Periodicity of period 3

N Goalby
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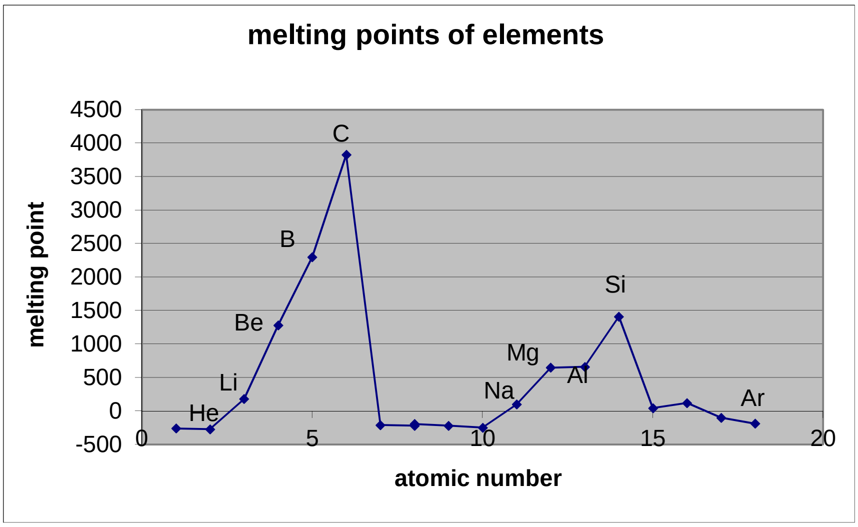
Periodicity is used to describe the repeating pattern of properties (either physical or chemical) from one period to the next.

Periodicity of the melting points



Note the repeating pattern corresponding to the change from metallic to macromolecular to simple molecular.

key

Periodic Variation of Physical Properties

key

Na, Mg, Al

Metallic bonding : strong bonding – gets stronger the more electrons there are in the outer shell that are released to the sea of electrons. A smaller positive centre also makes the bonding stronger

Si

Macromolecular: very strong covalent bonds between atoms. High energy needed to break covalent bonds – very high mp +bp

P_4, S_8, Cl_2

Molecular (Simple covalent): weak van der waals between molecules, so little energy is needed to break them – low mp+ bp

S_8 has a higher mp than P_4 because it has more electrons (S_8 =128)(P_4=60) so has stronger v der w

Ar

The noble gases are monatomic : weak van der waals between atoms so little energy is needed to break them –leads to very low mp+ bp

Reactions of period 3 elements with water

Sodium reacts with cold water

$2\ Na\ (s) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_{2\ (g}$

key

Magnesium reacts very slowly with cold water to form the hydroxide but reacts more readily with steam to form the oxide

$Mg\ (s) + H_2O\ (g) \rightarrow MgO\ (s) + H_2\ (g)$

key

Chlorine disproportionates in water

$Cl_2\ (g) + H_2O\ (l) \rightleftharpoons HClO_{(aq)} + HCl_{(aq)}$

Reactions of period 3 elements with oxygen

The elements all react with oxygen to form oxides.
Na, Mg ,P burn vigorously.

$4\ Na\ (s) + O_{2\ (g)} \rightarrow 2\ \mathbf{Na_2O}\ (s).$
$2Mg\ (s) + O_{2\ (g)} \rightarrow 2\mathbf{MgO}\ (s).$
$4Al + 3O_{2\ (g)} \rightarrow 2Al_2O_3\ (s)$
$Si + O_{2\ (g)} \rightarrow SiO_2\ (s)$
$4P + 5O_{2\ (g)} \rightarrow P_4O_{10}\ (s)$
$S + O_{2\ (g)} \rightarrow SO_2\ (g)$

Sodium burns with a yellow flame to give a white solid

Mg, Al, Si and P burn with a white flame to give white solid smoke

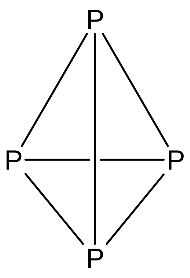
S burns with a blue flame to an acidic choking gas.

Phosphorous can form two oxides P_4O_{10}, P_4O_6
Sulphur can form two oxides SO_2, SO_3

Allotropes of Phosphorus

White phosphorus is P_4 and is simple molecular. It is highly reactive and spontaneously combustible in air. It used in incendiary bombs in the second world war.

Red phosphorus is macromolecular and has a higher melting point. It is still reactive and reacts with oxygen but is it not spontaneously combustible.



Sodium is stored under oil and white phosphorus under water to stop these elements coming into contact and reacting with air

Oxides: bonding and structure

Na_2O MgO Al_2O_3	SiO_2	P_4O_{10} SO_2
Ionic lattices	macromolecular	Simple molecular

The metal oxides are ionic

Larger electronegativity difference between metal and O

Ionic giant lattice structures: strong forces of attraction between ions : higher mp. The increased charge on the cation makes the ionic forces stronger

SiO_2 is **Macromolecular**: very strong covalent bonds between atoms. High energy needed to break covalent bonds – very high mp +bp

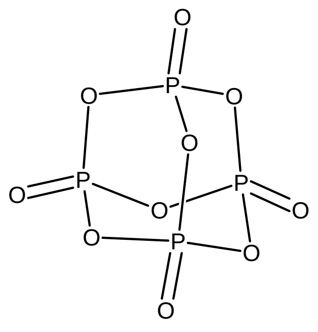
P_4O_{10}, SO_2 are simple molecular

smaller electronegativity difference between non-metal and O

Simple molecular: weak intermolecular forces (van der waals + permanent dipoles) so lower mp's

key

P_4O_{10}

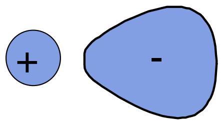


Commonly called phosphorus pentoxide but actually contains 10 oxygens

P_4O_{10} is a molecule containing 4P's and 10 O's.
As it is a bigger molecule and has more electrons than SO_2 it will have larger van der waals forces and a higher melting point. It is a solid

Aluminium Oxide

Al_2O_3 is ionic but does show some covalent character. This can be explained by the electronegativity difference being less big or alternatively by the small aluminium ion with a high charge being able to get close to the oxide ion and distorting the oxide charge cloud



Ionic with covalent character

Aluminium metal is protected from corrosion in moist air by a thin layer of aluminium oxide. The high lattice strength of aluminium oxide and its insolubility in water make this layer impermeable to air and water.

Acid base properties of the oxides

	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2
	basic		amphoteric		acidic	
pH when added to water	13	9	7	7	1	1
			Do not dissolve			

The basic trend is the ionic metal oxides show basic behaviour and the non-metal covalent oxides show acidic behaviour

The slightly intermediate nature of Aluminium oxide is reflected in its amphoteric behaviour: it can act as both a base and an acid

We need to be able to write equations to show the acid base behaviour

Equations to show the basic behaviour of the metal oxides

Ionic metal oxides tend to react with water to form hydroxides which are alkaline

$Na_2O\ (s) + H_2O\ (l) \rightarrow 2Na^+\ (aq) + 2OH^-\ (aq)$ pH14

(this is a vigorous reaction)

$MgO\ (s) + H_2O\ (l) \rightarrow Mg(OH)_2\ (s)$ pH9

MgO is only slightly soluble in water as its lattice is stronger so fewer OH^- ions are produced and so lower pH

The oxide ions accept protons to become hydroxide ions in this reaction so act as bases.

MgO is better than NaOH for treating acid in rivers and the stomach as it is only sparingly soluble and weakly alkaline so using an excess would not make the water excessively alkaline.

Metal oxides also show their basic nature by neutralising acid

$Na_2O\ (s) + 2\ HCl\ (aq) \rightarrow 2NaCl\ (aq) + H_2O\ (l)$

$MgO\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2O\ (l)$

Or show ionically by

$Na_2O\ (s) + 2\ H^+\ (aq) \rightarrow 2Na^+\ (aq) + H_2O\ (l)$

$MgO\ (s) + 2\ H^+\ (aq) \rightarrow Mg^{2+}\ (aq) + H_2O\ (l)$

The strong ionic lattice of Al_2O_3 mean this oxide does not dissolve in water. pH is therefore 7

Aluminium oxide can act as both an acid and an alkali and is therefore called amphoteric

$Al_2O_3\,_{(s)} + 3H_2SO_4\,(aq) \rightarrow Al_2(SO_4)_3\,(aq) + 3H_2O\,(l)$

$Al_2O_3\,_{(s)} + 6HCl\,(aq) \rightarrow 2\,AlCl_3\,(aq) + 3H_2O\,(l)$

$Al_2O_3\,_{(s)} + 2NaOH\,(aq) + 3H_2O \rightarrow 2NaAl(OH)_4$

Sodium aluminate

Or show ionically

$Al_2O_3\,_{(s)} + 6H^+\,(aq) \rightarrow 2\,Al^{3+}\,(aq) + 3H_2O\,(l)$

$Al_2O_3\,_{(s)} + 2OH^-\,(aq) + 3H_2O \rightarrow 2Al(OH)_4^-$

SiO_2

The strong macromolecular structure of covalent bonds in SiO_2 mean this oxide does not dissolve in water. pH is therefore 7

SiO_2 has a giant covalent structure with very strong bonds. This stops SiO_2 reacting with water and weak solutions of alkali. It will, however, react with very concentrated NaOH

$2NaOH\,(l) + SiO_2\,(s) \rightarrow Na_2SiO_3\,_{(aq)} + H_2O$

It is still classed as an acidic oxide

Equations to show the acidic nature of the non-metal oxides

Some of the non-metal, covalent, oxides react with water to give acids

P_4O_{10} (s) + 6 H_2O (l) → $4H_3PO_{4(aq)}$ (this is a vigorous reaction) pH0

SO_2 (g) + H_2O (l) → $H_2SO_{3\ (aq)}$ pH3 (weak acid)

SO_3 (g) + H_2O (l) → $H_2SO_{4\ (aq)}$ pH0

They also react with bases to form salts.

P_4O_{10} (s) + 12 NaOH (aq) → $4Na_3PO_{4(aq)}$ + 6 H_2O (l)

SO_2 (g) + 2NaOH (aq) → $Na_2SO_{3\ (aq)}$ + H_2O (l)

SO_3 (g) + 2NaOH (aq) → $Na_2SO_{4\ (aq)}$ + H_2O (l)

Or show ionically

P_4O_{10} (s) + 12 OH^- (aq) → $4PO_4^{3-}$(aq) + 6 H_2O

SO_2 (g) + $2OH^-$ (aq) → SO_3^{2-} (aq) + H_2O

SO_3 (g) + $2OH^-$ (aq) → SO_4^{2-} (aq) + H_2O

	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10} (or P_4O_6)	SO_3 (or SO_2)	Cl_2O_7
Adding H_2O	Na_2O + H_2O → 2NaOH	MgO + H_2O → $Mg(OH)_2$	Insoluble	Insoluble	P_4O_{10} + $6H_2O$ → $4H_3PO_4$	SO_3 + H_2O → H_2SO_4	Cl_2O_7 + H_2O → $HClO_4$
Adding HCl	Na_2O + H^+ → $2Na^+$ + H_2O	MgO + $2H^+$ → Mg^{2+} + H_2O	Al_2O_3 + $6H^+$ → $2Al^{3+}$ + $3H_2O$	No reaction	No reaction	No reaction	No reaction
Adding NaOH	No reaction	No reactio n	Al_2O_3 + $2OH^-$ + $3H_2O$ → $2Al(OH)_4^-$	SiO_2 + $2OH^-$ → SiO_3^{2-} + H_2O	P_4O_{10} + $12OH^-$ → $4PO_4^{3-}$ + $6H_2O$	SO_3 + OH^- → SO_4^{2-} + H_2O	Cl_2O_7 + OH^- → $2ClO_4^-$ + H_2O
Nature	Basic Oxide	Basic Oxide	Amphot eric Oxide	Acidic Oxide	Acidic Oxide	Acidic Oxide	Acidic Oxide