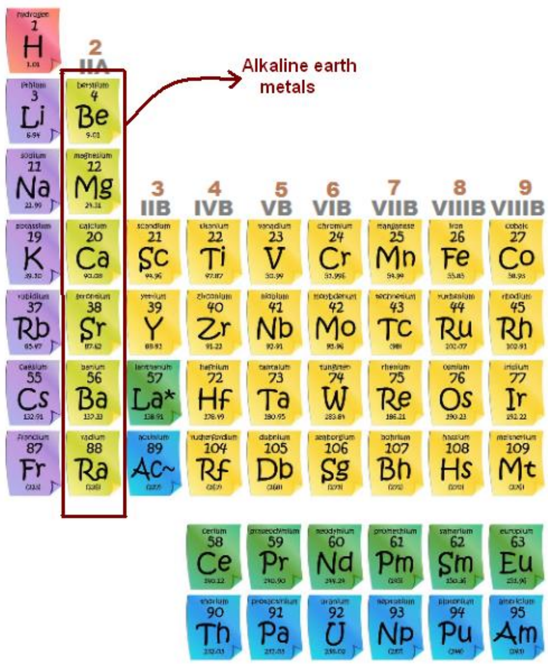
Group 1 2 Elements Alkali Metals Alkaline Earth Metals

The group 2 of the periodic table consists of six metallic elements. They are Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra). The name alkaline earth metals was given to magnesium, calcium, barium & strontium since their oxides were alkaline in nature and these oxide remained unaffected by heat or fire and existed in earth.

So, group 2 metals are called alkali earth metals because their hydroxides are strong alkali (just like those of alkali metals) plus these all are found in earth crust.

Occurrence of Alkali Earth Metals



Like alkali metals, alkaline earth metals are also highly reactive and hence do not occur in the free state but are likely distributed in nature in the combined state as silicates, carbonates, sulphates and phosphates.

Elements	Abundance	Main Minerals	Uses
Beryllium	2.8 to 10-3%	First detected in 1798 in the gemstone beryl and emerald ($Be_3Al_2Si_6O_1$)	Used in corrosion resistant alloys.
Magnesium	2.33%, 7th most abundant element in earth's crust	Pure Mg first prepared in 1800, named after the magnesia district in Thessaly Greece where large deposits of the mineral are found	When alloyed with Al, Mg is widely used as structural materials because of its high strength, low density and ease in machining.
Calcium	4.15%, 5thmost abundant element	$CaCO_3.2H_2O$ obtained in pure form in 1808, calcium is derived	As an alloying agent for hardness in aluminium compounds.

	in earth's crust.	from latin word calx, meaning "lime"	Calcium is the primary constituent of teeth and bones.
Strontium	0.038%	Discovered in 1787 and named after the small town of strontion (Scotland)	$SrCO_3$ is used for the manufacture of glass for colour TV picture tubes.
Barium	0.042%	Found in minerals witherite ($BaCO_3$) and barite ($BaSO_4$) after which it is named.	$BaSO_4$ is used in medicine as a contrast medium for stomach and intestine X – rays
Radium	Traces	Isolated as chloride in 1898 from the mineral pitchblende	Used in cancer radiotheraphy

Group IIA (Alkaline earth metals) and groups IIB (Zn, Cd, Hg) Mg acts as a bridge element between IIA and IIB.

S.No.	Properties	IIA(Be, Mg, Ca, Sr, Ba, Ra)	IIB (Zn, Cd, Hg)
1	Electronic configuration	[Inert gas] ns^2	[Inert gas] $(n – 1)d^{10}ns^2$
2.	Block	S – block	d – block
3.	Oxidation state	+2	+2, mercury also forms dimeric Hg_2^{+2}
4.	Nature of oxide	BeO is amphoteric, other oxides are basic.	ZnO is amphoteric, CdO and MgO are basic
5.	Nature of Halides	Electron – deficient BeX2, others (MX2) are ionic: $MgCl_2 < CaCl_2 < SrCl_2 < BaCl_2$	$ZnCl_2$, $CdCl_2$ are ionic but less than IIA, $HgCl_2$ is covalent.
6.	Nature of sulphates	Less soluble in water and solubility decreases down the group $BeSO_4 > MgSO_4 > CaSO_4 > SrSO_4 > BaSO_4$	More soluble than IIA
7.	Nature of	Solubility of hydroxides increases as we	Solubility of hydroxides

	hydroxides	move down the group.	decrease as we move down the group.
8.	Nature of sulphides	Soluble	ZnS, CdS, HgS insoluble and precipitate in salt analysis.
9.	Reactivity	Increases as we move down the group Be < Mg < Ca < Sr < Ba	Decreases as we move down the group Zn > Cd > Hg

Electronic Configuration

The general electronic configuration of alkaline earth metals is ns^2.

Elements	Electronic Configuration
Be	$1s^22s^2$
Mg	$1s^22s^2sp^63s^2$
Ca	$1s^22s^22p^63s^23p^64s^2$
Sr	$[Kr]5s^2$
Ba	$[Xe]6s^2$
Ra	$[Rn]7s^2$

Physical Properties of Group II elements

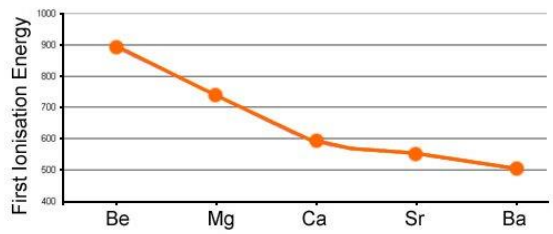
Atomic and ionic radii

The atomic radii as well as ionic radii of the members of the family are smaller than the corresponding members of alkali metals.

Ionization energy

The alkaline earth metals owing to their large size of atoms have fairly low values of ionization energies as compared to the p – block elements. However with in the group, the ionization energy decreases as the atomic number increases. It is because of increase in atomic size due to addition of new shells and increase in the magnitude of screening effect of the electrons in inner shells. Because their (IE)1 is larger than that of their alkali metal neighbours, the group IIA metals trend to the some what less reactive than alkali metals.

The general reactivity trend is Ba > Sr > Ca > Mg > Be.



Oxidation state

The alkaline earth metal have two electrons in their valence shell and by losing these electrons, these atoms acquire the stable noble gas configuration. Thus, unlike alkali metals, the alkaline earth metals exhibit +2 oxidation state in their compounds.

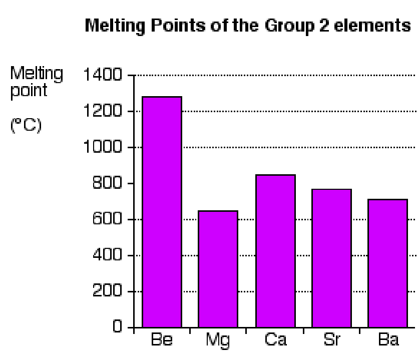
$M \rightarrow M^{+2} + 2e^-$
[noble gas]

Density of Alkali Earth Metals

Atomic weight increases from Be to Ba in a group and volume also increases, but increase in atomic weight is more as compare to atomic volume. Therefore the density increases from Be to Ba.

Exception: Density of Mg is more as compare to that of Ca.

Order: Ca < Mg < Be < Sr < Ba



Melting and Boiling Points

The alkaline earth metals have higher melting and boiling points as compared to those of alkali metals which is attributed to their small size and more close packed crystal lattice as compared to alkali metals and presence of two valence electrons.

Heat of Hydration

The heats of hydration of M^{2+} decreases with an increase in their ionic size and their values are greater than that of alkali metal ions.

Alkaline earth metal ions, because of their larger charge to size ratio, exert a much stronger electrostatic attraction on the oxygen of water molecule surrounding them.

Since the alkaline earth metals (except Be) tend to lose their valence electrons readily, they act as strong reducing agents as indicated by E^0 red values. The particularly less negative value for Be arises from the large hydration energy associated with the small size of Be2+ and the relatively large value of heat of sublimation.

Solubility

Basic nature of oxides increases down the group but solubilities of sulphates and carbonates decrease as ionic size increases.

The solubility of most salts decreases with increased atomic weight, though usual trend is reversed with fluorides and hydroxides in this group.

Property		Elements					
		Be	Mg	Ca	Sr	Ba	Ra
Atomic number		4	12	20	38	56	88
Atomic mass		9.01	24.31	40.08	87.62	137.33	226.03
Metallic radius/pm		112	160	197	215	222	-
Ionic radius/pm		51	72	100	118	135	148
Ionization enthalpy (kJ mol^{-1})	I	899	737	590	549	503	509
	II	1757	1450	1146	1064	965	979
Enthalpy of hydration of M^{2+} ions (kJ mol^{-1})		-2494	-1921	-1577	-1443	-1305	-
Electronegativity (Pauling Scale)		1.57	1.31	1.00	0.95	0.89	0.9
Density/g mol^{-} at 298 K		1.85	1.74	1.55	2.63	3.62	5.5
Melting Point/K		1562	924	1124	1062	1002	973
Boiling point /K		2745	1363	1767	1655	2078	(1973) (uncertain)
E°(V) at 298 K for $M^{2+}(aq) + 2e^- \rightarrow M(s)$		-1.97	-2.37	-2.87	-2.89	-2.90	-2.92

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Occurrence in Lithosphere	2*	2.76**	4.6**	384*	390*	10^{-10}**

* ppm (parts per million) ** Percentage by weight

Reactivity and Electrode potential

All the alkaline earth metals are highly reactive elements since they have a strong tendency to lose the two valences s-electrons to form the corresponding dipositive ions having inert gas configuration. The high reactivity arises due to their low ionization energies and high negative values of their standard electrode potentials. Further, the chemical reactivity of alkaline earth metals increase on moving down the group because the I.E. decreases and electrode potentials become more and more negative with increasing atomic number from Be to Ra. Thus, beryllium is the least reactive while Ba (or Ra) is the most reactive element. Further since the ionization energies of alkaline earth metals are higher and their electrode potential is less negative than the corresponding alkali metals. They are less reactive than corresponding alkali metals.

Reducing Character

The alkaline earth metals are weaker reducing agents than the alkali metals. Like alkali metals, their reducing character also increases down the group. This is due to the reason that the alkaline earth metals have greater tendency to lose electrons so, they act as reducing agent but since their I.E. are higher and their electrode potentials are less negative than the corresponding alkali metals, therefore alkaline earth metals are weaker reducing agents than alkali metals. The sulphates are stable to heat whereas the carbonates decompose to give MO and CO2, the temperature of decomposition increasing from Mg to Ba. BeCO3 is kept in the atmosphere of CO2 to prevent its decomposition.

$BeCO_3$	$MgCO_3$	$CaCO_3$	$SrCO_3$	$BaCO_3$
<100°C	540°C	900°C	1290°C	1360°C
Increasing Reducing Character →				

Flame Test

Ba and Mg do not impart any colour to the fame i.e. they do not give flame test. This is due to their very small size. Ca, Sr and Ba impart brick red, Blood red and Apple green colours respectively to the flame.

Difference between alkaline earth metals and alkali metals

Both alkaline earth metals and alkali metals are s – block elements as the last electron enters the ns – orbital. They resemble with each other in some respects but still there are certain dissimilarities in their properties

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on account of different number of electrons in the valency shell, smaller atomic radii, high ionization

	Properties	Alkaline earth metals	Alkali metals

potential, higher electro negativity etc.

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1.	Electronic configuration	Two electrons are present in the valency shall. The configuration is ns2 (bivalent)	One electron is present in the valency shell. The configuration is ns1 (monovalent) more electropositive
2.	Valency	Bivalent	Monovalent
3.	Electropositive nature	Less electropositive	More electropositive
4.	Hydroxides	Weak bases, less soluble and decompose on heating.	Strong bases, highly soluble and stable towards heat.
5.	Bicarbonates	These are not known in free state. Exist only in solution.	These are known in solid state.
6.	Carbonates	Insoluble in water. Decompose on heating.	Soluble in water. Do not decompose on heating (LiCO3 is an exception)
7.	Action of nitrogen	Directly combine with nitrogen and form nitrides	Do not directly combine with nitrogen except lithium
8.	Action of carbon	Directly combine with carbon and form carbides	Do not directly combine with carbon
9.	Nitrates	Decompose on heating evolving a mixture of NO2 and oxygen	Decompose on heating evolving only oxygen
10.	Solubility of salts	Sulphates, phosphates fluorides, chromates, oxalates etc are insoluble in water	Sulphates, phosphates, fluorides, chromates, oxides etc are soluble in water.
11.	Physical properties	Comparatively harder. High melting points. Diamagnetic.	Soft, low melting points paramagnetic.
12.	Hydration of compounds	The compounds are extensively hydrated. $MgCl_2.6H_2O$, $CaCl_2.6H_2O$, $BaCl_2.2H_2O$ are hydrated chlorides.	The compounds are less hydrated. NaCl, KCl, RbCl form non – hydrated chlorides
13.	Reducing power	Weaker as ionization potential values are high and oxidation potential values are low.	Stronger as ionization potential values are low and oxidation potential values are high.

Chemical Properties of Alkali Earth Metals

Reaction with hydrogen – (Formation of hydrides)

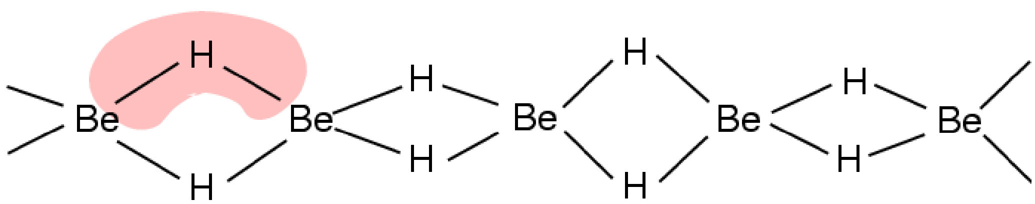
All the alkaline earth metals except be combine with hydrogen directly on heating to form metal hydrides of formula MH_2.

$M + H_2 \xrightarrow{\Delta} MH_2$

The hydride of beryllium can also be obtained by the reduction of $BeCl_2$ with $LiAlH_4$

$2BeCl2 + LiAlH_4 \rightarrow 2BeH_2 + LiCl + AlCl_3$

Both BeH_2 and MgH_2 are covalent compounds having polymeric structures in which H – atoms between beryllium atoms are held together by three centre – two electron (3C - 2e) bonds as shown below:



The hydrides of other elements of this group i.e. CaH_2, SrH_2 and BaH_2 are ionic and contain the H- ions.

All the hydrides of alkaline earth metals reacts with water liberating H_2 gas and thus act as reducing agents.

$MH_2 + 2H_2O \rightarrow M(OH)_2 + 2H_2$

CaH_2 is called Hydrolith and is used for production of H_2 by action of water on it.

Reaction with carbon – (Formation of carbides)

When BeO is heated with carbon at 2175 – 2275 K a brick red coloured carbide of the formula Be_2C is formed

$2BeO + 2C \xrightarrow{2175-2275\ K} Be_2C + 2CO$.

It is a covalent compound and react water forming methane.

$Be_2C + 4H_2O \rightarrow 2Be(OH)_2 + CH_4$

The rest of the alkaline earth metals (Mg, Ca, Sr & Ba) form carbides of the general formula, MC_2 either when the metal is heated with carbon in an electric furnace or when their oxides are heated with carbon.

$Ca + 2C \xrightarrow{1375\ K} CaC_2$

$CaO + 3C \xrightarrow{2275\ K} CaC_2 + CO$

All these carbides react with water producing acetylene gas.

$CaC_2 + 2H_2O \rightarrow HC \equiv CH + Ca(OH)_2$

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Reaction with Halogens

The alkaline earth metals react with halogens at elevated temperature to form the halides of the types MX_2.

Action of Acids

The alkaline earth metals readily react with acids liberating hydrogen.

$M + 2HCl \rightarrow MCl_2 + H_2$ (M = Be, Mg, Ca, Sr, Ba)

Reaction with Ammonia

Like alkali metal, the alkaline earth metals dissolve in liquid ammonia to give deep blue black solution from which ammoniates $[M(NH_3)_6]^{2+}$ can be recovered.

Solved Problem

Question

How does the basicity of oxides of group 2 increases down the group?

Solution:

The basicity increases down the group

$BeO < MgO < CaO < SrO < BaO$

amphoteric strongly - basic

Formation of Peroxides

Since larger cations stabilize larger anions. Therefore, tendency to form peroxide increases as the size of the metal ion becomes larger. Thus BaO_2 is formed by passing air over heated BaO at 773K.

$$2BaO + O_2 \xrightarrow{773\ K} 2BaO_2$$

$$2SrO + O_2 \xrightarrow{773\ K} 2SrO_2$$

SrO_2 is prepared in similar way but under high pressure and temperature. CaO_2 is not formed this way but can be prepared as the hydrate by treating $Ca(OH)_2$ with $H_2O_2$and then dehydrating the product.

$Ca(OH)_2 + H_2O_2 \rightarrow CaO_2.2H_2O$

Crude MgO_2 has been made using H_2O_2 but peroxide of beryllium is not known.

All peroxide are white crystalline ionic solids containing the peroxide ion O^{2-}_2. Treatment of peroxide with acids liberates H_2O_2.

$BaO_2 + 2HCI \rightarrow BaCI_2 + H_2O_2$

Reaction with water(Formation of hydroxides)

The electrode potential of Be (Be^{2+}/Be = -1.97 V) is least negative amongst all the alkaline earth metals. This means that Be is much less electropositive than other alkaline earth metals and hence does not react with water or steam even at red heat.

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The electrode potential of Mg (Mg^{+2}/Mg = -2.37 V), although more negative than that of Be yet is still less negative than those of alkali metals and hence it does not react with cold water but reacts with boiling water or steam.

$Mg + H_2O \rightarrow MgO + H_2$

or, $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$

Mg, infact, forms a protective layer of oxide on its surface, therefore, despite its favourable electrode potential it does not react readily with water unless the oxide layer is removed by amalgamating it with mercury. In the formation of oxide film, Mg resembles Al.

Ca, Sr and Ba have more negative electrode potentials similar to those of the corresponding group I alkali metals and hence react with even with cold water, liberating H_2 and forming the corresponding metal hydroxides.

$Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$

Reactivity of alkaline earth metals increases as we move down the group. However, the reaction of alkaline earth metals is less vigorous as compared to alkali metals.

Reaction with air (Nitrogen and Oxygen)

Formation of oxides and nitrides

Be metal is relatively unreactive in the massive form and hence does not react below 873K. However, powdered Be is more reactive and burns brilliantly on ignition to give a mixture of BeO & Be_3N_2.

$2Be + O_2$ (air) $M + H_2 \xrightarrow{\Delta} MH_2$ $2BeO$

$3Be + N2$ (air) $M + H_2 \xrightarrow{\Delta} MH_2$ Be_3N_2

magnesium is more electropositive than Be and hence burns with dazzling brilliance in air to form a mixture of MgO and magnesium nitride.

Mg + air $M + H_2 \xrightarrow{\Delta} MH_2$ $MgO + Ng_3N_2$

Ca, Sr and Ba being even more electropositive react with air readily to form a mixture of their respective oxides and nitrides.

The reactivity towards oxygen increases as we go down the group. Thus Ca, Ba and Sr are stored in paraffin but Be and Mg are not because they form protective oxide layer on their surface.

Formation of Nitrides

All the alkaline metals burn in dinitrogen to form ionic nitrides of the formula, M3N2. This is in contrast to alkali metals where only Li forms Li_3N.

$3M + N_2$ $M + H_2 \xrightarrow{\Delta} MH_2$ M_3N_2

Be_3N_2 being covalent is volatile while the nitrides of all other elements are crystalline solids.

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All these nitrides decompose on heating and react with water liberating NH_3.

Be_3N_2 M + $H_2 \xrightarrow{\Delta}$ MH_2 3Be + N_2

Ba3N2 + 6H2O M + $H_2 \xrightarrow{\Delta}$ MH_2 3Ba $(OH)_2$ + 2NH3

Ca_3N_2 + 6H_2O M + $H_2 \xrightarrow{\Delta}$ MH_2 3Ca $(OH)_2$ + 2NH_3