PERIOD 3 ELEMENTS AND THEIR COMPOUNDS

Introduction
- the first two periods in the periodic table are not typical
- the first contains only two elements (H, He)
- the second (Li - Ne) contains the top elements of each group; these have small sizes and relatively high ionisation energies so are atypical
- Period 3 is best for studying periodic trends.

ELEMENTS

Structure As you move from left to right the elements go from highly electropositive metals through metalloids with giant structures to the simple molecular structure of non-metals.

Na	Mg	Al	Si	P_4	S_8	Cl_2	Ar
< - - - - *metals* - - - - >			*metalloid*	< - *non metals (simple molecules)* - >			

Reactions with...

Water As you move from left to right across a period the metals become less reactive

Sodium vigorous reaction with cold water; strong alkaline solution formed

$$2Na_{(s)} + 2H_2O_{(g)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$$

very soluble

Magnesium very slow reaction with cold water

$$Mg_{(s)} + 2H_2O_{(g)} \longrightarrow Mg(OH)_{2(s)} + H_{2(g)}$$

sparingly soluble

vigorous reaction with steam

$$Mg_{(s)} + H_2O_{(g)} \longrightarrow MgO_{(s)} + H_{2(g)}$$

Oxygen
- elements must be heated to react; however...
- dry phosphorus can ignite spontaneously which is why it is stored under water
- the reactivity depends a lot on the state of subdivision

Sodium vigorous reaction with ignited sodium
ionic sodium oxide formed

$$4Na_{(s)} + 2O_{2(g)} \longrightarrow 2Na_2O_{(s)}$$

Magnesium vigorous reaction with ignited magnesium
ionic magnesium chloride formed

$$2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$$

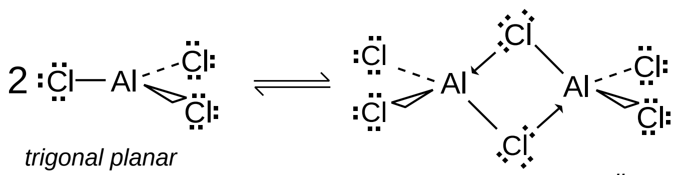
Aluminium	sheets of aluminium get slowly coated with thin oxide layer powdered aluminium shows a vigorous reaction with sparks ionic aluminium oxide formed $4Al_{(s)} + 3O_{2(g)} \longrightarrow 2Al_2O_{3(s)}$
Silicon	vigorous reaction with silicon powder covalent giant molecular silicon dioxide formed $Si_{(s)} + O_{2(g)} \longrightarrow SiO_{2(s)}$
Phosphorus	ignites spontaneously in oxygen - white solid produced $P_{4(s)} + 5O_{2(g)} \longrightarrow P_4O_{10(s)}$
Sulphur	burns with a lilac flame to give a choking gas which fumes in moist air covalent molecules of sulphur dioxide formed $S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$

Chlorine Most can be prepared by direct combination by passing the gas over the heated element
If two chlorides are possible, the higher oxidation state one is formed - get PCl_5 not PCl_3

e.g.	*Sodium*	$2Na_{(s)} + Cl_{2(g)} \longrightarrow 2NaCl_{(s)}$
	Magnesium	$Mg_{(s)} + Cl_{2(g)} \longrightarrow MgCl_{2(s)}$
	Aluminium	$2Al_{(s)} + 3Cl_{2(g)} \longrightarrow 2AlCl_{3(s)}$
	Silicon	$Si_{(s)} + 2Cl_{2(g)} \longrightarrow SiCl_{4(l)}$
	Phosphorus	$2P_{(s)} + 5Cl_{2(g)} \longrightarrow 2PCl_{5(s)}$

Structures

sodium chloride	*giant ionic lattice*	
magnesium chloride	*giant ionic lattice*	
aluminium chloride	*covalent molecule which can exist as a* ***dimer*** *Lewis acid - 6 electrons in outer shell of aluminium*	



trigonal planar
dimer

silicon(IV) chloride	*covalent molecule*	tetrahedral
phosphorus(V) chloride	*covalent molecule*	trigonal bipyramidal

PERIODICITY IN COMPOUNDS

Chlorides - Summary

	NaCl	**$MgCl_2$**	**$AlCl_3$**	**$SiCl_4$**	**PCl_5**	SCl_2	Cl_2
melting point / K	1074	987	450 *(sub)*	203	435 *(sub)*	195	172
bonding	ionic	ionic	covalent	covalent	covalent	covalent	covalent
structure	lattice	lattice	molecular	molecular	molecular	molecular	molecular
solubility in water	very	very	hydrolysed	hydrolysed	hydrolysed		
pH of solution	7	7	5	0	0		

NaCl, $MgCl_2$ — Typical **ionic solids** existing as giant ionic lattices with high melting points
Both dissolve in water to give **neutral solutions** containing separate aqueous ions

Sodium $\mathbf{NaCl_{(s)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}}$

Magnesium $\mathbf{MgCl_{2(s)} \longrightarrow Mg^{2+}_{(aq)} + 2Cl^-_{(aq)}}$

$AlCl_3$ — High charge density of Al^{3+} favours covalency
It is readily hydrolysed giving an **acidic solution**.

$$\mathbf{AlCl_{3(s)} + 6H_2O_{(l)} \longrightarrow [Al(H_2O)_6]^{3+}_{(aq)} + 3Cl^-_{(aq)}}$$

$SiCl_4$ — Availability of 3d orbitals means that it is easily hydrolysed producing an **acidic solution**.

$$\mathbf{SiCl_{4(l)} + 4H_2O_{(l)} \longrightarrow SiO_2.2H_2O_{(s)} + 4HCl_{(aq)}}$$

PCl_5 — Unusual for a non-metallic chloride, it exists as $[PCl_4^+][PCl_6^-]$
Hydrolysed giving **acidic solution**.

$$\mathbf{PCl_{5(s)} + 4H_2O_{(l)} \longrightarrow H_3PO_{4(aq)} + 5HCl_{(aq)}}$$

Across the period...

- *bonding changes from ionic to covalent (more likely to be hydrolysed)*
- *react with water rather than dissolve in it*
- *change from giving neutral solutions to acidic solutions*

Oxides - Summary

	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	SO_3
melting point / K	1548	3125	2345	1833	573 *(subl)*	200	290
bonding	ionic	ionic	ionic/cov	covalent	covalent	covalent	covalent
structure	lattice	lattice	lattice	macromol.	molecular	molecular	molecular
classification	alkaline	alkaline	amphoteric	acidic	acidic	acidic	acidic
solubility in water	very	sparingly	insoluble	insoluble	reacts	reacts	reacts
pH of solution	14	9	7	7	0	3	0

Preparation

- metals produce basic, non-metals produce acidic oxides
- aluminium oxide is an **amphoteric** oxide (it shows acidic and basic properties)
- ionic oxides have high melting points and conduct electricity when molten
- most oxides can be prepared by direct combination (EXC. SO_3)

$$2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)} \qquad S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

Na_2O

Basic, hydrolysed by water to form a strongly alkaline solution.

$$Na_2O_{(s)} + H_2O_{(l)} \longrightarrow 2NaOH_{(aq)}$$

MgO

Very low solubility due to metal's greater charge density

Basic, reacts with acids to form salts.

e.g. $MgO_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2(aq)} + H_2O_{(l)}$

$MgO_{(s)} + H_2SO_{4(aq)} \longrightarrow MgSO_{4(aq)} + H_2O_{(l)}$

Al_2O_3

Insoluble in water.

Amphoteric, it reacts with acids and alkalis to give salts.

with acids $Al_2O_{3(s)} + 6HCl_{(aq)} \longrightarrow 2AlCl_{3(aq)} + 3H_2O_{(l)}$

with alkalis $Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \longrightarrow 2NaAl(OH)_{4(aq)}$

SiO_2

Insoluble in water

Weakly acidic and reacts with alkalis giving silicates.

$$SiO_{2(s)} + 2NaOH_{(aq)} \longrightarrow Na_2SiO_{3(aq)} + H_2O_{(l)}$$

P_4O_{10} Dissolves to give an acidic solution.

$$P_4O_{10(s)} + 6H_2O_{(l)} \longrightarrow 4H_3PO_{4(aq)}$$

SO_2 / SO_3 Acidic, non-metal oxides

Both very soluble and react with water to give acidic solutions.

$$SO_{2(g)} + H_2O_{(l)} \rightleftharpoons 2H^+_{(aq)} + SO_3^{2-}{}_{(aq)}$$ *weak acid*

$$SO_{3(l)} + H_2O_{(l)} \longrightarrow 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$ *strong acid*

Across the period...

- *bonding changes from ionic to covalent*
- *basic metal oxides change to acidic non-metal oxides*
- *change from giving alkaline solutions to acidic solutions*

Q.1 *What are Fajans' Rules? How can they applied to predict covalency?*

Q.2 *What is the difference between a weak acid and a strong acid?*

Q.3 *What shapes have the following ions/molecules;*

SO_2 SO_3^{2-}

SO_3 SO_4^{2-}

Q.4 *Write an equation for the reaction between MgO and nitric acid.*

Q.5 *Explain, in terms of its structure and bonding, why silica has a high melting point*