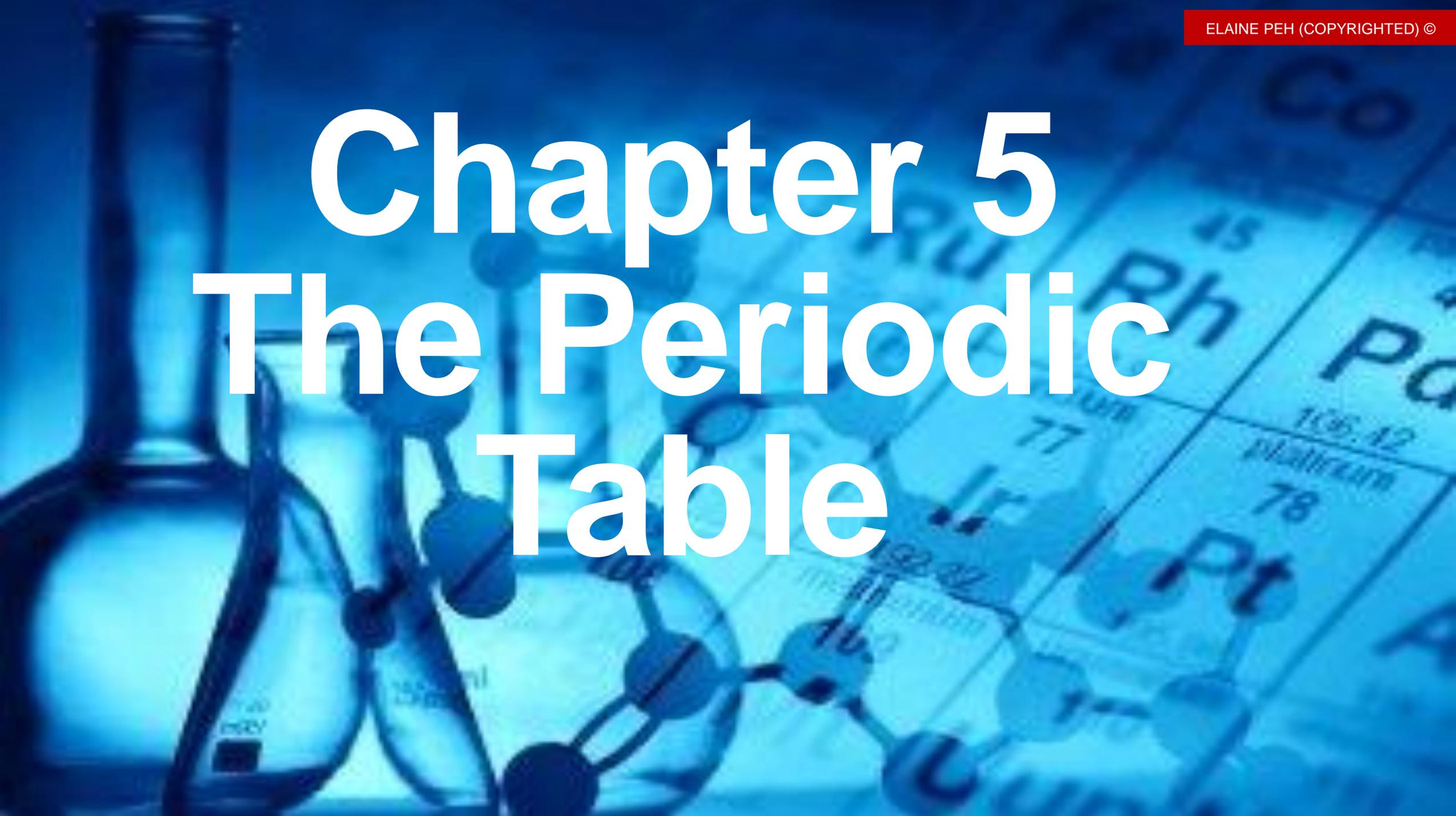


Chapter 5 The Periodic Table



CHAPTER ANALYSIS



FOCUS

- Content Heavy Chapter
- 4 **key** concepts



EXAM

- A lot of memorising work



WEIGHTAGE

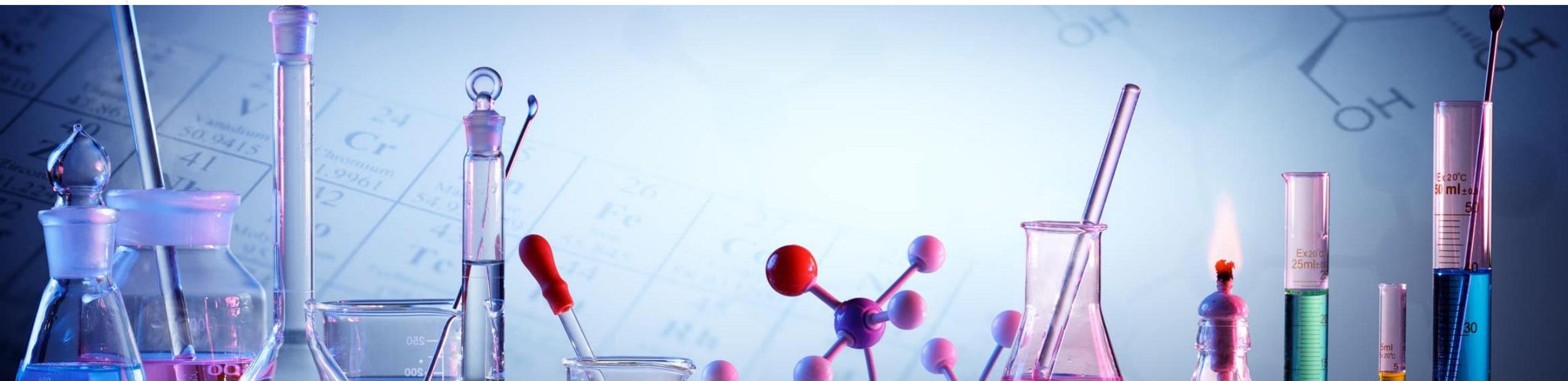
- Appears yearly in at least 1 question for theory paper



KEY CONCEPT

General Trends & Variations of Properties of Elements Across the Period and Down the Group in The Periodic Table

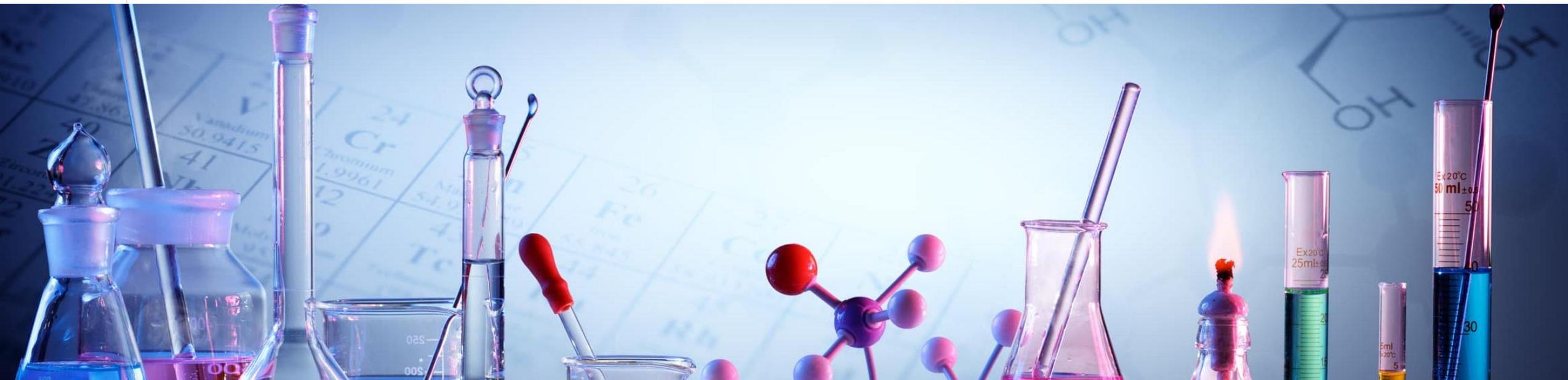
Trends & Variations of Properties of Period 3 Elements, Oxides & Chlorides



KEY CONCEPT

Trends & Variations of Properties of Group 2 Elements & Their Compounds

Trends & Variations of Properties of Group 17 Elements & Their Compounds



General Trends & Variations of Properties of Elements Across the Period and Down the Group in The Periodic Table

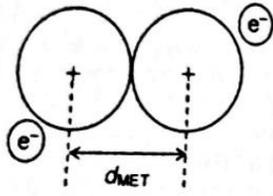
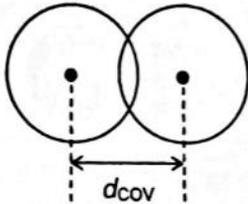
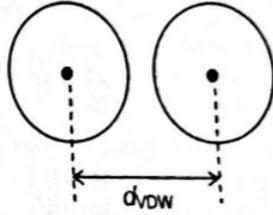
PERIOD NUMBER

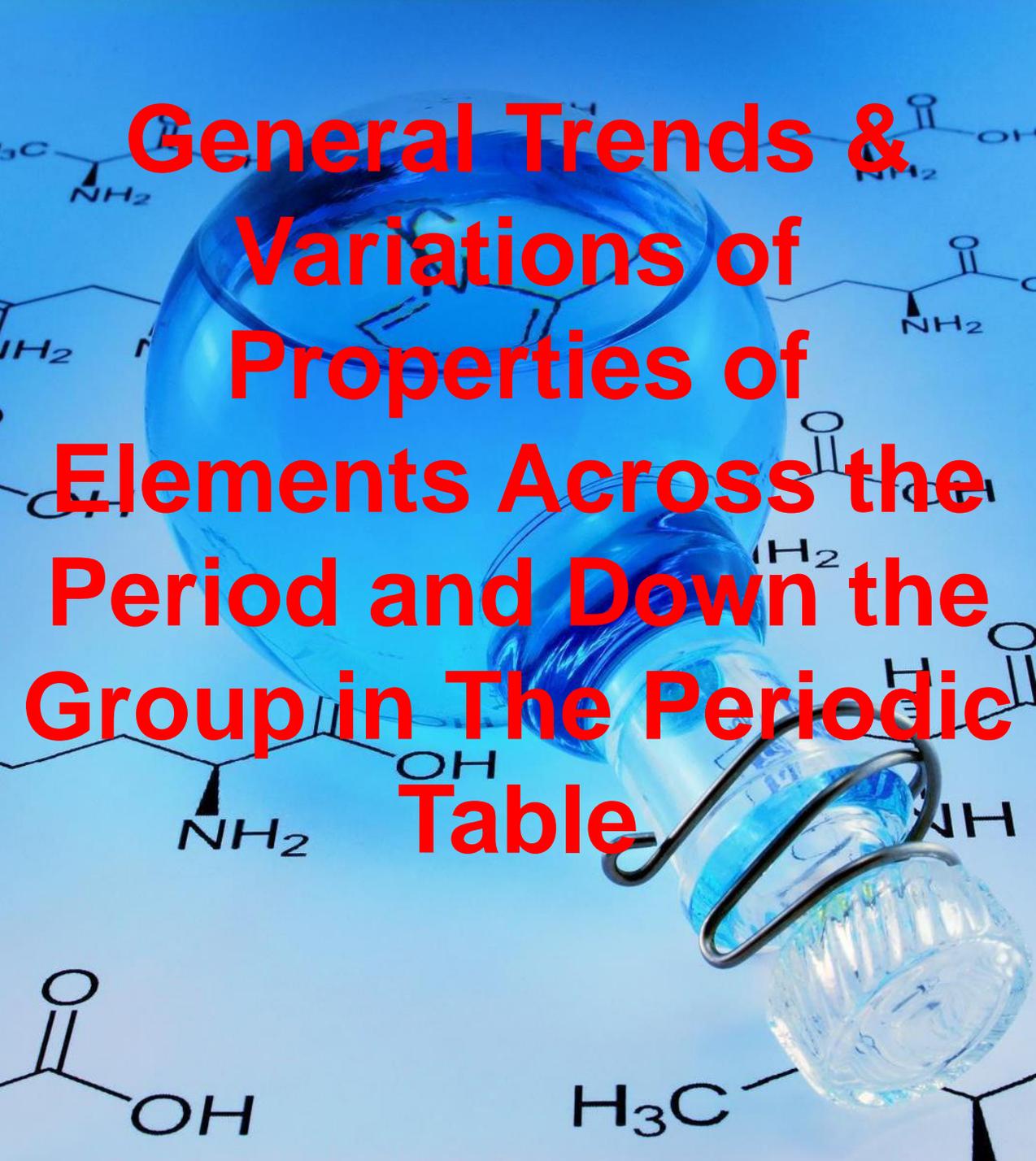
Period numbers are assigned to the **horizontal rows**.

GROUP NUMBER

Group numbers are assigned to the **vertical columns**.

ATOMIC RADIUS

Metallic Compounds	Simple Covalent Compounds	Noble Gases (Group 18)
Half the inter-nuclear distance between two neighbouring atoms in the metal	Half the inter-nuclear distance between two covalently bonded atoms	Half the inter-nuclear distance between two atoms which are not chemically bonded
 <p>metallic radius = $\frac{1}{2} \times d_{\text{MET}}$</p>	 <p>covalent radius = $\frac{1}{2} \times d_{\text{COV}}$</p>	 <p>VDW radius = $\frac{1}{2} \times d_{\text{VDW}}$</p>



General Trends & Variations of Properties of Elements Across the Period and Down the Group in The Periodic Table

ANSWERING QUESTION ON ATOMIC RADIUS:

Step 1: Compared the number of protons = nuclear charge

Step 2: Compared the number of inner electron shells = shielding effect

Step 3: If both increase/decrease, determine which of the increase/decrease is more significant

Step 4: Determine the impact on effective nuclear charge and the attraction between the valence electrons to the nucleus

Step 5: Linking the change in effective nuclear charge to the radius

Recap in Chapter 1: Atomic Structure

Note: The explanation of the trend of atomic radius is usually used in the explanation of the other physical properties

IONIC RADIUC

Cationic Radius is Smaller than the Atomic Radius

- **nuclear charge is the same** as the number of protons is the same
- **cations have lesser electron shells** than the atom
- **shielding effect of cations are thus weaker** than the atoms
- **effective nuclear charge is greater** for cations
- **valence electrons are more strongly attracted** to the nucleus
- **cationic radius thus decreased** as compared to atomic radius



General Trends
Across the Period and
Down the Group in
The Periodic Table
Atomic Radius, Ionic
Radius, First
Ionisation Energy,
Electronegativity

Physical Property	General Trend Across Period	General Trend Down the Group
Atomic Radius	Decrease	Increase
Ionic Radius	Decrease	Increase
First Ionisation Energy	Increase	Decrease
Electronegativity	Increase	Decrease

Recap in Chapter 1: Atomic Structure there are exception cases against the general trend

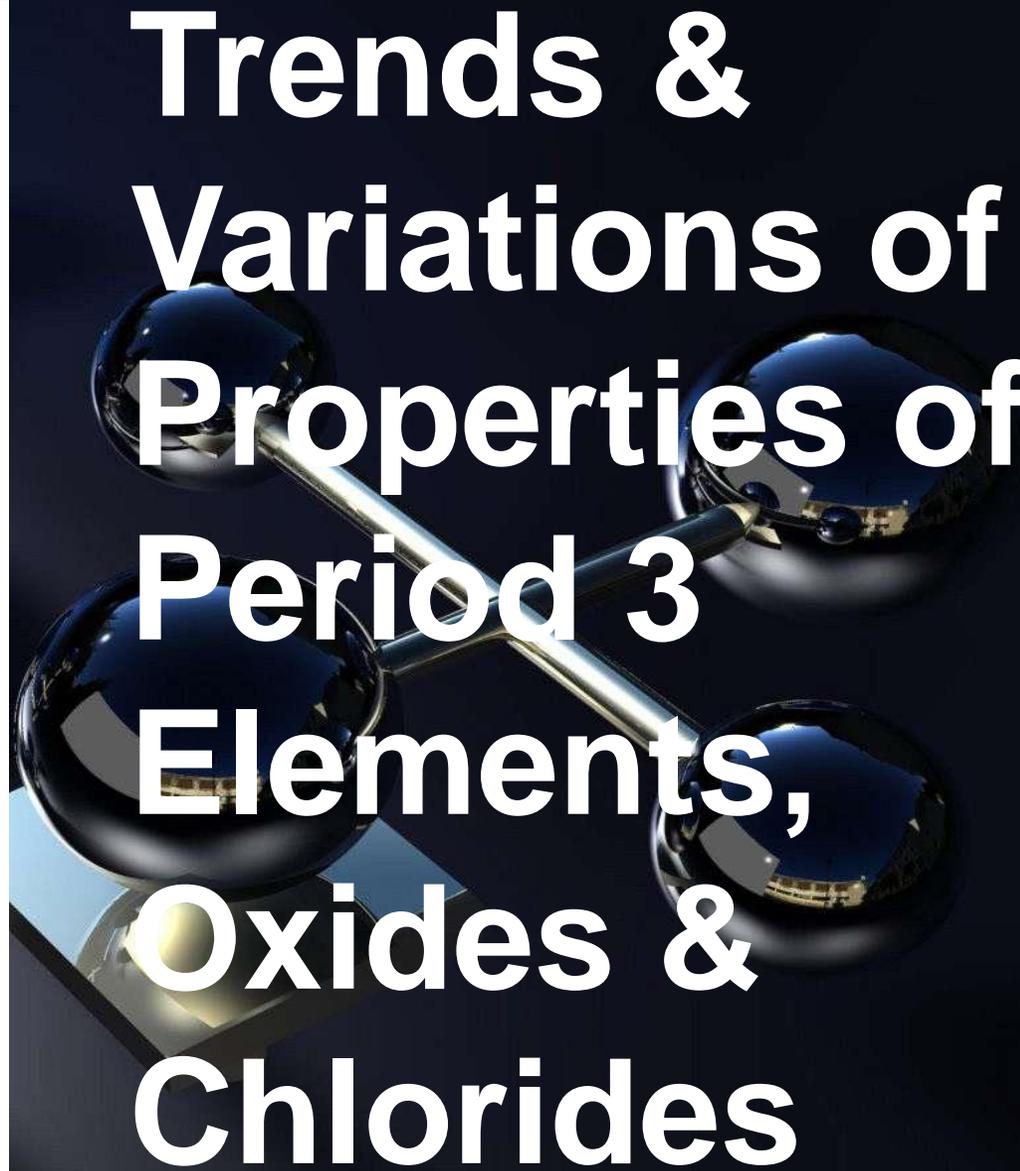
STRUCTURE & BONDING

	Na	Mg	Al	Si	P ₄	S ₈	Cl ₂
Structure	Giant metallic			Giant covalent	Simple covalent		

- P, S and Cl have vacant 3d-orbitals for bonding, allowing it to expand its octet structure
- Going across the Period, the oxides/chlorides formed become **less ionic and more covalent**
- Across the period electronegativity of the elements increase
- This decrease the difference in electronegative between the elements
- Period 3 elements become less likely to lose electron to the O²⁻/Cl⁻ ions to form ionic bonds
- Sharing of electrons to form covalent bonds is now preferred
- *Recap in Chapter 2: Chemical Bonding*

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₃
Structure	Ionic	Ionic	Ionic with covalent characteristic	Giant covalent	Simple covalent	Simple covalent

	NaCl	MgCl ₂	AlCl ₃	SiCl ₄	PCl ₅
Structure	Ionic	Ionic	Simple covalent	Simple covalent	Simple covalent

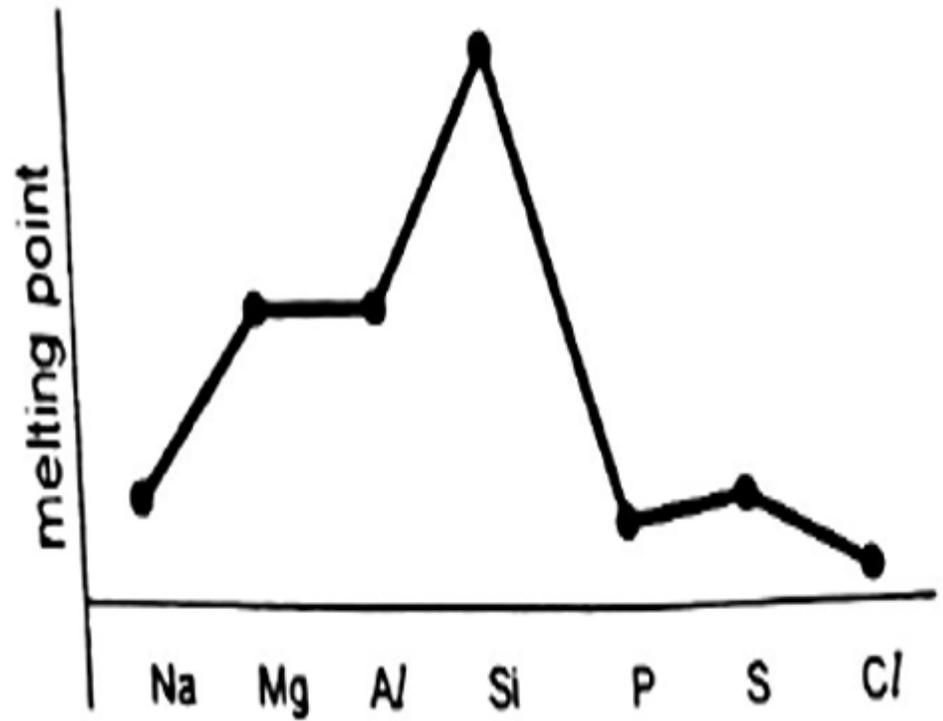


Trends & Variations of Properties of Period 3 Elements, Oxides & Chlorides

	Na (s)	Mg (s)	Al (s)	Si (s)	P ₄ (s)	S ₈ (s)	Cl ₂ (g)
Structure	Giant metallic			Giant covalent	Simple covalent		
Bonds Broken	Metallic Bond			Covalent Bond	Instantaneous Dipole – Induce Dipole (id-id) interactions		
Melting Point	High			Very High	Low		
Trend Across Period	Increase across the Period due to: <ul style="list-style-type: none"> • Increase in number of delocalised valence electrons • Increase in charge density 			Melting point reaches the peak within this period for Si.	Melting point drops sharply from Si to P. Slight increase from S ₈ to P ₄ and subsequently decrease from S ₈ to Cl ₂ due to: <ul style="list-style-type: none"> • S₈ has more electrons hence more id-id than P₄ • S₈ has more electrons hence more id-id interactions than Cl₂ • P₄ has more electrons hence more id-id than Cl₂ 		

Trends & Variations of Melting & Boiling Point of Period 3 Elements

Melting Points of Period 3 Elements

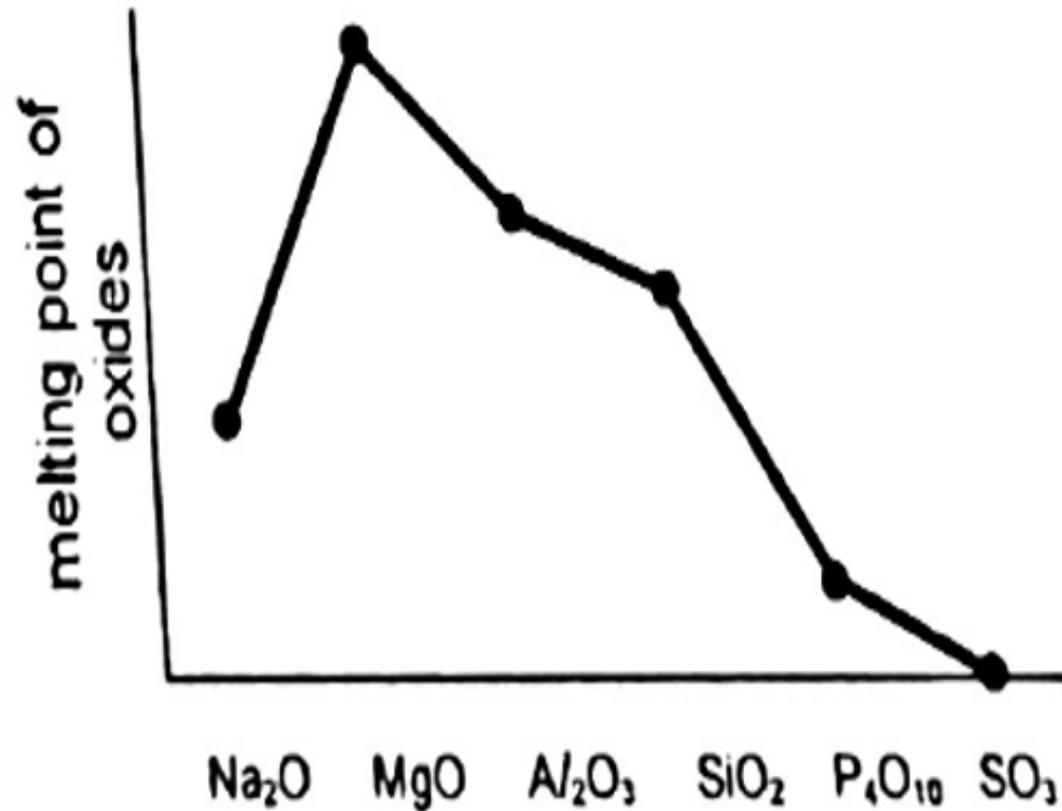


Trends & Variations of Melting & Boiling Point of Period 3 Elements

	Na ₂ O (s)	MgO (s)	Al ₂ O ₃ (s)	SiO ₂ (s)	P ₄ O ₁₀ (s)	SO ₃ (l)
Structure	Giant ionic			Giant covalent	Simple covalent	
Bonds Broken	Ionic Bonds			Covalent Bond	Instantaneous Dipole – Induce Dipole (id-id) interactions	
Melting Point	High			Very High	Low	
Variation Across Period	<p>Melting point of MgO > Al₂O₃ > Na₂O</p> <p>- Melting point of MgO and Al₂O₃ is higher than Na₂O due to the lower charge density of the Na⁺ as compared to Al³⁺ and Mg²⁺ ions. Weaker electrostatic forces of attraction is formed between Na⁺ and O²⁻ ions and lesser amount of energy is required to overcome the attractions.</p> <p>- Al₂O₃ has lower melting point than MgO due to its higher covalent characteristics.</p>			<p>SiO₂ is a giant covalent molecule and large amount of energy is required to overcome the strong electrostatic forces of attraction.</p>	<p>Both P₄O₁₀ and SO₃ are simple covalent molecules with weak id-id interactions.</p> <p>- P₄O₁₀ have higher melting point due to a larger electron cloud size than SO₃.</p> <p>- Hence more energy is required to break the stronger id-id interaction between P₄O₁₀ molecules as compared to SO₃ molecules.</p>	

Trends & Variations of Melting & Boiling Point of Period 3 Oxides

Melting Points of Period 3 Elements Oxides

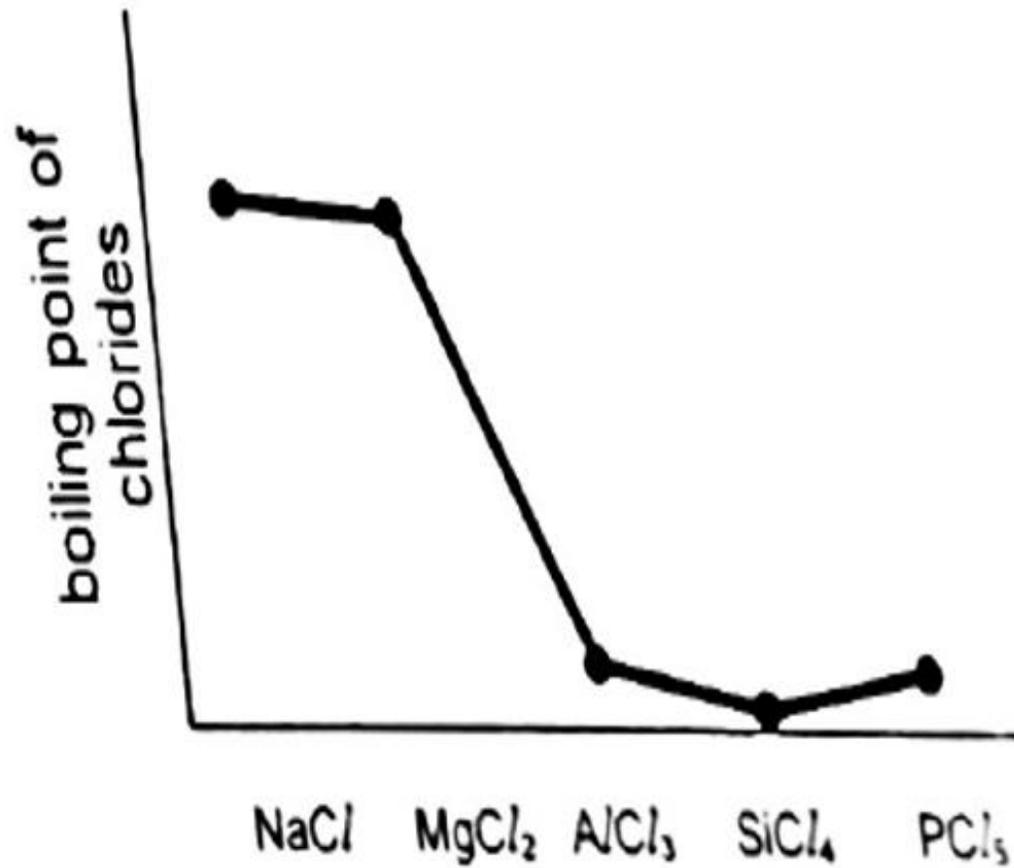


Trends & Variations of Melting & Boiling Point of Period 3 Oxides

	NaCl (s)	MgCl ₂ (s)	AlCl ₃ (s)	SiCl ₄ (l)	PCl ₅ (s)
Structure	Giant Ionic		Simple covalent		
Bonds Broken	Ionic Bonds		Instantaneous Dipole – Induce Dipole (id-id) interactions		
Melting Point	High		Low		
Variation Across Period	Decrease across the Period due to: <ul style="list-style-type: none"> MgCl₂ having more covalent characteristic than NaCl (even though Mg²⁺ has higher charge density than Na⁺ ion). Recap of the anomaly in boiling/melting point in Chapter 2: Chemical Bonding		Increase across the Period due to: <ul style="list-style-type: none"> Increase in size of electron cloud and hence more id-id interactions are formed More energy is required to break the stronger id-id interaction across the period hence melting/boiling point increase. 		

Trends & Variations of Melting & Boiling Point of Period 3 Chlorides

Boiling Points of Period 3 Elements Chlorides



Trends & Variations of Melting & Boiling Point of Period 3 Chlorides



Trends & Variations of Acid-Base Properties of Period 3 Hydroxides

The general trend is that **ionic compounds** are **basic** in nature whereas **covalent compounds** are **acidic** in nature. Those in **group 13** are **amphoteric**.

	NaOH (s)	Mg(OH) ₂ (s)	Al(OH) ₃ (s)
Acid-Base Property	Basic	Basic	Amphoteric
Reaction with HCl			
Solubility	Soluble	Soluble	Soluble
Observation	Dissolve to give colourless solution	Dissolve to give colourless solution	Dissolve to give colourless solution
Products formed	NaOH (s) + HCl (aq) → NaCl (aq) + H ₂ O (l)	Mg(OH) ₂ (s) + 2HCl (aq) → MgCl ₂ (aq) + 2H ₂ O (l)	Al(OH) ₃ (s) + 3HCl (aq) → AlCl ₃ (aq) + 3H ₂ O (l)
Reaction with NaOH			
Solubility	Insoluble	Insoluble	Soluble
Observation	Does not dissolve	Does not dissolve	Dissolve to give colourless solution
Products formed			Al(OH) ₃ (s) + NaOH (aq) → NaAl(OH) ₄ (aq)



Trends & Variations of Acid-Base Properties of Period 3 Oxides

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₃
Acid-Base Property	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic
Reaction with HCl						
Solubility	Soluble	Soluble	Soluble	Insoluble	Insoluble	Insoluble
Observation	Dissolve to give colourless solution	Dissolve to give colourless solution	Dissolve to give colourless solution	Does not dissolve	Does not dissolve	Does not dissolve
Products formed	Na ₂ O (s) + HCl (aq) → 2NaCl (aq) + H ₂ O (l)	MgO (s) + 2HCl (aq) → MgCl ₂ (aq) + H ₂ O (l)	Al ₂ O ₃ (s) + 6HCl (aq) → 2AlCl ₃ (aq) + 3H ₂ O (l)			



Trends & Variations of Acid-Base Properties of Period 3 Oxides

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₃
Acid-Base Property	Basic	Basic	Amphoteric	Acidic	Acidic	Acidic
Reaction with NaOH						
Solubility	Insoluble	Insoluble	Soluble	Soluble only in concentrated NaOH	Soluble	Soluble
Observation	Does not dissolve	Does not dissolve	Dissolve to give colourless solution	Dissolve to give colourless solution	Dissolve to give colourless solution	Dissolve to give colourless solution
Products formed			Al ₂ O ₃ (s) + 2NaOH (aq) + 3H ₂ O (l) → 2NaAl(OH) ₄ (aq)	SiO ₂ (s) + 2NaOH (aq) → Na ₂ SiO ₃ (aq) + H ₂ O (l)	P ₄ O ₁₀ (s) + 12NaOH (aq) → 4Na ₃ PO ₄ (aq) + 6H ₂ O (l)	SO ₃ (l) + 2NaOH (aq) → Na ₂ SO ₄ (aq) + 2H ₂ O (l)

The ease of solubility is dependent on the **type of solute-solute interaction, solvent-solvent interaction & solute-solvent interaction.**

Recap in Chapter 2: Chemical Bonding

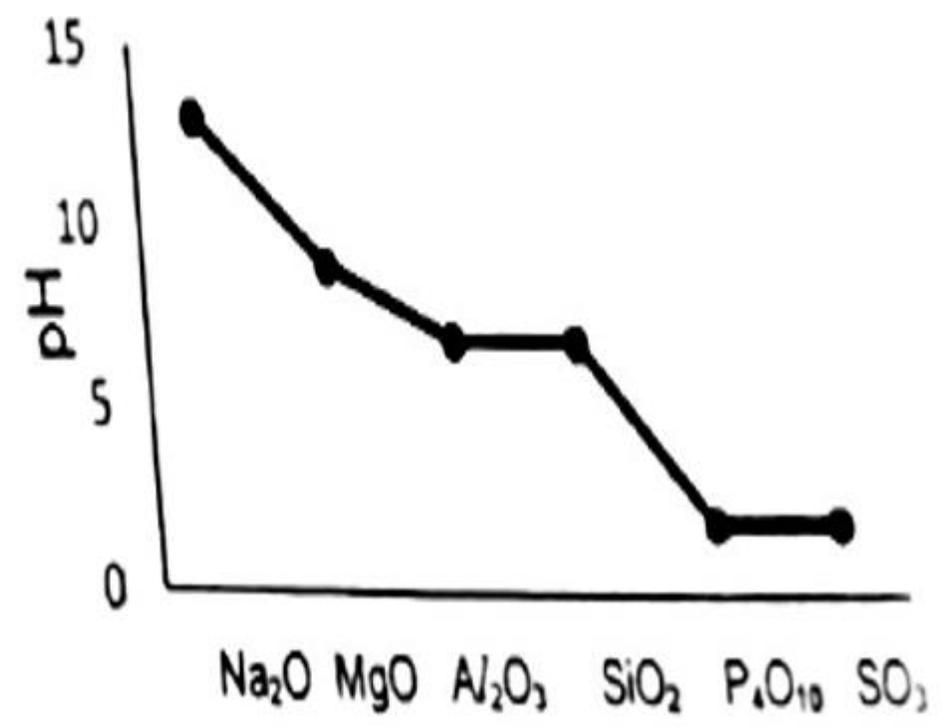
	Na	Mg	Al
Reaction in Water	Soluble	Insoluble	Insoluble
Products formed	NaOH		

Trends & Variations of Solubility in Water of Period 3 Elements

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₃
Reaction in Water	Soluble	Sparingly soluble	Insoluble	Insoluble	Soluble	Soluble
Observation	Reacts vigorously and dissolved to give a colourless solution	Does not dissolve	Does not dissolve	Does not dissolve	Reacts vigorously and dissolved to give a colourless solution	Reacts vigorously and dissolved to give a colourless solution
Products formed	Na ₂ O (s) + H ₂ O (l) → 2NaOH (aq)	MgO (s) + H ₂ O (l) ⇌ Mg(OH) ₂ (aq)			P ₄ O ₁₀ (s) + 6H ₂ O (l) → 4H ₃ PO ₄ (aq)	SO ₃ (l) + H ₂ O (l) → H ₂ SO ₄ (aq)
pH of resultant solution	13-14	9	7	7	1-2	1-2

Trends & Variations of Solubility in Water of Period 3 Oxides

pH of resultant solution when water is added to Period 3 element oxides



Trends & Variations of Solubility in Water of Period 3 Oxides

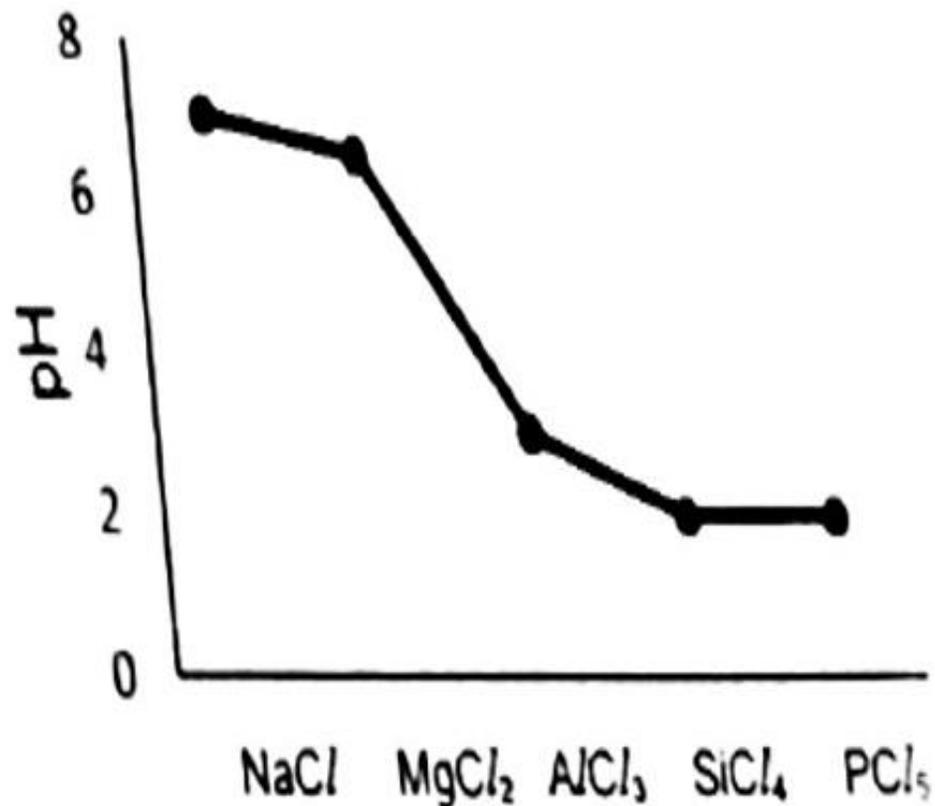
	NaCl	MgCl ₂	AlCl ₃	SiCl ₄	PCl ₅
Reaction in Water	Soluble	Soluble	Soluble	Soluble	Soluble
Observation	Dissolve to give colourless solution	Dissolve to give colourless solution	In limited amount of water: Dissolved to give a colourless solution with white solid (Al(OH) ₃) & steamy white fumes (HCl) When excess amount of water is added: Dissolve to give colourless solution	Reacts vigorously and dissolved to give a colourless solution with white solid (SiO ₂) & steamy white fumes (HCl)	In limited amount of water (or cold water): Dissolved to give a colourless solution with steamy white fumes (HCl) When excess amount of water is added: Reacts vigorously and dissolved to give a colourless solution with steamy white fumes (HCl)

Trends & Variations of Solubility in Water of Period 3 Chlorides

	NaCl	MgCl ₂	AlCl ₃	SiCl ₄	PCl ₅
Products formed	NaCl (s) → Na ⁺ (aq) + Cl ⁻ (aq)	MgCl ₂ (aq) + 6H ₂ O (l) → [Mg(H ₂ O) ₆] ²⁺ (aq) + 2Cl ⁻ (aq) [Mg(H ₂ O) ₆] ²⁺ (aq) ⇌ [Mg(H ₂ O) ₅ (OH)] ⁺ (aq) + H ⁺ (aq)	In limited amount of water: AlCl ₃ (s) + 3H ₂ O (l) → Al(OH) ₃ (s) + 3HCl (g) When excess amount of water is added: AlCl ₃ (s) + 6H ₂ O (l) → [Al(H ₂ O) ₆] ³⁺ (aq) + 3Cl ⁻ (aq) [Al(H ₂ O) ₆] ³⁺ (aq) ⇌ [Al(H ₂ O) ₅ (OH)] ²⁺ (aq) + H ⁺ (aq)	SiCl ₄ (l) + 2H ₂ O (l) → SiO ₂ (s) + 4HCl (g)	In limited amount of water: PCl ₅ (s) + H ₂ O (l) → POCl ₃ (aq) + 2HCl (g) When excess amount of water is added: PCl ₅ (s) + 4H ₂ O (l) → H ₃ PO ₄ (aq) + 5HCl (g) OR POCl ₃ (aq) + 3H ₂ O (l) → H ₃ PO ₄ (aq) + 3HCl (g)
pH of resultant solution	7	6.5	3	1-2	1-2

Trends & Variations of Solubility in Water of Period 3 Chlorides

pH of resultant solution when water is added to Period 3 element chlorides



Trends & Variations of Solubility in Water of Period 3 Chlorides

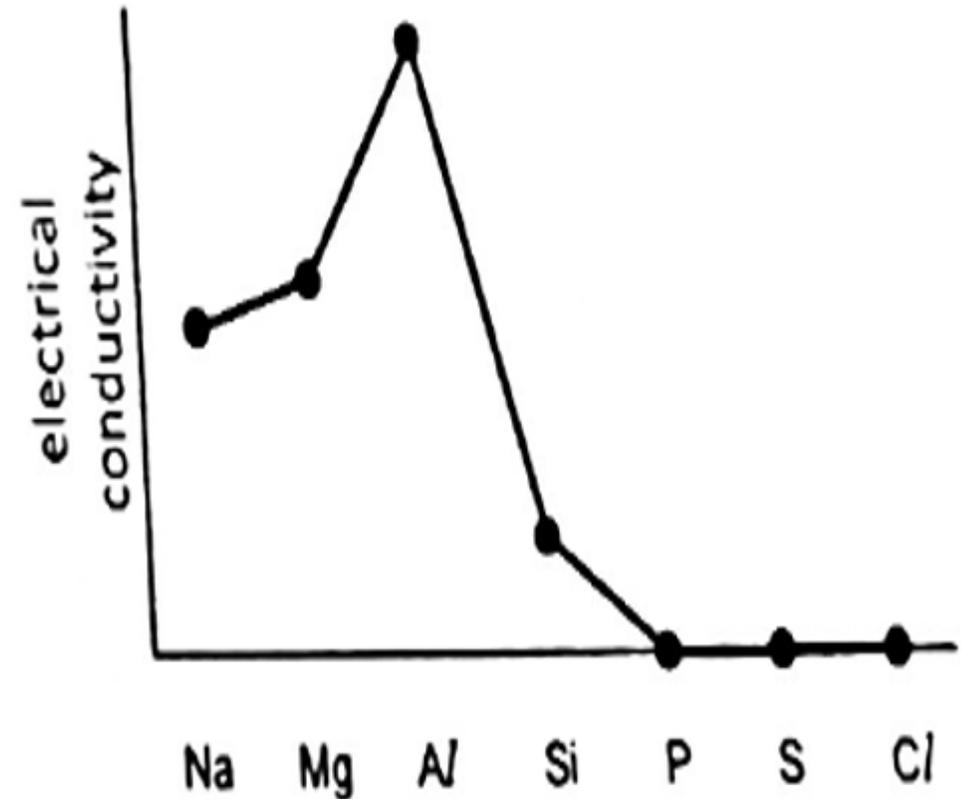


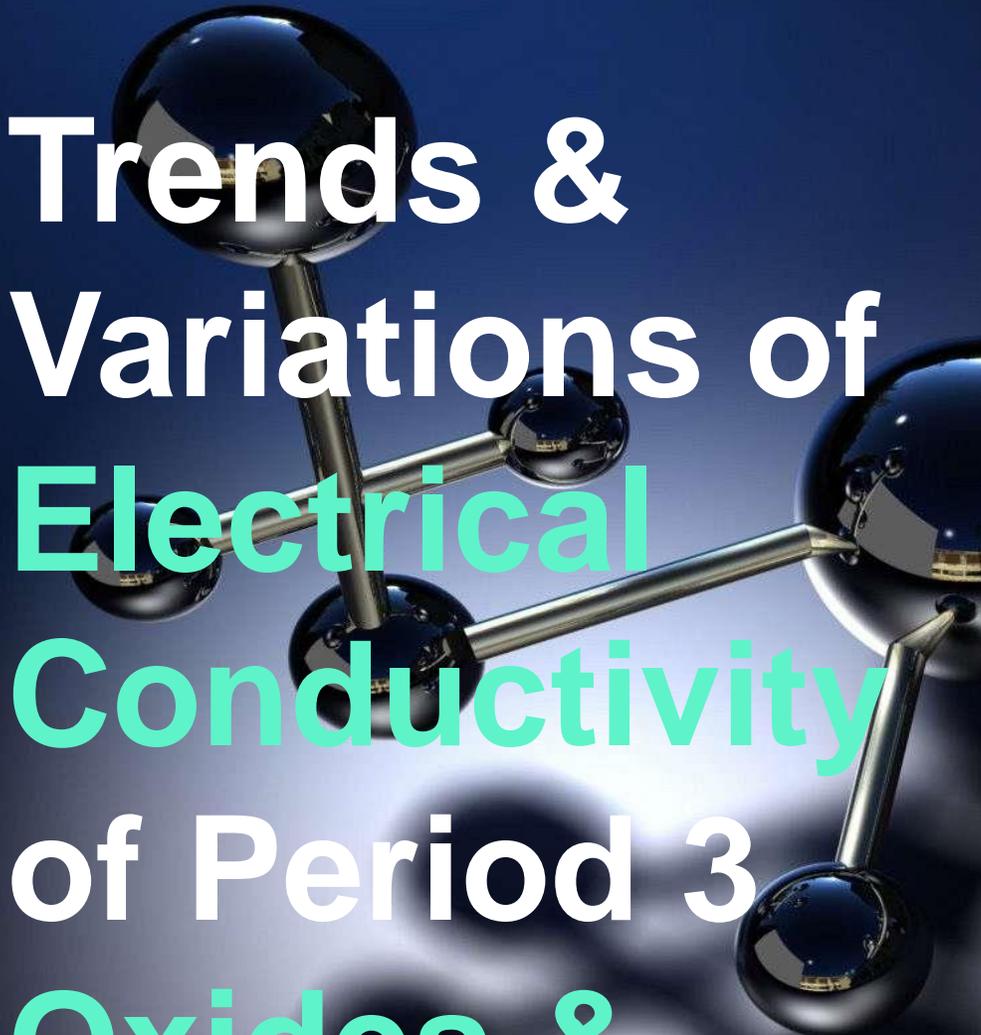
Trends & Variations of Electrical Conductivity of Period 3 Elements

	Na	Mg	Al	Si	P ₄	S ₈	Cl ₂
Structure	Giant metallic			Giant covalent	Simple covalent		
Electrical Conductivity	Good Conductor			Poor Conductor	Do not conduct electricity		
Trend Across Period	Increase across the Period due to increase in number of delocalised valence electrons			Drop sharply from Al to Si as Si is a metalloids and has poor electrical conductivity.	Drop to zero from Si to P ₄ /S ₈ /Cl ₂ due to absence of mobile valence electrons.		

Trends & Variations of Electrical Conductivity of Period 3 Elements

Electrical Conductivity of Period 3 Elements





Trends & Variations of Electrical Conductivity of Period 3 Oxides & Chlorides

	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	SO ₃
Structure	Giant ionic			Giant covalent	Simple covalent	
Electrical Conductivity	Good Conductor			Poor Conductor	Poor Conductor	

	NaCl	MgCl ₂	AlCl ₃	SiCl ₄	PCl ₅
Structure	Giant Ionic		Simple covalent		
Electrical Conductivity	Good Conductor		Poor Conductor in solid state. Good Conductor in aqueous state.	Poor Conductor	

MELTING & BOILING POINT

- General Trend **Down** the Group : **Decrease**
- All group 2 elements have metallic structure
- Down the Group charge density decreases as radius increase
- Resulting in weaker metallic bonds
- Melting & Boiling Point decrease as lesser energy is required to break the weaker metallic bonds

REDUCING POWER

Group 2 elements have **two valence electrons** which can be **readily lost to form stable ions** to achieve noble gas configuration. Hence they are able to **act as reducing agents** (they reduce other compounds)



- General Trend **Down** the Group : **Increase**
- As the ionisation energy decrease down the group, the atoms are able to lose electrons more readily
- Hence there is an increasing ease of the element to undergo oxidation
- Hence the strength of the reducing power increases down the group



Trends & Variations of Properties of Group 2 Elements

REACTIVITY

Reactivity depends on the ease with which the Group 2 elements lose their electrons.

- General Trend **Down** the Group : **Increase**
 - As the reducing power increase down the group, the atoms are able to lose electrons more readily
 - Hence reactivity increases down the group

Element	Reaction with Water $M(s) + 2H_2O(l) \rightarrow M(OH)_2 + H_2(g)$	Reaction with dilute acid $M(s) + 2H^+(aq) \rightarrow M^{2+} + H_2(g)$
Mg	React only with steam	React vigorously
Ca	Reacts with increasing vigour from Ca to Ba	Reacts violently
Sr		
Ba		



Trends & Variations of Properties of Group 2 Elements

GROUP 2 COMPOUNDS

- Carbonates ($M\text{CO}_3$)
- Nitrates [$M(\text{NO}_3)_2$]
- Hydroxides $M(\text{OH})_2$

THERMAL STABILITY

Group 2 compounds all decompose to their metal oxide upon heating:

Carbonates: $(M\text{CO}_3) (\text{s}) \rightarrow MO (\text{s}) + \text{CO}_2 (\text{g})$

Nitrates: $[M(\text{NO}_3)_2] (\text{s}) \rightarrow MO (\text{s}) + 2\text{NO}_2 (\text{g}) + \text{CO}_2 (\text{g})$

Hydroxides $M(\text{OH})_2 (\text{s}) \rightarrow MO (\text{s}) + \text{H}_2\text{O} (\text{g})$

- General Trend **Down** the Group : **Increase**
- Down the group cationic radius increases
- Charge of the cation remain the same
- Hence charge density of the cation decrease, decreasing the polarising power of the cation
- As the anion remains constant, the electron cloud of the anion is polarise to a lesser extent down the group
- Ease of thermal decomposition thus decreases down the group
- Leading to an increase in thermal decomposition temperature
- Hence thermal stability increases down the group



Trends & Variations of Properties of Group 2 Compounds

Trends & Variations of Melting & Boiling Point of Group 17 Elements

➤ General Trend **Down** the Group : **Increase**

- All group 17 elements are simple covalent structures
- Down the Group the size of the electron cloud increases
- Resulting in more intensive id-id interactions
- Melting & Boiling Point increase as more energy is required to break more id-id interactions

Group 17 element	Physical State at 20°C
Fluorine (F ₂)	Pale yellow gas
Chlorine (Cl ₂)	Yellowish green gas
Bromine (Br ₂)	Reddish brown liquid
Iodine (I ₂)	Purple (black) solid
Astatine (At ₂)	Black solid

Note: you need to memorise the colour of the halogens

Trends & Variations of Volatility of Group 17 Elements

Volatility refers to the **ease of changing from solid/liquid state to the gaseous state**. It has a **reciprocal relationship with boiling point**.

➤ General Trend **Down** the Group : **Decrease**

- All group 17 elements are simple covalent structures
- Down the Group the number of electrons increases
- Resulting in more intensive id-id interactions
- Boiling Point increase as more energy is required to break more id-id interactions
- Volatility decrease

Trends & Variations of Solubility of Group 17 Elements

➤ General Trend **Down** the Group : **Decrease**

- All group 17 elements are simple covalent structures, forming id-id interactions
- As the size of the molecules increase down the group, more intensive id-id interactions are formed
- Solubility thus decrease as more id-id interactions needed to be broken

Element	Chlorine	Bromine	Iodine
Observation when dissolved in Water	Undergoes disproportionation, forming an acidic solution. Chlorine water turns litmus paper red and then bleaches it. $\text{Cl}_2 (\text{g}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}^+ (\text{aq}) + \text{Cl}^- (\text{aq}) + \text{HClO} (\text{aq})$	Moderately soluble in water, containing mainly aqueous Br_2 .	Very sparingly soluble in water.
	Pale yellow solution	Orange solution	Brown solution
Observation when dissolved in Organic Solvents	More soluble in organic solvent than polar solvent		
	Pale yellow solution	Orange-red solution	Purple solution

Trends & Variations of Bond Energy of Group 17 Elements

Bond energy is the **average energy required to break 1 mole of a covalent bond** between two atoms in the gaseous state.

- General Trend **Down** the Group : **Decrease**
 - Down the group the size of the atom increase
 - The effectiveness of the orbitals overlap decrease and bond length increase
 - Weaker covalent bonds are formed
 - Bond energy thus decrease as lesser amount of energy is required to break the weaker covalent bonds

Recap in Chapter 2: Chemical Bonding

Trends & Variations of Oxidising Power of Group 17 Elements

Group 17 elements have **seven valence electrons** and thus **have the tendency to accept one electron to achieve noble gas configuration**. Hence they are able to act as **oxidising agents** (they oxidise other compounds)



- General Trend **Down** the Group : **Decrease**
 - As the electronegativity decrease down the group, the atoms are less likely to accept electrons
 - Hence there is an decreasing ease of the element to undergo reduction
 - Hence the strength of the oxidising power decreases down the group

Trends & Variations of Properties of Group 17 Compounds (Hydrogen Halides)

MELTING & BOILING POINT

- General Trend **Down** the Group (**only for HCl – HI**) : **Increase** (same as its element)
- Hydrogen halides are simple covalent structures
- Down the Group the size of the electron cloud of the halide increases
- Resulting in more intensive id-id & pd-pd interactions
- Melting & Boiling Point increase as more energy is required to break more id-id interactions

Note: HF is not included in the general trend as it has the highest melting/boiling point among the other hydrogen halides. This is due to the presence of H-bonding forming between the HF molecules, which are stronger than the id-id & pd-pd interactions between the other hydrogen halides (recap Chapter 2: Chemical Bonding)

Trends & Variations of Properties of Group 17 Compounds (Hydrogen Halides)

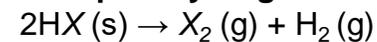
BOND ENERGY

- General Trend **Down** the Group : **Decrease** (same as its element)
 - Down the group the size of the halide increase
 - The effectiveness of the orbitals overlap decrease and bond length increase
 - Weaker covalent bonds are formed between hydrogen and halide
 - Bond energy thus decrease as lesser amount of energy is required to break the weaker covalent bonds

Recap in Chapter 2: Chemical Bonding

THERMAL STABILITY

Group 17 hydrogen halides exist as white fumes with sharp odours



- General Trend **Down** the Group : **Decrease**
 - Down the group bond energy of the hydrogen halides decrease
 - Easier to break the covalent bond
 - Ease of thermal decomposition thus increases down the group
 - Leading to an decrease in thermal decomposition temperature
 - Hence thermal stability decreases down the group

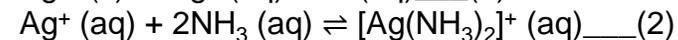
Trends & Variations of Properties of Group 17 Compounds (Hydrogen Halides)

REACTION OF AgX WITH NH₃ (dilute & concentrated)

The reaction between the precipitate (AgX) formed and NH₃ (dilute or concentrated) can also be used as the extension to the previous distinguish test to identify the identity of the halides.

- **Why only AgCl is soluble in dilute NH₃** (*the explanation involves K_{sp} and Ionic Product which will be touched on in Chapter 10: Solubility Equilibria*):

When NH₃ is added to AgX (s) the following reaction occurs:



As [Ag(NH₃)₂]⁺ is formed, it decreases the [Ag⁺] in (1). Such decrease in [Ag⁺] also decrease the ionic product of AgX. However, only the ionic product of AgCl falls below its K_{sp} value as the K_{sp} of AgCl is the highest among the other halides, causing AgCl to dissolve. On the other hand, the ionic products of AgBr and AgI are still above their K_{sp} values as the K_{sp} of AgBr and AgI are very small, hence AgBr and AgI do not dissolve.

- **Why only AgCl and AgBr are soluble in concentrated NH₃** (*the explanation involves K_{sp} and Ionic Product which will be touched on in Chapter 10: Solubility Equilibria*):

When more NH₃ is added, more [Ag(NH₃)₂]⁺ is formed which further decreases the [Ag⁺] in (1). This decrease the ionic product of AgX even further. Now both the ionic product of AgCl and AgBr falls below their K_{sp} value, causing both AgCl and AgBr to dissolved. However the ionic products of AgI is still above its K_{sp} values as the K_{sp} of AgI is very small, hence AgI do not dissolve.

Practice Questions

Question: Which of the following have the largest radius; P^{3-} , Cl^- , Al^{3+} , K^+ ?

Answer: P^{3-}

Question: Arrange the first ionisation energy of Radon (Rn), Francium (Fr) and Radium (Ra) in increasing order. Explain your answer.

Answer: Fr, Ra, Rn

Rn is in Group 18, Fr is in Group 1 and Ra is in Group 2.

Rn is in the period before Fr and Ra. Fr and Ra have higher nuclear charge than Rn since they have more protons and greater shielding effect than Rn as they have more inner electron shells. The increase in shielding effect outweighs the increase in nuclear charge. Therefore Fr and Ra have smaller effective nuclear charge than Rn. Valence electrons in Rn are thus more strongly attracted to the nucleus as compared to Fr and Ra hence greater amount of energy is required to remove the outermost electron in Rn as compared to Fr and Ra.

Fr and Ra are both in the same period. Ra has higher nuclear charge than Fr due to higher number of protons. Both Fr and Ra have approximately the same shielding effect as they have the same number of inner electron shells. Hence Ra has a higher effective nuclear charge than Fr. Valence electrons in Ra are thus more strongly attracted to the nucleus as compared to Fr hence greater amount of energy is required to remove the outermost electron in Ra as compared to Fr.

Practice Questions

Question: Which of the following statements are correct?

1. The ionic radius of the cation increases from calcium to barium.
2. The energy required for the formation of the cation increase from calcium to barium.

Answer: 1

Question: Compare the relative radii of the atom and ion of sodium (Na) and chlorine (Cl).

Answer: Na has a larger atomic radius than Cl since it has fewer number of proton and thus lower nuclear charge. They both have approximately the same shielding effect since they have the same number of inner shell electrons. Hence Na has a lower effective nuclear charge and its valence electrons are less strongly attracted to its nucleus resulting in it have a larger atomic radius than Cl. Cl⁻ has a larger ionic radius than Na⁺ since it has more protons and thus higher nuclear charge. It also experience a higher shielding effect by the additional inner shell electrons. The increase in shielding effect outweighs the increase in nuclear charge hence the effective nuclear charge for Cl⁻ is lower than that of Na⁺. The valence electrons in Cl⁻ is less strongly attracted to the nucleus than that of Na⁺ hence Cl⁻ has a larger ionic radius than Na⁺.

Practice Questions

Question: Predict whether Ga_2O_3 is acidic, basic or amphoteric.

Answer: Like Al_2O_3 , Ga_2O_3 is amphoteric.

Question: Which statement explains why a solution of AlCl_3 is acidic?

1. Chloride ions react with water to form HCl
2. Aluminum ions have large charge density
3. The H-O bonds are weaker in $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ than in H_2O

Answer: 2 and 3

Question: Which statement shows a general decrease for Period 3 chlorides?

1. pH of the resulting solution when dissolve in water
2. maximum oxidation states of the elements in the chlorides
3. electrical conductivity in solid state

Answer: 1

Practice Questions

Question: The oxide and chloride of an element E are mixed separately with water. The two resulting solutions have the same effect on litmus. What is element E?

1. Mg
2. Al
3. Si
4. P

Answer: 4

Question: With reference to the Data Booklet, explain why copper (Cu) is much less reactive than calcium (Ca).

Answer:

From the Data Booklet, the first and second ionisation energy of Cu is higher than that of Ca, indicating more energy is required for Cu to lose 2 moles of electrons as compared to Ca, thus it is less reactive. This is also supported by the more positive $E^\ominus(\text{Cu}^{2+}/\text{Cu})$ value as compared to the $E^\ominus(\text{Ca}^{2+}/\text{Ca})$ value, indicating that Cu is oxidised less readily than Ca.

Practice Questions

Question: Similar to the decomposition of Group 2 carbonates, anhydrous barium nitrate and anhydrous magnesium nitrate both decompose on heating, forming an oxide and evolving a brown gas and another gas that relights a glowing splint. Which of the following statement(s) is/are correct?

1. The brown gas is evolved at a lower temperature from magnesium nitrate than from barium nitrate.
2. For both nitrates, the volume of the brown gas evolved is four times greater than the volume of gas that relights a glowing splint.
3. The melting point for magnesium nitrate is smaller than the melting point for barium nitrate.

Answer: 1 and 2.

Question: HCl is stable to heat, but HI decomposes into its element when heated. What is responsible for this difference?

1. HI is a stronger reducing agent than HCl.
2. HI is more volatile than HCl.
3. The H-I bond is weaker than the H-Cl bond.
4. The I-I bond is weaker than the Cl-Cl bond.

Answer: 3 (Note: 1 & 4 are correct, but it does not explain the difference in the observation mentioned in this question.)

Test yourself!

For elements in the third period (sodium to chlorine), and in Group 2 (magnesium to barium) and Group 17 (chlorine to iodine) candidates should be able to:

- (a) recognise variation in the electronic configurations across a Period and down a Group
- (b) describe and explain qualitatively the general trends and variations in atomic radius, ionic radius, first ionisation energy and electronegativity:
 - i. across a Period in terms of shielding and nuclear charge
 - ii. down a Group in terms of increasing number of electronic shells, shielding and nuclear charge
- (c) interpret the variation in melting point and in electrical conductivity across a Period in terms of structure and bonding in the elements (metallic, giant molecular, or simple molecular)
- (d) describe and explain the trend in volatility of the Group 17 elements in terms of instantaneous dipole-induced dipole attraction

Test yourself!

For elements in the third period (sodium to chlorine) candidates should be able to:

(e)

- i. state and explain the variation in the highest oxidation number of the elements in oxides (for Na_2O ; MgO ; Al_2O_3 ; SiO_2 ; P_4O_{10} ; SO_3) and chlorides (for NaCl ; MgCl_2 ; AlCl_3 ; SiCl_4 ; PCl_5)
- ii. state and explain the variation in bonding in oxides and chlorides in terms of electronegativity (with the exception of AlCl_3)
- iii. describe the reactions of the oxides with water (for Na_2O ; MgO ; Al_2O_3 ; SiO_2 ; P_4O_{10} ; SO_3)
- iv. describe and explain the acid/base behaviour of oxides (for Na_2O ; MgO ; Al_2O_3 ; SiO_2 ; P_4O_{10} ; SO_3) and hydroxides (for NaOH ; $\text{Mg}(\text{OH})_2$; $\text{Al}(\text{OH})_3$), including, where relevant, amphoteric behaviour in reaction with sodium hydroxide (only) and acids
- v. describe and explain the reactions of the chlorides with water (for NaCl ; MgCl_2 ; AlCl_3 ; SiCl_4 ; PCl_5)
- vi. suggest the types of structure and bonding present in the oxides and chlorides from observations of their chemical and physical properties

Test yourself!

For elements in Group 2 (magnesium to barium) and Group 17 (chlorine to iodine) candidates should be able to:

(f) describe and deduce from E^\ominus values the relative reactivity of elements of:

- i. Group 2 as reducing agents
- ii. Group 17 as oxidising agents

(g) describe and explain the trend in thermal stability of:

- i. Group 2 carbonates in terms of the charge density of the cation and the polarisability of the large anion
- ii. Group 17 hydrides in terms of bond energies

(h) predict the characteristic properties of an element in a given Group by using knowledge of chemical periodicity

(i) deduce the nature, possible position in the Periodic Table, and identity of unknown elements from given information of physical and chemical properties

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