

Topic 5.2

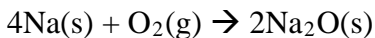
PERIODICITY

The oxides of period 3 elements
The reaction of period 3 elements with water

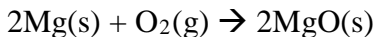
THE OXIDES OF PERIOD 3 ELEMENTS

1. Formation of oxides

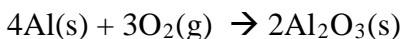
All the elements in Period 3 except chlorine and argon combine directly with oxygen to form oxides.



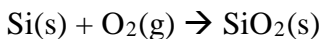
Na_2O is an ionic oxide.



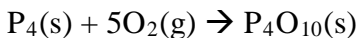
MgO is also an ionic oxide.



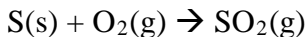
Al_2O_3 is mostly ionic, but there is significant covalent character.



SiO_2 is a giant covalent oxide.



P_4O_{10} is a molecular covalent oxide. The oxidation number of P in this oxide is +5.



SO_2 is a molecular covalent oxide.

Another oxide, SO_3 is formed in a reversible process when SO_2 and O_2 are heated with a V_2O_5 catalyst (the Contact Process)

2. Physical properties of oxides

The physical properties of these oxides depend on the type of bonding.

Na₂O, Al₂O₃ and MgO are ionic oxides and hence have a high melting point. MgO and Al₂O₃ have a higher melting point than Na₂O since the charges are higher, resulting in a stronger attraction between the ions.

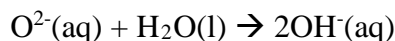
SiO₂ has a giant covalent structure and hence a high melting point. There are strong covalent bonds between all the atoms and thus lots of energy is required to break them.

P₄O₁₀ and SO₃ are molecular covalent and so only intermolecular forces exist between the molecules. The melting points are thus much lower. P₄O₁₀ is a much bigger molecule than SO₃ and so has a much higher melting point, as the van der Waal's forces are stronger.

| Element | Na | Mg | Al | Si | P | S |
|----------------------------|-------------------|-------|--------------------------------|------------------|--------------------------------|--------------------|
| Formulae of oxide | Na ₂ O | MgO | Al ₂ O ₃ | SiO ₂ | P ₄ O ₁₀ | SO ₃ |
| Structure of oxide | Ionic | Ionic | Mostly ionic | Giant covalent | Molecular covalent | Molecular covalent |
| Melting point of oxide /°C | 1275 | 2852 | 2072 | 1703 | 300 | -10 |

3. Acid-base character of oxides

Ionic oxides contain the O²⁻ ion. This is a strongly basic ion which reacts with water to produce hydroxide ions:



Thus all ionic oxides are BASIC.

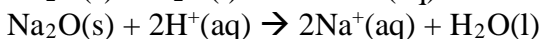
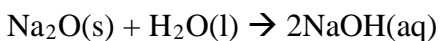
Covalent oxides do not contain ions, but have a strongly positive dipole on the atom which is not oxygen. This attracts the lone pair on water molecules, releasing H⁺ ions:



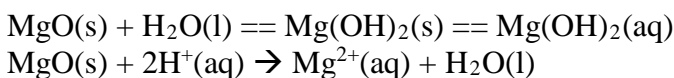
Thus all covalent oxides are ACIDIC.

Intermediate oxides can react in either of the above ways, depending on the conditions. They can thus behave as either acids or bases and are thus AMPHOTERIC.

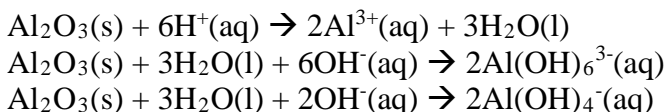
Na₂O is a basic oxide. It dissolves in water to give an alkaline solution (pH = 14). It also reacts with acids:



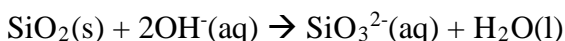
MgO is a basic oxide. It is only slightly soluble in water and so the solution is only slightly alkaline (pH = 9). It reacts readily with acids:



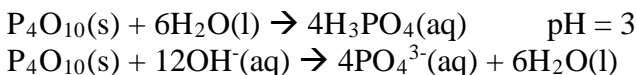
Al₂O₃ is an amphoteric oxide. It is insoluble in water (pH = 7) but dissolves in both acids and alkalis:



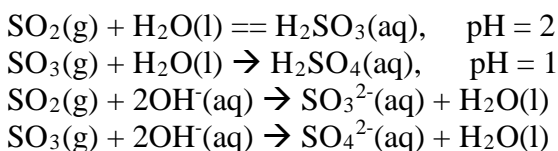
SiO₂ is an acidic oxide. It is insoluble in water (pH = 7) but dissolves in hot concentrated alkalis:



P₄O₁₀ is an acidic oxide. It dissolves in water to give acidic solutions and is also soluble in alkalis:



SO₂ and SO₃ are acidic oxides. They dissolve in water to give acidic solutions, and also react with alkalis:



SO₂ is a waste gas in many industrial processes. It is harmful because it dissolves in rain water to give acid rain. It can be removed from waste gases because it dissolves in alkali and so it is passed through an alkaline solution in waste gas outlets to minimise the amount which escapes into the atmosphere.

The acid-base properties of the oxides of Period 3 can be summarised in the following table:

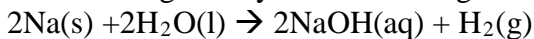
| Element | Na | Mg | Al | Si | P | S |
|--|-------------------|-------|--------------------------------|------------------|--------------------------------|--|
| Formulae of oxides | Na ₂ O | MgO | Al ₂ O ₃ | SiO ₂ | P ₄ O ₁₀ | SO ₂ SO ₃ |
| Acid-base character of oxide | Basic | Basic | Amphoteric | Acidic | Acidic | Acidic |
| pH of solution when dissolved in water | 12 - 14 | 8 - 9 | 7 (insoluble) | 7 (insoluble) | 2 - 4 | 2 - 4 (SO ₂) 1 - 3 (SO ₃) |

The oxides therefore become more acidic on moving from left to right in the periodic table.

THE REACTION OF PERIOD 3 ELEMENTS WITH WATER

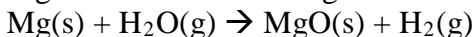
Na, Mg, Al and Si are more electropositive than H and can reduce the water to hydrogen gas:

Na reacts vigorously with water to give the hydroxide and hydrogen:



The resulting solution is strongly alkaline, and will have a pH of 14.

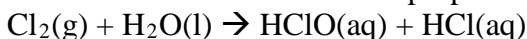
Mg reacts with steam to give the oxide and hydrogen:



The resulting solution is weakly alkaline, since the oxide is slightly basic (pH = 9).

Al and Si also react with steam under certain conditions.

P, S and Cl₂ do not reduce water to hydrogen gas. Phosphorus and sulphur do not react with water but chlorine will disproportionate to give an acidic solution:



The resulting solution contains HCl(aq) and is thus acidic (pH = 2).

The reactivity of the elements of period 3 towards water thus decreases from Na to Si, and then increases from P to Cl. The resulting solutions become increasingly acidic.