

## ---Periodic Table---

IE increase, atomic radius decrease, increasing electronegativity, same outermost quantum shell, show periodic changes in physical and chemical properties

IE decrease, atomic radius increase, decreasing electronegativity, same number of valence electrons, similar physical and chemical properties

Group																				
1	2											13	14	15	16	17	18			
		<div>Key</div> <div>atomic number</div> <div>atomic symbol</div> <div>name</div> <div>relative atomic mass</div>										<div>1</div> <div>H</div> <div>hydrogen</div> <div>1.0</div>								<div>2</div> <div>He</div> <div>helium</div> <div>4.0</div>
<div>3</div> <div>Li</div> <div>lithium</div> <div>6.9</div>	<div>4</div> <div>Be</div> <div>beryllium</div> <div>9.0</div>											<div>5</div> <div>B</div> <div>boron</div> <div>10.8</div>	<div>6</div> <div>C</div> <div>carbon</div> <div>12.0</div>	<div>7</div> <div>N</div> <div>nitrogen</div> <div>14.0</div>	<div>8</div> <div>O</div> <div>oxygen</div> <div>16.0</div>	<div>9</div> <div>F</div> <div>fluorine</div> <div>19.0</div>	<div>10</div> <div>Ne</div> <div>neon</div> <div>20.2</div>			
<div>11</div> <div>Na</div> <div>sodium</div> <div>23.0</div>	<div>12</div> <div>Mg</div> <div>magnesium</div> <div>24.3</div>											<div>13</div> <div>Al</div> <div>aluminium</div> <div>27.0</div>	<div>14</div> <div>Si</div> <div>silicon</div> <div>28.1</div>	<div>15</div> <div>P</div> <div>phosphorus</div> <div>31.0</div>	<div>16</div> <div>S</div> <div>sulfur</div> <div>32.1</div>	<div>17</div> <div>Cl</div> <div>chlorine</div> <div>35.5</div>	<div>18</div> <div>Ar</div> <div>argon</div> <div>39.9</div>			
<div>19</div> <div>K</div> <div>potassium</div> <div>39.1</div>	<div>20</div> <div>Ca</div> <div>calcium</div> <div>40.1</div>	<div>21</div> <div>Sc</div> <div>scandium</div> <div>45.0</div>	<div>22</div> <div>Ti</div> <div>titanium</div> <div>47.9</div>	<div>23</div> <div>V</div> <div>vanadium</div> <div>50.9</div>	<div>24</div> <div>Cr</div> <div>chromium</div> <div>52.0</div>	<div>25</div> <div>Mn</div> <div>manganese</div> <div>54.9</div>	<div>26</div> <div>Fe</div> <div>iron</div> <div>55.8</div>	<div>27</div> <div>Co</div> <div>cobalt</div> <div>58.9</div>	<div>28</div> <div>Ni</div> <div>nickel</div> <div>58.7</div>	<div>29</div> <div>Cu</div> <div>copper</div> <div>63.5</div>	<div>30</div> <div>Zn</div> <div>zinc</div> <div>65.4</div>	<div>31</div> <div>Ga</div> <div>gallium</div> <div>69.7</div>	<div>32</div> <div>Ge</div> <div>germanium</div> <div>72.6</div>	<div>33</div> <div>As</div> <div>arsenic</div> <div>74.9</div>	<div>34</div> <div>Se</div> <div>selenium</div> <div>79.0</div>	<div>35</div> <div>Br</div> <div>bromine</div> <div>79.9</div>	<div>36</div> <div>Kr</div> <div>krypton</div> <div>83.8</div>			
<div>37</div> <div>Rb</div> <div>rubidium</div> <div>85.5</div>	<div>38</div> <div>Sr</div> <div>strontium</div> <div>87.6</div>	<div>39</div> <div>Y</div> <div>yttrium</div> <div>88.9</div>	<div>40</div> <div>Zr</div> <div>zirconium</div> <div>91.2</div>	<div>41</div> <div>Nb</div> <div>niobium</div> <div>92.9</div>	<div>42</div> <div>Mo</div> <div>molybdenum</div> <div>95.9</div>	<div>43</div> <div>Tc</div> <div>technetium</div> <div>—</div>	<div>44</div> <div>Ru</div> <div>ruthenium</div> <div>101.1</div>	<div>45</div> <div>Rh</div> <div>rhodium</div> <div>102.9</div>	<div>46</div> <div>Pd</div> <div>palladium</div> <div>106.4</div>	<div>47</div> <div>Ag</div> <div>silver</div> <div>107.9</div>	<div>48</div> <div>Cd</div> <div>cadmium</div> <div>112.4</div>	<div>49</div> <div>In</div> <div>indium</div> <div>114.8</div>	<div>50</div> <div>Sn</div> <div>tin</div> <div>118.7</div>	<div>51</div> <div>Sb</div> <div>antimony</div> <div>121.8</div>	<div>52</div> <div>Te</div> <div>tellurium</div> <div>127.6</div>	<div>53</div> <div>I</div> <div>iodine</div> <div>126.9</div>	<div>54</div> <div>Xe</div> <div>xenon</div> <div>131.3</div>			
<div>55</div> <div>Cs</div> <div>caesium</div> <div>132.9</div>	<div>56</div> <div>Ba</div> <div>barium</div> <div>137.3</div>	<div>57–71</div> <div>lanthanoids</div>		<div>72</div> <div>Hf</div> <div>hafnium</div> <div>178.5</div>	<div>73</div> <div>Ta</div> <div>tantalum</div> <div>180.9</div>	<div>74</div> <div>W</div> <div>tungsten</div> <div>183.8</div>	<div>75</div> <div>Re</div> <div>rhenium</div> <div>186.2</div>	<div>76</div> <div>Os</div> <div>osmium</div> <div>190.2</div>	<div>77</div> <div>Ir</div> <div>iridium</div> <div>192.2</div>	<div>78</div> <div>Pt</div> <div>platinum</div> <div>195.1</div>	<div>79</div> <div>Au</div> <div>gold</div> <div>197.0</div>	<div>80</div> <div>Hg</div> <div>mercury</div> <div>200.6</div>	<div>81</div> <div>Tl</div> <div>thallium</div> <div>204.4</div>	<div>82</div> <div>Pb</div> <div>lead</div> <div>207.2</div>	<div>83</div> <div>Bi</div> <div>bismuth</div> <div>209.0</div>	<div>84</div> <div>Po</div> <div>polonium</div> <div>—</div>	<div>85</div> <div>At</div> <div>astatine</div> <div>—</div>	<div>86</div> <div>Rn</div> <div>radon</div> <div>—</div>		
<div>87</div> <div>Fr</div> <div>francium</div> <div>—</div>	<div>88</div> <div>Ra</div> <div>radium</div> <div>—</div>	<div>89–103</div> <div>actinoids</div>		<div>104</div> <div>Rf</div> <div>rutherfordium</div> <div>—</div>	<div>105</div> <div>Db</div> <div>dubnium</div> <div>—</div>	<div>106</div> <div>Sg</div> <div>seaborgium</div> <div>—</div>	<div>107</div> <div>Bh</div> <div>bohrium</div> <div>—</div>	<div>108</div> <div>Hs</div> <div>hassium</div> <div>—</div>	<div>109</div> <div>Mt</div> <div>meitnerium</div> <div>—</div>	<div>110</div> <div>Ds</div> <div>darmstadtium</div> <div>—</div>	<div>111</div> <div>Rg</div> <div>roentgenium</div> <div>—</div>	<div>112</div> <div>Cn</div> <div>copernicium</div> <div>—</div>	<div>114</div> <div>Fl</div> <div>flerovium</div> <div>—</div>	<div>116</div> <div>Lv</div> <div>livermorium</div> <div>—</div>						
lanthanoids		<div>57</div> <div>La</div> <div>lanthanum</div> <div>138.9</div>	<div>58</div> <div>Ce</div> <div>cerium</div> <div>140.1</div>	<div>59</div> <div>Pr</div> <div>praseodymium</div> <div>140.9</div>	<div>60</div> <div>Nd</div> <div>neodymium</div> <div>144.2</div>	<div>61</div> <div>Pm</div> <div>promethium</div> <div>—</div>	<div>62</div> <div>Sm</div> <div>samarium</div> <div>150.4</div>	<div>63</div> <div>Eu</div> <div>europium</div> <div>152.0</div>	<div>64</div> <div>Gd</div> <div>gadolinium</div> <div>157.3</div>	<div>65</div> <div>Tb</div> <div>terbium</div> <div>158.9</div>	<div>66</div> <div>Dy</div> <div>dysprosium</div> <div>162.5</div>	<div>67</div> <div>Ho</div> <div>holmium</div> <div>164.9</div>	<div>68</div> <div>Er</div> <div>erbium</div> <div>167.3</div>	<div>69</div> <div>Tm</div> <div>thulium</div> <div>168.9</div>	<div>70</div> <div>Yb</div> <div>ytterbium</div> <div>173.1</div>	<div>71</div> <div>Lu</div> <div>lutetium</div> <div>175.0</div>				
actinoids		<div>89</div> <div>Ac</div> <div>actinium</div> <div>—</div>	<div>90</div> <div>Th</div> <div>thorium</div> <div>232.0</div>	<div>91</div> <div>Pa</div> <div>protactinium</div> <div>231.0</div>	<div>92</div> <div>U</div> <div>uranium</div> <div>238.0</div>	<div>93</div> <div>Np</div> <div>neptunium</div> <div>—</div>	<div>94</div> <div>Pu</div> <div>plutonium</div> <div>—</div>	<div>95</div> <div>Am</div> <div>americium</div> <div>—</div>	<div>96</div> <div>Cm</div> <div>curium</div> <div>—</div>	<div>97</div> <div>Bk</div> <div>berkelium</div> <div>—</div>	<div>98</div> <div>Cf</div> <div>californium</div> <div>—</div>	<div>99</div> <div>Es</div> <div>einsteinium</div> <div>—</div>	<div>100</div> <div>Fm</div> <div>fermium</div> <div>—</div>	<div>101</div> <div>Md</div> <div>mendelevium</div> <div>—</div>	<div>102</div> <div>No</div> <div>nobelium</div> <div>—</div>	<div>103</div> <div>Lr</div> <div>lawrencium</div> <div>—</div>				

^^Atomic Structure and Chemical Bonding explanations will come in handy. Make sure you know how to interpret IE across different element graph and successive IE of an element type graphs. AND need to be able to predict/ suggest properties and possible position in periodic table like AS for this chapter

Note: When describing reactions, you should have:

- How it reacts/ dissolves (readily/ vigorously?). Or does it just react/ dissolve?
- Description of acidity/ basicity, with pH value
- Equation

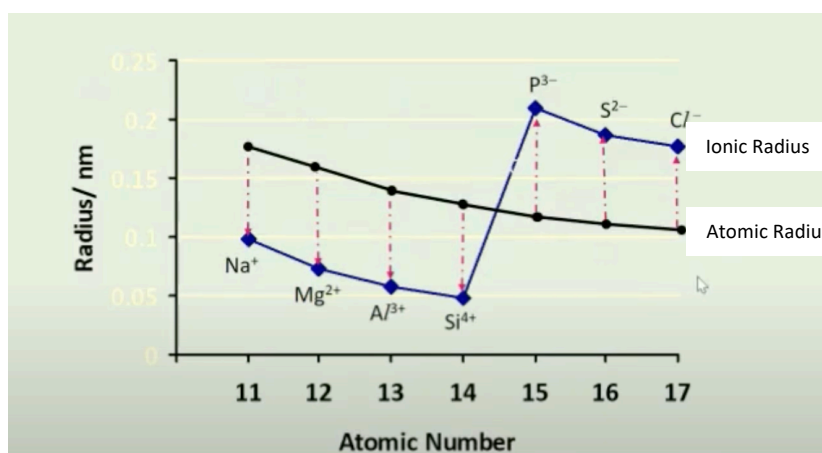
## A) Definitions

- The **enthalpy change of fusion** of a substance is the enthalpy change when **1 mole** of the substance changes state from a **solid to a liquid**. (Endothermic, positive value)
- The **enthalpy change of vaporization** of a substance is the enthalpy change when **1 mole** of the substance changes state from a **liquid to a gas**. (Endothermic, positive value)
- **Volatility** is the **tendency of a substance to vaporize** and depend on boiling point of the substance (**higher boiling point = less volatile**).

## B) Period 3 Elements

- Atomic and Ionic Radius

Comment on and explain the shapes of the 2 plots obtained (Tut Q9, 5-7m):



Across period 3, the **atomic radii of the elements decrease** gradually. This is because there is an **increase in nuclear charge**, while **shielding effect by inner shells of electrons remains relatively constant**.

The **radii of cations are smaller than the radii of corresponding atoms**. Atoms lose their valence electrons to form cations. As a result, the cations formed have **one less quantum shell of electrons**.

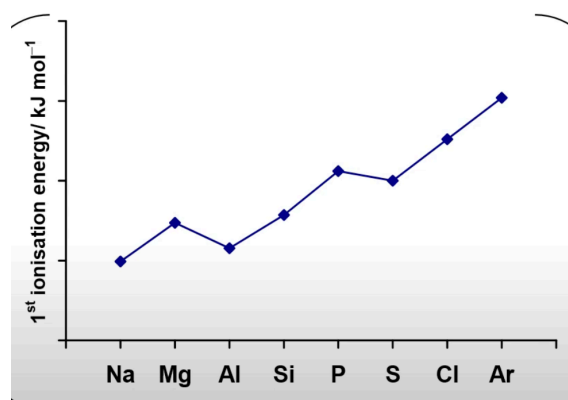
The **radii of anions are larger than the radii of corresponding atoms**. In forming the anions, electrons are added to the outermost quantum shell of atoms. As a result, there is **greater electron-electron repulsion in the outermost quantum shell** of the anions formed. (5m)

Across the period, there is a **decrease in cationic radius** from Na<sup>+</sup> to Si<sup>4+</sup>, which are isoelectronic with Ne due to increasing nuclear charge. There is also a **decrease in anionic radius** from P<sup>3-</sup> to Cl<sup>-</sup>, which are isoelectronic with Ar due to increasing nuclear charge. (7m)

Note: Nuclear charge  $\neq$  ionic charge

Tip: Use "radius loosely" when it's hard to be precise (e.g., comparing between ion and atom)

- First Ionisation Energy (Recap of Atomic Structure, Tut Q4a, 4m)



The **1<sup>st</sup> IE generally increases across the period**. Across the period, **nuclear charge increases**, while **shielding effect by inner shells of electrons remains relatively constant**. Hence, **effective nuclear charge increases**. The **atomic radius also decreases**. Hence, more energy is required to remove the valence electron from the atom.

However, anomalies are observed from Mg to Al and from P to S.

Mg has electronic configuration:  $1s^2 2s^2 2p^6 3s^2$ .

Al has electronic configuration:  $1s^2 2s^2 2p^6 3s^2 3p^1$ .

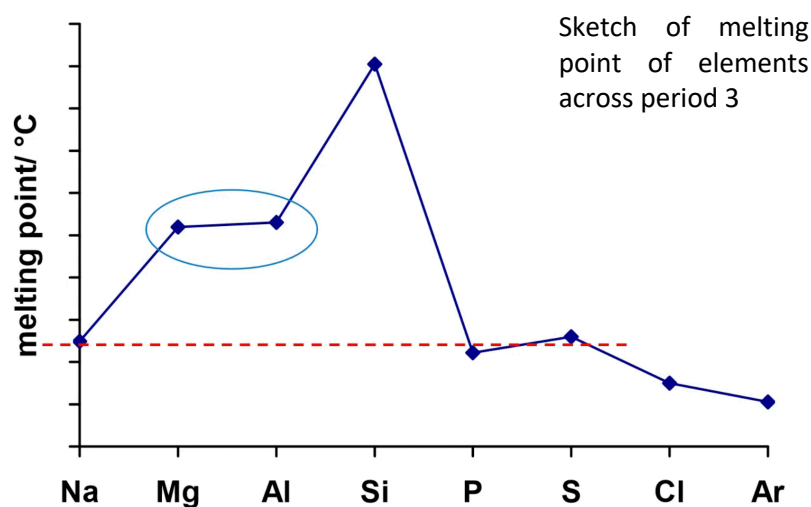
The **3p electron to be removed from Al has a higher energy than the 3s electron to be removed from Mg**. Hence, the 2p electron of Al requires less energy to be removed and **1<sup>st</sup> IE of Al is lower than 1<sup>st</sup> IE of Mg**.

P has electronic configuration:  $1s^2 2s^2 2p^6 3s^2 3p^3$ .

S has electronic configuration:  $1s^2 2s^2 2p^6 3s^2 3p^4$ .

**Coulombic repulsion between the paired 3p electrons in S makes it easier to remove one of the paired 3p electrons** than the unpaired 3p electrons from P. Hence, **1<sup>st</sup> IE of S is lower than 1<sup>st</sup> IE of P**.

- Melting point and Boiling point (Recap of Chemical Bonding, Tut Q4b, 5m)



Note: The electrostatic attraction between the positively charged  $\text{Na}^+$  ions and delocalised valence electrons is actually weaker than the id-id I between  $\text{S}_8$  molecules, but it is stronger than the id-id I between  $\text{P}_4$  molecules.

The metals (notably Mg and Al) generally have **high melting points** as they all have **giant metallic structures**, and a large amount of energy is required to overcome the **strong EA between the positively charged metal cation and the delocalised valence electrons**.

The melting points increase from Na to Al due to the **increase in strength of the metallic bond** as the **charge density of the metal cations increases together with the increase in the number of delocalised valence electrons**.

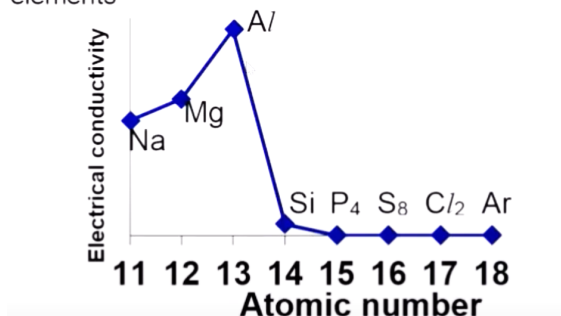
Si has the **highest melting point** as it has **a giant covalent structure**, and a **large amount of energy is required to overcome the strong covalent bonds between Si atoms**.

The non-metals (P to Ar) have **low melting points** as they all have **simple covalent structures or monoatomic structures in the case of Ar**. Less energy is required to overcome the **weak id-id I between the molecules or between atoms in the case of Ar**.

Melting points of sulfur > phosphorus > chlorine > argon as the **number of electrons in  $\text{S}_8$  molecule >  $\text{P}_4$  molecule >  $\text{Cl}_2$  molecule > Ar atom**. Hence the **strength of the id-id I between the molecules/ atoms decreases from  $\text{S}_8$  to  $\text{P}_4$  to  $\text{Cl}_2$  to Ar**.

- Electrical Conductivity (Recap of Chemical Bonding, Tut Q4c, 3m)

Variation in electrical conductivities of Period 3 elements



Electrical conductivity are high for the metals (Na, Mg and Al) due to the presence of delocalised valence electrons which are able to act as mobile charge carriers. Electrical conductivity increases from Na to Al due to an increasing number of delocalised valence electrons.

Electrical conductivity drops sharply at Si as it is a semi-conductor. (N) Few electrons have enough energy at room temperature to break free from the attraction of the nuclei and contribute to some electrical conductivity.

Electrical conductivity drops to almost 0 from P to Ar due to an absence of mobile charge carriers to conduct electricity.

Others:

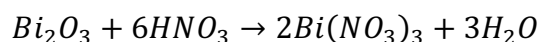
- Describe the way in which the oxide of the named element is reacting and discuss whether its behaviour is what you would expect from the position of the element in the periodic table (Tut Q10ii/iii, 2m each):



BeO is behaving as an **acidic oxide**, which is not quite expected.

Be is a Group 2 element and thus is expected to form ionic oxides which have basic properties.

(N) However, **Be<sup>2+</sup> has high charge density**. Thus, **BeO shows a high degree of covalent character and is amphoteric** (N.B. diagonal relationship → Be displays similar chemical properties as Al). BeO thus have both **acidic and basic properties**. Hence, it is able to react with basic NaOH to form a salt  $\text{Na}_2\text{Be}(\text{OH})_4$ .



$\text{Bi}_2\text{O}_3$  is behaving as a **basic oxide**, which is not quite expected.

Bi is in Group 15, thus it is expected to form covalent oxides which have acidic properties.

(N) However, as **Bi is at the bottom of the group**, it will **display greater metallic character**. Thus,  $\text{Bi}_2\text{O}_3$  shows a **high degree of ionic character and is amphoteric**.  $\text{Bi}_2\text{O}_3$  can hence show basic properties and react with  $\text{HNO}_3$  to form a salt  $\text{Bi}(\text{NO}_3)_3$  and water.

- Explain why AgI is insoluble in aqueous ammonia (Tut Q12b):

Solubility of silver halides in aqueous ammonia decreases from Group 17 due to **decreasing K<sub>sp</sub> of silver halides**. (N.B.  $K_{sp}(\text{AgCl}) > \text{AgBr} > \text{AgI}$ ).

Since AgI is insoluble in aqueous ammonia, **AgI**, which **has a smaller K<sub>sp</sub> value than AgCl will also be insoluble in aqueous ammonia**.

- Thermal decomposition vs combustion: Thermal decomposition does not require oxygen, but combustion requires oxygen.

- Chlorides of Period 3 Elements

Formula of chloride	NaCl (s)	MgCl <sub>2</sub> (s)	AlCl <sub>3</sub> (s) (covalent due to high charge density)	SiCl <sub>4</sub> (l) <sup>1</sup>	PCl <sub>5</sub> (s) <del>PCl<sub>3</sub>(l)</del>	<del>SCl<sub>2</sub>(l)</del>
Oxidation number of period 3 element	+1	+2	+3	+4	+5	+1
Oxidation number of period 3 elements in their chloride always positive as chlorine is more electronegative than period 3 elements and maximum oxidation number correspond to number of valence electrons in each element (all used for bonding with chlorine).						
Electronegativity diff. between element and chlorine	2.1	1.8	1.5	1.2	0.9	0.5
Structure	Giant ionic		Simple covalent			
Melting point/ °C	808	714	Sublime at 180	-70	PCl <sub>5</sub> (s): 167 <del>PCl<sub>3</sub>(l): -92</del>	-76
	Large amount of energy required to overcome the strong EFOA between metal cation and chloride ions		Small amount of energy required to overcome the weak id-id interactions between the discrete molecules			
Effect of adding chloride to water	<b>Dissolve readily</b> to give a <b>neutral</b> solution ( <b>hydration</b> only as Na <sup>+</sup> has low charge density)	<b>Dissolve readily. Hydration and partial hydrolysis</b> to give a <b>weakly acidic</b> solution.	<b>Dissolve readily</b> and undergoes <b>hydration and substantial hydrolysis</b> to give an <b>acidic</b> solution	<b>Dissolve</b> and undergo <b>hydrolysis</b> to form <b>strongly acidic</b> solution, as Si/P atom has <b>energetically accessible vacant 3d orbitals for dative bonding with water molecules</b> . (white fumes of HCl formed if amount of water used is small)		
Approx. pH of solution	7	6.5	3	2	2	2

N.B. Extent of hydrolysis is highest for Al<sup>3+</sup> because its charge density is highest among Na<sup>+</sup>, Mg<sup>2+</sup> and itself. High charge density polarizes and weakens the O-H bond in surrounding water molecules, causing O-H bonds to break, releasing H<sup>+</sup> ions.

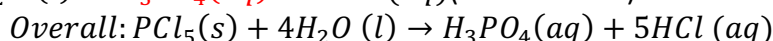
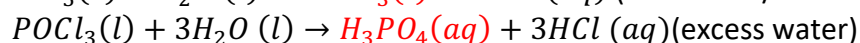
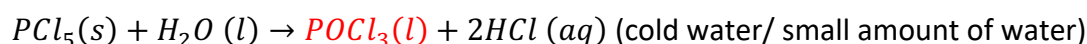
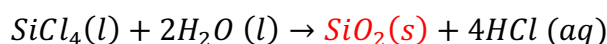
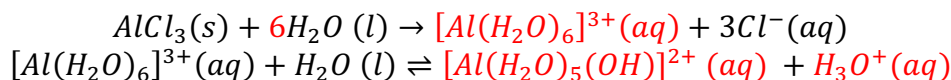
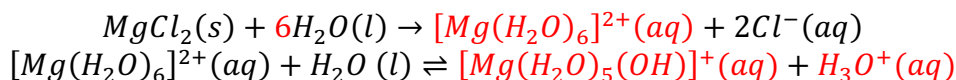
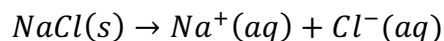
<sup>1</sup> Note that CCl<sub>4</sub> does not react in water due to the lack of energetically accessible vacant 3d orbitals

- Oxides of Period 3 Elements

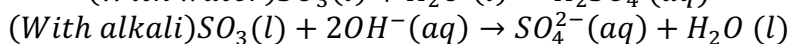
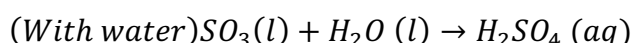
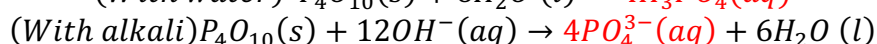
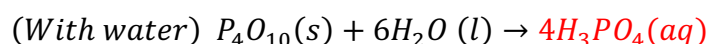
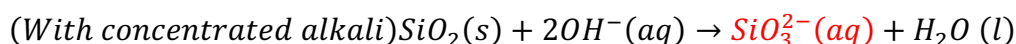
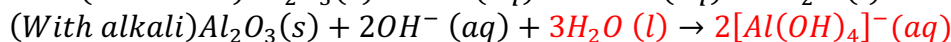
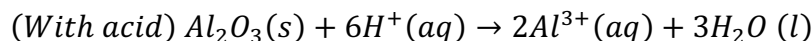
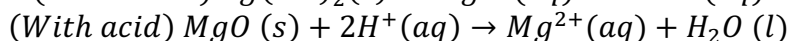
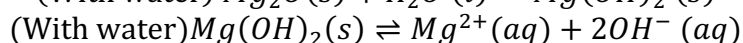
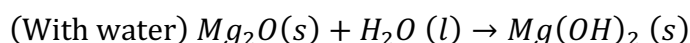
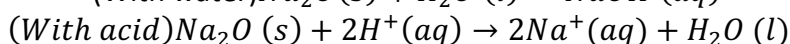
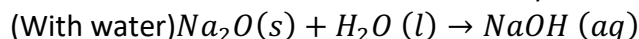
Formula of oxide	$Na_2O(s)$	$MgO(s)$	$Al_2O_3(s)$ (with covalent character)	$SiO_2(s)$	$P_4O_{10}(s)$ $P_4O_6(s)$	$SO_3(l)$ $SO_2(l)$	$Cl_2O_7(l)$ $Cl_2O(g)$
Oxidation number	+1	+2	+3	+4	$P_4O_{10}$ : +5 $P_4O_6$ : +3	$SO_3$ : +6 $SO_2$ : +4	$Cl_2O_7$ : +7 $Cl_2O$ : +1
Electronegativity diff. between element and oxygen	2.6	2.3	2.0	1.7	1.4	1.0	0.5
Structure	Giant ionic			Giant covalent	Simple covalent		
Melting point/ °C	Sublime at 1275	2800	2054	1700	$P_4O_{10}$ : sublime at 300 $P_4O_6$ : 24	$SO_3$ : -75 $SO_2$ : 17	$Cl_2O_7$ : 3.5 $Cl_2O$ : -121
	Large amount of energy required to overcome EFOA between metal cation and oxide ions			Large amount of energy required to overcome strong covalent bonds between Si and O atom	Small amount of energy is required to overcome the weak id-id interactions between the discrete molecules		
Acid, Base behaviour	Basic		Amphoteric	Acidic			
Effect of adding oxide to water	React <b>vigorously</b> to form a <b>strongly alkaline</b> solution	React to form a <b>weakly alkaline</b> solution	Insoluble		React <b>vigorously</b> to form an <b>acidic</b> solution	React to form an <b>acidic</b> solution	
Approx. pH	13	8	7	7	2	2	2



Reactions of Period 3 chloride with water<sup>2</sup>:



Reactions of Period 3 oxides with water<sup>3</sup> and reaction with acid/ base:

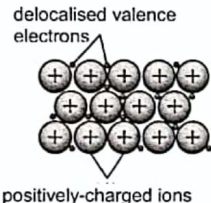
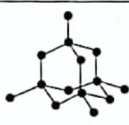
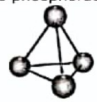



Reactions of Period 3 hydroxides:

Hydroxide (ionic)	Nature	Reaction with acid or base
$NaOH$	Basic	Typical Acid + Base $\rightarrow$ Salt + Water
$Mg(OH)_2$		
$Al(OH)_3$	Amphoteric	$Al(OH)_3(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2O(l)$ $Al(OH)_3(s) + OH^-(aq) \rightarrow [Al(OH)_4]^-(aq)$

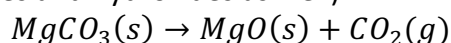
<sup>2</sup> Exclude  $PCl_3(s)$ ,  $S_2Cl_2(l)$  not under learning outcome

<sup>3</sup> Exclude  $SO_2(g)$ ,  $Cl_2O_7(l)$ ,  $Cl_2O(g)$  not under learning outcome

	Group 1	Group 2	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
Period 3	Sodium	Magnesium	Aluminium	Silicon	Phosphorus	Sulfur	Chlorine	Argon
Type of structure	Giant metallic		Giant covalent		Simple covalent			Monoatomic
	 <p>delocalised valence electrons</p> <p>positively-charged ions</p>		 <p>A metalloid</p>		<p>Phosphorus has 3 main allotropic forms known as red, white and black phosphorus.</p> <p>Discussion is usually based on white phosphorus, which contains tetrahedral P<sub>4</sub> molecules.</p> <p>White phosphorus (P<sub>4</sub>):</p> 	<p>Sulfur has 2 main allotropic forms known as rhombic and monoclinic sulfur. Both forms of sulfur consist of S<sub>8</sub> molecules arranged differently. The eight S atoms are joined to form a puckered octagonal ring, a 'crown shape'.</p> <p>S<sub>8</sub> molecule:</p> 	Cl-Cl	Ar atoms
Bonding	Metallic: Strong electrostatic attraction between positively-charged ions and delocalised valence electrons.		Covalent: Strong covalent bonds between atoms (due to strong attraction between the nuclei and the bonding electrons.)		<p>- Within each molecule: Atoms are held together by strong covalent bonds.</p> <p>- Between molecules: Weak id-id interactions hold the discrete molecules together.</p>			Weak id-id interactions hold the discrete atoms together.
Melting point and boiling point	High (increasing from Group 1 to Group 13)		Very high (maxima at Group 14)		Low			Lowest
Electrical conductivity	Very Good (increasing from Group 1 to Group 13)		Low (Semi-conductor)		Non-Conductor			Non-Conductor

### C) Group 2 Elements<sup>4</sup>

- Reducing power increase down the group from Mg to Ba (increasingly negative E<sup>⊖</sup> value) (can be explained with Atomic Structure: ease of losing electrons by metal)
- All Group 2 metal carbonates are thermally unstable and decompose on heating to give simple metal oxide and carbon dioxide. Thermal stability increases down the group (for Group 2 nitrates and hydroxides as well)



This is because, down the group, radius of metal cation increases, and its charge density decreases. As a result, the ability of M<sup>2+</sup> to polarize the electron cloud of the large CO<sub>3</sub><sup>2-</sup> anion decreases, and the C-O bonds are weakened to a smaller extent. Hence, thermal stability of Group 2 carbonates increases down the group.

<sup>4</sup> exclude reaction of group 2 nitrate and hydroxides (not in H2 syllabus)

## D) Group 17 Elements

- Volatility of halogen decreases down the group (stronger id-id interaction)
- Metals have the highest oxidation state in metal fluoride compared to other halides because fluorine is the most electronegative element (strongest OA) which allows it to gain electrons from metals easily.

Element	$F_2$	$Cl_2$	$Br_2$	$I_2$
Physical state at r.t.p	Pale yellow gas	Pale greenish-yellow gas	Reddish-brown liquid	Black solid
Colour when dissolved in non-polar solvent	Colourless	Pale yellow	Orange-red	Purple
Colour when dissolved in polar solvent (i.e. water)	Colourless	Pale yellow	Orange	Brown

- Oxidizing strength decreases down the group (decreasing positive  $E^\ominus$  value) (i.e. oxidizing power of  $Cl_2 > Br_2 > I_2$ ). Hence, when halogens are added to (i) aqueous solution of different halide ions, followed by (ii) the addition of organic solvent  $CCl_4$  (non-polar), we can observe displacement of the less reactive halide from its salt by another halogen molecule. (e.g.  $Cl_2 + 2I^- \rightarrow I_2 + 2Cl^-$ )

Halogen	Reaction
$F_2$	$H_2(g) + F_2(g) \rightarrow 2HF(g)$ React explosively even in the dark
$Cl_2$	$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ React explosively in sunlight, but slowly in the dark
$Br_2$	$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$ React at above 200°C over Pt catalyst
$I_2$	$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ React at above 400°C over Pt catalyst to form equilibrium mixture

- Hydrogen halide dissolve in polar (e.g. water  $\rightarrow$  dissociate to form strong acid) and non-polar solvents (retain covalent character).
- Boiling point highest for HF (hydrogen bond) and increases from HCl to HBr to HI (strength of id-id interaction increases).
- Thermal stability of hydrogen halide decreases down group due to decreasing H-X bond energy<sup>5</sup>. (CB: Orbital overlap)

Hydrogen halide	Reaction
HF/ HCl	Little tendency to decompose
HBr	$2HBr(g) \rightarrow H_2(g) + Br_2(g)$ Produces red brown bromine vapour on strong heating
HI	$2HI(g) \rightarrow H_2(g) + I_2(g)$ Gives copious violet fumes of iodine when a red hot steel needle is plunged into a jar of hydrogen iodide

<sup>5</sup> Explanation is part of learning outcome.