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FSc / ICS Part-II Chemistry — Punjab Board

CHAPTER 2

s-Block Elements

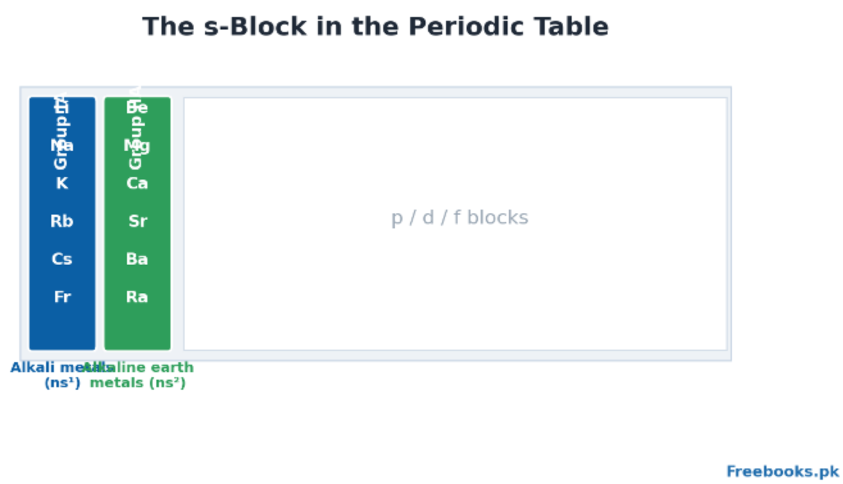

Figure 2.1 — Group IA (alkali metals) and Group IIA (alkaline earth metals) make up the s-block.

1. Chapter Overview

The s-block contains the elements of Group IA (the alkali metals: Li, Na, K, Rb, Cs, Fr) and Group IIA (the alkaline earth metals: Be, Mg, Ca, Sr, Ba, Ra). They are called s-block elements because their last electron enters an s-orbital. These are the most reactive metals in the whole periodic table — they are shiny, soft, light, and give beautiful colours in a flame. Because they are so reactive, they are never found free in nature; they always occur as compounds such as common salt ($NaCl$), limestone ($CaCO_3$) and gypsum.

In this chapter we study why these metals behave the way they do, how their properties change down each group, the special (anomalous) behaviour of lithium and beryllium, and the industrially important compounds made from them — including caustic soda, washing soda (Solvay process), plaster of Paris and bleaching powder.

2. Learning Objectives

- Identify the members of Group IA and Group IIA and write their general electronic configuration.
- Explain the general physical and chemical properties of s-block elements and their trends down the group.
- Explain why s-block metals are strong reducing agents and very reactive.
- Describe the reactions of these metals with water, oxygen and hydrogen.
- Explain the flame colours of s-block metals and their cause.
- Describe the anomalous behaviour of lithium and beryllium and the diagonal relationship.
- Explain the manufacture of sodium carbonate by the Solvay process.
- State the preparation, properties and uses of important compounds such as $NaOH$, Na_2CO_3, plaster of Paris and bleaching powder.
- Appreciate the biological importance of Na, K, Mg and Ca.

3. Key Concepts

3.1 The Two Families of the s-Block

Group	Name	Members
IA (ns^1)	Alkali metals	Li, Na, K, Rb, Cs, Fr
IIA (ns^2)	Alkaline earth metals	Be, Mg, Ca, Sr, Ba, Ra

Why the names? Group IA metals are called “alkali” metals because they react with water to form strong alkalis (hydroxides). The word alkali comes from the Arabic al-qali, meaning “the ashes” — early alkalis were obtained from plant ash. Group IIA metals are called “alkaline earth” metals because their oxides are alkaline and are found in the earth's crust.

□ Memory Trick

> **"Lithium Never Kisses Rabia's Friend"** → Li, Na, K, Rb, Cs, Fr (Group IA order).
> **"Beta Maango Call Serious Baat Rakho"** → Be, Mg, Ca, Sr, Ba, Ra (Group IIA order).

3.2 General Properties and Their Trends

Because the s-block metals have only one or two loosely held valence electrons, they share a set of common properties. Understanding the reason behind each one is much easier than memorising a list:

Large atomic size. They have the largest atoms in their period, and the size increases down the group as new shells are added.

Low ionization energy. The single/double outer electrons are far from the nucleus and well shielded, so little energy is needed to remove them. This is why these metals are so reactive and electropositive. IE decreases further down the group.

Strong electropositive / metallic character. They readily lose electrons to form +1 (IA) or +2 (IIA) ions, so they are the most metallic elements.

Soft and light. Metallic bonding is weak because only one or two electrons are available, so the metals are soft (sodium and potassium can be cut with a knife) and have low densities (lithium, sodium and potassium even float on water).

Low melting and boiling points. Again due to weak metallic bonding; these fall down the group for Group IA.

Fixed oxidation state. Group IA always show +1 and Group IIA always show +2 in their compounds.

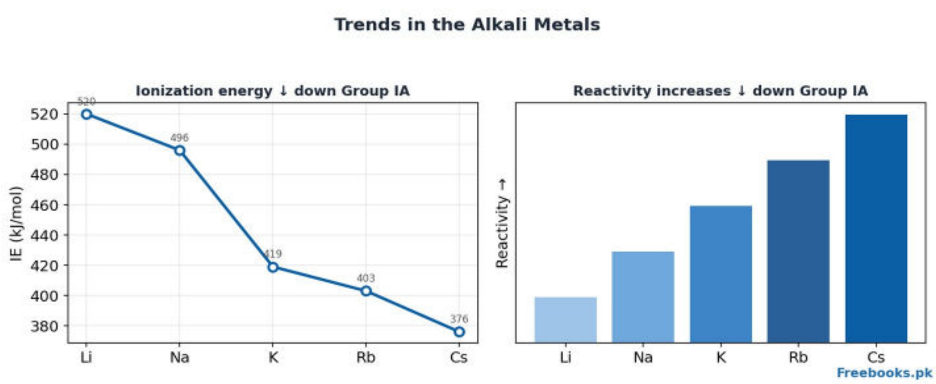

Figure 2.2 — Down Group IA, ionization energy decreases and reactivity increases.

> **Teacher's Note**
> Ask students to connect every property back to ONE idea: "one or two loosely-held outer electrons." Softness, low m.p., low IE, high reactivity and reducing power all flow from this single fact — this stops rote learning.

3.3 Reducing Nature

A reducing agent is a substance that loses electrons (and gets oxidised) while reducing something else. Since s-block metals lose their outer electrons very easily, they are powerful reducing agents. The reducing power increases down the group because ionization energy decreases. Lithium is a special case — although it is at the top, its very high hydration energy makes it the strongest reducing agent in aqueous solution.

3.4 Important Reactions

With water: Alkali metals react vigorously, giving a hydroxide and hydrogen gas: $2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$. The reaction becomes more violent down the group (K, Rb, Cs can catch fire).

With oxygen: They burn in air to form oxides. Lithium forms a normal oxide (Li_2O), sodium forms a peroxide (Na_2O_2), and potassium, rubidium and caesium form superoxides (e.g. KO_2). The basic character of the oxides increases down the group.

With hydrogen: They form ionic hydrides, e.g. $2Na + H_2 \rightarrow 2NaH$, which contain the H^- ion.

Nature of hydroxides: All Group IA hydroxides are strong bases. In Group IIA the basic strength increases down the group; $Be(OH)_2$ is amphoteric (like $Al(OH)_3$), while the others are basic.

Nitrates on heating: Most alkali metal nitrates decompose to the nitrite and oxygen (e.g. $2NaNO_3 \rightarrow 2NaNO_2 + O_2$), while $LiNO_3$ (and Group IIA nitrates) give the oxide, NO_2 and O_2.

3.5 Flame Colours

When an s-block metal or its salt is heated in a flame, the heat energy excites its valence electrons to higher energy levels. When these electrons fall back to their original levels, they release the extra energy as visible light of a definite colour. Each metal gives its own characteristic colour, which is used to identify it (flame test).

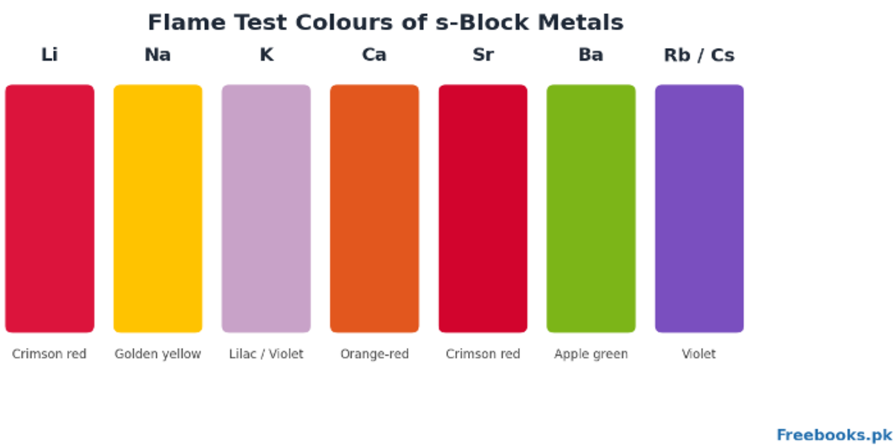

Figure 2.3 — Characteristic flame-test colours of s-block metals.

□ Memory Trick

Colours to remember: Li = crimson red, Na = golden yellow, K = lilac/violet, Ca = orange-red, Sr = crimson red, Ba = apple green, Rb & Cs = violet.

Tip: "Na is yellow like the Sun (Na = Sodium = Sooraj)."

Teacher's Note

Beryllium and magnesium do NOT give a flame colour because their electrons are too tightly held (small size, high IE) to be excited by an ordinary Bunsen flame — a favourite exam point.

3.6 Anomalous Behaviour and the Diagonal Relationship

The first member of each group (lithium in IA and beryllium in IIA) behaves differently from the rest of its family because of its very small size, high charge density and high polarising power. As a result, lithium resembles magnesium (the element diagonally below and to the right of it), and beryllium resembles aluminium. This similarity between an element and the one placed diagonally to it is called the diagonal relationship.

Diagonal pair	Some common points
Li and Mg	Both form normal oxides; nitrates give the oxide on heating; both form covalent, soluble compounds; both react slowly with water.
Be and Al	Both are amphoteric; both form covalent halides; both are passivated by concentrated HNO_3; oxides are amphoteric.

□ Memory Trick

Diagonal pairs: "Lithium ka dost Magnesium, Beryllium ka dost Aluminium."

3.7 Comparison of Group IA and Group IIA

Property	Group IA	Group IIA
Outer configuration	ns^1	ns^2
Oxidation state	+1	+2
Reactivity	Very high	High (less than IA)
Ionization energy	Lower	Higher
Hardness	Very soft	Comparatively harder
Basic nature of oxide	Strongly basic	Basic (Be amphoteric)

3.8 Important Compounds

(a) Caustic Soda — NaOH

Sodium hydroxide is called caustic soda because it is highly corrosive ('caustic' means 'which corrodes'). It is a white, deliquescent solid, a strong base, and dissolves in water with a lot of heat. It is manufactured by the electrolysis of brine (Nelson's / Castner–Kellner cell). It is used in making soap, paper, artificial silk, and in refining petroleum.

(b) Sodium Carbonate (Washing Soda) — Solvay Process

Sodium carbonate, Na_2CO_3, is manufactured on a large scale by the Solvay (ammonia-soda) process. Ammoniacal brine is treated with carbon dioxide in a carbonating tower to precipitate sodium bicarbonate, which is then heated to give sodium carbonate. The great advantage of this process is that ammonia and carbon dioxide are recovered and reused, making it cheap and almost waste-free.

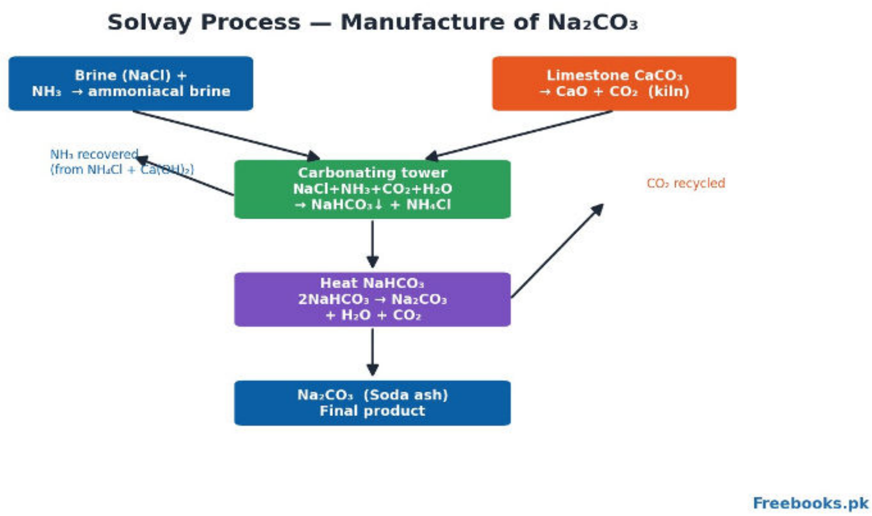

Figure 2.4 — The Solvay process for manufacturing sodium carbonate.

Key Solvay Reactions

1. $CaCO_3 \rightarrow CaO + CO_2$ (heating limestone)

2. $NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3\downarrow + NH_4Cl$

3. $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$ (heating)

4. $2NH_4Cl + Ca(OH)_2 \rightarrow 2NH_3 + CaCl_2 + 2H_2O$ (ammonia recovery)

(c) Plaster of Paris and Gypsum

Gypsum is calcium sulphate dihydrate, $CaSO_4\cdot 2H_2O$. When gypsum is heated to about 120 °C it loses part of its water and forms plaster of Paris, $CaSO_4\cdot \frac{1}{2}H_2O$. When plaster of Paris is mixed with water it sets into a hard mass, so it is used for making casts for broken bones, statues and blackboard chalk. Gypsum itself is added (2–5%) to cement to control (slow down) its setting time.

(d) Bleaching Powder

Bleaching powder, $Ca(OCl)Cl$, is made by passing chlorine over slaked lime. It is used for bleaching cloth and paper and for disinfecting drinking water.

3.9 Biological Importance

The s-block metals are essential for life. Sodium and potassium ions control the water balance and nerve signals in our bodies (the sodium–potassium pump). Calcium is the main mineral in bones and teeth and helps blood to clot, while magnesium is the central metal ion in chlorophyll, the green pigment that lets plants carry out photosynthesis.

4. Important Definitions

Term	Definition
s-block elements	Elements in which the last electron enters an s-orbital (Groups IA and IIA).
Alkali metals	Group IA metals whose hydroxides are strong alkalis.
Alkaline earth metals	Group IIA metals whose oxides are alkaline and found in the earth.
Reducing agent	A substance that loses electrons and reduces another species.
Flame test	Identification of a metal by the characteristic colour it gives to a flame.
Diagonal relationship	The similarity in properties between an element and the one placed diagonally below it (Li–Mg, Be–Al).
Deliquescent	A substance that absorbs moisture from air and dissolves in it (e.g. NaOH).
Plaster of Paris	Calcium sulphate hemihydrate, $CaSO_4 \cdot \frac{1}{2}H_2O$, which sets hard with water.

5. Formulas / Rules

Must-Know Formulae and Facts

Caustic soda = $NaOH$ | Washing soda = $Na_2CO_3 \cdot 10H_2O$ | Baking soda = $NaHCO_3$

Gypsum = $CaSO_4 \cdot 2H_2O$ | Plaster of Paris = $CaSO_4 \cdot \frac{1}{2}H_2O$ | Lime = CaO

Bleaching powder = $Ca(OCl)Cl$ | Slaked lime = $Ca(OH)_2$

Down a group: size ↑, ionization energy ↓, reactivity ↑, reducing power ↑, basic nature of oxide ↑.

Oxidation state: Group IA = +1 always; Group IIA = +2 always.

6. Diagrams / Illustrations

The must-know diagrams for this chapter, gathered for quick revision:

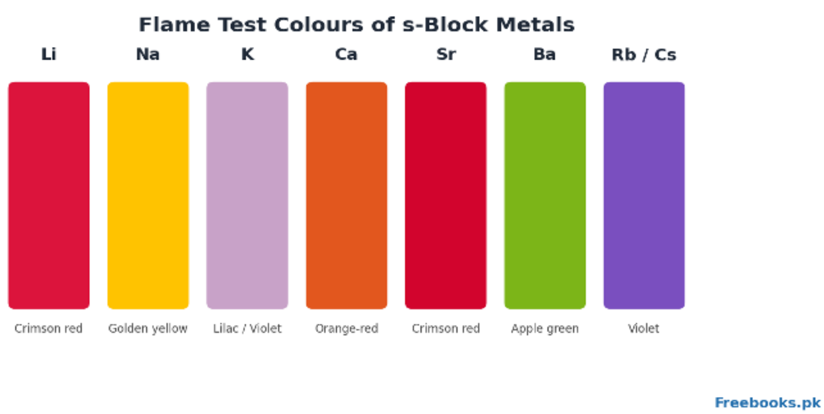

Diagram 1 — Flame test colours.

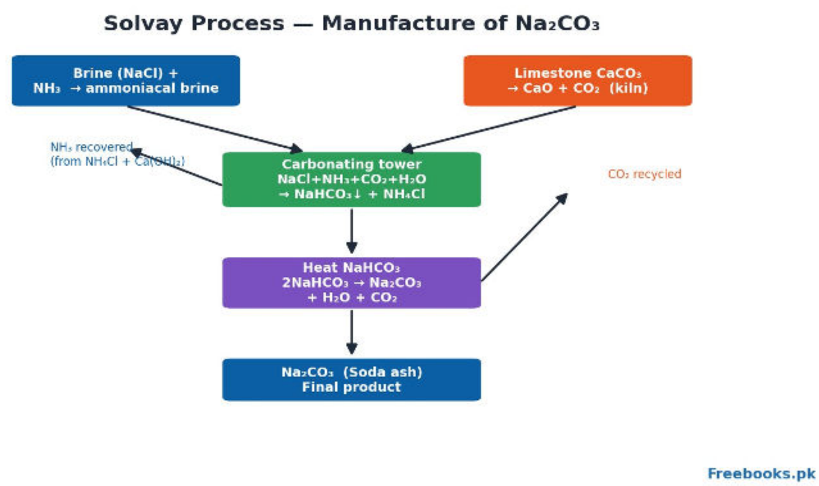

Diagram 2 — Solvay process flow chart.

7. Solved Examples

Example 1 — Reactivity order
Q: Which is more reactive, sodium or potassium? Why?

Solution: Potassium is more reactive. Going down Group IA the atom becomes larger and its ionization energy decreases, so potassium loses its outer electron more easily than sodium.

Example 2 — Identifying a metal
Q: An unknown salt gives an apple-green colour in a flame test. Which metal is present?

Solution: Apple-green flame colour is characteristic of barium (Ba). So the salt contains barium.

Example 3 — Products of a reaction
Q: Write the products when sodium reacts with water.

Solution: Sodium gives sodium hydroxide and hydrogen gas: $2Na + 2H_2O \rightarrow 2NaOH + H_2\uparrow$. The solution turns basic (pink with phenolphthalein).

8. Short Questions

Q1. Why are Group IA metals called alkali metals?
Ans. Because they react with water to form strong alkalis (hydroxides); the name comes from Arabic al-qali, 'the ashes'.

Q2. Why are s-block metals soft?
Ans. Their metallic bonding is weak because only one or two valence electrons are available.

Q3. Why does reactivity increase down Group IA?
Ans. Atomic size increases and ionization energy decreases, so the outer electron is lost more easily.

Q4. Why do Be and Mg not give a flame colour?
Ans. Their electrons are held too tightly (small size, high IE) to be excited by an ordinary flame.

Q5. What is the diagonal relationship?
Ans. The similarity in properties between an element and the one placed diagonally to it, e.g. Li–Mg and Be–Al.

Q6. Why is $Be(OH)_2$ different from other Group IIA hydroxides?
Ans. It is amphoteric (reacts with both acids and bases), like $Al(OH)_3$, whereas the others are basic.

Q7. What is caustic soda and why is it called so?
Ans. Sodium hydroxide (NaOH); 'caustic' means corrosive, as it corrodes skin and many materials.

Q8. Why is gypsum added to cement?
Ans. To slow down (control) the setting time of the cement (about 2–5% is added).

9. Long Questions

Q1. Describe the general characteristics of the s-block elements.

The s-block elements are the metals of Groups IA and IIA, whose last electron enters an s-orbital. They have one (ns^1) or two (ns^2) loosely held valence electrons, and almost all their properties follow from this fact. They have large atomic sizes and low ionization energies, so they are strongly electropositive and lose electrons easily to form +1 or +2 ions. Their metallic bonding is weak, which makes them soft, light and low-melting. Because they lose electrons so readily, they are powerful reducing agents and among the most reactive metals known, reacting with water to give hydrogen and a hydroxide, and burning in oxygen to form basic oxides. They give characteristic colours in a flame, and their reactivity increases down each group as size increases and ionization energy falls. Owing to their high reactivity they are never found free in nature.

Q2. Explain the manufacture of sodium carbonate by the Solvay process.

In the Solvay (ammonia-soda) process, sodium carbonate is manufactured from cheap raw materials: brine (NaCl), limestone ($CaCO_3$) and ammonia. Limestone is heated in a kiln to give quicklime and carbon dioxide ($CaCO_3 \rightarrow CaO + CO_2$). The carbon dioxide is passed up a carbonating tower through ammoniacal brine, precipitating sparingly soluble sodium bicarbonate: $NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$. The bicarbonate is filtered off and heated to give sodium carbonate, water and carbon dioxide: $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$. The quicklime is slaked to $Ca(OH)_2$ and used to recover ammonia from ammonium chloride: $2NH_4Cl + Ca(OH)_2 \rightarrow 2NH_3 + CaCl_2 + 2H_2O$. Because both the ammonia and the carbon dioxide are recycled, the process is economical and produces little waste (only $CaCl_2$ as a by-product).

Q3. Discuss the anomalous behaviour of lithium and its diagonal relationship with magnesium.

Lithium, the first member of Group IA, differs from the other alkali metals because of its very small size and high charge density (high polarising power). Unlike the others, lithium forms a normal oxide (Li_2O) rather than a peroxide or superoxide, its nitrate decomposes to the oxide instead of the nitrite, and many of its compounds are covalent and less stable to heat. These features make lithium resemble magnesium, the element placed diagonally to it. Both lithium and magnesium form normal oxides, both have nitrates that give the oxide on heating, both form covalent, hygroscopic compounds, and both react only slowly with water. This close similarity between an element and the one diagonally placed to it is known as the diagonal relationship, and it arises because the two elements have similar charge-to-size ratios.

10. Multiple Choice Questions (MCQs)

1. The general electronic configuration of alkali metals is:
(A) ns^2 (B) ns^1 (C) $ns^2\ np^1$ (D) $ns^2\ np^2$

2. Which metal gives a golden-yellow flame colour?
(A) Potassium (B) Calcium (C) Sodium (D) Barium

3. Washing soda is:
(A) $NaHCO_3$ (B) $Na_2CO_3{\cdot}10H_2O$ (C) NaOH (D) Na_2O_2

4. Plaster of Paris is:
(A) $CaSO_4{\cdot}2H_2O$ (B) $CaSO_4{\cdot}\frac{1}{2}H_2O$ (C) $CaCO_3$ (D) $Ca(OH)_2$

5. Which hydroxide is amphoteric?
(A) NaOH (B) KOH (C) $Be(OH)_2$ (D) $Ca(OH)_2$

6. The Solvay process is used to manufacture:
(A) NaOH (B) Na_2CO_3 (C) CaO (D) NaCl

7. Lithium shows a diagonal relationship with:
(A) Sodium (B) Calcium (C) Magnesium (D) Aluminium

8. Which of the following is the strongest reducing agent in aqueous solution?
(A) Na (B) K (C) Cs (D) Li

9. Caustic soda is:
(A) Na_2CO_3 (B) $NaHCO_3$ (C) NaOH (D) NaCl

10. Bleaching powder is prepared by passing chlorine over:
(A) Quicklime (B) Slaked lime (C) Gypsum (D) Limestone

MCQ Answer Key

1-B 2-C 3-B 4-B 5-C 6-B 7-C 8-D 9-C 10-B

11. Quick Revision / Summary

- s-block = Group IA (alkali, ns^1, +1) and Group IIA (alkaline earth, ns^2, +2).
- Large size, low IE → very reactive, strongly electropositive, powerful reducing agents.
- Soft, light, low melting; reactivity increases down the group.
- Flame colours: Li crimson, Na yellow, K lilac, Ca orange-red, Ba apple-green.
- Anomalous first members: Li (like Mg) and Be (like Al) — diagonal relationship.
- Solvay process makes Na_2CO_3; NH_3 and CO_2 are recycled.
- Caustic soda = NaOH; gypsum = $CaSO_4{\cdot}2H_2O$; plaster of Paris = $CaSO_4{\cdot}\frac{1}{2}H_2O$.
- Na, K control nerve signals; Ca in bones; Mg in chlorophyll.

12. Exam Tips

Score-Boosting Tips

Learn the flame colours cold — they appear almost every year as an MCQ or short question.

For any 'trend down the group' answer, give BOTH the change and the reason (size ↑, IE ↓).

Memorise the four Solvay reactions in order; a labelled flow diagram earns full marks.

Do not confuse washing soda (Na_2CO_3), baking soda ($NaHCO_3$) and caustic soda (NaOH).

Remember the exceptions: Li forms a normal oxide, $Be(OH)_2$ is amphoteric, Be & Mg give no flame colour.

Common formulae confusion: gypsum has $2H_2O$, plaster of Paris has $\frac{1}{2}H_2O$ — never mix them up.