Mr and Molar Volume of Gases- Chemical Formulae & Chemical Equations

Question Paper

Level	GCSE
Subject	Chemistry
Exam Board	Edexcel IGCSE
Module	Double Award (Paper 1C)
Topic	Principles of Chemistry
Sub-Topic	Chemical Formulae & Chemical Equations
Booklet	Question Paper

Time Allowed: **211 minutes**

Score: **/176**

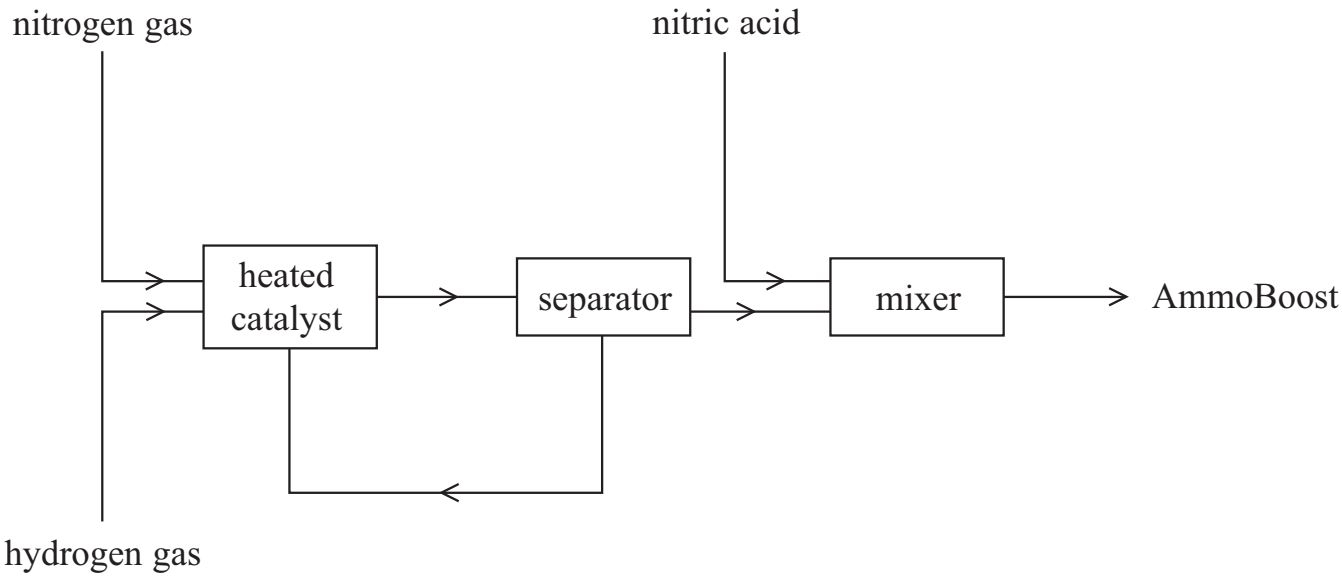
Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

1. AmmoFert Chemicals is a company that manufactures fertilisers.

The flow chart shows how the company manufactures a fertiliser called AmmoBoost.



(a) The first step in the process is the conversion of nitrogen gas and hydrogen gas into ammonia.

(i) State a raw material used as the source of each gas.

(2)

nitrogen .....

hydrogen .....

(ii) Identify the catalyst used in this conversion.

(1)

.....

(iii) State **one** other condition used in this conversion.

(1)

.....

(iv) Only a small percentage of the nitrogen gas and hydrogen gas is converted into ammonia.
Explain how the unreacted gases are separated from the ammonia.

(2)

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.....

(b) The equation for the production of ammonia is

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ/mol}$$

Calculate the maximum mass of ammonia that can be obtained from 56 tonnes of nitrogen.
(1 tonne = 1 000 000 grams)

(3)

(c) EnAitchThree is another company that manufactures ammonia using the same reaction as AmmoFert but using different conditions.
EnAitchThree uses a higher temperature and a higher pressure than AmmoFert.

(i) Predict the effect on the rate of reaction and on the equilibrium position by changing to the temperature used by EnAitchThree.

(2)

Effect of higher temperature on rate of reaction

.....

.....

Effect of higher temperature on equilibrium position

.....

.....

(ii) Predict the effect on the equilibrium position by changing to the pressure used by EnAitchThree. Justify your prediction.

(2)

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.....

.....

(d) The main compound in AmmoBoost contains 35% nitrogen and 5% hydrogen by mass. The remainder is oxygen.

(i) Calculate the percentage by mass of oxygen in the compound.

(1)

(ii) Determine the empirical formula of the compound.

(3)

(iii) What is the **name** of the main compound in AmmoBoost?

(1)

.....

(Total for Question 1 = 18 marks)

2. The element carbon has three common isotopes.
These are carbon-12, carbon-13 and carbon-14.

(a) Complete the table to show the number of protons and neutrons in each isotope of carbon.

(2)

Isotope	Mass number	Number of protons	Number of neutrons
carbon-12	12	6	6
carbon-13	13		
carbon-14	14		

(b) Explain, in terms of electrons, why the three isotopes have the same chemical properties.

(1)

.....

.....

(c) (i) State what is meant by the term **relative atomic mass, A_r**

(2)

.....

.....

.....

.....

(ii) A sample of carbon contained 98.90% carbon-12 and 1.10% carbon-13.

Use this information to calculate the relative atomic mass of carbon in the sample.
Give your answer to **two** decimal places.

(3)

Relative atomic mass .....

(Total for Question 2 = 8 marks)

3. When sodium is burned in air, one of the products is a pale yellow solid, **X**.

(a) A sample of solid **X** was found to contain 1.15 g of sodium and 0.80 g of oxygen.

(i) Show, by calculation, that the empirical formula of **X** is NaO.

(2)

(ii) The relative formula mass of **X** is 78.

Deduce the formula of **X**.

(2)

Formula of **X** .....

(b) Solid **X** reacts with water to form sodium hydroxide, NaOH, and hydrogen peroxide, H_2O_2

(i) Write a chemical equation to represent the reaction between **X** and water.

(2)

.....

(ii) The solution formed in the reaction between **X** and water turns red litmus blue.

Identify the ion that causes this change.

(1)

.....

(iii) The displayed formula for hydrogen peroxide is H—O—O—H.

Complete the dot and cross diagram to show the arrangement of the outer shell (valence) electrons in a molecule of hydrogen peroxide.

(2)

(Total for Question 3 = 9 marks)

4. Lead can be extracted from lead(II) sulfide, PbS, in two stages.

Stage 1: Lead(II) sulfide is heated in air. It reacts with oxygen to produce lead(II) oxide and sulfur dioxide.

Stage 2: The lead(II) oxide is then heated in a blast furnace with coke.

(a) Write a chemical equation for the reaction in **Stage 1**.

(2)

.....

(b) The equation for the reaction that occurs when lead(II) oxide is heated with coke in a blast furnace is:

$$2PbO + C \rightarrow 2Pb + CO_2$$

(i) State, with a reason, whether PbO is oxidised or reduced in this reaction.

(1)

.....

.....

.....

(ii) Calculate the minimum mass, in tonnes, of coke needed to react with 44.6 tonnes of lead(II) oxide.
[1 tonne = 10^6 g]

(3)

Mass of coke needed = ... tonnes

(c) The molten lead obtained from the blast furnace contains 0.1% silver dissolved as an impurity.

The silver is removed by:

- adding zinc to the mixture of molten lead and silver at 530 °C and removing the mixture of molten zinc and silver that forms on top of the molten lead
- heating the mixture of molten zinc and silver until the zinc boils off as a gas, leaving almost pure, solid silver behind

Use the information above to answer the following questions.

(i) What can you deduce about the relative solubility of silver in zinc and in lead?

(1)

.....

.....

(ii) What can you deduce about the melting point of the mixture of zinc and silver?

(1)

.....

.....

(iii) What can you deduce about the boiling point of zinc compared to that of silver?

Explain your answer.

(2)

.....

.....

.....

.....

(iv) Suggest why so much trouble is taken to remove such a small amount of silver from the lead.

(1)

.....

.....

(Total for Question 4 = 11 marks)

5. (a) Crystals of hydrated zinc sulfate, $ZnSO_4.xH_2O$, contain water of crystallisation.

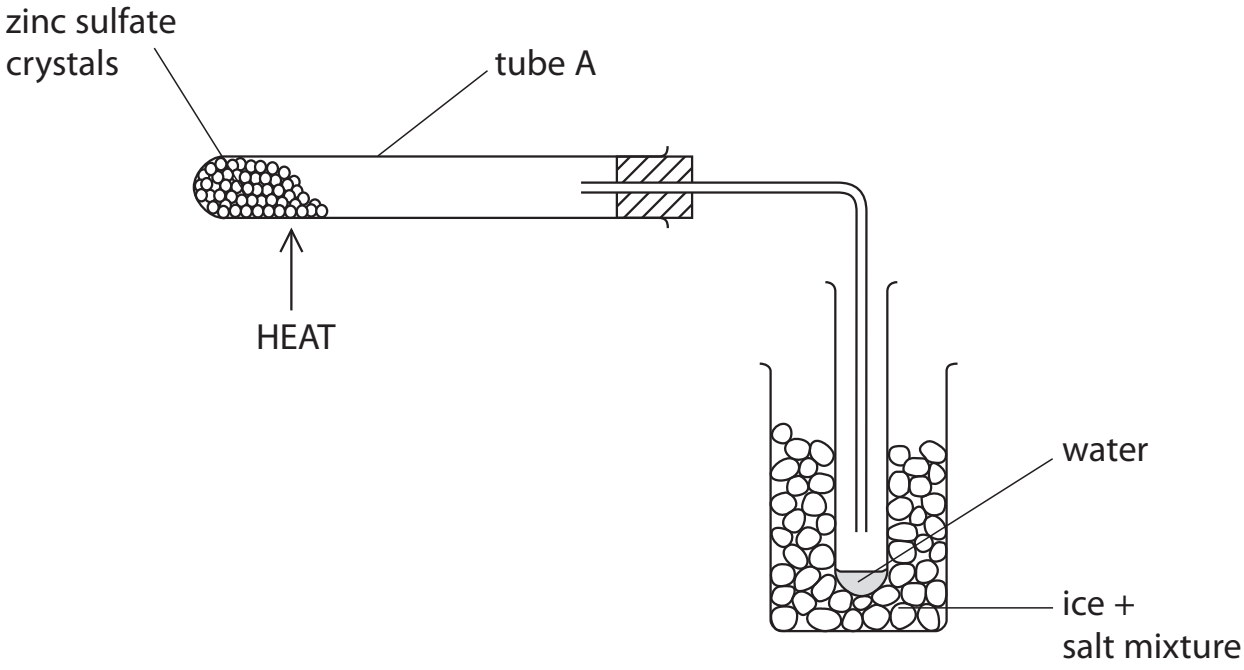
A student used the apparatus shown to remove and collect the water of crystallisation from the crystals in order to find the value of x.

He weighed the empty tube A.

He placed a sample of hydrated zinc sulfate crystals in tube A and reweighed it.

He heated the tube, allowed it to cool and weighed it again.

He repeated this process until two consecutive masses were the same. This is known as 'heating to constant mass'.



When hydrated zinc sulfate crystals are heated gently, they decompose according to the following equation:

$$ZnSO_4.xH_2O \rightarrow ZnSO_4 + xH_2O$$

The following masses were recorded:

Mass of tube A	= 10.12 g
Mass of tube A + $ZnSO_4.xH_2O$	= 18.73 g
Mass of tube A and $ZnSO_4$ after heating to constant mass	= 14.95 g

(i) Calculate the mass of $ZnSO_4$ formed after heating to constant mass.

(1)

.....

(ii) Calculate the mass of water collected after heating to constant mass.

(1)

.....

(iii) The relative formula mass of $ZnSO_4$ is 161

The relative formula mass of water is 18

Use this information, and your answers to (a)(i) and (a)(ii), to calculate the value of x in the formula $ZnSO_4.xH_2O$

Show your working.

(3)

x = ...

(b) Why is it necessary to heat the crystals to constant mass?

(1)

.....

.....

(c) Describe how the student could use a chemical test to show that the liquid collected was water.

(2)

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.....

.....

.....

(Total for Question 5 = 8 marks)

6. Most metals are extracted in a blast furnace or by electrolysis.

(a) (i) The chemical equations for two reactions that occur during the extraction of aluminium are

A $\underline{Al^{3+}} + 3e^- \rightarrow Al$

B $\underline{C} + O_2 \rightarrow CO_2$

For each of these reactions, complete the table to show whether the underlined species is being oxidised or reduced. In each case, explain your choice.

(3)

Reaction	Species oxidised or reduced	Explanation of choice
A		
B		

(ii) Reaction **A** takes place at the negative electrode during the extraction of aluminium.

Write an ionic half-equation for the reaction at the positive electrode.

(2)

.....

(iii) Reaction **B** gives a waste product during the extraction of aluminium.

What effect does this reaction have on the positive electrodes?

(1)

.....

.....

(iv) Reaction **B** is also important in the extraction of iron in a blast furnace.

Name the raw material that reacts with oxygen and state why the reaction is important.

(2)

Raw material .....

Importance of reaction .....

.....

(b) Galena (PbS) and cerussite ($PbCO_3$) are two ores of lead. A mining company is considering which of these two ores to use for the extraction of lead.

The equations for the reactions occurring are

Process using galena:

$$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$$

$$2PbO + C \rightarrow 2Pb + CO_2$$

Process using cerussite:

$$PbCO_3 \rightarrow PbO + CO_2$$

$$2PbO + C \rightarrow 2Pb + CO_2$$

(i) Both processes form carbon dioxide, which the mining company hopes to sell.

Complete the table to show **two** uses of carbon dioxide and a property on which each use depends.

(4)

Use	Property

(ii) One disadvantage of using galena is that the sulfur dioxide produced can cause acid rain.

Write a chemical equation to show the formation of an acidic solution from sulfur dioxide and state one effect of acid rain.

(2)

Equation .....

Effect .....

.....

(c) The company uses a sample of cerussite containing 500 g of $PbCO_3$

Calculate the maximum mass of lead that can be obtained from this sample of cerussite.

(3)

Mass of lead = ... g

(Total for Question 6 = 17 marks)

7. This question is about bromine and some of its compounds.

(a) Atoms of bromine can be represented as ^{79}Br and ^{81}Br

(i) State the number of protons, neutrons and electrons in an atom of ^{79}Br

(2)

Protons .....

Neutrons .....

Electrons .....

(ii) What name is used for atoms of bromine that have different numbers of neutrons?

(1)

.....

(iii) Why do all atoms of bromine have the same chemical properties?

(1)

.....

.....

(iv) The relative atomic mass of bromine is given in the Periodic Table as 80, but a more accurate value is 79.9

Suggest, with a reason, which of the atoms ^{79}Br and ^{81}Br exists in greater numbers in a sample of bromine.

(2)

.....

.....

.....

.....

(b) Hydrogen bromide (HBr) and sodium bromide (NaBr) are compounds of bromine.

(i) Draw a dot and cross diagram to represent a hydrogen bromide molecule.

Show only the outer electrons in each atom.

(2)

(ii) Explain how the atoms are held together in a hydrogen bromide molecule.

(2)

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.....

.....

(iii) Explain why sodium bromide has a higher melting point than hydrogen bromide.

(3)

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.....

(c) A compound has the percentage composition 13.8% sodium, 47.9% bromine and 38.3% oxygen by mass.

Calculate its empirical formula.

(3)

Empirical formula = ...

(Total for Question 7 = 16 marks)

8. Ethene can be converted into many useful substances.

(a) Draw a dot and cross diagram to show the covalent bonding in a molecule of ethene. Only the outer electrons in each atom need to be shown.

(2)

(b) Compound X is made from ethene and is used in cars to prevent the engine coolant from freezing in cold weather.

(i) Compound X contains 38.7% carbon, 9.7% hydrogen and 51.6% oxygen by mass.

Calculate the empirical formula of X.

(3)

Empirical formula .....

(ii) The relative formula mass (M_r) of X is 62

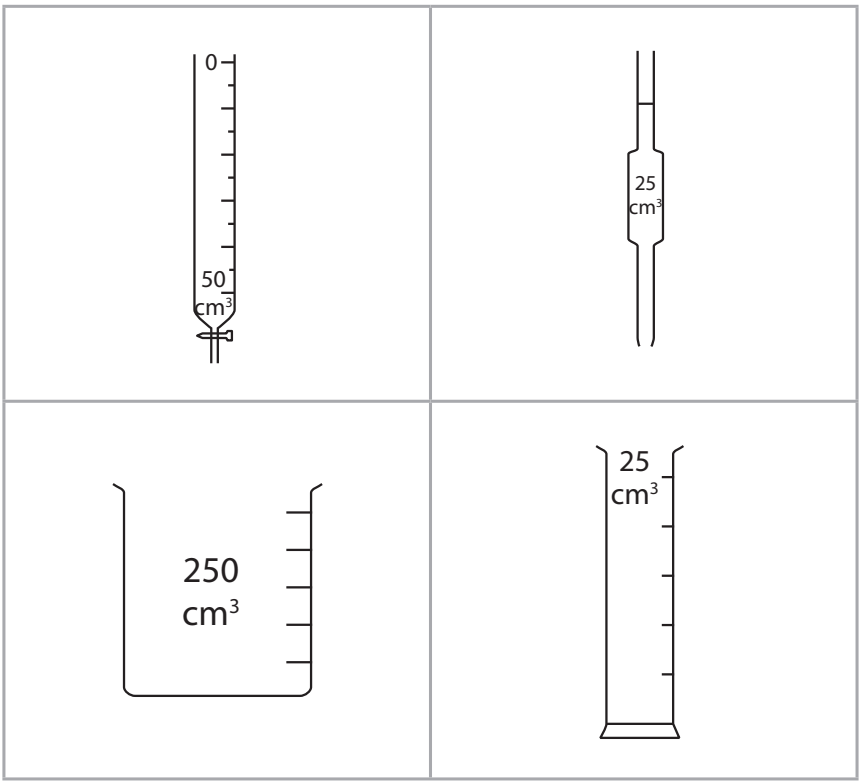
What is the molecular formula of X?

(1)

Molecular formula .....

(Total for Question 8 = 6 marks)

9. The diagram shows some pieces of apparatus used to measure volumes.



A student was given a large bottle containing sodium hydroxide solution and a supply of dilute sulfuric acid of known concentration.

He was allowed to use normal laboratory apparatus, including the pieces of apparatus shown in the diagram.

He was told to plan an experiment to find the concentration of the sodium hydroxide solution.

This is his plan.

Step 1 Obtain about 150 cm^3 of each solution.

Step 2 Use a measuring cylinder to add exactly 25.0 cm^3 of sodium hydroxide solution to a conical flask.

Step 3 Add a few drops of universal indicator to the conical flask.

Step 4 Use a burette to add the sulfuric acid to the conical flask until the indicator changes colour.

(a) (i) Give the name of the most suitable piece of apparatus in the diagram that should be used in Step 1.

(1)

.....

(ii) Give the name of the piece of apparatus in the diagram that should be used instead of a measuring cylinder in Step 2.

(1)

.....

(iii) State why universal indicator is **not** a good choice for this experiment and suggest an indicator that would be more suitable.

(2)

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.....

.....

(iv) Why is a pipette not suitable for adding the acid in Step 4?

(1)

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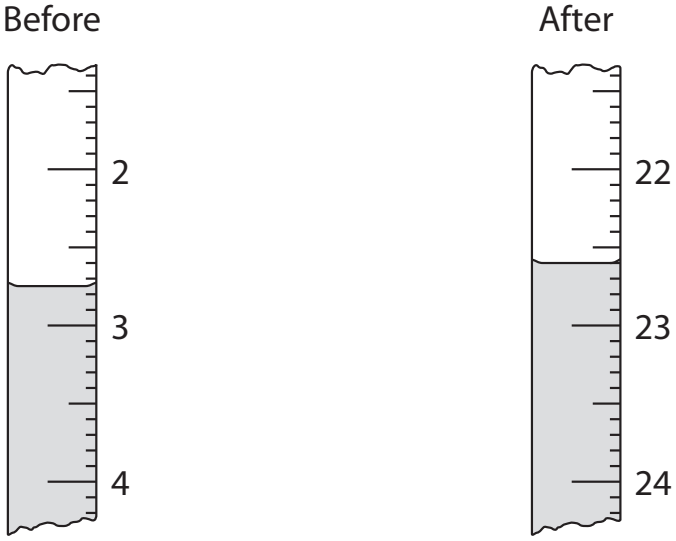
.....

(b) The diagram shows the burette readings in one experiment before and after adding the acid.



Use the readings to complete the table, entering all values to the nearest 0.05 cm^3.

(3)

Burette reading after adding acid in cm^3	
Burette reading before adding acid in cm^3	
Volume of acid added in cm^3	

(c) The student repeated the experiment using a different concentration of sodium hydroxide solution and recorded these results.

Burette reading after adding acid in cm^3	24.90	25.85	24.85	25.55
Burette reading before adding acid in cm^3	1.20	2.75	1.50	2.10
Volume of acid added in cm^3	23.70	23.10	23.35	23.45
Titration results to be used (✓)				

The volumes of acid added during these titrations are not all the same. The average (mean) volume of acid should be calculated using only concordant results.

Concordant results are those volumes that differ from each other by 0.20 cm^3 or less.

(i) Identify the concordant results by placing ticks (✓) in the table where appropriate.

(1)

(ii) Use your ticked results to calculate the average (mean) volume of acid added.

(2)

Average (mean) volume of acid = ... cm^3

(d) The student used the same method to find the concentration of a solution of potassium hydroxide. The equation for the reaction is

$$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$$

These are his results.

Volume of potassium hydroxide solution	25.0 cm^3
Volume of sulfuric acid	23.60 cm^3
Concentration of sulfuric acid	0.0500 mol/dm^3

He used these results to calculate the concentration of the potassium hydroxide solution.

Step 1 amount of $H_2SO_4 = \frac{0.0500 \quad 23.60}{100} = 0.0118$ mol

Step 2 amount of $KOH = \frac{0.0118}{2} = 0.00590$ mol

Step 3 concentration of $KOH = \frac{0.00590}{23.60} \quad 1000 = 0.250$ mol/dm^3

There is one mistake in each step of the calculation.

What correction should the student make in each step?

(i) Step 1

(1)

.....

.....

(ii) Step 2

(1)

.....

.....

(iii) Step 3

(1)

.....

.....

(Total for Question 9 = 14 marks)

10. The Haber process is used to convert nitrogen and hydrogen into ammonia.

(a) Which raw material is the source of the nitrogen?

(1)

.....

(b) The hydrogen for this process is obtained using reactions 1 and 2

Reaction 1 $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +210$ kJ mol^{-1}

Reaction 2 $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -42$ kJ mol^{-1}

(i) Predict what will happen to the equilibrium position in reaction 1 when the pressure is increased. Give a reason for your prediction.

(2)

Prediction .....

.....

Reason .....

.....

.....

(ii) Predict what will happen to the equilibrium position in reaction 2 when the temperature is increased. Give a reason for your prediction.

(2)

Prediction .....

.....

Reason .....

.....

.....

(c) Predict what will happen to the rate of reaction 1 when the pressure and temperature are increased.

(2)

Effect of increased pressure .....

Effect of increased temperature .....

(d) Some of the ammonia from the Haber process is made into fertilisers such as ammonium nitrate.

The equation for the formation of ammonium nitrate is

$$NH_3 + HNO_3 \rightarrow NH_4NO_3$$

A manufacturer makes a batch of 40 kg of ammonium nitrate.

(i) Calculate the amount, in moles, of NH_4NO_3 in 40 kg of ammonium nitrate.

(2)

Amount of NH_4NO_3 ..... mol

(ii) Deduce the amount, in moles, of ammonia needed to make this amount of ammonium nitrate.

(1)

Amount of ammonia ..... mol

(iii) Calculate the mass, in kg, of ammonia needed.

(2)

Mass of ammonia ..... kg

(e) The manufacturer also produces fertilisers that are labelled NPK.

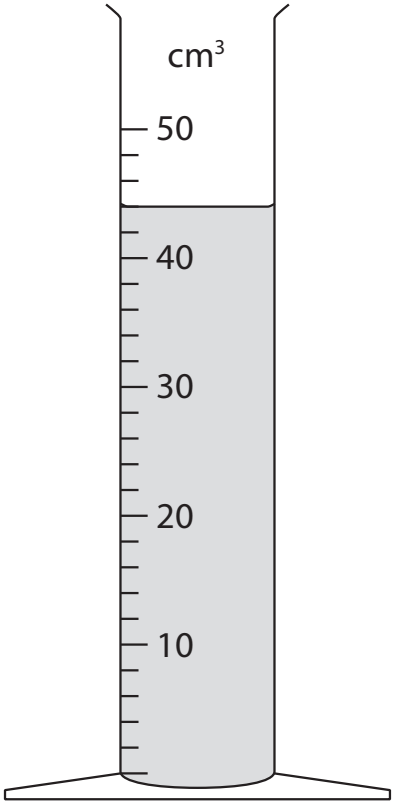
Suggest the names of two elements, other than nitrogen, that are likely to be present in NPK fertilisers.

(1)

..... and .....

(Total for Question 10 = 13 marks)

11. The piece of apparatus shown contains 0.010 mol / dm^3 hydrochloric acid.



(a) (i) Give the name of this piece of apparatus.

(1)

.....

(ii) What volume of hydrochloric acid is in the apparatus?

(2)

.....

(iii) Use your answer in (a)(ii) to calculate the amount, in moles, of hydrochloric acid in the apparatus.

(2)

Amount = ... mol

(b) A student poured a solution containing 0.010 mol of hydrochloric acid into a beaker.

He then added 0.0075 mol of zinc powder and collected the hydrogen given off in a gas syringe.

The equation for the reaction is

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

Is the zinc or the hydrochloric acid in excess? Explain your answer.

(2)

.....

.....

.....

(c) The student repeated the experiment with 0.0075 mol of magnesium powder with the same total surface area as the zinc.

The equation for the reaction is

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

(i) What effect would this change have on the rate at which the hydrogen is given off?

(1)

.....

.....

.....

(ii) What effect would this change have on the volume of hydrogen produced?

(1)

.....

.....

.....

(Total for Question 11 = 9 marks)

12. Magnesium reacts with dilute hydrochloric acid. The equation for the reaction is

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

(a) 0.0960 g of magnesium was added to 25.0 cm^3 of 0.400 mol/dm^3 hydrochloric acid.

(i) Calculate the amount, in moles, of magnesium used.

(2)

amount of magnesium = ... mol

(ii) Calculate the amount, in moles, of HCl in the 25.0 cm^3 of hydrochloric acid.

(2)

amount of HCl = ... mol

(b) Use your answers from (a) to determine which of the reactants is in excess.

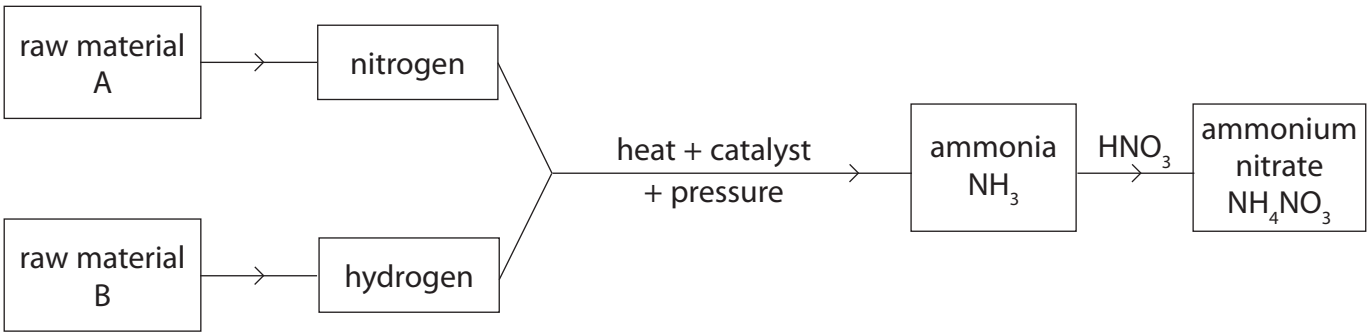
Show your reasoning.

(2)

The reactant in excess is .....

(Total for Question 12 = 6 marks)

13 The diagram shows the manufacture of ammonia by the Haber process and its conversion into the fertiliser ammonium nitrate.



(a) Give the names of the raw materials A and B.

(2)

A .....

B .....

(b) State the temperature, pressure and catalyst used to convert the mixture of nitrogen and hydrogen into ammonia.

(3)

temperature .....

pressure .....

catalyst .....

(c) Give the name of the substance that has the formula HNO_3

(1)

.....

(d) The equation for the formation of ammonium nitrate from ammonia is

$$NH_3(aq) + HNO_3(aq) \rightarrow NH_4NO_3(aq)$$

25.0 cm^3 of a solution of ammonia of concentration 0.300 mol/dm^3 were reacted with a solution of HNO_3

15.0 cm^3 of HNO_3 were required to exactly neutralise the ammonia solution.

Calculate the concentration, in mol/dm^3, of the HNO_3 solution.

(3)

concentration of HNO_3 = ... mol/dm^3

(Total for Question 13 = 9 marks)

14. A sample of a chlorofluorocarbon (CFC) contains 0.24 g of carbon, 0.38 g of fluorine and 1.42 g of chlorine.

(a) (i) Show, by calculation, that the empirical formula of the CFC is $CFCl_2$

(3)

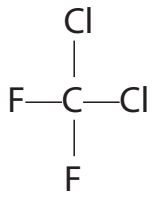
(ii) The relative formula mass of the CFC is 204.

Deduce the molecular formula of the CFC.

(2)

molecular formula .....

(b) The displayed formula of another CFC is



Draw a dot and cross diagram of this CFC.

Show only the outer electrons.

(2)

(Total for Question 14 = 7 marks)

15. (a) A student made a solution of sodium hydroxide by dissolving 10.0 g of solid sodium hydroxide in distilled water to make 250 cm^3 of solution.

(i) Calculate the amount, in moles, of NaOH in 10.0 g of sodium hydroxide.

(3)

amount = ... mol

(ii) Calculate the concentration, in mol/dm^3, of this solution of sodium hydroxide.

(2)

concentration = ... mol/dm^3

(b) (i) The student uses the sodium hydroxide solution to find the concentration of a solution of hydrochloric acid.

He uses this method

- use a pipette to put 25.0 cm^3 of the sodium hydroxide solution into a conical flask
- add a few drops of methyl orange indicator to the solution
- gradually add the hydrochloric acid from a burette until the solution in the flask just changes colour

The diagram shows his burette readings.

start end

Complete the table, giving all values to the nearest 0.05 cm^3.

(3)

burette reading at end in cm^3	
burette reading at start in cm^3	
volume of acid added in cm^3	

(ii) State the colour of the methyl orange at the start and at the end of the experiment.

(2)

colour at start .....

colour at end .....

(iii) Why is a burette used instead of a pipette for adding the acid?

(1)

.....

.....

(c) Sodium hydroxide reacts with carbon dioxide.

The equation for this reaction is

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

A solution of sodium hydroxide of concentration 2.00 mol/dm^3 is used.

(i) Calculate the amount, in moles, of sodium hydroxide in 200 cm^3 of this solution.

(2)

amount of sodium hydroxide = ... mol

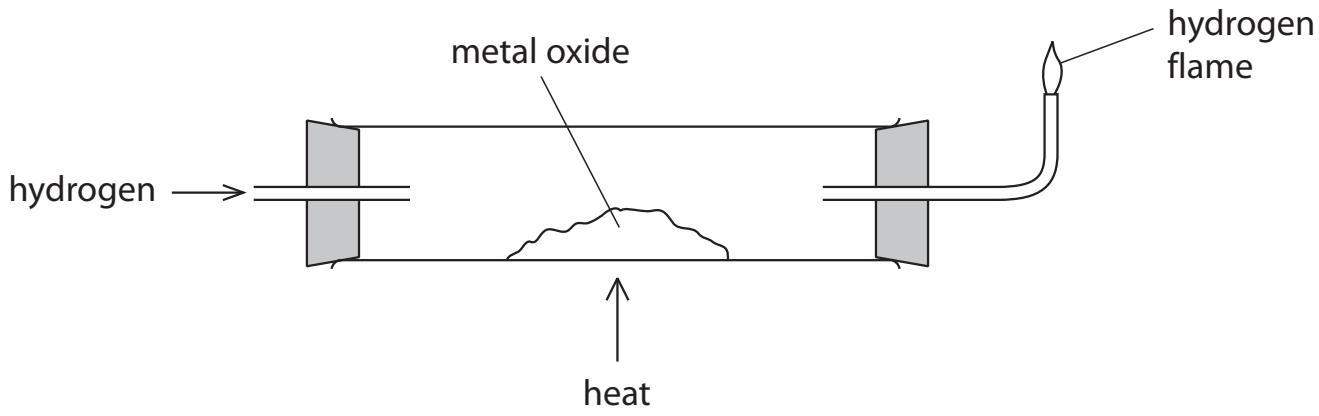
(ii) Deduce the maximum mass, in grams, of carbon dioxide that can react with this solution of sodium hydroxide.

(2)

mass of carbon dioxide = ... g

(Total for Question 15 = 15 marks)

16. This apparatus can be used to investigate the reduction of metal oxides.



The mass of the metal oxide is measured before and after heating it in hydrogen.

The results can be used to determine the formula of the oxide.

(a) The hydrogen gas burns as it leaves the tube.

(i) What substance is formed when hydrogen burns in air?

(1)

.....

(ii) Why is it important to relight the flame if it goes out?

(1)

.....

.....

(b) These are the results for one experiment.

Mass of solid before heating = 4.2 g

Mass of solid after heating = 3.4 g

These results may not be sufficient to find the mass of metal for use in determining the formula of the metal oxide.

What further practical steps should be taken to confirm that an accurate value for the mass of metal has been obtained?

(2)

.....

.....

.....

.....

(c) In an experiment using a different metal oxide, a mass of 2.8 g of metal is obtained from 3.6 g of the metal oxide.

(i) Calculate the mass of oxygen in the sample of the metal oxide.

(1)

mass of oxygen = ... g

(ii) Calculate the amount, in moles, of oxygen atoms in the sample of the metal oxide.

(2)

amount of oxygen = ... mol

(iii) The formula of the metal oxide is MO, where M is the symbol of the metal.

Deduce the amount, in moles, of M in the sample of the metal oxide.

(1)

amount of M = ... mol

(iv) What is the relative atomic mass of M?

(2)

relative atomic mass of M = ...

(Total for Question 16 = 10 marks)