



Dr. Bbosa Science

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Group 2A: The alkaline earth metals.

The members of group 2A or the alkaline earth metals are beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra). Radium is radioactive.

All the members of this group are highly reactive and are essentially found as compounds in nature. Some physical properties of group 2A elements are given in a table below:

Table 1 Some properties of group 2A elements

Elements	Atomic number	Electronic configuration	M.p. /°C	B.pt. /°C	Atomic radii (nm)	Ionic radii (nm)	First ionisation energy /kJ mol ⁻¹	2nd Energies /kJ mol ⁻¹	Standard electrode potential / V
Be	4	2.2	1280	2477	0.089	0.031	899	1757	-1.85
Mg	12	2.8.2	650	1100	0.130	0.065	738	1451	-2.37
Ca	20	2.8.8.2	850	1487	0.174	0.099	590	1145	-2.87
Sr	38	2.8.18.8.2	768	1380	0.191	0.113	549	1064	-2.89
Ba	56	2.8.18.18.8.2	714	1640	0.198	0.135	502	965	-2.90
Ra	88	2.8.18.32.18.8.2	700	1140		0.148	508	975	-2.92

Uniqueness of Beryllium

The chemistry of Beryllium differs considerably from the other members of the group because it has

- A small atomic radius
- High electronegativity
- Has very high ionization energy that it hardly form Be²⁺ ions leading to covalent compounds.
- Its ions have high charge density

Trial 1

Beryllium chloride is more soluble in ethanol than in water whereas magnesium chloride is more soluble in water than in ethanol. Explain.

Atomic radii of group 2 elements

Atomic radii of group 2 elements increase down the group due

- (i) Increase in the number of electron shells.
- (ii) increase in the screening effect of the inner electrons

Ionization energy

a. The ionization energy is decrease down the group due to the decrease in the effective nuclear charge.

Down the group both the nuclear charge and screening effect increase but increase in the screening outweighs increase in nuclear charge.

b. Group 2 elements have higher ionization energy than group 1 elements, leading to less ionic compounds since less energy is required to form M^+ than M^{2+} .

However, Group 2 elements are highly metallic that they form mainly ionic compound. The metallic property increases down the group.

Electronegativity of group 2 elements

Decreases down the group because increase in screening effect outweigh increases in nuclear attraction as the number of electron shells increase.

Electronegativity is the relative tendency of an atom to attract bonding electrons.

Electropositivity of group 2 Element

Increase down the group due to decrease in effective nuclear charge. Down the group the number of electron shells and protons increase. Both nuclear charge and screening effect increase but increase in screening effect outweigh increase in nuclear charge.

Trial 2

The elements Be, Mg, Ca, Sr, Ba are in group II of the Periodic table. Explain how the following factors vary within the group.

- (i) atomic radius.
- (ii) ionisation energy.
- (iii) electropositivity.

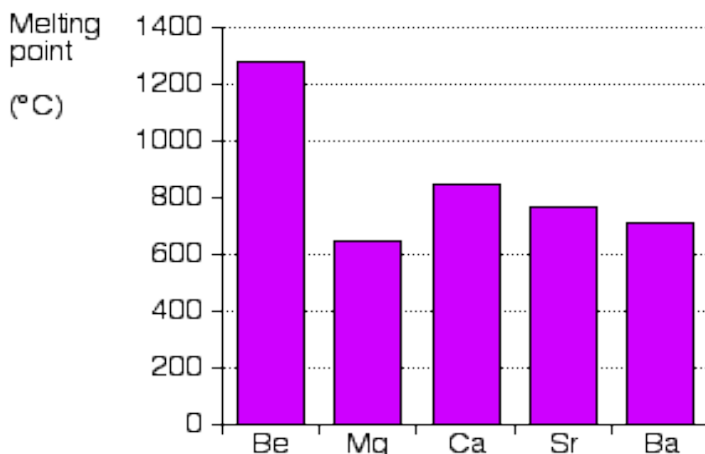
Trial 3

Give one reason to explain why the elements of group II of the periodic table are strong reducing agents.

Melting points

a. The melting points generally decrease down the group as shown below

Melting Points of the Group 2 elements



The melting points of group 2 generally decrease down the group due to the decrease in the strength of metallic bonds.

The strength of metallic bonds decreases down the group due to decrease in nuclear attraction to the delocalized electrons as the electronegativity decrease.

- (b) The melting point of magnesium is lower than expected probably because magnesium atoms are loosely packed in the metal crystal.
- (c) The melting and boiling points of alkaline earth metals are higher than those of the alkali metals because they contribute 2 electrons to form stronger metallic bond. Whereas Group 1 element have 1 electron in the outermost shell and contribute one electron to form weak metallic bonds
- (d) The melting and boiling points of beryllium are higher than expected, because beryllium has a small atomic size and shows non-metallic behavior, it forms strong Be-Be covalent bonds that lead to high melting and boiling points.

NB. Factors affecting the strength of metallic bonds include

1. The strength of metallic bonds increase with the number electrons contributed by each metal atom in the electron cloud in the formation of metallic bonds. The bigger the number of electron contributed to the formation of metallic bond, the stronger the metallic bonds.
2. Nuclear charge: small atoms with high nuclear charge for delocalized electrons form stronger metallic bonds than bigger atom. This is the reason why the melting and boiling points generally decrease down the group as atomic size increase.

Trail 4

Explain the following observations

- (i) the melting point of magnesium is lower than expected. (3marks)
- (ii) group 2 elements have higher melting points than group 1 elements?
- (iii) The melting point of beryllium is higher than expected

Flame test

Calcium, strontium and barium give characteristic flame coloration

- calcium - yellowish-red
- strontium - crimson
- barium - apple-green.

The colored flames can be used to identify these metals or their salts

Complex ion formation

Definition

- (i) A complex ion is a cation bonded to small molecules called ligands by dative bonds.
- (ii) A dative bond is covalent bond in which both the shared electrons are provided by one atom only.

Factors that promote formation of complex ions

- (i) Cations should have high charge density to attract the electrons from the ligands
- (ii) Cations should have vacant orbitals to accommodate the lone pairs of electrons from the ligands to form dative

The tendency to form complexes by group 2 elements decreases as the size of M^{2+} ions increases due to the decrease in charge density.

For instance, Be^{2+} on account of its small size and high charge density, forms stable complexes, e.g., $[BeF_4]^{2-}$ while Ba^{2+} forms very few.

Trial 5

Explain why

- (i) Group 2 elements do not form many complex compounds. (have low charge density)
- (ii) The tendency to form complexes in group 2 elements decreases

Electron configuration

The outermost configuration group 2 elements is ns^2 .

Oxidation state of group 2 elements

Group 2 elements form compounds with oxidation state +2.

In Oxidation state +2, M^{2+} ions have stable full electron configuration of noble gases.

Trial 6

Give one reason in explain why the elements of group II of the periodic table are divalent.

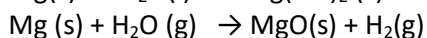
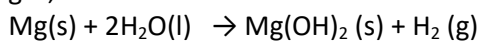
Reactivity trend of group 2 element

The reactivity of alkali earth metals increases with increasing atomic number due to increase in metallic property.

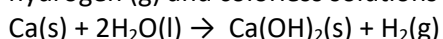
1. Reaction with water

Beryllium has no reaction with water;

Very clean Magnesium reacts slowly with water to form colorless solution of magnesium hydroxide. Magnesium burns with bright flame in steam to form white crystal of magnesium oxide and hydrogen gas,



Calcium, strontium and barium react with water with increasing vigor to give off effervesce of hydrogen (g) and colorless solutions of hydroxides.



Trial 7

State what would be observed and write an equation for the reaction which takes place when:

- (i) *magnesium is reacted with steam.* (3½ marks)
- (ii) *barium is reacted with water.* (03 marks)

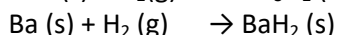
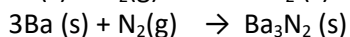
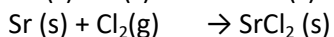
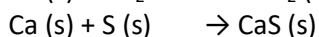
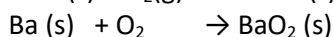
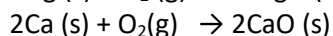
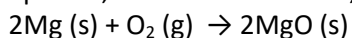
Trial 9

*Describe and explain the trend in the reactivity of elements of group II **with cold water** down the*

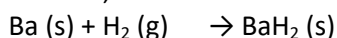
group. (8 marks)

2. Reaction with nonmetals

At suitable conditions, alkaline earth metals react with a variety of nonmetals to give oxides, sulphides, halides and nitrides;



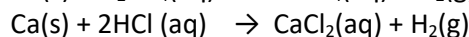
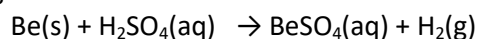
Calcium, strontium and barium combine with hydrogen to give hydrides.



3. Reaction with acids

(i) Dilute acids

With dilute hydrochloric and sulphuric acids, they give the corresponding salts and hydrogen gas.

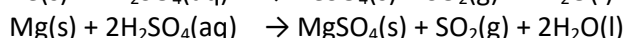
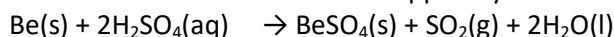


(ii) Dilute sulphuric acid

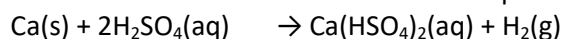
Calcium and barium react slowly with cold dilute sulphuric acid but the reaction immediately stops because their sulphates are insoluble.

(iii) Reaction with concentrated sulphuric acid

With hot concentrated acid group II metals react to form sulphates, sulphur dioxide and water but the reaction with barium is stopped by the formation of an insoluble sulphate.



Calcium dissolves in hot concentrated sulphuric acid to form calcium hydrogen sulphate



Barium reacts shortly with sulphuric acid due to insoluble sulphate formed

Trial 10.

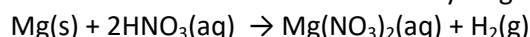
Compare the reaction of beryllium and barium with sulphuric acid under various conditions.

(7½ marks)

(iv) Reaction with nitric acid

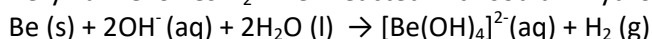
Beryllium does not react with concentrated nitric acid because it forms a layer of insoluble BeO.

The rest react to form nitrates and hydrogen gas



4. Reactions with sodium hydroxide

Beryllium evolves H₂ when reacted with sodium hydroxide solution to form a complex and hydrogen.

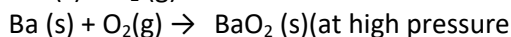
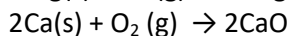
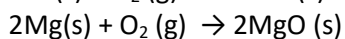
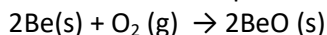


Other group II elements do not react with sodium hydroxide.

Oxides of the Group 2A metals

Alkaline earth metals form ionic oxides of the form M²⁺O²⁻ when heated with oxygen. Strontium and barium form peroxides, M²⁺O₂²⁻ on prolonged heating, particularly if pressure is used.

Oxides of the Group 2A metals



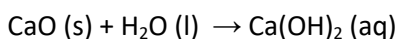
Uses of oxides of group 2

1. Magnesium oxide (m.pt. 2800°C) is used for manufacturing lining for open-hearth steel furnaces.
2. CaO is used in many metallurgical operations to produce a slag with impurities in metal ores and as a drying agent.

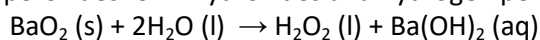
Reaction of oxides with water

i) Beryllium oxide (BeO) does not react with water.

ii) Oxides react with water to give hydroxides.

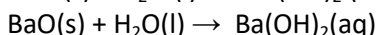
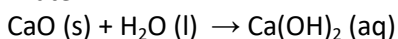


iii) The peroxides form hydroxides and hydrogen peroxide with water.



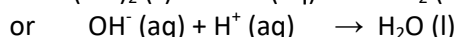
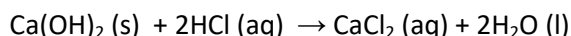
Hydroxides of alkaline earth metal

Group 2A elements form ionic hydroxides. They can be prepared by reaction of corresponding oxides with water.

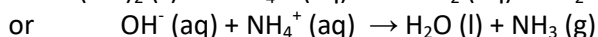
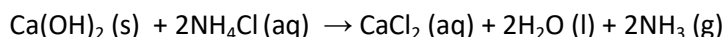


Reaction

i) Hydroxides neutralise acids to form salts.



ii) They displace ammonia from ammonium salts.



Solubility of group 2 metal hydroxides

The solubility of group 2A hydroxides increases down the group from Be(OH)_2 to Ba(OH)_2 due to

- (i) an increase in ionic character of the hydroxides and
- (ii) the decrease in lattice energy as the sizes of the cations increase. Down the group, both hydration and lattice energies decrease; but the lattice energy decreases more rapidly than the hydration energies leading to the increase in the solubility of the hydroxides down the group.

The solubility of group II hydroxides is less than that of group I hydroxides because

- (i) they are less ionic and
- (ii) they have higher lattice energy due to their high charge density. The low solubility of group 2 metal hydroxides in water makes them weaker alkalis.

Trial 11

Describe and explain how the solubility of hydroxides of group (II) elements of the periodic table varies down the group. (6 marks)

Trial 12

Compare the solubility and basicity of hydroxides of group II elements with the hydroxides of group (I) elements (3½ marks)

Uses of group II metals

Beryllium is used for making containers for uranium-238 as it does not absorb neutrons and therefore does not become radioactive.

Magnesium

1. Is alloyed with aluminium to make Duralumin® used in construction of airplanes and small boats.
2. Used in extraction of titanium.
3. It used as a sacrificial anode to prevent iron from rusting.
4. The intense white light of burning magnesium is used in flares and distress signals.

Trial 9.1

(a) Give one reason in each case to explain why the elements of group II of the periodic table

- (i) are divalent.
- (ii) form mainly ionic compounds.
- (iii) are strongly reducing agents.
- (iv) do not form many complex compounds. (8 marks)

(b) Although lithium is in group 1 of the periodic table, it resembles elements of group II in some of its properties

- (i) State two properties in which lithium resembles group II elements. (2 marks)
- (ii) Give one reason for the anomalous behaviours of lithium. (2 marks)

(c) Explain why lithium ion has a smaller electrical conductivity than caesium ion when ions are in aqueous solution. (2 marks)

(d) Compare the reactivity of the elements of group I and group II with water and indicate the trend in the reactivity within each group. (5 marks)

(e) Explain why beryllium carbonate is thermally less stable than barium carbonate. (2 marks)

Trial 9.2

Beryllium chloride is more soluble in ethanol than in water whereas magnesium chloride is more soluble in water than in ethanol.

Trial 9.3

(a) Group II metals form few complexes. However, the tendency to form complexes decreases down the group. Explain

- i. What is meant by the term complex. (3 marks)
- ii. Why the tendency to form complexes decreases down the group. (4 marks)

(b) $[V(CN)_6]^{3-}$ and $[CoCl_4]^{2-}$ are complexes formed by vanadium and cobalt respectively. State:

- i. The oxidation states of
Vanadium
Cobalt
- ii. The co-ordination numbers of
Vanadium
Cobalt

Trial 9.4

The elements beryllium, magnesium and barium belong to group II in the periodic table.

- (a) (i) State three chemical properties shown by the elements. For each property, write an equation to illustrate your answer. (6 marks)
- (ii) Explain the trend in the solubilities of the hydroxides of the elements in water. (3 marks)

Trial 9.5

- (a) Write electronic configuration of strontium. (1 mark)
- (b) What is the principal oxidation state of strontium? (1 mark)
- (c) State whether the first ionisation energy of strontium is greater or less than that of barium. Explain your answers. (2marks)

Trial 9.6

The elements Be, Mg, Ca, Sr, Ba are in group II of the Periodic table.

- (i) Explain how the following factors vary within the group.
 - a. atomic radius.
 - b. ionisation energy.
 - c. electropositivity.

Trial 9.7

- (a)(i) State how the melting and boiling points of group II metals differ from those of group (I). (1 mark)
- (ii) Give reasons for your answer in (a)(i). (2 marks)
- (b) State why beryllium differs from the rest of the elements in group (II) of the periodic table (4 marks)

Physical properties of group 2A metals

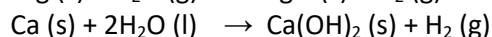
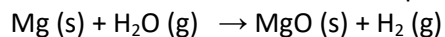
The metals are very much harder than alkali metals; they are good conductors of heat and electricity. When pure, these metals are silvery coloured but quickly tarnish on exposure to air due to formation of oxides.

Chemical reactions

The reactivity of alkali earth metals increases with increasing atomic number.

Reaction with water

Beryllium has no reaction with water; magnesium reacts with steam to form the oxide and hydrogen gas, while calcium, strontium and barium react with water with increasing vigour to give hydrogen and hydroxides. This is due to increase in electropositivity of the metals down the group.



Trial 9.8

State what would be observed and write an equation for the reaction which takes place when:

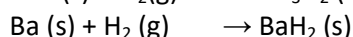
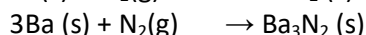
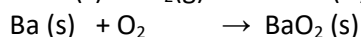
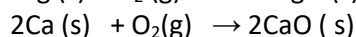
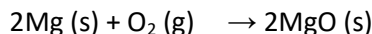
- (i) magnesium is reacted with steam. (3½ marks)
- (ii) barium is reacted with water. (03 marks)

Trial 9.9

Describe and explain the trend in the reactivity of elements of group II **with cold water** down the group. (8 marks)

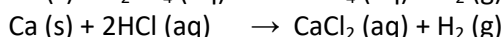
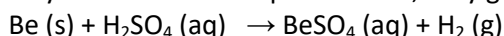
(b) Reaction with non metals

At suitable conditions, alkaline earth metals react with a variety of non metals to give oxides, sulphides, halides and nitrides; calcium, strontium and barium also combine with hydrogen to give hydrides.

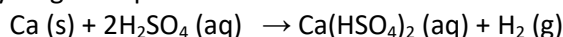


(c) Reaction with dilute acids

With dilute hydrochloric and sulphuric acids, they give the corresponding salts and hydrogen gas.



Calcium and barium do react slowly with cold dilute dilute sulphuric acid but the reaction immediately stops because their sulphates are insoluble. Calcium dissolves in hot concentrated sulphuric acid to form calcium hydrogen sulphate



With hot concentrated acid group II metals react to form sulphates, sulphur dioxide and water but the reaction with barium is stopped by the formation of an insoluble sulphate.



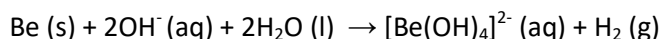
Beryllium does not react with concentrated nitric acid because it forms a layer of insoluble BeO.

Trial 9.10

Compare the reaction of beryllium and barium with sulphuric acid under various conditions. (7 ½ marks)

(d) Reactions with sodium hydroxide

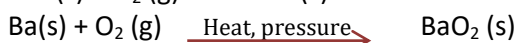
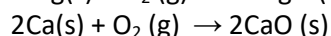
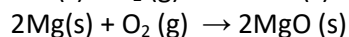
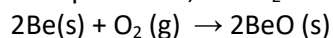
Beryllium evolves H₂ when reacted with sodium hydroxide solution to form a complex and hydrogen.



Other group II elements do not react with sodium hydroxide.

Oxides of the Group 2A metals

Alkaline earth metals form ionic oxides of the form M²⁺O²⁻ when heated with oxygen. Strontium and barium form peroxides, M²⁺O₂²⁻ on prolonged heating, particularly if pressure is used.

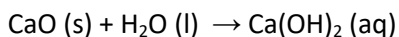


The normal oxides can also be produced by thermal decomposition of corresponding carbonates.

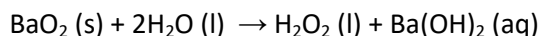


Reaction of oxides with water

- i) Beryllium oxide (BeO) does not react with water.
- ii) Oxides react with water to give hydroxides.



iii) The peroxides form hydroxides and hydrogen peroxide with water.

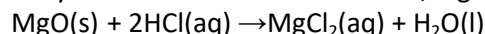


Uses

1. Magnesium oxide (m.pt. 2800°C) is used for manufacturing lining for open-hearth steel furnaces.
2. CaO is used in many metallurgical operations to produce a slag with impurities in metal ores and as a drying agent.

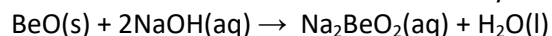
Reactions of group 2A metal oxides with dilute hydrochloric acid

They react to form salts and water, e.g.



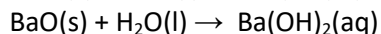
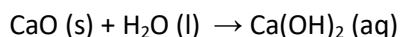
Reactions of group 2A metal oxides with sodium hydroxide solution

These oxides do not react with sodium hydroxide. But, BeO reacts to form a complex salt



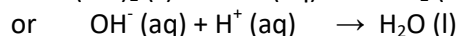
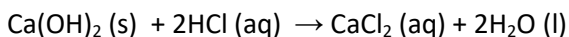
Hydroxides of alkaline earth metal

Group 2A elements form ionic hydroxides. They can be prepared by reaction of corresponding oxides with water.

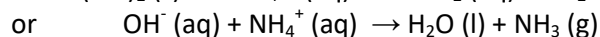
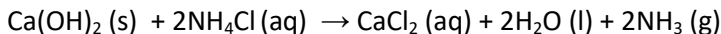


Reaction

i) Hydroxides neutralise acids to form salts.



ii) They displace ammonia from ammonium salts.



Solubility of group 2 metal hydroxides

The solubility of group 2A hydroxides increases down the group from Be(OH)_2 to Ba(OH)_2 due to (i) an increase in ionic character of the hydroxides and (ii) the decrease in lattice energy as the sizes of the cations increase. Down the group, both hydration and lattice energies decrease; but the lattice energy decreases more rapidly than the hydration energies leading to the increase in the solubility of the hydroxides down the group.

The solubility of group II hydroxides is less than that of group I hydroxides because (i) they are less ionic and (ii) they have higher lattice energy due to their high charge density. The low solubility of group 2 metal hydroxides in water makes them weaker alkalis.

Trial 11

Explain how the solubility of hydroxides of group (II) elements of the periodic table varies down the group.
(6 marks)

Trial 12

Compare the solubility and basicity of hydroxides of group II elements with the hydroxides of group (I) elements.
(3½ marks)

Trial 9.13

Be, Mg, Ca, Sr and Ba are elements in group II of the periodic table.

(a) Describe and explain the trend in the reactivity of the elements with cold water down the group.

(08 marks)

(b) Compare the solubility and basicity of the hydroxides of group (II) elements with the hydroxides of group (I) elements.
(3½ marks)

(c) (i) Explain why beryllium and aluminium show a diagonal relationship.

(2 marks)

(ii) Write equations to show how beryllium and aluminium react with concentrated sodium hydroxide solution.

(3 marks)

(d) A chloride of beryllium, Z, contains 11.25% beryllium and 88.75% chlorine.

(i) Calculate the empirical formula of Z.

(1½ marks)

(ii) Determine the molecular formula of Z, (the vapour density of Z = 80).

(01 mark)

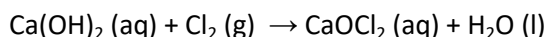
(iii) Write the structural formula of Z.

(1 mark)

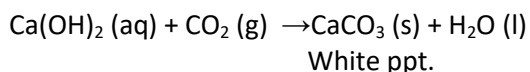
Uses

Calcium hydroxide has many uses, e.g.

- Calcium hydroxide displaces ammonia from ammonium salts when heated within the mixture. It is thus used in recovering ammonia from ammonium chloride in the Solvay process. It is also employed in the laboratory preparation of this gas.
- It can be used as a cheap alkali for neutralizing acidic soils.
- It is used to soften temporary hard water by addition of calculated amounts.
- It is used in preparation of calcium hydrogen sulphite solution that removes the lignin from wood, leaving cellulose used in paper manufacturing.
- Bleaching powder is manufactured by passing chlorine over moist calcium hydroxide. Its composition is complex but it is known to contain Ca^{2+} , OCl^- , Cl^- and OH^- ions and water. However, it is usually represented by the simplified formula, CaOCl_2 .



- A dilute solution of Ca(OH)_2 is used for testing for carbon dioxide.

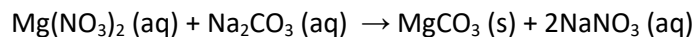


The carbonates of alkaline earth metals

Magnesium carbonate occurs naturally as magnesite (MgCO_3) and in association with calcium carbonate as dolomite, $\text{MgCO}_3 \cdot \text{CaCO}_3$. Calcium carbonate occurs naturally as calcite, marble, lime stone and chalk.

Preparation

By reaction of corresponding soluble salts with alkali carbonates, e.g.



Properties

- i) Carbonates of alkaline earth metals are sparingly soluble in water. Solubility decreases down the group due to increase in lattice energy and a decrease in hydration energy.
- ii) Carbonates decompose on heating to form oxides and carbon dioxide. The stability of carbonates increases down the group due to increase in ionic character and lattice energy of the carbonates.
$$\text{MgCO}_3 (\text{s}) \rightarrow \text{MgO} (\text{s}) + \text{CO}_2 (\text{g})$$
- iii) They react with acids to give off carbon dioxide.



Uses

1. MgCO_3 is used to provide MgO for the lining of open-hearth steel furnaces.
2. CaCO_3 is a basic raw material in the Solvay process and glass industry.
3. It is used to remove impurities from iron ore during extraction of iron.
4. Calcium carbonate is used for making chalk.
4. Calcium carbonate is used to make antacids (drugs for ulcers).

Portland cement

Portland cement, so called because it resembles portland stone when set.

Composition of cement

The average composition of different oxides is

Lime (CaO)	50-60%
Silica (SiO ₂)	20-25%
Alumina (Al ₂ O ₃)	5-10%
Magnesia (MgO)	2-3%
Ferric oxide (Fe ₂ O ₃)	1-2%
Sulphur trioxide (SO ₃)	1%
Sodium oxide (Na ₂ O)	1%
Potassium oxide (K ₂ O)	1%

The essential constituents of cement are lime (obtained from lime stone) silica and alumina (present in clay). For cement of good quality, the oxides should be kept in the following ratio.

$$\left[\frac{\% \text{SiO}_2}{\% \text{Al}_2\text{O}_3} = 25 - 40, \quad \frac{\% \text{CaO}}{\% \text{SiO}_2 + \% \text{Al}_2\text{O}_3 + \% \text{Fe}_2\text{O}_3} = 1.9 - 2.3 \right]$$

Cement without iron is white but hard to burn. If less lime is present than given in the ratio above, the cement is low in strength and sets very soon. If more lime is present, cement cracks. Excess of silica provides slow hardening cement, while excess of alumina gives a quick-setting product.

Raw materials

1. Lime stone, CaCO₃ provides CaO.
2. Clay (Al₂O₃.SiO₃. Fe₂O₃.H₂O) supplies silica (SiO₂) and alumina (Al₂O₃). Some clay doesn't contain Fe₂O₃ and the cement obtained in this case is white and hard to burn.
3. Gypsum, CaSO₄.2H₂O decreases the setting time of cement.

Manufacture of cement

1. **Preparation of raw material or slurry.** Lime stone and clay are mixed in the proper ratio by any of the following processes.

(a) **Dry process:** This is employed when the raw materials (clay and sand) are hard and dry. In this process, the lime stone is first broken into small pieces. It is then mixed with clay in the proper ratio and finally pulverised to such a fine powder that 90-95 passes through a 100 mesh size. The mixture is made homogeneous to produce a raw meal.

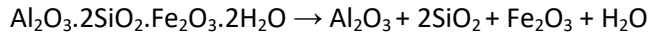
(b) **Wet process.** This process is used when the raw materials (i.e. lime stone and clay) are soft and the fuel is fairly cheap. In this process, lime stone is crushed to a suitable size and the clay is washed with water in a wash mill to remove foreign materials like flint. The powdered lime stone is mixed with the clay paste in the proper proportion (limestone 75% and clay 25%) and the mixture is finely ground and made homogeneous by means of a compressed air mixing arrangement. The result is a paste or slurry containing about 40% water.

2. Burning (calcinations) of raw meal or slurry in rotary kiln.

The raw meal or slurry is heated in a rotary kiln up to 1500°C between 2-3 hours to cover the journey in the kiln. The reactions taking place in the rotary kiln can be divided into the following:

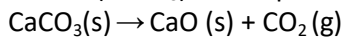
(i) Reaction taking place in moderate temperature zone (up to 800°C)

In this zone, free moisture is removed and clay ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot \text{Fe}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$) is broken into Al_2O_3 , SiO_2 and Fe_2O_3



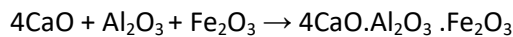
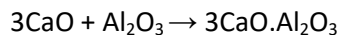
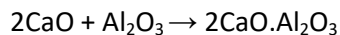
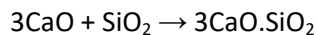
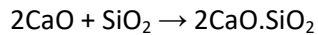
(ii) Reaction taking place in average temperature zone (800°C - 1000°C)

Lime stone (CaCO_3) decomposes into lime (CaO) and CO_2 .



(iii) Reaction in maximum temperature zone (1000°C - 1500°C)

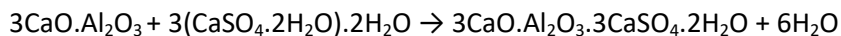
The oxides CaO , Al_2O_3 , SiO_2 , Fe_2O_3 combine together to form silicates, $2\text{CaO} \cdot \text{SiO}_2$, $3\text{CaO} \cdot \text{SiO}_2$, calcium aluminates, $2\text{CaO} \cdot \text{Al}_2\text{O}_3$ and tetra calcium aluminoferrite, $4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$



The mixture of the above silicates, aluminates and tetracalciumaluminoferrite is called cement clinker.

3. Mixing the cement clinker with gypsum.

The cooled clinker is mixed with 2-3% of its weight of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). $3\text{CaO} \cdot \text{Al}_2\text{O}_3$, which is a fast setting constituent of the clinker, reacts with gypsum to form the crystal calcium sulfoaluminate, $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.



Thus, gypsum removes the fast setting $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ and the process of setting cement gets retarded resulting in better strength of the mass which forms.

Setting of cement

The use of cement in construction of buildings is based on its property of setting to a hard mass, when its paste with water is allowed to stand for some time. When cement is mixed with water, it absorbs water and the mass becomes hard and resistant to pressure. This is known as setting of cement. The reactions involved are;

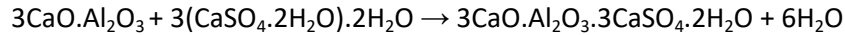
(i) Reactions taking place during first 24hours/short time after the cement is mixed with water, the following reactions take place

(a) $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ absorbs water and forms a hydrated colloidal gel of tricalciumaluminate.



The gel of $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$, so formed starts crystallizing slowly.

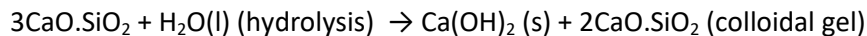
- (b) $3\text{CaO} \cdot \text{Al}_2\text{O}_3$, which is a fast setting material, reacts with gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to form crystals of calcium sulphoaluminate, $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.



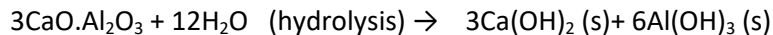
Thus, gypsum removes the fast setting $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ and the process of setting cement gets retarded and results in better strength of the mass which results.

(ii) **Reactions taking place between 1-7 days**

$3\text{CaO} \cdot \text{SiO}_2$ and $3\text{CaO} \cdot \text{Al}_2\text{O}_3$ get hydrolysed according to the equation;



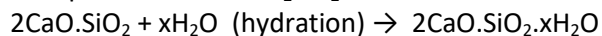
Ca(OH)_2 formed starts changing into needle shaped crystals which get studded in the colloidal gel, $2\text{CaO} \cdot \text{SiO}_2$ formed above, and thus impart strength to it.



Al(OH)_3 formed fills the interstices in the hardening mass.

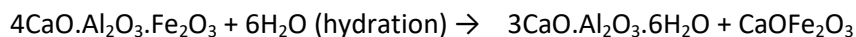
(i) **Reactions taking place between 7-28 days**

$2\text{CaO} \cdot \text{SiO}_2$ begins to hydrate (very slowly) and forms the hydrate colloidal gel of dicalcium silicate of composition $2\text{CaO} \cdot \text{SiO}_2 \cdot x\text{H}_2\text{O}$.



Needles of Ca(OH)_2 formed, get studded in the hydrate colloidal gel of $2\text{CaO} \cdot \text{SiO}_2 \cdot x\text{H}_2\text{O}$ and thus impart strength to it.

$4\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{Fe}_2\text{O}_3$ also gets hydrated to form a colloidal gel of composition $3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{H}_2\text{O}$.



The gel formed above starts losing water partially by evaporation and partly by forming a hydrate constituent. Thus cement sets to a hard mass.

Concrete

Concrete is a mixture of cement with sand and gravel. Concrete is used to make floors, bricks and pillars that are used to construct strong buildings and roads, figure 9.2.



Fig. 9.2 (a) Concrete bricks and pillars for strong walls and (b) concrete pavers

Trial 9.14

Cement is a mixture of inorganic compounds and is widely used in construction industry.

(a) Name:

(i) the two processes by which cement can be made.

(1 ½ marks)

(b) Describe briefly how cement is manufactured and explain the main physical and chemical changes involved.

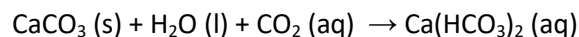
(13 marks)

(c) Describe what happens when water is added to a mixture of cement and sand.

(4½ marks)

Hydrogen carbonates of alkaline earth metals

The solid hydrogen carbonates are unknown at room temperature, but they cause temporary hardness of water. Rain water attacks any rocks containing calcium and magnesium carbonates and a dilute solution of hydrogen carbonate is formed.

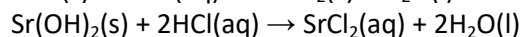
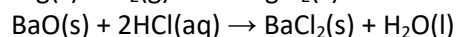
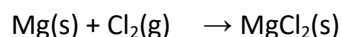


When water containing the dissolved hydrogen carbonates is boiled, deposits of the carbonates are formed.



The halides of alkaline earth metals

They are formed by reacting metals with halogens, or metal oxides and hydroxides with hydrohalic acids e.g.



- a. The **solubility** of group 2A metal halides increases in order $\text{MF}_2 < \text{MCl}_2 < \text{MBr}_2 < \text{MI}_2$ and for any given halide, X, the solubility increases in order $\text{BeX}_2 < \text{MgX}_2 < \text{CaX}_2 < \text{SrX}_2 < \text{BaX}_2$.

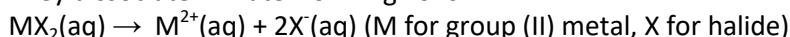
Reasons

1. Because the lattice (bond) energy decreases in order $\text{MF}_2 > \text{MCl}_2 > \text{MBr}_2 > \text{MI}_2$.
2. The ionic character increases in order $\text{BeX}_2 < \text{MgX}_2 < \text{CaX}_2 < \text{SrX}_2 < \text{BaX}_2$.

The bromides and iodides are appreciably soluble in organic solvents such as alcohols, carbonyl compounds and ether, due to formation of complexes.

b. Reaction of halides with water

They dissociate in water forming ions



Hydrides of group II elements

Beryllium and magnesium form partially ionic and partially covalent hydrides whereas Ca, Sr and Ba form ionic hydrides.

Preparation

- (i) By heating the metal with in a current of hydrogen between $150^\circ - 300^\circ\text{C}$
- $$\text{M}(\text{M} = \text{Ca, Sr, Ba})(\text{s}) + \text{H}_2(\text{g}) \rightarrow \text{MH}_2(\text{s})$$

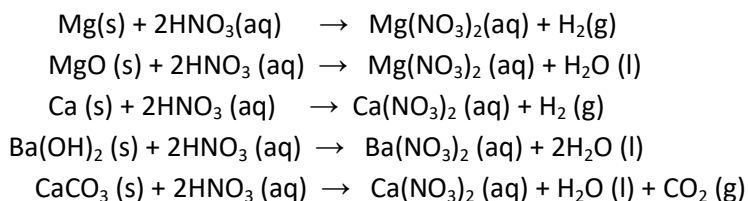
- (ii) By Alexander's method. CaH_2 is prepared by heating CaO with metallic Mg in a current of hydrogen at 250°C and 50 cm pressure hydrogen. The yield of 99.2% of CaH_2 is obtained in two hours.

Properties of group (II) metal hydrides

- (i) CaH_2 , SrH_2 and BaH_2 are white powders with ionic lattices. They have high melting and boiling points, conduct electricity in molten form liberating hydrogen at the anode.
- (ii) The thermostability of group (II) hydrides decrease down the group. They decompose on heating in absence of air liberating hydrogen.
$$\text{CaH}_2(\text{s}) \rightarrow \text{Ca}(\text{s}) + \text{H}_2(\text{g})$$
- (iii) The heat of formation of the hydrides decreases down the group.
- (iv) Action of air. They are oxidise in air forming oxides and water.
$$\text{CaH}_2(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CaO}(\text{s}) + \text{H}_2\text{O}(\text{l})$$
- (v) Reaction with water. They react with water forming hydroxides and hydrogen gas.
$$\text{CaH}_2(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{OH})_2(\text{aq}) + \text{H}_2(\text{g})$$
- (vi) Decomposition with SO_2 . Calcium hydride is decomposed with SO_2 , forming calcium hyposulphite (CaS_2O_4)
$$\text{CaH}_2(\text{s}) + 2\text{SO}_2(\text{g}) \rightarrow \text{CaS}_2\text{O}_4(\text{s}) + 2\text{H}_2(\text{g})$$

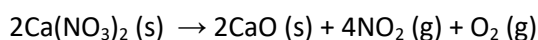
The nitrates of alkaline earth metals

They are obtained by reacting metals oxides, hydroxides and carbonates with dilute nitric acid and crystallisation of the resultant solutions.



Reactions

1. The nitrates decompose on heating to give the oxides, nitrogen dioxide and oxygen.



Uses: Calcium nitrate is used as nitrogenous fertilizer e.g., CAN, NPK.

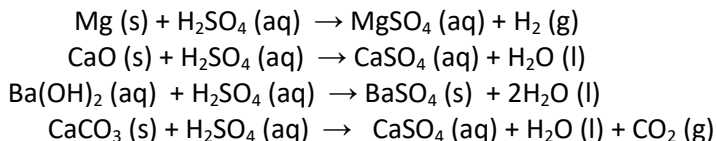
The sulphates of alkaline earth metals

Occurrence

Magnesium sulphate occurs as epsom salts, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. Calcium sulphate occurs as an anhydrite, CaSO_4 , and as gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$.

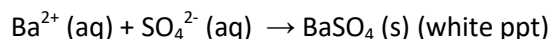
Preparation

By reaction of corresponding metal oxides, hydroxides or carbonates with dilute sulphuric acid.



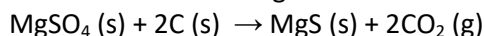
Solubility:

Like carbonates, the solubility of the sulphates decreases down the group due to increase in lattice energies; thus, Ba^{2+} ions are used for testing for sulphate ions. This is due to increase in lattice energies and decrease in hydration energies.



Reactions

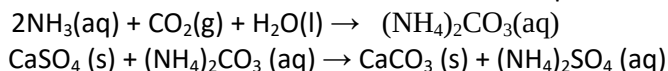
1. Sulphates of calcium and magnesium are reduced to sulphides when heated with carbon.



Uses

When heated to a temperature a little in excess of 100°C , gypsum loses three-quarters of its water of crystallisation and becomes **plaster of Paris**, $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$. Plaster of Paris sets solid, with slight expansion, on mixing with water and standing. It is widely used in making plaster casts, as a surface for walls, moulds and in surgery to keep injured limbs rigid. Plaster board, which is used in building, is also made from plaster of Paris.

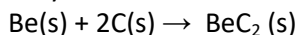
Ammonium sulphate, a nitrogenous fertiliser, is manufactured by reacting powdered calcium sulphate with an ammonia solution containing carbon dioxide ($(\text{NH}_4)_2\text{CO}_3$). This reaction takes place because calcium carbonate is less soluble in water than calcium sulphate.



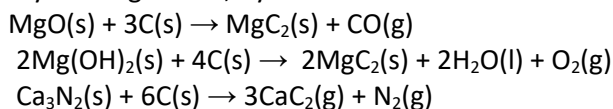
The carbides of group 2A metals

(a) Preparation

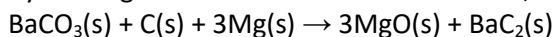
- (i) Beryllium carbide is formed by heating beryllium with carbon.



- (ii) By heating oxides, hydroxides and nitrides of metals with carbon.

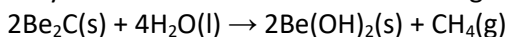


- (iii) By heating metallic carbonates with carbon, in presence of oxidisable metal.

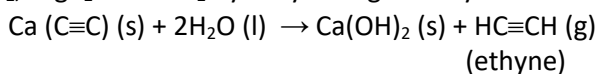


Hydrolysis of carbides

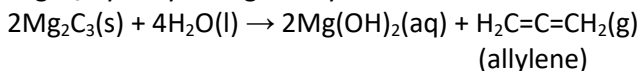
- i) Beryllium carbide reacts with water to give methane.



- ii) BaC_2 , MgC_2 and CaC_2 hydrolyse to give ethyne.

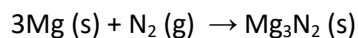


- iii) Mg_2C_3 hydrolyse to give allylene.

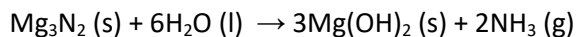


The nitrides of group 2A metals

- ii) The nitrides, $(\text{M}^{2+})_3(\text{N}^{3-})_2$, are formed on heating metals with nitrogen.

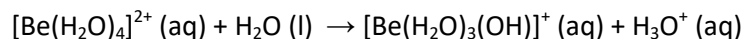


Addition of water causes hydrolysis and ammonia is liberated.

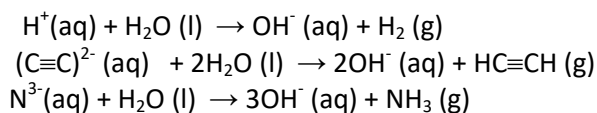


Hydrolysis of group 2A metal salts

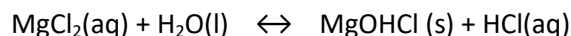
Soluble salts of beryllium with strong acids undergo some acidic hydrolysis. Although the majority of beryllium compounds are essentially covalent, the hydrated ion $[\text{Be}(\text{H}_2\text{O})_4]^{2+}$ exists in solution because, beryllium ions are small and attract water molecules more strongly. The hydrolysis of beryllium salts can be represented, thus:



However, salts of weak acids with the most electropositive alkaline earth metals undergo an alkaline hydrolysis in water:



Magnesium chloride hydrolyses to give a basic chloride.



Qualitative analysis of Mg^{2+} , Ca^{2+} , and Ba^{2+}

Compounds containing these ions are white and when dissolved in water, give colourless solutions. Unlike other white compounds (Pb^{2+} , Zn^{2+} , and Al^{3+}) which form white precipitates with sodium hydroxide solution that **are soluble in excess**, these form curdy /powder like precipitates with sodium hydroxide solution which are **insoluble in excess**. Because alkaline earth metals behave very similarly to each other in aqueous solutions, it is very difficult to distinguish among them and especially to separate them. The different reactions used to distinguish among them are shown in table 9.2 below:

Qualitative analysis of Mg^{2+} , Ca^{2+} , and Ba^{2+}

1. Dilute sodium hydroxide solution

Mg^{2+} , Ca^{2+} , and Ba^{2+} form white ppt. Insoluble in excess

2. Dilute ammonia solution

Mg^{2+} forms a white ppt.

Ca^{2+} no observable change

Ba^{2+} with freshly prepared ammonia solution no observable change
with old solution forms white ppt. due to presence of carbonate ions

3. Potassium chromate solution

Mg^{2+} no observable change

Ca^{2+} no observable change

Ba^{2+} yellow ppt.

4. Ammonium oxalate solution followed by a few drops of acetic acid.

Mg^{2+} no observable change

Ca^{2+} White ppt. insoluble in acetic acid

Ba^{2+} White ppt. soluble in acetic acid

Trial 14

(a) Name a reagent that can be used to distinguish between the following pairs of ions. In each case, state what is observed when each ion is separately treated with the reagent.

(i) Ba^{2+} and Ca^{2+}

(03 marks)

Trial 15

Explain each of the following observations;

(a) Beryllium belongs to group (II) of PT and yet its Chemistry and that of its compounds resemble that of aluminium. (4marks)

(b) Calcium phosphate is insoluble in water but dissolves in dilute hydrochloric acid. (5marks)

Trial 16

5(a) State what would be observed and write equations for the reactions which take place when:

- (i) magnesium is reacted with steam. (3½marks)
- (ii) barium is reacted with water. (3marks)
- (b) Compare the reaction of beryllium and barium with sulphuric acid under various conditions. (7½marks)
- (c) Explain how the solubility of hydroxides of elements of group (II) elements of the periodic table varies down the group. (06marks)

Responses

Trial 1

Beryllium chloride is mainly a covalent compound since a lot of energy is required to form Be^{2+} ; secondly, Be^{2+} has high polarizing power than Mg^{2+} ; Be^{2+} polarizes the chloride ion forming a covalent compound soluble in ethanol whereas magnesium chloride is an ionic compound insoluble in organic solvents.

NB. Covalent compounds are soluble in organic solvents like ethanol whereas ionic compounds are soluble in water.

Trial 6

The ions of oxidation state +2 have stable electron configuration of noble gases.

Trial 9

Hint: beryllium does not react with cold water, very clean magnesium reacts very slowly with cold water to give magnesium hydroxide.

Secondly, remember to write equations for the reactions

Trial 12

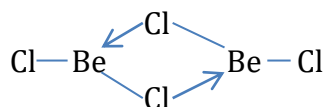
Group 1 hydroxides are more soluble than group II hydroxide because they have high ionic character and low lattice energy. Consequently group 1 hydroxide form strong alkaline solutions than group 2 hydroxides.

Trial 13 (d)

(i) BeCl_2

(ii) Be_2Cl_4

(iii)



Trial 15 (b)

Because it reacts with dilute acids to form soluble dihydrogen phosphates. ($\text{Ca}(\text{H}_2\text{PO}_4)_2$)

