

Oldest paper

SECTION B Questions linked to this year's theme of Sustainable Chemistry

8. This question is about fertilisers.



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As the population of the world increases more food has to be produced on the finite amount of land available.

Plants need water, sunlight and certain chemical elements – nitrogen, phosphorus and potassium to grow. They obtain these elements from the soil and the air.

If the plants are harvested as food crops, these elements are lost from the soil.

Fertilisers replace these nutrients in the soil and help to improve crop yield.

- a. Fertilisers are made from ammonia.

A molecule of ammonia is shown in **Figure 1**.

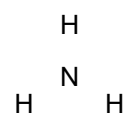
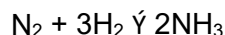


Figure 1

- i. State the number of **atoms** in a molecule of ammonia. _____ [1]
- ii. State the number of **elements** in a molecule of ammonia. _____ [1]
- b. Ammonia is made using the Haber Process in which nitrogen is reacted with hydrogen in the presence of an iron catalyst at 450 °C and 200 atm pressure.

An equation for the reaction is shown below:



Explain why this process has 100% **atom economy**. [1]

In order to be absorbed by the roots, the ammonia must be converted into a soluble salt.

A company wishes to make a fertiliser containing the soluble salt **ammonium nitrate**.

- c. i. Circle the name of the acid ammonia must be reacted with to make ammonium nitrate. [1]

hydrochloric acid

sulfuric acid

nitric acid

phosphoric acid

- ii. Write the formula for ammonium nitrate. [1]

Only small amounts of ammonium nitrate should be stored in any one place owing to the fact that it undergoes thermal decomposition to produce nitrogen, oxygen and water vapour when heated suddenly to a high temperature.

- d. i. Circle the hazard symbol you would expect to see on a bag of ammonium nitrate to reflect the explosive hazard it presents. [1]



- ii. Write a balanced symbol equation for the thermal decomposition of ammonium nitrate and use this equation to explain why the reaction produces an explosion. [3]

Equation _____

Explanation _____

A different company makes the fertiliser **ammonium phosphate**.

- e. The relative formula mass of a compound can be determined by adding the relative atomic masses of the atoms in a compound together.
- i. Calculate the relative formula mass of ammonium phosphate, $(\text{NH}_4)_3\text{PO}_4$ [1]
(Relative atomic masses: H = 1, N = 14, O = 16, P = 31)

- ii. Calculate the percentage by mass of nitrogen in ammonium phosphate. [2]

9. This question is about water.

In 2020, 2 billion people lacked access to safely managed drinking water.



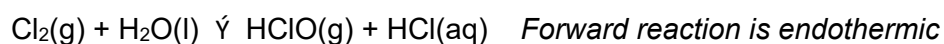
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Water can be obtained from many different sources including surface water (from lakes, rivers and reservoirs) and ground water (from underground).

a. After filtering to remove solid impurities, both surface and ground water are sterilised using chlorine to kill any harmful bacteria or microbes.

i. State the **name** of the group chlorine belongs to on the Periodic table. [1]

The chlorine reacts with the water as shown by the equation below.



ii. Explain how the pH of the water changes on bubbling chlorine through it. [2]

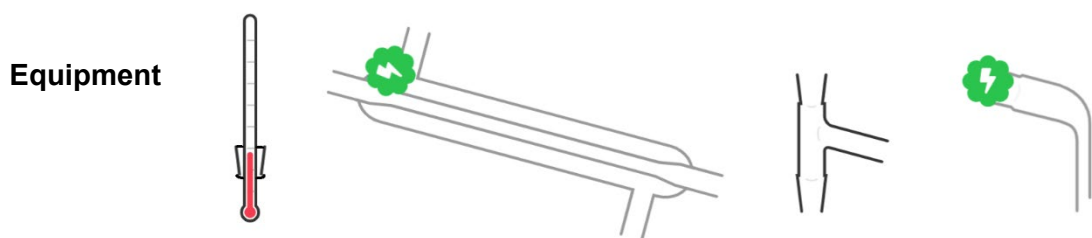
The reaction between chlorine and water is a dynamic equilibrium. The position of the equilibrium will be affected by the conditions.

iii. Use le Chatelier's principle to predict and explain the impact of an increase in temperature on the position of the equilibrium. [3]

Question 9 continues on the next page

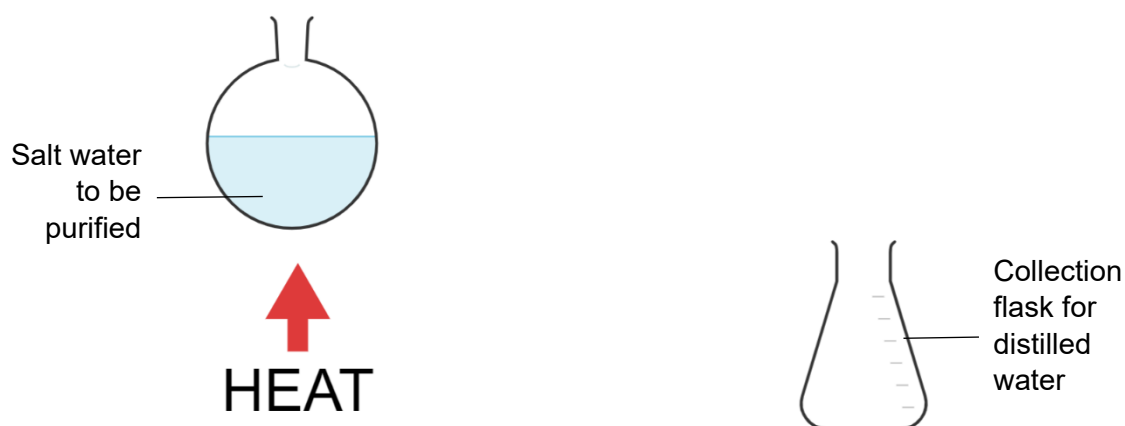
Pure water can also be obtained from salt water using distillation.

- b. i. Uses the images of the pieces of equipment to complete the diagram to show how the equipment should be set up to obtain a sample of pure water from the salt water.



[2]

Diagram to complete:



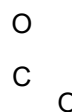
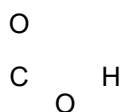
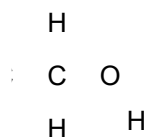
- ii. If the specific latent heat of vaporisation of pure water is 2260 kJ/kg calculate the amount of energy needed to vaporise 10 kg of water during distillation. [1]

- iii. Purification of water by distillation is not sustainable owing to the large amounts of energy required to vapourise the water initially.

Suggest one way the process could be made more sustainable without using an alternative energy source. [1]

10. This question is about the use of biodiesel as a sustainable alternative to petrol and diesel.

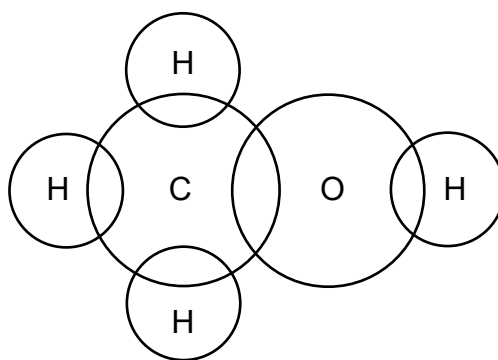
- a. i. Biodiesel is a methyl ester. Circle the functional group found in an **ester**. [1]



- ii. Biodiesel can be made from vegetable oils by reacting the vegetable oils with methanol, CH_3OH , in the presence of a strong alkaline catalyst.

Complete the dot and cross diagram to show the bonding in a molecule of methanol.

[2]



When biodiesel undergoes complete combustion in excess oxygen, carbon dioxide and water are produced.

- b. Balance the chemical equation for the complete combustion of the biodiesel molecule shown. [2]



- c. 1 kg of biodiesel releases 42 MJ of energy when undergoing complete combustion.

A lorry has a tank size of 650 litres.

To transport a typical load of 25 000 kg one mile the lorry requires 15.4 MJ of energy.

If biodiesel has a density of 0.88 kg / L calculate how far the lorry can travel on one full tank of biodiesel. [3]
