2.4 Periodicity of Period 3

Trends in the reactions of the elements with water, limited to Na and Mg

Learn the equations

Sodium reacts with cold water. It fizzes around on surface etc.
$2\ Na\ (s) + 2\ H_2O\ (l) \rightarrow 2\ NaOH\ (aq) + H_2\ (g)$

Magnesium reacts very slowly with cold water to form the hydroxide but reacts more readily with **steam** to form the oxide
$Mg\ (s) + H_2O\ (g) \rightarrow MgO\ (s) + H_2\ (g)$

Trends in the reactions of the elements Na, Mg, Al, Si, P and S with oxygen

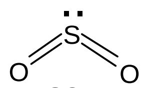
The elements all react with oxygen to form oxides.
Sodium burns with **a yellow flame** to produce a **white solid**
Mg, Al, Si and P burn with a **white flame** to give **white solid** smoke
S burns with a **blue flame** to form an acidic **choking gas**.

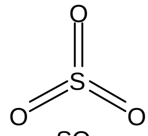
$4\ Na\ (s) + O_2\ (g) \rightarrow 2\ Na_2O\ (s)$
$2Mg\ (s) + O_2\ (g) \rightarrow 2MgO\ (s)$
$4Al + 3O_2\ (g) \rightarrow 2Al_2O_3\ (s)$
$Si + O_2\ (g) \rightarrow SiO_2\ (s)$
$4P + 5O_2\ (g) \rightarrow P_4O_{10}\ (s)$
$S + O_2\ (g) \rightarrow SO_2\ (g)$

You should be able to write these equations.

Learn the formulae of the oxides

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


SO_2


SO_3

A survey of the properties of the oxides of Period 3 elements

Understand the link between the physical properties of the highest oxides of the elements Na $\rightarrow$ S and their structure and bonding.

Ionic oxides
The metal oxides (Na_2O, MgO, Al_2O_3) are ionic. They have high melting points. They have **Ionic giant lattice structures**: strong forces of attraction between ions : higher mp. They are ionic because of the large electronegativity difference between metal and O

The increased charge on the cation makes the ionic forces stronger (bigger lattice enthalpies of dissociation) going from Na to Al so leading to increasing melting points.

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

Macromolecular oxides
SiO_2 is Macromolecular: It has many very strong covalent bonds between atoms. High energy needed to break the many strong covalent bonds – very high mp +bp

Simple molecular oxides:
$P_4O_{10\ (s)}$, $SO_{2\ (g)}$ are simple molecular with weak intermolecular forces between molecules (van der waals + permanent dipoles) so have lower mp's. They are covalent because of the small electronegativity difference between the non-metal and O atoms. 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.

To prove that the above compounds contain ions experimentally - **melt** the solids and show they conduct electricity

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.

Learn the equations !

The reactions of the oxides of the elements Na → S with water

Metal ionic oxides tend to react with water to form hydroxides which are alkaline
Na_2O (s) + H_2O (l) → $2Na^+$ (aq) + $2OH^-$ (aq) **pH 13 (This is a vigorous exothermic reaction)**
The ionic oxides are basic as the oxide ions accept protons to become hydroxide ions in this reaction (acting as a bronsted lowry base)
MgO (s) + H_2O (l) → $Mg(OH)_2$ (s) **pH 9**
$Mg(OH)_2$ is only slightly soluble in water as its lattice is stronger so fewer free OH^- ions are produced and so lower pH

know the change in pH of the resulting solutions across the Period.

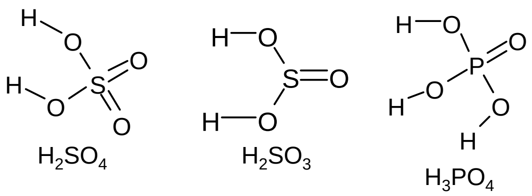
Al_2O_3 and SiO_2 **do not dissolve** in water because of the high strength of the Al_2O_3 ionic lattice and the SiO_2 macromolecular structure, so they give a neutral **pH 7**

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.

The non-metal, **simple molecular**, covalent, oxides react with water to give acids
P_4O_{10} (s) + 6 H_2O (l) → 4 H_3PO_4(aq) **pH 0 (this is a vigorous exothermic reaction)**
SO_2 (g) + H_2O (l) → H_2SO_3 (aq) **pH 3 (weak acid)**
SO_3 (g) + H_2O (l) → H_2SO_4 (aq) **pH 0**

Equations showing formation of ions in solution
SO_2 + H_2O → H^+ + HSO_3^-
SO_3 + H_2O → H^+ + HSO_4^-

The trend is the **ionic metal oxides** show **basic** behaviour and the **non-metal covalent** oxides show **acidic** behaviour. The slightly intermediate nature of the bonding in Aluminium oxide is reflected in its amphoteric behaviour: it can act as both a base and an acid



Displayed formulae of acids

Acid base reactions between period 3 oxides and simple acids and bases.

The **basic oxides** react with acids to make salts
Na_2O (s) + 2 HCl (aq) → 2NaCl (aq) + H_2O (l)
Na_2O (s) + H_2SO_4 (aq) → Na_2SO_4 (aq) + H_2O (l)
MgO (s) + 2 HCl (aq) → $MgCl_2$ (aq) + H_2O (l)
Or ionically
Na_2O (s) + $2H^+$ (aq) → $2Na^+$ (aq) + H_2O (l)
MgO (s) + 2 H^+ (aq) → Mg^{2+} (aq) + H_2O (l)

Rather than learning the equations by rote, learn the pattern.
Most follow the pattern acid + base → salt + water
Know the charges on the ions e.g. PO_4^{3-} , SO_4^{2-}

Amphoteric Oxides
Aluminium oxide can act as both an acid and an alkali and is therefore called amphoteric
Aluminum oxide acting as a **base**
Al_2O_3 (s)+ $3H_2SO_4$ (aq)→ $Al_2(SO_4)_3$ (aq) + $3H_2O$ (l)
Al_2O_3 + 6HCl → $2AlCl_3$ + $3H_2O$
Or ionically Al_2O_3 + $6H^+$ → $2Al^{3+}$ + $3H_2O$

Aluminum oxide acting as a **acid**
Al_2O_3 (s)+ 2NaOH (aq) + $3H_2O$ (l) → $2NaAl(OH)_4$ (aq) (this equation needs learning carefully)
Al_2O_3 (s)+ $2OH^-$ (aq) + $3H_2O$ (l) → $2Al(OH)_4^-$ (aq)

Be careful for whether the question is asking for an ionic equation or a full one

The other simple molecular acidic oxides react with bases to form salts.
P_4O_{10} (s) + 12 NaOH (aq) → $4Na_3PO_4$(aq) + 6 H_2O (l)
P_4O_{10} + 6 Na_2O → $4Na_3PO_4$
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 (l)
SO_2 (g) + $2OH^-$ (aq) → SO_3^{2-} (aq) + H_2O (l)
SO_3 (g) + $2OH^-$ (aq) → SO_4^{2-} (aq) + H_2O (l)

SiO_2 has a **giant covalent structure** with very strong bonds. This stops SiO_2 dissolving or reacting with water and weak solutions of alkali. It will, however, react with very concentrated NaOH
2NaOH (l) + SiO_2 (s)→ Na_2SiO_3 (aq) + H_2O
It is still classed as an acidic oxide