

9 The Periodic Table: chemical periodicity

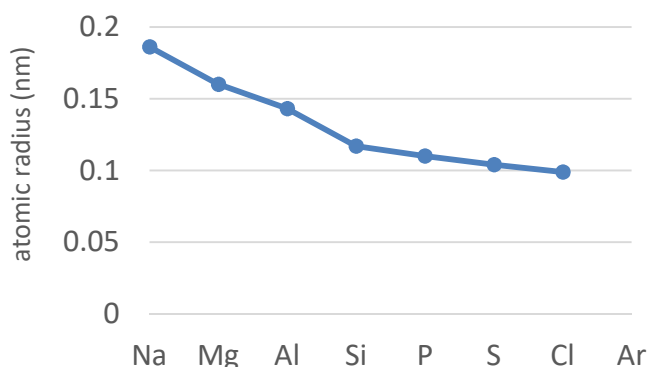
Period 2 = Li, Be, B, C, N, O, F, Ne

Period 3 = Na, Mg, Al, Si, P, S, Cl, Ar

Atomic radius

Atomic radii **decrease** as you move from left to right across a period, because the **increased number of protons** create more positive charge attraction for **electrons which are in the same shell** with similar shielding.

Exactly the same trend in period 2

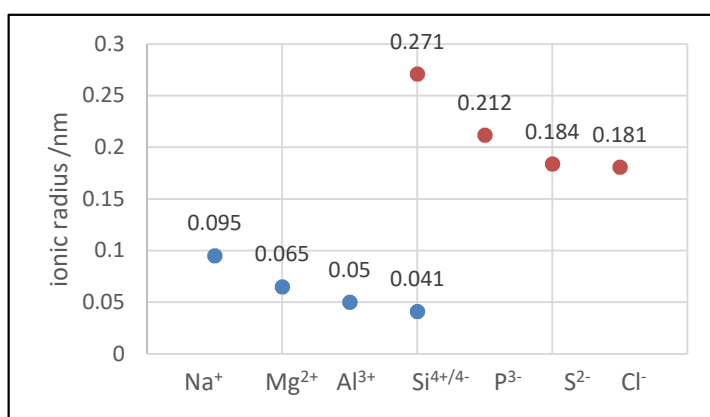


Ionic radius

Na^+ Mg^{2+} Al^{3+} Si^{4+} all have the same electronic structure (of the noble gas Ne)

There are increasing numbers of protons from Na to Si but the same number of electrons. The effective nuclear attraction per electron therefore increases and ions get smaller

Positive ions are smaller compared to their atoms because it has one less shell of electrons and the ratio of protons to electrons has increased so there is greater net force on remaining electrons holding them more closely.



Similarly Si^{4-} P^{3-} S^{2-} Cl^- all have the same electronic structure (of the noble gas Ar)

There are increasing numbers of protons from Si to Cl but the same number of electrons. The effective nuclear attraction per electron therefore increases and ions get smaller

Melting and boiling points

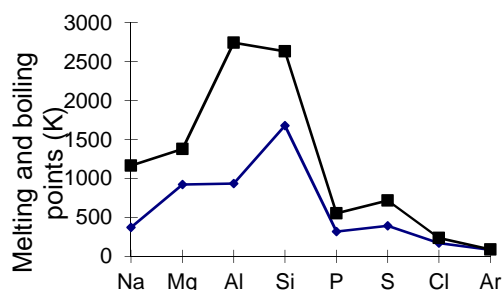
For **Na, Mg, Al** - **Metallic** bonding : strong bonding – gets stronger the more electrons there are in the outer shell that are released to the sea of electrons. A smaller positive centre also makes the bonding stronger. Higher energy is needed to break bonds.

Si is **Macromolecular**: many strong covalent bonds between atoms, high energy needed to break covalent bonds– very high mp +bp

Cl_2 (g), S_8 (s), P_4 (s) - **simple Molecular** : 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 ($\text{S}_8 = 128$)($\text{P}_4 = 60$) so has stronger v der w between molecules

Ar is **monoatomic** weak **van der waals** between atoms



Similar trend in period 2

Li, Be metallic bonding (high mp)

B, C macromolecular (very high mp)

N_2 , O_2 molecular (gases! Low mp as small v der w)

Ne monoatomic gas (very low mp)

Electrical conductivity

Elements with metallic bonding

Sodium, magnesium and aluminium are all good conductors of electricity. The conductivity increases as you go from sodium through to aluminium, as they have successively more delocalized electrons per atom

Macromolecular

Silicon is a semiconductor.

Simple molecular P₄ S₈ Cl₂, mono atomic Ar

These do not conduct electricity. There are no free electrons to move.

1st ionisation energy

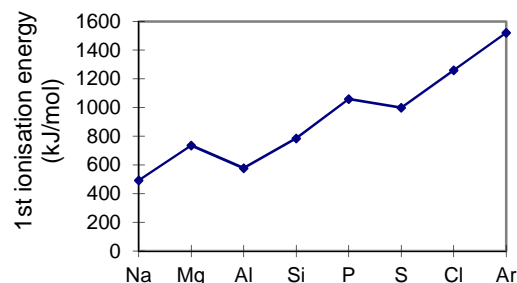
There is a **general trend** across is to **increase**. This is due to **increasing number of protons** as the electrons are being added to the same shell

There is a **small drop between Mg + Al**. Mg has its outer electrons in the 3s sub shell, whereas **Al is starting to fill the 3p** subshell. Al's electron is slightly easier to remove because the **3p electrons are higher in energy**.

There is a **small drop between phosphorous and sulphur**.

Sulphur's outer electron is being **paired up** with another electron in the **same 3p orbital**.

When the second electron is added to an orbital there is a slight **repulsion** between the two negatively charged electrons which makes the second electron easier to remove.



Exactly the same trend in period 2 with drops between Be & B and N to O for same reasons- make sure change 3s and 3p to 2s and 2p in explanation!

Ceramics

Magnesium oxide (giant ionic), aluminium oxide (giant ionic) and silicon dioxide (giant covalent) can all be classed as ceramics. They have important properties in common that are useful.

High melting points and strength - high

For ionic ones high because of giant lattice of ions with strong electrostatic forces between oppositely charged ions

For giant covalent ones- high- because of many strong covalent bonds in macromolecular structure. Take a lot of energy to break the many strong bonds

Electrical conductivity -low

For ionic ones poor: ions can't move/ fixed in lattice

For giant covalent ones- poor, because electrons can't move (localised)

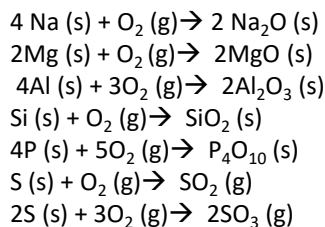
Trends in the reactions of the elements Na, Mg, Al, Si, P and S with oxygen

The elements all react with oxygen to form oxides.

Sodium burns with a **yellow flame** to produce a **white solid**

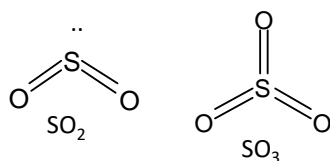
Mg, Al, Si and P burn with a **white flame** to give **white solid** smoke

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



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

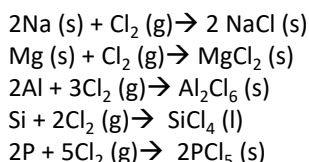


Note: the highest oxidation number of the element in the oxide is the same as the number of valence electrons in the element

oxide	O.N.
Na ₂ O	+1
MgO	+2
Al ₂ O ₃	+3
SiO ₂	+4
P ₄ O ₁₀	+5
SO ₃	+6

Reactions of the elements Na, Mg, Al, Si, P and S with chlorine

The elements of period 3 all react with chlorine to form chlorides.



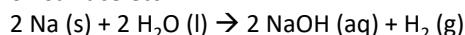
Note: the highest oxidation number of the element in the chloride is the same as the number of valence electrons in the element

oxide	O.N.
NaCl	+1
MgCl ₂	+2
Al ₂ Cl ₆	+3
SiCl ₄	+4
PCl ₅	+5

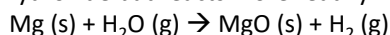
Trends in the reactions of the elements with water, limited to Na and Mg

Learn the equations

Sodium reacts with cold water. It fizzes around on surface etc.



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



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

Ionic oxides

The metal oxides (Na₂O, MgO, Al₂O₃) 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.

Al₂O₃ 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

SiO₂ 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

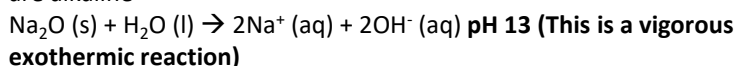
Simple molecular oxides:

P₄O_{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. P₄O₁₀ is a molecule containing 4P's and 10 O's. As it is a bigger molecule and has more electrons than SO₂ it will have larger van der waals forces and a higher melting point.

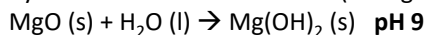
The reactions of the oxides of the elements Na → S with water

Learn the equations !

Metal ionic oxides tend to react with water to form hydroxides which are alkaline



The ionic oxides are basic as the oxide ions accept protons to become hydroxide ions in this reaction (acting as a bronsted lowry base)



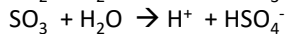
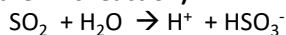
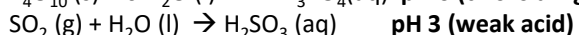
Mg(OH)₂ is only slightly soluble in water as its lattice is stronger so fewer free OH⁻ ions are produced and so lower pH

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

Al₂O₃ and SiO₂ **do not dissolve** in water because of the high strength of the Al₂O₃ ionic lattice and the SiO₂ 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.

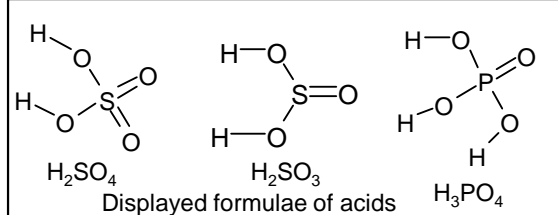
The non-metal, **simple molecular**, covalent, oxides react with water to give acids



Equations showing formation of ions in solution

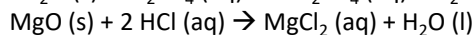
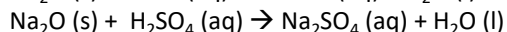
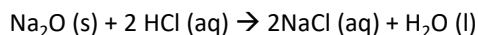
The trend is the **ionic metal oxides** show **basic** behaviour and the **non-metal covalent** oxides show **acidic** behaviour.

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

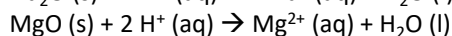
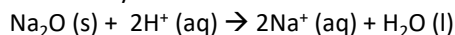


Acid base reactions between period 3 oxides and simple acids and bases.

The **basic oxides** react with acids to make salts



Or ionically

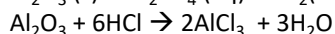
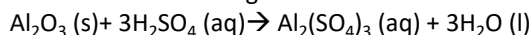


Rather than learning the equations by rote, learn the pattern. Most follow the pattern acid + base \rightarrow salt + water
Know the charges on the ions e.g. PO_4^{3-} , SO_4^{2-}

Amphoteric Oxides

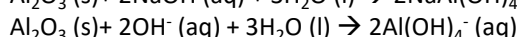
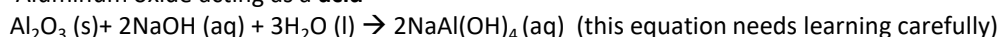
Aluminium oxide can act as both an acid and an alkali and is therefore called amphoteric

Aluminium oxide acting as a **base**



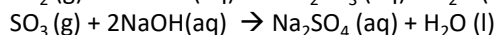
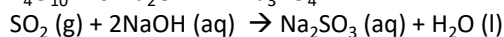
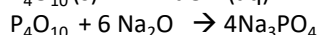
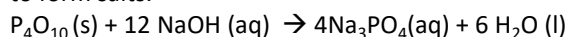
Or ionically $\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$

Aluminium oxide acting as a **acid**

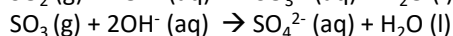
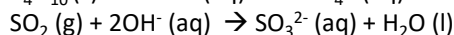
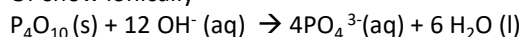


Be careful for whether the question is asking for an ionic equation or a full one

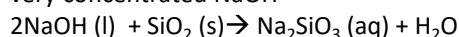
The other simple molecular acidic oxides react with bases to form salts.



Or show ionically



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



It is still classed as an acidic oxide

Bonding in period 3 chlorides

The metal chlorides (Na and Mg) are ionic

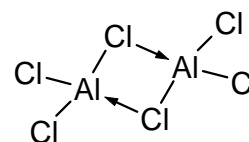
Ionic giant lattice structures: strong forces of attraction between ions : higher mp

Aluminium chloride is a simple covalent molecule because of the relatively small difference in electronegativity between Al and Cl. It exists as a dimer Al_2Cl_6

The non-metal chlorides are simple molecular SiCl_4

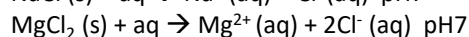
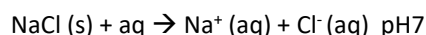
Simple molecular: weak intermolecular forces (van der Waals) so lower mp's

PCl_5 has a higher than expected melting point because in solid phase it exists as a ionic structure of $\text{PCl}_4^+ \text{PCl}_6^-$



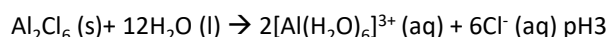
The reactions of the chlorides of the elements Na \rightarrow P with water

Ionic chlorides eg Na + Mg **dissolve** (and not hydrolyse) in water to form aqueous ions and **neutral** solutions

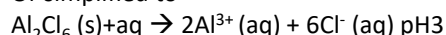


Covalent chlorides **react with water (hydrolyse)** to form **acidic** solutions

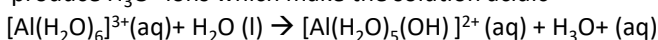
Aluminium chloride has covalent character. It dissolves in water to form an acidic solution. (Unlike Na and Mg which form neutral solutions when they dissolve in water.)



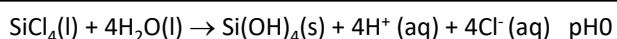
Or simplified to



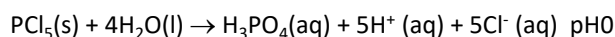
The $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ then reacts (hydrolyses) with water to produce H_3O^+ ions which make the solution acidic



Note: Al acts more like the non-metals because its chloride is covalent



Observation: this is a vigorous exothermic reaction and a white solid/gel forms



Observation: this is a vigorous exothermic reaction