AS: Moles and Stoichiometry (Theory)

4 Compound **Q** is a viscous liquid which is very soluble in water.
The M_r of **Q** is 90.0.

Three possible structures for **Q** are shown below.

R	S	T
$HOCH_2CH_2CO_2H$	$HOCH_2CO_2CH_3$	$HCO_2CH_2CH_2OH$

(a) (i) What type of isomerism do **R**, **S** and **T** show?

.....

(ii) What oxygen-containing functional groups are present in **R**, **S** and **T**?
Give their **full names**.

R ..... and .....

S ..... and .....

T ..... and .....

(iii) Which functional group(s) in **(ii)** will react with sodium carbonate?

.....

(iv) Which functional group(s) in **(ii)** will react with sodium metal?

.....

[6]

(b) When 0.002 mol of **Q** is reacted with an excess of solid sodium carbonate, Na_2CO_3, 24 cm^3 of carbon dioxide, measured at room temperature and pressure, is produced.

(i) Calculate the amount, in moles, of carbon dioxide produced in this reaction.

(ii) Hence calculate the amount, in moles, of carbon dioxide produced by 1 mol of **Q**.

[2]

When 0.002 mol of **Q** is reacted with an excess of metallic sodium, 48 cm^3 of hydrogen, measured at room temperature and pressure, is produced.

(c) **(i)** Calculate the amount, in moles, of hydrogen molecules produced in this reaction.

(ii) Hence calculate the amount, in moles, of hydrogen molecules produced by 1 mol of **Q**.

[2]

(d) Use your answers to **(b)** and **(c)** to deduce which structure, **R**, **S** or **T**, corresponds to the structure of **Q** and write balanced equations for the reactions that occurred.

identity of **Q** is .....

equation for reaction with sodium carbonate

.....

equation for reaction with sodium metal

..... [5]

[Total: 15]

w/13/qp23

4 Compound **R** is a weak diprotic (dibasic) acid which is very soluble in water.

(a) A solution of **R** was prepared which contained 1.25 g of **R** in 250 cm^3 of solution. When 25.0 cm^3 of this solution was titrated with 0.100 mol dm^{-3} NaOH, 21.6 cm^3 of the alkali were needed for complete reaction.

(i) Using the formula H_2X to represent **R**, construct a balanced equation for the reaction between H_2X and NaOH.

.....

(ii) Use the data above to calculate the amount, in moles, of OH^- ions used in the titration.

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

(iv) Calculate the amount, in moles, of **R** present in 250 cm^3 of solution.

(v) Calculate M_r of **R**.

[5]

(b) Three possible structures for **R** are shown below.

S	T	U
$HO_2CCH{=}CHCO_2H$	$HO_2CCH(OH)CH_2CO_2H$	$HO_2CCH(OH)CH(OH)CO_2H$

(i) Calculate the M_r of each of these acids.

M_r of **S** = ... M_r of **T** = ... M_r of **U** = ...

(ii) Deduce which of the structures, **S**, **T** or **U**, correctly represents the structure of the acid, **R**.

R is represented by .....

[2]

w/13/qp21

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]

s/14/qp22

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]

s/14/qp23

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

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

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

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

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]

[Total: 14]

w/12/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]

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 Compound **A** is an organic compound which contains carbon, hydrogen and oxygen.

When 0.240 g of the vapour of **A** is slowly passed over a large quantity of heated copper(II) oxide, CuO, the organic compound **A** is completely oxidised to carbon dioxide and water. Copper is the only other product of the reaction.

The products are collected and it is found that 0.352 g of CO_2 and 0.144 g of H_2O are formed.

(a) In this section, give your answers to <u>three</u> decimal places.

(i) Calculate the mass of carbon present in 0.352 g of CO_2.

Use this value to calculate the amount, in moles, of carbon atoms present in 0.240 g of **A**.

(ii) Calculate the mass of hydrogen present in 0.144 g of H_2O.

Use this value to calculate the amount, in moles, of hydrogen atoms present in 0.240 g of **A**.

(iii) Use your answers to calculate the mass of oxygen present in 0.240 g of **A**.

Use this value to calculate the amount, in moles, of oxygen atoms present in 0.240 g of **A**.

[6]

(b) Use your answers to **(a)** to calculate the empirical formula of **A**.

[1]

(c) When a 0.148 g sample of **A** was vapourised at 60°C, the vapour occupied a volume of 67.7 cm^3 at a pressure of 101 kPa.

(i) Use the general gas equation $pV = nRT$ to calculate M_r of **A**.

M_r =.....

(ii) Hence calculate the molecular formula of **A**.

[3]

w/11/qp21

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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

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 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

(c) In a laboratory preparation of 1-bromobutane, when 15.4 g of butan-1-ol was used, 22.5 g of 1-bromobutane was obtained after purification.

Calculate the yield of 1-bromobutane as a percentage of the theoretical maximum yield.

[2]

w/09/qp22

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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

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

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

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

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

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

.....

[4]

w/07/qp2

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

(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

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

(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

5 Organic compounds which contain oxygen may contain alcohol, aldehyde, carboxylic acid, ester or ketone functional groups. The functional groups may be identified by their reactions with specific reagents.

Compound **X** has the empirical formula CH_2O and M_r of 90.

(a) There is no reaction when **X** is treated with $NaHCO_3$.

What functional group does this test show to be **not** present in **X**?

..... [1]

(b) When 0.600 g of **X** is reacted with an excess of Na, 160 cm^3 of H_2, measured at room temperature and pressure, is produced.

(i) What functional group does this reaction show to be present in **X**?

.....

(ii) Use the data to calculate the amount, in moles, of hydrogen **atoms** produced from 0.600 g of **X**.

(iii) Hence, show that each molecule of **X** contains **two** of the functional groups you have given in **(i)**.

[4]

s/12/qp21

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

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 7.5×10^{-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.

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

(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

(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

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

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]

s/10/qp21

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

(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

(b) When used for cutting or welding, ethyne is transported in cylinders which contain the gas under pressure. A typical cylinder has a volume of 76 dm^3 and contains ethyne gas at 1515 kPa pressure at a temperature of 25 °C.

Use the general gas equation, $pV = nRT$, to calculate the amount, in moles, of ethyne in this cylinder.

[2]

(c) In some countries, ethyne is manufactured from calcium carbide, CaC_2, which is produced by heating quicklime and coke together at 2300 K.

$$CaO + 3C \rightarrow CaC_2 + CO$$

When water is added to the CaC_2, calcium hydroxide, $Ca(OH)_2$, and ethyne, C_2H_2, are produced.

(i) Construct a balanced equation for the formation of ethyne from calcium carbide.

.....

(ii) Use this equation and your answer to part **(b)** to calculate the mass of CaC_2 which will react with an excess of water to produce enough ethyne to fill 100 cylinders of the gas.

[3]

s/06/qp2

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

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

(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

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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

(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