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INORGANIC

CH 05

s-Block Elements — Alkali & Alkaline Earth Metals

05

Trends in groups 1 and 2, flame colours, reactions with oxygen, water and liquid ammonia, the anomalous behaviour of Li and Be, stability and solubility of carbonates, sulphates and hydroxides, and key compounds from NaOH to plaster of Paris — with an exam trap gallery, graded MCQs and a one-page revision sheet.

WHAT YOU WILL BE ABLE TO DO

- Explain trends in size, ionisation enthalpy, hydration and reducing power down groups 1 and 2
- Predict the oxide formed by each alkali metal with oxygen and explain solutions in liquid ammonia
- Explain the anomalous behaviour of Li and Be and their diagonal relationships
- Order thermal stability and solubility of carbonates, sulphates and hydroxides, with reasons
- Write the preparation and uses of NaOH, Na_2CO_3, $NaHCO_3$, CaO and plaster of Paris

INSIDE

A The big picture
B Physical trends
C Chemical reactions
D Hydrides, halides and salts
E Lithium: the odd one out
F Group 2 and beryllium

HOW TO USE THESE NOTES

IN ONE LINE The core idea of a section	**KEY IDEA** The concept to remember	**EXAM TRAP** Where marks are usually lost
SOLVED EXAMPLE Worked step by step	**CHECK YOURSELF** Quick self-test	**MEMORY HOOK** A line that sticks

SECTION A

The big picture

A

Easy-to-lose s electrons drive everything.

IN ONE LINE

Group 1 (ns^1) and group 2 (ns^2) metals lose their s electrons easily to form M^+ and M^{2+} ions; they are strong reducing agents whose reactivity rises down the group, while the small first members Li and Be behave differently.

Property	Group 1 (Li → Cs)	Group 2 (Be → Ba)
Configuration	[noble gas] ns^1	[noble gas] ns^2
Common ion	M^+	M^{2+}
Atomic size	Largest in each period; increases down	Smaller than group 1; increases down
Ionisation enthalpy	Lowest in each period; decreases down	Higher than group 1; decreases down
Hydration enthalpy	$Li^+ > Na^+ > K^+ > Rb^+ > Cs^+$	$Be^{2+} > Mg^{2+} > Ca^{2+} > Sr^{2+} > Ba^{2+}$
Metallic character	Soft; low m.p.	Harder; higher m.p.

THINK OF IT LIKE THIS

The single outer electron of an alkali metal is like a loose coin in a large pocket: the bigger the pocket (atom), the easier it falls out. Group 2 has two coins in a slightly smaller, tighter pocket — still easy to lose, but it takes more effort.

SECTION B

Physical trends

B

Size, colour and motion in water.

Group 1	Li	Na	K	Rb	Cs
Metallic radius / pm	152	186	227	248	265
Ionic radius M^+ / pm	76	102	138	152	167
ΔiH_1 / kJ mol^{-1}	520	496	419	403	376

Group 1	Li	Na	K	Rb	Cs
Hydration enthalpy / kJ mol^{-1}	−506	−406	−330	−310	−276
E° (M^+/M) / V	−3.04	−2.71	−2.93	−2.93	−2.93
m.p. / K	454	371	336	312	302

Group 2	Be	Mg	Ca	Sr	Ba
Metallic radius / pm	112	160	197	215	222
Ionic radius M^{2+} / pm	31	72	100	118	135
ΔiH_1 / kJ mol^{-1}	899	737	590	549	503
Hydration enthalpy / kJ mol^{-1}	−2494	−1921	−1577	−1443	−1305
E° (M^{2+}/M) / V	−1.97	−2.36	−2.84	−2.89	−2.92

KEY IDEA

Read the tables together. Group 2 ions have hydration enthalpies four to five times those of group 1, because they carry twice the charge on a smaller ion. That is why group 2 compounds are more often hydrated ($MgCl_2 \cdot 6H_2O$, $CaCl_2 \cdot 6H_2O$) while group 1 compounds mostly are not (except Li).

- **Melting points** fall down group 1 (Li 454 K to Cs 302 K) because metallic bonding weakens as atoms grow.
- **Flame colours:** the energy from the flame excites the outer electron, which emits visible light as it falls back.
- **Hydrated radius** is the reverse of ionic radius: small Li^+ holds the most water, so in water it is the **largest** hydrated ion and the **least mobile**. Ionic mobility and conductance in water: $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$.
- Cs and K emit electrons when light falls on them, so they are used in photoelectric cells.

Element	Li	Na	K	Rb	Cs	Ca	Sr	Ba
Flame colour	Crimson red	Golden yellow	Violet (lilac)	Red-violet	Blue	Brick red	Crimson	Apple green

KEY IDEA

Be and Mg give no flame colour. Their electrons are held too tightly for the flame to excite them into the visible range.

SECTION C

Chemical reactions

C

Strong reducing agents meet oxygen, water and ammonia.

With oxygen

Metal	Main product in excess air	Oxide type
Li	Li_2O	Normal oxide (O^{2-})
Na	Na_2O_2	Peroxide (O_2^{2-})
K, Rb, Cs	KO_2, RbO_2, CsO_2	Superoxide (O_2^-), paramagnetic and coloured

Larger cations stabilise larger anions: the small Li^+ cannot stabilise the big peroxide or superoxide ion; K^+ and heavier ions can.

With water

$$2M + 2H_2O \rightarrow 2MOH + H_2$$

Reactivity with water increases down the group: Li slowly, Na vigorously, K catches fire, Cs explodes

KEY IDEA

Li has the most negative E° (−3.04 V), yet reacts most slowly with water. E° reflects the overall energy, which is dominated by Li^+'s huge hydration enthalpy. The speed depends on kinetics — Li has a high melting point and does not melt on the water surface, so it reacts more gently.

In liquid ammonia

- Alkali metals dissolve to give **blue** solutions containing ammoniated cations and **ammoniated electrons**: $M + (x + y)NH_3 \rightarrow [M(NH_3)_x]^+ + [e(NH_3)_y]^-$.
- Dilute solutions are blue, paramagnetic and good conductors (the free electrons). Concentrated solutions turn **bronze-coloured** and **diamagnetic** as the electrons pair up.
- The solution is a powerful reducing agent (Birch reduction). On standing it slowly gives the amide and H_2.

SOLVED EXAMPLE 01 — SUPEROXIDE IN BREATHING MASKS

Why is KO_2 used in space suits and submarine breathing apparatus? Write the reaction.

SOLUTION

1. Exhaled CO_2 reacts with KO_2 and releases oxygen.
2. $4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$.

ANSWER It absorbs CO_2 and regenerates O_2 at the same time.

SOLVED EXAMPLE 02 — PEROXIDE WITH WATER AND CO_2

Write the reactions of Na_2O_2 with water and with CO_2.

SOLUTION

1. With water: $Na_2O_2 + 2H_2O \rightarrow 2NaOH + H_2O_2$ (in cold water; warm water gives O_2).
2. With CO_2: $2Na_2O_2 + 2CO_2 \rightarrow 2Na_2CO_3 + O_2$.

ANSWER Na_2O_2 gives H_2O_2 with water and releases O_2 with CO_2 — another way to purify air in closed spaces.

SOLVED EXAMPLE 03 — ORDERING CONDUCTANCE

Arrange LiCl, NaCl, KCl and CsCl (same concentration in water) in order of increasing molar conductance, and explain.

SOLUTION

1. Conductance depends on how fast the cation moves through water.
2. Li^+ is the most hydrated, so it is the largest moving unit and the slowest.
3. Cs^+ is the least hydrated and the fastest.

ANSWER LiCl < NaCl < KCl < CsCl.

CHECK YOURSELF

C1 Which alkali metal forms a normal oxide in excess air?

C2 Why does a concentrated solution of Na in liquid NH_3 become diamagnetic?

Answers at the end of the chapter.

SECTION D

Hydrides, halides and salts

D

The compounds group 1 and 2 metals make with H, X, CO_3^{2-} and NO_3^-.

Hydrides

- Alkali metals heated with H_2 give **ionic (saline) hydrides** M^+H^-. Their stability **decreases** down the group: LiH > NaH > KH > RbH > CsH (lattice energy falls).
- They react with water to give H_2: $NaH + H_2O \rightarrow NaOH + H_2$. LiH reacts with Al_2Cl_6 to give $LiAlH_4$, the reducing agent of organic chemistry.
- Group 2: all except Be form ionic hydrides directly. **BeH_2** is made indirectly ($BeCl_2 + LiAlH_4$) and is a covalent, polymeric hydride with Be–H–Be bridges; MgH_2 is also partly covalent.

Halides

- Group 1 halides MX are ionic solids with high melting points, except that Li halides are partly covalent (LiI most covalent).
- Melting points fall in the order fluoride > chloride > bromide > iodide for a given metal.
- Group 2 halides are mostly ionic; $BeCl_2$ is covalent. Group 2 chlorides crystallise as hydrates; heating hydrated $MgCl_2 \cdot 6H_2O$ does not give anhydrous $MgCl_2$ — it hydrolyses to MgO (or Mg(OH)Cl) and HCl.
- **CaF_2 is almost insoluble**: F^- is small, so its lattice energy with Ca^{2+} is very high. Other group 2 fluorides are also poorly soluble, while the chlorides are soluble.

Nitrates and carbonates on heating

Salt	On heating
Group 1 nitrates (Na → Cs)	$2MNO_3 \rightarrow 2MNO_2 + O_2$
$LiNO_3$ and group 2 nitrates	$4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$; $2M(NO_3)_2 \rightarrow 2MO + 4NO_2 + O_2$
Group 1 carbonates (Na → Cs)	Stable — melt without decomposing
Li_2CO_3 and group 2 carbonates	$MCO_3 \rightarrow MO + CO_2$ (easier for smaller cations)
Group 1 bicarbonates	$2MHCO_3 \rightarrow M_2CO_3 + H_2O + CO_2$

SOLVED EXAMPLE 04 — HYDRIDE WITH WATER

Write the reactions of CaH_2 and LiH with water, and explain why CaH_2 is used to make H_2 in the field.

SOLUTION

1. $CaH_2 + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$.
2. $LiH + H_2O \rightarrow LiOH + H_2$.
3. CaH_2 is a stable solid that releases two moles of H_2 per mole and is easy to carry ("hydrolith").

ANSWER Ionic hydrides give H_2 and the hydroxide with water; CaH_2 is a portable source of hydrogen.

CHECK YOURSELF

C3 Arrange LiH, NaH and KH in order of decreasing thermal stability.

C4 What does $NaNO_3$ give on heating? And $LiNO_3$?

Answers at the end of the chapter.

SECTION E

E

Lithium: the odd one out

Small size and high polarising power.

Li^+ is very small with high charge density, so it polarises anions strongly and its compounds have covalent character. Its chemistry resembles magnesium's (diagonal relationship).

Property	Lithium (and Mg)	Other alkali metals
Reaction with N_2	Forms Li_3N (Mg_3N_2 too)	No nitride
Carbonate on heating	$Li_2CO_3 \rightarrow Li_2O + CO_2$ ($MgCO_3$ too)	Stable to heat
Nitrate on heating	$4LiNO_3 \rightarrow 2Li_2O + 4NO_2 + O_2$ (like Mg)	$2NaNO_3 \rightarrow 2NaNO_2 + O_2$
Hydrogencarbonate	$LiHCO_3$ not obtained as a solid	$NaHCO_3$, $KHCO_3$ are solids
Halides	LiCl is deliquescent, soluble in ethanol (covalent)	Ionic
Oxide in air	Li_2O only	Peroxides, superoxides

SOLVED EXAMPLE 05 — **WHY LITHIUM SALTS ARE HYDRATED**

LiCl crystallises as $LiCl{\cdot}2H_2O$ but NaCl is anhydrous. Explain.

SOLUTION

1. Li^+ is the smallest alkali metal ion (76 pm), with the highest charge density.
2. It attracts water molecules strongly (hydration enthalpy −506 kJ mol^{-1} against −406 for Na^+).
3. So water of crystallisation is held in the solid for Li salts but not for Na salts.

ANSWER Small, highly hydrated Li^+ holds water of crystallisation; Na^+ does not.

SECTION F

F

Group 2 and beryllium

Two electrons, higher charge, smaller ions.

- Group 2 metals are harder, denser and higher-melting than group 1, because two electrons take part in metallic bonding.
- They are less reactive: Be and Mg are protected by an oxide film; Mg reacts with hot water or steam; Ca, Sr and Ba react with cold water.
- All burn in air to give MO (and nitride M_3N_2); Mg burns with a dazzling white flame, used in flash photography and fireworks.

Reactions of group 2 metals

Reagent	Product	Note
O_2 (burning)	MO	Ba also forms BaO_2 (peroxide)
N_2 (heating)	M_3N_2	$M_3N_2 + 6H_2O \rightarrow 3M(OH)_2 + 2NH_3$
H_2O	$M(OH)_2 + H_2$	Be none; Mg with hot water; Ca, Sr, Ba with cold water
Dilute acids	M^{2+} salt + H_2	Be dissolves slowly; Be is passive to conc. HNO_3
Halogens	MX_2	$BeCl_2$ also made from BeO + C + Cl_2 at 600–800 K
Liquid NH_3	Blue solutions, like group 1	Ammoniates $[M(NH_3)_6]^{2+}$ form

Beryllium is anomalous

- Be^{2+} is tiny and highly polarising, so Be compounds are largely **covalent**.
- $BeCl_2$ is a **polymeric chain** in the solid (each Be bridged by two Cl), a **dimer** in the vapour, and a linear monomer above about 1200 K.
- $Be(OH)_2$ and BeO are **amphoteric**: $Be(OH)_2 + 2OH^- \rightarrow [Be(OH)_4]^{2-}$.

- Maximum covalency of Be is 4 (no d orbitals), e.g. $[Be(OH)_4]^{2-}$; Mg can reach 6.
- **Diagonal relationship with Al:** both are rendered passive by conc. HNO_3, form amphoteric oxides and hydroxides, form covalent chlorides that are Lewis acids and fume in moist air, and give complexes such as $[BeF_4]^{2-}$ and $[AlF_6]^{3-}$.

SECTION G

Stability and solubility

G

Two competing energies decide every order.

KEY IDEA

Solubility = hydration enthalpy versus lattice enthalpy. Down a group both fall. If the anion is **large** (sulphate, carbonate), lattice enthalpy hardly changes, so falling hydration enthalpy wins → solubility **decreases**. If the anion is **small** (OH^-, F^-), lattice enthalpy falls faster → solubility **increases**.

Compound class (group 2)	Trend down the group	Example
Sulphates	Solubility decreases	$BeSO_4$, $MgSO_4$ soluble; $BaSO_4$ insoluble
Hydroxides	Solubility and basic strength increase	$Be(OH)_2$ amphoteric; $Ba(OH)_2$ soluble, strong base
Carbonates	Thermal stability increases	$BeCO_3 < MgCO_3 < CaCO_3 < SrCO_3 < BaCO_3$
Nitrates	All decompose to MO + NO_2 + O_2	Easier for smaller cations

- **Thermal stability of carbonates increases down both groups:** a small, highly polarising cation distorts the large carbonate ion and pulls it apart into CO_2 + O^{2-}. Group 1 carbonates (except Li_2CO_3) are stable to heat.
- **Group 1 hydroxides** are all strong bases, strength increasing down: LiOH < NaOH < KOH < RbOH < CsOH.
- **Group 1 carbonates and bicarbonates** are soluble (Li_2CO_3 only slightly); solubility increases down the group.

SOLVED EXAMPLE 06 — EXPLAINING A SOLUBILITY ORDER

Explain why $BaSO_4$ is insoluble while $MgSO_4$ is soluble in water.

SOLUTION

1. SO_4^{2-} is a large anion, so the lattice enthalpy changes little from $MgSO_4$ to $BaSO_4$.
2. The hydration enthalpy falls sharply as the cation grows ($Mg^{2+} \rightarrow Ba^{2+}$).
3. For $BaSO_4$ the hydration enthalpy can no longer overcome the lattice enthalpy.

ANSWER Hydration enthalpy drops faster than lattice enthalpy down the group.

SOLVED EXAMPLE 07 — EXPLAINING A STABILITY ORDER

Why does $BeCO_3$ decompose at a much lower temperature than $BaCO_3$?

SOLUTION

1. Be^{2+} is tiny (31 pm) with a very high charge density; Ba^{2+} is large (135 pm).
2. Be^{2+} strongly polarises the carbonate ion, weakening a C–O bond and favouring loss of CO_2.
3. The product BeO also has a very high lattice energy, which helps the decomposition.

ANSWER Small, highly polarising Be^{2+} destabilises the carbonate; thermal stability increases down the group.

SOLVED EXAMPLE 08 — HYDROXIDE SOLUBILITY

$Mg(OH)_2$ is sparingly soluble but $Ba(OH)_2$ dissolves readily. Explain.

SOLUTION

1. OH^- is small, so lattice enthalpy depends strongly on cation size.
2. From Mg^{2+} to Ba^{2+} the lattice enthalpy falls faster than the hydration enthalpy.

ANSWER Solubility of group 2 hydroxides increases down the group; $Ba(OH)_2$ is soluble and a strong base.

CHECK YOURSELF

C5 Arrange $BeCO_3$, $CaCO_3$ and $BaCO_3$ in increasing thermal stability.

C6 Which is more basic: $Mg(OH)_2$ or $Ba(OH)_2$?

Answers at the end of the chapter.

SECTION H

Sodium compounds

H

The industrial chemicals of this chapter.

Compound	Preparation	Key facts and uses
NaOH (caustic soda)	Electrolysis of brine in the Castner–Kellner cell (mercury cathode): Na amalgam + water → NaOH + H_2	Deliquescent; soap, paper, petroleum refining
$Na_2CO_3 \cdot 10H_2O$ (washing soda)	Solvay (ammonia–soda) process	Effloresces to $Na_2CO_3 \cdot H_2O$; above 373 K → anhydrous soda ash; water softening, glass
$NaHCO_3$ (baking soda)	Intermediate of the Solvay process	On heating: $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$; antacid, fire extinguishers, baking
NaCl	Evaporation of sea water; purified with HCl gas (common ion)	Impure salt is deliquescent because of $MgCl_2$ and $CaCl_2$

Solvay process

1. $2NH_3 + H_2O + CO_2 \rightarrow (NH_4)_2CO_3$
2. $(NH_4)_2CO_3 + H_2O + CO_2 \rightarrow 2NH_4HCO_3$
3. $NH_4HCO_3 + NaCl \rightarrow NH_4Cl + \mathbf{NaHCO_3}\downarrow$ (sparingly soluble, crystallises)
4. $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$ (on heating); NH_3 recovered from NH_4Cl with $Ca(OH)_2$

> KEY IDEA
>
> **K_2CO_3 cannot be made by the Solvay process.** $KHCO_3$ is too soluble to crystallise out in step 3.

SECTION I

Calcium compounds

From limestone to the plaster on your wall.

Compound	Preparation	Key facts
CaO (quicklime)	Heat limestone at 1070–1270 K: $CaCO_3 \rightarrow CaO + CO_2$	CO_2 removed to push equilibrium forward; basic oxide
$Ca(OH)_2$ (slaked lime)	$CaO + H_2O \rightarrow Ca(OH)_2$	Clear solution = lime water; suspension = milk of lime; turns milky with CO_2 ($CaCO_3$), clear again with excess CO_2 ($Ca(HCO_3)_2$)
Bleaching powder	Cl_2 on slaked lime: $2Ca(OH)_2 + 2Cl_2 \rightarrow CaCl_2 + Ca(OCl)_2 + 2H_2O$	Disinfectant and bleach (via OCl^-)

Compound	Preparation	Key facts
$CaSO_4 \cdot \frac{1}{2}H_2O$ (plaster of Paris)	Heat gypsum $CaSO_4 \cdot 2H_2O$ at 393 K	Sets with water back to gypsum; above 393 K gives anhydrous "dead burnt plaster" that does not set

- **Cement** is a mixture of calcium silicates and aluminates (CaO about 50–60%); gypsum is added to slow setting.

SOLVED EXAMPLE 09 — PLASTER OF PARIS

Why does plaster of Paris harden when mixed with water, and why must gypsum not be overheated when making it?

SOLUTION

1. Setting: $2CaSO_4 \cdot \frac{1}{2}H_2O + 3H_2O \rightarrow 2CaSO_4 \cdot 2H_2O$ — gypsum crystals interlock as a hard mass, with slight expansion.
2. Above 393 K all water of crystallisation is lost: anhydrous $CaSO_4$ (dead burnt plaster) cannot rehydrate quickly.

ANSWER Rehydration to gypsum makes it set; overheating destroys this ability.

SECTION J

More compounds you should know

Magnesium salts, calcium carbonate and cement in detail.

Compound	Formula	Use or fact
Epsom salt	$MgSO_4 \cdot 7H_2O$	Laxative; sulphates of Be and Mg are soluble
Magnesia	MgO	Refractory lining of furnaces (very high m.p.)
Milk of magnesia	$Mg(OH)_2$ suspension	Antacid
Dolomite	$CaCO_3 \cdot MgCO_3$	Source of Mg; used in construction
Calcium carbonate	$CaCO_3$	Limestone, chalk, marble; $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$, or $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$
Calcium chloride (anhydrous)	$CaCl_2$	Drying agent (not for NH_3 or alcohols, with which it forms adducts)

Cement

Component	Approximate %
CaO	50–60
SiO_2	20–25
Al_2O_3	5–10
MgO	2–3
Fe_2O_3	1–2
SO_3	1–2

- For good cement, the ratio $SiO_2 : Al_2O_3$ is between 2.5 and 4, and the ratio of CaO to the total of SiO_2, Al_2O_3 and Fe_2O_3 is close to 2.
- Raw materials: limestone and clay, heated in a rotary kiln to give **clinker**; about 2–3% gypsum is ground in to slow down setting.
- Main constituents of clinker: dicalcium silicate (Ca_2SiO_4, 26%), tricalcium silicate (Ca_3SiO_5, 51%) and tricalcium aluminate ($Ca_3Al_2O_6$, 11%).

Castner–Kellner cell in equations

Cathode (Hg): $Na^+ + e^- + Hg \rightarrow$ Na–amalgam

Anode (graphite): $Cl^- \rightarrow \frac{1}{2}Cl_2 + e^-$

Denuder: $2Na\text{–amalgam} + 2H_2O \rightarrow 2NaOH + 2Hg + H_2$

The mercury cathode makes Na discharge (not H_2) because of hydrogen's high overvoltage on Hg

- NaOH absorbs CO_2 from air: $2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$.
- Na_2CO_3 solution is alkaline by hydrolysis: $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$.
- $NaHCO_3$ is only mildly alkaline, which is why it can be used as an antacid.

SOLVED EXAMPLE 10 — LIME WATER AND CO_2

CO_2 is bubbled through lime water. Explain why it first turns milky and then clear again.

SOLUTION

1. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow + H_2O$ — insoluble $CaCO_3$ makes it milky.
2. Excess CO_2: $CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2$, which is soluble.

ANSWER Milky from $CaCO_3$; clear again as soluble calcium bicarbonate forms. (This is also how temporary hardness arises in nature.)

CHECK YOURSELF

C7 Why can anhydrous $MgCl_2$ not be made simply by heating $MgCl_2 \cdot 6H_2O$?

C8 Name the three main constituents of cement clinker.

Answers at the end of the chapter.

SECTION K

Biological role

K

Four ions you depend on every second.

- Na^+ mainly outside cells and K^+ mainly inside; the **sodium–potassium pump** (driven by ATP) keeps these gradients for nerve impulses.
- Mg^{2+} is at the centre of chlorophyll and activates many enzymes that use ATP.
- Ca^{2+} builds bones and teeth (as hydroxyapatite) and is needed for muscle contraction and blood clotting.

SECTION L

Exam trap gallery

L

Where marks are lost in the s-block.

✗ TRAP 01 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Li reacts most vigorously with water because its E° is most negative.	Li reacts most slowly; E° is thermodynamics, speed is kinetics.
WHY High hydration enthalpy of Li^+ explains E°, not the rate.	

✗ TRAP 02 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Li^+ is the most mobile ion in water because it is smallest.	Li^+ is the least mobile: it is the most hydrated.
WHY Hydrated radius: Li^+ largest.	

✗ TRAP 03 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Na burns in air to Na_2O.	Mainly Na_2O_2 (peroxide); K gives KO_2.
WHY Larger cations stabilise larger anions.	

✗ TRAP 04 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Solubility of group 2 sulphates increases down the group.	It decreases: $BaSO_4$ is insoluble.
WHY Hydration enthalpy falls faster than lattice enthalpy.	

✗ TRAP 05 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Solubility of group 2 hydroxides decreases down the group.	It increases: $Ba(OH)_2$ is soluble.

WHY Small OH^-: lattice enthalpy falls faster.

✗ TRAP 06 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
K_2CO_3 can be made by the Solvay process.	No: $KHCO_3$ is too soluble to precipitate.

WHY The process depends on $NaHCO_3$ crystallising.

✗ TRAP 07 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
$BeCl_2$ is ionic like $MgCl_2$.	$BeCl_2$ is covalent: polymeric solid, dimer in vapour.

WHY Tiny Be^{2+} is very polarising.

✗ TRAP 08 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Heating gypsum strongly makes better plaster.	Above 393 K it gives dead burnt plaster that will not set.

WHY All water of crystallisation is lost.

✗ TRAP 09 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Thermal stability of alkali metal hydrides increases down the group.	It decreases: LiH is the most stable.

WHY Lattice energy falls as the cation grows.

✗ TRAP 10 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
Heating $MgCl_2 \cdot 6H_2O$ gives anhydrous $MgCl_2$.	It hydrolyses to MgO (or Mg(OH)Cl) and HCl.

WHY Mg^{2+} is small and strongly hydrated.

✗ TRAP 11 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
All group 1 nitrates give the nitrite on heating.	$LiNO_3$ gives $Li_2O + NO_2 + O_2$, like $Mg(NO_3)_2$.

WHY Diagonal relationship of Li with Mg.

✗ TRAP 12 · WHAT STUDENTS WRITE	✓ WHAT IS ACTUALLY CORRECT
CaF_2 is soluble like $CaCl_2$.	CaF_2 is almost insoluble.

WHY Very high lattice energy with the small F^- ion.

MEMORY HOOK

"Li-Na-K: oxide, peroxide, superoxide."

"Big anion — down goes solubility; small anion — up it goes."

"Small cation cracks carbonate" — less stable to heat.

"Blue dilute, bronze concentrated" — metals in liquid NH_3.

SECTION M

M

Practice MCQs

Levels: Easy, Moderate, Tough.

Q01 The alkali metal giving a crimson red flame is: [EASY]

(a) Na (b) K
(c) Li (d) Cs

Q02 Potassium burns in excess oxygen to give: [EASY]

(a) K_2O (b) K_2O_2
(c) KO_2 (d) KOH

Q03 Which group 2 element gives no flame colour? [EASY]

(a) Ca (b) Sr
(c) Ba (d) Mg

Q04 The chemical formula of plaster of Paris is: [EASY]

(a) $CaSO_4 \cdot 2H_2O$ (b) $CaSO_4 \cdot \frac{1}{2}H_2O$
(c) $CaSO_4$ (d) $CaCO_3$

Q05 Washing soda is: [EASY]

(a) $NaHCO_3$ (b) $Na_2CO_3 \cdot 10H_2O$
(c) NaOH (d) $Na_2SO_4 \cdot 10H_2O$

Q06 The least mobile ion in aqueous solution is: [MODERATE]

(a) Li^+ (b) Na^+
(c) K^+ (d) Cs^+

Q07 Which carbonate decomposes most easily on heating? [MODERATE]

(a) Na_2CO_3 (b) K_2CO_3
(c) Li_2CO_3 (d) Cs_2CO_3

Q08 Least soluble in water: [MODERATE]

(a) $MgSO_4$ (b) $CaSO_4$
(c) $SrSO_4$ (d) $BaSO_4$

Q09 Most basic hydroxide: [MODERATE]

(a) $Be(OH)_2$
(b) $Mg(OH)_2$
(c) $Ca(OH)_2$
(d) $Ba(OH)_2$

Q10 Blue colour of alkali metals in liquid ammonia is due to: [MODERATE]

(a) metal ions
(b) ammoniated electrons
(c) NH_2^- ions
(d) metal atoms

Q11 Diagonal relationship is shown by: [MODERATE]

(a) Li and Mg
(b) Na and Mg
(c) Be and Mg
(d) Li and Be

Q12 The Solvay process cannot make K_2CO_3 because: [MODERATE]

(a) K is too reactive
(b) $KHCO_3$ is too soluble
(c) KCl is insoluble
(d) NH_3 reacts with K

Q13 $Be(OH)_2$ dissolves in excess NaOH because it is: [TOUGH]

(a) basic
(b) acidic only
(c) amphoteric
(d) neutral

Q14 A concentrated solution of Na in liquid NH_3 is: [TOUGH]

(a) blue, paramagnetic
(b) bronze, diamagnetic
(c) colourless, diamagnetic
(d) blue, diamagnetic

Q15 Li has the most negative E° among alkali metals mainly because of: [TOUGH]

(a) lowest ionisation enthalpy
(b) highest hydration enthalpy of Li^+
(c) lowest sublimation enthalpy
(d) largest atomic size

Q16 The alkali metal with the highest melting point is: [EASY]

(a) Li
(b) Na
(c) K
(d) Cs

Q17 Epsom salt is: [EASY]

(a) $MgSO_4 \cdot 7H_2O$
(b) $CaSO_4 \cdot 2H_2O$
(c) $Na_2SO_4 \cdot 10H_2O$
(d) $BaSO_4$

Q18 Most stable alkali metal hydride: [EASY]

(a) LiH
(b) NaH
(c) KH
(d) CsH

Q19 $NaNO_3$ on heating gives: [MODERATE]

(a) $Na_2O + NO_2 + O_2$
(b) $NaNO_2 + O_2$
(c) $Na + NO_2$
(d) $Na_2O_2 + N_2$

Q20 Mg_3N_2 with water gives: [MODERATE]

(a) $Mg(OH)_2 + N_2$ (b) $Mg(OH)_2 + NH_3$
(c) $MgO + NO_2$ (d) $Mg + HNO_3$

Q21 BeH_2 is: [MODERATE]

(a) ionic (b) covalent and polymeric
(c) a gas at room temperature (d) unknown

Q22 Gypsum is added to cement to: [MODERATE]

(a) speed up setting (b) slow down setting
(c) increase strength only (d) change its colour

Q23 In the Castner–Kellner cell, the cathode is: [MODERATE]

(a) graphite (b) iron
(c) mercury (d) platinum

Q24 The least soluble fluoride is: [TOUGH]

(a) LiF (b) NaF
(c) CaF_2 (d) KF

Q25 Hydration enthalpy of Mg^{2+} is much larger than that of Na^+ because: [TOUGH]

(a) Mg^{2+} is larger (b) Mg^{2+} has higher charge and smaller size
(c) Na^+ is more electronegative (d) Mg is in group 2 only

Answer key with explanations

Q01 (c) **Li** — Li → crimson.

Q02 (c) **KO_2** — Superoxide.

Q03 (d) **Mg** — Electrons held too tightly.

Q04 (b) **$CaSO_4 \cdot \frac{1}{2}H_2O$** — Hemihydrate.

Q05 (b) **$Na_2CO_3 \cdot 10H_2O$** — Decahydrate of sodium carbonate.

Q06 (a) **Li^+** — Largest hydrated radius.

Q07 (c) **Li_2CO_3** — Small polarising Li^+.

Q08 (d) **$BaSO_4$** — Solubility falls down the group.

Q09 (d) **$Ba(OH)_2$** — Basic strength increases down.

Q10 (b) **ammoniated electrons** — Solvated electrons absorb red light.

Q11 (a) **Li and Mg** — Similar charge/size ratio.

Q12 (b) **$KHCO_3$ is too soluble** — No precipitate forms.

Q13 (c) **amphoteric** — Forms $[Be(OH)_4]^{2-}$.

Q14 (b) **bronze, diamagnetic** — Electrons pair up.

Q15 (b) **highest hydration enthalpy of Li^+** — Hydration energy outweighs the higher ionisation enthalpy.

Q16 (a) **Li** — Strongest metallic bonding.

Q17 **(a) $MgSO_4 \cdot 7H_2O$** — Magnesium sulphate heptahydrate.

Q18 **(a) LiH** — Highest lattice energy.

Q19 **(b) $NaNO_2 + O_2$** — Group 1 nitrate (not Li).

Q20 **(b) $Mg(OH)_2 + NH_3$** — Nitride hydrolysis.

Q21 **(b) covalent and polymeric** — Bridging Be–H–Be bonds.

Q22 **(b) slow down setting** — Retards setting.

Q23 **(c) mercury** — Forms sodium amalgam.

Q24 **(c) CaF_2** — Very high lattice energy.

Q25 **(b) Mg^{2+} has higher charge and smaller size** — Charge density.

Check-yourself answers

C1 Lithium (Li_2O).

C2 The ammoniated electrons pair up at high concentration, so there are no unpaired electrons.

C3 LiH > NaH > KH.

C4 $NaNO_3 \rightarrow NaNO_2 + O_2$; $LiNO_3 \rightarrow Li_2O + NO_2 + O_2$.

C5 $BeCO_3 < CaCO_3 < BaCO_3$.

C6 $Ba(OH)_2$.

C7 The hydrated salt hydrolyses on heating, giving MgO (or Mg(OH)Cl) and HCl; it must be heated in a stream of HCl gas.

C8 Dicalcium silicate, tricalcium silicate and tricalcium aluminate.

QUICK REVISION

One-page revision

Read this page the night before the exam.

Trends

- ns^1 / ns^2; size ↑, IE ↓ down
- Hydration: Li^+ largest → least mobile
- Mobility $Li^+ < Na^+ < K^+ < Rb^+ < Cs^+$
- m.p. falls down group 1

Flames and oxygen

- Li crimson, Na yellow, K lilac, Cs blue
- Ca brick red, Sr crimson, Ba apple green
- Be, Mg: no colour
- Li_2O, Na_2O_2, KO_2

Water and ammonia

- Li most negative E° but slowest with water
- $2M + 2H_2O \rightarrow 2MOH + H_2$
- Liquid NH_3: blue, paramagnetic (dilute)
- Concentrated: bronze, diamagnetic

Li and Be

- Li–Mg: nitride, carbonate and nitrate decompose
- Be–Al: amphoteric, covalent chlorides
- $BeCl_2$ polymer (solid), dimer (vapour)
- Be max covalency 4

Solubility and stability

- Sulphates: solubility ↓ down group 2
- Hydroxides: solubility, basicity ↑
- Carbonates: stability ↑ down
- Li_2CO_3 decomposes; Na_2CO_3 stable

Compounds

- NaOH: Castner–Kellner
- Solvay: $NaHCO_3$ precipitates; not K_2CO_3
- Gypsum → PoP at 393 K; above: dead burnt
- $4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$

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