

2020/2021 Academic Year Chemistry Lesson Note for Grade 12

Extraction, properties and uses of some selected metals

1. Sodium

Extraction of sodium

Sodium

- is a very reactive metal and is not found free in nature.
- It exists in the form of compounds.
- obtained by the electrolysis of molten mixture of about 40% NaCl and 60% CaCl_2 in a Downs cell. CaCl_2 is added to lower the melting point of NaCl from 800°C to 600°C .
- The Na metal formed at the cathode and Chlorine gas forms at the anode.

Chemical properties of sodium

- Rxn with water
 $2\text{Na(s)} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH(aq)} + \text{H}_2(\text{g})$
- Rxn with air
 $4\text{Na(s)} + \text{O}_2(\text{g}) \rightarrow \text{Na}_2\text{O}_2(\text{s}) + 2\text{NaO(s)}$
- Rxn with hydrogen
 $2\text{Na(s)} + \text{H}_2(\text{g}) \rightarrow 2\text{NaH(s)}$
- Rxn with halogens (F_2 , Cl_2 , Br_2 and I_2)
 $2\text{Na(s)} + \text{F}_2(\text{g}) \rightarrow 2\text{NaF(s)}$

Uses of sodium

- Liquid Na metal is used as a coolant in nuclear reactors.
- Na vapour is used in street lights and produces a brilliant yellow light.
- Important for proper muscle and nerve function.

2. Calcium

Occurrence of calcium

- is the 5th most abundant element in the earth's crust.

The main ores of Ca are:

Limestone, Chalk and marble (CaCO_3)
Dolomite ($\text{CaCO}_3 \cdot \text{MgCO}_3$)
Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$)
Fluorite (CaF_2)

Extraction of calcium

Calcium is prepared by the electrolysis of molten calcium chloride (CaCl_2)

Anode (ox): $2\text{Cl}^-(\text{l}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$

Cathode (Red): $\text{Ca}^{+2}(\text{l}) + 2\text{e}^- \rightarrow \text{Ca(l)}$

Overall rxn: $\text{Ca}^{+2}(\text{l}) + 2\text{Cl}^-(\text{l}) \rightarrow \text{Cl}_2(\text{g})$

Chemical properties calcium

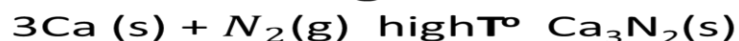
a) rxn with water



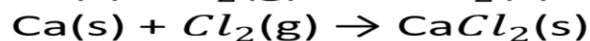
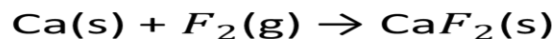
b) rxn with oxygen



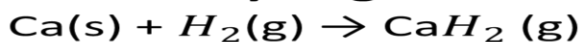
c) rxn: with nitrogen



d) rxn with halogen



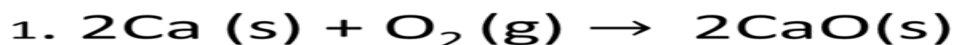
e) rxn with hydrogen



Exercise

When exposed to air, calcium 1st forms calcium oxide, which is then converted to calcium hydroxide and finally to calcium carbonate. Write a balanced chemical equation for each step.

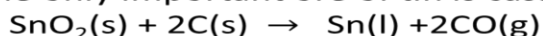
Answer



3. Tin (Sn)

Occurrence

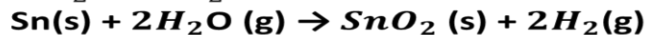
The only important ore of tin is cassiterite, SnO_2



Chemical property of Tin

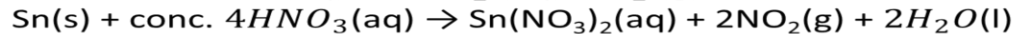
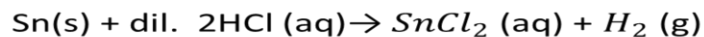
a) Rxn with water

tin does not react with cold water, but it reacts with steam to form SnO_2 and H_2 .



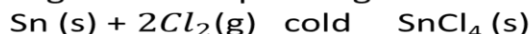
b) Rxn with acids

Tin reacts with dilute and conc. acids



c) Rxn with halogens

Tin reacts with Cl_2 and Br_2 in the cold and with F_2 & I_2 on warming forming the corresponding tin tetra halide.



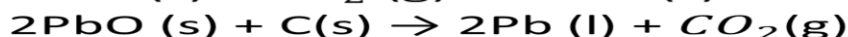
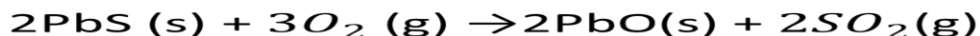
4. Lead (Pb)

Occurrence of lead

The main ore of lead is galena, PbS , It is black, shiny & very dense

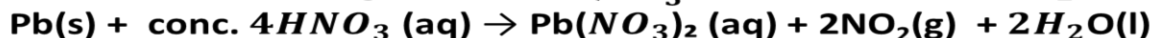
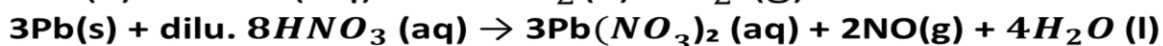
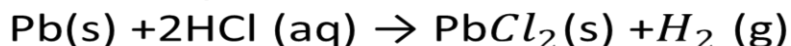
Extraction of lead

Galena is mined and separated from its impurities by froth flotation.



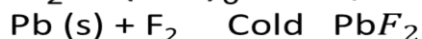
Chemical properties of lead

-Lead is not affected by water because the metal is covered by a thin oxide film.



It does not dissolve in dilute H_2SO_4 because a surface of coating of $PbSO_4$ is formed

Is slowly attacked by cold alkali and rapidly by hot alkali giving $Na_2Pb(OH)_6$ Thus, lead is **amphoteric**



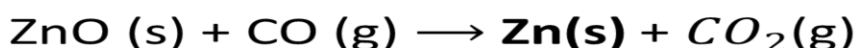
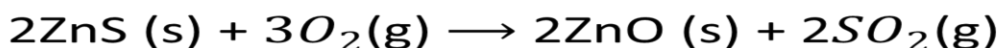
The major use of lead is to make lead-acid storage batteries And also used for **paints**, **pipes** and **alloys**.

5. Zinc (Zn)

- the 24th most abundant element in the earth's crust.
- the most important ore of zinc is **zinc blende (ZnS)**

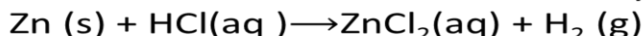
Extraction of zinc

- ZnS is concentrated by froth flotation and then roasted in air to give ZnO and SO_2



Chemical properties of zinc

Zinc is a silvery solid that tarnishes rapidly in most air. It dissolves in dilute HCl and liberates hydrogen gas.



Zinc also reacts with an aqueous solution of NaOH and forms sodium zincate, $\text{Na}_2\text{Zn(OH)}_4$. Hence, zinc shows amphoteric properties.

Zinc reacts with oxygen to form zinc oxide



Uses of Zinc

- Used in large amounts for coating iron to prevent it from rusting. The process is called galvanizing.
- Used for alloys (example brass (Cu & Zn)).
- Zinc is also used as the negative electrode (anode) in dry cell batteries such as leclanche cells, mercury cells and alkaline cells.

6. Chromium (Cr)

– The most important ore of Cr is chromite, $(\text{FeCr}_2\text{O}_4)$

Four basic steps are followed to get pure chromium

- **Step 1:** when chromite is fused with NaOH in air, chromium (III) is oxidized to chromium (VI).
$$4\text{FeCr}_2\text{O}_4(\text{s}) + 16\text{NaOH}(\text{s}) + 7\text{O}_2(\text{g}) \xrightarrow{1100^\circ\text{C}} 8\text{Na}_2\text{CrO}_4(\text{s}) + 2\text{Fe}_2\text{O}_3(\text{s}) + 8\text{H}_2\text{O}(\text{l})$$
- **Step 2:** Ferric oxide (Fe_2O_3) is insoluble, but sodium chromate (Na_2CrO_4) is soluble in water. Thus the sodium chromate is separated from ferric oxide by dissolving with water, followed by decantation or filtration. The sodium chromate solution is acidified to convert it to a less soluble sodium dichromate.
$$2\text{Na}_2\text{CrO}_4(\text{aq}) + 2\text{HCl}(\text{aq}) \rightarrow \text{Na}_2\text{Cr}_2\text{O}_7(\text{s}) + 2\text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- **Step 3:** The sodium dichromate is reduced to Cr_2O_3 by heating with carbon.
$$\text{Na}_2\text{Cr}_2\text{O}_7 + 2\text{C}(\text{s}) \rightarrow \text{Cr}_2\text{O}_3(\text{s}) + \text{Na}_2\text{CO}_3(\text{s}) + \text{CO}(\text{g})$$
- **Step 4:** Finally, Cr_2O_3 is reduced to the metal by Al
$$\text{Cr}_2\text{O}_3(\text{s}) + 2\text{Al}(\text{s}) \rightarrow 2\text{Cr}(\text{s}) + \text{Al}_2\text{O}_3(\text{s})$$

Chemical Properties

- Cr is an active metal but it is protected from corrosion by a very thin transparent oxide film
$$4\text{Cr}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{Cr}_2\text{O}_3(\text{s})$$
- Cr dissolves in HCl and dil. H_2SO_4 .

Uses of chromium

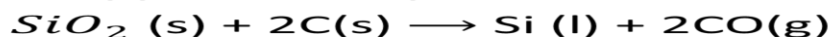
- nichrome wire, commonly used in chemistry laboratories for flame tests.
nichrome (an alloy of Ni and Cr)
- **Ferrochrome** (Iron – chromium alloy) is used in the production of stainless steel.
- Used for electroplating

7. Silicon (Si)

- Is the 2nd most abundant element in the earth's crust.
- If occurs as silica (SiO_2) and silicate compounds containing the silicate ion, (SiO_4^{4-}).

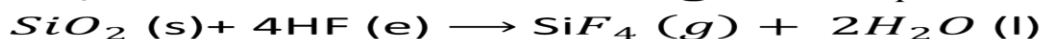
Extraction

- Silicon is prepared by heating silica with coke to approximately 3000°C in an electric furnace.



Chemical properties

- Silica is resistant to attack by all acids except HF, with which it reacts to give SiF_4 and H_2O



Silicon is used for the production of polymer.

Uses of Silicon

- It is a semiconductor and is used in the construction of transistors and microprocessor.
- Quartz crystals (a pure crystalline form of silica) are used to control the frequency of radio and television transmissions.
- Si polymers are used in making lubricants, lipstick, car polish and other materials. Because Silicon polymers are non-toxic and have good stability to heat, light, moisture and oxygen.

Extraction, properties and use of some selected metals

Element or compound	Some properties	Main ore (ores)	Extraction or preparation	Some Chemical properties	Some uses
sodium (Na)	Very reactive, exist in compound form, strong reducing agent	Rock salt (NaCl), Borax ($NaB_4O_7 \cdot 10H_2O$)	Downs cell electrolysis	Can react with: water H_2O , air (O_2), hydrogen (H_2), halogens (F_2 , Cl_2 , Br_2 , I_2)	used as a coolant in nuclear reactors, street lights and produces a brilliant yellow light, for proper muscle and nerve function.
Calcium (Ca)	The 5 th most abundant element in the earth crust	Limestone, Chalk & marble ($CaCO_3$) Dolomite ($CaCO_3 \cdot MgCO_3$) Gypsum ($CaSO_4 \cdot 2H_2O$)	Electrolysis of molten calcium chloride ($CaCl_2$)	Can react with water, Oxygen (O_2), Nitrogen (N_2), Hydrogen (H_2), Halogens (F_2 , Cl_2 , Br_2 , I_2)	major component of bones and teeth, plays a vital role in heart action, blood clotting, muscle contraction, and nerve impulse Transmission.

Tin (Sn)		Cassiterite, SnO_2	From SnO_2 using Carbon as a reducing agent	Can react with water, acids(like: dil HCl, conc HNO_3), Halogens (F_2 , Cl_2 , Br_2 , I_2)	For electroplating, to make alloys including type metal (Sn, Sb & Pb), bronze (Sn & Cu) & solder (Sn & Pb).
Lead (Pb)	It is black, shiny and very dense	galena , PbS	froth flotation	Not affected by water, it dissolve slowly in dil HCl, but not in dil H_2SO_4	to make lead-acid storage batteries And also used for paints, pipes and alloys.
Zinc (Zn)	the 4 th most abundant element in the earth crust	Blende (ZnS)	ZnS is concentrated by froth flotation and then roasted in air to give ZnO	It dissolve in dil HCl, and aq NaOH, It react with Oxygen(O_2)	For galvanizing, alloys like brass (Cu& Zn) negatives electrode (anode) in dry cell battery leclanche cells,
Chromium (Cr)	The 21 th most abundant element in the earth crust,	Chromite, FeCr_2O_4	By reducing chromite with carbon	Can react with oxygen(O_2), dissolve in HCl, in dil H_2SO_4	Nichrome wire(used in chemistry laboratories for flame tests) Ferrochrome (Fe – Cr alloy) Electroplating
Ammonia (NH_3)	Has latrine (bad) smell,	Can be prepared from hydrogen(H_2) & nitrogen(N_2)	Haber process	Soluble in water, can react with HCl, reduce some metals from their oxide.	Used for source of H_2 , to prepare fibers, HNO_3 , Na_2CO_3 , medicines (like: sylph drugs, anti malaria), $(\text{NH}_3)_{(l)}$ as a refrigerator.....etc
Nitric acid (HNO_3)	Pure HNO_3 color less liquid, but on exposure to light it turns to yellow	From NH_3 and O_2 in Ostwald process	Ostwald process		used to synthesize ammonium nitrate, a water soluble fertilizer, to make- plastics drugs explosives such as Trinitrotoluene(TNT) and nitroglycerine.
Sulfuric acid (H_2SO_4)	The world's most important industrial chemical	Prepared industrially from S and O_2 by contact process	contact process		Use to make fertilizers, detergents, plastics, paints and explosives. car batteries and also the manufacture of many chemicals.

REVIEW EXERCISES

1. What are the four most abundant metals, in increasing order of abundance?
2. What is the difference between roasting and calcinations?
3. Explain why some elements exist free in nature while others exist in the form of compounds
4. List, in order, the ten (10) most abundant elements in the earth's crust and classify them as metals, non-metals and metalloids.
5. What is the distinction between a mineral and an ore?
6. Write the names of the following minerals :

A) ZnS	D) Al_2O_3	G) FeS_2
B) CaCO_3	E) HgS	H) Fe_2O_3
C) $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$	F) $\text{CaCO}_3 \cdot \text{MgCO}_3$	I) Na_3AlF_6
7. Discuss how green plants and animals incorporate carbon atoms from atmospheric carbon dioxide gas. And describe how carbon returns to the atmosphere.
8. One of the possible consequences of global warming is an increase in the temperature of ocean water. The oceans serve as a “sink” for CO_2 by dissolving a large amount of the substance. How would the solubility of CO_2
9. In the oceans be affected by an increase in the temperature of water?
10. What are the effects of using phosphate fertilizers on the environment?
11. What makes the phosphorus cycle different from the carbon and nitrogen cycles?
12. What are the major uses of phosphorus in living organism?
13. Discuss the main steps in obtaining a pure metal from its ore.
14. What is meant by pre-treatment of an ore? Give some examples of pre- treatment.
15. Describe, with examples, the chemical and electrolytic reduction processes used in the production of metals.
16. Describe the process by which a metal is purified by zone refining.
17. A copper sample containing gold, lead, silver, and zinc as impurities is refined electrolytically using a copper sulphate as electrolyte. Use. state which substances will be found in the anode sludge.
18. Write the main ore, chemical properties and use of Na, Ca, Zn, Cr, Pb and Sn?