

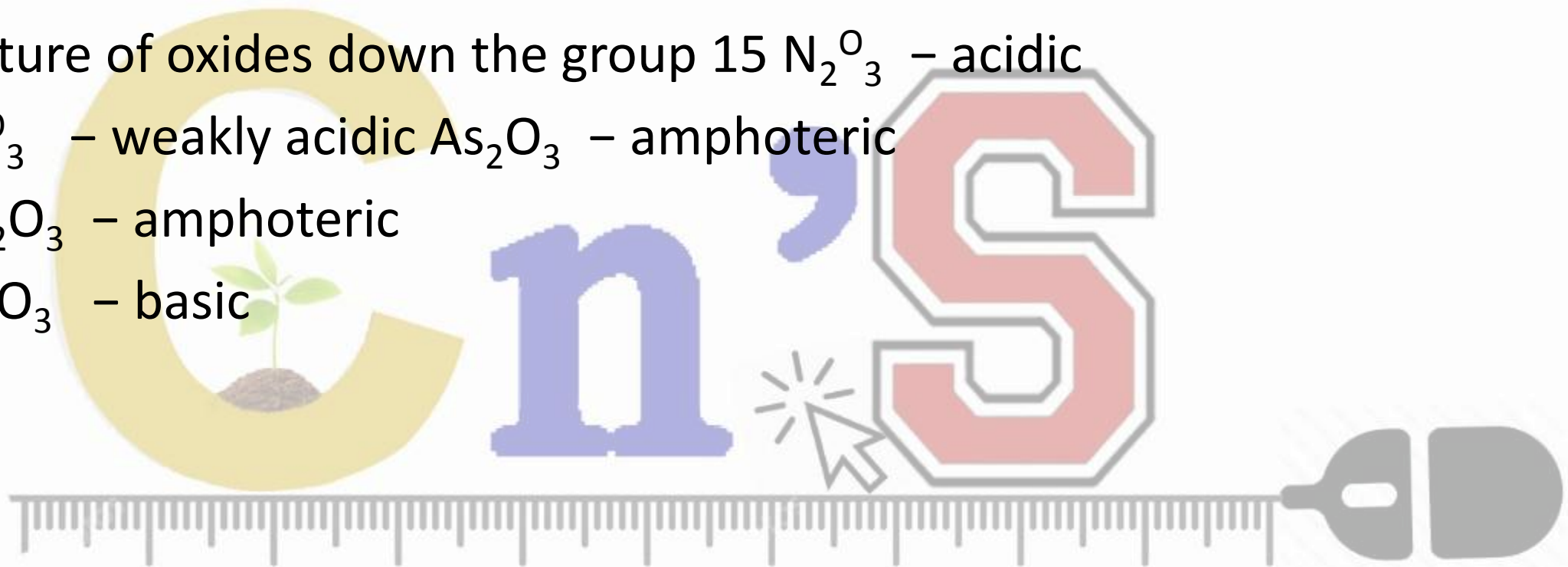
- Acidic/basic/amphoteric nature of halides (eg. chlorides) of third period

NaCl	MgCl <sub>2</sub>	AlCl <sub>3</sub>	SiCl <sub>4</sub>	PCl <sub>5</sub>	SCl <sub>2</sub> /S <sub>2</sub> Cl <sub>2</sub>
Neutral	very weakly acidic	acidic	acidic	acidic	acidic

- Acidic/basic/amphoteric nature of oxides of elements of the 3<sup>rd</sup> period

Na <sub>2</sub> O	MgO	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	P <sub>2</sub> O <sub>5</sub>	SO <sub>2</sub> /SO <sub>3</sub>	Cl <sub>2</sub> O <sub>7</sub>
Strongly basic	Basic	Amphoteric	Very weakly acidic	Weakly acidic	Acidic	Strongly acidic

- Nature of oxides down the group 15  $\text{N}_2\text{O}_3$  – acidic
- $\text{P}_2\text{O}_3$  – weakly acidic  $\text{As}_2\text{O}_3$  – amphoteric
- $\text{Sb}_2\text{O}_3$  – amphoteric
- $\text{Bi}_2\text{O}_3$  – basic



- Acidic/basic/amphoteric nature of hydroxides of elements of the 3<sup>rd</sup> period

NaOH	Mg(OH) <sub>2</sub>	Al(OH) <sub>3</sub>	Si(OH) <sub>4</sub>	P(OH) <sub>5</sub>	S(OH) <sub>6</sub>	Cl(OH) <sub>7</sub>
			-H <sub>2</sub> O	-H <sub>2</sub> O	-2H <sub>2</sub> O	-3H <sub>2</sub> O
NaOH	Mg(OH) <sub>2</sub>	Al(OH) <sub>3</sub>	H <sub>2</sub> SiO <sub>3</sub>	H <sub>3</sub> PO <sub>4</sub>	H <sub>2</sub> SO <sub>4</sub>	HClO <sub>4</sub>
Strongly basic	Basic	Amphoteric	Very weakly acidic	Weakly acidic	Strongly acidic	Very strongly acidic

- Acidic/basic/amphoteric nature of hydrides of the 3<sup>rd</sup> period

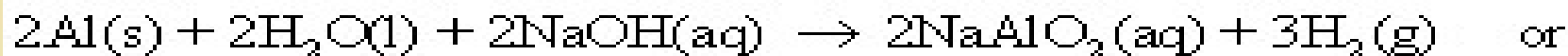
NaH	MgH <sub>2</sub>	AlH <sub>3</sub>	SiH <sub>4</sub>	PH <sub>3</sub>	H <sub>2</sub> S	HCl
Strongly basic	Weakly basic	Amphoteric	Very weakly acidic	Very weakly basic	Weakly acidic	Very strongly acidic

- Carries out the suggested practical under the competency level 6.3 and reports them.

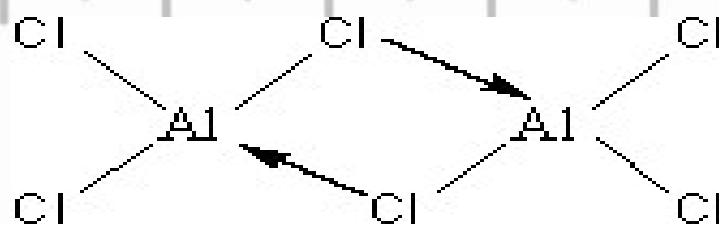
### Guidance for teacher elaboration :

- **Aluminium**

Al is an amphoteric metal. It reacts with acids and strong bases.



$\text{AlCl}_3$  is an electron deficient compound and also highly covalent when anhydrous.  $\text{AlCl}_3$  exists as a dimer thus attaining an octet of electrons.



$\text{Al}_2\text{Cl}_6$  Dimer

# 13.1 REACTIONS OF PERIOD 3 ELEMENTS

## GROUP 3

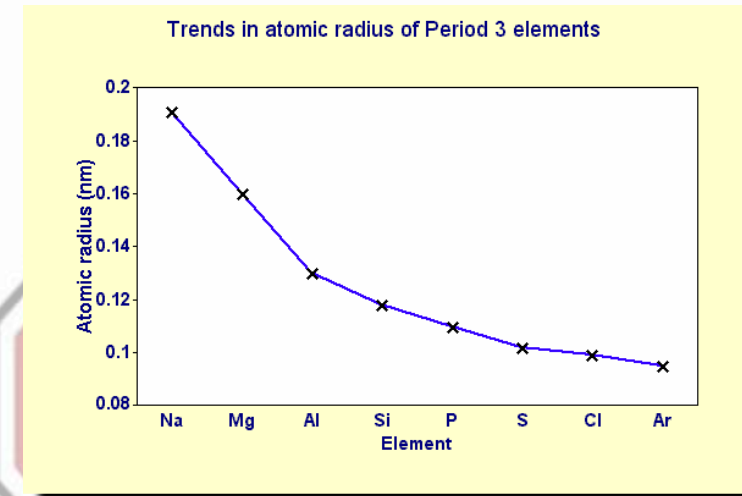
1	2											3	4	5	6	7	0
																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg							

Alkali metals	Halogens
Transition metals	Noble gases

# 13.1 REACTIONS OF PERIOD 3 ELEMENTS

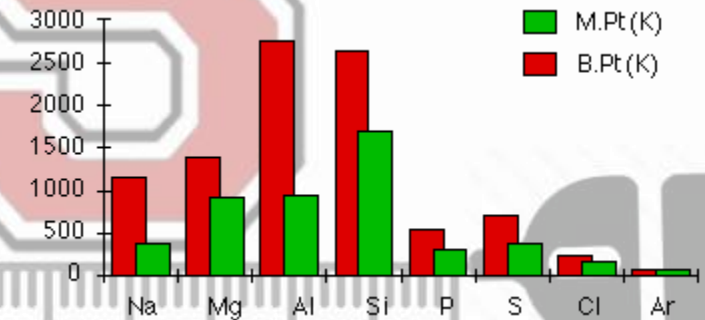
## Atomic Radius

- Decreases across period
- Extra protons pull electrons closer
- No extra shielding



## Melting/Boiling Point

- Increase up to silicon then decrease
- Metallic bonding in Na, Mg and Al
- Macromolecular tetrahedral structure in Si
- P, S, Cl are all molecular - M.P & B.P depend on VdW
- Ar exists as individual atoms





Formula of Chloride	$\text{Na}_2\text{O}$	$\text{MgO}$	$\text{Al}_2\text{O}_3$	$\text{SiO}_2$	$\text{P}_4\text{O}_{10}$ (or $\text{P}_4\text{O}_6$ )	$\text{SO}_3$ (or $\text{SO}_2$ )	$\text{Cl}_2\text{O}_7$ $\text{Cl}_2\text{O}$
<b>Melting Point</b>	1275	2852	2027	1610	24	17	-92
<b>Electrical in molten state</b>	Good	Good	Good	None	None	None	None
<b>Nature</b>	Basic Oxide	Basic Oxide	Amphoteric Oxide	Acidic Oxide	Acidic Oxide	Acidic Oxide	Acidic Oxide

For IB you need to think about why the chlorides and oxides have these properties



- **Na<sub>2</sub>O** Basic  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$
- **MgO** Basic  $\text{MgO} + \text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2$
- **Al<sub>2</sub>O<sub>3</sub>** Aluminium Oxide is amphoteric
  - As a base:  $\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 2\text{H}_2\text{O}$
  - As an acid:  $\text{Al}_2\text{O}_3 + 6\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{Na}_3\text{Al(OH)}_6$
- **SiO<sub>2</sub>** Acidic  $\text{SiO}_2 + 2\text{NaOH} \rightarrow 2\text{Na}_2\text{SiO}_3 + \text{H}_2\text{O}$
- **P<sub>4</sub>O<sub>10</sub>** Acidic  $\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$
- **SO<sub>2</sub>** Acidic  $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$
- **SO<sub>3</sub>** Acidic  $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$

13.1.1 Explain the physical states and electrical conductivity (in the molten state) of the chlorides and oxides of the elements in period 3 in terms of their bonding and structure.

## Solids, liquids and Gases

- $\text{Na}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{P}_4\text{O}_{10}$ ,  $\text{P}_4\text{O}_6$ ,  $\text{NaCl}$ ,  $\text{MgCl}_2$ ,  $\text{Al}_2\text{Cl}_6$ , and  $\text{AlCl}_3$  are all **SOLIDS** under standard conditions, due to their **strong ionic bonds** (lattice structure) or **network covalent bonds** (i.e.  $\text{SiO}_2$ ,  $\text{P}_4\text{O}_{10}$ ,  $\text{P}_4\text{O}_6$ ,  $\text{Al}_2\text{Cl}_6$ , and  $\text{AlCl}_3$ ).
- $\text{SO}_3$ ,  $\text{Cl}_2\text{O}_7$ ,  $\text{SiCl}_4$ , and  $\text{PCl}_3$  are liquids at room temperature due to their weaker covalent bonds and stronger intermolecular forces.
- $\text{SO}_2$ ,  $\text{Cl}_2\text{O}$ , and  $\text{Cl}_2$  are gases under standard conditions due to their weaker intermolecular forces.

- $\text{Na}_2\text{O}$ ,  $\text{MgO}$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{NaCl}$ , and  $\text{MgCl}_2$  are good electrical conductors in the molten state, as their ionic bonds give up mobile charged electrons when the compounds undergo melting.
- $\text{SiO}_2$ ,  $\text{Al}_2\text{Cl}_6$ , and  $\text{AlCl}_3$  are network covalent compounds and so have no significant conductivity.
- The other compounds are covalent compounds and do not have mobile electrons to transport charge, so they are not conductors.

# To summarise.....

- The compounds ionic and covalent nature will determine its physical state and conductivity in its molten state.
- The intermolecular forces will determine its melting and boiling points of course.

Study Note: This where the periodic table comes in handy. Instead of memorising which is ionic covalent etc, look at the trends in the information above.

# 13.1 REACTIONS OF PERIOD 3 ELEMENTS

## REACTIONS WITH WATER

### Sodium:

Reacts vigorously forming a molten ball on the surface, fizzing and producing  $H_2$  gas



### Magnesium:

Reacts slowly with no visible reaction

It forms a weakly alkaline solution  $\rightarrow$  how we know it reacts



## 13.1 REACTIONS OF PERIOD 3 ELEMENTS

### WHY DOES SODIUM REACT MORE?

When they react:

- Na loses 1 electron
- Mg loses 2 electrons

It takes less energy to remove 1 electron than it does 2

More energy (usually heat) is needed for Mg to react

$\text{Mg}(\text{OH})_2$  is not very soluble in water, so produces relatively few  $\text{OH}^-$  ions. This makes it a weaker alkali than  $\text{NaOH}$



## 13.1 REACTIONS OF PERIOD 3 ELEMENTS

### REACTIONS WITH OXYGEN

Element	Oxide	Oxidation State of Element	Extent of Reaction	Flame
Na	$\text{Na}_2\text{O}$	+1	Vigorous	Yellow
Mg	$\text{MgO}$	+2	Vigorous	Brilliant White
Al	$\text{Al}_2\text{O}_3$	+3	Slow	N/A
Si	$\text{SiO}_2$	+4	Slow	N/A
P	$\text{P}_4\text{O}_{10}$	+5	One allotrope* spontaneously combusts; the other requires heating	Brilliant White
S	$\text{SO}_2$	+4	Burns steadily	Blue

\***Allotrope**: same element but atoms arranged differently



## 13.2 OXIDES OF ELEMENTS IN PERIOD 3

### TRENDS IN THE PHYSICAL PROPERTIES

*Metal Oxides*  $\rightarrow$   $\text{Na}_2\text{O}$ ,  $\text{MgO}$  &  $\text{Al}_2\text{O}_3$

- High melting points  $\rightarrow$  giant ionic lattices
- Strong forces of attraction between each ion
- Lots of heat energy required to break bonds
- $\text{MgO}$  is higher than  $\text{Na}_2\text{O}$  because  $2+$  ions attract  $\text{O}^{2-}$  ions more strongly than  $1+$  sodium ions
- $\text{Al}_2\text{O}_3$  is lower than expected because  $3+$  ions are small with a high charge  $\rightarrow$  this distorts oxygen's electron cloud making the bond partially covalent

## 13.2 OXIDES OF ELEMENTS IN PERIOD 3

### TRENDS IN THE PHYSICAL PROPERTIES

*Non-metal Oxides* →  $\text{SiO}_2$ ,  $\text{P}_4\text{O}_{10}$  &  $\text{SO}_2$

$\text{SiO}_2$  is highest of non-metal oxides:

- forms a giant macromolecular structure.
- Strong bonds that require lots of energy to be broken

$\text{P}_4\text{O}_{10}$  &  $\text{SO}_2$  are simple covalent molecules.

→ Weak intermolecular forces

→ Dipole-Dipole forces

→ Van der Waals forces

## 13.2 OXIDES OF ELEMENTS IN PERIOD 3

Ionic oxides of Na & Mg dissolve to form hydroxides

Form alkaline solutions

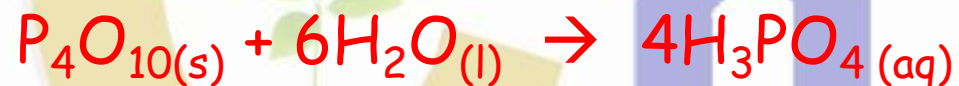
Sodium hydroxide is more soluble in water, so forms a more alkaline solution than magnesium hydroxide



## 13.2 OXIDES OF ELEMENTS IN PERIOD 3

Simple covalent oxides (P and S) form acidic solutions

Phosphorous (V) oxide reacts violently to form phosphoric acid:



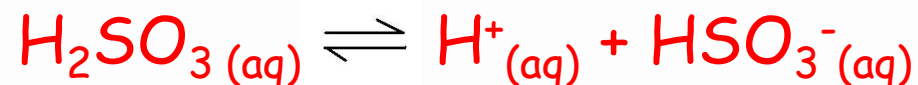
← This ionises:



Sulphur dioxide reacts to form sulphuric (IV) acid:



← partially dissociates



## 13.2 OXIDES OF ELEMENTS IN PERIOD 3

Sulphur trioxide reacts violently to form sulphuric (VI) acid:

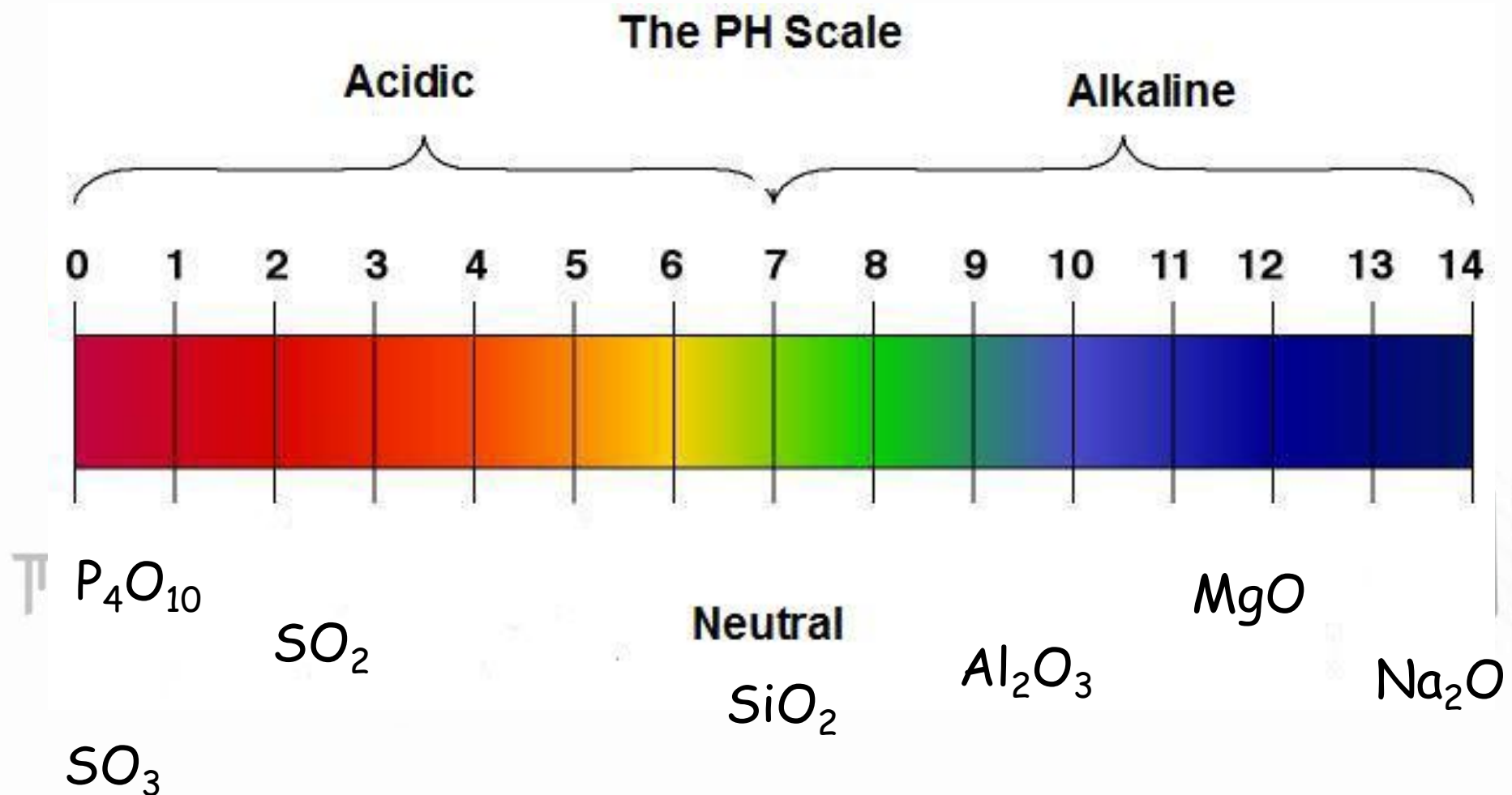


Giant covalent structure of silicon dioxide means it is insoluble. It will react with bases to form salts so is classed as acidic

Aluminium oxide is also insoluble. It will react with acids AND bases to form salts. i.e. it can act as an acid OR a base → **AMPHOTERIC**

## 13.3 OXIDES WITH ACIDS & BASES

pH OF PERIOD 3 OXIDES:



## 13.3 OXIDES WITH ACIDS & BASES

### A CLASSIC

The equation for neutralising an acid with a base is a classic



It's no different for Period 3 oxides

You will be expected to write the equations



## 13.3 OXIDES WITH ACIDS & BASES

### SODIUM & MAGNESIUM:

These oxides are basic so will neutralise acids.

E.g. Sodium oxide reacts with hydrochloric acid to form Sodium chloride and water



E.g. Magnesium oxide reacts with sulphuric acid to form magnesium sulphate and water



## 13.3 OXIDES WITH ACIDS & BASES

### ALUMINIUM OXIDE:

This is an **amphoteric** oxide → it can react with both acids and alkalis

E.g. With sulphuric acid, aluminium sulphate is formed



E.g. With hot, concentrated sodium hydroxide, sodium aluminate is formed



## 13.3 OXIDES WITH ACIDS & BASES

### SILICON, PHOSPHOROUS & SULPHUR:

These oxides are all acidic so will neutralise bases



Phosphorous (V) Oxide (Phosphorous pentoxide) is actually more complicated than this.

# Diamond



Since all the valence electrons of carbon are strongly held in carbon-carbon bonds, diamond is a poor conductor of electricity.

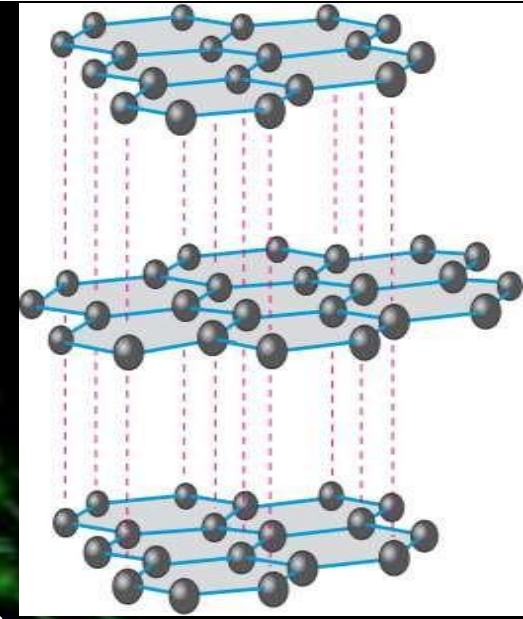
- (a) Diamond: Diamond has a network structure consisting of a very large number of carbon atoms bonded to each other. Each carbon atom is  $sp^3$  hybridized and is bonded to four other carbon atoms by single covalent bonds. There is a three – dimensional network of strong covalent bonds in diamond. This makes diamond an extremely hard crystal with very high melting point (about 3843 K).
- Since all the valence electrons of carbon are strongly held in carbon – carbon bonds, diamond is a poor conductor of electricity.1/18/2017



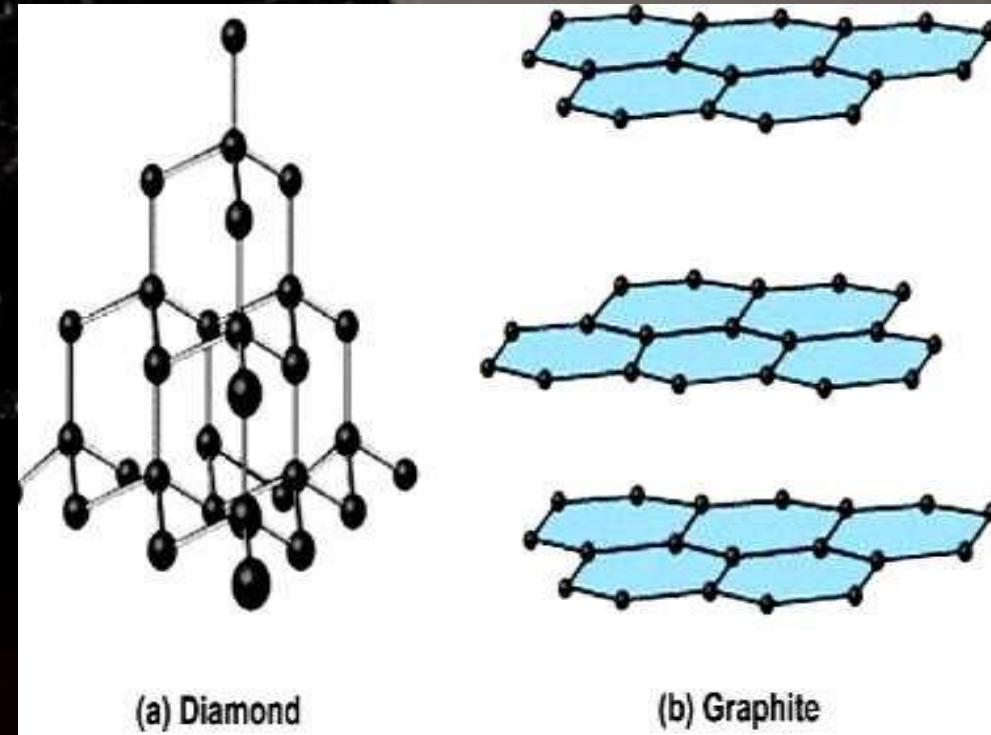
### (b) Graphite:

- In graphite, each carbon atom undergoes **sp<sup>2</sup> hybridisation** and is covalently bonded to three other carbon atoms by single bonds.
- The fourth electron on each carbon atom forms  $\pi$  bonds. In this way, graphite consists of hexagonal rings in two dimensions.
- The C–C covalent distance in rings is **141.5 pm** indicating strong bonding.
- These arrays of ring form layers. The layers are separated by a distance of **340 pm**.

The large distance between these layers indicates that only **weak van der Waals' forces** hold these layers together. The weak van der Waals' forces which hold these layers together are responsible for soft nature of graphite.



- Because of the weak Van der Waals' forces between layers, one layer can move over the other layer and this account for the **slippery nature** of graphite. Therefore, graphite is used as **lubricant**.
- The electrons forming  $\pi$  bonds in the rings of graphite are delocalized and are relatively free to move under the influence of electric field. Therefore, graphite is a **good conductor of electricity**





- Allotropes of Carbon:
- Allotrope forms or allotropes are the different forms of the same elements having different physical properties but similar chemical properties.
- 1. Crystalline form: Diamond and graphite are two crystalline forms of carbon having well defined structure
- 2. Amorphous form: Coal, wood charcoal, animal charcoal, lamp black, coke, etc. Are amorphous forms of carbon

- (b)Graphite: • In graphite, each carbon atom undergoes  $sp^2$  hybridisation and is covalently bonded to three other carbon atoms by single bonds. • The fourth electron on each carbon atom forms bonds. In this way, graphite consists of hexagonal rings in two dimensions. • The C–C covalent distance in rings is 141.5 pm indicating strong bonding. • These arrays of ring form layers. The layers are separated by a distance of 340 pm. • The large distance between these layers indicates that only weak van der Waals' forces hold these layers together1

- Because of the weak Van der Waals' forces between layers, one layer can move over the other layer and this account for the slippery nature of graphite. Therefore, graphite is used as lubricant. • The electrons forming bonds in the rings of graphite are delocalized and are relatively free to move under the influence of electric field. Therefore, graphite is a good conductor of electricity

