Moles & Stoichiometry

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Moles, Mass & Ratios

16 *Use of the Data Booklet is relevant to this question.*

What mass of solid residue can be obtained from the thermal decomposition of 4.10 g of anhydrous calcium nitrate?

A 0.70g **B** 1.00g **C** 1.40g **D** 2.25g

s/06/qp1

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15 *Use of the Data Booklet is relevant to this question.*

The combustion of fossil fuels is a major source of increasing atmospheric carbon dioxide, with a consequential rise in global warming. Another significant contribution to carbon dioxide levels comes from the thermal decomposition of limestone, in the manufacture of cement and of lime for agricultural purposes.

Cement works roast 1000 million tonnes of limestone per year and a further 200 million tonnes is roasted in kilns to make lime.

What is the total annual mass output of carbon dioxide (in million tonnes) from these two processes?

A 440 **B** 527 **C** 660 **D** 880

s/08/qp1

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33 *Use of the Data Booklet is relevant to this question.*

Zinc reacts with hydrochloric acid according to the following equation.

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Which statements are correct?

[All volumes are measured at room conditions.]

1 A 3.27 g sample of zinc reacts with an excess of hydrochloric acid to give 0.050 mol of zinc chloride.

2 A 6.54 g sample of zinc reacts completely with exactly 100 cm^3 of 1.00 mol dm^{-3} hydrochloric acid.

3 A 13.08 g sample of zinc reacts with an excess of hydrochloric acid to give 9.60 dm^3 of hydrogen.

s/11/qp11

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1 *Use of the Data Booklet is relevant to this question.*

Titanium(IV) oxide, TiO_2, is brilliantly white and much of the oxide produced is used in the manufacture of paint.

What is the maximum amount of TiO_2 obtainable from 19.0 tonnes of the ore ilmenite, $FeTiO_3$?

A 10.0 tonnes **B** 12.7 tonnes **C** 14.0 tonnes **D** 17.7 tonnes

w/08/qp1

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14 *Use of the Data Booklet is relevant to this question.*

Which mass of solid residue can be obtained from the thermal decomposition of 4.10 g of anhydrous calcium nitrate?

A 0.70g **B** 1.00g **C** 1.40g **D** 2.25g

w/10/qp12

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14 *Use of the Data Booklet is relevant to this question.*

A significant contribution to atmospheric carbon dioxide levels comes from the thermal decomposition of limestone, in the manufacture of cement and of lime for agricultural purposes.

Cement works roast 1000 million tonnes of limestone per year and a further 200 million tonnes is roasted in kilns to make lime.

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A 440 **B** 527 **C** 660 **D** 880

w/11/qp11

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16 *Use of the Data Booklet is relevant to this question.*

Magnesium nitrate, $Mg(NO_3)_2$, will decompose when heated to give a white solid and a mixture of gases. One of the gases released is an oxide of nitrogen, X.

7.4g of anhydrous magnesium nitrate is heated until no further reaction takes place.

What mass of X is produced?

A 1.5g **B** 2.3g **C** 3.0g **D** 4.6g

s/13/qp11

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13 *Use of the Data Booklet is relevant to this question.*

Magnesium nitrate, $Mg(NO_3)_2$, will decompose when heated to give a white solid and a mixture of gases. One of the gases released is oxygen.

29.7 g of anhydrous magnesium nitrate is heated until no further reaction takes place.

What mass of oxygen is produced?

A 3.2 g **B** 6.4 g **C** 12.8 g **D** 19.2 g

s/13/qp12

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19 *Use of the Data Booklet is relevant to this question.*

In an experiment, 0.125 mol of chlorine gas, Cl_2, is reacted with an excess of cold aqueous sodium hydroxide. One of the products is a compound of sodium, oxygen, and chlorine.

Which mass of this product is formed?

A 9.31 g **B** 13.3 g **C** 18.6 g **D** 26.6 g

s/14/qp12

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17 *Use of the Data Booklet is relevant to this question.*

In an experiment, 0.6 mol of chlorine gas, Cl_2, is reacted with an excess of hot aqueous sodium hydroxide. One of the products is a compound of sodium, oxygen and chlorine.

Which mass of this product is formed?

A 21.3 g **B** 44.7 g **C** 63.9 g **D** 128 g

s/14/qp13

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12 *Use of the Data Booklet is relevant to this question.*

The reaction between aluminium powder and anhydrous barium nitrate is used as the propellant in some fireworks. The reaction produces the metal oxides and nitrogen.

$$10Al + 3Ba(NO_3)_2 \rightarrow 5Al_2O_3 + 3BaO + 3N_2$$

Which mass of barium oxide is produced when 5.40 g of aluminium powder reacts with an excess of anhydrous barium nitrate?

A 1.62 g **B** 3.06 g **C** 9.18 g **D** 10.2 g

w/13/qp13

Moles and Gas Volume

3 *Use of the Data Booklet is relevant to this question.*

Most modern cars are fitted with airbags. These work by decomposing sodium azide to liberate nitrogen gas, which inflates the bag.

$$2NaN_3 \rightarrow 3N_2 + 2Na$$

A typical driver's airbag contains 50 g of sodium azide.

Calculate the volume of nitrogen this will produce at room temperature.

A 9.2 dm^3 **B** 13.9 dm^3 **C** 27.7 dm^3 **D** 72.0 dm^3

s/04/qp1

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31 For complete combustion, 1 mol of an organic compound **X** was found to require 2.5 mol of molecular oxygen.

Which compounds could be **X**?

1 C_2H_5OH

2 C_2H_2

3 CH_3CHO

s/08/qp1

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9 Which mass of gas would occupy a volume of 3 dm^3 at 25 °C and 1 atmosphere pressure?
[1 mol of gas occupies 24 dm^3 at 25 °C and 1 atmosphere pressure.]

A 3.2 g O_2 gas

B 5.6 g N_2 gas

C 8.0 g SO_2 gas

D 11.0 g CO_2 gas

s/10/qp11

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35 In a car engine, non-metallic element X forms a pollutant oxide Y.

Further oxidation of Y to Z occurs in the atmosphere. In this further oxidation, 1 mol of Y reacts with ½ mol of gaseous oxygen.

What can X be?

1 carbon

2 nitrogen

3 sulfur

s/10/qp11

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14 *Use of the Data Booklet is relevant to this question.*

The reaction between aluminium powder and anhydrous barium nitrate is used as the propellant in some fireworks. The metal oxides and nitrogen are the only products.

Which volume of nitrogen, measured under room conditions, is produced when 0.783 g of anhydrous barium nitrate reacts with an excess of aluminium?

A 46.8 cm^3 **B** 72.0 cm^3 **C** 93.6 cm^3 **D** 144 cm^3

s/12/qp11

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15 One mole of each of the following compounds is strongly heated and any gas produced is collected at room temperature and pressure.

From which compound is 24 dm^3 of gas likely to be collected?
[One mole of any gas occupies 24 dm^3 at room temperature and pressure.]

A $MgCl_2$ **B** $MgCO_3$ **C** $Mg(NO_3)_2$ **D** $Mg(OH)_2$

w/03/qp1

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3 The foul smell that skunks spray is due to a number of thiols, one of which is methanethiol, CH_3SH, which burns as follows.

$$CH_3SH + 3O_2 \rightarrow CO_2 + SO_2 + 2H_2O$$

A sample of 10 cm^3 of methanethiol was exploded with 60 cm^3 of oxygen.

What would be the final volume of the resultant mixture of gases when cooled to room temperature?

A 20 cm^3 **B** 30 cm^3 **C** 50 cm^3 **D** 70 cm^3

w/04/qp1

15 *Use of the Data Booklet is relevant to this question.*

What volume of oxygen, measured under room conditions, can be obtained from the thermal decomposition of 8.2 g of calcium nitrate (M_r = 164)?

A 150 cm^3 **B** 300 cm^3 **C** 600 cm^3 **D** 1200 cm^3

w/05/qp1

2 Carbon disulphide vapour burns in oxygen according to the following equation.

$$CS_2(g) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$$

A sample of 10 cm^3 of carbon disulphide was burned in 50 cm^3 of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again. All measurements were made at the same temperature and pressure, under such conditions that carbon disulphide was gaseous.

What were the measured volumes?

	volume of gas after burning/cm^3	volume of gas after adding NaOH(aq)/cm^3
A	30	0
B	30	20
C	50	20
D	50	40

w/08/qp1

2 A mixture of 10 cm^3 of methane and 10 cm^3 of ethane was sparked with an excess of oxygen. After cooling to room temperature, the residual gas was passed through aqueous potassium hydroxide.

All gas volumes were measured at the same temperature and pressure.

What volume of gas was absorbed by the alkali?

A 15 cm^3 **B** 20 cm^3 **C** 30 cm^3 **D** 40 cm^3

s/13/qp11

26 *Use of the Data Booklet is relevant to this question.*

Which volume of oxygen measured at room temperature and pressure is needed for complete combustion of 0.1 mol of propan-1-ol?

A 10.8 dm^3 **B** 12.0 dm^3 **C** 21.6 dm^3 **D** 24.0 dm^3

s/13/qp12

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27 *Use of the Data Booklet is relevant to this question.*

Which volume of oxygen, at room temperature and pressure, is needed for complete combustion of 0.1 mol of ethanol?

A 7.2 dm^3 **B** 8.4 dm^3 **C** 14.4 dm^3 **D** 16.8 dm^3

s/13/qp13

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18 *Use of the Data Booklet is relevant to this question.*

A chemist took 2.00 dm^3 of nitrogen gas, measured under room conditions, and reacted it with a large volume of hydrogen gas, in order to produce ammonia. Only 15.0% of the nitrogen gas reacted to produce ammonia.

What mass of ammonia was formed?

A 0.213 g **B** 0.425 g **C** 1.42 g **D** 2.83 g

s/14/qp11

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9 *Use of the Data Booklet is relevant to this question.*

In an experiment, 12.0 dm^3 of oxygen, measured under room conditions, is used to burn completely 0.10 mol of propan-1-ol.

What is the final volume of gas, measured under room conditions?

A 7.20 dm^3 **B** 8.40 dm^3 **C** 16.8 dm^3 **D** 18.00 dm^3

s/14/qp12

Moles and Percentage

(purity, yield, empirical formula etc)

2 *Use of the Data Booklet is relevant to this question.*

Oxides of nitrogen are pollutant gases which are emitted from car exhausts.

In urban traffic, when a car travels one kilometre, it releases 0.23 g of an oxide of nitrogen N_xO_y, which occupies 120 cm^3.

What are the values of *x* and *y*?
(Assume 1 mol of gas molecules occupies 24.0 dm^3.)

A $x = 1, y = 1$

B $x = 1, y = 2$

C $x = 2, y = 1$

D $x = 2, y = 4$

s/07/qp1

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1 *Use of the Data Booklet is relevant to this question.*

In leaded petrol there is an additive composed of lead, carbon and hydrogen only. This compound contains 29.7 % carbon and 6.19 % hydrogen by mass.

What is the value of **x** in the empirical formula PbC_8H_x?

A 5 **B** 6 **C** 16 **D** 20

s/09/qp1

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10 Tanzanite is used as a gemstone for jewellery. It is a hydrated calcium aluminium silicate mineral with a chemical formula $Ca_2Al_xSi_yO_{12}(OH).6½H_2O$. Tanzanite has M_r of 571.5.

Its chemical composition is 14.04 % calcium, 14.17 % aluminium, 14.75 % silicon, 54.59 % oxygen and 2.45 % hydrogen.

(A_r values: H = 1.0, O = 16.0, Al = 27.0, Si = 28.1, Ca = 40.1)

What are the values of x and y?

	x	y
A	1	1
B	2	3
C	3	3
D	6	1

s/11/qp12

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38 A number of alcohols with the formula $C_4H_{10}O$ are separately oxidised. Using 70 g of the alcohols a 62 % yield of organic product is achieved.

What mass of product could be obtained?

1 42.2 g of butanone

2 51.6 g of butanoic acid

3 51.6 g of 2-methyl propanoic acid

s/12/qp11

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2 *Use of the Data Booklet is relevant to this question.*

A garden fertiliser is said to have a phosphorus content of 30.0 % 'P_2O_5 soluble in water'.

What is the percentage by mass of phosphorus in the fertiliser?

A 6.55 % **B** 13.1 % **C** 26.2 % **D** 30.0 %

w/03/qp1

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12 Camphor is a white solid which was used to make the early plastic celluloid. Camphor contains the same percentage by mass of hydrogen and oxygen.

What is the molecular formula of camphor?

A $C_{10}H_6O_6$ **B** $C_{10}H_8O$ **C** $C_{10}H_{16}O$ **D** $C_{10}H_{10}O_2$

w/10/qp11

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39 *Use of the Data Booklet is relevant for this question.*

In an organic synthesis, a 62% yield of product is achieved.

Which of these conversions are consistent with this information?

1 74.00g of butan-2-ol → 44.64g of butanone

2 74.00g of butan-1-ol → 54.56g of butanoic acid

3 74.00g of 2-methylpropan-1-ol → 54.56g of 2-methylpropanoic acid

w/10/qp12

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25 *Use of the Data Booklet is relevant to this question.*

2.76g of ethanol were mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for one hour. The organic product was then collected by distillation.

The yield of product was 75.0%.

What mass of product was collected?

A 1.98g **B** 2.07g **C** 2.70g **D** 4.80g

w/11/qp11

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26 *Use of the Data Booklet is relevant to this question.*

2.30 g of ethanol were mixed with aqueous acidified potassium dichromate(VI). The desired product was collected by immediate distillation under gentle warming.

The yield of product was 70.0%.

What mass of product was collected?

A 1.54g **B** 1.61g **C** 2.10g **D** 3.14g

w/11/qp12

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25 *Use of the Data Booklet is relevant to this question.*

2.30 g of ethanol were mixed with aqueous acidified potassium dichromate(VI) and the desired organic product was collected by immediate distillation under gentle warming. The yield of product was 70.0%.

What mass of product was collected?

A 1.54g **B** 1.61g **C** 2.10g **D** 2.20g

w/12/qp13

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26 *Use of the Data Booklet is relevant to this question.*

2.30 g of ethanol were mixed with an excess of aqueous acidified potassium dichromate(VI). The reaction mixture was then boiled under reflux for one hour. The desired organic product was then collected by distillation. The yield of product was 60.0%.

What mass of product was collected?

A 1.32g **B** 1.38g **C** 1.80g **D** 3.20g

s/13/qp11

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40 *Use of the Data Booklet is relevant to this question.*

In an organic synthesis, a 62% yield of product is achieved.

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1 74.00g of butan-2-ol → 44.64g of butanone

2 74.00g of butan-1-ol → 54.56g of butanoic acid

3 74.00g of 2-methylpropan-1-ol → 54.56g of 2-methylpropanoic acid

s/14/qp11

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10 *Use of the Data Booklet is relevant to this question.*

Which sodium compound contains 74.2% by mass of sodium?

A sodium carbonate

B sodium chloride

C sodium hydroxide

w/13/qp11

6 *Use of the Data Booklet is relevant to this question.*

In some countries, anhydrous calcium chloride is used as a drying agent to reduce dampness in houses. The anhydrous salt absorbs enough water to form the dihydrate $CaCl_2.2H_2O$.

What is the percentage increase in mass?

A 14% **B** 24% **C** 32% **D** 36%

w/14/qp13

8 *Use of the Data Booklet is relevant to this question.*

The approximate percentage composition of the atmosphere on four different planets is given in the table below.

The density of a gas may be defined as the mass of 1 dm^3 of the gas measured at s.t.p.

Which mixture of gases has the greatest density?

	planet	major gases / % by number of molecules
A	Jupiter	H_2 89.8, He 10.2
B	Neptune	H_2 80.0, He 19.0, CH_4 1.0
C	Saturn	H_2 96.3, He 3.25, CH_4 0.45
D	Uranus	H_2 82.5, He 15.2, CH_4 2.3

w/13/qp11

Moles, Titration & Solutions

9 Which substance, in 1 mol dm^{-3} aqueous solution, would have the same hydrogen ion concentration as 1 mol dm^{-3} of hydrochloric acid?

A ethanoic acid

B nitric acid

C sodium hydroxide

D sulphuric acid

s/04/qp1

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1 N_2O_4 is a poisonous gas. It can be disposed of safely by reaction with sodium hydroxide.

$$N_2O_4(g) + 2NaOH(aq) \rightarrow NaNO_3(aq) + NaNO_2(aq) + H_2O(l)$$

What is the minimum volume of 0.5 mol dm^{-3} NaOH(aq) needed to dispose of 0.02 mol of N_2O_4?

A 8 cm^3 **B** 12.5 cm^3 **C** 40 cm^3 **D** 80 cm^3

s/06/qp1

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2 *Use of the Data Booklet is relevant to this question.*

A typical solid fertiliser for use with household plants and shrubs contains the elements N, P, and K in the ratio of 15 g : 30 g : 15 g per 100 g of fertiliser. The recommended usage of fertiliser is 14 g of fertiliser per 5 dm^3 of water.

What is the concentration of nitrogen atoms in this solution?

A 0.03 mol dm^{-3}

B 0.05 mol dm^{-3}

C 0.42 mol dm^{-3}

D 0.75 mol dm^{-3}

s/08/qp1

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2 A household bleach contains sodium chlorate(I), NaC*l*O, as its active ingredient. The concentration of NaC*l*O in the bleach can be determined by reacting a known amount with aqueous hydrogen peroxide, H_2O_2.

$$NaClO(aq) + H_2O_2(aq) \rightarrow NaCl(aq) + O_2(g) + H_2O(l)$$

When 25.0 cm^3 of bleach is treated with an excess of aqueous H_2O_2, 0.0350 mol of oxygen gas is given off.

What is the concentration of NaC*l*O in the bleach?

A 8.75×10^{-4} mol dm^{-3}

B 0.700 mol dm^{-3}

C 0.875 mol dm^{-3}

D 1.40 mol dm^{-3}

s/09/qp1

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13 0.02 mol of aluminium is burned in oxygen and the product is reacted with 2.00 mol dm^{-3} hydrochloric acid.

What minimum volume of acid will be required for complete reaction?

A 15 cm^3 **B** 20 cm^3 **C** 30 cm^3 **D** 60 cm^3

s/11/qp11

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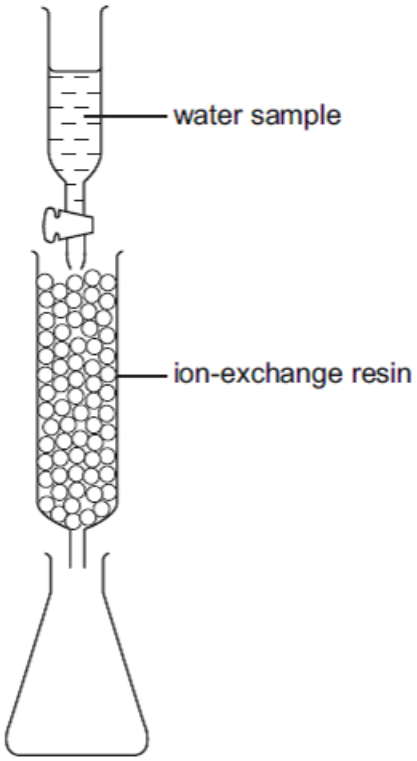
1 The amount of calcium ions in a sample of natural water can be determined by using an ion-exchange column as shown in the diagram.



A 50 cm^3 sample of water containing dissolved calcium sulphate was passed through the ion-exchange resin. Each calcium ion in the sample was exchanged for two hydrogen ions. The resulting acidic solution collected in the flask required 25 cm^3 of 1.0×10^{-2} mol dm^{-3} potassium hydroxide for complete neutralisation.

What was the concentration of the calcium sulphate in the original sample?

A 2.5×10^{-3} mol dm^{-3}

B 1.0×10^{-2} mol dm^{-3}

C 2.0×10^{-2} mol dm^{-3}

D 4.0×10^{-2} mol dm^{-3}

w/06/qp1

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10 *Use of the Data Booklet is relevant to this question.*

A washing powder contains sodium hydrogencarbonate, $NaHCO_3$, as one of the ingredients. In a titration, a solution containing 1.00 g of washing powder requires 7.15 cm^3 of 0.100 mol dm^{-3} sulfuric acid for complete reaction. The sodium hydrogencarbonate is the only ingredient that reacts with the acid.

What is the percentage by mass of sodium hydrogencarbonate in the washing powder?

A 3.0 **B** 6.0 **C** 12.0 **D** 24.0

s/13/qp13

8 *Use of the Data Booklet is relevant to this question.*

Ferrochrome is an alloy of iron and chromium. Ferrochrome can be dissolved in dilute sulfuric acid to produce a mixture of $FeSO_4$ and $Cr_2(SO_4)_3$. The $FeSO_4$ reacts with $K_2Cr_2O_7$ in acid solution according to the following equation.

$$14H^+ + 6Fe^{2+} + Cr_2O_7^{2-} \rightarrow 2Cr^{3+} + 6Fe^{3+} + 7H_2O$$

When 1.00 g of ferrochrome is dissolved in dilute sulfuric acid, and the resulting solution titrated, 13.1 cm^3 of 0.100 mol dm^{-3} $K_2Cr_2O_7$ is required for complete reaction.

What is the percentage by mass of Fe in the sample of ferrochrome?

A 1.22 **B** 4.39 **C** 12.2 **D** 43.9

w/14/qp13

15 *Use of the Data Booklet is relevant to this question.*

A sample of potassium oxide, K_2O, is dissolved in 250 cm^3 of distilled water. 25.0 cm^3 of this solution is titrated against sulfuric acid of concentration 2.00 mol dm^{-3}. 15.0 cm^3 of this sulfuric acid is needed for complete neutralisation.

Which mass of potassium oxide was originally dissolved in 250 cm^3 of distilled water?

A 2.83 g **B** 28.3 g **C** 47.1 g **D** 56.6 g

w/14/qp11

Moles and Number of Particles

1 *The use of the Data Booklet is relevant to this question.*

What is the number of molecules in 500 cm^3 of oxygen under room conditions?

A 1.25×10^{22}

B 1.34×10^{22}

C 3.0×10^{22}

D 3.0×10^{26}

s/03/qp1

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1 Which of these samples of gas contains the same number of atoms as 1g of hydrogen (M_r : H_2, 2)?

A 22 g of carbon dioxide (M_r : CO_2, 44)

B 8 g of methane (M_r : CH_4, 16)

C 20 g of neon (M_r : Ne, 20)

D 8 g of ozone (M_r : O_3, 48)

s/04/qp1

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1 *Use of the Data Booklet is relevant to this question.*

Analytical chemists can detect very small amounts of amino acids, down to 3×10^{-21} mol. How many molecules of an amino acid (M_r = 200) would this be?

A 9 **B** 200 **C** 1800 **D** 360 000

w/03/qp1

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1 *Use of the Data Booklet is relevant to this question.*

When a sports medal with a total surface area of 150 cm^2 was evenly coated with silver, using electrolysis, its mass increased by 0.216 g.

How many atoms of silver were deposited per cm^2 on the surface of the medal?

A 8.0×10^{18}

B 1.8×10^{19}

C 1.2×10^{21}

D 4.1×10^{22}

w/07/qp1

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31 A monomer undergoes addition polymerisation. A 1 mol sample of the monomer is completely polymerised.

How many moles of polymer might, theoretically, be formed?

1 1

2 10^{-6}

3 $\frac{1}{6.02 \times 10^{23}}$

w/09/qp11

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5 *Use of the Data Booklet is relevant to this question.*

Nickel makes up 20 % of the total mass of a coin. The coin has a mass of 10.0 g.

How many nickel atoms are in the coin?

A 2.05×10^{22} **B** 4.30×10^{22} **C** 1.03×10^{23} **D** 1.20×10^{24}

w/10/qp11

Moles & Balancing Equations

2 Self-igniting flares contain Mg_3P_2. With water this produces diphosphane, P_2H_4, which is spontaneously flammable in air.

Which equation that includes the formation of diphosphane is balanced?

A $Mg_3P_2 + 6H_2O \rightarrow 3Mg(OH)_2 + P_2H_4$

B $Mg_3P_2 + 6H_2O \rightarrow 3Mg(OH)_2 + P_2H_4 + H_2$

C $2Mg_3P_2 + 12H_2O \rightarrow 6Mg(OH)_2 + P_2H_4 + 2PH_3$

D $2Mg_3P_2 + 12H_2O \rightarrow 6Mg(OH)_2 + 3P_2H_4$

s/04/qp1

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18 In an historically famous experiment Wöhler heated "inorganic" ammonium cyanate in the absence of air. The only product of the reaction was "organic" urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CNO^- **B** CNO^{2-} **C** CO^- **D** NO^-

s/05/qp1

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36 The number of moles of chlorine that react with 1 mol of *X* is twice the number of moles of chlorine that react with 1 mol of *Y*.

Which of these pairs could be *X* and *Y*?

	X	*Y*
1	Mg(s)	Na(s)
2	H_2	KBr(aq)
3	cold NaOH(aq)	hot NaOH(aq)

s/05/qp1

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1 In the Basic Oxygen steel-making process the P_4O_{10} impurity is removed by reacting it with calcium oxide. The only product of this reaction is the salt calcium phosphate, $Ca_3(PO_4)_2$.

In this reaction, how many moles of calcium oxide react with one mole of P_4O_{10}?

A 1 **B** 1.5 **C** 3 **D** 6

s/08/qp1

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19 Ammonium sulphate in nitrogenous fertilisers in the soil can be slowly oxidised by air producing sulphuric acid, nitric acid and water.

How many moles of oxygen are needed to oxidise completely one mole of ammonium sulphate?

A 1 **B** 2 **C** 3 **D** 4

w/04/qp1

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1 The petrol additive tetraethyl-lead(IV), $Pb(C_2H_5)_4$, is now banned in many countries. When it is completely burned in air, lead(II) oxide, CO_2 and H_2O are formed.

How many moles of oxygen are required to burn one mole of $Pb(C_2H_5)_4$?

A 9.5 **B** 11 **C** 13.5 **D** 27

w/05/qp1

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19 In an historically famous experiment Wöhler heated 'inorganic' ammonium cyanate in the absence of air. The only product of the reaction was 'organic' urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CNO^- **B** CNO^{2-} **C** CO^- **D** NO^-

w/09/qp11

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15 Ammonium sulfate in nitrogenous fertilisers in the soil can be slowly oxidised by air producing sulfuric acid, nitric acid and water.

How many moles of oxygen gas are needed to oxidise completely one mole of ammonium sulfate?

A 1 **B** 2 **C** 3 **D** 4

w/10/qp11

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2 The following equations the letters **W**, **X**, **Y** and **Z** all represent whole numbers.

When correctly balanced, which equation requires one of letters **W**, **X**, **Y** or **Z** to be 5?

A $\mathbf{W}C_3H_7COOH + \mathbf{X}O_2 \rightarrow \mathbf{Y}CO_2 + \mathbf{Z}H_2O$

B $\mathbf{W}C_4H_8 + \mathbf{X}O_2 \rightarrow \mathbf{Y}CO_2 + \mathbf{Z}H_2O$

C $\mathbf{W}H_3PO_4 + \mathbf{X}NaOH \rightarrow \mathbf{Y}Na_2HPO_4 + \mathbf{Z}H_2O$

D $\mathbf{W}NH_3 + \mathbf{X}O_2 \rightarrow \mathbf{Y}N_2 + \mathbf{Z}H_2O$

w/11/qp12

---

9 During steel-making the impurity P_4O_{10} is removed by reacting it with calcium oxide. The only product of this reaction is the salt calcium phosphate, $Ca_3(PO_4)_2$.

In this reaction, how many moles of calcium oxide react with one mole of P_4O_{10}?

A 1 **B** 1.5 **C** 3 **D** 6

w/12/qp13

---

18 In a famous experiment, Wöhler heated 'inorganic' ammonium cyanate in the absence of air. The only product of the reaction was 'organic' urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CNO^- **B** CNO^{2-} **C** CO^- **D** NO^-

s/13/qp13

---

14 Ammonium sulfate in the soil is slowly oxidised by air, producing sulfuric acid, nitric acid and water as the only products.

How many moles of oxygen gas are needed for the complete oxidation of one mole of ammonium sulfate?

A 1 **B** 2 **C** 3 **D** 4

s/14/qp12

---

6 Aluminium carbide, Al_4C_3, reacts readily with aqueous sodium hydroxide. The two products of the reaction are $NaAlO_2$ and a hydrocarbon. Water molecules are also involved as reactants.

What is the formula of the hydrocarbon?

A CH_4 **B** C_2H_6 **C** C_3H_8 **D** C_6H_{12}

w/14/qp11

Moles and Ratios

28 In its reaction with sodium, 1 mol of a compound **X** gives 1 mol of $H_2(g)$.

Which compound might **X** be?

A $CH_3CH_2CH_2CH_2OH$

B $(CH_3)_3COH$

C $CH_3CH_2CH_2CO_2H$

D $CH_3CH(OH)CO_2H$

s/03/qp1

---

18 *Use of the Data Booklet is relevant to this question.*

In the commercial electrolysis of brine, the products are chlorine, hydrogen and sodium hydroxide.

What is the maximum yield of each of these products when 58.5 kg of sodium chloride are electrolysed as brine?

	yield of chlorine / kg	yield of hydrogen / kg	yield of sodium hydroxide / kg
A	35.5	1	40
B	35.5	2	40
C	71	1	40
D	71	2	80

s/04/qp1

---

2 On collision, airbags in cars inflate rapidly due to the production of nitrogen.

The nitrogen is formed according to the following equations.

$$2NaN_3 \rightarrow 2Na + 3N_2$$

$$10Na + 2KNO_3 \rightarrow K_2O + 5Na_2O + N_2$$

How many moles of nitrogen gas are produced from 1 mol of sodium azide, NaN_3?

A 1.5 **B** 1.6 **C** 3.2 **D** 4.0

s/05/qp1

---

8 *Use of the Data Booklet is relevant to this question.*

2.920 g of a Group II metal, **X**, reacts with an excess of chlorine to form 5.287 g of a compound with formula **X**Cl_2.

What is metal **X**?

A barium

B calcium

C magnesium

D strontium

s/10/qp11

---

11 0.144 g of an aluminium compound **X** react with an excess of water, to produce a gas. This gas burns completely in O_2 to form H_2O and 72 cm^3 of CO_2 only. The volume of CO_2 was measured at room temperature and pressure.

What could be the formula of **X**?
[C = 12.0, Al = 27.0; 1 mole of any gas occupies 24 dm^3 at room temperature and pressure]

A Al_2C_3 **B** Al_3C_4 **C** Al_4C_3 **D** Al_5C_3

s/11/qp12

---

23 The products obtained by cracking an alkane, **X**, are methane, ethene and propene.

The mole fraction of ethene in the products is 0.5.

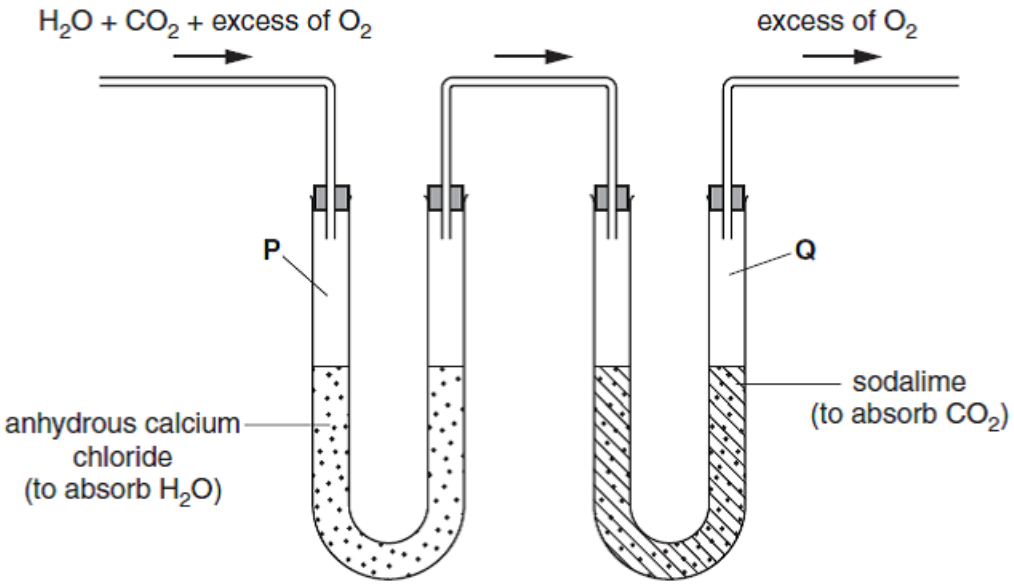
What is the identity of **X**?

A C_6H_{14} **B** C_8H_{18} **C** C_9H_{20} **D** $C_{11}H_{24}$

s/11/qp12

---

3 A sample of the hydrocarbon C_6H_{12} is completely burned in dry oxygen and the product gases are collected as shown.
[A_r : H, 1 ; C, 12 ; O, 16.]



The increases in mass of the collecting vessels **P** and **Q** of the apparatus are M_P and M_Q, respectively.

What is the ratio M_P / M_Q?

A 0.41 **B** 0.82 **C** 1.2 **D** 2.4

w/03/qp1

---

22 On strong heating a hydrocarbon produces ethene, propane and but-1-ene in the mole ratio 5 : 1 : 1.

What is the molecular formula of the hydrocarbon?

A $C_{17}H_{34}$ **B** $C_{17}H_{36}$ **C** $C_{19}H_{38}$ **D** $C_{19}H_{40}$

w/03/qp1

---

14 A 5.00 g sample of an anhydrous Group II metal nitrate loses 3.29 g in mass on strong heating.

Which metal is present?

A magnesium

B calcium

C strontium

D barium

w/06/qp1

---

15 *Use of the Data Booklet is relevant to this question.*

A 5.00 g sample of an anhydrous Group II metal nitrate loses 3.29 g in mass when heated strongly.

Which metal is present?

A magnesium

B calcium

C strontium

D barium

w/11/qp11

---

4 *Use of the Data Booklet is relevant to this question.*

560 kg of nitrogen and 120 kg of hydrogen are pressurised, heated and passed over an iron catalyst. When the mixture of gases reaches equilibrium, it contains 96 kg of hydrogen.

Which mass of ammonia does it contain?

A 24 kg **B** 68 kg **C** 136 kg **D** 680 kg

w/11/qp12

---

15 *Use of the Data Booklet is relevant to this question.*

The nitrates of beryllium, calcium, magnesium, and strontium all decompose in the same way when heated. When 2.00 g of one of these anhydrous nitrates is decomposed, 1.32 g of gas is produced.

What is the nitrate?

A beryllium nitrate

B calcium nitrate

C magnesium nitrate

D strontium nitrate

w/12/qp11

---

17 *Use of the Data Booklet is relevant to this question.*

1.15 g of a metallic element reacts with 300 cm^3 of oxygen at 298 K and 1 atm pressure, to form an oxide which contains O^{2-} ions.

What could be the identity of the metal?

A calcium

B magnesium

C potassium

D sodium

w/12/qp11

---

34 An element X and compound YZ react separately with acid as shown.

$$X(s) + 2H^+(aq) \rightarrow X^{2+}(aq) + H_2(g)$$

$$YZ(s) + 2H^+(aq) \rightarrow Y^{2+}(aq) + H_2Z(g)$$

When 1.0 g of either X or YZ is reacted with an excess of acid, the total volume of gas formed is the same.

Which statements are correct?

1 $A_r(X) = M_r(YZ)$

2 X and Y are metals.

3 X and Y must both be in the same Group of the Periodic Table.

w/12/qp13

---

12 *Use of the Data Booklet is relevant to this question.*

Anhydrous magnesium nitrate, $Mg(NO_3)_2$, will decompose when heated, giving a white solid and a mixture of two gases **X** and **Y**.

Y is oxygen.

What is the ratio $\frac{\text{mass of X released}}{\text{mass of Y released}}$?

A $\frac{1}{0.174}$ **B** $\frac{1}{0.267}$ **C** $\frac{1}{0.348}$ **D** $\frac{1}{3.43}$

s/13/qp13

Limiting Reactant & Excess Reactant

30 *Use of the Data Booklet is relevant to this question.*

Ethyl ethanoate can be obtained from ethanoic acid and ethanol by the following reaction.

$$CH_3CH_2OH + CH_3CO_2H \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

Ethanol (30 g) and ethanoic acid (30 g) are heated under reflux together, and 22 g of ethyl ethanoate are obtained.

What is the yield of the ester?

A 25 % **B** 38 % **C** 50 % **D** 77 %

w/08/qp1

Redox Reactions & Moles

9 In an experiment, 50.0 cm^3 of a 0.10 mol dm^{-3} solution of a metallic salt reacted exactly with 25.0 cm^3 of 0.10 mol dm^{-3} aqueous sodium sulphite.

The half-equation for oxidation of sulphite ion is shown below.

$$SO_3^{2-}(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$$

If the original oxidation number of the metal in the salt was +3, what would be the new oxidation number of the metal?

A +1 **B** +2 **C** +4 **D** +5

w/07/qp1

---

2 *Use of the Data Booklet is relevant to this question.*

Lead(IV) chloride will oxidise bromide ions to bromine. The Pb^{4+} ions are reduced to Pb^{2+} ions in this reaction.

If 6.980 g of lead(IV) chloride is added to an excess of sodium bromide solution, what mass of bromine would be produced?

A 0.799 g **B** 1.598 g **C** 3.196 g **D** 6.392 g

w/11/qp11

---

11 A solution of Sn^{2+} ions will reduce an acidified solution of MnO_4^- ions to Mn^{2+} ions. The Sn^{2+} ions are oxidised to Sn^{4+} ions in this reaction.

How many moles of Mn^{2+} ions are formed when a solution containing 9.5 g of $SnCl_2$ (M_r: 190) is added to an excess of acidified $KMnO_4$ solution?

A 0.010 **B** 0.020 **C** 0.050 **D** 0.125

s/13/qp11

---

3 A 10 cm^3 sample of 0.30 mol dm^{-3} $Tl^+NO_3^-$ required 20 cm^3 of 0.10 mol dm^{-3} acidified NH_4VO_3 to oxidise it to Tl^{3+} in solution. Vanadium is the only element reduced in this reaction.

What is the oxidation number of the vanadium in the reduced form?

A +1 **B** +2 **C** +3 **D** +4

w/13/qp13

Combustion Analysis

1 A pure hydrocarbon is used in bottled gas for cooking and heating.

When 10 cm^3 of the hydrocarbon is burned in 70 cm^3 of oxygen (an excess), the final gaseous mixture contains 30 cm^3 of carbon dioxide and 20 cm^3 of unreacted oxygen. All gaseous volumes were measured under identical conditions.

What is the formula of the hydrocarbon?

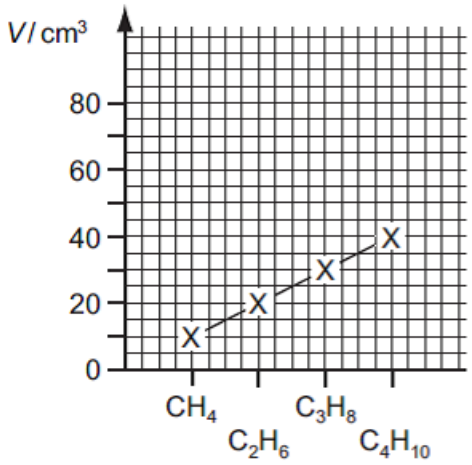
A C_2H_6 **B** C_3H_6 **C** C_3H_8 **D** C_4H_{10}

s/05/qp1

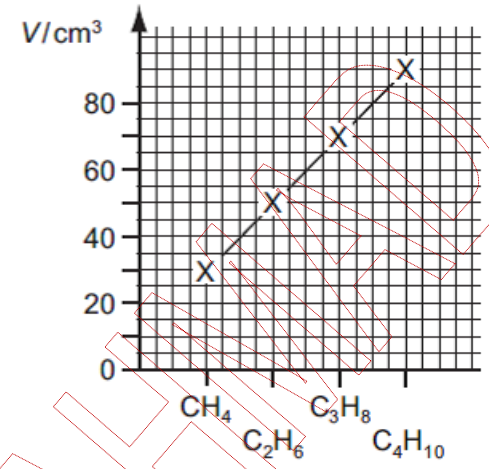
4 Samples of 10 cm^3 of each of the first four members of the alkane series are separately mixed with 70 cm^3 of oxygen. Each is then burned and the total volume, *V*, of residual gas measured again at room temperature and pressure.

Which graph represents the results that would be obtained?

A



B



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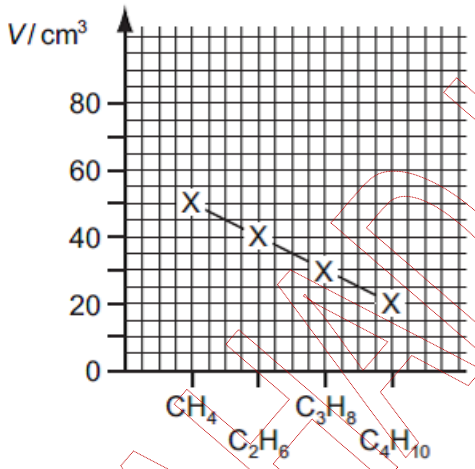
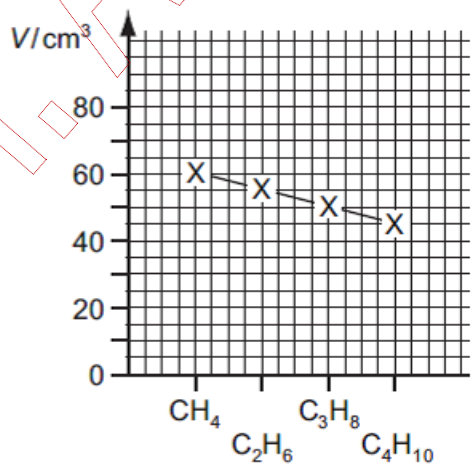


D



w/06/qp1

---

2 0.200 mol of a hydrocarbon undergo complete combustion to give 35.2 g of carbon dioxide and 14.4 g of water as the only products.

What is the molecular formula of the hydrocarbon?

A C_2H_4 **B** C_2H_6 **C** C_4H_4 **D** C_4H_8

w/09/qp11

---

29 Which equation correctly represents the balanced equation for the complete combustion of a hydrocarbon with the formula C_xH_y?

A $C_xH_y + (x + \frac{y}{2})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$

B $C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + yH_2O$

C $C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{4}H_2O$

D $C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$

w/14/qp11

Hydrogen sulphide burns with a blue flame in an excess of oxygen to form sulphur dioxide and water.

(d) **(i)** Write a balanced equation for the complete combustion of H_2S.

.....

(ii) What is the change in the oxidation number of sulphur in this reaction?

from ..... to .....

(iii) What volume of oxygen, measured at room temperature and pressure, is required for the complete combustion of 8.65 g of H_2S? Give your answer to two decimal places.

[5]

s/05/qp2

---

2 Ketene, C_2H_2O, is a member of a class of unsaturated organic compounds that is widely used in pharmaceutical research for the synthesis of organic compounds.

$CH_2=C=O$

ketene

(b) Ketene burns completely in air to form carbon dioxide and water.

(i) Write a balanced equation for this reaction.

.....

(ii) Use your equation to calculate the volume of CO_2, in dm^3, measured at room temperature and pressure, which will be formed when 3.5 g of ketene are burned in an excess of air.

Give your answer to **two** significant figures.

volume of CO_2 = ... dm^3 [4]

w/08/qp2

(c) 1.20 dm^3 of ammonia gas were dissolved in water to form 200 cm^3 of aqueous alkali at room temperature and pressure.

(i) Use the *Data Booklet* to calculate how many moles of $NH_3(g)$ were dissolved.

(ii) Write the equation for the neutralisation of aqueous ammonia by dilute sulphuric acid.

.....

(iii) Calculate the volume of 0.50 mol dm^{-3} sulphuric acid that is required to neutralise the 200 cm^3 of aqueous ammonia.

[3]

s/04/qp2

Titanium also reacts with chlorine.

(d) When an excess of chlorine was reacted with 0.72 g of titanium, 2.85 g of a chloride **A** was formed.

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

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Hence, determine the empirical formula of **A**.

(iv) Construct a balanced equation for the reaction between titanium and chlorine.

.....

[4]

s/09/qp2

(c) In a redox reaction, 0.83 g of lithium reacted with water to form 0.50 dm^3 of aqueous lithium hydroxide.

$$2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$$

(i) Calculate the amount, in moles, of lithium that reacted.

(ii) Calculate the volume of hydrogen produced at room temperature and pressure.

(iii) Calculate the concentration, in mol dm^{-3}, of the LiOH(aq) formed.

[5]

s/10/qp23

1 Methanoic acid, HCO_2H, was formerly known as formic acid because it is present in the sting of ants and the Latin name for ant is *formica*. It was first isolated in 1671 by John Ray who collected a large number of dead ants and extracted the acid from them by distillation.

In this question, you should give all numerical answers to <u>two</u> significant figures.

At room temperature, pure methanoic acid is a liquid which is completely soluble in water.

When we are stung by a 'typical' ant a solution of methanoic acid, **A**, is injected into our skin.

Solution **A** contains 50% by volume of pure methanoic acid.

A 'typical' ant contains $7.5 \times 10^{-6}\,dm^3$ of solution **A**.

(a) (i) Calculate the volume, in cm^3, of solution **A** in one ant.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the volume, in cm^3, of pure methanoic acid in one ant.

volume = ... cm^3

(iii) Use your answer to **(ii)** to calculate how many ants would have to be distilled to produce $1\,dm^3$ of pure methanoic acid.

number = ...
[3]

When we are stung by an ant, the amount of solution **A** injected is 80% of the total amount of solution **A** present in one ant.

The density of pure methanoic acid is $1.2\,g\,cm^{-3}$.

(b) (i) Calculate the volume, in cm^3, of **pure** methanoic acid injected in one ant sting.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the mass of methanoic acid present in one ant sting.

mass = ... g
[3]

Bees also sting us by using methanoic acid. One simple treatment for ant or bee stings is to use sodium hydrogencarbonate, $NaHCO_3$.

(c) (i) Construct a balanced equation for the reaction between methanoic acid and sodium hydrogencarbonate.

.....

(ii) In a typical bee sting, the mass of methanoic acid injected is 5.4×10^{-3} g. Calculate the mass of $NaHCO_3$ needed to neutralise one bee sting.

mass = ... g
[3]

[Total: 9]

s/11/qp23

1 Some intercontinental jet airliners use kerosene as fuel. The formula of kerosene may be taken as $C_{14}H_{30}$.

(a) To which homologous series of compounds does kerosene belong?

..... [1]

(b) When kerosene burns in an excess of air, carbon dioxide and water form.
Balance the following equation for the complete combustion of kerosene.

$$.....C_{14}H_{30}(l) + ...O_2(g) \rightarrow .....CO_2(g) + ...H_2O(g)$$ [1]

(c) **In this section, give your answers to <u>one</u> decimal place.**

The flight path from Beijing to Paris is approximately 8195 km.
A typical intercontinental jet airliner burns 10.8 kg of kerosene for each kilometre covered.

(i) Calculate the mass, in tonnes, of $C_{14}H_{30}$ burnt on a flight from Beijing to Paris.
[1 tonne = 1 000 kg]

(ii) Use your equation in **(b)** to calculate the mass, in tonnes, of CO_2 produced during this flight.

[4]

s/11/qp21

(d) Antimony, Sb, has been known for about 6000 years. It is present in many ancient forms of bronze, but now its main use is to strengthen lead alloys.

Antimony is produced in a two-stage process from stibnite, a sulphide ore, Sb_2S_3.

The ore is first roasted in oxygen to form the oxide.

$$2Sb_2S_3 + \ldots\ldots\ldots\ldots O_2 \longrightarrow Sb_4O_6 + \ldots\ldots\ldots\ldots SO_2$$

(i) Balance the above equation.

The oxide is then reduced with carbon.

$$Sb_4O_6 + 3C \longrightarrow 4Sb + 3CO_2$$

(ii) What is the oxidation number of antimony in Sb_4O_6?

.....

(iii) Calculate the volume of carbon dioxide, measured at room temperature and pressure, that would be produced by the processing of 10 moles of Sb_2S_3.

[4]

w/02/qp2

1 Most submarines travel under water using electrical power from batteries. The German engineer Helmut Walter designed a diesel engine that could be used to propel a submarine beneath the surface of the sea. Instead of taking air from above the surface of the sea, Walter's engine used hydrogen peroxide, H_2O_2, to provide oxygen for a conventional diesel engine.

Hydrogen peroxide may be catalytically decomposed to give water and oxygen.

(a) (i) What is meant by the term *catalyst*?

.....

.....

(ii) Construct a balanced equation for the decomposition of H_2O_2.

..... [3]

Diesel fuel may be considered to consist of the hydrocarbon $C_{15}H_{32}$ which reacts completely with oxygen according to the following equation.

$$C_{15}H_{32} + 23O_2 \rightarrow 15CO_2 + 16H_2O$$

(b) (i) To which homologous series does $C_{15}H_{32}$ belong?

.....

(ii) Use the equation above and your answer to **(a)(ii)** to calculate the amount, in moles, of H_2O_2, that will provide sufficient oxygen for the complete oxidation of one mole of $C_{15}H_{32}$.

amount of H_2O_2 = ... mol

[3]

A submarine equipped with a Walter engine used 212 tonnes of diesel fuel during an underwater voyage. The submarine also carried concentrated aqueous H_2O_2.
[1 tonne = 10^6 g]

(c) **(i)** Calculate the amount, in moles, of diesel fuel used during the underwater voyage.

amount of diesel fuel = ... mol

(ii) Use your answers to **(b)(ii)** and **(c)(i)** to calculate the mass, in tonnes, of hydrogen peroxide used during the underwater voyage.

mass of H_2O_2 = ... tonnes
[4]

(d) The exhaust products of the Walter engine were passed into the sea.

What would happen to them?

..... [1]

[Total: 11]

w/08/qp2

Antimony, Sb, proton number 51, is another element which is used in alloys.

Magnesium and antimony each react when heated separately in chlorine.

(d) Construct a balanced equation for the reaction between magnesium and chlorine.

.....[1]

When a 2.45 g sample of antimony was heated in chlorine under suitable conditions, 4.57 g of a chloride **A** were formed.

(e) **(i)** Calculate the amount, in moles, of antimony atoms that reacted.

(ii) Calculate the amount, in moles, of chlorine atoms that reacted.

(iii) Use your answers to **(i)** and **(ii)** to determine the empirical formula of **A**.

(iv) The empirical and molecular formulae of **A** are the same.

Construct a balanced equation for the reaction between antimony and chlorine.

.....[5]

w/10/qp23

1 Zinc is an essential trace element which is necessary for the healthy growth of animals and plants. Zinc deficiency in humans can be easily treated by using zinc salts as dietary supplements.

(a) One salt which is used as a dietary supplement is a hydrated zinc sulfate, $ZnSO_4.xH_2O$, which is a colourless crystalline solid.

Crystals of zinc sulfate may be prepared in a school or college laboratory by reacting dilute sulfuric acid with a suitable compound of zinc.

Give the formulae of **two** simple compounds of zinc that could **each** react with dilute sulfuric acid to produce zinc sulfate.

..... and ..... [2]

(b) A simple experiment to determine the value of x in the formula $ZnSO_4.xH_2O$ is to heat it carefully to drive off the water.

$$ZnSO_4.xH_2O(s) \rightarrow ZnSO_4(s) + xH_2O(g)$$

A student placed a sample of the hydrated zinc sulfate in a weighed boiling tube and reweighed it. He then heated the tube for a short time, cooled it and reweighed it when cool. This process was repeated four times. The final results are shown below.

mass of empty tube / g	mass of tube + hydrated salt / g	mass of tube + salt after fourth heating / g
74.25	77.97	76.34

(i) Why was the boiling tube heated, cooled and reweighed four times?

.....

.....

(ii) Calculate the amount, **in moles**, of the anhydrous salt produced.

(iii) Calculate the amount, **in moles**, of water driven off by heating.

(iv) Use your results to **(ii)** and **(iii)** to calculate the value of x in $ZnSO_4.xH_2O$.

[7]

(c) For many people, an intake of approximately 15 mg per day of zinc will be sufficient to prevent deficiencies.

Zinc ethanoate crystals, $(CH_3CO_2)_2Zn.2H_2O$, may be used in this way.

(i) What mass of pure crystalline zinc ethanoate (M_r = 219.4) will need to be taken to obtain a dose of 15 mg of zinc?

(ii) If this dose is taken in solution as 5 cm^3 of aqueous zinc ethanoate, what would be the concentration of the solution used?
Give your answer in mol dm^{-3}.

[4]

[Total: 13]

w/12/qp21

1 Carbon dioxide, CO_2, makes up about 0.040 % of the Earth's atmosphere. It is produced by animal respiration and by the combustion of fossil fuels.

In animal respiration, oxygen reacts with a carbohydrate such as glucose to give water, carbon dioxide and energy.

The typical daily food requirement of a human can be considered to be the equivalent of 1.20 kg of glucose, $C_6H_{12}O_6$.

You should express all of your numerical answers in this question to three significant figures.

(a) (i) Construct a balanced equation for the complete oxidation of glucose.

.....

(ii) Use your equation to calculate the amount, in moles, of CO_2 produced by one person in one day from 1.20 kg of glucose.

(iii) On the day on which this question was written, the World population was estimated to be 6.82×10^9.

Calculate the total mass of CO_2 produced by this number of people in one day. Give your answer in tonnes. [1 tonne = 1.00×10^6 g]

[5]

(b) When fossil fuels are burned in order to give energy, carbon dioxide and water are also produced.

The hydrocarbon octane, C_8H_{18}, can be used to represent the fuel burned in motor cars. A typical fuel-efficient motor car uses about 4.00 dm^3 of fuel to travel 100 km.

(i) Construct a balanced equation for the complete combustion of octane.

.....

(ii) The density of octane is 0.700 g cm^{-3}.

Calculate the amount, in moles, of octane present in 4.00 dm^3 of octane.

(iii) Calculate the mass of CO_2 produced when the fuel-efficient car is driven for a distance of 100 km.

[5]

(c) Calculate how many kilometres the same fuel-efficient car would have to travel in order to produce as much CO_2 as is produced by the respiration of 6.82×10^9 people during one day. Use your answer to **(a)(iii)**.

[2]

(d) Carbon dioxide is one of a number of gases that are responsible for global warming. When fossil fuels such as octane are burned in a car engine, other atmospheric pollutants are also produced.
Give the formula of **one** atmospheric pollutant that may be produced in a car engine, other than CO_2, and state how this pollutant damages the environment.

pollutant .....

damage caused ..... [2]

Theory : Relative Atomic Mass (Mass Spectroscopy)

A third polycarboxylic acid present in unripe fruit is a colourless crystalline solid, **W**, which has the following composition by mass: C, 35.8%; H, 4.5%; O, 59.7%.

(d) (i) Show by calculation that the empirical formula of **W** is $C_4H_6O_5$.

(ii) The M_r of **W** is 134. Use this value to determine the molecular formula of **W**.

[3]

A sample of **W** of mass 1.97 g was dissolved in water and the resulting solution titrated with 1.00 mol dm^{-3} NaOH. 29.4 cm^3 were required for complete neutralisation.

(e) (i) Use these data to deduce the number of carboxylic acid groups present in one molecule of **W**.

(ii) Suggest the displayed formula of **W**.

[5]

The unsaturated hydrocarbon **Z** is obtained by cracking hexane and is important in the chemical industry.

The standard enthalpy change of combustion of **Z** is –2059 kJ mol^{-1}.

(d) Define the term *standard enthalpy change of combustion*.

.....

..... [2]

When 0.47 g of **Z** were completely burnt in air, the heat produced raised the temperature of 200 g of water by 27.5 °C.

(e) **(i)** Calculate the amount of heat released in this experiment.

(ii) Use the data above and your answer to **(i)** to calculate the relative molecular mass of **Z**.

[4]

(f) Deduce the molecular formula of **Z**.

[1]

w/06/qp2

1 **(a)** Explain what is meant by the term *nucleon number*.

.....

..... [1]

(b) Bromine exists naturally as a mixture of two stable isotopes, ^{79}Br and ^{81}Br, with relative isotopic masses of 78.92 and 80.92 respectively.

(i) Define the term *relative isotopic mass*.

.....

.....

..... [2]

(ii) Using the relative atomic mass of bromine, 79.90, calculate the relative isotopic abundances of ^{79}Br and ^{81}Br.

[3]

(c) Bromine reacts with the element **A** to form a compound with empirical formula $\mathbf{A}Br_3$. The percentage composition by mass of $\mathbf{A}Br_3$ is **A**, 4.31; Br, 95.69.

Calculate the relative atomic mass, A_r, of **A**.
Give your answer to **three** significant figures.

A_r of **A** = ... [3]

s/14/qp22

Theory : Combustion Analysis

1 In 1814, Sir Humphrey Davy and Michael Faraday collected samples of a flammable gas, **A**, from the ground near Florence in Italy.
They analysed **A** which they found to be a hydrocarbon. Further experiments were then carried out to determine the molecular formula of **A**.

(a) What is meant by the term *molecular formula*?

.....

.....

.....[2]

Davy and Faraday deduced the formula of **A** by exploding it with an excess of oxygen and analysing the products of combustion.

(b) Complete and balance the following equation for the complete combustion of a hydrocarbon with the formula C_xH_y.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow \text{.....} + \text{.....}$$

[2]

(c) When 10 cm^3 of **A** was mixed at room temperature with 50 cm^3 of oxygen (an excess) and exploded, 40 cm^3 of gas remained after cooling the apparatus to room temperature and pressure.
When this 40 cm^3 of gas was shaken with an excess of aqueous potassium hydroxide, KOH, 30 cm^3 of gas still remained.

(i) What is the identity of the 30 cm^3 of gas that remained at the end of the experiment?

.....

(ii) The combustion of **A** produced a gas that reacted with the KOH(aq).

What is the identity of this gas?

.....

(iii) What volume of the gas you have identified in **(ii)** was produced by the combustion of **A**?

..... cm^3

(iv) What volume of oxygen was used up in the combustion of **A**?

..... cm^3 [4]

(d) Use your equation in **(b)** and your results from **(c)(iii)** and **(c)(iv)** to calculate the molecular formula of **A**.
Show all of your working.

[3]

[Total: 11]

w/10/qp21

2 When 0.42 g of a gaseous hydrocarbon **A** is slowly passed over a large quantity of heated copper(II) oxide, CuO, **A** is completely oxidised.

The products are collected and it is found that 1.32 g of CO_2 and 0.54 g of H_2O are formed. Copper is the only other product of the reaction.

(a) (i) Calculate the mass of carbon present in 1.32 g of CO_2.

Use this value to calculate the amount, in moles, of carbon atoms present in 0.42 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.54 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.42 g of **A**.

(iii) It is thought that **A** is an alkene rather than an alkane.

Use your answers to **(i)** and **(ii)** to deduce whether this is correct.

Explain your answer.

.....

..... [5]

(b) Analysis of another organic compound, **B**, gave the following composition by mass: C, 64.86%; H, 13.50%, O, 21.64%.

(i) Use these values to calculate the empirical formula of **B**.

w/11/qp23

1 **(a)** Define the term *mole*.

.....

..... [1]

(b) 10 cm^3 of a gaseous hydrocarbon, C_xH_y, was reacted with 100 cm^3 of oxygen gas, an excess.

The final volume of the gaseous mixture was 95 cm^3.

This gaseous mixture was treated with concentrated, aqueous sodium hydroxide to absorb the carbon dioxide present. This reduced the gas volume to 75 cm^3.

All gas volumes were measured at 298 K and 100 kPa.

(i) Write an equation for the reaction between sodium hydroxide and carbon dioxide.

..... [1]

(ii) Calculate the volume of carbon dioxide produced by the combustion of the hydrocarbon.

volume of CO_2 produced = ... cm^3 [1]

(iii) Calculate the volume of oxygen used up in the reaction with the hydrocarbon.

volume of O_2 used = ... cm^3 [1]

(iv) Use your answers to **(b)(ii)** and **(b)(iii)**, together with the initial volume of hydrocarbon, to balance the equation below.

.....C_xH_y + ...O_2 → .....CO_2 + zH_2O [2]

(v) Deduce the values of *x*, *y* and *z* in the equation in **(iv)**.

x = ...

y = ...

z = ...

[3]

s/14/qp23

Theory : Titration

1 Mohr's salt is a pale green crystalline solid which is soluble in water. Mohr's salt is a 'double salt' which contains

two cations, one of which is Fe^{2+},

one anion which is SO_4^{2-},

and water of crystallisation.

(a) The identity of the second cation was determined by the following test.
Solid Mohr's salt was heated with solid sodium hydroxide and a colourless gas was evolved. The gas readily dissolved in water giving an alkaline solution.

(i) What is the gas?

.....

(ii) What is the formula of the second cation identified by this test?

.....

(iii) In this test, a grey/green solid residue was also formed.

Suggest a name **or** formula for this solid.

.....
[3]

(b) The identity of the anion present in Mohr's salt was confirmed by adding dilute hydrochloric acid followed by aqueous barium chloride to an aqueous solution of Mohr's salt. A white precipitate was formed.

Suggest the identity of the white precipitate.

.....[1]

(c) When a double salt such as Mohr's salt is made, the two individual salts are mixed together in a 1:1 molar ratio, dissolved in water and the solution crystallised.

(i) Give the formula of **each** of the two salts that would be mixed to make the double salt, Mohr's salt.

salt 1 .....

salt 2 .....

(ii) Calculate the relative formula mass of **each** of the salts present in Mohr's salt.

salt 1

relative formula mass of salt 1 .....

salt 2

relative formula mass of salt 2 .....

(iii) The crystals of the double salt contain water of crystallisation.

The relative formula mass of Mohr's salt is 392. Use your answers to **(ii)** to calculate the number of moles of water of crystallisation present in one mole of Mohr's salt.

[6]

[Total: 10]

s/06/qp2

2 Ammonium sulfate, $(NH_4)_2SO_4$, is widely used as a fertiliser.

In order to determine its percentage purity, a sample of ammonium sulfate fertiliser was analysed by reacting a known amount with an excess of NaOH(aq) and then titrating the unreacted NaOH with dilute HC*l*.

(a) Ammonium sulfate reacts with NaOH in a 1 : 2 ratio.
Complete and balance the equation for this reaction.

$$(NH_4)_2SO_4 + 2NaOH \rightarrow \text{.....}NH_3 + \text{.....} + \text{.....}$$

[2]

(b) A 5.00 g sample of a fertiliser containing $(NH_4)_2SO_4$ was warmed with 50.0 cm^3 (an excess) of 2.00 mol dm^{-3} NaOH.

When all of the ammonia had been driven off, the solution was cooled.

The remaining NaOH was then titrated with 1.00 mol dm^{-3} HC*l* and 31.2 cm^3 were required for neutralisation.

(i) Write a balanced equation for the reaction between NaOH and HC*l*.

.....

(ii) Calculate the amount, in moles, of HC*l* in 31.2 cm^3 of 1.00 mol dm^{-3} HC*l*.

(iii) Calculate the amount, in moles, of NaOH in 50.0 cm^3 of 2.00 mol dm^{-3} NaOH.

(iv) Use your answers to **(i)**, **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH used up in the reaction with $(NH_4)_2SO_4$.

(v) Use your answer to **(iv)** and the equation in **(a)** to calculate the amount, in moles, of $(NH_4)_2SO_4$ that reacted with NaOH.

(vi) Use your answer to **(v)** to calculate the mass of $(NH_4)_2SO_4$ that reacted with NaOH.

(vii) Hence, calculate the percentage purity of the ammonium sulfate fertiliser.

[7]

[Total: 9]

s/12/qp21

2 Washing soda is hydrated sodium carbonate, $Na_2CO_3.xH_2O$.

A student wished to determine the value of x by carrying out a titration, with the following results.

> 5.13 g of washing soda crystals were dissolved in water and the solution was made up to 250 cm^3 in a standard volumetric flask.
>
> 25.0 cm^3 of this solution reacted exactly with 35.8 cm^3 of 0.100 mol dm^{-3} hydrochloric acid and carbon dioxide was produced.

(a) (i) Write a balanced equation for the reaction between Na_2CO_3 and HC*l*.

.....

(ii) Calculate the amount, in moles, of HC*l* in the 35.8 cm^3 of solution used in the titration.

(iii) Use your answers to **(i)** and **(ii)** to calculate the amount, in moles, of Na_2CO_3 in the 25.0 cm^3 of solution used in the titration.

(iv) Use your answer to **(iii)** to calculate the amount, in moles, of Na_2CO_3 in the 250 cm^3 of solution in the standard volumetric flask.

(v) Hence calculate the mass of Na_2CO_3 present in 5.13 g of washing soda crystals.

[6]

(b) Use your calculations in **(a)** to determine the value of x in $Na_2CO_3.xH_2O$.

[2]

[Total: 8]

s/12/qp23

1 A sample of a fertiliser was known to contain ammonium sulfate, $(NH_4)_2SO_4$, and sand only.

A 2.96 g sample of the solid fertiliser was heated with 40.0 cm^3 of NaOH(aq), an excess, and all of the ammonia produced was boiled away.

After cooling, the remaining NaOH(aq) was exactly neutralised by 29.5 cm^3 of 2.00 mol dm^{-3} HC*l*.

In a separate experiment, 40.0 cm^3 of the original NaOH(aq) was exactly neutralised by 39.2 cm^3 of the 2.00 mol dm^{-3} HC*l*.

(a) (i) Write balanced equations for the following reactions.

NaOH with HC*l*

.....

$(NH_4)_2SO_4$ with NaOH

.....

(ii) Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of the original NaOH(aq) that was neutralised by 39.2 cm^3 of 2.00 mol dm^{-3} HC*l*.

(iii) Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of NaOH(aq) that remained after boiling the $(NH_4)_2SO_4$.

(iv) Use your answers to **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH that reacted with the $(NH_4)_2SO_4$.

(v) Use your answers to **(i)** and **(iv)** to calculate the amount, in moles, of $(NH_4)_2SO_4$ that reacted with the NaOH.

(vi) Hence calculate the mass of $(NH_4)_2SO_4$ that reacted.

(vii) Use your answer to **(vi)** to calculate the percentage, by mass, of $(NH_4)_2SO_4$ present in the fertiliser.
Write your answer to a suitable number of significant figures.

[9]

(b) The uncontrolled use of nitrogenous fertilisers can cause environmental damage to lakes and streams. This is known as *eutrophication*.

What are the processes that occur when excessive amounts of nitrogenous fertilisers get into lakes and streams?

.....

.....

..... [2]

(c) Large quantities of ammonia are manufactured by the Haber process.
Not all of this ammonia is used to make fertilisers.
State **one** large-scale use for ammonia, **other than** in the production of nitrogenous fertilisers.

..... [1]

[Total: 12]

s/13/qp21

2 Chile saltpetre is a mineral found in Chile and Peru, and which mainly consists of sodium nitrate, $NaNO_3$. The mineral is purified to concentrate the $NaNO_3$ which is used as a fertiliser and in some fireworks.

In order to find the purity of a sample of sodium nitrate, the compound is heated in NaOH(aq) with Devarda's alloy which contains aluminium. This reduces the sodium nitrate to ammonia which is boiled off and then dissolved in acid.

$$3NaNO_3(aq) + 8Al(s) + 5NaOH(aq) + 18H_2O(l) \rightarrow 3NH_3(g) + 8NaAl(OH)_4(aq)$$

The ammonia gas produced is dissolved in an excess of H_2SO_4 of known concentration.

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

The amount of unreacted H_2SO_4 is then determined by back-titration with NaOH of known concentration.

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

(a) A 1.64 g sample of impure $NaNO_3$ was reacted with an excess of Devarda's alloy.
The NH_3 produced was dissolved in 25.0 cm^3 of 1.00 mol dm^{-3} H_2SO_4.
When all of the NH_3 had dissolved, the resulting solution was titrated with NaOH(aq).
For neutralisation, 16.2 cm^3 of 2.00 mol dm^{-3} NaOH were required.

(i) Calculate the amount, in moles, of H_2SO_4 present in the 25.0 cm^3 of 1.00 mol dm^{-3} H_2SO_4.

(ii) Calculate the amount, in moles, of NaOH present in 16.2 cm^3 of 2.00 mol dm^{-3} NaOH.

(iii) Use your answer to **(ii)** to calculate the amount, in moles, of H_2SO_4 that reacted with 16.2 cm^3 of 2.00 mol dm^{-3} NaOH.

(iv) Use your answers to **(i)** and **(iii)** to calculate the amount, in moles, of H_2SO_4 that reacted with the NH_3.

(v) Use your answer to **(iv)** to calculate the amount, in moles, of NH_3 that reacted with the H_2SO_4.

(vi) Use your answer to **(v)** to calculate the amount, in moles, of $NaNO_3$ that reacted with the Devarda's alloy.

(vii) Hence calculate the mass of $NaNO_3$ that reacted.

(viii) Use your answer to **(vii)** to calculate the percentage by mass of $NaNO_3$ present in the impure sample.
Write your answer to a suitable number of significant figures.

[9]

(b) The above reaction is an example of a redox reaction.
What are the oxidation numbers of nitrogen in $NaNO_3$ and in NH_3?

$NaNO_3$ ..... NH_3 ..... [1]

[Total: 10]

s/13/qp22

(c) Another CFC contains the following elements by mass. The value of its M_r is 135.

C, 17.8%; H, 1.5%; Cl, 52.6%; F, 28.1%

Use these data to determine the molecular formula of the CFC.

[3]

s/02/qp2

---

6 A compound, **A**, has the following composition by mass.

C, 66.7%; H, 11.1%; O, 22.2%.

It has an M_r of 72.

(a) Calculate the molecular formula of **A**.

[2]

s/03/qp2

(b) When CH_2Cl_2 is heated under reflux with an excess of NaOH(aq), a compound **W** is formed.

W has the following composition by mass: C, 40.0%; H, 6.7%; O, 53.3%.

Use this information and the *Data Booklet* to show that the empirical formula of **W** is CH_2O.

[2]

s/07/qp2

---

4 An organic compound, **E**, has the following composition by mass:
C, 48.7%; H, 8.1%; O, 43.2%.

(a) Calculate the empirical formula of **E**.

[2]

s/10/qp22

(e) The food additive E330 is another organic compound which occurs naturally in fruit. E330 has the following composition by mass: C, 37.5 %; H, 4.17 %; O, 58.3 %. Calculate the empirical formula of E330.

[3]

s/12/qp22

---

4 Although few halogenoalkanes exist naturally, such compounds are important as intermediates in organic reactions and as solvents.

The bromoalkane **B** has the following composition by mass: C, 29.3%; H, 5.7%; Br, 65.0%. The relative molecular mass of **B** is 123.

(a) Calculate the molecular formula of **B**.

[3]

w/10/qp23

(c) Sulphur and chlorine can be reacted together to form disulphur dichloride, S_2Cl_2.

Disulphur dichloride, S_2Cl_2, is decomposed by water forming sulphur and a mixture of hydrochloric acid and sulphurous acid.

When 2.7 g of S_2Cl_2 is reacted with an excess of water, 0.96 g of sulphur, S, is produced.

(i) What is the amount, in moles, of S_2Cl_2 present in 2.7 g?

(ii) What is the amount, in moles, of S produced from 1.0 mol of S_2Cl_2?

(iii) Construct a balanced equation for the reaction of S_2Cl_2 with water.

.....

[4]

w/07/qp2

2 The commonest form of iron(II) sulfate is the heptahydrate, $FeSO_4.7H_2O$. On heating at 90 °C this loses **some** of its water of crystallisation to form a different hydrated form of iron(II) sulfate, $FeSO_4.xH_2O$.

3.40 g of $FeSO_4.xH_2O$ was dissolved in water to form 250 cm^3 of solution.

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0200 mol dm^{-3} potassium manganate(VII).

In this titration 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the Fe^{2+} ions present in the sample.

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the Fe^{2+} ions in the acidified solution.

(i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

.....

..... [1]

(ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the iron(II) ions.

$MnO_4^-(aq) + 5Fe^{2+}(aq) + ...H^+(aq) \rightarrow .....(aq) + 5Fe^{3+}(aq) + ...H_2O(l)$

[3]

(b) **(i)** Calculate the number of moles of manganate(VII) used in the titration.

[1]

(ii) Use the equation in **(a)(ii)** and your answer to **(b)(i)** to calculate the number of moles of Fe^{2+} present in the 25.0 cm^3 sample of solution used.

[1]

(iii) Calculate the number of moles of $FeSO_4.xH_2O$ in 3.40 g of the compound.

[1]

(iv) Calculate the relative formula mass of $FeSO_4.xH_2O$.

[1]

(v) The relative formula mass of anhydrous iron(II) sulfate, $FeSO_4$, is 151.8.

Calculate the value of x in $FeSO_4.xH_2O$.

[1]

[Total: 9]

2 A 6.30 g sample of hydrated ethanedioic acid, $H_2C_2O_4.xH_2O$, was dissolved in water and the solution made up to 250 cm^3.

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.100 mol dm^{-3} potassium manganate(VII) solution. 20.0 cm^3 of this potassium manganate(VII) solution was required to react fully with the ethanedioate ions, $C_2O_4^{2-}$, present in the sample.

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the ethanedioate ions.

(i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

.....

..... [1]

(ii) Complete and balance the ionic equation for the reaction between the manganate(VII) ions and the ethanedioate ions.

$2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) + ...H^+(aq) \rightarrow .....(aq) + 10CO_2(aq) + ...H_2O(l)$

[3]

(b) **(i)** Calculate the number of moles of manganate(VII) used in the titration.

[1]

(ii) Use the equation in **(a)(ii)** and your answer to **(b)(i)** to calculate the number of moles of $C_2O_4^{2-}$ present in the 25.0 cm^3 sample of solution used.

[1]

(iii) Calculate the number of moles of $H_2C_2O_4.xH_2O$ in 6.30 g of the compound.

[1]

(iv) Calculate the relative formula mass of $H_2C_2O_4.xH_2O$.

[1]

(v) The relative formula mass of anhydrous ethanedioic acid, $H_2C_2O_4$, is 90.

Calculate the value of x in $H_2C_2O_4.xH_2O$.

[1]

[Total: 9]