RSC TOP OF THE BENCH NATIONAL FINAL 2022

Oldest paper

Name: _____   **School Year:** _____

School: _____

Answer all questions in the spaces provided.

You are provided with a Periodic table.

Write your answers clearly. Show all working.

The total marks allocated to the paper are 40 marks (Section A 10 marks, Section B 30 marks)

The time allocated to the paper is 30 minutes.

Scoring: Section A .... / 10   Section B .... / 30   **Total** .... **/ 40**

SECTION A General chemistry knowledge

1. State the number of protons, neutrons and electrons in an atom of $^{31}_{15}P$.   [1]

protons 15   neutrons 16   electrons 15   *All correct for 1 mark*

2. State the number of particles in one mole of a substance. 6.02×10^{23} [1]

3. Name the gas produced from the incomplete combustion of a fuel. It is known as the silent killer because it is colourless, odourless and tasteless.   carbon monoxide   [1]

**4.** When metals react do they undergo oxidation or reduction?   oxidation   [1]

5. Complete the word equations: one each equation one mark for all products correct   [2]

iron oxide + aluminium → aluminium oxide + iron

sodium carbonate + hydrochloric acid → sodium chloride + water + carbon monoxide

6. Write a balanced symbol equation for the following reaction: [2]

sodium + water → sodium hydroxide + hydrogen

$2Na + 2H_2O \rightarrow 2NaOH + H_2$ one mark all formulae correct; one mark balancing

7. Name the following pieces of equipment.   one mark for each correct name   [2]

crucible   pipette

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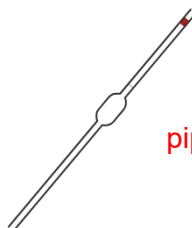
SECTION B Questions linked to this year's theme of Sustainable Chemistry

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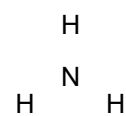
A molecule of ammonia is shown in **Figure 1.**

$$\begin{array}{c} H \\ N \\ H \quad \quad H \end{array}$$

Figure 1

   i. State the number of **atoms** in a molecule of ammonia.   4   [1]

   ii. State the number of **elements** in a molecule of ammonia.   2   [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 ºC and 200 atm pressure.

An equation for the reaction is shown below:

$$N_2 + 3H_2 \; Ý \; 2NH_3$$
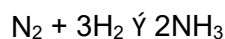
Explain why this process has 100% **atom economy**.   [1]

All atoms in the reactants are incorporated into the desired product / there are no by-products / ammonia is the only product

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]

NH_4NO_3 *(accept the inclusion of correct charges on ions)*

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 $NH_4NO_3 \rightarrow N_2 + \frac{1}{2}O_2 + 2H_2O$ *(accept multiples; allow ecf from c ii)*
One mark correct products; one mark balancing [2]

Explanation One mole of ammonium nitrate produces 3½ moles of gas / large
quantities of gas are produced [1]

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, $(NH_4)_3PO_4$ [1]
(Relative atomic masses: H = 1, N = 14, O = 16, P = 31)

$(14 + 4) \times 3 + 31 + (4 \times 16) = 149$ _____

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

$(3 \times 14) / 149 \times 100 = $ <u>28.2 %</u> *(Allow ecf from e i)*

One mark mass of N = 3 × 14 = 42   One mark substitution into equation

9. This question is about water.

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

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]

halogens _____

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

$$Cl_2(g) + H_2O(l) \ Ý \ HClO(g) + HCl \ (aq) \quad \textit{Forward reaction is endothermic}$$
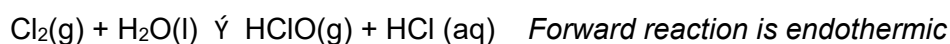
ii. Explain how the pH of the water changes on bubbling chlorine through it. [2]

pH will decrease (one mark) _____

because HCl / HClO is being produced / the products are acidic (one mark) _____

_____

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]

[1] Equilibrium will shift to the right

[1] In favour of the endothermic direction / because the forward reaction is endothermic

[1] To cool the system back down / to oppose the increase in temperature

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.
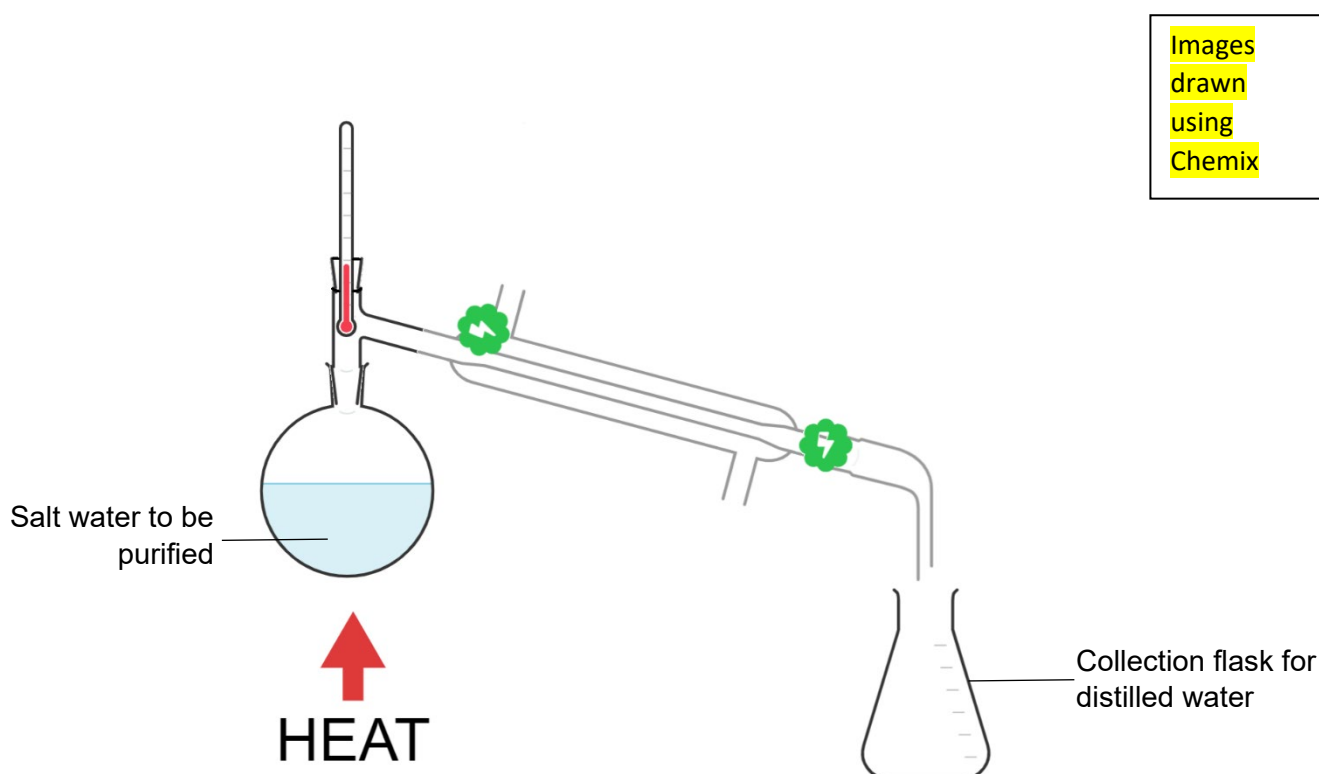
Equipment [2]

1 mark still head and Liebig condenser in place (receiver adaptor optional)

1 mark thermometer in place to seal potential escape route out of the top of still head

Diagram to complete:

Images drawn using Chemix

Salt water to be purified

HEAT

Collection flask for distilled water

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]

Energy = 2260 kJ / kg × 10 kg = <u>22 600 kJ</u>

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]

[1] Capture the heat energy released when the hot water vapour condenses to form liquid water and recycle / put back into the system

10. This question is about the use of biodiesel as a sustainable alternative to petrol.
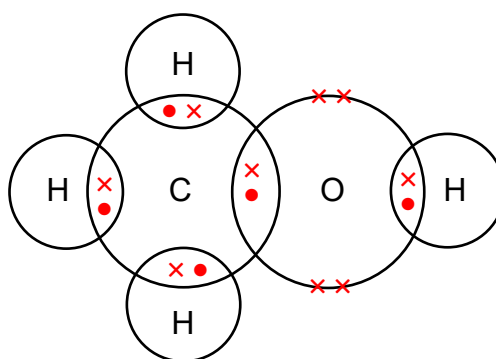
a. i. Biodiesel is a methyl ester. Circle the functional group found in an **ester**. [1]
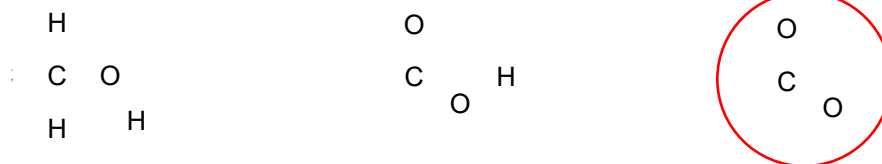
ii. Biodiesel can be made from vegetable oils by reacting the vegetable oils with methanol, CH_3OH, in the presence of a strong alkaline catalyst.

Complete the dot and cross diagram to show the bonding in a molecule of methanol. [2]

One mark dot and cross in each overlap

One mark for four non-bonding electrons on oxygen

Ignore dots, crosses, triangles etc. for different electrons

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]

___ $CH_3(CH_2)_{14}COOCH_3$ + 25 ½ O_2 → 17 CO_2 + 17 H_2O

One mark 17 CO_2 and 17 H_2O; one mark 25½ O_2. *Allow multiples*

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]

[1] Mass of biodiesel in 650 L = density × volume = 0.88 kg/L × 650 L = 572 kg

[1] Energy released by 572 kg = 572 kg × 42 MJ/kg = 24024 MJ

[1] Distance travelled on one tank of fuel = 24042 MJ / 15.4 MJ/mile = 1560 miles

Alternative method for M1 and M2:

[1] Energy released by 1 L of biodiesel = 0.88 × 42 MJ = 36.96 MJ

[1] Energy released by 650 L tank = 650 L × 36.96 MJ/L = 24024 MJ