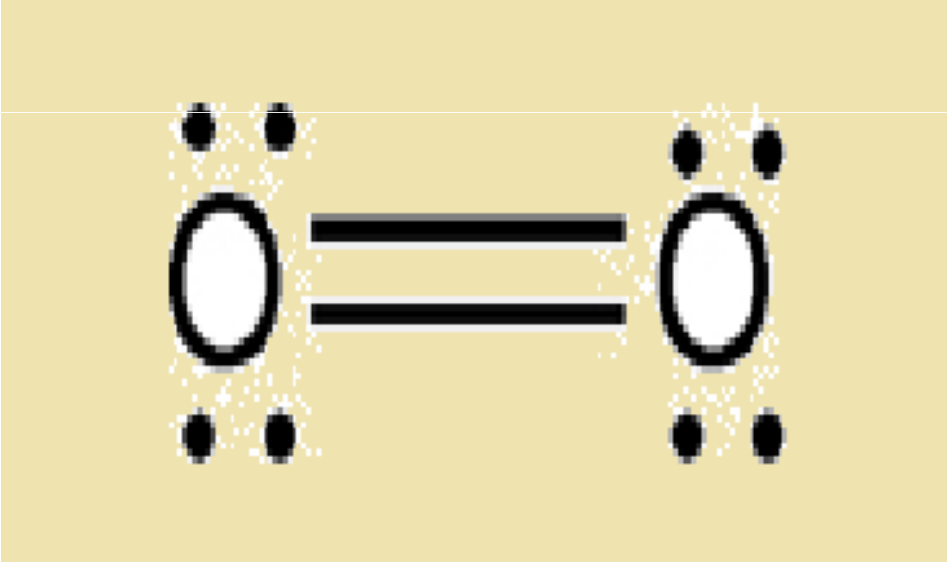
Oxygen

Lewis structure of oxygen



Preparation of Oxygen

a. **Thermal decomposition of potassium chlorate(V)**

$$2KClO_3(s) \xrightarrow[MnO_2]{heat,300^oC} 2KCl(s) + 3O_2(g)$$

Drying agent: $CaCl_2$, CaO, concentrated H_2SO_4

b. Catalytic decomposition of hydrogen peroxide solution

$$2H_2O_2(aq) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$$

c. Reaction between sodium peroxide and water

$2Na_2O_2(s) + 2\ H_2O\ (l) \rightarrow 4NaOH\ (aq) + \ O_2\ (aq)$

Other substances that produce O_2

$$2F_2(g) + 2H_2O(l) \longrightarrow 4HF(aq) + 2O_2(g)$$

$$2HClO(aq) \xrightarrow{sunlight} 2HCl(aq) + O_2(g)$$

$$2KNO_3(s) \xrightarrow{heat} 2KNO_2(s) + O_2(g)$$

$$2AgNO_3(s) \xrightarrow{heat} 2Ag(s) + 2NO_2(g) + O_2(g)$$

Industrial Preparation

a. **electrolysis of water and molten sodium hydroxide .**

$$2H_2O(l) \xrightarrow{electrolysis} H_2(g) + O_2(g)$$

$$2NaOH(l) \xrightarrow{electrolysis} 2Na(s) + H_2(g) + O_2(g)$$

b. **fractional distillation of liquid air.**

Physical Properties

- Oxygen is a diatomic gas.
- colorless, odorless and tasteless
- neutral to moist litmus paper.
- slightly soluble in water, i.e. only about 2% by volume of it will dissolve at room temperature.
- denser than air.
- Gaseous oxygen liquefies at –183°C (b.p) and solidifies at –225°C (m.p)

Chemical Properties

- very reactive.
- combines readily with all other elements (except the noble gases, some halogens and some un-reactive metals) to form oxides.

Reaction with metals

- Many metals react with oxygen to form basic oxides(contains the O^{2-} ion).
- Example:
- 2 Cu (s) + O_2 (g) $\rightarrow$ ***2 CuO (s)***
- 2 Mg (s) + O_2 (g) $\rightarrow$ 2MgO(s)

Reaction between alkali metals and oxygen

- The basic oxide is not formed when sodium or potassium is heated in a plentiful supply of oxygen.
- **Metal peroxides (contains O_2^{2-} ion) are formed.**

- Sodium burns with a **bright yellow** **flame** to form sodium peroxide, Na_2O_2.

$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$ (sodium peroxide)

Oxidation state of oxygen in **peroxides is –1.**

superoxides

- **Very reactive alkali metals -K, Rb and Cs *can* also form superoxides (O_2^- ion)**
- Potassium burns in excess oxygen with a **lilac flame to** form a higher oxide, KO_2 .
- $K(s) + O_2(g) \rightarrow KO_2(s)$ (potassium superoxide)
- Oxidation state of oxygen in superoxides is

$$-\frac{1}{2}$$

Reaction with non-metals

- Nonmetals burn in oxygen to form acidic oxides.
- Example:

① $S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$

② $P_4\ (s) + 3\ O_2\ (g) \rightarrow P_4O_6\ (s)$

Reaction of oxygen with

a. hydrogen sulphide

b. Methane

c. ammonia

$$2H_2S(g) + 3O_2(g) \xrightarrow{ignited} 2SO_2(g) + 2H_2O(l)$$

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$$

$$4NH_3(g) + 5O_2(g) \xrightarrow{pt-Rh, 850^oC} 4NO(g) + 6H_2O(l)$$

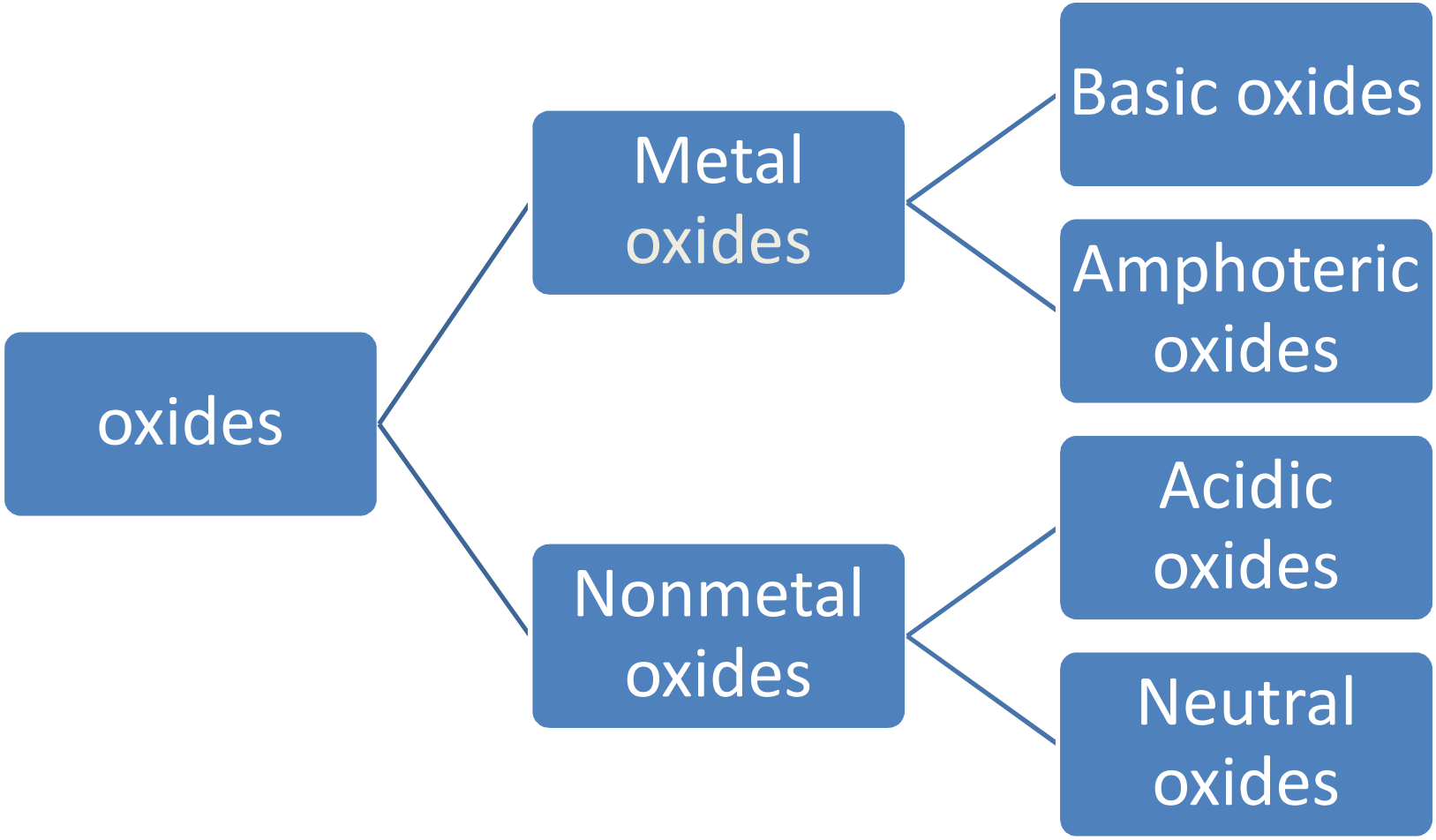
Test for oxygen

- Rekindle a glowing splinter.
- Dinitrogen monoxide also does this.
- it can be distinguished from oxygen by reactions with NO

  $NO + O_2 (g) \rightarrow NO_2$

  Produces reddish-brown fumes of NO_2
- $N_2O + O_2 (g) \rightarrow$ No reaction

Classification of Oxides



Basic Oxides

- most metal oxides are ionic compounds.
- Example: CaO , BaO, K_2O , Na_2O ….
- dissolve in water to form hydroxides.

  $K_2O(s) + H_2O(l) \rightarrow 2KOH\ (aq)$
- metallic oxide reacts with acid to produce a salt and water only.

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

Acidic oxides

- non-metal oxides are covalent compounds

Example: CO_2, SO_3 , SO_2 ,P_4O_{10}….

- dissolved in water to give acid
- also known as ***<u>acid anhydrides</u>***.
- $SO_2\ (g) + H_2O(l) \rightarrow H_2SO_3\ (aq)$
- $SO_3\ (g) + H_2O(l) \rightarrow H_2SO_4\ (aq)$

- $P_4O_6\ (g) + 6\ H_2O(l) \rightarrow 4\ H_3PO_3\ (aq)$
- $P_4O_{10}\ (g) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4\ (aq)$

Amphoteric oxides

- a metallic oxide which can show both basic and acidic properties
- can react with both acid and alkali to produce a salt and water only
- Example: ZnO , PbO, SnO, Al_2O_3 , ….
- For example, aluminium oxide reacts with hydrochloric acid to form aluminium chloride

$$Al_2O_3 + 6\ HCl \rightarrow 2\ AlCl_3(aq) + 3\ H_2O\ (aq)$$

Amphoteric oxides with alkali

- aluminium oxide reacts with sodium hydroxide to form sodium aluminate:

  $Al_2O_3 + 2KOH + 3\,H_2O \rightarrow 2\,KAl(OH)_4\,(aq)$

  Or

  $Al_2O_3 + 2KOH \rightarrow 2\,KAlO_2\,(aq) + H_2O$

- $ZnO + 2NaOH \rightarrow Na_2ZnO_2\,(aq) + H_2O$

  or

  $ZnO + 2\,NaOH + H_2O \rightarrow Na_2Zn(OH)_4\,(aq)$

Neutral oxides

- shows neither basic nor acidic character.

  Example: N_2O , CO, NO, H_2O ….

Peroxides

- ***Peroxide is a compound with oxygen in the –1 oxidation state***.
- Peroxides contain either $\mathbf{O_2^{2-}}$ ion or the covalently bonded group —O—O—.
- Example: BaO_2 , H_2O_2 , Na_2O_2 (pale yellow powder)

Sodium peroxide

- React with cold water or cold dilute acids, it reacts to form hydrogen peroxide.
- $2\ Na_2O_2(s) + 2\ H_2O\ (l) \rightarrow 4\ NaOH\ (aq) + O_2\ (aq)$

- $Na_2O_2\ (s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O_2\ (aq)$

- It is used in air purifiers in submarines and portable breathing apparatus.
- it reacts carbon dioxide, forming oxygen and sodium carbonate.

$$2Na_2O_{2(s)} + 2CO_2\,(g) \rightarrow \; 2Na_2CO_3(s) + O_2(g)$$

Hydrogen Peroxide

Chemical Properties

Thermal decomposition

- hydrogen peroxide solution is warmed in a test tube.
- Effervescence occurs. The gas is oxygen, but it will not rekindle a glowing splint because of the presence of steam.

$$2\ H_2O_{2\ (aq)} \rightarrow\ 2\ H_2O_{\ (g)}\ +\ O_{2\ (g)}$$

preparation

- Reaction between barium peroxide and dilute sulphuric acid.
- insoluble barium sulphate(VI) formed is filtered off.

$$BaO_{2\,(s)} + H_2SO_{4\,(aq)} \rightarrow H_2O_{2\,(aq)} + BaSO_{4\,(s)}$$

H_2O_2 act as an oxidizing agent

- Oxidised lead (II) sulphide

  $PbS_{(s)} + 4\,H_2O_{2\,(aq)} \rightarrow PbSO_{4\,(s)} + 4\,H_2O_{(l)}$

- This reaction is used in restoring pictures. Hydrogen sulphide in the air reacts with the white lead paint, lead(II) carbonate
- lead(II) sulphide, which is brown and makes the picture dingy.
- Washing with hydrogen peroxide restores the white colour.

H_2O_2 act as a reducing agent

- *With a stronger oxidising agent , it act as a reducing agent.*
- *Reduces silver oxide*

$$Ag_2O_{(s)} + H_2O_{2(aq)} \rightarrow 2\ Ag_{(s)} + H_2O_{(l)} + O_{2\ (g)}$$

Oxygen gas is formed.

Reduces acidified $KMnO_4$

$$2\ MnO_4^-{}_{(aq)} + 5\ H_2O_{2\ (aq)} + 6\ H^+{}_{(aq)} \rightarrow$$
$$2\ Mn^{2+}{}_{(aq)} + 8\ H_2O_{(l)} + 5\ O_{2\ (g)}$$

- *purple solution decolourised.*

Superoxides

- binary compound.
- oxidation state of oxygen in superoxides is –½.
- dissolve in water to produce oxygen.

  $4\ KO_{2\ (s)} + 2H_2O_{\ (l)} \rightarrow 4\ KOH + 3\ O_2(g)$
- is used as oxygen source in masks worn for rescue work.
- moisture in the breath causes the compound to decompose to form O_2 and KOH. The KOH formed will remove CO_2 from the exhaled breath.
- $KOH(s) + CO_2 \rightarrow KHCO_3\ (s)$

The end