## St Ninian's High School

## Chemistry Department

# National 5 Chemistry

# Unit 3: Chemistry in Society

# Fertilisers

# Summary Notes

**Name** _____

# Learning Outcomes

**After completing this topic you should be able to :**

1 state that the increasing world population has led to a need for more efficient food production
2 state that growing plants require nutrients, including compounds of phosphorus, potassium and nitrogen
3 state that nutrients can be provided by fertilisers
4 give examples of natural fertilisers
5 work out the percentage mass of elements in fertilisers from formulae
6 state that ammonia and nitric acid and nitrogen compounds are important feedstocks for the manufacture of fertilisers
7 describe the industrial manufacture of ammonia from nitrogen and hydrogen (Haber Process)
8 explain that in the Haber Process nitrogen from the air combines with hydrogen from the natural gas
9 explain that the reaction of nitrogen and hydrogen to make ammonia is reversible and the ammonia breaks down if the temperature is too high
10 state that the Haber Process needs a temperature of 450°C, pressure of 200 atmospheres and an iron catalyst
11 state that ammonia can be converted to ammonium compounds
12 state that ammonia can be prepared in the laboratory by the reaction of an ammonium salt with a base
13 state that ammonia is very soluble and forms an alkaline solution when dissolved
14 state that nitric acid is made industrially by the Ostwald Process
15 state that in the Ostwald Process ammonia and oxygen are passed over a platinum catalyst at 900°C
16 state that the Ostwald Process reaction is exothermic so external heat can be removed when the reaction gets started
17 state that nitrogen monoxide is initially formed then nitrogen dioxide dissolves in water
18 state that the reaction of nitric acid with ammonia to make ammonium nitrate is an example of a neutralisation reaction
19 state that ammonium nitrate is used as a fertiliser
20 state that the catalytic oxidation of ammonia can be carried out in the laboratory
21 explain why it is not necessary to continue to supply heat once the catalytic oxidation of ammonia has started.

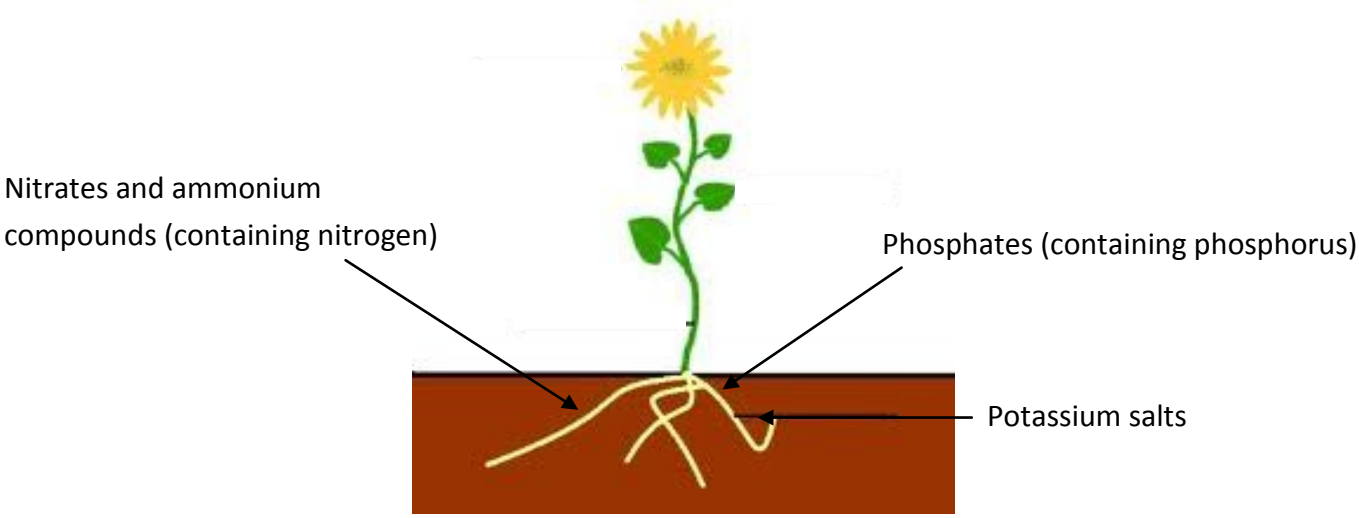
## World Population

The world's population (the number of people who presently share this planet) is increasing. Your teacher may show you a 'population clock' which gives an estimate of the current world population. (www.worldometers.info) This **increasing world population** has lead to a need for **more efficient food production**.

# Nutrients

## Essential Elements for Plant Growth

Healthy crops provide more food and growing plants require nutrients, chemicals essential for healthy plant growth. Elements required by plants include hydrogen, carbon and oxygen, most importantly plants need **nitrogen, phosphorous** and **potassium** (NPK). Plants take these elements in from the soil through their roots. The elements are taken as compounds which are dissolved in water from the soil.




When crops grow, they remove some of the essential elements from the soil since crops are harvested to feed people. The nutrients removed by the crops need to be added back to the soil to make it fertile again allowing for future plant growth.

## Nutrient Cycles

Plants can suffer if even one essential nutrient is missing. In nature, most elements are readily available from the soil. In nature, plants do not seem to suffer shortages of nutrients even though they may have grown in the same soil for hundreds of years. This is because **when they die they rot down**, returning the essential elements to the soil. This is known as **decomposition.** The nutrient elements are naturally recycled.

## The Nitrogen Cycle

Plants are unable to use nitrogen directly from the air as it is very unreactive. Plants must take in nitrogen in the form of nitrate or ammonium compounds from the soil.

The balance of nitrogen compounds in the soil can be shown in the nitrogen cycle. The nitrogen cycle show that nitrate and ammonium compounds can be returned to soil by **natural** or **artificial fertilisers**, **lightning storms** or nitrifying bacteria in **leguminous plants**.

# Nutrients

## Leguminous Plants

Some plants have **root nodules**, which look like tiny bags, attached to the root. These contain **nitrogen-fixing bacteria** which can take nitrogen directly from the air and change it into nitrates that can be used by the plants. These are known as **leguminous** plants, examples include **peas, beans** and **clover**.

## Lightning Storms

Lightning storms can provide enough energy to make nitrogen react with oxygen from the air to form nitrogen dioxide. This in turn dissolves in rain water to form nitric acid, $HNO_3$. The nitrate ions present in nitric acid can get into soils.

## Natural Fertilisers

**Natural Fertilisers** are made by the natural breakdown of animal and plant remains. Examples are **manure** and **compost**, both of which are rich in nitrogen compounds and are cheaper than artificial or synthetic (man-made) fertilisers.

Nature recycles nutrients through the processes of growth, death and decay. Man, on the other hand, constantly breaks this cycle.

Crops are harvested and transported away to:

- Feed town and city dwellers
- Supply requirements in other areas/ countries.

Thus, soil nutrients are **not** returned to the soil in which the crops were grown. Also, the world population is rising and ever increasing numbers of people need to be fed. As a result natural fertilisers are no longer enough to nourish the soil. The idea that plant growth would benefit from fertilisers developed gradually. Farmers found that grass grew better on fields which had animal manure spread on them in the spring. Seaweed was harvested along the coast and used to boost crops, including Ayrshire tatties! Bird droppings were collected from islands such as Ailsa Craig and used as fertilisers.

# Suitable Fertilisers

For a fertiliser to be suitable it must first of all contain one of the three essential nutrients (NPK) and be able to dissolve in rain water and be taken up by the roots of the plant. Ammonium compounds are often used as synthetic fertilisers since they contain the element nitrogen. Phosphate compounds are often used since they contain the element phosphorus.

# Fertilisers

## Percentage Composition of Fertilisers

Different crops need different proportions of nitrogen, phosphorus and potassium. Labels on artificial fertiliser give these percentages. The percentages are calculated using the gram formula mass of the compounds contained in the fertiliser. The percentage composition of a compound gives the percentage by mass of each element present in the compound. (See Unit 3 Topic 1.)

**Example:** What is the percentage of nitrogen in sodium nitrate, $NaNO_3$?

Step 1: Find the gram formula mass using the data booklet

GRM = (1 x 23) + (1 x 14) +(3 x 16) = 23 + 14 + 48 = 85 g

Step 2: State the mass of the element within the GFM

Mass of nitrogen = 14

Step 3: Carry out the calculation using the relationship in the data booklet.

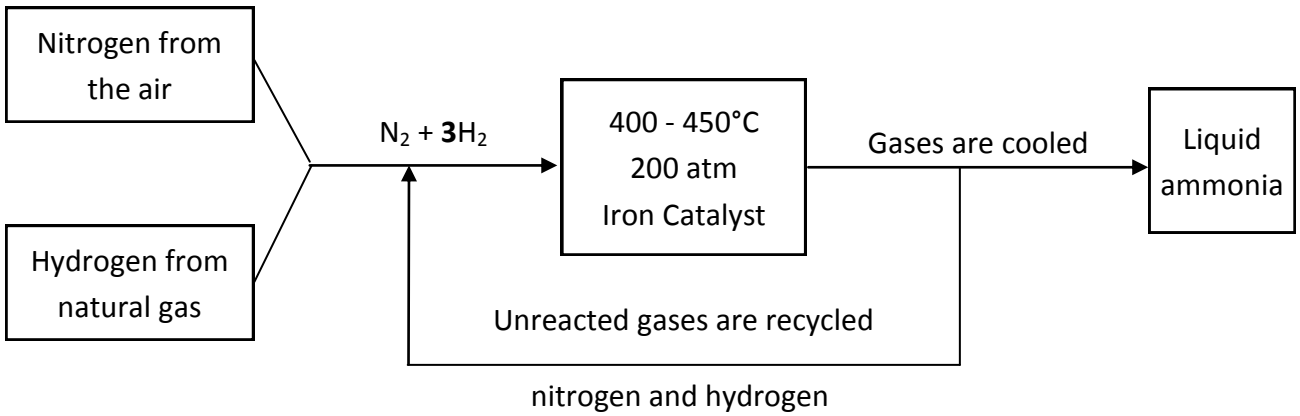
% by mass = (14 ÷ 85) x 100 = 16.5 %

## Making Ammonia - The Haber Process.

Chemists began to look at ways of producing **artificial fertilisers containing nitrogen compounds.** Although nitrogen was the obvious starting point, they had huge difficulty getting it to react.

The sparking of air using a high energy spark can be used to fix nitrogen, but the cost of the electricity makes this process uneconomical. The breakthrough came in 1904 when a German Chemist, FRITZ HABER, found a way of turning nitrogen and hydrogen into AMMONIA.

Ammonia is manufactured commercially by the **Haber Process.**




The reaction between nitrogen and hydrogen to make ammonia is reversible. This means that as ammonia is produced, it begins to break back down into nitrogen and hydrogen again.

This means it is not possible to convert all of the hydrogen and nitrogen into ammonia.

The use of a double arrow indicates a reversible reaction.

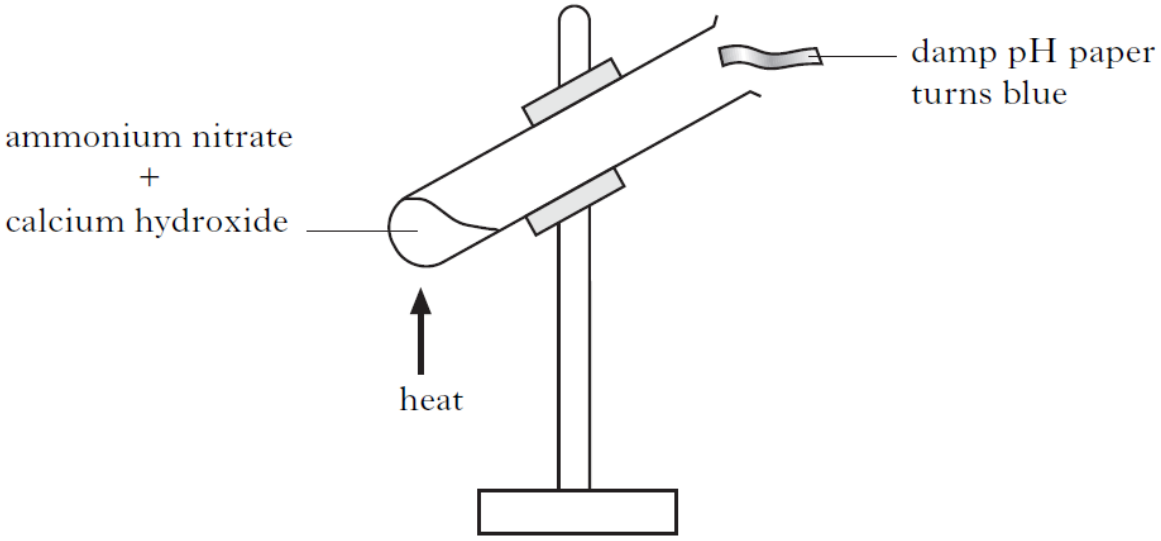
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

In order to improve the yield of ammonia a **high pressure** and **moderately high temperature** is used.

# Ammonia

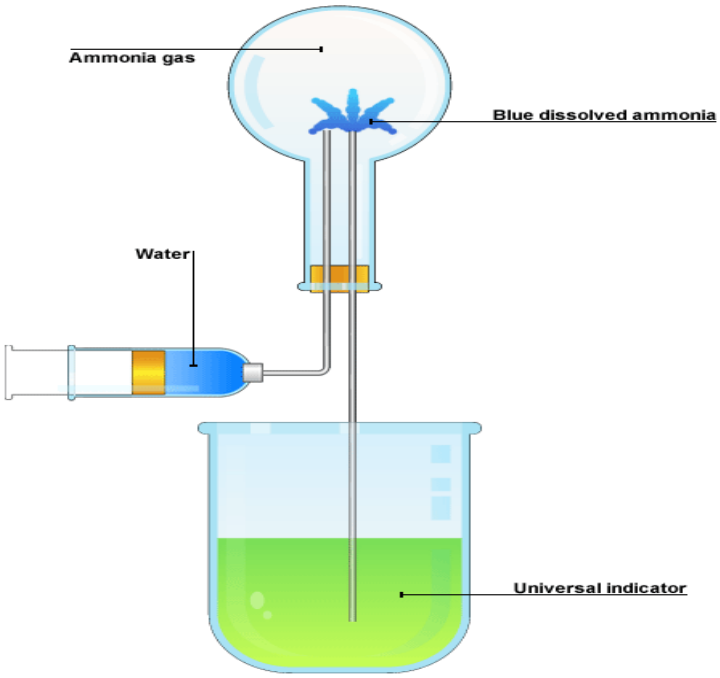
## Making Ammonia in the Laboratory

Ammonia gas can be made in the lab using an ammonium salt and an alkali. The two reactants are heated to release ammonia. Once you have collected a sample of ammonia you will test the pH.




Word Equation: Ammonium nitrate + calcium hydroxide ⟶ ammonia + calcium nitrate

As the ammonia gas is produced the damp pH paper will turn blue. Ammonia gas can also be shown to be alkali using the fountain experiment. As the water with indicator is added the gas dissolves since it is highly soluble turning the indicator blue/purple. Ammonia gas has a sharp unpleasant smell.



# Nitric Acid

Nitric acid is used to make nitrate fertilisers, like potassium nitrate and ammonium nitrate. It can be made by nitrogen dioxide produced in lightning storms and in car engines due to the spark plug which ignites the gases present in the air. To make nitrogen dioxide, nitrogen molecules need to react with oxygen molecules. This requires large quantities of energy due to the very strong triple covalent bond between the nitrogen atoms.

**Word Equation:** nitrogen + oxygen ⟶ nitrogen dioxide

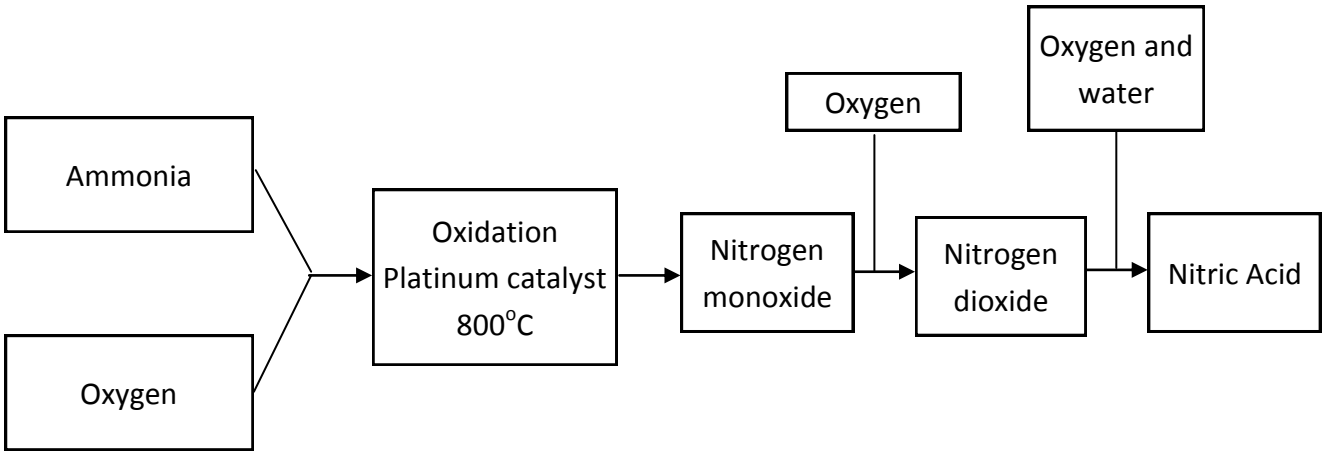
Nitrogen dioxide dissolves in water in the presence of air to make nitric acid.

**Word Equation:** nitrogen dioxide + oxygen + water ⟶ nitric acid

This method for making nitric acid is very expensive due to the large amounts of electricity required to make nitrogen and oxygen react.

## Making Nitric Acid - The Ostwald Process

The Ostwald Process is the industrial process for making nitric acid using ammonia and oxygen.




**Stage 1.** Ammonia reacts with oxygen to form nitrogen monoxide.

This part of the process involves the use of a platinum catalyst along with a moderately high temperature. The platinum catalyst must be heated to start with, after a while the reaction, which is **exothermic**, gives out enough heat to keep the catalyst hot and no further heating is required.

**Stage 2.** Nitrogen monoxide reacts with more oxygen to form nitrogen dioxide.

**Stage 3.** Nitrogen dioxide reacts with further oxygen and water to produce nitric acid.

## Summary Statements

- ☐ The increasing world population has led to a need for more efficient food production.
- ☐ Growing plants require nutrients, including compounds of phosphorus, potassium and nitrogen.
- ☐ Nutrients (NPK) can be provided by fertilisers.
- ☐ Natural fertilisers include manure and compost.
- ☐ The percentage mass of elements in fertilisers can be calculated from formulae using the relationship:

$$\%\ by\ mass = \frac{m}{GFM} \times 100$$

- ☐ Ammonia and nitric acid and nitrogen compounds are important feedstocks for the manufacture of fertilisers.
- ☐ The industrial manufacture of ammonia is in the Haber process.
- ☐ The Haber process uses nitrogen from the air and combines it with hydrogen from natural gas.
- ☐ The reaction of nitrogen and hydrogen to make ammonia is reversible and the ammonia breaks down if the temperature is too high.
- ☐ The Haber Process needs a temperature of 450°C, pressure of 200 atmospheres and an iron catalyst.
- ☐ Ammonia can be converted to ammonium compounds e.g. ammonium nitrate.
- ☐ Ammonia can be prepared in the laboratory by the reaction of an ammonium salt with a base.
- ☐ Ammonia is very soluble and forms an alkaline solution when dissolved.
- ☐ Nitric acid is made industrially by the Ostwald Process.
- ☐ In the Ostwald Process ammonia and oxygen are passed over a platinum catalyst at 800°C.
- ☐ The Ostwald Process reaction is exothermic so external heat can be removed when the reaction gets started.
- ☐ In the Ostwald process nitrogen monoxide is initially formed then nitrogen dioxide dissolves in water.
- ☐ The reaction of nitric acid with ammonia to make ammonium nitrate is an example of a neutralisation reaction.
- ☐ Ammonium nitrate is used as a fertiliser.
- ☐ The catalytic oxidation of ammonia can be carried out in the laboratory but it is not necessary to continue to supply heat once the catalytic oxidation of ammonia has started since it is exothermic.