3 Record your results in the following table:

Substance electrolyzed	Product at anode	Product at cathode
Water		
Sodium chloride		
Aqueous potassium iodide		
Concentrated HCl		

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Name:

Electrolysis of sodium chloride solution

Aim

To carry out electrolysis of concentrated sodium chloride solution and identify the gases produced

You need:

- a concentrated solution of sodium chloride
- electrolytic cell (carbon electrodes)
- 6V power supply
- two small test tubes to fit over the electrodes
- two wires with crocodile clips
- retort stand, clamp, and boss
- dropping pipette
- wooden splint
- safety glasses

Introduction

A solution of sodium chloride contains ions—so it will conduct electricity. But the electricity brings about decomposition. Gases are formed at the electrodes. you can collect the gases Using a special electrolytic cell. Then you can test them.

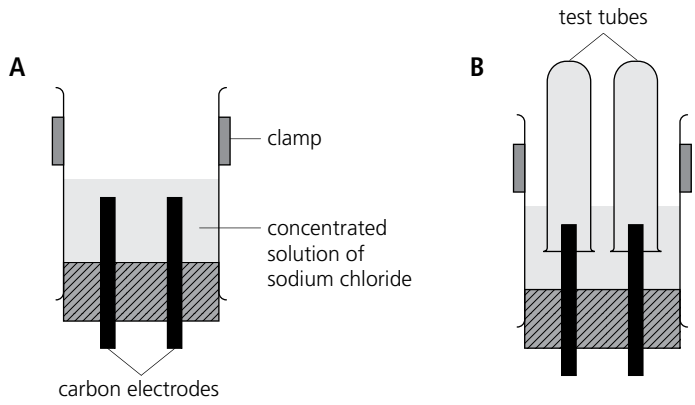
Preparation

1 Draw a large table with the headings shown here. Make it page-wide, and about 14 lines deep. (You will be carrying out three tests.)

Test	Observation	Conclusion

2 Clamp the electrolytic cell to the retort stand. Half-fill it with sodium chloride solution, as in **A**.

3 Now fill two small test tubes with the electrolyte (sodium chloride solution) and place them as in **B**. Do it like this:
- Fill one test tube using a dropping pipette.
- Seal it with your finger.
- Turn it over and place it over an electrode.
- Repeat for the second test tube.



Procedure

1 Connect the inert carbon electrodes to the power supply, using the wires and crocodile clips.

2 Raise the test tubes a little to let the current flow. Gas begins to collect in them.

3 Disconnect the power supply as soon as one test tube is full of gas.

4 Then carry out these tests. Record the tests and observations in your table.

(a) Place some universal indicator paper in the solution in the cell.

(b) Test the gas in the test tube from the cathode (–) with a lighted splint.

(c) Place a piece of universal indicator in the test tube from the anode (+). (Do not breathe in the gas that collects in this test tube. It is poisonous.)

5 Record your conclusion from each test in the last column of your table.

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Name: .....

Electroplating copper with nickel

Aim

To coat a sheet of copper with nickel using electricity

You need:

- one sheet of nickel and one sheet of copper, 5 cm × 3 cm
- 0.4 mol dm^{-3} sodium hydroxide solution *(corrosive)*
- 30 g dm^{-3} nickel(II) sulfate solution *(toxic)*
- propanone *(highly flammable)*
- nail varnish *(flammable)*
- distilled water
- electrode holder
- three connecting wires with crocodile clips
- 6V battery
- 6V bulb and holder
- two 100 cm^3 beakers
- paintbrush
- paper towels
- steel wool
- safety glasses

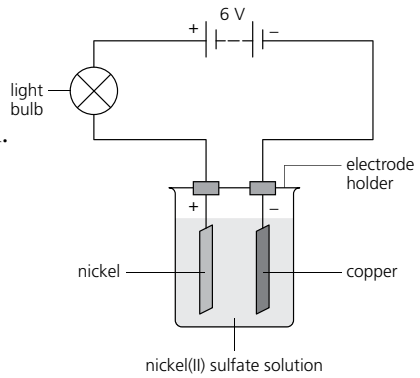
Introduction

In electroplating, electrolysis is used to coat or plate one metal with another. The plating metal becomes the anode, and the object to be plated is the cathode. The electrolyte is a solution of a compound of the plating metal.

Preparation

1 Make a larger copy of this table for your observations. Make it page-wide, with space to write at least two lines for each observation.

Appearance of …	Nickel sheet	Copper sheet	Electrolyte
before electrolyis			
after electrolysis			



2 The copper sheet must be clean and grease-free. So …

- First, scrub it on both sides with steel wool to clean it.
- Next, dip it into a beaker of dilute sodium hydroxide solution for a few seconds to remove any grease.
- Wash it with distilled water; dry it using a paper towel.

Procedure

1 Write your name, or draw a simple picture, on the copper sheet, using nail varnish and a paintbrush. Blow on the varnish to dry it.

2 Fill a beaker almost full with nickel(II) sulfate solution.

3 Set up the apparatus as shown above (nickel is the anode, and copper the cathode).

4 Fill in the first row of your table of observations.

5 Turn on the power supply, and let the current flow for about 10 minutes.

6 Take out the copper sheet. Remove the nail varnish using a piece of paper towel dipped in propanone.

7 Complete your table of observations.

Questions

1 The copper sheet is not completely coated with nickel. Why not?

2 What changes would you make to the set-up, to plate the copper sheet with zinc?

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Name:

Exothermic and endothermic reactions

Aim

To identify reactions as exothermic or endothermic by measuring the temperature change

You need:

- sherbet (a mixture of equal parts of citric acid and sodium hydrogen carbonate)
- zinc powder *(can be harmful)*
- anhydrous copper(II) sulfate *(irritant)*
- measuring cylinder, 50 cm^3
- plastic cup
- thermometer
- spatula
- safety glasses

Introduction

- There is always an overall energy change during chemical reactions.
- An exothermic reaction gives out energy; an endothermic reaction takes in energy.
- The energy is usually in the form of heat.

Preparation

Make a larger, wider copy of this table in which to record your results and observations.

	Chemical reaction	Temperature / °C			Other observations	Exothermic or endothermic?
		before	after	change		
1	Add anhydrous copper(II) sulfate to water.					
2	Add zinc to the mixture in 1.					
3	Add water to sherbet.					

Procedure

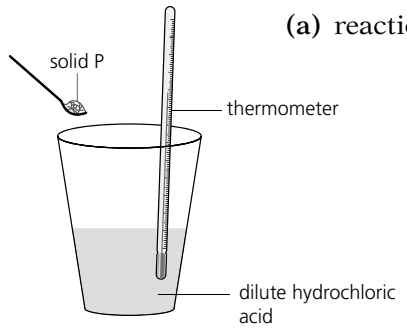
1 Pour 50 cm^3 of water into the plastic cup. Measure and record its temperature.

2 Add three spatula measures of anhydrous copper(II) sulfate to the water. Stir with the thermometer. Keep checking the temperature.

3 In your table, record the temperature when the reaction has just finished. (That is, before the temperature change starts to reverse.) Record your other observations too.

4 Add three spatula measures of zinc powder to the solution from step 3. Stir the mixture. Record the temperature and your observations as before.

5 Rinse the plastic cup, put 50 cm^3 of water into it, and add three spatula measures of sherbet. Then repeat step 3.



Analysis

1 Identify each reaction as exothermic or endothermic, in the last column of the table.

2 Explain the observations in the second last column, by describing the chemical reactions that occur.

3 Look at reaction 3 in your table. How would the temperature change be affected if you used:
(a) 25 cm^3 of water instead of 50 cm^3?
(b) a glass beaker, instead of the plastic cup?

4 Draw an energy diagram for:
(a) reaction 2 **(b)** reaction 3

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Name:

Reaction rate and surface area

Aim

To investigate the effect of a change in surface area on the rate of a reaction

You need:

- 1 M dilute hydrochloric acid *(corrosive)*
- three sets of marble chips—large, medium, and small
- 100 cm^3 beaker
- test tube with side-arm, fitted with a bung and delivery tube
- 25 cm^3 measuring cylinder
- balance
- filter paper
- stopwatch
- retort stand, clamp, and boss
- sieve
- safety glasses

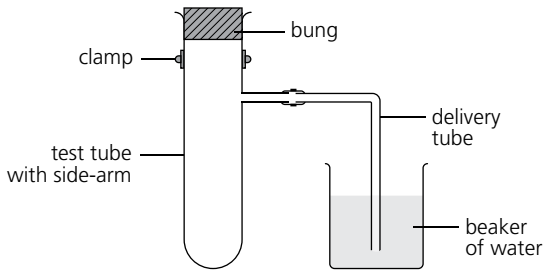
Introduction

Surface area just means how large the surface of something is, in terms of area. 1 gram of small particles has a larger total surface area than 1 gram of large particles.

Preparation

1 Prepare a table for your results, like this one.

Size of marble chips	Number of bubbles given off in 1 minute
large	
medium	
small	



2 Set up the apparatus as shown. Notice where the test tube is clamped.

3 Weigh out about 10 grams of each size of marble chips onto filter paper.

Procedure

1 Remove the bung, and add 15 cm^3 of dilute hydrochloric acid to the test tube.

2 Carefully drop the large chips into the acid. Replace the bung and start the stopwatch immediately. Count the number of bubbles given off in 1 minute, and record the result.

3 Pour the used mixture through a sieve, to retrieve the marble chips. (They should not go down the sink.)

4 Repeat steps 1–3 for the other two samples of marble chips.

Analysis and discussion

1 Write a word equation for the reaction that takes place here.

2 Draw a graph to illustrate how the rate of reaction is related to surface area.

3 Describe how the rate of the reaction changes with surface area.

4 See if you can explain the relationship you described in 2.

5 See if you can suggest ways to make the results of the experiment more reliable *without* changing the apparatus.

6 Suggest another way to measure the rate of this reaction.

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Name: .....

Reaction rate and concentration

Aim

To investigate the effect of a change in concentration on the rate of a reaction

You need:

- 40 g dm^{-3} sodium thiosulfate solution
- 2 M dilute hydrochloric acid *(corrosive)*
- 100 cm^3 conical flask
- two measuring cylinders, 10 cm^3 and 100 cm^3
- stopwatch
- piece of white paper
- graph paper
- safety glasses

Introduction

Sodium thiosulfate solution reacts with dilute hydrochloric acid like this:

$$Na_2S_2O_3\,(aq) + 2HCl\,(aq) \longrightarrow 2NaCl\,(aq) + SO_2\,(g) + S\,(s) + H_2O\,(l)$$

sodium thiosulfate hydrochloric acid sodium chloride sulfur dioxide sulfur water

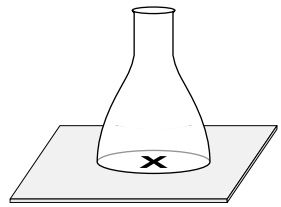
The sulfur forms as fine particles that make the solution cloudy. After a time, the solution becomes so cloudy that you cannot see through it. The time taken for this to happen is a measure of the reaction rate.

Preparation

1 Prepare a table like this one in which to record your results.

Run	Volumes of liquids put in flask / cm^3		Concentration of the sodium thiosulfate solution / g dm^{-3}	Time taken to hide cross / s
	sodium thiosulfate solution	water		
1	50	0	40	
2	40	10	32	
3	30	20	24	
4	20	30	16	
5	10	40	8	

2 Draw a cross on the piece of white paper to fit under the flask as shown.



Procedure

1 Measure 50 cm^3 of sodium thiosulfate solution into the conical flask (for run 1 in your table). Place the flask over the cross.

2 Measure 5 cm^3 of hydrochloric acid into the 10 cm^3 measuring cylinder.

3 Add the acid to the sodium thiosulfate. Start the stopwatch immediately. Swirl the flask to mix the reactants. *Do not breathe in the sulfur dioxide that forms. It is harmful.*

4 Look down through the solution, and record the time the moment you can no longer see the cross.

5 Repeat for runs 2–5 in your table. Each time add water to the sodium thiosulfate solution in the flask. Use the volumes given in the table.

Analysis and discussion

1 How is the **concentration** of the thiosulfate solution changed in this experiment?

2 Plot a graph of the time taken for the cross to become hidden against the concentration of the sodium thiosulfate solution.

3 Write down any conclusions you can draw from your results.

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Name: .....

Reaction rate and temperature

Aim

To investigate the effect of a change in temperature on the rate of a reaction

You need:

- 40 g dm^{-3} sodium thiosulfate solution
- 2 M dilute hydrochloric acid *(corrosive)*
- conical flask, 100 cm^3
- two measuring cylinders, 10 cm^3 and 100 cm^3
- stopwatch
- Bunsen burner and heat-resistant mat
- thermometer
- tripod and gauze
- piece of white paper
- graph paper
- safety glasses

Introduction

Sodium thiosulfate solution and dilute hydrochloric acid react together to form fine particles of sulfur. These make the solution go cloudy. After a time, the solution becomes so cloudy that you cannot see through it. The time taken for this to happen is a measure of the reaction rate.

Preparation

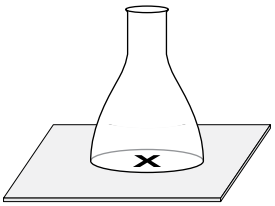
1 Prepare a table with the headings shown on the right. You will carry out the experiment at five different temperatures, so put in five rows for your results.

2 Draw a cross on the piece of white paper, to fit under the flask.

Temperature of solution / °C	Time taken to hide cross / s

Procedure

1 Take 50 cm^3 of sodium thiosulfate solution in the conical flask, and place the flask over the cross on the paper.



2 Take 5 cm^3 of hydrochloric acid in the 10 cm^3 measuring cylinder.

3 Add the acid to the sodium thiosulfate. Start the stopwatch immediately. Swirl the flask to mix the reactants. *Do not breathe in the sulfur dioxide gas that forms. It is harmful.* Quickly measure the temperature of the mixture.

4 Look down through the solution, and stop the watch the moment you can no longer see the cross. Record the time it takes (in seconds).

Repeat the experiment at four different temperatures, by repeating steps 5–8.

5 Empty and rinse the conical flask, and allow it to drain well.

6 Take another 50 cm^3 of sodium thiosulfate solution in the conical flask and 5 cm^3 of acid into the measuring cylinder.

7 Place the conical flask on the tripod and gauze. Heat gently, stirring the solution with the thermometer, until its temperature is about 10°C higher than the previous reading.

8 Take the flask off the tripod and place it over the cross on the paper. (If hot, take care!) Repeat steps 3 and 4.

Analysis

1 Plot a graph of the time taken for the cross to become hidden against the temperature of the reactants in the flask.

2 Write down any conclusions you can draw from your graph.

3 What factors might affect the reliability of the results in this experiment?

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Name:

Reaction rate and quantity of catalyst

Aim

To investigate whether the rate of a reaction depends on the *amount* of catalyst used

You need:

- hydrogen peroxide solution, *(corrosive)*
- 100 cm^3 conical flask
- delivery tube
- two measuring cylinders, 25 cm^3 and 50 cm^3
- trough for water
- manganese(IV) oxide powder *(harmful)*
- spatula
- stopwatch
- two retort stands, clamps, and bosses
- safety glasses

Introduction

Aqueous hydrogen peroxide decomposes very slowly to water and oxygen:

$2H_2O_2\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g)$

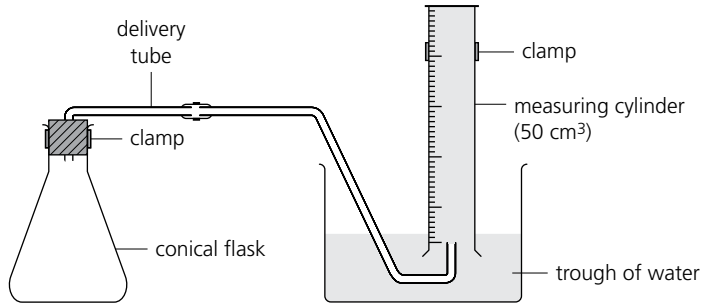
Manganese(IV) oxide speeds up this reaction. It is a catalyst for it.

Preparation

1 Prepare a table in which to write your results, like this one.

Amount of catalyst	Volume of gas (cm^3) collected after …			
	10 seconds	20 seconds	30 seconds	40 seconds
one spatula				
two spatula				

2 Set up the apparatus as below. Note that the measuring cylinder is full of water, and its mouth is below the water level. Note where the apparatus is clamped.



Procedure

1 Measure 20 cm^3 of hydrogen peroxide solution into the flask.

2 Add one spatula measure of manganese (IV) oxide to the flask. Quickly put the bung back in, and start the stopwatch.

3 Measure the volume of gas collected after 10, 20, 30, and 40 seconds. Record the results in your table.

4 Repeat the experiment using two spatula measures of manganese(IV) oxide.

Analyzing the results

1 Plot volume of gas against time for one spatula measure of catalyst. Join the four points with a smooth curve.

2 Now draw the graph for two spatula measures, on the same axes.

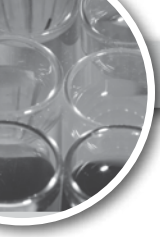
3 Compare the curves. Do they show a link between the amount of catalyst, and the rate at which hydrogen peroxide decomposes? Write down your evidence and conclusion.

Question

1 How would you investigate whether the mass of the catalyst changes, during the reaction above?

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Name: .....

Comparing two reversible reactions

Aim

To investigate two reversible reactions

You need:

- 0.5 M copper(II) sulfate solution *(irritant)*
- 2 M ammonia solution, *(corrosive)*
- 1 M dilute sulfuric acid *(corrosive)*
- 50 cm^3 measuring cylinder
- blue copper(II) sulfate crystals *(irritant)*
- plastic or polystyrene cup
- thermometer
- spatula
- test tube holder
- Bunsen burner and heat-resistant mat
- test tube rack
- safety glasses

Introduction

Reversible reactions can go both ways: reactants ⟶ products and products ⟶ reactants.

Preparation

1 Draw up a large table like the one started here. Add rows for steps 2, 3, and 4. Leave enough space to write at least two lines in each empty box.

Steps	Observations	
	Experiment 1	Experiment 2
1		

You must record all your observations in your table, for each step of each experiment.

Experiment 1

1 Put 15 drops of aqueous copper(II) sulfate into a test tube.

2 Add 5 drops of ammonia solution. Carefully shake the test tube.

3 Add more drops of ammonia solution, while shaking. Stop when there is no further change.

4 Now add dilute sulfuric acid, shaking the test tube. Count the number of drops needed to reverse the changes in steps 2 and 3.

Questions

1 Explain why this is an example of a reversible reaction.

2 How would you repeat the forward reaction?

Experiment 2

1 Add one spatula measure of blue copper(II) sulfate crystals to a test tube.

2 Heat the bottom of the test tube gently, with a small Bunsen flame, while holding the test tube near its mouth using a test tube holder.

3 Leave the test tube to cool in a test tube rack.

4 When it is cool, carefully add a few drops of water to the test tube.

Questions

1 How would you repeat the forward reaction in this experiment?

2 Does the reverse reaction give out heat or take it in?

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Name:

Comparing the reactions of two acids

Aim

To compare the reactions of hydrochloric acid and ethanoic acid

You need:

- 2 M hydrochloric acid *(corrosive)*
- sodium carbonate powder *(irritant)*
- 2 M ethanoic acid *(harmful)*
- copper(II) oxide powder *(irritant)*
- limewater *(harmful)*
- 5 cm magnesium ribbon *(flammable)*
- four test tubes
- test tube rack
- boiling tube
- spatula
- dropper
- pH colour chart for universal indicator
- wooden splint
- safety glasses

Introduction

Acids have a pH less than 7. You can tell their pH roughly by using universal indicator paper. Acids show characteristic reactions with metals, bases, and carbonates. These reactions always produce a salt. Bases are metal oxides and metal hydroxides.

Preparation

1 Make a larger copy of this table, to record all your observations in. Leave room to write at least two lines in each empty box.

2 Place the four test tubes and the boiling tube in the test tube rack.

On adding …	Obervations for …	
	Hydrochloric acid	Ethanoic acid
universal indicator		
magnesium		
sodium carbonate		
copper(II) oxide		

Procedure

1 Half-fill the boiling tube with limewater.

2 Half-fill the four test tubes with hydrochloric acid.

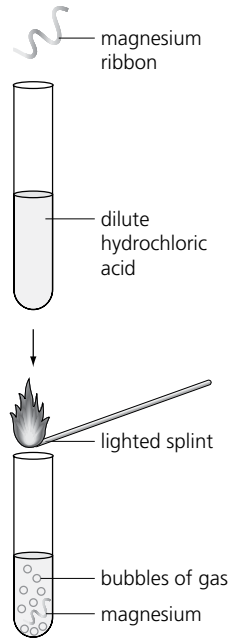
3 Add a piece of universal indicator to one test tube. Record the colour and pH. (Use the pH chart.)

4 Add magnesium to another test tube. A gas forms. Test it with a lighted splint.

5 Add a spatula measure of sodium carbonate to the third. Use a dropper to remove some of the gas that forms, and bubble it through the limewater.

6 Add a spatula measure of copper(II) oxide to the last test tube. Shake the test tube for a minute.

7 Rinse out the glassware and repeat steps 1–6, this time with ethanoic acid.



Questions

1 Identify the gases given off in the reactions with:

(a) magnesium (b) sodium carbonate

2 Name the three salts formed in the reactions with hydrochloric acid, and give their formulae.

3 In their reactions, in what way(s) are the two acids:

(a) similar? (b) different?

4 What reason can you give for any differences in the reactions of the two acids?

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Name:

Neutralizing vinegar with slaked lime

Aim

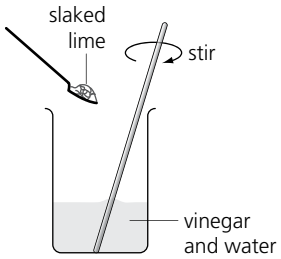
To follow the progress of a neutralization reaction using universal indicator paper

You need:

- vinegar *(irritant)*
- beaker, 100 cm^3
- measuring cylinder, 25 cm^3
- glass rod
- spatula
- slaked lime (calcium hydroxide) *(corrosive)*
- white tile
- strip of universal indicator paper
- scissors
- pH colour chart
- graph paper
- safety glasses

Introduction

Acids are neutralized by bases, giving a salt and water. As neutralization proceeds, the pH of the solution changes. Metal oxides and hydroxides are bases. Vinegar is mainly a dilute solution of ethanoic acid. Slaked lime is the common name for calcium hydroxide.

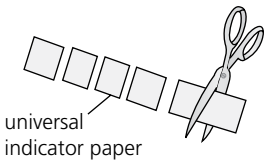


Preparation

1 Prepare a table with the headings shown below. Give six rows in which to write.

2 Cut the universal indicator paper into six pieces. Place them on the tile.

Number of spatula measures of slaked lime added	Colour of indicator paper	pH



Procedure

1 Take 20 cm^3 of vinegar in a beaker. Add 20 cm^3 of water, and stir with a glass rod.

2 Using the glass rod, place a drop of the solution onto a strip of universal indicator paper. Record the new colour of the paper in your table.

3 Compare the colour on the strip with a pH chart, and record the pH in your table.

4 Now add one spatula measure of slaked lime to the beaker. Stir well. Place a drop of the solution on a new strip of universal indicator paper. Record the colour of the paper, and the matching pH, in your table.

5 Repeat step 4 several times, adding one spatula measure of slaked lime at a time. Record the colour of the paper, and the pH, each time.

6 When the pH no longer changes, stop the experiment.

Analysis

1 Plot a graph of pH against the number of spatula measures of slaked lime added.

2 Using your graph to help you, describe how the pH changes during the neutralization.

3 How many spatula measures of calcium hydroxide were needed to neutralize the vinegar? Explain how you reached your answer.

4 Comment on the accuracy of this experiment.

Questions

1 From your experiment, what can you deduce about the solubility of slaked lime? Give your evidence.

2 (a) Explain why slaked lime is often sprinkled on soil by farmers.

(b) Do you think its level of solubility is an advantage or a disadvantage for this use?

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Name:

Making Epsom salts

Aim

To prepare a salt by first carrying out a neutralization reaction, followed by crystallization

You need:

- 1 M dilute sulfuric acid *(corrosive)*
- beaker, 100 cm^3
- measuring cylinder, 25 cm^3
- conical flask, 100 cm^3
- glass rod
- magnesium carbonate powder
- spatula
- evaporating basin
- Bunsen burner and heat-resistant mat
- tripod and gauze
- filter funnel
- filter paper
- safety glasses

Introduction

Epsom salts is the common name for crystals of magnesium sulfate. Epsom salts can be made by reacting magnesium carbonate with sulfuric acid:

$$MgCO_3\,(s) + H_2SO_4\,(aq) \longrightarrow MgSO_4\,(aq) + H_2O\,(l) + CO_2\,(g)$$

After the reaction, the excess magnesium carbonate is removed by filtration. Crystals of magnesium sulfate are obtained by crystallization.

Preparation

1 Set the filter funnel into the conical flask. Fold a piece of filter paper to fit inside the funnel.

2 Place the evaporating dish on the tripod and gauze.

Procedure

1 Pour 25 cm^3 of dilute sulfuric acid into the beaker.

2 Add magnesium carbonate to the acid one spatula measure at a time. Stir the mixture with a glass rod after each addition.

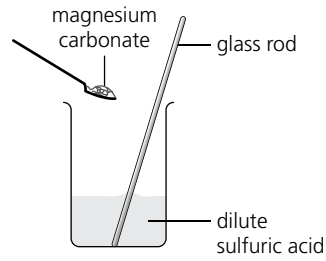
3 Stop adding magnesium carbonate when no more will dissolve.

4 Filter the solution into the conical flask.

5 Pour the filtrate into the evaporating dish. Heat it gently until only half the volume remains.

6 Leave the solution to cool. Crystals will form.

7 Pour off most of the liquid. Then remove the crystals from the dish with a spatula, and place them on a piece of filter paper.



Observations

Describe the colour and shape of the crystals you obtained.

Questions

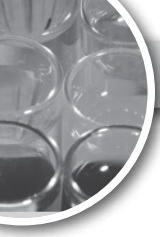
1 Magnesium carbonate is insoluble in water. Explain why this property is useful, in the preparation above.

2 How does the solubility of magnesium sulfate change with temperature?

3 Name another chemical that you could react with sulfuric acid to obtain Epsom salts.

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PRACTICAL

Name:

Arranging metals in order of reactivity

Aim

To put four metals in order of reactivity using their reactions with hydrochloric acid

You need:

- 2 M dilute hydrochloric acid *(corrosive)*
- four 100 cm^3 beakers
- 25 cm^3 measuring cylinder
- spatula
- magnesium, iron, zinc, and copper, in powder form *(all are irritants, and magnesium and zinc powders are highly flammable)*
- thermometer
- safety glasses

Introduction

The reaction between a metal and an acid gives out energy—it is exothermic. The energy is mainly in the form of heat. The temperature rises. The more reactive the metal is, the more energy is given out during the reaction. So the temperature rise can be used to arrange metals in order of reactivity.

Preparation

1 Prepare a table with the headings shown below.

In the first column list four metals: magnesium, iron, zinc, and copper.

Powdered metal	Temperature of the solution in the beaker / ˚C		Change in temperature / ˚C	Observation
	Before metal added	Highest reached		
magnesium				

Procedure

1 Take 15 cm^3 of hydrochloric acid in a beaker.

2 Measure its temperature and record it in your table.

3 Add two spatula measures of powdered magnesium. (TAKE CARE: vigorous reaction!) Note that the metal is in excess.

4 Stir the mixture with the thermometer and check the temperature. Record the highest temperature reached. Calculate the temperature change.

5 Note what you observe during the reaction in the last column of your table.

6 Repeat steps 1–5 for the other metals, using a clean beaker each time.

Analysis

1 Using the temperature change, list the four metals in order of their apparent reactivity with the acid, the most reactive first.

2 (a) Does the order in 1 fit in with your observations in the last column? Explain.

(b) Does it match the order of these four metals in the reactivity series?

3 Comment on the accuracy of the experiment as a way to compare metals.

4 How would you improve the experiment to make the results more valid?

Questions

1 For each reaction that takes place, write:

(a) a word equation

(b) a balanced symbol equation.

2 How would you confirm the identity of the gas that forms?

3 Where would you insert this gas in the order of reactivity for the four metals?

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Name: .....

Investigating rusting

Aim

To investigate the conditions needed for iron to rust

You need:

- 4 small iron nails
- powdered anhydrous calcium chloride *(harmful)*
- cooking oil
- 100 cm^3 beaker
- four dry test tubes
- two bungs for test tubes
- test tube rack
- sandpaper
- spatula
- Bunsen burner and heat-resistant mat
- four small sticky labels (or a marker pen)
- safety glasses
- tripod and gauze

Introduction

Iron rusts readily, in the atmosphere. That is a problem, since we use so much of it. Rust is hydrated iron(III) oxide.

Preparation

1 Prepare a larger copy of this table, in which to record your observations.

2 Half-fill the beaker with water, and boil gently for about 5 minutes.

3 Clean the four nails with sandpaper.

4 Label the four test tubes A, B, C, and D, and stand them in the test tube rack.

Test tube	Conditions for the nail	Observation
A	normal air	
B	tap water	
C	boiled water	
D	dry air	

Procedure

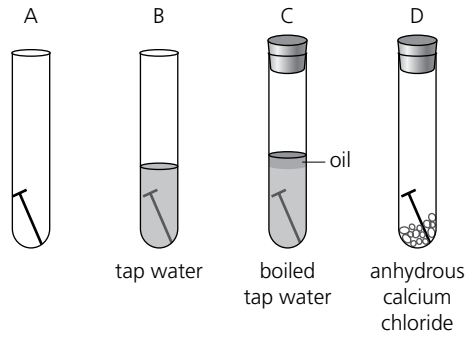
1 Place a nail in test tube A.

2 Place a nail in test tube B. Add tap water to cover it.

3 Place a nail in test tube C. Add boiled water to cover it. Then carefully add a little oil. Seal C with a bung.

4 Place a nail in test tube D. Add one spatula measure of anhydrous calcium chloride and seal D with a bung.

5 Leave the rack of test tubes aside for several days. Then inspect the nails. Record your observations.



Analysis and discussion

1 Arrange the letters A–D to match the amount of rust you observe in the test tubes. Put the test tube with most rust first.

2 **(a)** Why was the water for test tube **C** boiled?
(b) What was the anhydrous calcium chloride for in test tube **D**?

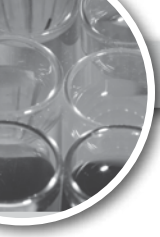
3 *'The rusting of iron requires both air and water.'* Evaluate how well your results confirm this statement.

4 Suggest a method for treating iron nails to prevent them from rusting.

5 Now see if you can design an experiment to investigate whether adding salt (sodium chloride) to the water speeds up rusting.

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PRACTICAL

Name:

Comparing antacid tablets

Aim

To compare how well antacid tablets work, by using them to neutralize hydrochloric acid

You need:

- a selection of antacid tablets
- dilute hydrochloric acid, 0.5M *(harmful)*
- methyl orange indicator *(toxic)*
- burette
- funnel
- pestle and mortar
- conical flask, 100 cm^3
- balance
- retort stand, clamp, and boss
- spatula
- safety glasses

Introduction

Our stomachs produce hydrochloric acid to help in digestion. Eating too much can cause excess acid to form. This gives a burning feeling in the chest: heartburn. Antacid tablets treat heartburn by neutralizing the excess acid. They contain chemicals such as calcium carbonate and magnesium hydroxide. Different brands of antacid tablets contain different mixtures of compounds.

Procedure

1 Prepare a table to record your results in, with these headings:

Brand of antacid	Mass of one tablet / g	Burette readings / cm^3		Volume of acid / cm^3 neutralized by …	
		Initial	Final	One tablet	1g of this tablet

2 Set up a burette on the retort stand. Use the funnel to fill it with hydrochloric acid.

Procedure

1 Select an antacid tablet. Record its brand name. Then weigh it. Record its mass.

2 Crush the tablet using a dry pestle and mortar. Transfer all the powder to a conical flask, and add a little water.

3 Then add 10 drops of methyl orange indicator, and swirl the flask.

4 Record the initial burette reading, in your table.

5 Now add acid from the burette, continually swirling the flask. The solution shows flashes of red, which get stronger. Near the end-point, add the acid a drop at a time. Stop when the solution stays **red** after swirling.

6 Record the final burette reading, in your table.

7 Repeat steps 1–6 using different brands of antacid tablet.

Analysis and discussion

1 Complete the last two columns of your table.

2 Which tablet would be the most effective, for heartburn? Explain your choice.

3 Which brand of antacid contains most active ingredient per gram?

4 Why are the tablets crushed in this experiment?

5 What evidence is there that the tablets are not soluble in water?

6 Suggest two factors that may influence people when buying an antacid.

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Name:

Extracting copper from copper(II) oxide

Aim

To obtain copper by extracting it from copper(II) oxide using carbon

You need:

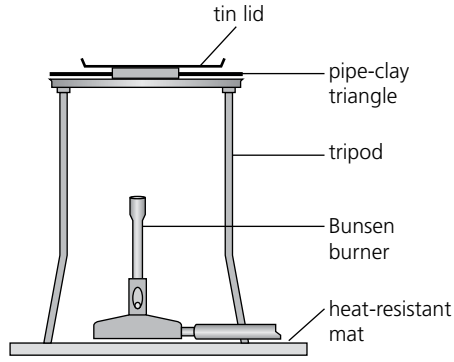
- carbon powder
- copper(II) oxide powder *(harmful)*
- test tube and bung
- tongs
- spatula
- tripod
- pipe-clay triangle
- Bunsen and heat-resistant mat
- tin lid
- safety glasses

Introduction

Most metals occur naturally in the Earth as compounds. These are often oxides. To obtain the metal, it must be extracted from the compound. A metal can be extracted from its compounds by heating with a more reactive substance. Carbon is more reactive than some metals. So there metals can be extracted from their oxides by heating with carbon.

Preparation

Set up the apparatus as shown here. Note the heat-resistant mat. The tin lid sits on top of the pipe-clay triangle.



Procedure

1 Take two spatula measures of carbon powder and two spatula measures of copper(II) oxide powder in the test tube.

2 Insert the bung, and shake the test tube thoroughly to mix the powders.

3 Pour the mixture onto the tin lid, and heat it strongly for 5 minutes. Then leave it to cool.

4 Using tongs, remove the lid and empty the contents onto the heat-resistant mat.

5 Look for evidence that copper has been formed.

Observation

1 What signs of a chemical reaction do you observe during heating?

2 What evidence of copper do you find in the final mixture?

Questions

1 Why are powders used instead of lumps in the experiment?

2 Complete the word equation for the reaction that takes place:
copper(II) oxide + carbon ⟶ ..... + ...

3 **(a)** Explain why the reaction is an example of a redox reaction.
(b) Which substance is the reducing agent in the reaction?

4 Name a metal that cannot be extracted by heating its oxide with carbon, and explain why.

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Name:

Cracking hydrocarbons

Aim

To break the long-chain molecules in liquid paraffin into molecules with shorter chains

You need:

- liquid paraffin
- aluminium oxide pellets *(catalyst)*
- bromine water *(corrosive)*
- ceramic wool
- water trough
- boiling tube with delivery tube and bung to fit
- six test tubes, four test tube bungs, test tube rack
- spatula
- dropper
- wooden splint
- retort stand, clamp, and boss
- Bunsen burner and heat-resistant mat
- safety glasses

Introduction

Liquid paraffin is a mixture of hydrocarbons that have molecules with long carbon chains. These long-chain molecules can be broken into shorter molecules by a process called cracking. Cracking requires heat and a catalyst.

Preparation

1 Prepare a larger copy of the table shown below.

2 Fill the trough with water. Place four test tubes and bungs in it so that the test tubes are full of water, ready for use.

3 Place a little liquid paraffin in the other two test tubes. Stand them in the test tube rack.

Procedure

1 Place a small piece of ceramic wool in the bottom of the boiling tube. Then, using the dropper, add 10 drops of liquid paraffin to the wool.

2 Using the spatula, place pellets of catalyst half-way along the boiling tube.

3 Clamp the boiling tube as in the diagram, with the clamp near the open end. Connect the delivery tube to it.

4 Start heating the boiling tube below the catalyst. (See the diagram.)

5 Allow gas to bubble off for 10 seconds or so. Then place a test tube full of water over the end of the delivery tube, as in the diagram.

6 When the test tube is full of gas, put the bung in quickly under the water. Then move the test tube to the test tube rack.

7 Fill the other three test tubes with gas in the same way. Then turn off the Bunsen burner. ***Remove the delivery tube from the water immediately, to prevent suck-back.***

8 Now answer the questions in your table, for the samples of liquid paraffin and gas.

Discussion

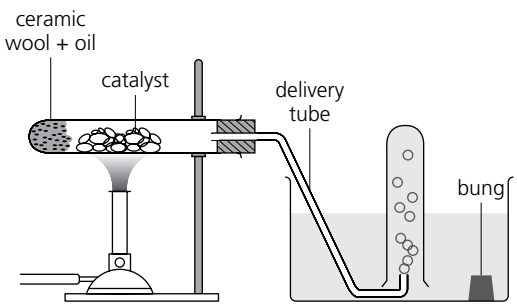
1 What is a hydrocarbon?

2 In studying the liquid paraffin and the gas, what evidence did you obtain that:

(a) larger molecules had been converted to smaller ones?

(b) an unsaturated hydrocarbon had been obtained from a saturated hydrocarbon?

Questions	Liquid paraffin	The gas that forms	
What does it look like?			
Does it smell?			
Does it burn easily? (Test with a lighted splint.)			
What happens when it is shaken with bromine water?			



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Name: .....

Collection of gas

1 In two separate laboratory experiments, hydrogen peroxide was decomposed by adding two different catalysts X and Y each time. Catalyst X was used first in the first experiment. The set-up is shown in Fig. 1.1 below:

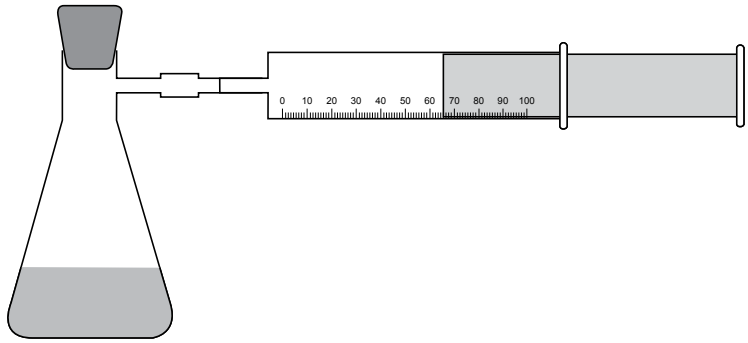


Fig. 1.1

(a) What is the purpose of using the rubber bung or cork?

..... **[1]**

(b)

(i) How will you test for the gas that evolves as a result of the decomposition of hydrogen peroxide?

.....

..... **[1]**

(ii) How will you interpret your observations?

.....

.....

..... **[2]**

(c) The volume of oxygen given off was measured at 1-minute intervals. Fig. 1.2 shows the total volume of oxygen collected in the syringe after each 1-minute time interval.

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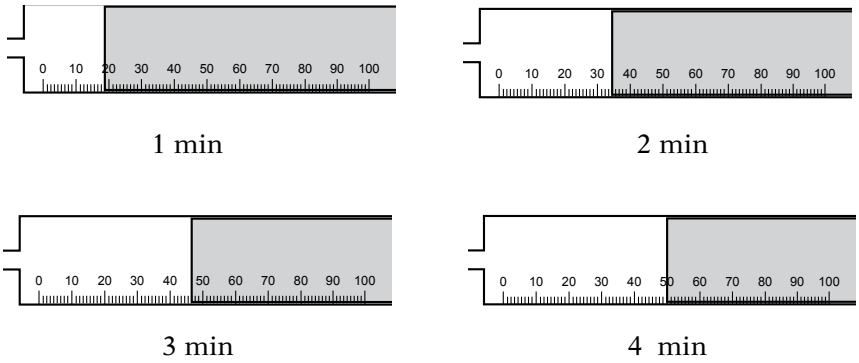


Fig. 1.2

(i) Fill in Table 1.1 below for catalyst X:

Table 1.1

Catalyst	**Total volume of oxygen (cm^3) collected after**					
X	1 min	2 min	3 min	4 min	5 min	6 min
					66	66

[1]

The same experiment was repeated with catalyst Y. The results are as under:

Table 1.2

Catalyst	**Total volume of oxygen (cm^3) collected after**					
Y	1 min	2 min	3 min	4 min	5 min	6 min
	8	13	17	21	24	24

(ii) Plot the graph for catalysts X and Y and draw a smooth curve through each set of points. Label the curves A and B respectively.

Time / s

Temperature / ^oC

[3]

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Name: .....

(iii) What does the shape of the curve tell you about the relationship between time and the volume of oxygen evolved during the reaction?

.....

.....

..... **[2]**

(iv) How can the volume of oxygen produced within a certain time interval be increased?

.....

.....

..... **[1]**

(v) Using the graph, estimate the time taken to double the volume of oxygen produced from 10 cm^3 to 20 cm^3 for each catalyst X and Y. Record your answers in Table 1.3 given below:

Table 1.3

	Catalyst X	**Catalyst Y**
Time taken to produce 10 cm^3 of the gas / m		
Time taken to produce 20 cm^3 of the gas / m		
Time taken to double the volume of the gas from 10 cm^3 to 20 cm^3 / m		

[1]

(vi) Catalyst ..... speeded up the reaction for decomposition of hydrogen peroxide faster compared to catalyst ..... . **[2]**

(vii) Explain why the volume of oxygen collected after 5 and 6 minutes was the same with both catalysts X and Y.

.....

.....

..... **[1]**

[Total: 15]

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Name: .....

Purification techniques I

1 A student set up the following apparatus using a mixture of 100 cm^3 water and 50 cm^3 denatured alcohol in a flask. He also added 3 to 4 small crystals of potassium dichromate (K_2CrO_4) to the flask.

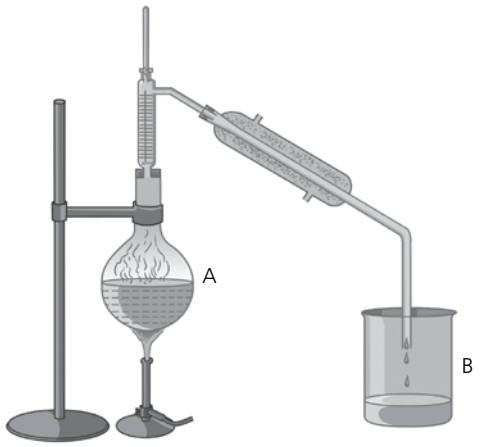


Fig. 1.1

(a) Label the following parts on Fig. 1.1:

a	distillate
b	thermometer
c	water inlet (on condenser)
d	water outlet (on condenser)
e	condenser
f	distilling flask

[3]

(b)

(i) Name the liquid collected in flask B.

..... **[1]**

(ii) Why did only one out of the two liquids originally used collect in the flask?

.....

..... **[1]**

(c) Why did the student add potassium dichromate (K_2CrO_4) crystals into the flask?

..... **[1]**

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Name: . . . . . .

(d) The process of separating two liquids by distillation is known as ..... . **[1]**

(e)

(i) Is the potassium dichromate distilled out? YES / NO **[1]**

(ii) Explain your answer to part (i).

.....

.....

..... **[2]**

[Total: 10]

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Purification techniques II

1 A student carried out an experiment to analyze the composition of a fruit-flavoured sweet. He dissolved the sweet in 10 cm^3 water to form a red solution. He called this sample X. The package mentioned that the sweet contained pigments B and C. The student wanted to investigate if the sweet also contained two harmful pigments A and D. The student took a sheet of filter paper and placed a spot of sample X and of the four dyes A, B, C, and D as shown in Fig. 1.1:

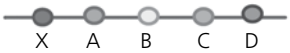


Fig. 1.1

He then rolled the filter paper and taped it to form a cylinder which he placed in a closed container that contained a solvent.

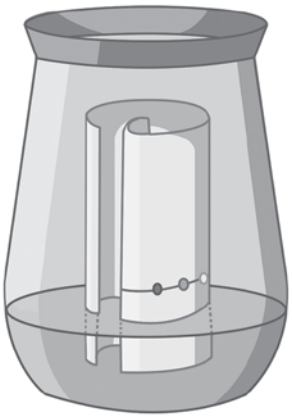


Fig. 1.2

He allowed the dyes to travel up the filter paper for half an hour and obtained the results as shown:

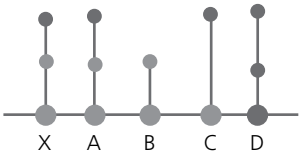


Fig. 1.3

(a) Why did the student conclude that A was a mixture?

.....

..... **[1]**

(b) Which of the four dyes A, B, C, and D were present in sample X?

.....

..... **[2]**

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(c) Why was the experiment carried out in a closed container?

.....

..... [1]

(d) Why was the experiment not allowed to proceed so that the line of solvent went beyond the edge of the paper?

.....

..... [1]

(e) Calculate the Rf value in mm for pigment D.

.....

..... [2]

[Total: 7]

2 A student wanted to separate the solvent benzene from a mixture of benzene and petrol. He set up the apparatus as shown in Fig. 2.1:

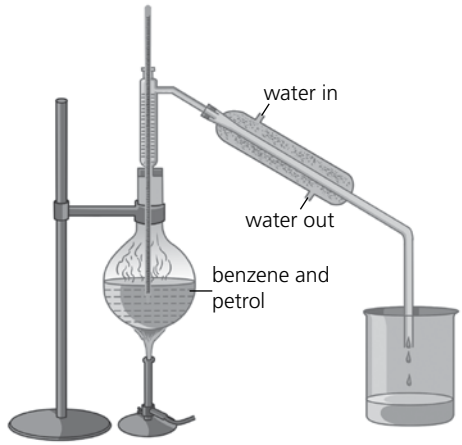


Fig. 2.1

(a) Identify three mistakes the student has made in setting up the experiment.

.....

..... [3]

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Name:

(b) What must the student do to correct these mistakes?

.....

..... **[3]**

(c) Suggest two safety precautions that the student should follow when carrying out this experiment.

.....

..... **[2]**

[Total: 8]

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Name:

Electrolysis

1 A student performed an electrolysis using electrodes made of inert elements. The electrodes were immersed in a solution of copper (II) sulfate. A circuit connected the two electrodes as shown in the Fig. 1.1 below:

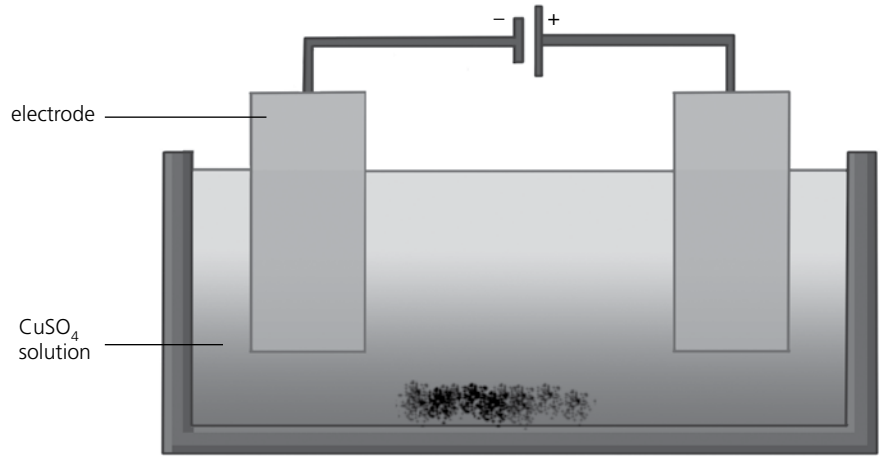


Fig. 1.1

(a) Name a suitable material for the inert electrodes.

..... **[1]**

(b) Why was a variable resistor added to the circuit?

..... **[1]**

(c) During electrolysis, the cathode was removed at intervals and weighed to note the deposition of any metal. After recording the mass, the electrode was washed, dried, and placed in the electrolyte again. The student recorded the weight of the cathode after every 10-minute interval as shown in the table below. Complete the table by filling out the increase in weight column left blank by the student.

Time / min	Mass of electrode / g	Total increase in mass / g
0	12.50	0.00
10	13.10	0.60
20		0.60
30	14.50	1.20
40	15.15	
50		0.15
60		0.15

[2]

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Name:

(d) Plot the total increase in mass / g against time / min on the grid below, and connect the points to draw a curve.



[4]

(e) Explain the shape of the curve.

..... **[1]**

(f) Write the name of substance that was deposited on the cathode.

..... **[1]**

(g) Using the graph, estimate the time taken to deposit 1.55 g of the substance.

..... **[1]**

(h) You may have observed that there was no change in the mass of the cathode for the last two readings taken at 50 and 60 minutes. Explain what may have caused the mass of the cathode to remain unchanged.

.....

.....

..... **[2]**

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Name: .....

(i) What was the appearance of the electrolyte at the start and the end of the electrolysis?

..... **[1]**

(j) The experiment was repeated by replacing the inert electrode with a copper electrode. The circuit and other conditions remained the same. Draw a line on the same graph and label it with T to represent the change in the mass of the copper electrode. **[1]**

[Total: 15]

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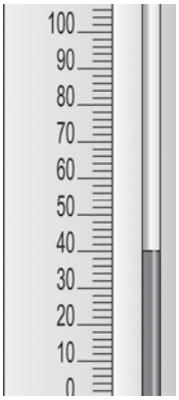
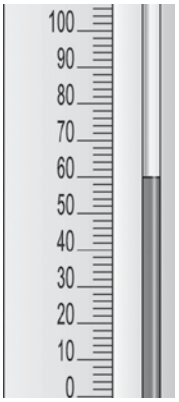
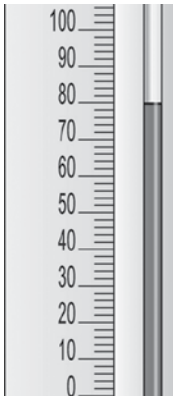
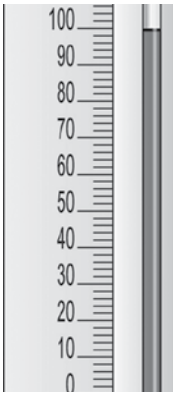
Name: .....

Salt solubility

1 A student set up an experiment to test the solubility of two different salts in water at different temperatures.

He poured 50 cm^3 water into a boiling tube. Next, he added crystals of salt X weighing 5 g to the contents of the boiling tube. The tube and the contents were allowed to heat slowly over a Bunsen burner flame. The solution was stirred well and the temperature was noted as soon as the salt crystals were dissolved. The experiment was repeated three times with different masses of salt X.

During the experiment, 5 g, 8 g, 10 g, and 12 g of salt X was dissolved in 50 cm^3 of water at different temperatures. The sections of the thermometer are shown below along with the quantities of salt X that were dissolved.

			
5 g of salt X	8 g of salt X	10 g of salt X	12 g of salt X

(a) Complete the table given below for salt X.

Mass of salt X in 50 cm^3 of water	5 g	8 g	10 g	12 g
Temperature at which salt X was dissolved / °C				

[1]

(b) The experiment was repeated wih salt Y with the following observations:

Mass of salt Y in 50 cm^3 water	5 g	8 g	10 g	12 g
Temperature at which salt Y was dissolved in / °C	34°C	46°C	59°C	88°C

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Plot curves using the above data for salt X and salt Y, recording temperature along the x-axis and mass of salt dissolved along the y-axis.



[4]

(c) Using the graph curves, deduce the following:

(i) The solubility of salt X at 30°C is ..... g. **[1]**

(ii) The solubility of salt Y at 30 °C is ..... g. **[1]**

(iii) The temperature at which equal quantities of salt X and salt Y are dissolved is ..... °C. **[1]**

(iv) The temperature at which 20 g of salt X is dissolved is ..... °C. **[1]**

(v) The temperature at which 20 g of salt Y is dissolved is ..... °C. **[1]**

(d) What does the graph tell you about the relationship between temperature and solubility?

.....

..... **[1]**

(e) Suggest how the accuracy of the graph might be improved.

..... **[1]**

[Total: 12]

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Heat of combustion

1 A student arranged the apparatus as shown in Fig. 1.1 below:

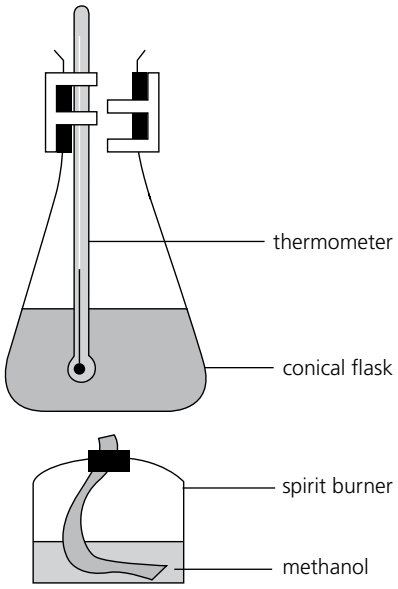


Fig. 1.1

Some methanol was poured into the spirit burner and weighed on a weighing scale. The temperature of the water in the flask was noted. The burner was lit and placed under the flask to heat the water. After a few minutes the burner was extinguished and the temperature of the water was recorded. The burner with the remaining methanol was weighed again.

The temperature of the water before lighting the burner and after extinguishing the burner is shown in the sections of the thermometer in Fig. 1.2 below:

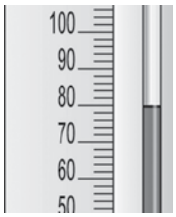
	
Initial temperature / °C	Final temperature / °C

Fig. 1.2

(a) Complete Table 1.1 by inserting the readings from Fig. 1.2:

Table 1.1

Initial mass of burner with methanol / g	65.5
Final mass of burner with remaining methanol / g	59.5
Mass of methanol consumed / g	
Initial temperature of water / °C	
Final temperature of water / °C	
Rise in temperature of water / °C	

[2]

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(b) What is the chemical formula for methanol?

.....

..... **[1]**

(c) Calculate the relative molecular mass of methanol.
(Ar: C = 12, H = 1, O = 16)

.....

..... **[2]**

(d) Using the data from the table in part (a) and the molecular mass calculated in part (c), calculate the number of moles of methanol burnt in raising the temperature of the water to the final temperature.

.....

..... **[2]**

(e) The experiment was repeated using four different alcohols for raising the temperature of water to 20°C. In each case the burner was weighed with alcohol and reweighed after extinguishing the burner. The results of the four cases are summarized in Table 1.2 below:

Table 1.2

Alcohol	Formula	Mass of alcohol consumed in raising water temperature to 20°C.
Methanol	CH_3OH	1.10
Ethanol	C_2H_5OH	0.65
Butane-1-ol	C_4H_9OH	0.58
Pentan-1-ol	$C_5H_{11}OH$	0.48

Plot a curve on the graph taking the number of carbon atoms along the x-axis and the mass of alcohol / g along the y-axis for each of the four types of alcohol given above. Assign letters A, B, C, and D to the four curves that you plot on the graph.

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Name:



[4]

(f) Calculate the number of moles of each of the four alcohols.

.....

.....

.....

.....

.....

.....

.....

..... **[2]**

(g) Using the formula for ΔH, calculate the value for enthalpy change per mole for butane-1-ol.

.....

.....

..... **[2]**

[Total: 15]

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Name: .....

Stoichiometry

1 A student decided to analyze a blue solid X. He took a sample of X in a previously weighed crucible which was then reweighed.

(a) Mass of empty crucible = 16.85 g

Mass of crucible + X = 22.25 g

Mass of X = ... **[1]**

(b) The crucible was cooled and then weighed. It was then reheated, cooled, and reweighed. Why was the crucible reheated?

.....

..... **[1]**

(c) The final mass of the crucible was 21.1 g. Calculate the mass of the residue.

.....

..... **[2]**

(d) Calculate the mass of the water lost on heating.

.....

..... **[2]**

(e) Calculate the number of moles of water lost.

.....

..... **[2]**

(f) Calculate the percentage of water in the solid.

.....

..... **[2]**

[Total: 10]

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Name: .....

Calculations with moles

1 A student measured out some solid iron(II) chloride in an evaporating dish. The mass of the evaporating dish was 14.17 g and the mass of the dish with the iron(II) chloride was 17.42 g.

(a) Calculate the mass of iron(II) chloride in the sample.

.....

..... **[1]**

(b) Iron(II) chloride was mixed with 25 cm^3 distilled water in a beaker to form a solution. Chlorine gas was passed into the beaker containing iron(II) chloride. A colour change was seen. The colour change was from ..... to ..... . **[2]**

(c) The iron(II) chloride was changed to iron(III) chloride in a redox reaction by passing chlorine gas. Explain why this is a redox reaction.

.....

..... **[3]**

(d) The iron(III) chloride was mixed with excess aqueous sodium hydroxide. A precipitate of iron(III) hydroxide was formed. This was filtered out as a residue, washed, and dried. How was this residue washed and dried?

.....

..... **[2]**

(e) Calculate the mass of iron(III) hydroxide formed.

.....

..... **[2]**

(f) Calculate the mass of iron present in the sample.

.....

..... **[2]**

[Total: 12]

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Name: .....

Salt analysis

1 A student performed the following tests on a salt S. Complete Table 1.1 below by adding the observations and the test for D.

Table 1.1

	Test	Observation	Conclusion
A	S is dissolved in water and the resulting solution divided into three parts for tests B, C, and D.		Transition metal ions are not present in the salt solution.
B (i)			
(ii)			Solution may contain Al^{3+} ions or Zn^{2+} ions.
C (i)	To the second part, aqueous ammonia is added until a change is observed.		
(ii)	Excess of aqueous ammonia is added.		The presence of Zn^{2+} ions is confirmed.
D			
			Solution contains NO^{3-} ions.

[4]

The salt S is ..... **[1]**

2 A student performed the following tests on a salt V**.** Complete Table 1.2 by adding the tests, observations, and conclusions.

Table 1.2

	Test	Observation	Conclusion
A	V is dissolved in water and the resulting solution divided into three parts for tests B, C, and D.	Colourless solution is obtained.	
B (i)			May contain Al^{3+}, Ca^{2+}, or Zn^{2+} ions
(ii)			May contain Cu^{2+} ions
C (i)	To the second part, aqueous ammonia is added until a change is observed.		The presence of Cu^{2+} ions is confirmed.
D			
			Contains Cl^- ions

[4]

The salt V is ..... **[1]**

[Total: 10]

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Name: .....

Titration

1 P is a mixture containing iron(II) sulfate. A student determined the percentage of iron(II) sulfate in the mixture using 0.0200 mol/dm^3 aqueous potassium manganate (VII), making solution **S.** Potassium manganate (VII), which is purple, reacts with the iron(II) ions in the mixture.

(a) Suggest why potassium manganate (VII) does not react with iron(III) ions.

..... **[1]**

(b) A sample of P was added to a previously weighed container, which was then reweighed.

Mass of container = 9.06 g

Mass of container + P = 15.14 g

Calculate the mass of P used in the experiment. ..... g **[1]**

(c) The sample was taken in a flask and dissolved in 100 cm^3 dilute sulfuric acid. The solution made up to 250 cm^3 with distilled water. This was solution T. 25.0 cm^3 of T was transferred into a conical flask. What piece of equipment should be used to transfer this volume of T?

..... **[1]**

(d) Solution S was taken in a burette and run into the conical flask containing T. What was the colour of the solution in the conical flask:

(i) before S was added?

..... **[1]**

(ii) at the end point?

..... **[1]**

(e) Three titrations were done. Fig. 1.1 below shows parts of the burette with the liquid levels at the beginning and end of each titration:

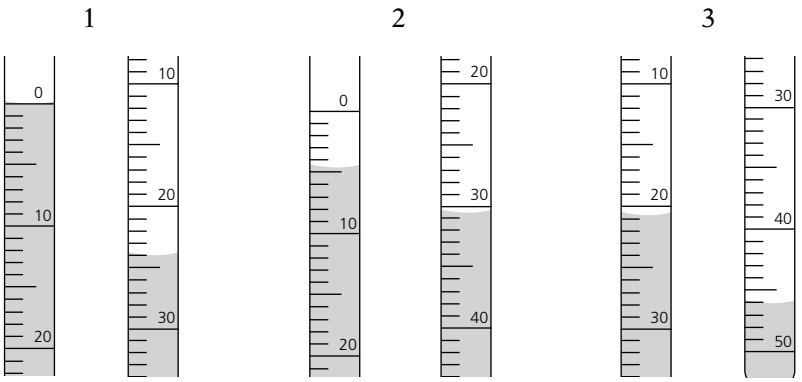


Fig. 1.1

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Name: .....

Use Fig. 1.1 to complete Table 1.1 below:

Table 1.1

Titration number	**1**	**2**	**3**
Final burette reading / cm^3			
Initial burette reading / cm^3			
Volume used / cm^3			
Best titration results			

[4]

(f) Using these results, the average volume of S used was ..... cm^3. **[1]**

(g) S is 0.0200 mol/dm^3 potassium manganate (VII). Calculate the numbers of moles of potassium manganate (VII) present in the average volume of S in part (f).

..... **[2]**

(h) One mole of potassium manganate (VII) is reacted with 5 moles of iron(II) sulfate.

(i) Calculate the number of moles of iron(II) sulfate in 25.0 cm^3 of T.

..... **[1]**

(ii) Calculate the number of moles of iron(II) sulfate in 250.0 cm^3 of T.

..... **[1]**

(iii) Using your answer for part (ii), calculate the mass of iron(II) sulfate present in the solution T. [Mr: $FeSO_4$ = 152]

..... **[1]**

[Total: 15]

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Name: .....

Separating substances

1 You can obtain clean water from sea water by distillation. Which of the following does the process involve?

(a) dissolving, then evaporation
(b) condensation, then evaporation
(c) condensation, then dissolving
(d) evaporation, then condensation

Circle letter a, b, c, or d. [1]

2 Substance X is a gas at room temperature. Which set of data on the right could be true for X? Circle letter a, b, c, or d.

	Melting point / °C	Boiling point / °C
a	–112	–108
b	–7	58
c	0	100
d	30	2400

[1]

3 Pure hexane condenses at 69°C and freezes at –95°C. Which set of data on the right could be true for a sample of *impure* hexane? Circle letter a, b, c, or d.

	Melting point / °C	Boiling point / °C
a	70	–93
b	68	–96
c	–94	67
d	–97	71

[1]

4 A mixture of barium sulfate and sodium chloride can be separated by adding water, stirring, and then filtering.

(a) Suggest one reason why this method is used to separate the two chemicals.

..... [1]

(b) Draw a diagram in this box, to show how the mixture is filtered.

Mark where the two chemicals are, after the separation, on your diagram.

[2]

(c) One chemical passes through the filter paper. The other does not. Explain why.

.....

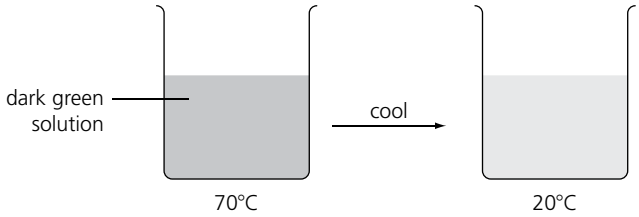
..... [1]

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Name:

5 A green compound is more soluble in hot water than in cold water. A saturated solution of the compound is left to cool from 70°C.

(a) Complete the diagram to show what will be seen when the solution has cooled to 20°C.



(b) How would you show that the solution at 70°C was saturated?

.....

[1]

(c) What colour would you expect the liquid to be 20°C? Give one reason.

.....

[1]

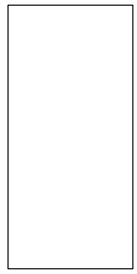
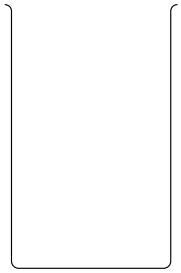
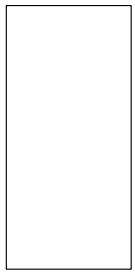
(d) Name the process that takes place in the beaker as the solution cools.

.....

[1]

6 A mixture of two water-soluble dyes can be separated by paper chromatography.

(a) You have a piece of chromatography paper, a glass dropper, a beaker, a ruler, and a pencil. Complete these diagrams to show:

(i) the correct place to put a spot of the mixture on the chromatography paper	**(ii)** the correct level of water in the beaker	**(iii)** the appearance of the paper at the end of the experiment
 chromatography paper	 beaker	 chromatogram

[3]

(b) The two dyes are different compounds, so they have different solubilities in solvent. Use the idea of solubility to explain *why* they can be separated using chromatography.

.....

.....

[1]

[Total: 15]

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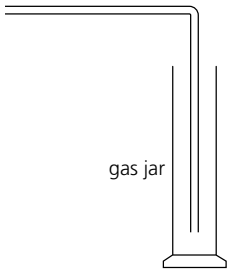
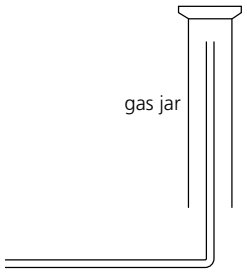
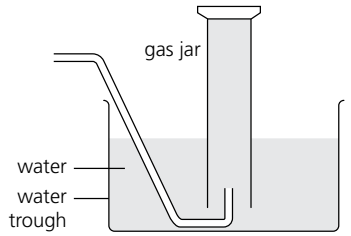
Ion identification

1 The table shows three ways of collecting gases in the laboratory.

(a) For each method:

(i) give the essential property the gas must have to allow collection in this way

(ii) name a gas that could be collected in this way.

Collection method			
(i) Essential property			
(ii) Example			

[2]

(b) In this box, draw and label one piece of apparatus that could be used to collect all three gases you named.

[1]

2 **(a)** What are anions? ..... **[1]**

(b) Complete this table, giving formulae and details of the tests for anions.

Ion	Formula	Test	Observation
chloride			white precipitate forms
iodide			yellow precipitate forms
sulfate			white precipitate forms
nitrate			ammonia gas released
carbonate			fizzing, and the gas that is released turns limewater milky

[3]

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Name: .....

3

(a) What are cations? ..... **[1]**

(b) Complete these three tables, giving formulae and details of the tests for cations.

Ion	**Iron(II)**	**Iron(III)**	**Copper(II)**
Formula			
Test			
Observation	green precipitate forms	red-brown precipitate forms	pale blue precipitate forms

[2]

Ion	**Aluminium**	**Calcium**	**Zinc**
Formula			
Test 1			
Observation	white precipitate forms	white precipitate forms	white precipitate forms
Test 2			
Observation	no change	no change	precipitate dissolves
Test 3			
Observation	the precipitate dissolves	no change	

[3]

Ion	**Ammonium**
Formula	
Test	
Observation	ammonia gas given off (turns damp red litmus blue)

[2]

[Total: 15]

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Name: .....

States of matter

1 Which change of state involves particles losing energy and moving closer together? Circle letter a, b, c, or d.

(a) gas to liquid **(b)** liquid to solid **(c)** solid to liquid **(d)** liquid to gas

[1]

2 The table shows melting and boiling points for four substances. In which are the particles in an ordered arrangement at room temperature? Circle letter a, b, c, or d.

	Melting point / °C	**Boiling point / °C**
a	– 115	79
b	– 91	– 88
c	80	218
d	– 23	77

[1]

3 A pure sample of ethanoic acid was heated from 10°C. The temperature was recorded at intervals of one minute. These are the results:

Time / min	0	1	2	3	4	5	6	7	8	9
Temperature / °C	10	17	17	17	17	17	20	40	60	80
Time / min	10	11	12	13	14	15	16	17	18	19
Temperature / °C	100	118	118	118	118	118	118	135	160	185

(a) Plot a graph to show how the temperature changes with time:

[3]

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(b) Add these two labels in the correct places on your graph:

- melting point
- boiling point

[2]

(c) Which change takes place between the first and fifth minutes? ..... **[1]**

(d) Identify a **time** when the ethanoic acid is evaporating, but not boiling: ..... **[1]**

(e) Identify a **temperature** at which all the particles of ethanoic acid are:

(i) moving around slowly, in a random way ..... **[1]**

(ii) vibrating about a fixed position ..... **[1]**

(iii) able to fill the available volume ..... **[1]**

(f) Ethanoic acid is cooled from 150°C to 0°C.

Sketch a curve in this box to show how its temperature will change over time.

Add these labels in the correct places:

- liquefying
- solidifying

[4]

4 Liquid bromine forms a red-brown vapour when placed in the bottom of a gas jar. Bromine is heavier than air.

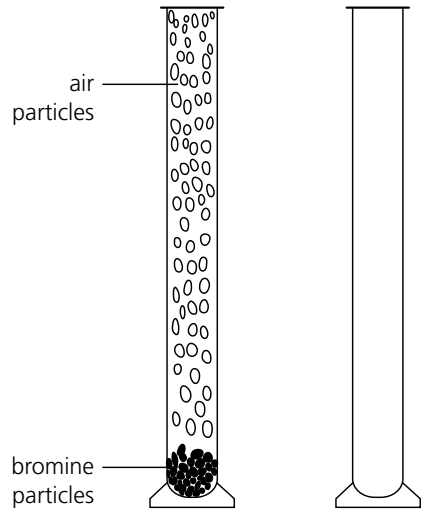
(a) Draw particles in the empty gas jar, to show how their distribution will have changed after 24 hours. **[1]**

(b) Fill in the missing words.

(i) Diffusion is caused by the ..... movement of particles. **[1]**

(ii) Cross out the incorrect one in each pair in italics.

The bromine particles in the gas jar moved from where their concentration was *high* / *low* to where it was *high* / *low*. Over time, the concentration of the bromine particles became *zero* / *the same* all through the gas jar. **[1]**



(c) Diffusion takes place in liquids too. Suggest one way to demonstrate this in the lab.

.....

.....

..... **[1]**

[Total: 20]

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Name: . . . . . .

Atoms and elements

1 Complete the statements **a–f** below by writing the letter **s**, **d**, **m**, or **f** in each box.

Key	
s = the same number of	**m** = more
d = a different number of	**f** = fewer

(a) Two atoms of the same element have ☐ protons, and ☐ electrons. **[1]**

(b) Compared to its atom, a positive ion has ☐ protons, and ☐ electrons. **[1]**

(c) Compared to its atom, a negative ion has ☐ protons, and ☐ electrons. **[1]**

(d) Two isotopes of the same element have ☐ protons, and ☐ neutrons. **[1]**

(e) All atoms of uranium-235 have ☐ neutrons, and ☐ electrons. **[1]**

(f) Compared to atoms of elements in Period 3, atoms of elements in Period 2 have ☐ protons and ☐ electrons. **[1]**

2 This table is about isotopes of some common elements. Complete it.

Isotope	Name of element	Proton number	Nucleon number	Number of		
				p	**e**	**n**
$^{16}_{8}O$	oxygen	8	16	8	8	8
$^{18}_{8}O$						
$^{12}_{6}C$						
$^{13}_{6}C$						
$^{24}_{12}Mg$						
$^{25}_{12}Mg$						
				17	17	18
				17	17	20

[3]

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Name: .....

3 The table describes the structures of four ions. Give the formula for each ion, using the Periodic Table to help you.

Number of protons	Number of neutrons	Number of electrons	Formula of ion
9	10	10	
16	16	18	
3	4	2	
20	20	18	

[3]

4 **(a)** This table is about five atoms P, Q, R, S, and T. (These letters are *not* their chemical symbols.) Complete the table to show their electron distribution.

Atom	Proton number	Electron distribution			
		1st shell	2nd shell	3rd shell	4th shell
P	2				
Q	4				
R	13				
S	15				
T	19				

[3]

(b) How many valence electrons does atom R have? ..... **[1]**

(c) How many of the atoms are from Period 2 of the Periodic Table? ..... **[1]**

(d) Which two atoms belong to the same group of elements? ..... **[1]**

(e) Draw a diagram to show the arrangement of the electrons in atom T.

[2]

[Total: 20]

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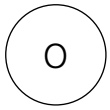
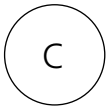
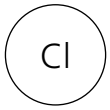
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Atoms combining I

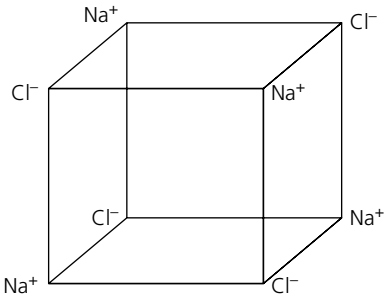
1 This is about the bonding in molecules of water, methane, and hydrogen chloride.

(a) First, draw hydrogen atoms in the boxes to complete the structures of the molecules. **[1]**

(b) Then use • and × to show their bonding. (Use × for an electron from hydrogen.) **[1]**

		
water	methane	hydrogen chloride

2 This diagram shows the structure of a common substance.



(a) Extend the structure to the right, by adding four more ions. **[1]**

(b) **(i)** Name the substance that has this structure.

..... **[1]**

(ii) Which type of bonding does it have? ..... **[1]**

(c) By studying the structure, it is possible to predict several properties of the substance.

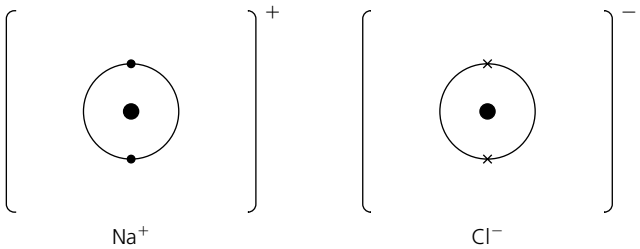
Underline the most likely property for the solid in each pair below.

(i) *solubility in water* soluble/insoluble

(ii) *melting point* / °C 59/801

(iii) *electrical conductivity* good/poor **[3]**

(d) Complete the diagrams for the ions in the structure, to show their electron arrangement. Show the missing electron shells. (The dark circles show the nucleii.)



[1]

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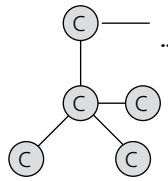
(e) Explain how electrons are transferred, when the ions in (d) are formed from their atoms.

.....

.....

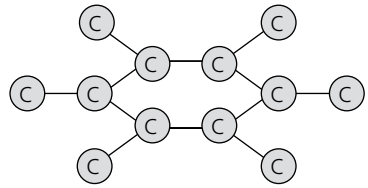
..... **[1]**

3 These diagrams show part of the structures of diamond and graphite.



.....

.....



.....

(a) Which do these structures represent—elements or compounds? ..... **[1]**

(b) Fill in the three missing labels for the atom and two structures. **[1]**

(c) Describe the differences in the bonding and structure of graphite and diamond. **[1]**

bonding .....

.....

structure .....

..... **[2]**

(d)

(i) One of the two substances is very hard, and the other is soft. Explain this difference.

.....

.....

.....

..... **[2]**

(ii) Which substance is therefore used in cutting tools, and which is used as a lubricant?

cutting tools: ..... lubricant: ..... **[2]**

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Name: . . . . . .

(e) One substance is an insulator, and the other is a good conductor of electricity. Explain this difference.

.....

.....

..... **[1]**

[Total: 20]

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Name:

Atoms combining II

1 Draw dot and cross diagrams for the following covalent compounds. Draw a key to explain the symbols you have chosen.

(a) HCl

(b) O_2

(c) CO_2

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Name: . . . . . .

(d) C_2H_6

(e) C_2H_4

[5]

2 Draw dot and cross diagrams of the ions present in the following ionic compounds:

(a) NaCl

(b) MgO

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Name:

(c) CaO

(d) Na_2O

(e) $CaCl_2$

[5]

3 Draw the molecular structure of a named metal and explain why metallic bonding is considered a form of ionic bonding.

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Name: .....

.....

.....

..... **[3]**

4 Whatever the type of bonding, atoms share electrons or form ions in order to reach the electronic configuration of the noble elements. Draw a dot and cross diagram for carbon monoxide CO so that the atoms attain noble gas configuration.

[2]

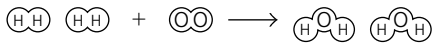
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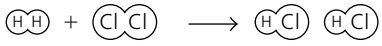
Reacting masses and chemical equations

1 Write a word equation and a chemical equation for each of these chemical reactions:

Example 

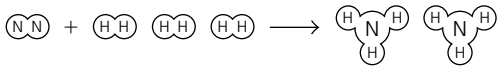
Word equation: hydrogen + oxygen ⟶ water

Chemical equation: $2H_2 + O_2 \longrightarrow 2H_2O$

(a) 

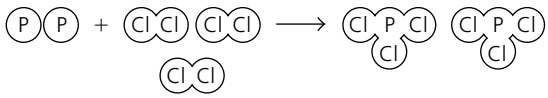
Word equation: .....

Chemical equation: ..... **[2]**

(b) 

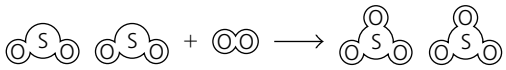
Word equation: .....

Chemical equation: ..... **[2]**

(c) 

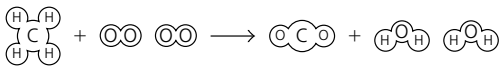
Word equation: .....

Chemical equation: ..... **[2]**

(d) 

Word equation: .....

Chemical equation: ..... **[2]**

(e) 

Word equation: .....

Chemical equation: ..... **[2]**

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Name: .....

2 Complete and balance these equations. (__ is for a number, and …….. for a formula.)

(a) the neutralization of phosphoric acid using potassium hydroxide

__KOH + H_3PO_4 ⟶ K_3PO_4 + **__**H_2O **[1]**

(b) the precipitation of lead(II) iodide from solutions of lead(II) nitrate and potassium iodide

$Pb(NO_3)_2$ + __ ..... ⟶ PbI_2 + **__**KNO_3 **[1]**

(c) the cracking of hexane, giving butene and ethane

C_6H_{14} ⟶ C_4H_8 + **[1]**

(d) the complete combustion of pentane, giving carbon dioxide and water

C_5H_{12} + **__**O_2 ⟶ **__**CO_2 + __ ..... **[1]**

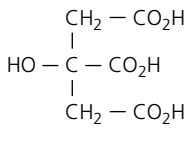
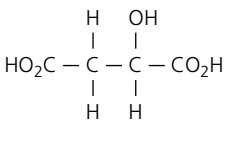
(e) the thermal decomposition of sodium nitrate to sodium nitrite and oxygen

__$NaNO_3$ ⟶ **__**$NaNO_2$ + ... **[1]**

(f) the displacement of silver from a solution of silver nitrate by copper

Cu + **__**$AgNO_3$ ⟶ $Cu(NO_3)_2$ + __ ..... **[1]**

3 80 g of a mixture is found to contain 35 g of citric acid and 42 g of malic acid. The rest comists of impurities. Complete rows **a** – **e** in this table for the mixture.

	Name of acid	**Citric acid**	**Malic acid**
	Structural formula of the acid		
(a)	How many atoms are there in one molecule of the acid?		
(b)	What is the molecular formula of the acid? (Give it in the form $C_xH_yO_z$.)	C ..... H ..... O	C ..... H ..... O .....
(c)	What is its relative molecular mass? (A_r: H = 1, C = 12, O = 16)		
(d)	What is the % of carbon in the acid?		
(e)	What % of the mixture is impurities?		

[9]

[Total: 25]

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Name: .....

Using moles

1 Masses from moles, and moles from masses

Remember

- **the mass of a substance (in grams) = no of moles × mass of 1 mole**
- **the mass of one mole is the A_r or M_r of the substance, given in grams**

Complete the table.

Substance	A_r or M_r	Number of moles	Mass / g
Cu		2	
Mg		0.5	
Cl_2			35.5
H_2		8	
P_4		2	
O_3			1.6
H_2O			54
CO_2		0.4	
NH_3			8.5
$CaCO_3$			100

(A_r values: H = 1, C = 12, N = 14, O = 16, Mg = 24, P = 31, Cl = 35.5, Ca = 40, Cu = 64) **[1]**

2 Masses and equations

(a) What mass of iron(III) oxide is needed to produce 100 g of iron in the blast furnace?

Equation: Fe_2O_3 (*s*) + 3CO (*g*) ⟶ 2Fe (*s*) + $3CO_2$ (*g*) (A_r: O = 16, Fe = 56)

100 g of iron is ..... moles of Fe, so ..... moles of Fe_2O_3 are needed, or ..... g of iron(III) oxide. **[2]**

(b) 0.05 moles of aluminium is reacted with 26 g of iodine. Which one is the *limiting* reagent?

Equation: 2Al (*s*) + $3I_2$ (*s*) ⟶ $2AlI_3$ (*s*) (A_r: Al = 27, I = 127)

26 g of I_2 is ..... moles of I_2. From the equation, this will react with ..... moles of Al. **[2]**

So the limiting reagent is .....(The other reagent is *in excess*.)

(c) 6.21 g of lead (Pb) is heated in oxygen and gives 6.85 g of lead oxide.

What is the equation for the reaction? (A_r: O = 16, Pb = 207)

The mass of oxygen that takes part in the reaction is .....g, which is ..... moles of O_2. The number of moles of Pb in 6.21 g of lead is .....

So the balanced equation is ..... **[2]**

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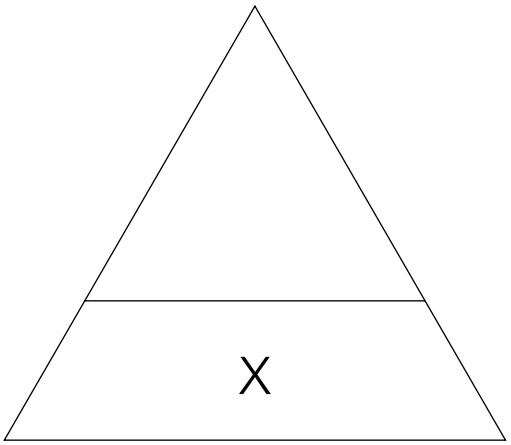
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3 Calculations involving solutions

Remember, for a solution:

- **no of moles of solute = volume (dm^3) × concentration (mol/dm^3)**
- **1 dm^3 = 1000 cm^3**

Fill in the calculation triangle below, for moles of solute, volume, and concentration. Then complete the table.



Solute	Volume of solution	Concentration of solution (mol/dm^3)	Moles of solute in it
sodium chloride	1 dm^3	2	
hydrochloric acid	100 cm^3	0.5	
sodium hydroxide	2 dm^3		1
sulfuric acid	250 cm^3		0.5
ammonium nitrate		2	0.3
copper(II) sulfate		0.25	0.75

[2]

4 Concentration and equations

(a) 25 cm^3 of 0.2 mol/dm^3 sodium hydroxide (NaOH) neutralizes 10 cm^3 of dilute sulfuric acid (H_2SO_4). What is the concentration of the sulfuric acid?

Equation: $2NaOH\ (aq) + H_2SO_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + H_2O\ (l)$

..... moles of NaOH are used, so they neutralize ..... moles of H_2SO_4.

So the concentration of the sulfuric acid is ..... mol/dm^3. **[2]**

(b) What mass of magnesium will react with 250 cm^3 of 2 mol/dm^3 hydrochloric acid?

Equation: $Mg\ (s) + 2HCl\ (aq) \longrightarrow MgCl_2\ (aq) + H_2\ (g)$ (*A*r: Mg = 24)

..... moles of HCl are present, so ..... moles of Mg will react with them.

So the mass of magnesium that will react is ..... g. **[2]**

(c) What volume of 0.05 mol/dm^3 potassium manganate(VII) ($KMnO_4$) will be reduced by 25 cm^3 of 0.2 mol/dm^3 iron(II) sulfate ($FeSO_4$) solution?

Ionic equation: $MnO_4^-\ (aq) + 5Fe^{2+}\ (aq) + 8H^+\ (aq) \longrightarrow Mn^{2+}\ (aq) + 5Fe^{3+}\ (aq) + 4H_2O\ (l)$

..... moles of $FeSO_4$ are used. From the equation, these will react with ..... moles of $KMnO_4$. So the volume of potassium manganate(VII) solution reduced is ..... cm^3. **[2]**

[Total: 15]

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Name:

Balancing equations

An equation is a symbolic representation of a chemical reaction.

A balanced chemical equation describes a ratio in which reactants combine to form products. A chemical change may occur in one step or in a series of steps that can be added up algebraically to get the overall reaction. This technique is useful in electrode reactions, redox reactions, and organic reactions. Each equation in a series should be written on a separate line. The rules to be followed are:

- All symbols and formulae with the same sign should be added and those with opposite signs should be subtracted.
- Same symbols and formulae on both sides of the equation should be cancelled out.
- Electrons should be balanced just like other reactants and products. For example, following equations represent the changes taking place at the anode and the cathode during electrolysis of water:

  $\mathbf{H_2O} \longrightarrow H^+ + OH^-$

  $\mathbf{2H^+} + 2e^- \longrightarrow H_2$

  $\mathbf{OH^-} - e^- \longrightarrow OH$

  $\mathbf{2OH^-} \longrightarrow H_2O + O$

  $\mathbf{O} + O \longrightarrow O_2$

Since equation 5 requires two oxygen atoms and equation 4 produces only one, therefore equation 4 should be multiplied by 2.

Since equation 4 now requires four OH groups and equation 3 produces only one, equation 3 should be multiplied by 4.

Similarly equation 1 needs to be multiplied by 4 and equation 2 by 2 to balance the number of hydrogen ions. The equations would then be rewritten as:

$4H_2O \longrightarrow 4H^+ + 4OH^-$

$4H^+ + 4e^- \longrightarrow 2H_2$

$4OH^- - 4e^- \longrightarrow 4OH$

$4OH^- \longrightarrow 2H_2O + 2O$

$2O \longrightarrow O_2$

$4H_2O \longrightarrow 2H_2 + O_2$

1 Balance the following equations and write the summation for each:

(a) Reaction between sulfuric acid and sodium hydroxide

.....

.....

.....

..... **[3]**

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Name:

(b) Reaction between iron oxide and carbon monoxide

.....

.....

.....

..... **[3]**

(c) Reaction between sulfuric acid and manganese dioxide

.....

.....

.....

..... **[4]**

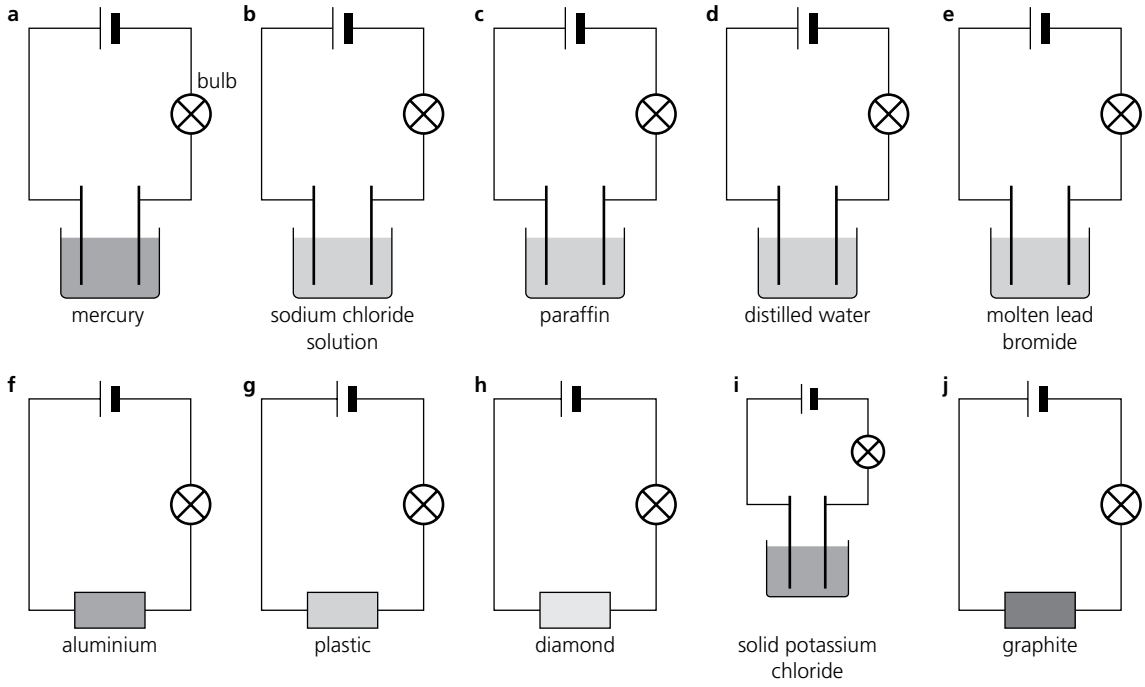
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Name: .....

Electricity and chemical change

1 (a) For **a**–**j** below, circle the letter if the bulb will light. Cross it out if the bulb will not light.



[2]

(b) For the substances above where the bulb lights, which will decompose?

..... **[1]**

2 Which row shows the products at the anode and cathode during electrolysis? Circle its letter.

	At the anode	At the cathode
a	metals	non-metals (except hydrogen)
b	metals	non-metals, including hydrogen
c	non-metals, including hydrogen	metals
d	non-metals (except hydrogen)	metals or hydrogen

[1]

3 Which row shows the products from the electrolysis of concentrated sodium chloride solution? Circle its letter.

	Positive electrode	Negative electrode
a	hydrogen	oxygen
b	hydrogen	chlorine
c	oxygen	hydrogen
d	chlorine	hydrogen

[1]

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Name: .....

4 Strontium chloride ($SrCl_2$) is melted and electricity is passed through it using inert electrodes.

Strontium is a reactive metal from Group II of the Periodic Table.

(a) Write ionic equations for the reactions at the electrodes:

At the cathode (–): ..... **[1]**

At the anode (+): ..... **[1]**

(b) Name the three products obtained from the electrolysis of concentrated aqueous strontium chloride.

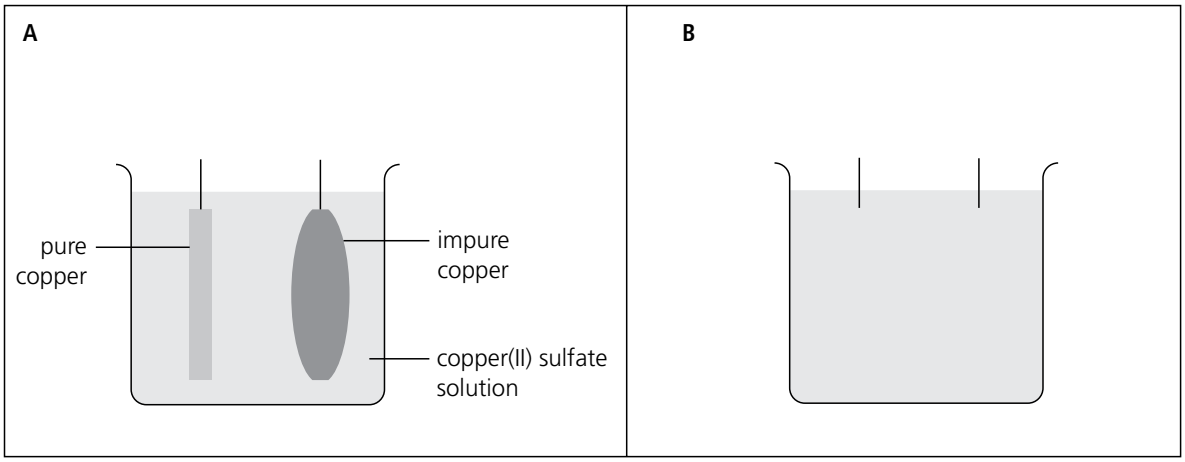
..... **[1]**

5 The diagrams below are to show apparatus for purifying copper by electrolysis.

(a) In diagram A:

(i) add a battery and wires to complete the circuit **[1]**

(ii) mark + and – on the correct electrodes **[1]**



(b) Complete diagram B to show when electrolysis is almost complete.
Mark in the battery, wires, electrodes, electrolyte, and impurities. **[2]**

(c) Write the half-equation for the reaction:

(i) at the positive electrode ..... **[1]**

(ii) at the negative electrode ..... **[1]**

(d) Give one use of copper that requires it to be very pure.

..... **[1]**

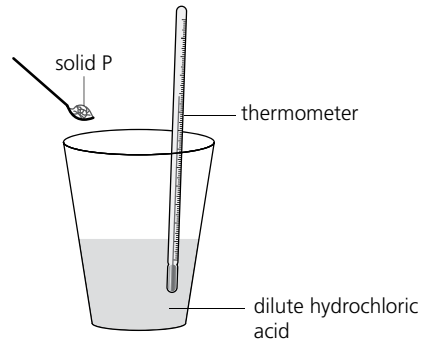
[Total: 15]

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Name: .....

Energy changes and reversible reactions I

1 The apparatus on the right is used to measure temperature changes during reactions in solution.



Dilute hydrochloric acid is placed in the polystyrene cup and its temperature recorded.

Some quantity of solid P is added. The mixture is continuously stirred and the temperature is checked regularly.

When there is no further change in temperature, the final temperature is recorded.

The experiment is repeated with solid Q.

This table shows the results:

Solid	Initial temperature/°C	Final temperature/°C	Temperature change/°C
P	20	33	+13
Q	20	12	+8

(a)

(i) Why is it important to stir continuously during the experiment?

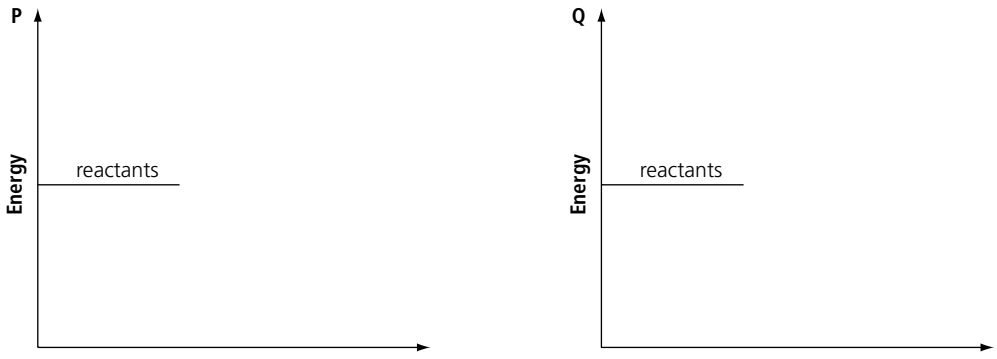
..... **[1]**

(ii) If the solution is put directly into the glass beaker, without the polystyrene cup, how will the results be affected?

.....

..... **[1]**

(b) Complete these energy diagrams for the two reactions by marking in the lines for the products and up or down arrows to show the energy change:



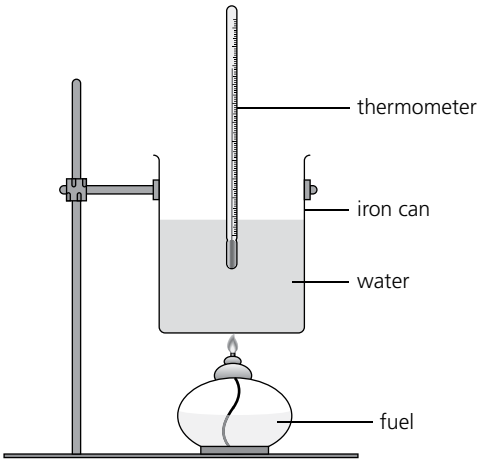
[1]

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Name:

2 You can compare the energy given out by different fuels using the apparatus on the right.



(a) What change will you observe to confirm that the reaction is exothermic?

.....

..... **[1]**

(b) What precautions will you take to make sure you are comparing the fuels in a fair test?

(i) **for the fuels** I will .....

..... **[1]**

(ii) **for the water** I will .....

..... **[1]**

(c) Suggest one change to the apparatus that will improve the accuracy of the comparison.

.....

..... **[1]**

(d) Complete and balance this equation for the combustion of ethanol when it is used as the fuel:

$C_2H_5OH + __ O_2 \longrightarrow$ ..... **[1]**

3 **(a)** Complete the table for this reversible reaction: $CuSO_4.5H_2O\ (s) \rightleftharpoons CuSO_4\ (s) + 5H_2O\ (l)$

Compound	Full chemical name	Colour
$CuSO_4.5H_2O$		
$CuSO_4$		

(b) How would you demonstrate that the reaction in **(a)** is reversible?

.....

.....

..... **[1]**

[Total: 10]

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Name:

Energy changes and reversible reactions II

The enthalpy or heat content of a system cannot be estimated because all the energy is stored within chemical bonds. However, ΔH or enthalpy change can be measured. Bond breaking is an endothermic process. Bond making is an exothermic process.

$\Delta H = H_p$ (products) – H_r (reactants)

Some bond energy values are given below:

Bond	Energy values / KJ mol^{-1}
O=O	498
C–H	435
C=O	805
O–H	464
C–C	348
C=C	612
C–O	452

1 $N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$ $\Delta H = -92.22$ KJ mol^{-1}.

What would be the sign of ΔH for the reaction below?

$2NH_3\,(g) \longrightarrow N_2\,(g) + 3H_2\,(g)$

.....

..... **[2]**

2 $CH_2{=}CH_2\,(g) + 3O_2\,(g) \longrightarrow 2CO_2\,(g) + 2H_2O\,(g)$ $\Delta H = ?$

(a) Calculate the value of enthalpy for bond breaking in the reactants.

.....

..... **[2]**

(b) Calculate the value of enthalpy for bond making in the products.

.....

..... **[2]**

(c) Calculate the overall value of ΔH for the complete reaction.

.....

..... **[2]**

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Name:

3 Petrol is used as a fuel in cars. However, many cars in Brazil run on ethanol. The chemical equations for the combustion of the two fuels are given below:

Combustion of ethanol

$C_2H_5OH\ (l) + 3O_2\ (g) \longrightarrow 2CO_2\ (g) + 3H_2O\ (g)$

Combustion of petrol

$C_5H_{12}\ (l) + 8O_2\ (g) \longrightarrow 5CO_2\ (g) + 6\ H_2O\ (g)$

Use the table given above to:

(a) Calculate ΔH for the combustion of ethanol.

.....

..... **[3]**

(b) Calculate ΔH for the combustion of petrol.

.....

..... **[3]**

(c) Use the values you arrived at in parts (a) and (b) to predict which is a more energy efficient fuel?

.....

..... **[1]**

[Total: 15]

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Name:

Fuel cells

Fossil fuels such as coal, oil, and gas, are used to provide energy for daily use. However, fossil fuels are a limited resource and cause a lot of pollution. Fuel cells are pollution-free because they use hydrogen and oxygen as their raw materials and produce water. Fuel cells are of two types: acid fuel cells and alkali fuel cells

Hydrogen gas is introduced at the negative electrode. It is converted to positive ions. Oxygen gas is introduced at the positive electrodes to form hydroxide ions. The hydrogen ions H^+ and the hydroxide ions OH^- form water.

1 What is the difference between the external circuit of a normal cell and an electrolytic cell?

.....

..... **[1]**

2 Write down the reaction that takes place at the cathode in an acid fuel cell.

.....

..... **[2]**

3 What happens to oxygen at the anode in an acid fuel cell?

.....

..... **[1]**

4 Differentiate between an acid fuel cell and an alkali fuel cell.

.....

..... **[2]**

5 State three advantages and one disadvantage of using a fuel cell to provide energy.

.....

..... **[4]**

[Total: 10]

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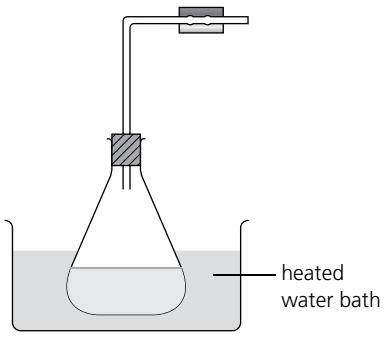
The rate of reaction

1 Nitrogen gas is insoluble in water. It is produced in the reaction between warm solutions of ammonium chloride and sodium nitrite:

$NH_4Cl\,(aq) + NaNO_2\,(aq) \longrightarrow NaCl\,(aq) + 2H_2O\,(l) + N_2\,(g)$

The rate of the reaction can be followed by measuring the volume of gas given off over time.

(a) The gas can be collected over water. Complete this diagram to show the apparatus needed:



[1]

(b) This table shows the results when the reaction is carried out at 70°C.

Time/min	0	1	2	3	4	5	6	7	8	9	10
Volume/cm^3	0	20	32	43	45	54	57	58.5	59.5	60	60

Plot a graph of volume against time, on a piece of graph paper. Join the points with a smooth curve that fits the points best. Then attach your graph to this worksheet. **[4]**

(c)

(i) Using your graph to help you, describe how the rate of the reaction varies with time.

.....

..... **[1]**

(ii) Why does the rate vary?

.....

..... **[1]**

(d)

(i) One of the results is *anomalous*—it does not fit the pattern. Circle that point on your graph. **[1]**

(ii) Suggest a reason for the anomalous result:

.....

..... **[1]**

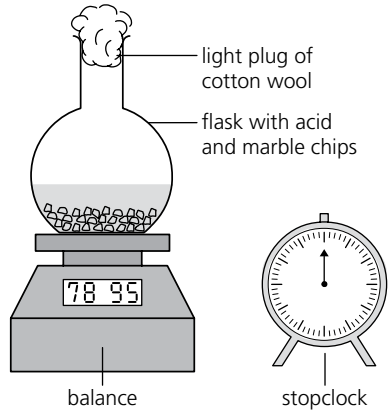
(e) The reaction is repeated at 80°C. Draw a rough sketch of the graph you would expect to obtain on the same axes as your graph in (b). **[4]**

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Name:

2 An experiment is carried out to investigate the rate of reaction between dilute hydrochloric acid and an excess of calcium carbonate in the form of marble chips:

$CaCO_3\ (s) + 2HCl\ (aq) \longrightarrow CaCl_2\ (aq) + H_2O\ (l) + CO_2\ (g)$



(a) What do you observe in the flask when the acid is added to the marble?

.....

..... **[1]**

(b) What is the purpose of the cotton wool?

..... **[1]**

(c) Why is there a loss of mass as the reaction proceeds? .....

..... **[1]**

3 The experiment in question 2 is repeated, keeping everything the same except the concentration of the acid. Two different concentrations A and B are used. Look at the results in this table.

Concentration of the acid	Loss of mass in first minute / g
A	0.5
B	1

(a) Which acid has a higher concentration, A or B?..... **[1]**

(b) Explain in terms of collisions between reacting particles why one reaction is faster.

.....

..... **[1]**

4 The experiment in question 2 is repeated, changing only the initial temperature of the acid.

Two temperatures C and D are used.

The results are shown in this table.

Initial temperature of the acid °C	Loss of mass in first minute / g
C	0.5
D	2

(a) Which temperature is higher, C or D? ..... **[1]**

(b) Explain, in terms of collisions between reacting particles, why one reaction is faster.

.....

..... **[1]**

[Total: 20]

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Name: .....

Redox reactions

In questions 1–3, circle letter a, b, c, or d.

1 A redox reaction is one in which ...

(a) oxidation and reduction take place together

(b) reduction takes place, but oxidation does not

(c) reduction occurs first, then oxidation

(d) reduction occurs after oxidation **[1]**

2 A reducing agent ...

(a) always contains hydrogen

(b) is oxidized in a redox reaction

(c) loses oxygen in a redox reaction

(d) is reduced in a redox reaction **[1]**

3 Iron(II) oxide can be oxidised to form iron(III) oxide. The (II) and (III) show ...

(a) the number of iron atoms in the two oxides

(b) the number of oxygen atoms added in the oxidation

(c) the oxidation state of the iron in the two oxides

(d) the nucleon number of the iron in the two oxides **[1]**

4 When hydrogen is passed over copper(II) oxide, this reaction takes place:

$CuO\ (s) + H_2\ (g) \longrightarrow Cu\ (s) + H_2O\ (l)$

(a) It is a redox reaction, because .....

..... **[1]**

(b) The reducing agent in this reaction is ..... **[1]**

5 This reaction takes place in the blast furnace: $Fe_2O_3\ (s) + 3CO\ (g) \longrightarrow 2Fe\ (l) + 3CO_2\ (g)$

(a) The word equation for the reaction is

..... **[1]**

(b) It is a redox reaction, because .....

..... **[1]**

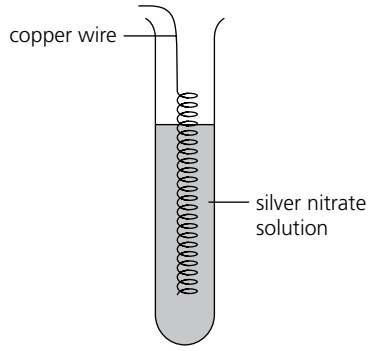
(c) The reducing agent in this reaction is

..... **[1]**

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Name: .....

6 A coil of copper wire (Cu) is placed in a colourless solution of silver nitrate ($AgNO_3$). The solution changes colour.



(a) What colour does the solution go, and why?

.....

..... **[1]**

(b) Write an ionic equation for the reaction that takes place.

..... **[1]**

(c) The copper is said to be oxidized during this reaction. Explain why.

..... **[1]**

7 Explain why this is not a redox reaction: $CuO\ (s) + H_2SO_4\ (aq) \longrightarrow CuSO_4\ (aq) + H_2O\ (l)$

..... **[1]**

8

Group	I	II	III	IV	V	VI	VII	O
Element	sodium	magnesium	aluminium	silicon	phosphorus	sulfur	chlorine	argon
Typical compound	NaCl	MgO	$AlCl_3$	SiO_2	PH_3	H_2S	HCl	none
Oxidation state of element in it	+I	+II	+III	+IV	–III	–II	–I	–

(a) The table above shows one period of the Periodic Table. Which one? ..... **[1]**

(b) Complete the three words. The oxidation state tells you how many electrons an atom has g ....., l ....., or s ....., in forming a compound. **[1]**

(c)

(i) Why are the oxidation states of the elements in the compounds negative after Group IV?

..... **[1]**

(ii) Why do they decrease after Group IV?

..... **[1]**

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Name: .....

(d) Using oxidation states, write the formulae of the compounds formed between:

(i) sodium and sulfur .....

(ii) silicon and chlorine .....

(iii) aluminium and sulfur .....

(iv) magnesium and phosphorus ..... **[4]**

[Total: 20]

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Name: .....

Acids and bases

1 To prepare the salt potassium chloride, 25 cm^3 of potassium hydroxide first titrated against a solution of acid, with phenolphthalein as indicator. Phenolphthalein is colourless in acid solution and pink in alkaline solution.

(a) The drawings below show the apparatus used.

(i) Name each piece. **(ii)** Say what is placed in each during the titration.

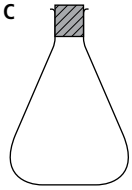
A



B



C



(i) ..... **(i)** ..... **(i)** .....

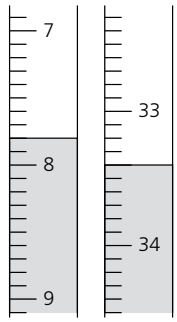
(ii) ..... **(ii)** ..... **(ii)** .....

[3]

(b) Describe the colour change that takes place, showing that neutralization is complete.

..... **[1]**

(c) The first burette on the right shows the initial reading for the titration. The second shows the final reading. Use them to complete this table.



Initial reading/ cm^3	Final reading/ cm^3	Volume used/ cm^3

[3]

(d) To prepare the salt, the titration is then repeated. But there is one important change. State the volumes of acid and alkali that are used, and the change that is made.

..... **[1]**

(e) The final stage is to evaporate water from the mixture obtained in **(d)**. Why is this done?

.....

..... **[1]**

(f) Write the word equation for the neutralization reaction that produces the salt.

..... **[1]**

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Name:

2 Below is a list of twelve salts in alphabetical order. There are four insoluble salts, and four pairs of soluble salts from which these insoluble salts can be made.

barium chloride, barium sulfate, calcium carbonate, calcium nitrate, lead iodide, lead nitrate, potassium iodide, potassium sulfate, silver nitrate, silver chloride, sodium carbonate, sodium chloride

(a) Complete this table using salts from the list.

	This insoluble salt …	**… can be made using this**	**… and this**
1			
2			
3			
4			

[4]

(b) The method for making an insoluble salt from two soluble salts is called ..... **[1]**

(c)

(i) In the table below, write ionic equations for the reactions that produce the four insoluble salts. Include the state symbols (but not the spectator ions).

(ii) Give the formulae for the two spectator ions present at each reaction.

	Ionic equation for the reaction	**Spectator ions**
1		
2		
3		
4		

[4]

3 These are all oxides: dinitrogen oxide calcium oxide phosphorus oxide zinc oxide

(a) Write their names in the correct places in this table and add their chemical formulae.

	Acidic oxide	**Basic oxide**	**Neutral oxide**	**Amphoteric oxide**
Name				
Formula				

[2]

(b)

(i) Which of the four oxides will react with sodium hydroxide? ..... **[1]**

(ii) Which of them will react with hydrochloric acid? ..... **[1]**

(iii) Explain the term *amphoteric*. .....

..... **[2]**

[Total: 25]

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Name:

The Periodic Table

1 Which statement about the Periodic Table is correct? Tick its box.

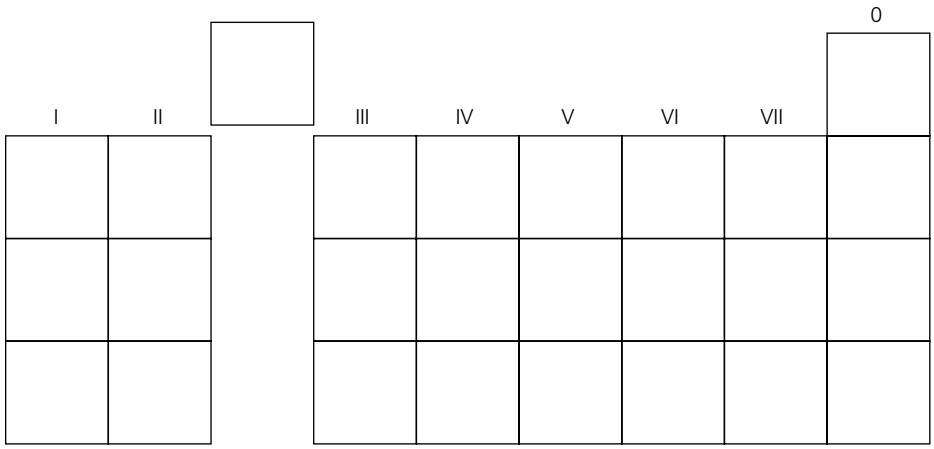
(a) It shows 8 periods. ☐

(b) The elements are arranged in order of their nucleon numbers. ☐

(c) The number of electrons increases by 1 from one element to the next, across a period. ☐

(d) Reactivity increases as you move down each group in the table, except for Group 0. ☐

2 This shows the main groups in the first four periods of the Periodic Table. **[1]**



Statements a–n below describe different elements. Your task is to write the letters a–n, and the symbols for the corresponding elements, in the correct places above.

(a) a solid in Period 2 which is quite soft, floats on water, and reacts steadily with it

(b) the most reactive non-metal element

(c) a green gas that forms diatomic molecules

(d) a liquid that does not conduct electricity

(e) the element that has two forms—graphite and diamond

(f) a gas used to provide an inert atmosphere, e.g. in light bulbs

(g) a colourless gas in which many substances burn readily

(h) of all the element in these four periods, it reacts the most violently with water

(i) the flammable gas produced when metals react with acid

(j) an element which, in ribbon form, burns with a white light, forming ions with a charge of 2+

(k) an unreactive gas that makes up most of the air around us

(l) one compound of this metal is called limestone

(m) a noble gas in Period 4

(n) an alkali metal in Period 3

[7]

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Name: . . . . . .

3 The groups in the Periodic Table show trends in their properties.

(a) Identify two properties that show trends, for Groups I and VII:

I

Li
Na
K
Rb

(i) This increases **down** the group:

.....

(ii) This increases **up** the group:

.....

VII

F
CI
Br
I

(i) This increases **down** the group:

.....

(ii) This increases **up** the group:

.....

[4]

(b) The next element in Group I is caesium. How does it compare to the elements above it for those two properties? ..... **[2]**

(c) The next element in Group VII is astatine. How does it compare to the elements above it for those two properties? ..... **[2]**

4 This table shows observations for reactions between halogens and halide ions.

When this ...	**... is added to a colourless solution containing**		
	chloride ions (Cl^-)	**bromide ions (Br^-)**	**iodide ions (I^-)**
chlorine (Cl_2)	there is no change	the solution turns orange	the solution turns red-brown
bromine (Br_2)	there is no change	there is no change	the solution turns red-brown
iodine (I_2)	there is no change	there is no change	there is no change

(a) **(i)** What is responsible for the orange colour? ..... **[1]**

(ii) What is responsible for the red-brown colour? ..... **[1]**

(b) Explain how these results show that:

(i) chlorine is the most reactive of those three halogens .....

..... **[1]**

(ii) iodine is the least reactive of those three halogens .....

..... **[1]**

[Total: 20]

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Name:

The behaviour of metals I

The reactivity series an arrangement of metallic elements in the order of their standard electrode potentials on the hydrogen scale.

The reactivity series indicates the relative ability of atoms to lose electrons. The higher up in the series a metal is the stronger is its tendency to exist as ions in solution.

1 Why does aluminium always occur in the form of a compound in its ores while gold occurs as nuggets or layers of uncombined gold in rocks?

.....

..... **[2]**

2 Aluminium is high in the reactivity series. Why does it not react with dilute acids whereas zinc does?

.....

..... **[2]**

3 Why does hydrogen reduce copper(II) oxide to copper but has no reaction with zinc oxide?

.....

..... **[2]**

4 Why do all metals excepting some, e.g. copper react with dilute acids?

.....

..... **[2]**

5 Why is the anode of an electrolytic cell always made of a metal higher in the reactivity series?

.....

..... **[1]**

6 How can fitting a magnesium plate on to the iron hull of a ship prevent it from rusting?

.....

..... **[1]**

[Total: 10]

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Name: .....

The behaviour of metals II

1 The first column in the table below lists some general properties of metals.

(a) Complete the second and third columns of the table. Write neatly!

General property of metals	Correct name for this property	One use that depends on this property
can be drawn into wires		
can be bent into shape		
reflect light		
make a ringing sound when struck		
allow electricity to pass through		
heavy for their volume		
their oxides react with acids		
transfer heat well		

[4]

(b)

(i) Which property above is a **chemical** property? ..... [1]

(ii) Some chemical properties apply only to metals high in the reactivity series. Give one example: ..... [1]

(iii) When metals react, they form ions with a ..... charge. [1]

2 Going down Group II in the Periodic Table, you will find magnesium, calcium, and strontium, in that order. Look at these observations:

Observation 1: Magnesium reacts very slowly with cold water, but more vigorously with steam.

Observation 2: Calcium reacts briskly with cold water, with a lot of fizzing.

(a) Those two observations show that reactivity ..... down Group II. [1]

(b)

(i) Predict how strontium will react with cold water. ..... [1]

(ii) Which gas is released in the reaction of those metals with water? ..... [1]

(c) One Group II element reacts with neither water nor steam. Which one? ..... [1]

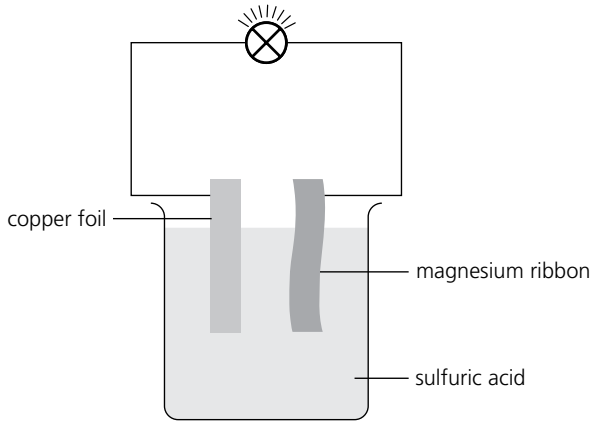
(d) Magnesium reacts with oxygen to form magnesium oxide (MgO). What forms when strontium reacts with oxygen? Give its name and formula. ..... [1]

(e) When magnesium oxide is heated with carbon, no reaction occurs. So carbon is ..... magnesium in the reactivity series. [1]

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Name: .....

3 Strips of copper foil and magnesium ribbon are connected as shown below. The bulb lights up.



(a) Name the electrolyte used: ..... **[1]**

(b) Why does the bulb light up? ..... **[1]**

(c) **(i)** Which metal, copper or magnesium, is more reactive? ..... **[1]**

(ii) Which of them releases electrons into the circuit? ..... **[1]**

(d) On the diagram above, mark in:

(i) the polarity of the two metal strips (using + and –) **[1]**

(ii) the direction in which the electrons flow in the wires **[1]**

(e) Complete this sentence: The arrangement above is an example of a simple .....

in which ..... energy is changed into ..... energy. **[2]**

(f) The set-up shown above would not be used as a torch battery. Give reasons. .....

..... **[1]**

4 In a further experiment, the bulb in 3 is replaced by a voltmeter. Then the copper is replaced by three other metals in turn. This table gives the results.

Metals used	Voltage (V)
magnesium and copper	2.70
magnesium and lead	2.24
magnesium and iron	1.93
magnesium and zinc	1.61

(a) These results show that the voltage depends on

..... **[1]**

(b) Predict the voltage of a cell using copper and zinc.

(A subtraction is needed!) ..... V. **[1]**

(c) Copper is replaced by an unknown metal. The voltage obtained is 3.17 V. What can you say about the unknown metal? ..... **[1]**

[Total: 25]

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Name: .....

Making use of metals

1 Which statement is not correct about metal alloys? Tick its box.

(a) They are attracted to a magnet. ☐

(b) They are mixtures. ☐

(c) They conduct electricity. ☐

(d) They have different properties from pure metals. ☐ [1]

2 Which of these will you choose, if you want a strong light metal that resists corrosion? Tick its box.

(a) aluminium ☐ (b) lead ☐ (c) iron ☐ (d) sodium ☐ [1]

3 Complete this paragraph about the extraction of iron:

Iron is extracted from an ore called ....., in a ..... furnace.

The other ..... materials are coke and ....., Coke is almost

pure ....., and burns in oxygen to form .....,

This reacts with more coke to form ....., which acts as the

..... agent. The two waste gases from the extraction are .....

and ..... [3]

4 For many uses, pure metals are turned into alloys.

(a) What is an alloy? .....

..... [1]

(b) Give two examples of metal properties that can be improved by making alloys.

..... [1]

(c)

(i) There are many different steels. Name the main metal in them: .....

(ii) Other metals are added to this metal to make stainless steel. Name two of them.

..... [2]

(d) Brass is an alloy of the metals ..... and ..... Unlike those two

metals, it has this new property: ..... [1]

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Name: .....

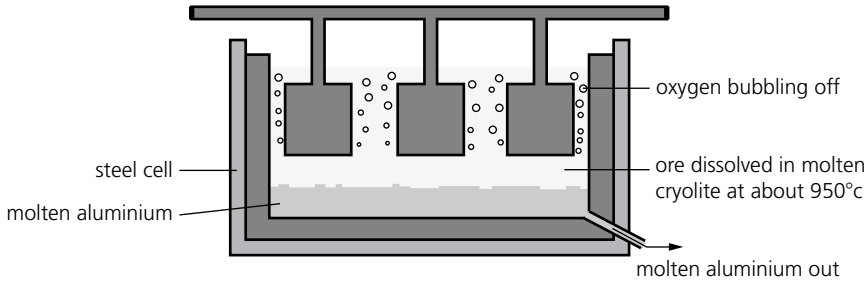
5

(a) Complete these sentences about the extraction of aluminium by electrolysis:

The main ore of aluminium is called ..... The compound obtained from it, for electrolysis, is called ..... and its formula is .....

[1]

(b) This diagram shows a cross-section of the electrolysis cell used in extracting aluminium:



(i) Label the anode and cathode on the diagram. **[1]**

(ii) What are the electrodes made of? ..... **[1]**

(c) One electrode must be replaced at intervals, because it is destroyed in a chemical reaction.

(i) Which electrode is it? ..... **[1]**

(ii) What reaction takes place? ..... **[1]**

(d) Why is cryolite needed? .....

..... **[1]**

(e) During the extraction, aluminium ions are reduced. Give the half-equation for this reaction.

..... **[1]**

6 **(a)** Aluminium has many uses. Give reasons why it is used:

(i) to make food containers ..... **[1]**

(ii) in electricity cables ..... **[1]**

(b) In air, the surface of aluminium becomes quickly coated with a thin layer of aluminium oxide. Comment about the effect of this on the apparent reactivity, and uses, of aluminium.

.....

..... **[1]**

[Total: 20]

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Name: .....

Some non-metals and their compounds

1

(a) Write a word equation for the reaction that takes place when limestone is heated strongly.

..... **[1]**

(b) State one use of limestone in industry. .....

..... **[1]**

2

(a) Using this diagram to help you, explain how greenhouse gases lead to global warming.

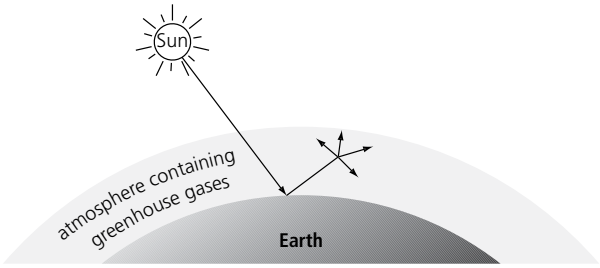
.....

.....

.....

.....

..... **[2]**



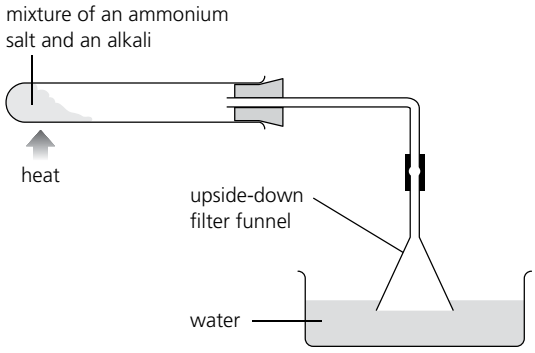
(b) Name two greenhouse gases. ..... **[2]**

3 Ammonia solution can be prepared in the lab using the apparatus on the right.

(a) Name two suitable starting compounds:

.....

..... **[2]**



(b) Without the filter funnel, water will get sucked up into the test-tube. What property of ammonia causes this? ..... **[1]**

(c) A few drops of litmus is added to the trough. What colour does it become?

..... **[1]**

(d) When the water in the trough is replaced by dilute nitric acid, a reaction occurs, producing a salt.

(i) Write a word equation for the reaction.

..... **[1]**

(ii) That salt is a good fertilizer. Why? ..... **[1]**

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Name:

4 Ammonia is manufactured from nitrogen and hydrogen by the Haber process.

(a) These tables show how the raw materials are obtained. Complete the equations.

How the hydrogen is obtained	Equation for the reaction
by reacting methane with steam	..... (*g*) + $2H_2O$ (g) ⟶ .....
by cracking ethane	C_2H_6 (g) ⟶ .....

How the nitrogen is obtained	Equation for the reaction
from the air. The oxygen is removed by burning hydrogen in air, leaving the nitrogen behind unchanged.	N_2 (*g*) 1 O_2 (*g*) + ... ⟶ N_2 (*g*) + ... in air

[3]

(b) The reaction between nitrogen and hydrogen is reversible, and reaches equilibrium:

N_2 (*g*) + $3H_2$ (*g*) ⇌ $2NH_3$ (*g*)

Answer the questions in this table about the conditions used in the Haber process. Write neatly!

Conditions	Questions
High pressure (200 atmospheres)	Why is high pressure used?
Moderate temperature (450ºC)	A higher temperature would speed up the reaction. So why is a moderate temperature used?
Catalyst: iron	A catalyst does not increase the yield, in a reversible reaction. So why is one used?
Reaction mixture is cooled and ammonia is removed as a liquid.	How does cooling the mixture help to improve the yield of ammonia?
The unreacted gases are recycled.	Why are the unreacted gases recycled?

[5]

[Total: 20]

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Name: .....

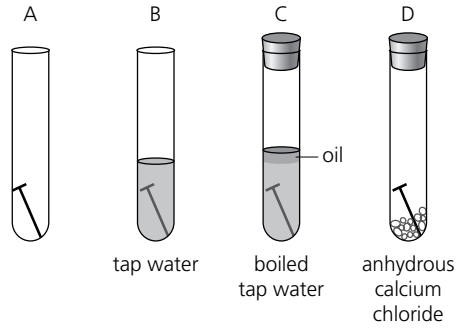
Air and water

1 Which gas is not a part of the composition of clean air? Tick its box.

(a) carbon dioxide ☐ **(b)** nitrogen ☐ **(c)** argon ☐ **(d)** hydrogen ☐

[1]

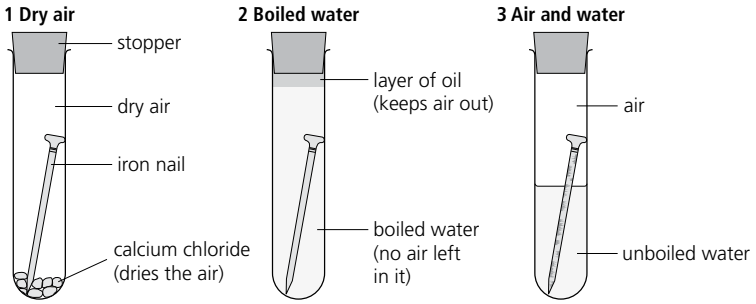
2 This diagram shows tests for water. Write word equations for the reactions taking place.



In A: ..... **[1]**

In B: ..... **[1]**

3



(a) Look at the experiment above. What would you expect to see in each test tube, after 1 week?

Test tube 1: .....

Test tube 2: .....

Test tube 3: ..... **[3]**

(b) What can be deduced from this experiment? .....

..... **[1]**

(c) Name two methods for preventing rusting. ..... **[1]**

(d) The equation for rusting is: $4Fe\ (s) + 3O_2\ (g) + 4H_2O\ (l) \longrightarrow 2Fe_2O_3{\cdot}2H_2O\ (s)$

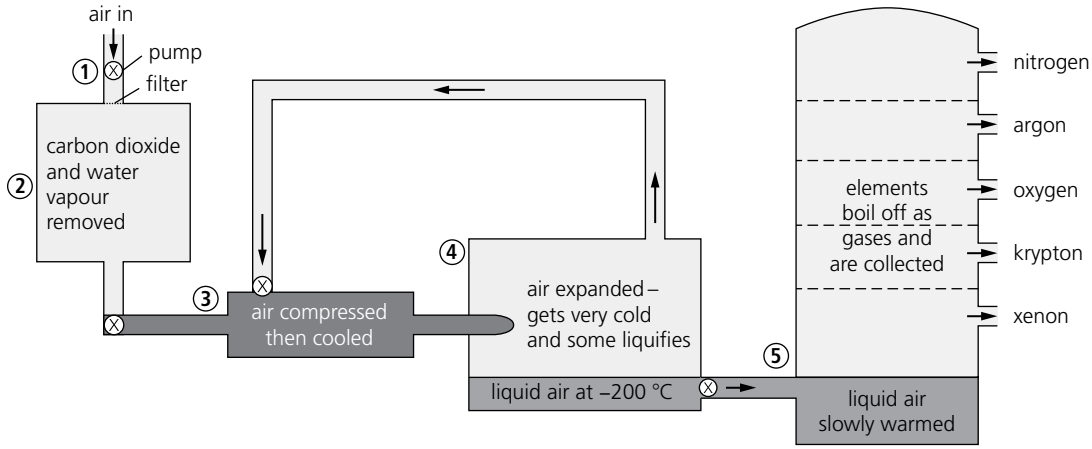
Write it as a word equation.

..... **[1]**

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Name:

4 This diagram shows the five stages in the fractional distillation of liquid air:



(a) Carbon dioxide (which solidifies at – 80 °C) and water vapour are removed at stage 2. Why?

..... **[1]**

(b) Two noble gases are removed at stage 4.

(i) Which noble gases are they? ..... **[1]**

(ii) What does this tell you about their boiling points? ..... **[1]**

(c)

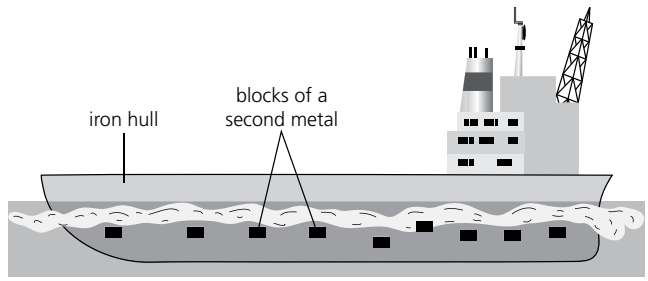
(i) Explain **why** nitrogen and oxygen can be separated from liquid air by fractional distillation.

..... **[1]**

(ii) Give two uses for nitrogen: .....

and two for oxygen: ..... **[2]**

5 This diagram shows a second metal used for sacrificial protection to protect an iron ship from rusting. Cross out the wrong choice from each pair in italics in the statements below.



(a) When iron rusts, the iron is *oxidized*/*reduced*.

(b) The ionic equation for the initial reaction is:
$Fe \longrightarrow Fe^{2+} + 2e^- / Fe^{2+} + 2e^- \longrightarrow Fe$

(c) The second metal must be *more*/*less* reactive than iron.

(d) The second metal is *oxidized*/*reduced* instead of the iron.

(e) The second metal has a *stronger*/*weaker* drive to form positive ions.

[5]

[Total: 20]

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Name: .....

Organic chemistry

1 Paraffin is one of the fractions distilled from petroleum. What is it used for? Tick the box.

(a) as bottled gas, for cooking ☐ (b) as aircraft fuel ☐

(c) as fuel for power stations ☐ (d) as a lubricant ☐

[1]

2 Which of these compounds has the formula C_2H_4? Tick its box.

(a) ethane ☐ (b) ethene ☐

(c) ethanol ☐ (d) ethanoic acid ☐ [1]

3 Long-chain alkanes are often cracked to produce more useful products.

(a) Give two reasons why long-chain alkanes are not very useful. .....

..... [2]

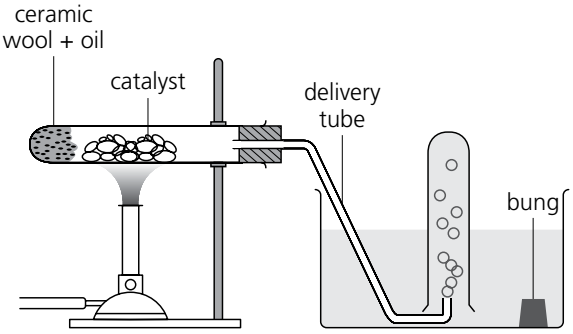
(b) When the liquid alkane decane is cracked, a gas is formed. It turns bromine water colourless.

(i) What can you deduce about this gas? ..... [1]

(ii) The reaction between the gas and bromine is called an ..... reaction. [1]

(c)

(i) This diagram shows part of the apparatus for cracking decane in the lab. Complete it.



[1]

(ii) What is the aluminium oxide for? ..... [1]

(iii) Mark on the diagram where the test tube should be heated.

(iv) The moment heating is stopped, the apparatus is removed from the water. Why?

..... [1]

(d) Complete this equation for the cracking of decane, and name the gas that formed:

$C_{10}H_{22} \longrightarrow C_8H_{18} +$ .....

decane octane [1]

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Name: .....

(e) Complete this table comparing decane with the gas that forms in the reaction in (d):

Compound	Decane (a liquid)	..... (a gas)
Organic family		
Is its boiling point above, or below, room temperature?		
Does it contain double bonds?		
Is it saturated or unsaturated?		
Will it react with bromine water?		
Will it polymerize?		

[1]

4 Ethanol is a member of the alcohol family.

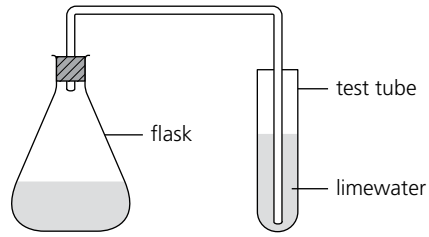
(a)

(i) What is the functional group of the alcohol family? ..... **[1]**

(ii) Write the formula for ethanol. ..... **[1]**

(b) Ethanol can be made by the fermentation of sugar, using the apparatus on the right.

The fermentation takes place in the flask.



(i) What is put in the flask? ..... **[1]**

(ii) Which of these temperatures is best for the reaction? Circle your choice.

0°C 10°C 25°C 75°C **[1]**

(iii) What would you observe in the test tube? ..... **[1]**

(iv) Complete the equation for the fermentation:

$C_6H_{12}O_6 \longrightarrow$ ..... **[1]**

(v) How would you separate the ethanol from the mixture in the flask?

..... **[1]**

(c) Ethanol is also made from ethene in an addition reaction.

(i) Give the balanced symbol equation for the reaction.

..... **[1]**

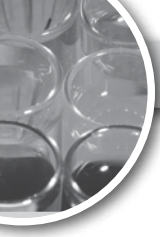
(ii) Name the catalyst used to speed up the reaction.

..... **[1]**

[Total: 20]

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WORKSHEET

Name:

Esters, fats, and soaps

An ester is formed when an alcohol combines with a carboxylic acid. Vegetable oils and animal fats are triesters. They have three ester linkages in a single molecule. Synthetic fibers of polyesters contain a large number of ester linkages (around 75,000) in a single molecule.

1 Write the formula of an ester linkage.

.....

..... **[1]**

2 What is the basic difference between the monomers of a simple ester and those of a polyester?

.....

..... **[2]**

3 Which alcohol is always present in fats?

.....

..... **[1]**

4 Draw the structural formula of a polyester showing three ester linkages.

[3]

5 Draw the structural formula of a fat. Show the carbon chain with a block.

[2]

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Name: .....

6 What is hydrolysis? Name the products of acid hydrolysis and alkaline hydrolysis of fats.

.....

..... **[3]**

7 What is meant by saponification?

..... **[1]**

8 What visible difference exists between the products formed by the reaction of a fat with potassium hydroxide and with sodium hydroxide?

.....

..... **[2]**

[Total: 15]

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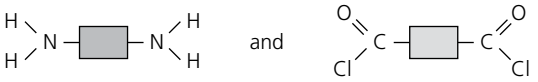
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Polymers

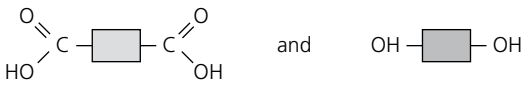
1 Polyamides, polyesters, and polysaccharides are three types of condensation polymer.

(a) Complete the following tables, for three different polymerization reactions **A** to **C**.

 and  represent carbon chains.

Reaction A	
The monomers used for the polymerization	
Structure of the polymer formed (show two units of each monomer joined up)	
The other product that forms	name: ..... formula: .....
Type of polymer formed (circle one)	polyamide polyester polysaccharide
Name of polymer formed (circle one)	starch nylon soap terylene sugar
Synthetic or natural? (circle one)	synthetic natural

[5]

Reaction B	
The monomers used	
Structure of the polymer formed (show two units of each monomer joined up)	
The other product that forms	name: ..... formula: .....
Type of polymer formed (circle one)	polyamide polyester polysaccharide
Name of polymer formed (circle one)	starch nylon soap terylene sugar
Synthetic or natural? (circle one)	synthetic natural

[5]

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Name: .....

Reaction C	
The monomers used	HO–□–OH and HO–□–OH
Structure of the polymer formed (show two units of each monomer joined up)	
The other product that forms	name: ..... formula: .....
Type of polymer formed (circle one)	polyamide polyester polysaccharide
Name of polymer formed (circle one)	starch nylon soap terylene sugar
Synthetic or natural? (circle one)	synthetic natural

[5]

(b) What happens during condensation polymerization? .....

..... **[1]**

(c)

(i) Which of the three polymers formed in reactions A–C contains a linkage like that found in proteins?

..... **[1]**

(ii) What is the main difference between the structure of this polymer and the structure of proteins?

.....

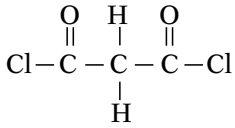
..... **[1]**

2

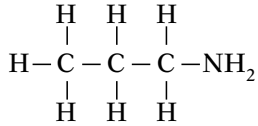
(a) Only one of these molecules can be used to make a condensation polymer. Which one?

..... **[1]**

(i)



(ii)



(b) State why the other molecule is unable to form a condensation polymer.

.....

..... **[1]**

[Total: 20]

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Name: .....

Separating substances

1 Which of these is an example of an impurity in water?

(a) salt
(b) sand
(c) soap
(d) all of the above [1]

2 Which of these would form a suspension?

(a) water and chalk
(b) water and salt
(c) water and sugar
(d) water and ink [1]

3 Crude oil is refined by…

(a) distillation
(b) fractional distillation
(c) condensation
(d) chromatography [1]

4 A solute can be separated from its solution by …

(a) filtration
(b) distillation
(c) crystallization
(d) chromatography [1]

5 Distillation, filtration, and crystallization are three of the techniques used to separate substances. From those three, choose the correct technique for:

(a) removing a precipitate from a solution .....

(b) purifying a new drug, which is soluble in hot water, but not in cold .....

(c) removing solid impurities from water .....

(d) recovering a volatile solvent from a solution, so that it can be reused.....

[4]

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Name:

6 A student is asked to analyze a sample of black ink, to see which dyes it contains.

Select the correct instructions for the student, from the list a–j below.

Then put them in the correct order, and write them in the flow chart below.

You will need to add more boxes and arrows to the flow chart.

(a) Allow the solvent to move up the paper.

(b) Filter the ink to remove the coloured substances.

(c) Compare how far the spots have moved, to identify the dyes in the ink.

(d) Measure the melting points of the separate coloured substances.

(e) Add spots of pure dyes along the same line.

(f) Shake the ink with distilled water, and allow the mixture to settle into layers.

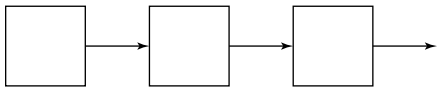
(g) Stand the paper in a beaker containing a small amount of a solvent.

(h) Distill the ink to remove the solvent.

(i) Remove the paper when the solvent is near the top, and allow it to dry.

(j) Place a spot of ink on a pencil line near the bottom of some chromatography paper.

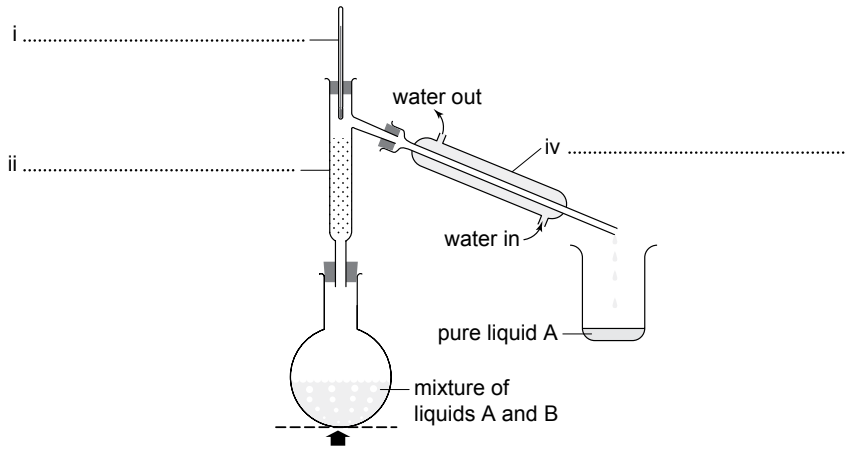
This is the flow chart to complete:



[5]

7 This apparatus was used to separate liquid A from a mixture of liquids A and B.

(a) Complete the labels for the apparatus.



[4]

(b) Which liquid has the lower boiling point—A or B? ..... **[1]**

(c) Describe how the temperature recorded on the thermometer changes during the process.

.....

.....

..... **[2]**

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Name: .....

(d) Give two examples of mixtures that can be separated by fractional distillation.

(i) .....

(ii) ..... **[2]**

(e) Give an example of a mixture that cannot be separated by fractional distillation.

..... **[1]**

(f) You need to obtain clean water to drink from sea water. Which item of apparatus in the diagram above will you not need? ..... **[1]**

8 A natural substance is broken down into two amino acids—glycine and lysine. The two amino acids are separated by chromatography using a suitable solvent. The R_f values for this solvent are: glycine 0.26, lysine 0.14.

(a) Define R_f value.

..... **[1]**

(b) The amino acids are colourless. How would you show their position on the

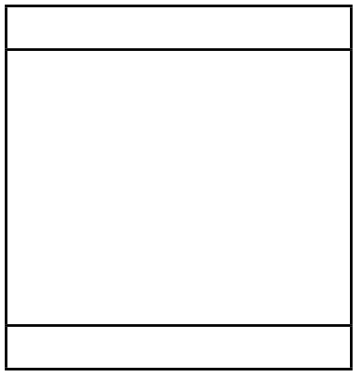
chromatography paper? ..... **[1]**

(c) Complete the diagram below for the chromatogram, as follows:

(i) Label the solvent front (where the solvent reached).

(ii) Indicate where the amino acid samples were placed.

(iii) Mark in the correct final position for each amino acid spot, using the Rf values given above.



[3]

(d) How would you change the procedure for two other amino acids that have almost identical R_f values in this solvent?

..... **[1]**

[Total: 30]

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Name: .....

Ion identification

1 Which of these forms a cation?

(a) zinc

(b) chlorine

(c) bromine

(d) iodine **[1]**

2 Chloride, bromide, and iodide are collectively termed …

(a) halogens

(b) noble ions

(c) metallic ions

(d) halides **[1]**

3 Carbon dioxide gas …

(a) is lighter than air

(b) turns limewater milky

(c) is an element

(d) none of the above **[1]**

4 A pale blue precipitate indicates the presence of …

(a) copper ions

(b) chloride ions

(c) bromide ions

(d) iron ions **[1]**

5 Which list shows increasing accuracy, for measuring the volume of a liquid?

(a)	measuring cylinder	burette	pipette	☐
(b)	measuring cylinder	pipette	burette	☐
(c)	pipette	burette	measuring cylinder	☐
(d)	burette	measuring cylinder	pipette	☐

[1]

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Name:

6 Which set of results indicates the presence of aluminium ions?

	1 Add a few drops of sodium hydroxide solution.	2 Then to one portion add excess ammonium hydroxide solution.	3 To the other portion add excess sodium hydroxide solution.	
(a)	no precipitate	no precipitate	no precipitate	
(b)	white precipitate	no precipitate	no precipitate	
(c)	white precipitate	white precipitate	no precipitate	
(d)	white precipitate	white precipitate	white precipitate	

[1]

7 An acidified solution of barium ions is added to an aqueous solution of an unknown compound.

A white precipitate forms. Which ion does the compound contain?

(a) Cl^- ☐ **(b)** NO_3^- ☐ **(c)** SO_4^{2-} ☐ **(d)** OH^- ☐ **[1]**

8 Excess aqueous ammonia is added to one portion of an unknown solution.

Excess sodium hydroxide solution is added to a second portion.

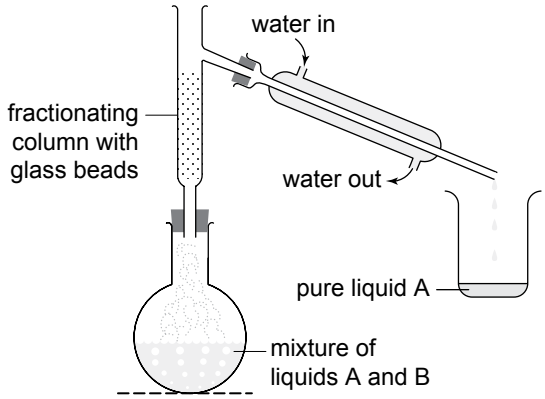
In each case a white precipitate forms, then redissolves. Which metal ion is present?

(a) Ca^{2+} ☐ **(b)** Cu^{2+} ☐ **(c)** Al^{3+} ☐ **(d)** Zn^{2-} ☐ **[1]**

9 A yellow precipitate forms when acidified aqueous silver nitrate is added to a solution of an unknown compound. Which ion does the compound contain?

(a) chloride ☐ **(b)** iodide ☐ **(c)** nitrate ☐ **(d)** sulfate ☐ **[1]**

10 This diagram shows the set-up for carrying out fractional distillation. It has mistakes, and is not complete. Correct and complete the diagram.

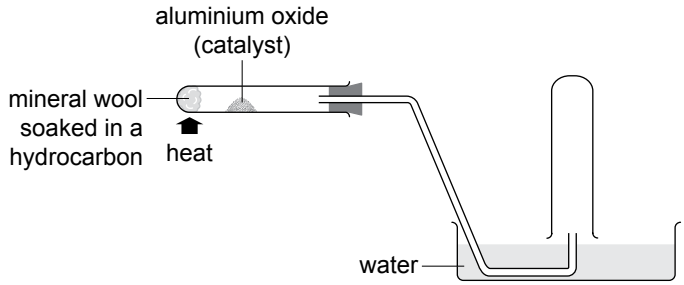


[2]

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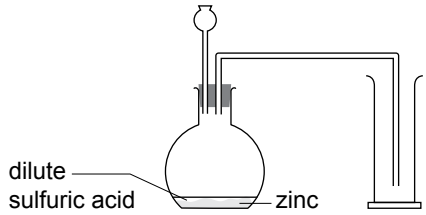
Name:

11 This diagram shows the set-up for cracking a hydrocarbon in the lab. Correct and complete the diagram.



[2]

12 This diagram shows the set-up for preparing and collecting hydrogen in the lab. Correct and complete the diagram.



[2]

[Total: 15]

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Name: .....

States of matter I

1 A liquid is changed to the gaseous state by …

(a) condensation

(b) boiling

(c) freezing

(d) heating [1]

2 The melting point of ice …

(a) is the same as the freezing point of water

(b) is the same as the boiling point of water

(c) lies in between the freezing and boiling points of water

(d) is above the freezing point of water [1]

3 Upon heating, the molecules of a solid …

(a) contract

(b) expand

(c) obtain energy

(d) lose energy [1]

4 The molecules in a gas …

(a) move in all directions

(b) possess strong intermolecular forces of attraction

(c) are packed close together

(d) vibrate to and fro [1]

5 Tungsten is a metal used to make filaments for light bulbs. When the filament breaks the light bulb stops glowing.

(a) Why is tungsten used in light bulbs?

.....

..... [1]

(b) Explain the change of state which must have occurred to cause the break in the filament.

.....

..... [2]

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Name:

6 An unknown substance X is heated from -5°C to 35°C when it starts melting. The temperature changes from 35°C to 37°C during the melting process.

(a) In which state are the particles at this point?

..... **[1]**

(b) How would you determine whether the sample is pure or impure?

..... **[2]**

(c) Is the substance ionic or covalent? Give a reason for your answer.

..... **[2]**

7 Three gases, ammonia (NH_3), chlorine (Cl_2), and carbon dioxide (CO_2) are allowed to diffuse through a long glass tube. A piece of damp litmus paper is placed at the other end of the glass tube.

(a) What changes would be observed in the litmus paper as the gases diffuse?

.....

..... **[2]**

(b) Give a reason for each change that you have stated in part (a).

..... **[1]**

[Total: 15]

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Name: . . . . . .

States of matter II

1 When a gas is compressed …

(a) the molecules become smaller

(b) the molecules are pushed closer

(c) the molecules lose energy

(d) the gas pressure is reduced **[1]**

2 When a gas is heated …

(a) the molecules gain energy

(b) the gas is compressed

(c) the molecules lose energy

(d) the gas changes state **[1]**

3 A gas with smaller molecules …

(a) diffuses faster than a gas with larger molecules

(b) diffuses slower than a gas with larger molecules

(c) diffuses at the same rate as a gas with larger molecules

(d) occupies a greater volume **[1]**

4 A gas diffuses faster …

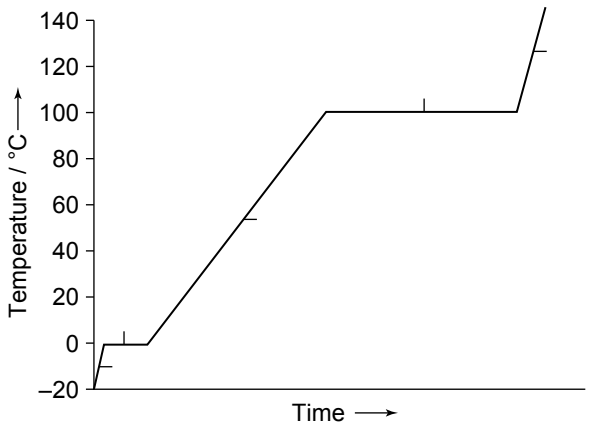
(a) at a higher temperature

(b) at a lower temperature

(c) at a higher pressure

(d) when its molecules are large **[1]**

5 A substance was removed from a freezer and heated. The temperature was recorded at regular intervals. The results are shown on this graph.



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Name: .....

(a) The letters V–Z represent the states of matter listed below. Write the five letters at the correct places on the graph above.

V = solid W = solid + liquid X = liquid Y = liquid + gas Z = gas **[5]**

(b) Explain what is happening to the particles at those five places on the graph:

at V: .....

at W: .....

at X: .....

at Y: .....

at Z: .....

[5]

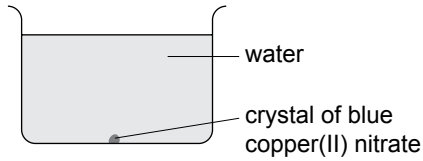
(c) The substance that was heated was pure. How can you tell this from the graph?

..... **[1]**

(d) Name the substance that was heated.

..... **[1]**

6 A crystal of blue copper(II) nitrate is placed in a beaker of water. The beaker is left sitting until there is no further change.



What would you expect to see in the beaker at that point? Tick the correct box.

(a) The blue colour spread through the liquid. ☐

(b) A blue layer at the bottom of the beaker. ☐

(c) Small particles of blue solid. ☐

(d) A blue layer above a colourless layer. ☐ **[1]**

7 Which process causes the change observed in question 6? ..... **[1]**

8 Arrange these four gases in order of the speed at which they diffuse, fastest first.

(Relative atomic masses, A_r: N = 14, O = 16, H = 1, Ne = 20)

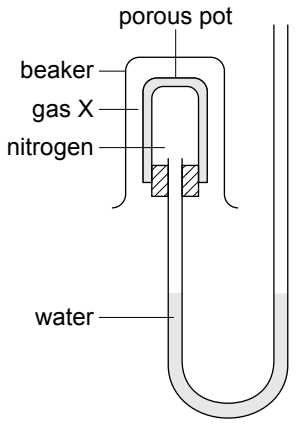
..... **[1]**

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Name:

9 The apparatus below was set up to investigate the diffusion of some gases:



The water level rose in the left side of the U-tube, and fell in the right side.

Which one of these is gas X? Tick its box. (Ar: H = 1, C = 12, N = 14, O = 16)

(a) hydrogen ☐

(b) carbon monoxide ☐

(c) oxygen ☐

(d) methane ☐

[1]

[Total: 20]

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Name: .....

Atoms and elements I

1 Which of these is not an element?

(a) carbon dioxide

(b) nitrogen

(c) oxygen

(d) sulfur **[1]**

2 The nucleon number is the …

(a) number of protons

(b) number of electrons

(c) number of neutrons

(d) number of protons plus the number of neutrons **[1]**

3 A stable atom possesses an equal number of …

(a) protons and neutrons

(b) neutrons and electrons

(c) protons and electrons

(d) none of the above **[1]**

4 The atomic number of carbon is …

(a) 10

(b) 11

(c) 12

(d) 13 **[1]**

5

(a) Define the following terms:

(i) Relative atomic mass

.....

..... **[1]**

(ii) Mass number

.....

..... **[1]**

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Name:

(iii) Relative isotopic mass

.....

..... **[1]**

(iv) Valence electron

.....

..... **[1]**

(b) Element X has mass number 24 and atomic number 12. Element Y has mass number 27 and atomic number 13. Why can a new element not be discovered that might fit between elements X and Y in the Periodic Table?

.....

..... **[2]**

[Total: 10]

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Name: .....

Atoms and elements II

1 The atoms in a period of the Periodic Table …

(a) have the same number of shells

(b) have the same number of electrons

(c) have the same number of protons

(d) have the same number of neutrons **[1]**

2 The atoms in the same group of the Periodic Table …

(a) have the same number of protons

(b) have the same number of electrons

(c) have the same number of valency electrons

(d) have the same number of neutrons **[1]**

3 Which of these is a metal?

(a) oxygen

(b) carbon

(c) iron

(d) nitrogen **[1]**

4 Group O elements are …

(a) halogens

(b) metals

(c) alkali metals

(d) unreactive **[1]**

5 Complete each of these correctly by writing in 0, 1, 1+ or 1–.

(a) charge on an electron .....

(b) relative mass of a proton .....

(c) charge on a proton .....

(d) relative mass of a neutron .....

(e) charge on a neutron .....

(f) relative mass of an electron .....

(g) number of neutrons in a hydrogen atom .....

(h) number of electrons in a hydrogen atom ..... **[4]**

6 The diagrams on the next page show the three isotopes of hydrogen—hydrogen, deuterium, and tritium.

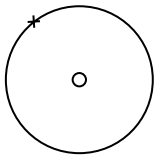
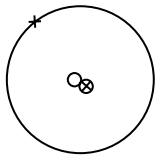
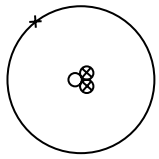
(a) Fill in the names of the subatomic particles which these symbols represent:

× ..... ○ ..... ⊗ ..... **[3]**

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Name: . . . . . .

isotope: hydrogen deuterium tritium

nucleon number: ....

(b) Now fill in the three nucleon numbers in the spaces below the diagrams. **[3]**

(c) Complete this statement: Isotopes of an element contain the same number of

..... and ..... but different numbers of ..... . **[3]**

(d) The average mass of an atom of naturally-occurring hydrogen is 1.008. Which of the three isotopes is present in the highest proportion in naturally-occurring hydrogen?

..... . **[1]**

7 This table gives the electronic structures and nucleon numbers for atoms of four elements A–D. (Those letters are not the chemical symbols of the elements.)

Element	Electronic structure of atom	Nucleon number of atom
A	2,8,4	28
B	2,4	12
C	2,8,18,8	84
D	2,8,3	27

(a) Which two elements belong to the same group in the Periodic Table? ..... **[1]**

(b) Which two elements belong to the same period in the Periodic Table? ..... **[1]**

(c) Which element is a metal? ..... . **[1]**

(d) Which element is a noble gas? ..... **[1]**

(e) Now name the four elements and give their chemical symbols. (One is krypton, Kr.)

A is ..... B is .....

C is ..... D is ..... **[4]**

(f) Atoms can be described like this: $^{7}_{3}$Li. Describe the four atoms above in this way.

A ..... B ..... C ..... D ..... **[4]**

[Total: 30]

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Name: .....

Atoms combining

1 Metals obtain a stable outer shell by …

(a) losing electrons

(b) gaining electrons

(c) sharing electrons

(d) retaining electrons **[1]**

2 A magnesium ion is represented as Mg^{2+}. This means the atom …

(a) has gained two electrons

(b) has lost two electrons

(c) has lost two protons

(d) has shared two electrons **[1]**

3 Which of these is a compound ion?

(a) Cu^{2+}

(b) OH^-

(c) Fe^{2+}

(d) Ag^+ **[1]**

4 Which of the following compounds has a pyramidal structure?

(a) carbon dioxide

(b) water

(c) ammonia

(d) methane **[1]**

5 Draw diagrams to show the bonding in these molecules. Show all the electrons.

(a) hydrogen, H_2

(b) chlorine, Cl_2

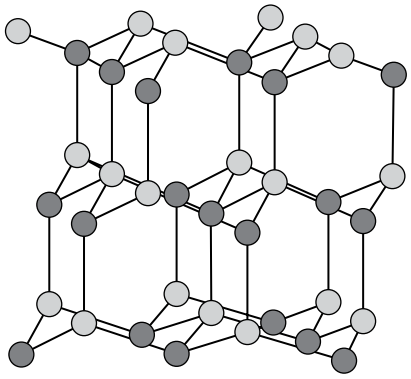
[2]

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Name: . . . . . .

6 This diagram represents a substance with giant structure:



(a) Is the substance an element, or a compound? ..... **[1]**

(b) Is its structure more like diamond, or graphite? ..... **[1]**

(c) Which type of bonding exists between its atoms? ..... **[1]**

(d) In each pair below underline the term that describes this substance.

(i) conductor / non-conductor **(ii)** high melting point / low melting point

(iii) soluble / insoluble in water **(iv)** hard / soft **[4]**

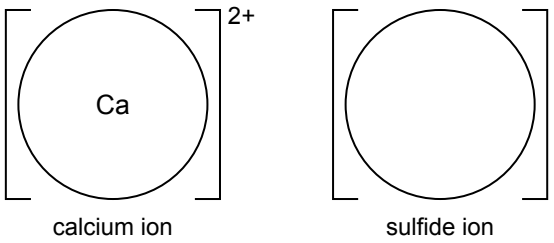
7 Write in the formula for each compound in this table, and give the type of bonding in it.

Compound	Formula	Bonding: ionic or covalent?
methane		
hydrogen chloride		
magnesium chloride		
sodium oxide		
ammonia		
iron(II) sulfate		

[4]

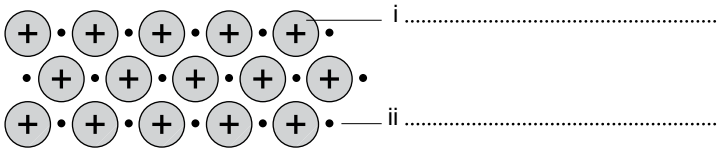
5 Complete this diagram to show the bonding in calcium sulphide.

Show only the outer electron shells. Use crosses for the electrons of one atom, and dots for the electrons of the other.



[2]

9 This diagram represents the bonding in a metal.



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Name:

(a) Fill in the missing labels for the two types of particle in the metal lattice. **[2]**

(b) What holds the particles together in the lattice?

..... **[1]**

(c) Why are metals so good at conducting electricity and heat?

..... **[1]**

(d) State another property of metals that can be explained by their structure, and draw a diagram in this box to illustrate it.

The property: .....

.....

[2]

[Total: 25]

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Name: .....

Reacting masses and chemical equations

1 Group IV atoms form compounds by …

(a) losing two electrons

(b) gaining four electrons

(c) losing four electrons

(d) sharing four electrons **[1]**

2 The number of electrons an atom needs to lose, gain, or share to form a compound is called its …

(a) valency

(b) atomic number

(c) outer shell

(d) mass number **[1]**

3 Which of these equations is not balanced?

(a) $2H_2 + O_2 \longrightarrow 2H_2O$

(b) $C + O_2 \longrightarrow O_2$

(c) $2Mg + O_2 \longrightarrow 2MgO$

(d) $H_2 + Cl_2 \longrightarrow HCl$ **[1]**

4 During a chemical reaction …

(a) the reactants retain their original chemical properties

(b) elements react in the same ratio

(c) total mass of reactants = total mass of products

(d) (b) & (c) **[1]**

5 Write the formulae for these six compounds:

Compound	Formula
sodium chloride	
magnesium chloride	
aluminium chloride	
hydrogen sulfide	
aluminium oxide	
copper(II) sulfate	

[3]

6 Write balanced equations for these reactions:

(a) hydrogen + oxygen ⟶ water

.....

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(b) copper(II) oxide + carbon ⟶ carbon dioxide + copper

.....

(c) nitrogen + oxygen ⟶ nitrogen dioxide

.....

(d) methane + oxygen ⟶ carbon dioxide + water

.....

[4]

7 Using the list of Ar values on the right, calculate Mr for these compounds:

(a) hydrogen iodide, HI .....

(b) sodium nitrate, $NaNO_3$ .....

(c) calcium nitrate, $Ca(NO_3)_2$ .....

(d) ethanoic acid, CH_3COOH .....

Symbol of element	A_r
Ca	40
C	12
H	1
I	127
N	14
Na	23
O	16

[4]

8 Iron and sulfur react together to form iron(II) sulfide. The equation for the reaction is:

Fe (*s*) + S (*s*) ⟶ FeS (*s*)

28 g of iron is reacted with 16 g of sulfur. Use this information to answer the questions below:

(a) When 28 g of iron is reacted with 16 g of sulfur, how many grams of iron(II) sulfide are formed?

..... **[1]**

(b) What mass of iron will react with 4 g of sulfur to form iron(II) sulfide? ..... **[1]**

(c) A mixture of iron and sulfur reacts completely, giving 88 g of iron(II) sulfide. What masses of iron and sulfur did the mixture contain? ..... **[2]**

(d) 14 g of iron was mixed with 10 g of sulfur, and the mixture was heated to start the reaction.

(i) Which reactant was in excess? .....

(ii) What mass of iron(II) sulfide was formed? ..... **[2]**

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Name: .....

9 The formula for the white anhydrous form of copper(II) sulfate is $CuSO_4$.
(A_r for Cu = 64; M_r for $CuSO_4$ = 160)

(a) What % by mass of the compound is copper? ..... **[1]**

(b) How many grams of oxygen are there in 80 g of the compound? ..... **[1]**

10 A chemical factory produced a large batch of impure salicylic acid. A 36 g sample of this was found to contain 12 g of pure salicylic acid.

(a) What was the % purity of the impure salicylic acid? ..... **[1]**

(b) What mass of the impure acid must be purified to give 40 kg of pure acid?

..... **[1]**

[Total: 25]

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Name: .....

Using moles

1 One mole of C contains …

(a) 6.02×10^{20} atoms

(b) 6.02×10^{20} molecules

(c) 6.02×10^{23} atoms

(d) 6.02×10^{23} molecules **[1]**

2 The number of moles can be determined by …

(a) mass x mass number

(b) mass / atomic number

(c) mass / mass of one mole

(d) mass / 6.02×10^{23} **[1]**

3 The number in a balanced equation indicates …

(a) how many grams of each substances are involved

(b) the number of atoms taking part in the reaction

(c) the number of ions taking part in the reaction

(d) the number of moles of each substance **[1]**

4 The empirical formula of benzene (C_6H_6) is …

(a) CH

(b) C_2H_2

(c) C_3H_3

(d) C_6H_6 **[1]**

5 This question is about masses, moles, and the Avogadro constant.

(a) How many atoms are there in 71 g of chlorine?
(A_r: Cl = 35.5) .....

(b) What is the mass of 0.2 moles of potassium hydroxide (KOH)?
(A_r: H = 1, O = 16, K = 39) .....

(c) How many moles of atoms are there in 1.4 g of lithium?
(A_r: Li = 7) .....

(d) What is the mass of 4 moles of sulfur molecules (S_8)?
(A_r: S = 32) .....

(e) How many moles of water molecules are there in 50 g of hydrated calcium nitrate, ($Ca(NO_3)_2.2H_2O$)?
(M_r: $Ca(NO_3)_2.2H_2O$ = 200) .....

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Name: .....

(f) How many oxygen atoms are there in 4.9 g of H_2SO_4?
(M_r: H_2SO_4 = 98) .....

(g) How many moles of oxygen molecules are there in
24 dm^3 of air at r.t.p.? Assume air is 20% oxygen. .....

(h) 125 cm^3 of a solution contains 0.25 moles of the solute.
What is the concentration of the solution? .....

(i) What mass of sodium hydroxide is there in 35 cm^3 of
a 2 mol / dm^3 solution of sodium hydroxide? (M_r: NaOH = 40) .....

[9]

6

(a) Calcium hydroxide decomposes when heated, as below. (M_r: $Ca(OH)_2$ = 74, CaO = 56)
$Ca(OH)_2$ (*s*) $\longrightarrow$ CaO (*s*) + H_2O (*l*)
What mass of calcium hydroxide will give 100 g of calcium oxide? ..... g

(b) On heating iron(III) sulfate (M_r = 400), sulfur trioxide is produced:
$Fe_2(SO_4)_3$ (*s*) $\longrightarrow$ Fe_2O_3 (*s*) + $3SO_3$ (*g*)
What volume of sulfur trioxide at r.t.p. will be produced
when 25 g of iron(III) sulfate is heated? ..... dm^3

(c) When aluminium and fluorine are heated together aluminium fluoride is formed:
2Al (*s*) + $3F_2$ (*g*) $\longrightarrow$ $2AlF_3$ (*s*)
What will be present after the reaction, and how much, when 40 g of aluminium and 57 g of fluorine react? (A_r: Al = 27, F = 19)

.....

(d) Ethene is obtained by the dehydration of ethanol:
C_2H_5OH (*l*) $\longrightarrow$ C_2H_4 (*g*) + H_2O (*l*)
What mass of ethene will be obtained from 10 g of ethanol if the yield from the reaction is 50%?
(M_r: C_2H_5OH = 46, C_2H_4 = 28) ..... g

[4]

7 Aluminium carbide contains only aluminium and carbon. It reacts with water to give aluminium hydroxide, $Al(OH)_3$, and methane, CH_4. 0.6 moles of the carbide were reacted with excess water to give 2.4 moles of $Al(OH)_3$ and 1.8 moles of CH_4.

Complete the formula for the carbide below, and balance the equation for the reaction:

..... Al .....C..... + ...H_2O .....$Al(OH)_3$ + ...CH_4 **[1]**

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Name:

8 A hydrocarbon contains 92.3% of carbon and 7.7% of hydrogen. It has a molar mass of 78.
Complete this table to find the molecular formula for the hydrocarbon:

	Carbon	**Hydrogen**
Mass of element in 100 g of compound		
Relative atomic masses, Ar	12	1
Moles of atoms that combine		
Ratio in which atoms combine		
Empirical formula		
Molecular formula		

[2]

[Total: 20]

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Name: .....

Electricity and chemical change I

1 Which of these is a non-metal that conducts electricity?

(a) oxygen

(b) carbon

(c) hydrogen

(d) nitrogen [1]

2 In the electrolysis of molten sodium chloride, chlorine gas …

(a) is liberated at the anode

(b) is liberated at the cathode

(c) is dissolved in the solution

(d) is ionized [1]

3 Which of the following takes place at the cathode?

(a) oxidation

(b) electrolysis

(c) decomposition

(d) reduction [1]

4 During electroplating, the cathode is …

(a) a carbon rod

(b) the metal to be coated

(c) the object to be electroplated

(d) gold [1]

5

(a) Sodium nitrate solution was electrolyzed using graphite electrodes. Name the products formed at the anode and the cathode.

.....

..... [1]

(b) Write the ionic equations for the reactions at the anode and the cathode.

.....

..... [2]

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Name:

(c) If an aqueous solution of sodium sulfate is electrolyzed using graphite electrodes, predict the products at the anode and the cathode.

.....

..... **[1]**

(d) Explain why the products identified in part (c) were formed at the anode and the cathode.

.....

..... **[1]**

(e) If sodium sulfate is electrolyzed using a carbon cathode and a magnesium anode, how would the reactions at the anode and the cathode differ. Explain your answer.

.....

..... **[1]**

[Total: 10]

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Name: .....

Electricity and chemical change II

1

(a) Complete this table, showing the product at each electrode:

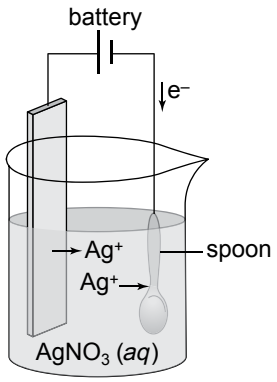
Substance undergoing electrolysis	Product	
	At the cathode	At the anode
molten lead bromide		
concentrated aqueous sodium chloride		
molten aluminium oxide		
concentrated hydrochloric acid		

[2]

2

(a) Name the process shown in the diagram on the right.

..... [1]



(b) Is the spoon the positive, or negative, electrode?

..... [1]

(c) What will be the result of the process?

..... [1]

(d) What happens to the number of silver ions present in the solution?

..... [1]

(e) Give two reasons why steel car bumpers are plated with chromium.

.....

..... [2]

3 Brine is a concentrated aqueous solution of sodium chloride.

Which chemical is not obtained from the electrolysis of brine? Tick its box.

(a) sodium ☐

(b) chlorine ☐

(c) hydrogen ☐

(d) sodium hydroxide ☐ [1]

4 Which process does not involve electrolysis? Tick its box.

(a) refining copper ☐

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(b) coating an iron bumper with a layer of chromium ☐

(c) manufacturing useful chemicals from sodium chloride ☐

(d) using a battery to make a bulb light up ☐ [1]

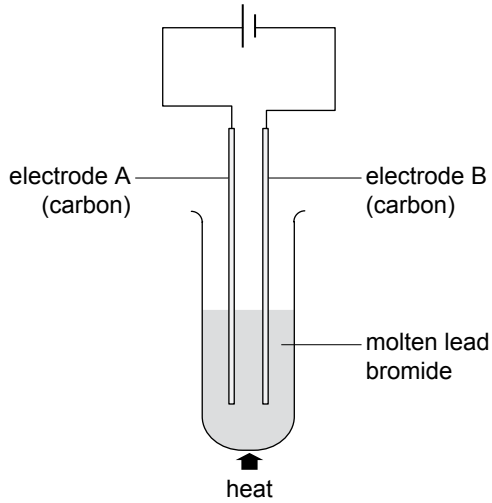
5 The electrolysis of aqueous copper(II) sulfate is carried out using copper electrodes.

Which pair of equations shows what happens during the electrolysis? Tick its box.

	At the cathode	At the anode	
a	$Cu^{2+} + 2e^- \longrightarrow Cu$	$4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$	
b	$Cu^{2+} + 2e^- \longrightarrow Cu$	$Cu \longrightarrow Cu^{2+} + 2e^-$	
c	$Cu \longrightarrow Cu^{2+} + 2e^-$	$Cu^{2+} + 2e^- \longrightarrow Cu$	
d	$4OH^- \longrightarrow 2H_2O + O_2 + 4e^-$	$Cu^{2+} + 2e^- \longrightarrow Cu$	

[4]

6 The diagram on the right shows apparatus for the electrolysis of molten lead bromide.



(a) What would you see at electrode A?

..... [1]

(b) Write the ionic equation for the reaction at electrode A:

..... [1]

(c) What would you see at electrode B?

..... [1]

(d) Write the ionic equation for the reaction at electrode B:

..... [1]

7 Aqueous zinc sulfate is electrolyzed using platinum electrodes.

Zinc forms at the negative electrode and oxygen at the positive electrode.

The aqueous solution contains four ions.

(a) Write the formulae for the four ions present in the aqueous solution.

..... [1]

(b) Write the equations for:

(i) the reaction at the negative electrode ..... [1]

(ii) the reaction at the positive electrode ..... [1]

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(c) Name the solution that remains when the electrolysis is complete.

..... [1]

8 The electrolysis of a concentrated aqueous solution produces the elements hydrogen and iodine, and leaves a solution of potassium hydroxide.

(a)

(i) At which electrode is the iodine produced? ..... [1]

(ii) Write the ionic equation for the reaction at that electrode.

..... [1]

(b)

(i) Name the aqueous solution used in the electrolysis. ..... [1]

(ii) How would the products differ if this solution were dilute instead of concentrated?

.....

..... [3]

10 Which four liquids below will produce hydrogen and oxygen, on electrolysis? Circle their letters.

(a) dilute sulfuric acid
(b) molten sodium chloride
(c) concentrated hydrochloric acid
(d) dilute sodium sulfate solution
(e) dilute sodium bromide solution
(f) dilute sodium hydroxide solution
(g) dilute copper(II) sulfate solution, using copper electrodes [2]

[Total: 30]

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Energy changes and reversible reactions

1 Which of these is not an exothermic reaction?

(a) burning of coal

(b) a reaction between iron and sulfur

(c) decomposition of calcium carbonate

(d) a reaction between calcium oxide and water **[1]**

2 When bonds between atoms are broken …

(a) energy is taken in

(b) energy is given out

(c) there is no change in energy

(d) the energy taken in is always greater than the energy given out **[1]**

3 The energy needed to get a reaction started is called …

(a) starting energy

(b) beginning energy

(c) initial energy

(d) activation energy **[1]**

4 Which of these is an alternative to fossil fuels?

(a) coal

(b) ethanol

(c) petroleum

(d) natural gas **[1]**

5

(a) Complete this table for the reactions that take place between the given reactants.

	Reactants	**Initial temp / °C**	**Final temp / °C**	**Exothermic or endothermic?**
i	white copper(II) sulfate + water	18	45	
ii	aqueous citric acid + sodium hydrogen carbonate	19	6	
iii	zinc + copper(II) sulfate solution	21	30	

[3]

(b)

(i) One of the reactions above is reversible. Which one? .....

(ii) How would you reverse it? .....

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(iii) Is the reverse reaction exothermic, or endothermic? .....

[3]

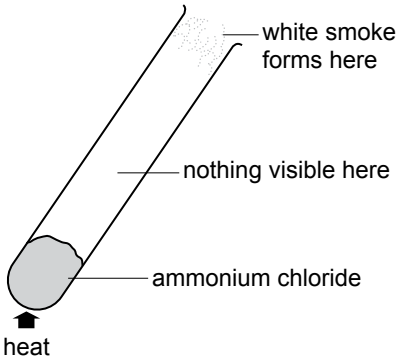
6 Ammonium chloride (NH_4Cl) is a white solid. On heating, it decomposes into two colourless gases ammonia and hydrogen chloride. The reaction is endothermic and reversible.

(a) Give the balanced chemical equation for the reaction using the 'reversible' symbol:

..... **[1]**

(b) As the gases cool, the reverse reaction occurs. Is it exothermic? ..... **[1]**

(c) Explain the observations in this drawing. .....



.....

.....

.....

.....

[2]

7 When hydrogen iodide is heated, it decomposes to hydrogen and iodine:

$2HI\ (g) \longrightarrow H_2\ (g) + I_2\ (g)$

The bond energies, in kJ/mol, are: H–I = 298, H–H = 436, I–I = 151.

(a) Calculate:

(i) the energy required to break the bonds in the reactant: ..... kJ / mol

(ii) the energy released on forming the two products: ..... kJ / mol

(iii) the overall energy change for the reaction: ..... kJ / mol **[3]**

(b) The reaction is therefore an ..... reaction. **[1]**

(c) Using the idea of bond breaking and making, explain why some reactions are exothermic.

.....

..... **[1]**

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8 This table shows four reversible reactions A–D, which are allowed to reach equilibrium:

	Reversible reaction	**The forward reaction is …**
a	$N_2O_4\ (g) \rightleftharpoons 2NO_2\ (g)$	endothermic
b	$H_2\ (g) + CO_2\ (g) \rightleftharpoons H_2O\ (g) + CO\ (g)$	endothermic
c	$2SO_2\ (g) + O_2\ (g) \rightleftharpoons 2SO_3\ (g)$	exothermic
d	$H_2\ (g) + I_2\ (g) \rightleftharpoons 2HI\ (g)$	exothermic

(a) In which two of the reactions A–D will the yield of the product increase if the temperature is raised?

Give their letters: ..... **[2]**

(b)

(i) In which reaction(s) will the yield be unaffected by a rise in pressure? .....

(ii) In which reaction(s) will the yield increase at higher pressure? ..... **[2]**

(c) In reaction B, how will the yield of carbon monoxide change if water vapour is removed from the equilibrium mixture? ..... **[1]**

(d) Explain why a catalyst is used for reaction B even though it does not shift the equilibrium.

..... **[1]**

{Total: 25]

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Name: . . . . . .

The rate of reaction

1 Which of these reactions is the slowest?

(a) electrolysis of sodium chloride

(b) rusting of a discarded machine

(c) burning of wood

(d) concrete setting [1]

2 The rate of a reaction can be increased by …

(a) reducing the concentration of the reactant

(b) reducing the surface area of the reactant

(c) increasing the concentration of the reactant

(d) none of the above [1]

3 A catalyst helps to …

(a) increase the rate of a reaction

(b) decrease the rate of a reaction

(c) increase the concentration of the reactant

(d) increase the volume of the reactant [1]

4 A catalyst present in the bodies of humans is called …

(a) an acid

(b) an enzyme

(c) an alkali

(d) a base [1]

5 Which statement about reaction rates is not correct? Tick its box.

(a) To find the average rate of a reaction, you need to know how long it lasted. ☐

(b) The average rate of a reaction is greater than the rate for the first minute. ☐

(c) As the temperature of the reactants increases, so does the rate. ☐

(d) Reactions can be so fast that they produce an explosion. ☐ [1]

6 Which statement about enzymes is not correct? Tick its box.

(a) Enzymes are made by living things. ☐

(b) Enzymes speed up the reactions that take place in our bodies. ☐

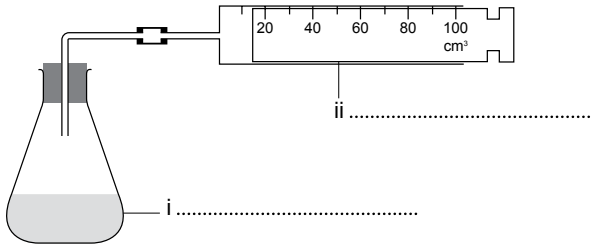
(c) Enzymes are natural proteins that act as catalysts. ☐

(d) The more you heat them, the better enzymes function . ☐ [1]

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Name: .....

7 This apparatus can be used to measure the rate of a reaction.



(a) Write in the two missing labels. **[2]**

(b) Complete this statement about the apparatus:

This apparatus can be used only if one of the ..... is a ..... **[2]**

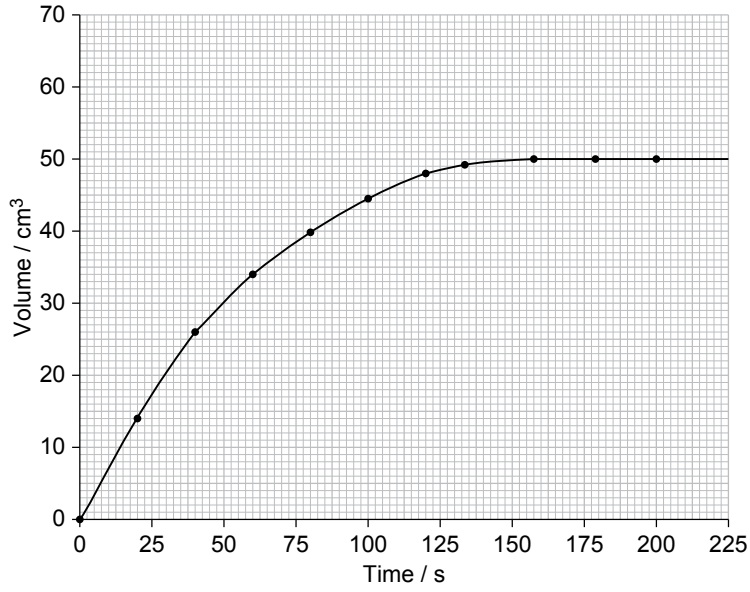
8 Hydrogen peroxide decomposes like this:

$2H_2O_2\ (aq) \longrightarrow 2H_2O\ (l) + O_2\ (g)$

Manganese(IV) oxide, a black solid, acts as a catalyst for the reaction. 1 g of manganese(IV) oxide was added to 50 cm^3 of a hydrogen peroxide solution at room temperature.

The oxygen was collected in a gas syringe and its volume measured at intervals.

The results are shown on this graph:



(a) How long did the reaction last? ..... **[1]**

(b) Describe how the rate of the reaction varied with time.

.....

..... **[1]**

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(c) At the end of the experiment, the reaction mixture was filtered to recover the black solid. It was found to be manganese(IV) oxide and had a mass of 1 gram. What does this confirm about catalysts?

..... [1]

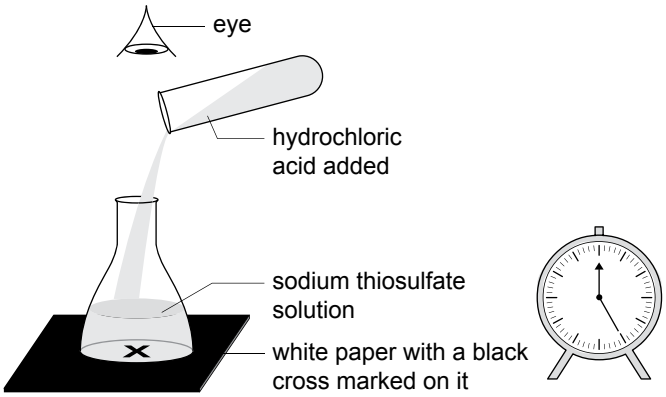
(d) The experiment was repeated at a higher temperature. Sketch the curve for this second experiment on the graph. Label it X. [1]

(e) The rate of the reaction will increase as the mass of the catalyst increases. The experiment was repeated at room temperature, but this time using 0.5 g of manganese(IV) oxide. Sketch the curve for this third experiment on the graph. Label it Y. [1]

(f) Catalase also acts as a catalyst for the decomposition of hydrogen peroxide.

What type of substance is catalase? ..... [1]

9 The rate of reaction between 5 cm^3 of hydrochloric acid and 50 cm^3 of aqueous sodium thiosulfate can be studied using this set-up:



A precipitate forms. When it is thick enough, it hides the cross.

The rate of the reaction is directly proportional to the concentration of the sodium thiosulfate solution. So if its concentration is doubled, the rate doubles too.

(a) Complete this table by predicting the time taken for the reaction when the concentration of the sodium thiosulfate is changed. (All three reactions are at room temperature.)

Concentration of thiosulfate / mol dm^{-3}	Time taken / s
0.2	100
0.1	
1	

[2]

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(b) Why does the concentration of the sodium thiosulfate solution affect the rate of the reaction?

.....

.....

..... **[1]**

(c) A student is asked to investigate the effect of temperature on the rate of the above reaction.

The student will repeat the experiment at different temperatures, but must keep everything else unchanged.

List three variables that the student must keep unchanged:

.....

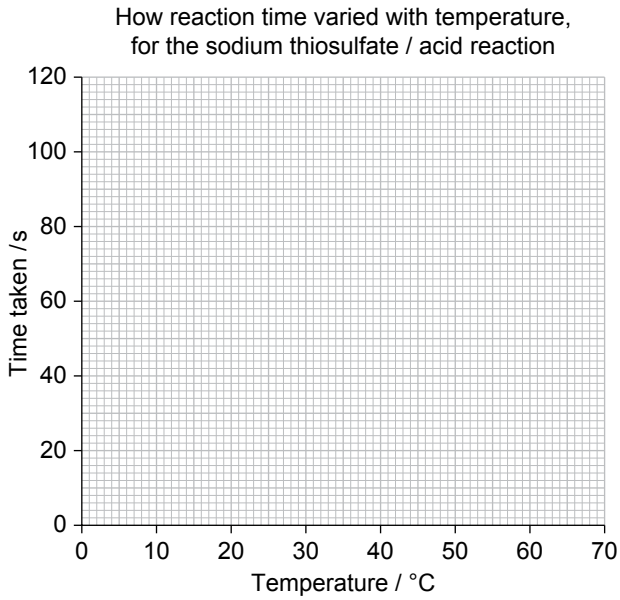
.....

..... **[3]**

(d) In investigating the effect of temperature, the student obtained the results on the right.

Plot these results on the grid below, and join the points to give a smooth line.

Temperature / °C	Time taken / s
20	100
30	69
40	48
50	32
60	26



[4]

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(e)

(i) At which temperature was the reaction fastest? Circle the point on the graph. **[1]**

(ii) Describe the trend the graph shows for the change in reaction time with temperature.

..... **[1]**

(iii) Explain your observation in part (ii) using the idea of collisions.

.....

.....

..... **[1]**

(f) From your graph, deduce how long the reaction will take at 65°C. ..... **[1]**

[Total: 30]

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Redox reactions

1 This shows how zinc and copper(II) oxide react together:

$Zn\ (s) + CuO\ (s) \longrightarrow ZnO\ (s) + Cu\ (s)$

(a) Explain what oxidation and reduction mean, as illustrated by the reaction above.

Oxidation means .....

Reduction means ..... **[2]**

(b) The reaction above is called a redox reaction because .....

..... **[1]**

(c) In the reaction above, the oxidizing agent is ..... and the reducing agent is ..... **[2]**

(d) A more reactive metal will take oxygen from the oxide of a less reactive metal.

Which metal is more reactive—zinc or copper? ..... **[1]**

(e) In the name copper(II) oxide, the Roman numeral tell us that .....

..... **[1]**

(f) Copper forms another oxide, called copper(I) oxide. Its formula is ..... **[1]**

2 In these reactions, is the underlined substance oxidized, reduced, or neither?

Underline your answer.

(a)	$\underline{N_2O_4} \longrightarrow 2NO_2$	oxidized	reduced	neither
(b)	$\underline{CO} + H_2O \longrightarrow CO_2 + H_2$	oxidized	reduced	neither
(c)	$\underline{CuO} + H_2 \longrightarrow Cu + H_2O$	oxidized	reduced	neither
(d)	$\underline{2Mg} + O_2 \longrightarrow 2MgO$	oxidized	reduced	neither
(e)	$\underline{H_2O_2} + 2HI \longrightarrow 2H_2O + I_2$	oxidized	reduced	neither
(f)	$\underline{CO_2} + C \longrightarrow 2CO$	oxidized	reduced	neither
(g)	$\underline{CaCO_3} \longrightarrow CaO + CO_2$	oxidized	reduced	neither

[7]

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Name: .....

3

(a) Add electrons to the correct side to balance the ionic equations in the table.

(b) Then identify each change as oxidation or reduction.

The balanced ionic equation			Oxidation, or reduction?
O_2	$\longrightarrow$	$2O^{2-}$	
$2Br^-$	$\longrightarrow$	Br_2	
Fe^{2+}	$\longrightarrow$	Fe^{3+}	
Al^{3+}	$\longrightarrow$	Al	

[5]

4 This table is about oxidizing and reducing agents. Complete the spaces labelled (i) – (viii).

Redox reagent	Colour before reaction	Product formed	Colour of this product	Is the reagent a reducing or oxidizing agent?
potassium dichromate(VI) ($K_2Cr_2O_7$) in the presence of acid	orange	chromium(III) ions (Cr^{3+})	green	(i)
potassium manganate(VII) ($KMnO_4$) in the presence of acid	(ii)	manganese(II) ions (Mn^{2+})	(iii)	(iv)
potassium iodide (KI)	(v)	iodine (I_2)	(vi)	(vii)
iron(II) ions (Fe^{2+})	green	iron(III) ions (Fe^{3+})	brown	(viii)

[8]

5 Zinc and iodine are reacted together to form zinc iodide:

$Zn + I_2 \longrightarrow ZnI_2$

Write ionic equations for the oxidation and reduction reactions that take place:

Oxidation: .....

Reduction: .....

[2]

[Total: 30]

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Acids and bases

1

(a) Underline the three bases in this list:

(i) ammonia **(ii)** carbon monoxide **(iii)** magnesium

(iv) copper(II) oxide **(v)** sodium hydroxide **(vi)** sulfur dioxide **[3]**

(b) Now underline the three properties of soluble bases in this list:

(i) turn red litmus blue **(ii)** neutralize acids to form salts and water

(iii) melt at low temperatures **(iv)** displace ammonia from ammonium salts

(v) react with metals to form hydrogen

(vi) release carbon dioxide from carbonates **[3]**

2 These are the first three steps in preparing nickel(II) sulfate from nickel oxide and sulfuric acid.

Step 1: Add excess powdered nickel(II) oxide to some hot sulfuric acid, and stir the mixture.

Step 2: Remove the excess solid oxide from the solution.

Step 3: Heat the solution to evaporate some of the water.

(a) Draw simple labelled diagrams to show how steps 1 to 3 should be carried out in the lab.

Step 1	**Step 2**	**Step 3**

[6]

(b) Why is the oxide used in powdered form rather than as lumps?

..... **[1]**

(c) How can you tell when an excess of the oxide has been added?

..... **[1]**

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(d) Complete: Step 3 gives a ..... solution in which no more salt can dissolve **at** that temperature. As it cools, ... will form. **[2]**

3 'Aspirin' is 2-ethanoyloxybenzoic acid.
It is soluble in hot water, and the solution turns blue litmus paper red.
The solution reacts with baking soda, releasing carbon dioxide gas.

(a) Which ion in the solution causes the litmus paper to change colour? ..... **[1]**

(b) Aspirin is a weak acid.

(i) Suggest a pH value for the solution. .....

(ii) Explain what is meant by the term weak acid.

..... **[2]**

(c)

(i) What would you expect to see when baking soda (sodium hydrogen carbonate) is added to the solution of aspirin? .....

(ii) The hydrogen carbonate ion (HCO_3^-) acts as a base in the reaction. It reacts with the ion you identified in part (a). Complete the ionic equation for the reaction:

HCO3– + ... ⟶ ..... + ... **[2]**

4 Hydrochloric acid is neutralized by sodium hydroxide solution. Which ions react together during the neutralization? Tick their box.

(a) sodium ions and hydrogen ions ☐
(b) hydroxide ions and chloride ions ☐
(c) sodium ions and chloride ions ☐
(d) hydrogen ions and hydroxide ions ☐ **[1]**

5 Tick a box to complete the sentence correctly.
A base is a substance that …

(a) donates hydrogen ions ☐ **(b)** accepts protons ☐
(c) accepts electrons ☐ **(d)** donates hydroxide ions ☐ **[1]**

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6 Which type of oxide is carbon monoxide (CO)?

(a) neutral ☐ **(b)** acidic ☐

(c) basic ☐ **(d)** amphoteric ☐ **[1]**

7 Zinc oxide is an amphoteric oxide. This means that it is …

(a) neutral ☐ **(b)** strongly acidic ☐

(c) strongly basic ☐ **(d)** both acidic and basic ☐ **[1]**

[Total: 25]

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Name: .....

The Periodic Table I

1 Hydrogen possesses the properties of …

(a) alkali metals and alkaline earth metals

(b) alkali metals and transition elements

(c) alkali metals and non-metals

(d) alkali metals and noble gases [1]

2 Which of these is untrue for alkali metals?

(a) density increases down the group

(b) melting point decreases down the group

(c) they are good conductors of heat

(d) hardness increases down the group [1]

3 Group VII elements are also called …

(a) halogens

(b) noble gases

(c) inert gases

(d) halides [1]

4 Noble gases are unreactive because …

(a) their atoms are heavier

(b) their outer shells are completely filled

(c) they are bad conductors

(d) they are not abundant [1]

5 a–n below describe elements.

Your task is to match sets of elements to each description.

Answer by writing AM, NG, TE, or H, in each space. These letters stand for:

AM – alkali metals NG – noble gases TE – transition elements H – halogens

Elements in this category …

(a) have atoms with 7 electrons in the outer shell .....

(b) are monatomic elements .....

(c) include gases, a liquid, and solids at room temperature .....

(d) form coloured compounds .....

(e) include elements used as catalysts in industrial processes .....

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Name: .....

(f) can provide an inert atmosphere for welding .....

(g) form compounds with more than one oxidation state .....

(h) react readily with water, forming alkaline solutions .....

(i) tend to have high melting points and high density .....

(j) form molecules with the formula X_2 .....

(k) are in Group I of the Periodic Table .....

(l) have atoms with a very stable arrangement of electrons .....

(m) occur naturally in air .....

(n) include precious metals such as silver, platinum, and gold .....

[14]

6 Why do the Group II elements have similar properties? Tick a box.

because they have similar melting points ☐

because they are all metals ☐

because their atoms have the same number of valence electrons ☐

because the first shell in their atoms contains 2 electrons ☐ **[1]**

7 An element has 5 valency electrons, and conducts electricity.
Where in the Periodic Table might this element be found? Tick a box.

	Group	Period	
a	V	3	
b	V	6	
c	I	5	
d	m	5	

[1]

8 The trends in properties going up Group VI follow a similar pattern to those going up Group VII.
Which element will most readily form an ion with a charge of 2^-?

(a) oxygen ☐ (b) sulfur ☐

(c) selenium ☐ (d) tellurium ☐ **[1]**

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Name: .....

9 This table shows data for elements in the third period of the Periodic Table.

Group	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**0**
Element	sodium	magnesium	aluminium	silicon	phosphorus	sulfur	chlorine	argon
Electrons in outer shell	1	2	3	4	5	6	7	8
Element is a ...	metal	metal	metal	metal-loid	nonmetal	non-metal	non-metal	nonmetal
Reactivity	high ⟶			low ⟶			high	unreactive
Melting point / °C	98	649	660	1410	590	119	–101	–189
Oxide is ...	basic ⟶		amphoteric	⟶ acidic 2				–

(a) The table indicates that silicon is a metalloid. What is a metalloid?

..... **[1]**

(b) Describe how these change as you go across the third period from left to right:

(i) the number of valency electrons

.....

(ii) the metallic / non-metallic character of the elements

.....

(iii) their melting points

.....

(iv) their reactivity

.....

(v) the nature of the oxides

..... **[5]**

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Name: .....

(c) Describe the relationship between an element's valency electrons and its metallic / non-metallic properties.

.....

.....

..... [1]

10 The elements across Period 2, from left to right, are:

lithium beryllium boron carbon nitrogen oxygen fluorine neon

The trends across the period follow the same pattern as for Period 3.

Using the table in question 9 to help you, name:

(a) the two most reactive elements in Period 2 ..... [1]

(b) the most unreactive element in Period 2 ..... [1]

[Total: 30]

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Name: .....

The Periodic Table II

1 Which of these is not a transition element?

(a) iron

(b) chromium

(c) silver

(d) aluminium [1]

2 Stainless steel is a/an …

(a) alloy

(b) catalyst

(c) element

(d) transition element [1]

3 An example of a metalloid is …

(a) carbon

(b) iron

(c) silicon

(d) silver [1]

4 Moving across a period from left to right …

(a) reactivity increases across metals

(b) reactivity decreases across metals

(c) reactivity decreases across non-metals

(d) there is no change in reactivity [1]

5

(a) Why does atomic size increase down a group but decrease along a period from left to right?

.....

..... [1]

(b) Explain why rubidium reacts more vigorously than sodium with cooled water?

.....

..... [1]

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Name:

6

(a) Why do metals never exist as diatomic molecules?

.....

..... **[1]**

(b) Non-metals can form covalent bonds with other non-metals and ionic bonds with metals. Why do non-metals form covalent bonds with other non-metals instead of forming ionic bonds?

.....

..... **[1]**

7

(a) Why do transition metals form coloured compounds?

.....

..... **[1]**

(b) Why are transition metals and their compounds often used as catalysts in industrial processes?

.....

..... **[1]**

[Total: 10]

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Name: .....

The behaviour of metals

1 Which of these is not a property of metals?

(a) lustre (b) malleability

(c) low melting point (d) high density [1]

2 Which of these is the most reactive?

(a) copper (b) iron

(c) calcium (d) potassium [1]

3 When metals react with hydrochloric acid …

(a) hydrogen is displaced (b) oxygen is produced

(c) a base is produced (d) water is produced [1]

4 Metal oxides are …

(a) acidic (b) basic

(c) alkaline (d) neutral [1]

5 Sonorous metals can be …

(a) made to make a ringing sound (b) made into wires

(c) made into sheets (d) made to shine [1]

6 Reactions with dilute hydrochloric acid can be used to compare metals for reactivity.

A student was given strips of four metals W, X, Y, and Z, and made the following observations:

Metal	When added to a solution of hydrochloric acid …
W	no apparent reaction
X	vigorous fizzing; the metal bobbed up and down, and soon disappeared
Y	a few bubbles arose from the metal surface
Z	a steady stream of bubbles arose from the metal surface

(a) Arrange the four metals in order of their reactivity:

least reactive ⟶ most reactive

[2]

(b) Reactions between metals and acid are exothermic.

(i) In the reactions above, which metal will give the greatest temperature rise? .....

(ii) How will the temperature rise compare if the metal is in powdered form?

..... [2]

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Name: .....

(c)

(i) Which of the four metals could have been copper? .....

(ii) Name another metal that will give the same observation as copper. ..... **[2]**

7 This table shows four metals, and the ions they form when they react with compounds of other metals in solution.

Answer the questions below using only the metals and metal ions given in the table.

Metals	**Order of reactivity**	**Ions formed in reactions**
magnesium	↑ increasing reactivity	Mg^{2+}
chromium		Cr^{3+}
nickel		Ni^{2+}
copper		Cu^{2+}

(a) Which ion shows the highest oxidation state? ..... **[1]**

(b)

(i) Which metal has the greatest tendency to form positive ions? .....

(ii) Write an ionic equation to show how it forms positive ions: .....

(iii) Is the metal being oxidized, or reduced, in this reaction? ..... **[3]**

(c)

(i) Which metal ion will most readily accept electrons? .....

(ii) Write an ionic equation to show how it accepts electrons: .....

(iii) Is the metal ion being oxidised, or reduced, in this reaction? ..... **[3]**

(d)

(i) Chromium reacts with a solution of nickel(II) sulfate. Why?

.....

(ii) Write a balanced ionic equation for the reaction between chromium and the nickel ions.

..... **[2]**

(e)

(i) Nickel does not react with chromium(III) oxide because nickel has a ..... drive to form positive ions than chromium does.

(ii) Which metal oxide will react with nickel? .....

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Name: .....

(iii) Which metal will react with chromium(III) oxide? ..... **[3]**

(f) On heating, the hydroxides of all four metals decompose to the oxide and one other compound.

(i) Name the other compound. .....

(ii) Which hydroxide will decompose the most readily? ..... **[2]**

[Total: 25]

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Name: .....

Making use of metals

1 The most abundant metal in the Earth's crust is …

(a) aluminium

(b) potassium

(c) silicon

(d) oxygen **[1]**

2 Iron is extracted from an ore called …

(a) galena

(b) haematite

(c) malachite

(d) pyrite **[1]**

3 The electrodes used in the electrolysis of aluminium are made of …

(a) aluminium

(b) copper

(c) carbon

(d) silver **[1]**

4 Brass is an alloy of …

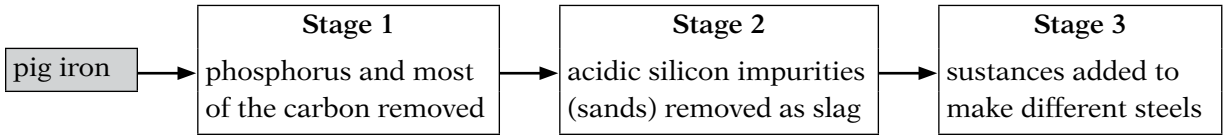
(a) copper and aluminium

(b) copper and zinc

(c) aluminium and iron

(d) zinc and chromium **[1]**

5 This flow chart shows the stages in the production of steel:



(a)

(i) Where does the pig iron come from? .....

(ii) What form is it in? ..... **[2]**

(b) Name the gas used in stage 1: ..... **[1]**

(c)

(i) A solid is added in stage 2. Name it. ..... **[1]**

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Name: .....

(ii) Which type of reaction takes place in stage 2? ..... **[1]**

(d) Name two substances that would be added in stage 3 to make stainless steel.

..... **[1]**

6 Many metals become more useful when mixed with other elements than when pure.

(a) What are the mixtures called? ..... **[1]**

(b) Give one use for:

(i) mild steel .....

(ii) stainless steel .....

(iii) brass ..... **[3]**

7 Cryolite is an aluminium compound. It is used in the extraction of aluminium from alumina. Why?

(a) to purify the aluminium as it forms ☐

(b) to provide Al^{3+} ions, which are then reduced to aluminium ☐

(c) to dissolve the alumina, at a temperature lower than its melting point ☐

(d) to allow a lower voltage to be used, making the process more economical ☐ **[1]**

8 During the extraction of aluminium, the carbon electrodes must be replaced at intervals. Why?

(a) They react with the oxygen that is released, forming carbon dioxide. ☐

(b) They slowly dissolve in the electrolyte. ☐

(c) They become contaminated with impurities, which makes them less effective. ☐

(d) As they heat up, they become poorer at conducting electricity. ☐ **[1]**

9 Which chemical reduces the zinc compound in the extraction of zinc?

(a) sulfur dioxide ☐ **(b)** hydrogen sulfide ☐

(c) carbon monoxide ☐ **(d)** carbon dioxide ☐ **[1]**

10 Galvanizing is a process in which iron is coated with another element. Which element?

(a) zinc ☐ **(b)** carbon ☐ **(c)** brass ☐ **(d)** copper ☐ **[1]**

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Name:

11 Aluminium alloys are used in building aircraft because …

(a) they rust less than iron does ☐

(b) aluminium is cheap to extract ☐

(c) they combine strength with low density ☐

(d) they are good conductors of heat and electricity ☐ **[1]**

12 Zinc is extracted from zinc blende. Zinc is used …

(a) as electrodes for the extraction of aluminium ☐

(b) to make food containers ☐

(c) to build car bodies ☐

(d) to form brass by mixing it with tin ☐ **[1]**

[Total: 20]

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Name: .....

Some non-metals and their compounds

1 The most abundant gas in the atmosphere is …

(a) oxygen

(b) carbon dioxide

(c) hydrogen

(d) nitrogen **[1]**

2 The Haber process is used to manufacture …

(a) fertilizers

(b) plastics

(c) ammonia

(d) pesticides **[1]**

3 Which of these is an important constituent of fertilizers?

(a) nitrogen

(b) carbon

(c) oxygen

(d) water **[1]**

4 Different physical forms of an element are called …

(a) ions

(b) isotopes

(c) allotropes

(d) compounds **[1]**

5 When methane burns in oxygen, carbon monoxide may be produced.

(a) Complete the sentence: Methane is also known as ..... gas. **[1]**

(b) What is the formula for carbon monoxide? ..... **[1]**

(c) Under what conditions will methane produce carbon monoxide?

..... **[1]**

(d) Balance this equation for the reaction:

$\ldots.CH_4\,(g) + \ldots.O_2\,(g) \longrightarrow \ldots.CO\,(g) + \ldots.H_2O\,(l)$ **[1]**

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Name:

(e) Carbon monoxide is dangerous. Why?

..... **[1]**

6 Limestone is a natural mineral used in the manufacture of lime (quicklime).

(a)

(i) The chemical name for lime is ..... and its formula is .....

(ii) Lime is produced by the *thermal decomposition* of limestone. Explain the term in italics.

.....

(iii) The reaction described in part (ii) is important in the manufacture of iron. Explain why.

.....

..... **[4]**

(b) Water is added to lime. Complete these sentences.

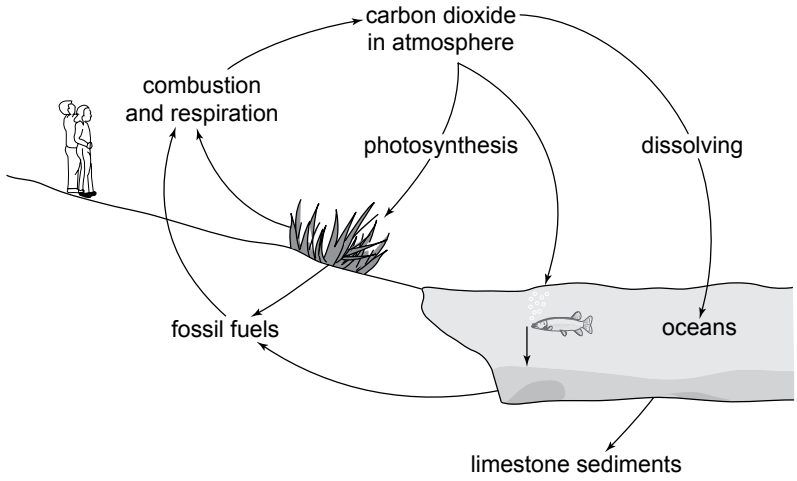
The chemical name for the compound that forms is .....

Its common name is ..... and its formula is ..... **[3]**

(c) What property do the calcium compounds in parts (a) and (b) have that makes them useful on farms?

..... **[1]**

7 This is a simplified outline of the carbon cycle.



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Name:

(a)

(i) Photosynthesis removes carbon dioxide from the atmosphere. Explain how.

.....

.....

(ii) Which other process removes this gas from the atmosphere?

..... **[2]**

(b) Some carbon dioxide is converted to limestone. The chemical name for this compound is

..... and its formula is ..... **[2]**

(c) Explain what respiration is.

.....

..... **[1]**

(d) The level of carbon dioxide in the atmosphere has increased over the years. Suggest a reason.

.....

..... **[1]**

8 Sulfuric acid is manufactured by the Contact Process. The key reaction in the process is:

$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g)$

(a) The sulfur dioxide is obtained from sulfur.

(i) Name one natural source of sulfur. .....

(ii) How is the sulfur dioxide made? ..... **[2]**

(b) In the key reaction, high pressure favours the production of sulfur trioxide. Why?

.....

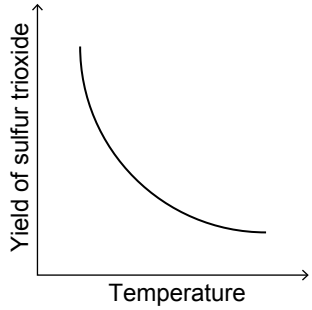
..... **[1]**

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Name:

(c) Name the catalyst used in the key reaction. ..... **[1]**

(d) This graph shows how the yield of sulfur trioxide varies with temperature.



(i) How does the yield change as the temperature rises? .....

(ii) Is the reaction to produce sulfur trioxide exothermic, or endothermic? .....

(iii) Give the reasoning behind your answer in part (ii).

.....

(iv) What other factor must be considered when choosing the temperature for the reaction?

.....

..... **[4]**

(e) The sulfur trioxide is then dissolved in concentrated sulfuric acid to form oleum ($H_2S_2O_7$).

Give the equation for this reaction. ..... **[1]**

(f) The oleum is then turned back to sulfuric acid by adding water.

(i) Give the equation for this reaction. ..... **[1]**

(ii) Why is the sulfur trioxide not dissolved directly in water?

..... **[2]**

[Total: 35]

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Name: .....

Air and water I

1 Gases can be separated from air by …

(a) fractional distillation

(b) distillation

(c) electrolysis

(d) heating air at very high temperatures [1]

2 Nitrogen is used …

(a) in advertising signs

(b) in light bulbs

(c) to quick-freeze food

(d) in respiration [1]

3 Which of these is not a polluting gas?

(a) carbon monoxide

(b) sulfur dioxide

(c) nitrogen oxides

(d) hydrogen [1]

4 A catalytic converter is used in cars to …

(a) convert ozone to oxygen

(b) convert harmful gases to harmless gases

(c) make sulfur dioxide harmless

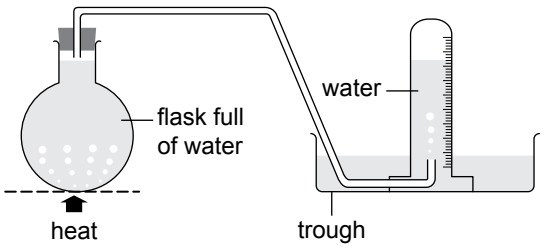
(d) make the car go faster [1]

2 Oxygen and nitrogen, the two main gases in air, are both slightly soluble in water.

Using the apparatus on the right, a sample of water was boiled until 100 cm^3 of dissolved air had been collected.

The collected air was then passed over heated copper.

Its final volume was 67 cm^3.



(a) How can you tell from the diagram that air is less soluble in hot water than in cold water?

..... [1]

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Name: .....

(b) Which gas—oxygen or nitrogen—is removed by the heated copper? ..... **[1]**

(c) Calculate:

(i) the volume of oxygen in 100 cm^3 of dissolved air .....

(ii) the percentage of oxygen in dissolved air .....

(iii) the percentage of nitrogen in dissolved air ..... **[3]**

(d) The value calculated for nitrogen in part (c) (iii) above is only approximate. Suggest a reason.

..... **[1]**

(e)

(i) How do the % of oxygen and nitrogen in dissolved air differ from their % in atmospheric air?

.....

.....

(ii) Which gas is more soluble in water—oxygen or nitrogen? ..... **[2]**

6

(a) Give one use of water:

(i) on farms .....

(ii) in power stations ..... **[2]**

(b) Making water fit to drink involves many different processes. Explain why the water:

(i) is passed through a bed of sand .....

(ii) has chlorine added to it ..... **[2]**

(c) The water from the treatment plant is sent to a storage reservoir.

(i) Will this water boil at exactly 100°C? .....

(ii) Give a reason for your answer in part (i). .....

..... **[2]**

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Name: .....

7 Modern car engines contain a catalytic converter through which the exhaust gases pass.

(a)

(i) Explain why oxides of nitrogen are present in the exhaust gases.

.....

(ii) What problems would these gases cause if they escaped into the air?

.....

(iii) In the catalytic converter these oxides are converted into two harmless gases. Name them.

..... **[3]**

(b)

(i) Which exhaust gas is the result of incomplete combustion of petrol?

.....

(ii) Why is every effort made to remove this gas?

.....

(iii) Name the gas it forms in the catalytic converter. ..... **[3]**

(c) 'The catalytic converter does not solve all the environmental problems associated with car engines.' Give one example to back up that statement.

..... **[1]**

[Total: 25]

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Name: .....

Air and water II

1 Carbon dioxide is removed from the air by …

(a) combustion

(b) photosynthesis

(c) respiration

(d) all of the above [1]

2 Which of these is a possible effect of climate change?

(a) rising sea levels

(b) changing weather patterns

(c) more frequent storms

(d) all of the above [1]

3 Eutrophication is caused by …

(a) insecticides

(b) pesticides

(c) fertilizers

(d) industrial waste [1]

4 At a water treatment plant, charcoal is used to …

(a) separate suspended particles

(b) kill bacteria

(c) remove bad odours

(d) remove harmful chemicals [1]

5

(a) Name the main industrial pollutants that contribute to acid rain.

.....

..... [1]

(b) Why does acid rain cause deforestation?

.....

..... [1]

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Name: .....

(c) How does acid rain over a pond or river cause the death of fish?

.....

..... **[1]**

6

(a) A marble statue was set up in the marketplace of an industrial town. The statue had iron supports inside it to give strength to the arms. After 10 years one of the arms fell off. Describe the changes that might have occurred in the marble statue to cause the arm to fall off.

.....

.....

..... **[2]**

(b) How might the release of sulfur dioxide from a factory chimney be prevented?

.....

..... **[1]**

[Total: 10]

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Name: .....

Organic chemistry I

1 A hydrocarbon is composed of …

(a) carbon

(b) hydrogen

(c) carbon and hydrogen

(d) carbon, hydrogen, and nitrogen **[1]**

2 Naphtha obtained from the fractional distillation of petroleum is used …

(a) in the manufacture of plastics

(b) as aircraft fuel

(c) to make wax

(d) as fuel for power stations **[1]**

3 Cracking ethane gives …

(a) ethane and water

(b) ethane and hydrogen

(c) ethylene and water

(d) ethane **[1]**

4 Alkanes have the general formula …

(a) C_nH_n

(b) C_nH_{2n+1}

(c) C_nH_{2n}

(d) C_nH_{2n+2} **[1]**

5

(a) State the general formula for alcohols.

..... **[1]**

(b) Ethanol can be manufactured by the fermentation of glucose using enzymes from yeast as catalysts. Write the equation for the fermentation of glucose.

..... **[1]**

(c) Name the enzyme, present in yeast, which is responsible for this conversion.

..... **[1]**

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Name: .....

(d) Why is this process carried out under anaerobic conditions?

..... [1]

6

(a) Differentiate between oxidation and combustion.

.....

..... [1]

(b) Ethanol is often used as a fuel. It is mixed with a small proportion of petrol and is called gasohol. State the advantages and disadvantages of ethanol as a fuel.

.....

..... [2]

7 Ethyl ethanoate is prepared by heating a mixture of ethanol and ethanoic acid in an oil bath. Concentrated sulfuric acid is added to the flask.

(a) Why is concentrated sulfuric acid used?

.....

..... [1]

(b) Why is the heating done over an oil bath?

.....

..... [1]

(c) Write the name and formula of the ester formed.

.....

..... [2]

[Total: 15]

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Name: .....

Organic chemistry II

1 Isomers of a compound have …

(a) the same formula and structure

(b) a different formula and structure

(c) the same formula and a different structure

(d) the same structure but a different formula **[1]**

2 The double bond in alkenes indicates …

(a) alkenes are hydrocarbons

(b) alkenes are unsaturated

(c) alkenes are saturated

(d) alkenes are less reactive than alkanes **[1]**

3 Which of these is not a hydrocarbon?

(a) pentane

(b) ethene

(c) butane

(d) ethanol **[1]**

4 Ethanoic acid and alcohol react to form …

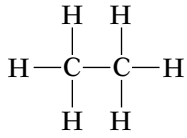
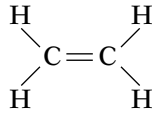
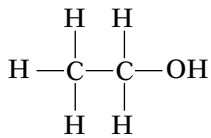
(a) esters

(b) alkanes

(c) alkenes

(d) carboxylic acid **[1]**

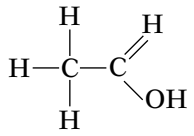
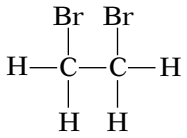
5 **(a)** Fill in the names of the compounds.

	Compound	Name
A		
B		
C		

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Name: .....

D		
E		

[5]

(b) Answer these questions about compounds A–E above.

(i) Which of the compounds are hydrocarbons? .....

(ii) One will react with magnesium ribbon releasing hydrogen. Which one? .....

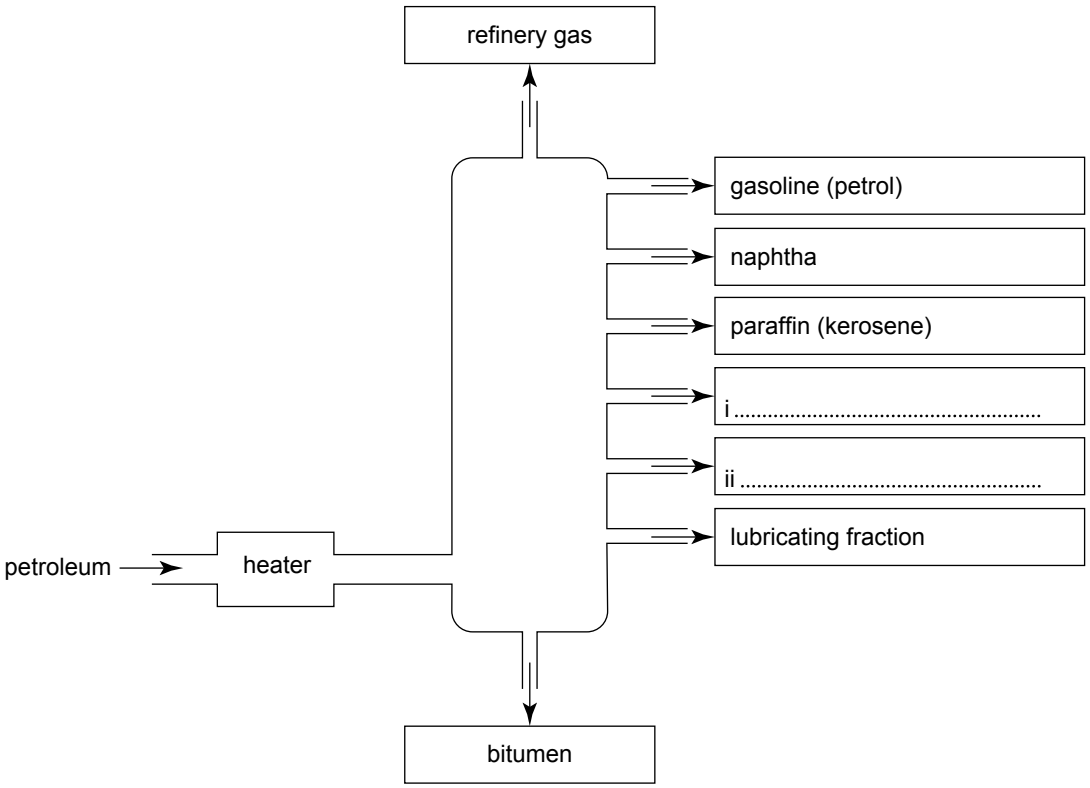
(iii) One can be obtained from compound B by adding steam. Which one? .....

(iv) One can be used as a monomer to make a useful polymer. Which one? .....

(v) One is used as motor fuel, often mixed with petrol. Which one? .....

[5]

6 Petroleum is a mixture of hydrocarbons. This diagram shows the process of separating or refining the mixture into groups or fractions of compounds close in chain length.



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Name: .....

(a) Why is the petroleum heated? ..... [1]

(b) Name the separation technique that is being used. ..... [1]

(c) Fill in the names of the two missing fractions, on the diagram. [2]

(d) Which fraction has the higher range of boiling points—paraffin or gasoline? ..... [1]

(e) (i) Give uses for the five fractions listed in this table.

Fraction	Use
refinery gas	
gasoline	
naphtha	
kerosene	
bitumen	

[5]

(f) Some of the hydrocarbons obtained from refining are broken down into smaller molecules.

(i) What is this process called? .....

(ii) Which two conditions are needed for the process? .....

(iii) The process is a very important one. Why?

..... [3]

7 (a) All members of a homologous series fit the same general formula. Complete this table by writing in the names of the series, and the formula and name for the third member of each series.

General formula	Name of homologous series	Third member of series (n = 3)	
		Formula	Name
$C_nH_{2n+1}OH$			
C_nH_{2n}			
$C_nH_{2n}O_2$			
C_nH_{2n+2}			

[3]

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Name: .....

(b) In a homologous series, the chain length increases by one carbon atom at a time.

How many hydrogen atoms are added each time? ..... **[1]**

(c) Members of a homologous series have similar chemical properties. Why?

..... **[1]**

(d) Members of a homologous series show differences in their physical properties. Why?

..... **[1]**

(e) What is the trend in boiling points as the chain length increases?

..... **[1]**

8 The simplest alkane is methane (CH_4).

(a) Draw a diagram in this box to show the bonding in a molecule of methane.

Show only the outer electrons for each atom.

[1]

(b) Alkanes are generally unreactive. Why?

..... **[1]**

(c) Under a certain condition, alkanes will react with chlorine.

(i) What is the essential condition for the reaction? .....

(ii) Name the type of reaction that occurs. .....

(iii) What might occur if an alkene is used in place of an alkane? ..... **[3]**

9 Carboxylic acids show similar properties to inorganic acids (such as hydrochloric acid).

(a) Write an ionic equation to show why ethanoic acid is a weak acid.

..... **[1]**

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Name: .....

(b) In this box:

(i) draw the structural formula of the salt formed when ethanoic acid reacts with sodium hydroxide.

(ii) write its name on the dotted line.

.....

[2]

10 Esters are compounds derived from carboxylic acids.

(a) Name the family of organic compound that reacts with carboxylic acids to form esters.

..... **[1]**

(b)

(i) Draw the structural formula of the ester ethyl ethanoate in the space below.

(ii) Then circle the part of the formula that is referred to as the ester linkage.

[2]

(c) Draw the structural formulae of the two chemicals you would use to make the ester butyl ethanoate, and write their names on the dotted lines.

.....

..... **[4]**

(d) Esters have a characteristic property that leads to their use in soaps, shampoos, and cosmetics.

What is this property? ..... **[1]**

[Total: 50]

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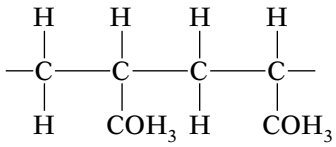
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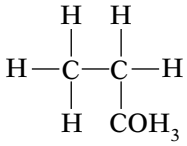
Polymers

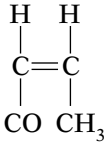
For questions 1– 5, select the correct answer by ticking inside the correct box.

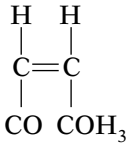
1 This shows the structure of a polymer:

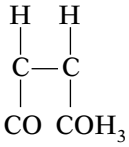


Which structure represents the monomer from which the polymer was made?

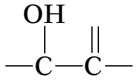
(a)  ☐

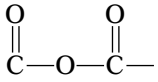
(b)  ☐

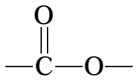
(c)  ☐

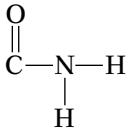
(d)  ☐ **[1]**

2 Which of these represents the linkage group in a polyester?

(a)  ☐

(b)  ☐

(c)  ☐

(d)  ☐ **[1]**

3 Nylon is made of macromolecules. Which pair of words correctly describes it?

	Type of macromolecule in nylon	**Type of polymerization that formed it**	
(a)	polyamide	condensation	
(b)	polyester	condensation	
(c)	polyamide	addition	
(d)	polyester	addition	

[1]

4 When proteins are broken down, the products are …

(a) hydrocarbons ☐ **(b)** ammonium compounds ☐

(c) fatty acids ☐ **(d)** amino acids ☐ **[1]**

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Name: .....

5 Which of these small molecules are the building blocks for carbohydrates?

(a) hydrocarbons ☐ **(b)** monosaccharides ☐

(c) alcohols ☐ **(d)** amino acids ☐ **[1]**

6 Addition polymerization and condensation polymerization are the two main ways in which polymers are formed.

(a) Describe the general structure of polymers. Include the terms monomer and macromolecule in your answer.

.....

..... **[3]**

(b) Give the two key differences between addition and condensation polymerization.

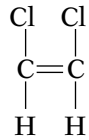
.....

.....

..... **[2]**

(c)

(i) In the space below, draw a section of the addition polymer formed from the monomer dichloroethene, which has this structure:



Show three units of the monomer joined up:

(ii) Describe one environmental problem that may be caused by the disposal of this polymer:

in landfill sites .....

by burning .....

(iii) Apart from environmental considerations, suggest two other benefits of recycling plastics.

.....

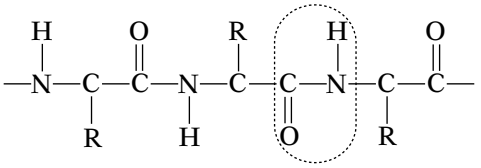
..... **[5]**

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Name: .....

7 Proteins are macromolecules with the structure shown on the right. R represents different groups of atoms.



(a)

(i) Name the linkage contained within the dotted loop. .....

(ii) Name a synthetic polymer with the same linkage. ..... **[2]**

(b) Proteins undergo hydrolysis when they are boiled in dilute acid.

(i) Explain what is meant by the term hydrolysis.

(ii) What type of compound is produced by the hydrolysis of proteins?

(iii) In this box, draw a structure to represent the units produced as a result of hydrolysis of proteins.

[3]

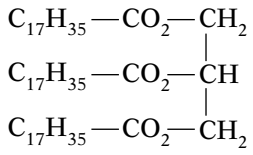
(c) Proteins are one of the three main constituents of food. Name the other two.

..... **[2]**

(d) Starch, another macromolecule, can also be hydrolyzed using acid.
What compound is produced in the complete hydrolysis of starch?

..... **[1]**

8 The structure on the right represents a macromolecule.



(a)

(i) Which type of macromolecule is it? .....

(ii) What type of linkage does it contain? .....

(iii) Name a synthetic polymer that contains the same linkage. ..... **[3]**

(b) Hydrolysis of this macromolecule gives a very useful product.

(i) Name the reagent used to bring about the hydrolysis. .....

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Name: .....

(ii) Name the useful product obtained. ..... [2]

(c)

(i) In the box on the right, draw the structural formula of the other compound formed during the hydrolysis.

(ii) Name the compound you have drawn.

..... [2]

[Total: 30]

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Separating substances

(1) d **(2)** a **(3)** d **(4) (a)** Sodium chloride is soluble in water, but barium sulfate is not. **(b)** Students' drawings should show a filter funnel with filter paper, set in a beaker or flask. The filter paper holds a solid labelled barium sulfate. The beaker or flask contains a solution labelled sodium chloride solution. **(c)** The tiny particles from the sodium chloride had spread out, so could pass through the holes in the filter paper. The barium sulfate particles were still held together, and the structures were too large to pass through the filter paper. **(5) (a)** Students should show crystals at the bottom of the second beaker. **(b)** Using a glass rod, place a drop of solution on a microscope slide. If it is saturated, crystals will form. **(c)** Pale green; as the coloured particles group together into crystals, the solution gets paler. **(d)** crystallization **(6) (a)** The diagrams should show: **(i)** a spot on a pencil line a little above the bottom of the paper **(ii)** the water level above the bottom of the paper, but below the pencil line **(iii)** two spots, at different heights above the position of the original spot **(b)** As the solvent (in this case, water) moves up the paper, the dyes dissolve in it. The more soluble a dye is, the further it will travel with the solvent.

Ion identification

(1) (a)

i	heavier (more dense) than air	lighter (less dense) than air	insoluble or only slightly soluble in water
ii	carbon dioxide, chlorine, hydrogen chloride, sulfur dioxide	ammonia, hydrogen	carbon dioxide, hydrogen, oxygen

(b) Students should draw a gas syringe **(2) (a)** negative ions **(b)**

chloride	Cl^-	add dilute nitric acid followed by silver nitrate solution
iodide	I^-	
sulfate	SO_4^{2-}	add dilute hydrochloric acid followed by barium nitrate solution
nitrate	NO_3^-	add dilute sodium hydroxide, then aluminium foil, and heat gently
carbonate	CO_3^{2-}	add dilute hydrochloric acid

(3) (a) positive ions **(b)**

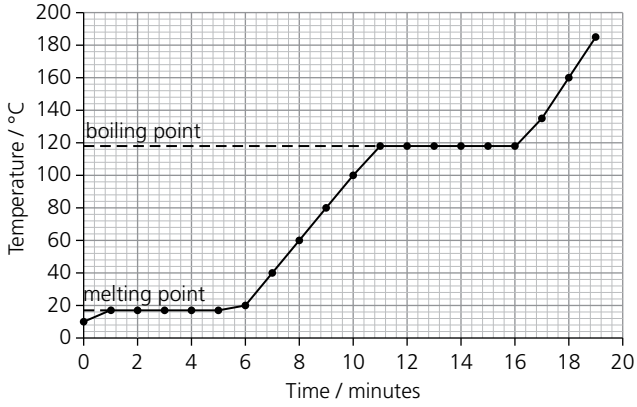
Ion	**copper(II)**	**iron(II)**	**iron(III)**
Formula	Cu^{2+}	Fe^{2+}	Fe^{3+}
Test	add dilute sodium hydroxide (or dilute ammonia solution)		

Ion	**aluminium**	**calcium**	**zinc**
	Al^{3+}	Ca^{2+}	Zn^{2+}
Test 1	add dilute sodium hydroxide		
Test 2	add dilute ammonia solution		
Test 3	add dilute sodium hydroxide		

Ion	ammonium
Formula	NH_4^+
Test	add sodium hydroxide solution and heat gently

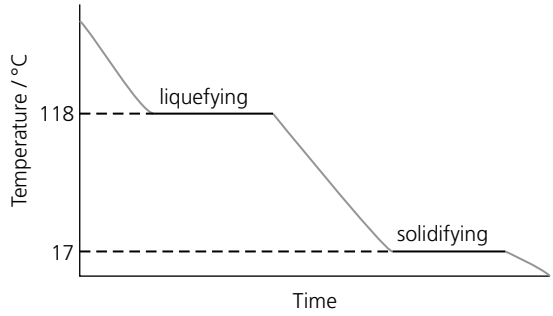
States of matter

(1) a **(2)** c **(3)** (a) and (b):



(c) melting **(d)** any time between the 5th and 11th minutes **(e) (i)** any temperature above 17°C but below 118°C **(ii)** any temperature below 17°C **(iii)** any temperature above 118°C

(f)



(4) (a) The drawing should show the two types of particles evenly mixed and spread through the whole gas jar. **(b) (i)** random **(ii)** These words should be crossed out, in this order: *low, high, zero*. **(c)** Place some crystals of a coloured soluble compound e.g. potassium manganate(VII) carefully at the bottom of a beaker of water, and leave it without stirring for several days.

Atoms and elements

(1) (a) s, s **(b)** s, f **(c)** s, m **(d)** s, d **(e)** s, s **(f)** f, f

(2)

Isotope	Name of element	Proton number	Nucleon number	Number of p	e	n
$^{16}_{8}O$	oxygen	8	16	8	8	8
$^{18}_{8}O$	oxygen	8	18	8	8	10
$^{12}_{6}C$	carbon	6	12	6	6	6
$^{13}_{6}C$	carbon	6	13	6	6	7
$^{24}_{12}Mg$	magnesium	12	12	12	12	12
$^{25}_{12}Mg$	magnesium	12	13	12	12	13
$^{35}_{17}Cl$	chlorine	17	35	17	17	18
$^{37}_{17}Cl$	chlorine	17	37	17	17	20

(3)

Number of protons	Number of neutrons	Number of electrons	Formula of ion
9	10	10	F^-
16	16	18	S^{2-}
3	4	2	Li^+
20	20	18	Ca^{2+}

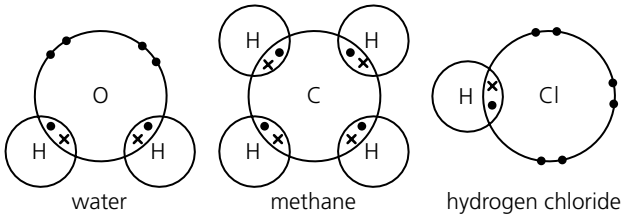
(4) (a)

Atom	Proton number	Electron distribution			
		1st shell	2nd shell	3rd shell	4th shell
P	2	2			
Q	4	2	2		
R	13	2	8	3	
S	15	2	8	5	
T	20	2	8	8	2

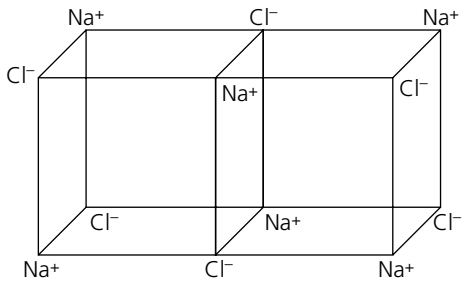
(b) (3) (c) only one: Q **(d)** Q and T **(e)** The diagram should show 4 shells, with 2 electrons in inner shell, 8 in next two, and 1 in the outermost.

Atoms combining I

(1) (a) and **(b)**

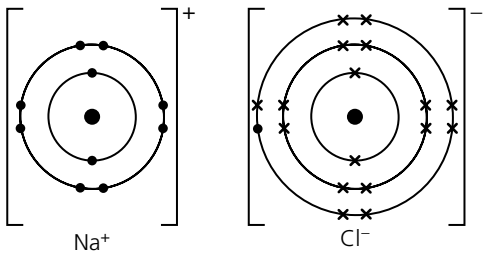


(2) (a)



(b) (i) sodium chloride **(ii)** ionic **(c) (i)** soluble **(ii)** 801 **(iii)** poor (for the solid)

(d)



(e) The outer electron from the sodium atom is transferred to the outer shell of the chlorine atom. **(3) (a)** elements **(b)** The missing labels are—left: carbon atom, diamond; right; graphite **(c)** bonding: In diamond each carbon atom forms four covalent bonds, but in graphite each forms only three; structure: Diamond has a 3-D structure, with the

carbon atoms in a tetrahedral arrangement; in graphite the carbon atoms form layers of flat rings, with six atoms in each ring **(d) (i)** Diamond is very hard because all bonds are strong; graphite is soft because the layers are held together with only weak forces, and can easily slide over each other. **(ii)** cutting tools: diamond; lubricant: graphite **(e)** Diamond has no electrons free to move, so it is an insulator. Graphite has free electrons that can move through the layers as a current, so it is a conductor.

Atoms combining II

See Chapter 4 of *Fundamental Chemistry*.

Reacting masses and chemical equations

(1) (a) hydrogen + chlorine → hydrogen chloride: $H_2 + Cl_2 \rightarrow 2HCl$ **(b)** nitrogen + hydrogen → ammonia: $N_2 + 3H_2 \rightarrow 2NH_3$ **(c)** phosphorus + chlorine → phosphorus (tri)chloride: $2P + 3Cl_2 \rightarrow 2PCl_3$ **(d)** sulfur dioxide + oxygen → sulfur trioxide: $2SO_2 + O_2 \rightarrow 2SO_3$ **(e)** methane + oxygen → carbon dioxide + water: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
(2) (a) $3KOH + H_3PO_4 \rightarrow K_3PO_4 + 3H_2O$ **(b)** $Pb(NO_3)_2 + 2Kl \rightarrow Pbl_2 + 2KNO_3$ **(c)** $C_6H_{14} \rightarrow C_4H_8 + C_2H_6$
(d) $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$ **(e)** $2NaNO_3 \rightarrow 2NaNO_2 + O_2$ **(f)** $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$

(3)

	Citric acid	Malic acid
a	21	15
b	$C_6H_8O_7$	$C_4H_6O_5$
c	192	134
d	37.5%	35.8%
e	3.75%	

Using moles

(1) $\dfrac{\text{mass}}{\text{no of moles} \times \text{mass of 1 mole}}$

Substance	A_r or M_r	Number of moles	Mass / g
Cu	64	2	128
Mg	24	0.5	12
Cl_2	71	0.5	35.5
H_2	2	*8*	16
P_4	124	2	248
O_3	48	0.033	1.6
H_2O	18	3	*54*
CO_2	44	0.4	17.6
NH_3	17	0.5	8.5
$CaCO_3$	100	1	100

(2) (a) 1.786 moles of Fe, 0.893 moles of Fe_2O_3, 142.9 g **(b)** 0.102 moles of I_2, 0.068 moles of Al, aluminium is the limiting reagent **(c)** 0.64g of oxygen, 0.02 moles of O_2, 0.03 moles of Pb, Equation: $3Pb + 2O_2 \rightarrow Pb_3O_4$

(3) $\dfrac{\text{no of moles}}{\text{volume} \times \text{concentration}}$

Solute	Volume of solution	Concentration (mol/dm^3)	Moles of solute in it
sodium chloride	1 dm^3	2	2
hydrochloric acid	100 cm^3	0.5	0.05
sodium hydroxide	2 dm^3	0.5	1
sulfuric acid	250 cm^3	2	0.5
ammonium nitrate	150 cm^3	2	0.3
copper(II) sulfate	3 dm^3	0.25	0.75

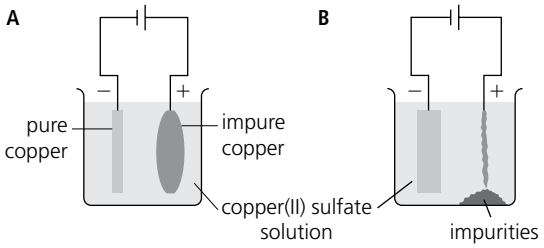
(4) (a) 0.005 moles of NaOH, 0.0025 moles of H_2SO_4, concentration of the sulfuric acid is 0.25 mol/dm^3. **(b)** 0.5 moles of HCl, 0.25 moles of Mg, mass of magnesium is 6 g **(c)** 0.005 moles of $FeSO_4$, 0.001 moles of $KMnO_4$, 20 cm^3 of potassium manganate(VII) solution

Balancing equations

(1) (a) H_2SO_4 *(l)* + 2NaOH *(l)* → Na_2SO_4 *(s)* + $2H_2O$ *(l)* **(b)** Fe_2O_3 *(s)* + 3CO *(g)* → 2Fe *(s)* + $3CO_2$ *(g)*
(c) $2H_2SO_4$ *(l)* + $2MnO_2$ *(s)* → $2MnSO_4$ *(s)* + O_2 *(g)* + $2H_2O$ *(l)*

Electricity and chemical change

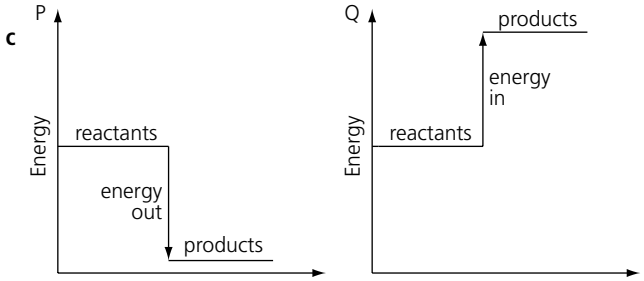
(1) (a) These letters should be circled: A, B, E, F, J **(b)** B, E **(2)** D **(3)** D
(4) (a) cathode: Sr^{2+} + $2e^-$ → Sr, anode: $2Cl^-$ → Cl_2 1 $2e^-$ **(b)** hydrogen, chlorine, strontium hydroxide **(5) (a)** and **(b)** Note how the battery is reversed:



(c) (i) Cu → Cu^{2+} + $2e^2$ **(ii)** Cu^{2+} 1 $2e^-$ → Cu **(d)** electrical circuits

Energy changes and reversible reactions I

(1) (a) temperature change: P +13, Q −8 **(b) (i)** to make sure all the solid reacts and that the temperature is the same throughout the mixture **(ii)** Temperature changes will be smaller because the glass will conduct heat to and from the surroundings.



(2) (a) The temperature of the water will rise. **(b) (i)** fuels: use a similar flame each time, keep same distance between burner and can, turn burner off immediately the required water temperature is reached. **(ii)** water: change water between fuels, use same volume of water each time, stir water the same way, stop heating at the same temperature rise each time **(c)** provide a shield around the flame to reduce heat loss **(d)** C_2H_5OH + $3O_2$ → $2CO_2$ + $3H_2O$ **(3) (a)** $CuSO_4.5H_2O$: hydrated copper(II) sulfate, blue $CuSO_4$: anhydrous copper(II) sulfate, white **(b)** Add water to anhydrous copper sulfate. It will turn blue.

Energy changes and reversible reactions II

(1) +ΔH
(2) (a)

Bond	Energy values / KJ mol^{-1}
1 C=C	612
4 C=H	435 × 4 = 1740
3 O=O	498 × 3 = 1494
Total	**+3846**

(b)

Bond	Energy values / KJ mol^{-1}
4 C=O	805 x 4 = 3220
4 H–O	464 x 4 = 1856
Total	**-5076**

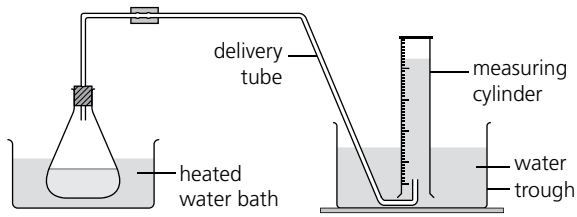
(c) ΔH = -5076 + 3846 = -1230 KJ mol^{-1}
(3) (a) $-\Delta H$ = 4(C=O) + 6(O–H) = (805 x 4) + (464 x 6) = 3220 + 2784 = 6004 KJ mol^{-1} ; $+\Delta H$ = (C–C) + 5(C–H) + (C–O) + (H–O) = (348) + (435 x 5) + (452) + (464) = 3439 KJ mol^{-1}; overall ΔH = -6004 + 3439 = -2565 KJ mol^{-1}
(b) $-\Delta H$ = 10(C=O) + 12(O–H) = (805 x 10) + (464 x 12) = 8050 + 5568 = 13 618 KJ mol^{-1} ; $+\Delta H$ = 12(C–H) + 4(C–C) + 8(O–O) = (435 x 12) + (348 x 4) + (498 x 8) = 5220 + 1392 + 3984 = 10 596 KJ mol^{-1}; overall ΔH = -13 618 + 10 596 = -3022 KJ mol^{-1} **(c)** Ethanol releases 2565 KJ mol^{-1} energy whereas petrol releases -3022 KJ mol^{-1}. Therefore, petrol is more efficient.

Fuel cells

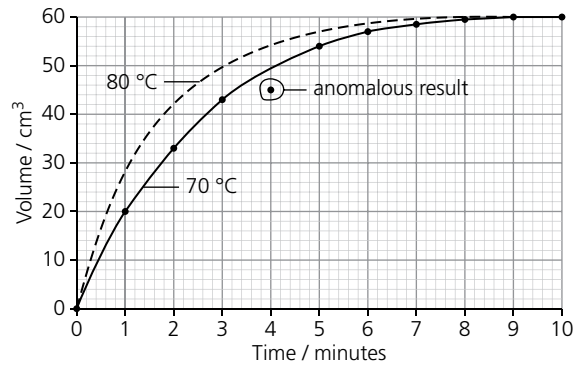
(1) In a normal cell, current flows from cathode to anode through the external circuit whereas in an electrolytic cell, current flows from anode to cathode through the external circuit. **(2)** $2H_2$ *(g)* → $4H^+$ *(aq)* + $4e^-$ **(3)** O_2 *(g)* + $4H^+$ *(aq)* + $4e^-$ → $2H_2O$ *(l)* **(4)** Acid fuel cells: Hydrogen gas loses electrons to form hydrogen ions at the cathode. Oxygen gas gains electrons to form oxide ions. The oxide ions react with hydrogen ions in the electrolyte to form water. Alkali fuel cell: Hydrogen gas reacts with hydroxyl ions to form water and release electrons. The oxygen gas at the anode reacts with electrons and water to form hydroxyl ions in the electrolyte. (**5)** Advantages: It does not produce pollution as the only product formed is water. It produces more energy per gram than any other fuel. It does not need recharging. Disadvantage: Hydrogen and oxygen gas needs to be carried in cylinders at high pressure. A small leak could cause an explosion to occur.

The rate of reaction

(1) (a)



(b), (d) (i), (e)



(c) (i) The rate is highest at the start but gradually decreases until it reaches zero at 9 minutes – the reaction is over. **(ii)** As the reaction proceeds, the reactants get used up. There is less and less of each reactant present to react, so the rate decreases. **(d) (i)** The anomalous reading is circled on the graph below. **(ii)** The volume could have been read wrongly, or recorded too early. **(e)** See the graph below. **(2) (a)** There will be fizzing, as carbon dioxide gas bubbles off. **(b)** to prevent acid spraying out **(c)** Carbon dioxide escapes through the cotton wool, leading to the loss of mass. **(3) (a)** B **(b)** In B, there were more acid particles present, so collisions between the particles of acid and marble were more frequent. This means there were more successful collisions too, so the reaction was faster. **(4) (a)** D **(b)** The temperature was higher for D. So the particles had more energy, and moved faster. This means that collisions between particles of marble and acid were more frequent, and more of them had enough energy to be successful. So the reaction was faster.

Redox reactions

(1) a **(2)** b **(3)** c **(4) (a)** Copper oxide loses oxygen—it is reduced, and hydrogen gains oxygen—it is oxidized. **(b)** hydrogen **(5) (a)** iron(III) oxide + carbon monoxide → iron + carbon dioxide **(b)** Iron oxide loses oxygen—it is reduced; and carbon monoxide gains oxygen – it is oxidised. **(c)** carbon monoxide **(6) (a)** It goes blue because blue copper(II) ions are produced. **(b)** Cu (*s*) + $2Ag^+$ (*aq*) → Cu^{2+} (*aq*) + 2Ag (*s*) **(c)** It loses electrons. **(7)** There is no change in the oxidation state of copper—it remains +II; so no electrons are transferred. **(8) (a)** Period **(3) (b)** gained, lost, shared **(c) (i)** Their atoms gain or share electrons from other atoms, to obtain a stable outer shell. (Covalent bonds are formed.) **(ii)** As you go from Group IV to Group VII, the number of electrons the atoms need, to gain a full shell, decreases. **(d) (i)** Na_2S **(ii)** $SiCl_4$ **(iii)** Al_2S_3 **(iv)** Mg_3P_2

Acids and bases

(1) (a) A **(i)** pipette **(ii)** potassium hydroxide B **(i)** burette **(ii)** hydrochloric acid C **(i)** conical flask **(ii)** 25 cm^3 of potassium hydroxide and phenolphthalein; hydrochloric acid then added from the burette **(b)** pink to colourless **(c)**

Initial reading / cm^3	Final reading / cm^3	Volume used / cm^3
7.8	33.4	25.6

(d) 25 cm^3 of potassium hydroxide, 25.6 cm^3 of hydrochloric acid, no indicator present **(e)** to remove water, in order to obtain solid potassium chloride **(g)** potassium hydroxide + hydrochloric acid → potassium chloride + water **(2) (a)** (no specific order needed):

	Insoluble salt …	made from …	and …
1	barium sulfate	barium chloride	potassium sulfate
2	calcium carbonate	calcium nitrate	sodium carbonate
3	lead iodide	lead nitrate	potassium iodide
4	silver chloride	silver nitrate	sodium chloride

(b) precipitation

(c) (i)

	Ionic equation for the reaction	Spectator ions
1	Ba^{2+} (*aq*) + SO_4^{2-} (*aq*) → $BaSO_4$ (*s*)	K^+ and Cl^-
2	Ca^{2+} (*aq*) + CO_3^{2-} (*aq*) → $CaCO_3$ (*s*)	Na^+ and NO_3^-
3	Pb^{2+} (*aq*) + $2I^-$ (*aq*) → PbI_2 (*s*)	K^+ and NO_3^-
4	Ag^+ (*aq*) + Cl^- (*aq*) → AgCl (*s*)	Na^+ and NO_3^-

(3) (a)

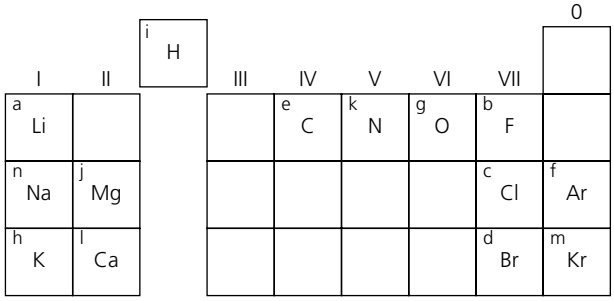
Acidic	Basic	Neutral	Amphoteric
phosphorus oxide	calcium oxide	dinitrogen oxide	zinc oxide
P_2O_5	CaO	N_2O	ZnO

(b) (i) P_2O_5 and ZnO **(ii)** CaO and ZnO **(iii)** will react with both acids and bases

The Periodic Table

(1) c

(2)



(3) (a) Group I: **(i)** reactivity, or density, or softness **(ii)** melting point, or boiling point, or hardness; Group VII: **(i)** melting point, or boiling point, or density **(ii)** reactivity **(b)** It will be more reactive, more dense, and softer. It will have a lower melting and boiling point. **(c)** It will have a higher melting and boiling point, and greater density. It will be less reactive **(4) (a) (i)** bromine **(ii)** iodine **(b) (i)** Chlorine displaces both bromine and iodine from their compounds. **(ii)** Iodine does not displace bromine or chlorine from their compounds.

The behaviour of metals I

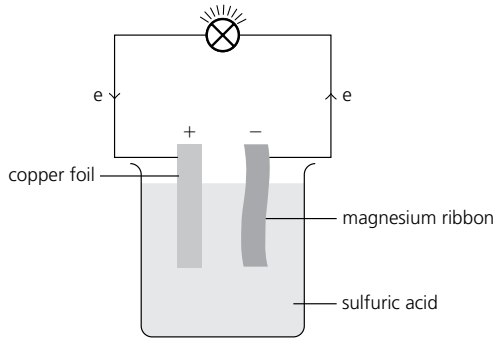
(1) Aluminium is highly reactive and combines readily with other elements to form compounds. Gold is unreactive and occurs in the elemental state. **(2)** Aluminium, being more reactive, forms an oxide layer which prevents the aluminium from reacting with dilute acids. **(3)** Hydrogen is above copper in the reactivity series and can displace copper from its oxide. Hydrogen is below zinc in the reactivity series and cannot displace zinc from its oxide. **(4)** The metals above copper are also above hydrogen in the reactivity series and can displace hydrogen from acids whereas those below hydrogen in the reactivity series, e.g. copper are not strong enough to displace hydrogen from acids. **(5)** Being more electropositive, it would probably lose electrons to form the positive electrode. **(6)** Magnesium is above iron in the reactivity series and would react sacrificially preventing iron from reacting.

The behaviour of metals II

(1) (a)

Property	Name	Example of use
can be drawn into wires	ductile	electrical wires
can be bent into shape	malleable	car bodies
reflect light	shiny	mirrors, car bumpers
make a ringing sound when struck	sonorous	bells
allow electricity to pass through	electrical conductor	electrical circuits
heavy for their volume	dense	weights
their oxides react with acids	have basic oxides	to remove acidic waste gases
transfer heat well	conductor of heat	saucepans

(b) (i) Their oxides react with acids. **(ii)** reaction with cold water, stability of compounds (for example carbonates and hydroxides do not break down on heating) **(iii)** positive **(2) (a)** increases **(b) (i)** very vigorously, with intense fizzing **(ii)** hydrogen **(c)** beryllium **(d)** strontium oxide, SrO **(e)** below **(3) (a)** sulfuric acid **(b)** A current flowed. **(c) (i)** magnesium **(ii)** magnesium
(d)



(e) Missing words, in order: *cell, chemical, electrical* **(f)** It is not easily portable, and the acid would spill out. **(4) (a)** the difference in reactivity of the two metals **(b)** 1.09 V **(c)** It is less reactive than copper.

Making use of metals

(1) a **(2)** a **(3)** The missing terms, in order, are: *hematite, blast, raw, limestone, carbon, carbon dioxide, carbon monoxide, reducing, nitrogen, carbon dioxide* **(4) (a)** mixture of a metal and at least one other substance (usually another metal) **(b)** strength, hardness, resistance to corrosion, more sonorous, etc **(c) (i)** iron **(ii)** chromium, nickel **(d)** copper and zinc; it is harder, or it does not corrode **(5) (a)** bauxite, aluminium oxide (alumina), Al_2O_3

(b) (i) anode: the blocks suspended in the cell; cathode: the lining of the cell (inside the steel) **(ii)** carbon (graphite) **(d) (i)** anode **(ii)** Carbon reacts with the released oxygen to form carbon dioxide. **(e)** to dissolve the aluminium oxide, giving a solution as electrolyte (the melting point of aluminium oxide is too high to make melting it feasible) Al^{3+} (*l*) + $3e^-$ → Al (*l*) **(6) (a) (i)** light, non-toxic, resists corrosion (once the thin layer of aluminium oxide has formed on its surface), can be rolled into thin sheets **(ii)** good conductor of electricity, light, resists corrosion **(b)** Aluminium is quite high in the reactivity series, so you would expect it to behave like a reactive metal. But once the thin layer of aluminium oxide forms, it protects the aluminium, making it appear unreactive. For this reason aluminium can be used for TV aerials, satellite dishes, panels on buildings, window frames, and so on.

Some non-metals and their compounds

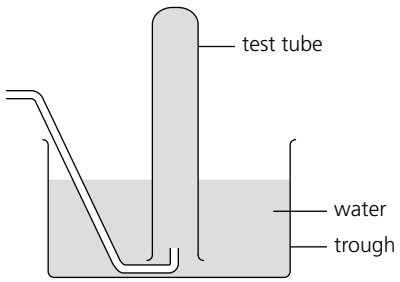
(1) (a) calcium carbonate → calcium oxide + carbon dioxide **(b)** building material, extracting iron, to neutralize acidity in soil, etc. **(2) (a)** Sunlight warms the Earth's surface. Then heat is reflected from the surface. Some escapes to space, but some is absorbed by the greenhouse gases in the atmosphere. So the air gets warmer, and air temperatures around the world rise. We call this global warming. **(b)** any two of: methane, carbon dioxide, water vapour, dinitrogen oxide, ozone **(3) (a)** ammonium chloride or sulfate, + calcium hydroxide or sodium hydroxide **(b)** It is highly soluble in water. **(c)** blue **(d) (i)** ammonia + nitric acid → ammonium nitrate **(ii)** It contains a high % of nitrogen, which all plants need, and it is soluble so can be sprayed onto the soil where crops are planted. **(4) (a)** using methane: CH_4 (*g*) + $2H_2O$ (*g*) → CO_2 (*g*) + $4H_2$ (*g*) using ethane: C_2H_6 (*g*) → C_2H_4 (*g*) + H_2 (*g*) nitrogen: N_2 (*g*) + O_2 (*g*) + $2H_2$ (*g*) → N_2 (*g*) + $2H_2O$ (l) **(b)** High pressure: This favours the side of the equation with fewer molecules—the product. Moderate temperature: A low temperature favours the forward reaction, which is exothermic; but at low temperatures the reaction is too slow, so a moderate temperature is chosen as a compromise. Catalyst: The catalyst speeds up both the forward and reverse reactions, so equilibrium is reached faster. Reaction mixture cooled: The mixture is cooled until the ammonia liquifies and can be removed. So more nitrogen and hydrogen react to restore equilibrium, which means more ammonia forms. Unreacted gases are recycled: This gives them another chance to react to form ammonia. So the overall yield of ammonia increases.

Air and water

(1) D **(2) In A:** anhydrous copper(II) sulfate + water → hydrated copper(II) sulfate **In B:** anhydrous cobalt chloride + water → hydrated cobalt chloride **(3) (a)** test tubes 1 and 2: no change; test tube 3: the nail has a coating of brown rust **(b)** Rusting requires both air (oxygen) and water. **(c)** coat the iron with something, such as paint, grease, plastic, or zinc (galvanizing); or use another metal for sacrificial protection **(d)** iron + oxygen + water → hydrated iron(III) oxide **(4) (a)** to prevent them from freezing, and blocking the pipes **(b) (i)** helium and neon **(ii)** They are lower than –200°C. **(c) (i)** They can be separated by this method because they have different boiling points. Nitrogen boils off first because it has the lower boiling point. **(ii)** Nitrogen: to quick-freeze food, flush oxygen from food packaging, shrink-fit metal machine parts, and for making ammonia. Oxygen: supplied to patients with breathing problems, and for astronauts and deep-sea divers; used for oxy-acetylene torches.
(5) The crossing-out should be as here: **(a)** ~~reduced~~ **(b)** ~~$Fe^{2+} + 2e^- \rightarrow Fe$~~ **(c)** ~~less~~ **(d)** ~~reduced~~ **(e)** ~~weaker~~

Organic chemistry

(1) b **(2)** b **(3) (a)** They tend to be viscous (thick), and do not burn easily. They are generally unreactive.
(b) (i) it contained a double bond—it was unsaturated. (It was an alkene.) **(ii)** addition **(c) (i)** This shows the missing part:



(ii) It is the catalyst. **(iii)** It should be heated directly below the catalyst. **(iv)** to prevent water being sucked back into the hot test tube (which would crack) **(d)** $C_{10}H_{22}$ → C_8H_{18} + C_2H_4

(e)

decane	ethene
alkane	alkene
above	below
no	yes
saturated	unsaturated
no	yes
no	yes

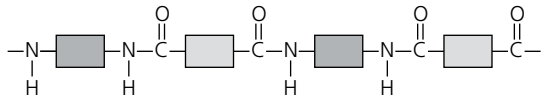
(4) (a) (i) OH **(ii)** C_2H_5OH **(b) (i)** sugar, yeast, and water **(ii)** 25ºC **(iii)** bubbles, and the limewater turns milky **(iv)** $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ **(v)** by fractional distillation **(c) (i)** $C_2H_4 + H_2O \rightarrow C_2H_5OH$ **(ii)** phosphoric acid

Esters, fats, and soaps

(1) See page 254 of *Fundamental Chemistry*. (**2)** The monomers of a simple ester have one alcoholic group and one carboxylic acid group that combine to form an ester linkage whereas the monomers of polyester are diols and dioic acids. (**3)** glycerol (**4)** See page 263 of *Fundamental Chemistry*. (**6)** Hydrolysis is the breaking up of a compound into two products with the aid of a water molecule. The products of acid hydrolysis are fatty acids and glycerol. The products of alkaline hydrolysis are soap and glycerol. (**7)** The process of reacting an ester or long-chained fatty acid with an alkali, e.g. sodium hydroxide or potassium hydroxide, to form soap. **(8)** With potassium hydroxide, the soap formed is more soluble and easier on the skin; so it is used as toilet soap. With sodium hydroxide, the soap formed is harder, less soluble, and makes the skin rough; so it is used as laundry soap.

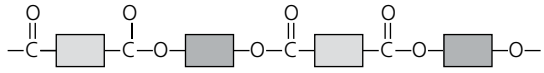
Polymers

(1) Reaction A



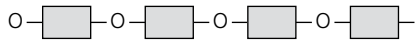
other product: hydrogen chloride, HCl type: polyamide name: nylon synthetic

Reaction B



other product: water, H_2O type: polyester name: terylene synthetic

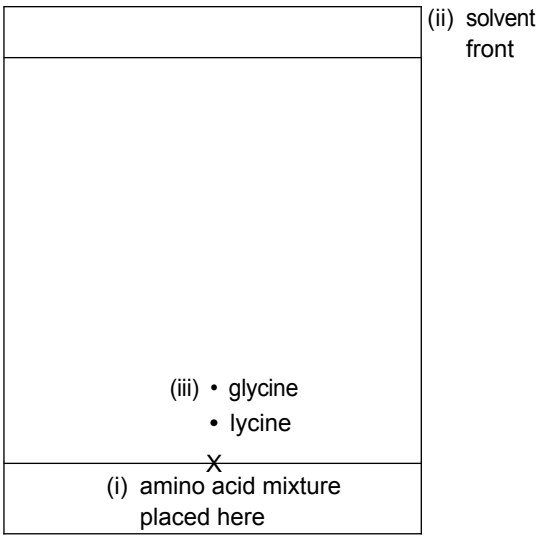
Reaction C



other product: water, H_2O type: polysaccharide name: starch natural **(b)** Molecules of monomer join up to form macromolecules, by eliminating small molecules. **(c) (i)** the polyamide formed in A **(ii)** They share the polyamide linkage—but nylon contains only two other types of unit, since it is made from only two monomers, while proteins contain many different units, since they are made from many different amino acids. **(2) (a)** (i) **(b)** The molecule has only one functional group at one end.

Separating substances

(1) d **(2)** a **(3)** b **(4)** c **(5) (a)** filtration **(b)** crystallization **(c)** filtration **(d)** distillation **(6)** j → e → g → a → i → c **(7) (a) (i)** thermometer **(ii)** fractionating column **(iii)** heat **(iv)** condenser **(b)** A **(c)** The temperature rises until it reaches the boiling point for A, then remains constant until all of A has evaporated, and then rises again until it reaches the boiling point for B. **(d) (i)** and **(ii)** liquid air, ethanol and water, petroleum, etc. **(e)** any solution, two immiscible liquids, two solids **(f)** thermometer **(8) (a)** the distance travelled by the amino acid divided by the distance travelled by the solvent **(b)** by using a locating agent (ninhydrin)
(c)



(d) Use a different solvent.

Ion identification

(1) a **(2)** d **(3)** b **(4)** a **(5)** a **(6)** c **(7)** c **(8)** d **(9)** b **(10)** Add a 'heat' arrow under the flask, and insert a thermometer at the top of the column, in a bung that seals the column. Note that the thermometer bulb should be level with the outlet to the condenser. Change the direction of the water flow in the condenser (in at the bottom, out at the top). Label the condenser. **(11)** The 'heat' arrow should be under the catalyst. The test tube should contain water, and its mouth should be below the water in the trough. The end of the delivery tube should be under the water in the trough. **(12)** The thistle should reach below the surface of the liquid in the flask. Hydrogen must be collected by downward displacement of air since it is lighter than air, so the gas jar should be inverted.

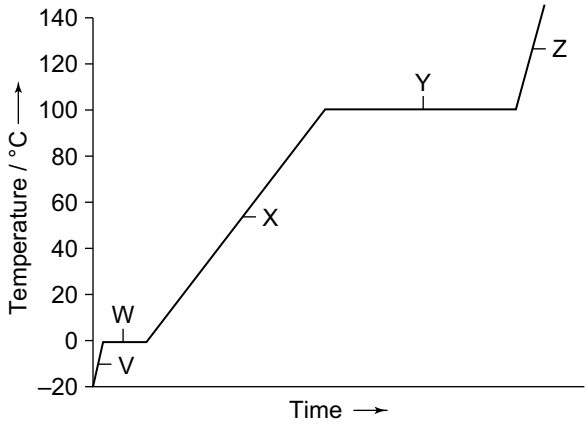
States of matter I

(1) b **(2)** a **(3)** c **(4)** a **(5) (a)** It has a high melting point and can conduct electricity. It gives off light when heated. **(b)** The tungsten changed from solid to liquid. **(6) (a)** a mixture of solid and liquid **(b)** It is impure because it is melting over a range of temperatures. **(c)** Covalent, because it has a low melting point **(7) (a)** It will first change from red to blue, then blue to red, and finally it will get bleached. **(b)** Ammonia gas dissolves in water to form ammonium hydroxide which changes the litmus first from red to blue because it is the lightest gas. Next, carbon dioxide reaches the litmus and changes it from blue to red. Chlorine being the heaviest reaches last and, being a bleaching agent, bleaches the litmus.

States of matter II

(1) b **(2)** a **(3)** a **(4)** a

(5) (a)



(b) at V: particles vibrating about a fixed position; at W: particles leaving the lattice and moving around, still touching; at X: particles touching, but moving faster as the temperature rises; at Y: particles moving apart to form a gas; at Z: all particles moving freely apart, and moving faster as the temperature rises **(c)** The line is horizontal for melting and boiling. (Melting and boiling take place at a specific temperature.) **(d)** ice (water) **(6)** a **(7)** diffusion **(8)** hydrogen, neon, nitrogen, oxygen **(9)** c

Atoms and elements I

(1) a **(2)** d **(3)** c **(4)** c **5 (a) (i)** Relative atomic mass is the ratio of the average mass of an atom to an atom of carbon-12. **(ii)** Mass number is the total numbers of neutrons and protons present in the nucleus of an atom. **(iii)** Relative isotopic mass is the average mass of all the isotopes of an element compared with the mass of an atom of carbon–12. **(iv)** Valence electrons are the electrons present in the outermost shell of an atom. **(b)** Elements are arranged in the Periodic Table as periodic functions of their atomic number which is taken as a whole number. Elements X and Y have atomic numbers 12 and 13 and no whole number can be placed between them. So no other element can be placed in between elements X and Y.

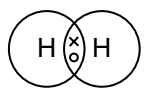
Atoms and elements II

(1) a **(2)** c **(3)** c **(4)** d **(5) (a)** 1^- **(b)** 1 **(c)** 1^+ **(d)** 1 **(e)** 0 **(f)** 0 **(g)** 0 **(h)** 1 **(6) (a)** electron; proton; neutron **(b)** 1; 2; 3 **(c)** protons; electrons; neutrons **(d)** hydrogen **(7) (a)** A and B **(b)** A and D **(c)** D **(d)** C **(e)** A silicon, Si; B carbon, C; C krypton, Kr; D aluminium, Al **(f)** A: $^{28}_{14}Si$; B: $^{12}_{6}C$; C: $^{84}_{36}Kr$; D: $^{27}_{13}Al$

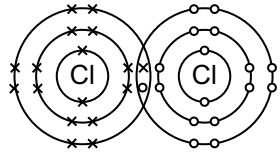
Atoms combining

(1) a **(2)** b **(3)** b **(4)** d **(5)**

(a)

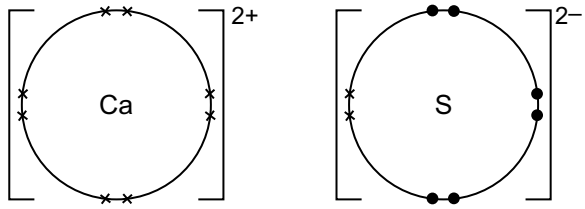


(b)



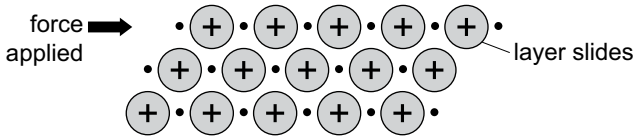
(6) (a) compound **(b)** diamond **(c)** covalent **(d) (i)** non-conductor **(ii)** high melting point **(iii)** insoluble in water **(iv)** hard **(7)** methane: CH_4, covalent; hydrogen chloride: HCl, covalent; magnesium chloride: $MgCl_2$, ionic; sodium oxide: Na_2O, ionic; ammonia: NH_3, covalent; iron(II) sulfate: $FeSO_4$, ionic

(8)



calcium ion sulfide ion

(9) (a) (i) metal ion **(ii)** electron **(b)** the attraction between positive ions and electrons **(c)** The free electrons can move through the lattice, forming a current and carrying heat.
(d)



malleable (or ductile)

Reacting masses and chemical equations

(1) d **(2)** a **(3)** d **(4)** d **(5)** sodium chloride: NaCl; magnesium chloride: $MgCl_2$; aluminium chloride; $AlCl_3$; hydrogen sulfide: H_2S; aluminium oxide: Al_2O_3; copper(II) sulfate: $CuSO_4$ **(6) (a)** $2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (l)$ **(b)** $2CuO\ (s) + C\ (s) \rightarrow CO_2\ (g) + 2Cu\ (s)$ **(c)** $N_2\ (g) + 2O_2\ (g) \rightarrow 2NO_2\ (g)$ **(d)** $CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (l)$ **(7) (a)** 128 **(b)** 85 **(c)** 164 **(d)** 60 **(8) (a)** 44 g **(b)** 7 g **(c)** 56 g iron, 32 g sulfur **(d) (i)** sulfur **(ii)** 22 g **(9) (a)** 40% **(b)** 32 g **(10) (a)** 33.3% **(b)** 120 kg

Using moles

(1) b **(2)** c **(3)** d **(4)** a **(5) (a)** 12.04×10^{23} **(b)** 11.2 g **(c)** 0.2 **(d)** 1024 g **(e)** 0.5 **(f)** 1.202×10^{23} **(g)** 0.2 **(h)** 2 mol/dm^3 **(i)** 2.8 g **(6) (a)** 132.1 g **(b)** 4.5 dm^3 **(c)** 13 g of aluminium and 84 g of aluminium fluoride **(d)** 3.04 g
(7) $Al_4Cl_3 + 12H_2O \rightarrow 4Al(OH)_3 + 3CH_4$
(8)

carbon	*hydrogen*
92.3 g	7.7 g
12	1
7.7	7.7
1	1
CH	
C_6H_6	

Electricity and chemical change I

(1) b **(2)** a **(3)** d **(4)** d **5 (a)** Anode: oxygen; Cathode: hydrogen **(b)** Anode: $4OH^-\ (aq) - 4e^- \rightarrow 2H_2O\ (l) + O_2\ (g)$; Cathode: $2H^+\ (aq) + 2e^- \rightarrow H_2\ (g)$ **(c)** Anode: oxygen; Cathode: hydrogen **(d)** Because of hydrogen and hydroxyl ions being lower in the reactivity series than sodium and sulfate. **(e)** The reaction at the cathode would remain the same as hydrogen is lower in the reactivity series than sodium. Sulfate would react with the magnesium anode forming magnesium sulfate which would then melt into the water.

Electricity and chemical change II

(1) (a) cathode: lead; anode: bromine **(b)** cathode: hydrogen; anode: chlorine **(c)** cathode: aluminium; anode: oxygen **(d)** cathode: hydrogen; anode: chlorine **(2) (a)** electroplating **(b)** negative **(c)** The spoon will become coated with silver. **(d)** The number of ions stays the same. **(e)** to prevent corrosion; to give an attractive appearance **(3)** a **(4)** d **(5)** b **(6) (a)** bubbles, and a red-brown gas forming **(b)** $2Br^-\ (l) \rightarrow Br_2\ (g) + 2e^-$ **(c)** a silvery metal forming below the electrode **(d)** $Pb^{2+}\ (l) + 2e^- \rightarrow Pb\ (l)$ **(7) (a)** Zn^{2+}, SO_4^{2+}, H^+, OH^- **(b) (i)** $Zn^{2+}\ (aq) + 2e^- \rightarrow Zn\ (s)$ **(ii)** $4OH^-\ (aq) \rightarrow 2H_2O\ (l) + O_2\ (g) + 4e^-$ **(c)** sulfuric acid **(8) (a) (i)** at the anode **(ii)** $2I^-\ (aq) \rightarrow I_2\ (aq) + 2e^-$ **(b) (i)** potassium iodide **(ii)** oxygen, rather than iodine, would form at the anode. **(9)** a, d, e, f

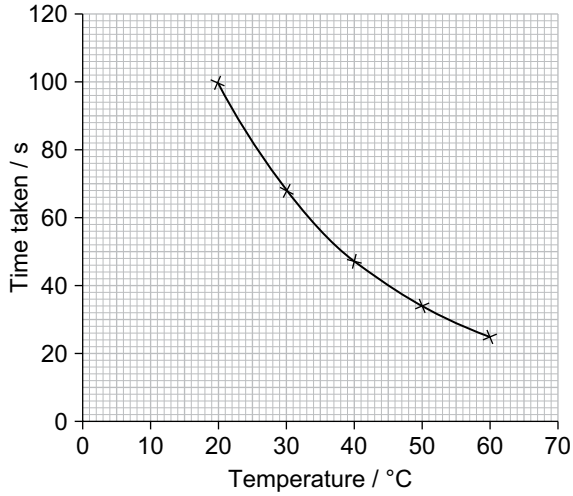
Energy changes and reversible reactions

(1) c **(2)** a **(3)** d **(4)** b **(5) (a) (i)** exothermic **(ii)** endothermic **(iii)** exothermic **(b) (i)** reaction i **(ii)** heat the product **(iii)** endothermic **(6) (a)** $NH_4Cl \rightleftharpoons NH_3 + HCl$ **(b)** yes **(c)** The ammonium chloride breaks down upon heating to give the two colourless gases. Further up the tube, where it is cooler, these gases recombine to form tiny particles

of solid white ammonium chloride. **(7) (a) (i)** 596 kJ/mol **(ii)** 587 kJ/mol **(iii)** +9 kJ/mol **(b)** endothermic **(c)** A reaction is exothermic if the energy released in bond making is greater than the energy taken in for bond breaking. **(8) (a)** A and B **(b) (i)** B and D **(ii)** C **(c)** The yield will increase. **(d)** It speeds up both the forward and reverse reactions so that equilibrium is reached faster.

The rate of reaction

(1) b **(2)** c **(3)** a **(4)** b **(5)** b **(6)** d **(7) (a) (i)** conical flask **(ii)** gas syringe **(b)** products; gas **(8) (a)** 160 s **(b)** The rate was fastest at the start, and gradually decreased with time, until it reached zero. **(c)** Catalysts are not used up in a reaction. **(d)** X: similar curve but steeper, and reaching 50 cm^3 before 160 s **(e)** Y: similar curve but half as steep, and reaching 50 cm^3 after 160 s **(f)** an enzyme **(9) (a)** The times in the second column, from the top, are: 100s, 200 s, 20 s. **(b)** The more concentrated the solution is, the more particles there are to collide with acid particles. So the number of successful collisions increases. So the rate of the reaction increases. **(c)** the concentration of the reactants, the volume of the reactants, and the conical flask that is used
(d)



(e) (i) 60°C **(ii)** As the temperature rises, the reaction time gets shorter. **(iii)** As the temperature rises, the particles gain more energy and move faster. So there are more collisions between particles, and more of the collisions have enough energy to be successful: reaction occurs. So the reaction gets faster, which means there is a shorter reaction time. **(f)** 24 $\pm$ 1 s

Redox reactions

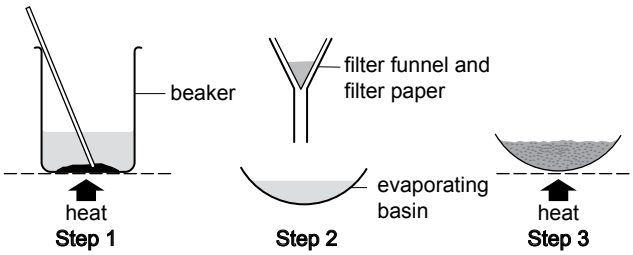
(1) (a) oxidation means a reactant gains oxygen (Zn); reduction means a reactant loses oxygen (CuO) **(b)** reduction and oxidation takes place together **(c)** oxidizing agent: copper(II) oxide; reducing agent: zinc **(d)** zinc **(e)** The oxidation state of copper is +II or the Cu^{2+} ion is present **(f)** Cu_2O **(2) (a)** neither **(b)** oxidized **(c)** reduced **(d)** oxidized **(e)** reduced **(f)** reduced **(g)** neither
(3)

	a	b
i	$O_2 + 4e^- \rightarrow 2O^{2-}$	reduction
ii	$2B^{4-} \rightarrow Br_2 + 2e^-$	oxidation
iii	$Fe^{2+} \rightarrow Fe_3^{3+} + e^-$	oxidation
iv	$A1^{3+} + 3e^- \rightarrow A1$	reduction

(4) (i) oxidizing agent **(ii)** purple **(iii)** colourless **(iv)** oxidizing agent **(v)** colourless **(vi)** red-brown **(vii)** reducing agent **(viii)** reducing agent **(5)** oxidation: $Zn \rightarrow Zn^{2+}$ $(aq) + 2e^-$; reduction: I_2 $(aq) + 2e^- \rightarrow 2I^-$ (aq)

Acids and bases

(1) (a) bases: i; iv; v **(b)** properties of soluble bases: i; iv; v
(2) (a)



(b) to speed up the reaction **(c)** Solid will remain after stirring. **(d)** saturated; crystals **(3) (a)** the hydrogen ion (H^+)
(b) (i) pH above 2, below 7 **(ii)** Only some of the molecules are dissociated into ions, in solution. **(c) (i)** fizzing
(ii) $HCO_3^- + H^+ \rightarrow CO_2 + H_2O$ **(4)** d **(5)** b **(6)** a **(7)** d

The Periodic Table I

(1) c **(2)** d **(3)** a **(4)** b **(5) (a)** H **(b)** NG **(c)** H **(d)** TE **(e)** TE **(f)** NG **(g)** TE **(h)** AM **(i)** TE **(j)** H **(k)** AM **(l)** NG **(m)** NG **(n)** TE **(6)** because their atoms have the same number of valence electrons **(7)** b **(8)** a **(9) (a) (b) (i)** increases by 1 **(ii)** The character of the elements changes from metallic to non-metallic. **(iii)** Melting points rise to a maximum at silicon followed by a big drop, and then a further more gradual drop. **(iv)** Reactivity falls as far as silicon, then increases again up to fluorine. Argon is unreactive. **(v)** Oxides are basic on the left, then change through amphoteric (aluminium) to acidic on the right. **(c)** The metals have less than 4 valency electrons, the metalloid has 4, and the non-metals have more than 4. **(10) (a)** lithium and fluorine **(b)** carbon

The Periodic Table II

(1) d **(2)** a **(3)** c **(4)** b **(5) (a)** The number of shells increases down the group so the atomic radius of the atoms increases. Along a period the shell remains the same but the number of positive charges in the nucleus and the number of negative charges in the valence shell increases. This increases the electrostatic force of attraction between the nucleus and the electron shell causing the valency shell to be pulled inwards resulting in a decrease in size. **(b)** They are both in the same group of the Periodic Table but rubidium is lower in the group and so loses its electrons more easily, and therefore reacts more vigorously. **(6) (a)** Diatomic molecules have covalent bonding and by being diatomic they would not be able to attain the noble gas configuration. **(b)** Atoms of non-metals cannot gain electrons from one another and so attain the noble gas configuration by sharing electrons. **(7) (a)** They have very large valence shells divided into smaller segments called orbitals. The electrons release energy as they move from one orbital to the next. **(b)** They have a large surface area for maximum adsorption of reactants.

The behaviour of metals

(1) c **(2)** d **(3)** a **(4)** c **(5)** a **(6) (a) (b)** W → Y → Z → X **(i)** X **(ii)** It will be greater, since the reaction will be faster so there will be more heat given out in a shorter time. **(c) (i)** W **(ii)** any metal below copper in reactivity, e.g. gold, silver, or platinum **(7) (a)** chromium **(b) (i)** magnesium **(ii)** $Mg \rightarrow Mg^{2+} + 2e^-$ **(iii)** oxidized **(c) (i)** the copper ion **(ii)** $Cu^{2+} + 2e^- \rightarrow Cu$ **(iii)** reduced **(d) (i)** Chromium is more reactive than nickel, so will displace it from its compound in solution. **(ii)** $2Cr\ (s) + 3Ni^{2+}\ (aq) \rightarrow 2Cr^{3+}\ (aq) + 3Ni\ (s)$ **(e) (i)** weaker **(ii)** copper oxide
(iii) magnesium **(f) (i)** water **(ii)** copper hydroxide

Making use of metals

(1) a **(2)** b **(3)** c **(4)** d **(5) (a) (i)** from the blast furnace **(ii)** liquid **(b)** oxygen **(c) (i)** calcium oxide (lime)
(ii) neutralization **(d)** nickel and chromium **(6) (a)** alloys **(b) (i)** buildings, ships, car bodies, machinery, etc.
(ii) cutlery, equipment in chemical factories and hospitals, etc. **(iii)** musical instruments, door knobs, and other decorative fittings **(7)** c **(8)** a **(9)** c **(10)** a **(11)** c **(12)** d

Some non-metals and their compounds

(1) d **(2)** c **(3)** a **(4)** c **(5) (a)** natural **(b)** CO **(c)** when there is a limited supply of air or oxygen, giving incomplete combustion **(d)** $2CH_4\ (g) + 3O_2\ (g) \rightarrow 2CO\ (g) + 4H_2O\ (l)$ **(e)** It reacts with haemoglobin in the blood, preventing it from carrying oxygen around the body. So people can die from oxygen starvation. **(6) (a) (i)** calcium oxide, CaO **(ii)** the breaking down of a compound, brought about by heat **(iii)** The calcium oxide is a basic oxide, and it reacts with acidic impurities in the blast furnace, giving a slag that can be removed. **(b)** calcium hydroxide, slaked lime, $Ca(OH)_2$ **(c)** They are bases, so can be used to control acidity in soil. **(7) (a) (i)** Carbon dioxide from the air combines with water in plant leaves in the presence of chlorophyll and sunlight, giving glucose. **(ii)** It dissolves in the oceans. **(b)** calcium carbonate, $CaCO_3$ **(c)** It is the reaction between glucose and oxygen in living cells, which provides energy. **(d)** More and more fossil fuel is being burned, because more power stations, factories, and homes are being built, and road and air traffic is increasing. **(8) (a) (i)** underground sulfur beds, galena (a sulfide ore), sulfur compounds in fossil fuels **(ii)** by burning the sulfur in air **(b)** In the forward reaction, three molecules react to form two molecules, and high pressure favours fewer molecules. **(c)** vanadium(V) oxide **(d) (i)** the higher the temperature, the lower the yield **(ii)** exothermic **(iii)** High temperature favours an endothermic reaction. So the back reaction must be endothermic, which means the forward reaction is exothermic. **(iv)** The temperature must be high enough to give a satisfactory reaction rate. **(e)** $SO_3\ (g) + H_2\ SO_4\ (l) \rightarrow H_2S_2O_7\ (l)$
(f) (i) $H_2S_2O_7\ (l) + H_2O\ (l) \rightarrow 2H_2SO_4\ (l)$ **(ii)** It would produce a thick, dangerous mist of acid.

Air and water I

(1) a **(2)** c **(3)** d **(4)** b **(5) (a)** Air bubbles off as the water is heated, and collects in the measuring tube. **(b)** oxygen **(c) (i)** 33 cm^3 **(ii)** 33% **(iii)** 67% **(d)** It does not take into account the other gases present (e.g. carbon dioxide and noble gases). **(e) (i)** Compared to atmospheric air, the % of oxygen is greater in dissolved air, and the 5 of nitrogen is less. **(ii)** oxygen **(6) (a) (i)** as a drink for animals, and to water crops **(ii)** to make steam to drive the turbines that generate electricity **(b) (i)** to filter out solid particles **(ii)** to kill bacteria **(c) (i)** no **(ii)** It still contains dissolved impurities. **(7) (a) (i)** They form when the oxygen and nitrogen in air react in the hot engine. **(ii)** They dissolve in rain to form acid rain, which can kill trees and other plants, fish and other water life, and attack metal structures and the stonework of buildings. **(iii)** nitrogen and oxygen **(b) (i)** carbon monoxide **(ii)** It is poisonous. **(iii)** carbon dioxide **(c)** Carbon dioxide is released in the car exhaust. It is a greenhouse gas, and many scientists believe that it is the main cause of global warming.

Air and water II

(1) b **(2)** d **(3)** c **(4)** c **(5) (a)** carbon dioxide, oxides of sulfur, and oxides of nitrogen **(b)** Acid rain dissolves aluminium ions in clay soil which forms a layer around the roots of plants preventing them from absorbing water and causing plants to die. **(c)** The aluminium ions in acid rain form a solid crust over the gills of fish so that they cannot breathe. **(6) (a)** Gases such as oxides of sulfur from the industrial area helped to form acid rain which dissolved the marble forming cracks. Moisture and oxygen along with the acid rain caused the iron supports to rust. The heavy marble arm then broke away. **(b)** By constructing a tower containing marble powder. The sulfur dioxide passes through the marble producing calcium sulfite and carbon dioxide.

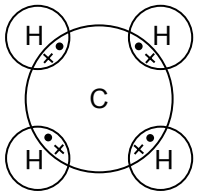
Organic chemistry I

(1) c **(2)** a **(3)** b **(4)** d **5 (a)** $C_nH_{2n+1}OH$ **(b)** $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ **(c)** zymase **(d)** Because yeast can produce zymase only under anaerobic conditions. **6 (a)** Oxidation does not produce a flame but combustion does. Oxidation requires an oxidizing agent while combustion does not require one. Oxidation results in oxidized products and water but combustion results in carbon dioxide and water. **(b)** Advantages: It is a renewable resource. It is inexpensive and does not produce pollution; Disadvantages: It produces less energy than petrol **7 (a)** To speed up the reaction **(b)** To reach a higher temperature without burning the liquid **(c)** ethyl ethanoate ($CH_3COOCH_2CH_3$)

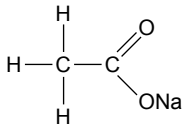
Organic chemistry II

(1) c **(2)** b **(3)** d **(4)** a **(5) (a)** A: ethane; B: ethane; C: ethanol; D: ethanoic acid; E: 1,2-dibromoethane **(b) (i)** A and B **(ii)** D **(iii)** C **(iv)** B **(v)** C **(6) (a)** to vapourize the compounds in it **(b)** fractional distillation **(c) (i)** diesel oil **(ii)** fuel oil **(d)** paraffin **(e) (i)** bottled gas for heating **(ii)** fuel for cars **(iii)** feedstock to make other products **(iv)** aircraft fuel/oil lamps **(v)** road surfaces/roofs **(f) (i)** cracking **(ii)** heat; catalyst **(iii)** It produces shorter-chain

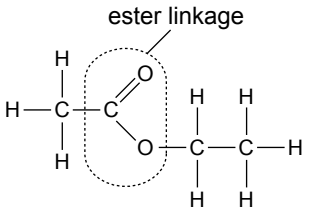
hydrocarbons that burn better so are better fuels, plus unsaturated hydrocarbons which are more reactive, so can be used to make many useful compounds. **(7) (a)** $C_nH_{2n+1}OH$: alcohols; C_3H_7OH; propanol, C_nH_{2n}: alkenes; C_3H_6; propene, $C_nH_{2n}O_2$: carboxylic acids; $C_3H_6O_2$; propanoic acid, C_nH_{2n+2}: alkanes; C_3H_8; propane **(b)** two **(c)** because they have the same functional group **(d)** They have different chain lengths, which leads to different levels of attraction between molecules. **(e)** Boiling points increase with chain length.
(8) (a)



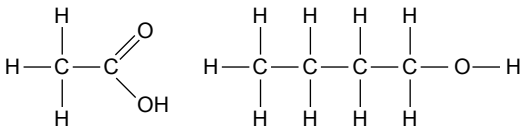
(b) The single covalent bonds are difficult to break. **(c) (i)** sunlight **(ii)** substitution **(iii)** an addition reaction
(9) (a) $CH_3COOH\ (aq) \xrightarrow{\text{only some molecules}} CH_3COO^-\ (aq) + H^+\ (aq)$ **or** the same equation but with an equilibrium sign **(b) (i)**



(ii) sodium ethanoate **(10) (a)** alcohols
(b) (i) and **(ii)**



(c)

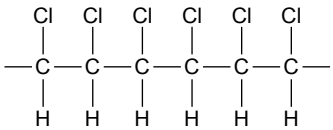


ethanoic acid butan-1-ol

(d) They have attractive smells.

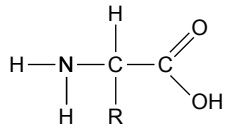
Polymers

(1) c **(2)** c **(3)** a **(4)** d **(5)** b **(6) (a)** Polymers are made up of large molecules called macromolecules, which form when small molecules called monomers join together. **(b)** Addition: only one monomer and one product. Condensation: more than one monomer, and two products (the macromolecules and the eliminated small molecules). **(c) (i)**

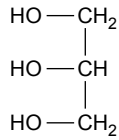


(ii) *in landfill sites*: They do not break down naturally, so fill up landfill sites quickly, and harm animals that try to eat them. *by burning*: They can produce harmful gases, including gases that cause global warming. **(iii)** Recycling plastics may use less energy than is used to make them in the first place. Also recycling them helps to reduce the

demand for petroleum, which is a limited resource. **(7) (a) (i)** amide **(ii)** nylon **(b) (i)** the breaking down of a compound by reaction with water **(ii)** amino acids **(iii)**



(c) carbohydrates; fats **(d)** glucose **(8) (a) (i)** fat **(ii)** ester **(iii)** terylene **(b) (i)** (dilute) sodium hydroxide **(ii)** soap **(c) (i)**



(ii) glycerol

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