WEEK ONE (15TH-19TH MARCH 2020)

CHEMISTRY

This is a continuation of notes for Chapter

1. Air (completed)
2. Water
3. Nitrogen and Fertilisers
4. Carbondioxide and Methane (to be done next week)

Nitrogen Oxides in Car Engines

Nitrogen oxides

- These compounds (NO and NO_2) are formed when nitrogen and oxygen react in the **high pressure** and **temperature** conditions of internal combustion engines and blast furnaces.
- Exhaust gases also contain unburned hydrocarbons and carbon monoxide.
- Cars are fitted with catalytic converters which form a part of their exhaust systems.
- Their function is to render these exhaust gases harmless.

Catalytic converters

- They contain a series of **transition metal catalysts** including platinum and rhodium.
- In the combustion engine, insufficient amounts of oxygen lead to incomplete combustion of the carbon containing fuel.
- The metal catalysts are in a **honeycomb** within the converter to increase the surface area available for reaction.
- A series of redox reactions occurs which neutralises the pollutant gases.

- Carbon monoxide is oxidised to carbon dioxide:

$$2CO + O_2 \rightarrow 2CO_2$$

- Nitrogen oxides are reduced to N_2 gas:

$$2NO \rightarrow N_2 + O_2$$

$$2NO_2 \rightarrow N_2 + 2O_2$$

- Unburned hydrocarbons are oxidised to carbon dioxide and water:

$$C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$$

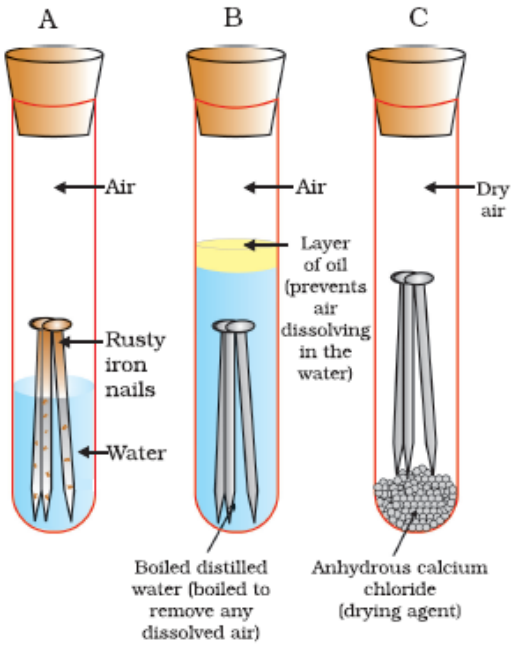
Rusting of Iron

Rusting is the red/orange coating that forms on the surface of iron when exposed to air and moisture.

Rusting is essentially a redox reaction whereby iron reacts with the air and water to form hydrated iron (III) oxide. Therefore both oxygen *and* water must be present for rusting to occur. It occurs faster in salty water since the presence of sodium chloride increases the electrical conductivity of the water.

$$\text{Iron} + \text{Water} + \text{Oxygen} \rightarrow \text{Hydrated Iron (III) Oxide}$$

$$4Fe(s) + 3O_2(g) + xH_2O(l) \rightarrow 2Fe_2O_3.xH_2O(s)$$



You will observe that iron nails rust in test tube A, but they do not rust in test tubes B and C. In the test tube A, the nails are exposed to both air and water. In the test tube B, the nails are exposed to only water, and the nails in test tube C are exposed to dry air. What does this tell us about the conditions under which iron particles rust?

Methods of Rust Prevention

Most methods of rust prevention involve coating the iron or steel in order to prevent contact with water and oxygen:

- Painting – For example, cars, ships, bridges etc.
- Using oil or grease – Effective for moving parts of machinery to be used as a lubricant and a protective coating
- Coating with plastic – Such as freezers, garden furniture etc.
- Plating – Cans of food are plated with tin
- Galvanising - This is coating with zinc and has the great advantage of sacrificial protection

Galvanising and Sacrificial Protection

- Iron can be prevented from rusting using the **reactivity** series. Metals above iron in the reactivity series can prevent iron from rusting.

  Eg. Magnesium blocks are attached to ships or legs of oil rigs.

Sacrificial Protection

- Magnesium is more reactive than iron and so it loses its electrons more readily:

$$Mg \rightarrow Mg^{+} + 2e^{-}$$

- The iron stays protected as it accepts the electrons released by magnesium, remaining in the reduced state and thus it does not undergo oxidation, therefore it cannot rust.
- The electrons donated by the magnesium react with hydrogen ions in the water producing hydrogen gas:

$$2H^{+} + 2e^{-} \rightarrow H_2$$

- Zinc therefore reacts with oxygen and water and corrodes instead of the iron.

Galvanising

- It is a process where the iron to be protected is coated with a layer of zinc.

- $ZnCO_3$ is formed when zinc reacts with oxygen and carbon dioxide in the air and protects the iron by acting as a barrier (barrier method).
- If the coating is damaged or scratched, the iron is still protected from rusting by the **sacrificial** method (zinc can also be used).

Nitrogen and Fertilisers

Fertilizers

Plants need the three elements nitrogen, phosphorus, and potassium for healthy growth. These are removed from the soil when plants are harvested. The essential plant nutrients are replaced by NPK fertilizers. A typical NPK fertilizer might containing ammonium Nitrate, ammonium Phosphate, and potassium (K) chloride.

- Nitrogen (N): needed to make chlorophyll and proteins to keep leaves healthy
- Phosphorous (P): helps roots to grow and crops to ripen
- Potassium (K): helps to make proteins and resist disease

Fertiliser compounds contain the following water-soluble ions:

- Ammonium ions, NH_4^+ and nitrate ions, NO_3^-, are sources of soluble nitrogen.
- Phosphate ions, PO_4^{3-} are a source of soluble phosphorus.
- Most common potassium compounds dissolve in water to produce potassium ions, K^+.

Displacement of ammonia from its salts

- Ammonia can be **displaced** from its salts by the addition of any alkali substance (eg. $NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_3$).
- Farmers regularly add basic substances such as **calcium** hydroxide to their soil to neutralise any excess soil acidity.
- If **too** much of the basic substance is added or if it has been added **too** soon after fertiliser has been added, then an ammonia displacement reaction may occur.
- This involves the loss of nitrogen from the fertiliser, nullifying its effectiveness as a fertiliser.
- For example, the salt ammonium chloride is used extensively in fertilisers and reacts with calcium hydroxide:

$$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2NH_3 + 2H_2O$$

- Another example is the addition of Sodium Hydroxide:

$$NaOH + NH_4Cl \rightarrow NaCl + H_2O + NH_3$$

- In both cases, ammonia gas is liberated and there is a loss of nitrogen fertiliser.

Manufacture of Ammonia by the Haber Process

Industrial manufacture of ammonia happens by the Haber Process

It occurs in five stages:

- **Stage 1:** Hydrogen and Nitrogen are obtained and are pumped into the compressor through pipes.
  - H_2 (obtained by cracking hydrocarbons eg. $C_2H_6 \rightarrow C_2H_4 + H_2$ or by the reaction of methane and steam $CH_4 + H_2O \rightarrow CO_2 + H_2$)
  - N_2 (obtained from air)

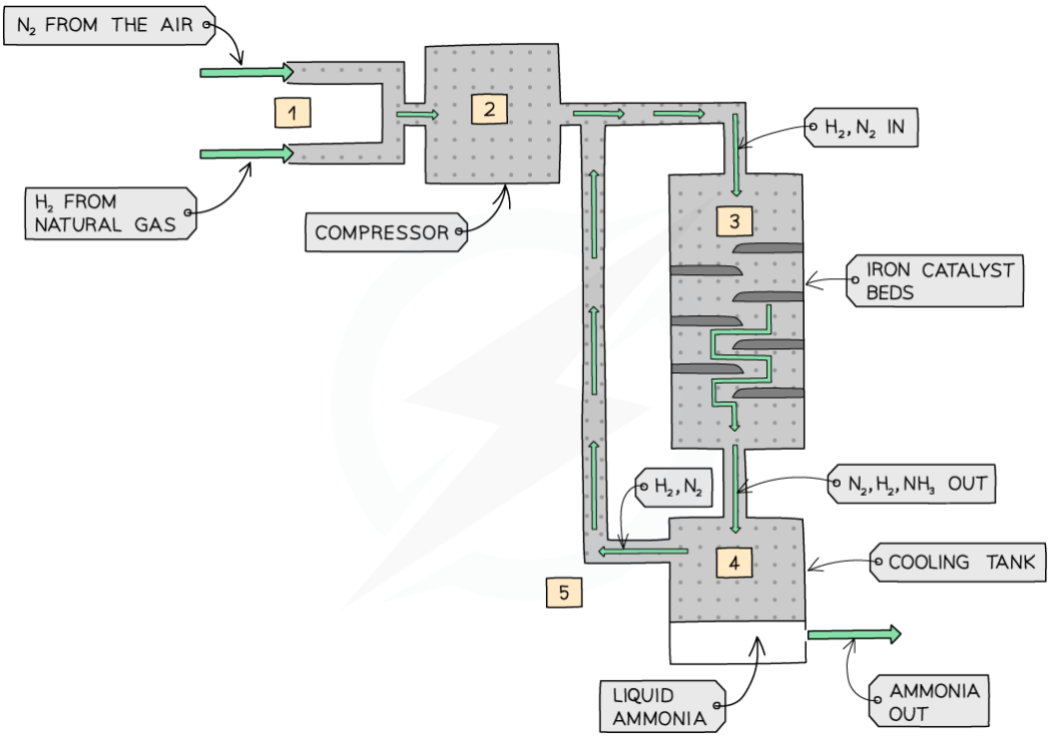
- **Stage 2:** The gases are compressed to about 200 atmospheres inside the compressor.

- **Stage 3**: The pressurised gases are pumped into a tank containing layers of catalytic iron beads at a temperature of 450°C. Some of the hydrogen and nitrogen react to form ammonia:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

- **Stage 4:** Unreacted H_2 and N_2 and product ammonia (since they are in equilibrium) pass into a cooling tank. The ammonia is liquefied and removed to pressurized storage vessels.

- **Stage 5**: the unreacted H_2 and N_2 gases are recycled back into the system and start over again.



Condition		Comment
Pressure	High (200 atm)	High pressures favour the side with fewer molecules: ammonia (forward reaction)
Temperature	Moderate (450^{0}C)	• The forward reaction is exothermic, so low temperatures are favoured • However, at low temperatures, the reaction is too slow
Catalyst	Iron	Speeds up the forward and backward reaction equally, so that equilibrium is reached faster (note that equilibrium is not shifted)
Remove Product	The reaction mixture is cooled to remove ammonia as a liquid	Removing the ammonia prevets it from breaking down to nitrogen and hydrogen again
Recycle	Unreacted gases are recycled	The gases are given another chance to react with the catalyst, so the overall yield improves

Conditions (further explanation)

1. **Temperature: 450ºC**

- A **higher** temperature would favour the reverse reaction as it is endothermic (takes in heat) so a higher yield of **reactants** would be made.
- If a **lower** temperature is used it favours the forward reaction as it is exothermic (releases heat) so a higher yield of **products** will be made.
- However at a lower temperature the rate of reaction is very **slow**.
- So 450ºC is a compromise temperature between having a **lower yield** of products but being made more quickly.

2. **Pressure: 200 atm**

- A **lower** pressure would favour the reverse reaction as the system will try to increase the pressure by creating more molecules (4 molecules of gaseous reactants) so a higher yield of **reactants** will be made.
- A **higher** pressure would favour the forward reaction as it will try to decrease the pressure by creating less molecules (2 molecules of gaseous products) so a higher yield of **products** will be made.
- However high pressures can be dangerous and very expensive equipment is needed.
- So 200 atm is a **compromise** pressure between a lower yield of products being made **safely** and **economically**.

3. Catayst: Iron

VIDEO LINKS

Rusting of Iron:
https://www.youtube.com/watch?v=LQ-prcAHM_U
https://www.youtube.com/watch?v=jQoE_9x37mQ

Haber Process:
https://www.youtube.com/watch?v=NWhZ77Qm5y4