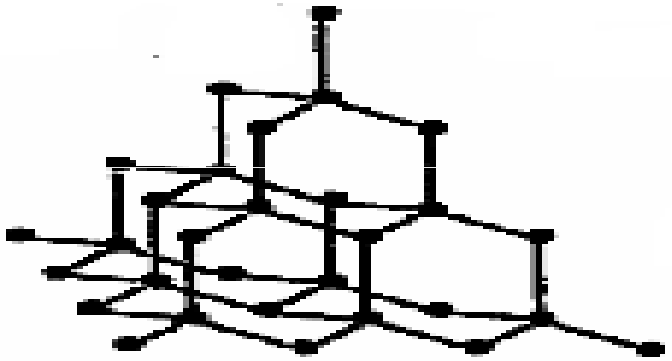
Carbon

Allotropes of carbon

1. Diamond
2. Graphite
3. Fullerenes

Structure of diamond & graphite

Arragnement of carbon atoms in the diamond crystal

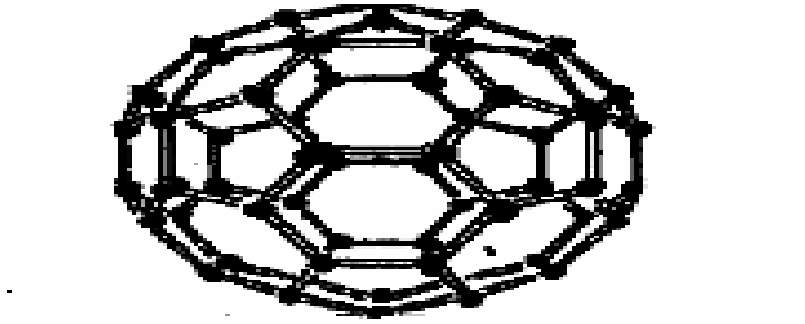


Arrangement of carbon atoms in the graphite crystal

Fullerenes

- Discovered in 1985.
- Compounds with spherical aggregates of carbon atoms.
- The most stable is C_{60}, called buckyball or buckminsterfullerene.

The teometry of a vuckyball C60 resembles a soccer ball



Carbon monoxide

Preparation: Reduction of carbon dioxide

Carbon dioxide is passed through red-hot carbon.

$CO_2(g) + C(s) \rightarrow 2CO(g)$

- Carbon monoxide is a colourless, and odourless gas.
- insoluble in water.
- dense than air.
- neutral to litmus

Chemical properties of CO

- Carbon monoxide burns in air with a pale blue flame, forming carbon dioxide.

  $2CO\,(g) + O_2\,(g) \rightarrow 2CO_2\,(g)$ + heat energy

- Carbon monoxide is a strong reducing agent.

  Example:

① $3\,CO_{(g)} + Fe_2O_{3(s)} \leftrightarrows 2\,Fe + 3\,CO_2\,(g)$

② $CO(g) + 2H_2(g) \xrightarrow[high\ temp\ \&high\ pressure]{Cr_2O_3, ZnO} CH_3OH(l)$

Carbon dioxide

Laboratory Preparation

- reaction of dilute acids on a carbonate or hydrogen carbonate.
- Example:

$$CaCO_{3\,(s)} + 2\,HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

$$NaHCO_{3(aq)} + HNO_{3(aq)} \rightarrow NaNO_{3(aq)} + H_2O_{(l)} + CO_{2(g)}$$

Physical properties of CO_2

- Carbon dioxide is a colourless, odourless gas.
- It is denser than air.
- It is soluble in water.
- It changes damp blue litmus paper pink.
- It solidifies at –78°C to form a white solid, commonly known as dry ice.

Chemical properties

- dissolves slightly in water to form carbonic acid.
- reacts with alkalis to yield carbonates.

① $CO_{2(g)} + 2\ NaOH_{(aq)} \rightarrow \boldsymbol{Na_2CO_{3(aq)} + H_2O_{(l)}}$

② $Na_2CO_{3(aq)} + H_2O_{(l)} + CO_{2\ (g)} \rightarrow \boldsymbol{2\ NaHCO_{3(aq)}}$

excess

alkalis absorb carbon dioxide readily, thus it can be used to remove CO_2 from a mixture.

- Carbon dioxide support the combustion of burning magnesium.

  $CO_{2(g)} + 2\ Mg_{(s)} \rightarrow 2\ MgO_{(s)} + C_{(s)}$

- When carbon dioxide gas is passed over red-hot carbon, it is reduced to carbon monoxide.

  $CO_{2(g)} + C_{(s)} \leftrightarrows 2\ CO_{(g)}$

Test for CO_2

- Turns limewater milky due to the precipitation of insoluble calcium carbonate.
- Continue bubbling excess carbon dioxide through the solution, a clear solution is formed.
- when the clear solution is heat ,it become milky again due to the decomposition of the soluble calcium hydrogen carbonate to insoluble calcium carbonate.

Equations of reaction involved are

- $CO_{2(g)} + 2\ Ca(OH)_{2(aq)} \rightarrow CaCO_{3(aq)} + H_2O_{(l)}$
-
- $CaCO_{3(aq)} + H_2O_{(l)} + CO_{2\ (g)} \rightarrow Ca(HCO_3)_{2\ (aq)}$

excess

- $Ca(HCO_3)_{2\ (aq)} \xrightarrow{heat} CaCO_3\ (s) + H_2O\ (l)$

Uses of carbon dioxide

① **Fire extinguisher**

- Because carbon dioxide does not support combustion and it is heavier than air, thus forms an envelope around the burning material.

②**Carbonated drinks**

- Carbon dioxide is used to give the refreshing and characteristic taste to soda water and other carbonated drinks.

③ **Raising agent in baking**

Yeast and baking powder (sodium hydrogen carbonate) are used in baking. Yeast produces carbon dioxide by fermenting the sugar in the dough. sodium hydrogen carbonate will react in the presence of water and acid to produce carbon dioxide.

④ **Refrigerant**

Dry ice is used as a refrigerant for perishable goods, e.g. ice-cream.

⑤ It is used in the Solvay process to produce sodium carbonate.

Sodium *carbonates*

- Sodium carbonate exist as

① **anhydrous form *(soda ash)*,**

② **monohydrate, $Na_2CO_3.\ H_2O$,**

③ **decahydrate, Na_2CO_3 .$10H_2O$, *(washing soda)*.**

General Properties of Carbonates

- All carbonates are insoluble
- EXCEPT potassium, sodium and ammonium carbonates.
- When sodium, potassium and ammonium carbonates are dissolved in water, they are hydrolysed to form carbonic acid and the corresponding hydroxides. The resulting solution is alkaline.
- All carbonates decompose on heating to liberate carbon dioxide EXCEPT sodium, potassium and barium carbonates.
- All carbonates react with dilute acids to form carbon dioxide , water and a salt.

Solvay process

- to manufacture sodium carbonate.

  Step I : decomposition of calcium carbonate

$$CaCO_3(s) \xrightarrow{heat} CaO(s) + CO_2(g)$$

Step II: ammonia and carbon dioxide react to form ammonium hydrogen carbonate. In the presence of sodium chloride, sodium hydrogen carbonate is formed.

① $\mathbf{NH_{3(g)} + H_2O_{(l)} + CO_{2(g)} \leftrightarrows NH_4HCO_{3(aq)}}$

② $\mathbf{NH_4HCO_{3(aq)} + NaCl_{(aq)} \rightarrow NaHCO_{3(s)} + NH_4Cl_{(aq)}}$

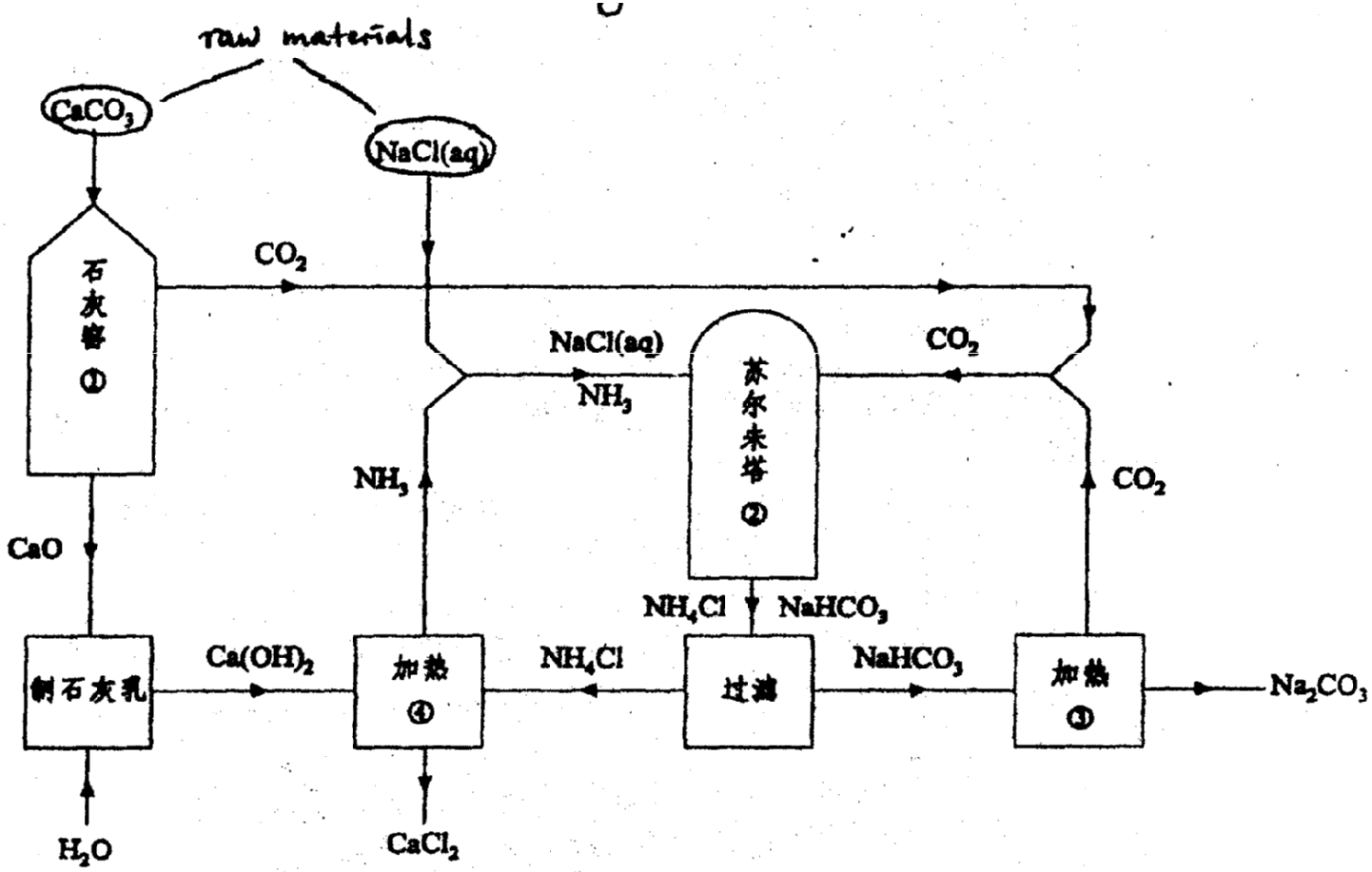
Step III

- $NaHCO_3$ is less soluble in water, separates out as a white sludge.Precipitation is further increased by cooling process.
- $NaHCO_3$ is filtered, washed and heated to yield anhydrous sodium carbonate, water and carbon dioxide.

$$\mathbf{2\ NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}}$$

Step IV : ammonia is regenerated by the process

- $CaO\ (s) + H_2O(l) \rightarrow Ca(OH)_2\ (s)$
- $\mathbf{NH_4Cl_{(aq)} + Ca(OH)_{2(s)} \rightarrow CaCl_{2(aq)} + 2\ H_2O_{(l)} + 2NH_{3(g)}}$


raw materials
$CaCO_3$
NaCl(aq)
石灰窑 ①
CO_2
NaCl(aq)
NH_3
蒸尔来塔 ②
CO_2
NH_3
CO_2
CaO
NH_4Cl
$NaHCO_3$
制石灰乳
$Ca(OH)_2$
加热 ④
NH_4Cl
过滤
$NaHCO_3$
加热 ③
Na_2CO_3
H_2O
$CaCl_2$

Uses of Na_2CO_3

manufacture of

- glass, water glass (sodium silicate)
- as a water-softener,
- detergents,
- sodium hydroxide …..

Hydrogen carbonates

General properties

- All hydrogencarbonates are soluble but most of them are unstable and unimportant.
- All hyrogen carbonates decompose readily on heating, or when their solutions are boiled, to yield carbon dioxide, water and the corresponding carbonates