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## S4 New Curriculum chemistry

### Theme: Periodicity

### Chapter 3 – Trends in Periodic Table

#### The periodic Table

Metals		H Hydrogen						8 He Helium	
1	2			3	4	5	6	7	
Li Lithium	Be Beryllium			B Boron	C Carbon	N Nitrogen	O Oxygen	F Fluorine	Ne Neon
Na Sodium	Mg Magnesium			Al Aluminium	Si Silicon	P Phosphorus	S Sulphur	Cl Chlorine	Ar Argon
K Potassium	Ca Calcium							I Iodine	

The periodic table is a tabular arrangement of elements such that the columns contain elements with electronically similar atoms. The rows of the periodic table are called **periods** while the vertical columns are called **groups**. There are 7 periods and 8 groups.

Elements are listed in order of increasing atomic number (i.e. the number of protons in the nucleus). Rows are arranged so that elements with similar properties fall into the same columns (group)

#### Trends in Periodic Table

- (a) **Nuclear charge (Z)** refers to the total positive charge of an atom's nucleus, which is determined by the number of protons present. The nuclear charge increases across A period of the periodic table.
- (b) **Number of electron on the outer most shells:** The number of electrons that reside on the outermost shell of an atom is equal the group number and hence increases across the period from group 1 to group 8.

(c) **Effective Nuclear Charge (  $Z_{\text{eff}}$  )** refers to the net positive charge experienced by an atom's outermost electrons due to the nucleus's attraction, considering the shielding effect of inner electrons.

#### Factors Affecting effective nuclear charge

1. **Nuclear Charge (Z)** – The total number of protons in the nucleus increases attraction.
2. **Electron Shielding** – Inner electrons repel outer electrons, reducing nuclear attraction.
3. **Atomic Size** – Smaller atoms experience stronger nuclear pull on valence electrons.

#### Trend of effective nuclear charge in the Periodic Table:

- **Across a Period:** Effective nuclear charge increases because more protons are added while shielding remains nearly constant.
- **Down a Group:** effective nuclear charge decreases slightly due to increased shielding from additional electron shells.

(d) **Atomic radius** is the distance from the center of the nucleus to the furthest electron under the influence of a nuclear charge of an atom.

#### Trend of atomic radii in the periodic Table

##### (i) **Atomic Radius decreases across a Period (Left to Right)**

**Reason:** Increasing nuclear charge pulls electrons closer to the nucleus, reducing the atomic size. Example: Sodium (Na) has a larger atomic radius than chlorine (Cl) in Period 3.

##### (ii) **Atomic Radius increases down a Group (Top to Bottom)**

**Reason:** Additional electron shells (energy levels) increase the atomic size, even though nuclear charge also rises. Example: Lithium (Li) is smaller than cesium (Cs) in Group 1

(e) **Metallic character** refers to how easily an element can lose electrons and exhibit typical metallic properties such as conductivity, malleability, and luster. It is influenced by an element's ability to form **positive ions (cations)** and its interaction with electrons.

#### Trend in the Periodic Table:

- (i) **Metallic character increases down a group ↓** – As atomic size increases, outer electrons are held less tightly, making electron loss easier.
- (ii) **Decreases across a period →** – As nuclear charge increases, electrons are more strongly attracted, reducing metallic behavior.

### Properties of High Metallic Character:

- **Good electrical and thermal conductivity**
- **High malleability and ductility**
- **Low ionization energy** (easy loss of electrons).
- **Shiny appearance (lustrous)**

### Examples:

- **High metallic character:** Cesium (Cs), Francium (Fr), Iron (Fe).
- **Low metallic character:** Nonmetals like Oxygen (O) and Sulfur (S).

### Melting points

The melting point of a substance or element is the measure of energy required to break down the regular arrangement of atoms, ions or molecules in the substance (solid state). Therefore, the melting point indicates the strength of the forces knitting atoms, ions or molecules together in the crystal. The strength of those forces in elements varies according to the type of crystals formed and due to this; the melting points of elements in a period do not change uniformly,

#### (a) Across a Period (Left to Right)

- **Metals (Groups 1- 3)** generally have **high melting and boiling points** due to strong **metallic bonding**.
- **Group 4 elements** (like carbon and silicon) have the **highest melting and boiling points** due to strong **covalent networks**.
- **Group 8 (Noble Gases)** have **low melting and boiling points** because they exist as individual atoms with weak Van der Waals forces.

#### (b) Down a Group (Top to Bottom) ↓

- **Metals (e.g., Alkali & Alkaline Earth Metals)** experience a **decrease** in melting and boiling points because metallic bonds weaken as atomic size increases.
- **Nonmetals (e.g., Halogens)** experience an **increase** in melting and boiling points due to stronger intermolecular forces in larger molecules.

### Chemistry of period 3 elements

Each element in a period provides representative Chemistry of the group into which it exists.

The elements of period 3 are Na, Mg, Al, Si, P, S, Cl and Ar.

## Electronic structure

The table below shows electron configuration of period 3 elements

Elements	Na	Mg	Al	Si	P	S	Cl	Ar
Electron configuration	2.8.1	2.8.2	2.8.3	2.8.4	2.8.5	2.8.6	2.8.7	2.8.8

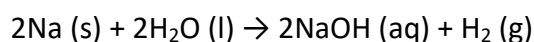
## Physical properties of period 3 element

Sodium, magnesium and aluminium are metals whose melting points increase in that order due to increase in the number of electrons contributed to form metallic bonds. Silicon, phosphorus, sulphur, chlorine and argon are non-metals. Silicon, phosphorus and sulphur are solids while chlorine and argon are gases at room temperature.

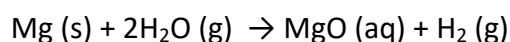
## Reaction period 3 elements with water

Reactivity with water decreases across the period because there is a decrease in metallic character of these elements across the period.

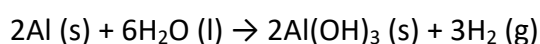
- i) Sodium reacts vigorously with cold water to form sodium hydroxide and hydrogen gas.



- ii) Magnesium does not react with cold water but reacts with steam to form magnesium oxide and hydrogen gas.



- iii) Aluminium reacts with steam very slowly to form aluminium hydroxide and hydrogen gas.



- iv) Silicon, phosphorus, sulphur and argon have no reaction with water.

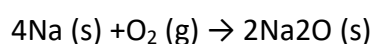
- v) Chlorine reacts with water to form chloric (I) acid and hydrochloric acid.



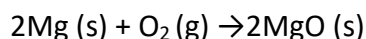
## Reaction period 3 elements with oxygen

Period 3 elements (sodium to argon) react differently with oxygen, forming oxides with varying properties.

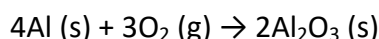
- (i) **Sodium (Na)** reacts violently with a yellow flame to form sodium oxide



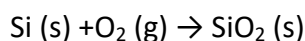
(ii) **Magnesium (Mg)** Burns in oxygen with a **bright white flame** to form white powder of magnesium oxide.



(iii) **Aluminum (Al)** forms aluminum oxide, which has a protective layer preventing further reaction:

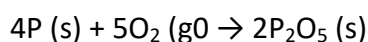


(iv) **Silicon (Si)** reacts at high temperatures to form silicon dioxide:

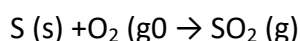


**Silicon dioxide is a major component of sand.**

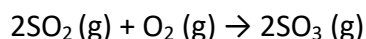
(v) **Phosphorus (P)** burns with a **bright white flame** to forms phosphorus pentoxide when burned in excess oxygen:



(vi) **Sulfur (S)** burn in oxygen with a blue flame to form sulphur dioxide



In excess oxygen, sulfur trioxide may also form:



(vii) **Chlorine (Cl<sub>2</sub>)** does not react directly with oxygen under normal conditions.

(viii) **Argon (Ar)** is **inert** and does not react with oxygen.

**The table below shows the properties of oxides of period elements**

<b>ELEMENTS</b>	Na	Mg	Al	Si	P	S	Cl
<b>OXIDES</b>	Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	SO <sub>3</sub>	Cl <sub>2</sub> O <sub>7</sub>
<b>PRINCIPAL BONDING</b>	Ionic	Ionic	Ionic-covalent	Covalent	Covalent	Covalent	Covalent
<b>CHARACTER</b>	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic	Acidic
<b>MP\°C</b>	1193	3075	2300	1728	563	30	-91

### Physical properties of oxides of period 3 elements

i) Across the period there is a gradual change in character of oxides from strongly basic to strongly acidic.  $\text{Al}_2\text{O}_3$  is amphoteric oxide, i.e., possesses both basic and acidic properties.

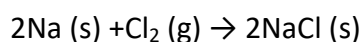
ii)  $\text{Na}_2\text{O}$ ,  $\text{MgO}$  and  $\text{Al}_2\text{O}_3$  have high melting points due to the strength of ionic bonding.  $\text{SiO}_2$ , although covalent, has a high melting point because the crystal of  $\text{SiO}_2$  is a giant structure in which silicon and oxygen atoms are bonded together by strong single covalent bonds.

$\text{P}_2\text{O}_5$  (white solid) consists of  $\text{P}_4\text{O}_{10}$  molecules; these contain electric dipoles due to electron displacements in their bonds and are quite strongly attracted to each other. This is why its melting point is high compared with that of  $\text{SO}_3$  which consists of simple  $\text{SO}_3$  molecules.

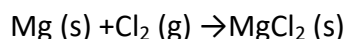
$\text{Cl}_2\text{O}_7$  has a low melting point because the molecules are held together by the weak van der Waals forces.

### Reaction of Period 3 elements with chlorine

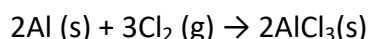
(i) **Sodium (Na)** reacts **vigorously** with chlorine, forming white solid of **sodium chloride**:



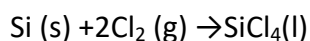
(ii) **Magnesium (Mg)** burns in chlorine to form white crystals of **magnesium chloride**:



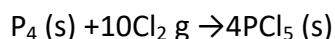
(iii) **Aluminum (Al)** reacts with chlorine gas at high temperatures to form **aluminum chloride**:



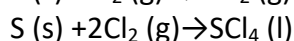
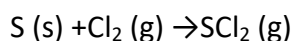
(iv) **Silicon (Si)** forms a liquid **silicon tetrachloride**:



(v) **Phosphorus (P)** reacts with excess chlorine to form a yellow crystalline solid of **phosphorus pentachloride**:



(vi) **Sulfur (S)** reacts with chlorine to form **sulfur dichloride or redish-brown liquid of sulfur tetrachloride**:



(vii) Chlorine (Cl<sub>2</sub>) No reaction since it is already chlorine.

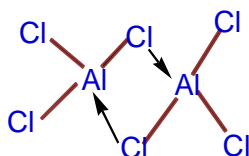
(viii) Argon (Ar) Does not react (inert noble gas).

The table below provides properties of chlorides of period 3 elements

ELEMENTS	Na	Mg	Al	Si	P	S	Cl
CHLORIDES	NaCl	MgCl <sub>2</sub>	AlCl <sub>3</sub>	SiCl <sub>4</sub>	PCl <sub>5</sub>	S <sub>2</sub> Cl <sub>2</sub>	Cl <sub>2</sub>
BONDING	Ionic	Ionic	Covalent	Covalent	Covalent	Covalent	Covalent
STATES	Solid	Solid	Solid	Liquid	Solid	Liquid	Gas
MP\°C	808	714	192	-68	160	-76	

### Physical properties of period 3 chlorides.

NaCl and MgCl<sub>2</sub> have high melting points due to the strength of the ionic bonding. AlCl<sub>3</sub> has a fairly high melting point because in the solid state, it consists of Al<sub>2</sub>Cl<sub>6</sub> molecules and not simple AlCl<sub>3</sub>. These molecules are produced through dative bonding between Al and Cl in the Al<sub>2</sub>Cl<sub>6</sub> molecules.



SiCl<sub>4</sub> and S<sub>2</sub>Cl<sub>2</sub> are liquids and consist of respective simple SiCl<sub>4</sub> and S<sub>2</sub>Cl<sub>2</sub> molecules and in the solid state the molecules are held by weak van der Waals force which explains their very low melting points. PCl<sub>5</sub> a pale yellow solid has a fairly high melting point because the solid undergoes partial ionisation.



### Group 1: The alkali metals

The elements of group 1, lithium, sodium, potassium, rubidium, caesium and francium are called the **alkali metals**. The alkali metals are soft and silvery coloured: They are good conductors of heat and electricity. Because they rapidly tarnish in air, they are generally stored under oil.

Some physical properties of group 1A elements are given in the table 8.1 below:

**Table 8.1 Some physical properties of alkaline metals**

Element	Atomic number	Electronic configuration	M.P. /°C	B.P. /°C	Atomic radius (nm)
Li	3	2.1	180	1326	0.133
Na	11	2.8.1	98	883	0.157
K	19	2.8.8.1	64	756	0.203
Rb	37	2.8.18.8.1	39	688	0.216
Cs	55	2.8.18.18.8.1	29	690	0.235

### Trend of physical properties of group 1 elements

**Hardness of group 1 elements** decreases down the group due to decrease in strength of metallic bonds as atomic size increases

**Density of group 1 elements** generally increases down the group (except for potassium) due to increase atomic masses

**Melting points of group 1 elements** decrease down the group as atomic size increases. Larger atoms have **weaker metallic bonds**, making them easier to melt.

### Chemical properties of group 1 elements

The alkali metals are extremely reactive and electropositive metals. In chemical combinations, this single electron is very readily transferred, giving a metal ion of single positive charge with a stable electronic configuration of a noble gas. Compounds of the alkali metals are therefore ionic and exist as high melting point solids.  $\text{Li}^+$  due to its smallest size, polarises anions most strongly and thus its compounds are highly covalent which is why they are soluble in organic solvents.

All the alkali metal compounds give characteristic flame colourations that can be used to identify them e.g. lithium (red), sodium (yellow), potassium (lilac), rubidium (red) and caesium (blue).

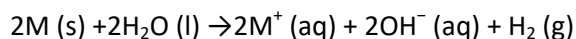
### Reaction of group 1 elements with oxygen

Element	Reaction with Oxygen	Equation
Lithium (Li)	Burns <b>red</b> to form <b>lithium oxide</b>	$4\text{Li (s)} + \text{O}_2(\text{g}) \rightarrow 2\text{Li}_2\text{O (s)}$
Sodium (Na)	Burns <b>yellow</b> to form <b>sodium peroxide</b>	$2\text{Na (s)} + \text{O}_2 (\text{g}) \rightarrow \text{Na}_2\text{O}_2$
Potassium (K)	Burns <b>purple</b> to form <b>potassium superoxide</b>	$\text{K (s)} + \text{O}_2 (\text{g}) \rightarrow \text{KO}_2 (\text{s})$
Rubidium (Rb)	Reacts <b>violently</b> to form <b>rubidium superoxide</b>	$\text{Rb (s)} + \text{O}_2 (\text{g}) \rightarrow \text{RbO}_2 (\text{s})$
Cesium (Cs)	Reacts <b>explosively</b> to form <b>cesium superoxide</b>	$\text{Cs (s)} + \text{O}_2 (\text{g}) \rightarrow \text{CsO}_2 (\text{s})$

### Reaction of group 1 elements with water

Generally group 1 elements react with water to form hydroxides and hydrogen

#### General Reaction



(where **M** represents the alkali metal)

#### Specific Reactions

Element	Reaction with Water	Observations
Lithium (Li)	Reacts <b>gently</b> , producing lithium hydroxide (LiOH) and hydrogen (H <sub>2</sub> )	Bubbles form; slow reaction
Sodium (Na)	Reacts <b>quickly</b> , forming sodium hydroxide (NaOH) and hydrogen gas	<b>Fizzes, moves on water surface, melts</b>
Potassium (K)	Reacts <b>violently</b> , forming potassium hydroxide (KOH) and hydrogen gas	<b>Ignites with a purple flame</b>
Rubidium (Rb)	Reacts <b>explosively</b> , forming rubidium hydroxide (RbOH) and hydrogen gas	<b>Very rapid, sparks may appear</b>
Cesium (Cs)	Reacts <b>extremely explosively</b> , forming cesium hydroxide (CsOH) and hydrogen gas	<b>Instant explosion, shatters container</b>

### Revision questions

1. Explain why metallic character increases down any group of the Periodic Table.
2. Explain why element in the same group of the Periodic Table show similar chemical properties
3. Which side of the periodic table has non-metals?
4. Explain why the boiling points of halogens increase down the group
5. Describe the trend in reactivity of groups 1 and 7 on moving down the groups.

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