1)

The European Union has set a limit (with effect from January 2010) of 3.13 ppm for the proportion of the toxic gas carbon monoxide in the air that we breathe. This is equivalent to

☐ **A** 3.13%

☐ **B** 0.0313%

☐ **C** 0.000313%

☐ **D** 0.00000313%

1 mark)

2)

For drivers in the UK, the legal limit of the concentration of ethanol (molar mass 46 g mol^{-1}) in the blood is 80 mg per 100 cm^3. This is equivalent to a concentration of

☐ **A** 17.4 mol dm^{-3}

☐ **B** 1.74 mol dm^{-3}

☐ **C** 0.0174 mol dm^{-3}

☐ **D** 0.00174 mol dm^{-3}

1 mark)

3)

An important reaction which occurs in the catalytic converter of a car is

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$$

In this reaction, when 500 cm^3 of CO reacts with 500 cm^3 of NO at 650 °C (the operating temperature of the catalyst) and at 1 atm, the **total** volume of gases produced at the same temperature and pressure is

☐ **A** 500 cm^3

☐ **B** 750 cm^3

☐ **C** 1000 cm^3

☐ **D** impossible to calculate without knowing the molar volume of gases under these conditions.

1 mark)

4)

The enthalpy change for the reaction between hydrochloric acid and sodium hydroxide is –56 kJ mol^{-1}. Therefore

☐ **A** the reaction is exothermic and the temperature rises.

☐ **B** the reaction is exothermic and the temperature falls.

☐ **C** the reaction is endothermic and the temperature rises.

☐ **D** the reaction is endothermic and the temperature falls.

1 mark)

5)

The standard enthalpy changes of formation of some sulfur species are:

Species	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$S_8(s)$	0
$S_8(g)$	+103
S(g)	+279

The enthalpy of atomization of sulfur is (in kJ mol^{-1})

☒ **A** 103 ÷ 8

☒ **B** 279 ÷ 8

☒ **C** 279

☒ **D** (103 ÷ 8) + 279

1 mark)

6)

For which of the following reactions is the enthalpy change equal to the bond enthalpy of H–I?

☐ **A** $HI(g) \rightarrow \frac{1}{2}H_2(g) + \frac{1}{2}I_2(s)$

☐ **B** $HI(g) \rightarrow \frac{1}{2}H_2(g) + \frac{1}{2}I_2(g)$

☐ **C** $HI(g) \rightarrow H(g) + I(g)$

☐ **D** $HI(g) \rightarrow H^+(g) + I^-(g)$

1 mark)

7)

The equation for the complete combustion of pentane is

$$C_5H_{12}(g) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(l) \qquad \Delta H_c^{\ominus} = -3509 \text{ kJ mol}^{-1}$$

The standard enthalpy change of formation of $CO_2(g)$ is –394 kJ mol^{-1} and that of $H_2O(l)$ is –286 kJ mol^{-1}.

The standard enthalpy change of formation of pentane (in kJ mol^{-1}) is

☐ **A** 5(–394) + 6(–286) + (–3509)

☐ **B** 5(–394) + 6(–286) – (–3509)

☐ **C** –5(–394) – 6(–286) + (–3509)

☐ **D** –5(–394) – 6(–286) – (–3509)

1 mark)

8)

All alkenes have

☐ **A** the same empirical formula and the same general formula.

☐ **B** the same molecular formula and the same general formula.

☐ **C** the same molecular formula and the same empirical formula.

☐ **D** the same empirical formula and the same structural formula.

1 mark)

9)

This question concerns the reaction of hydrogen bromide with propene.

(a) This reaction requires

(1)

☒ **A** normal laboratory conditions.

☒ **B** the presence of UV light.

☒ **C** the presence of a suitable catalyst.

☒ **D** heating under reflux.

(b) The reaction is best described as

(1)

☒ **A** nucleophilic substitution.

☒ **B** electrophilic substitution.

☒ **C** nucleophilic addition.

☒ **D** electrophilic addition.

(c) The major product of the reaction will be

(1)

☒ **A** 1-bromopropane

☒ **B** 2-bromopropane

☒ **C** 1,2-dibromopropane

☒ **D** 2-bromopropene

3 marks)

10)

Ethanol (molar mass 46 g mol^{-1}) is manufactured by the hydration of ethene (molar mass 28 g mol^{-1}):

$$C_2H_4 + H_2O \rightarrow C_2H_5OH$$

In a typical process 28 tonnes of ethene produces 43.7 tonnes of ethanol. The percentage yield of ethanol in this process is

☒ **A** 64%

☒ **B** 95%

☒ **C** 100%

☒ **D** 156%

1 mark)

11)

When a solution of barium chloride is added to sulfuric acid, a white precipitate is formed. The ionic equation (including state symbols) for this reaction is

☒ **A** $H^+(aq) + Cl^-(aq) \rightarrow HCl(s)$

☒ **B** $Ba^+(aq) + SO_4^-(aq) \rightarrow BaSO_4(s)$

☒ **C** $Ba^{2+}(aq) + 2SO_4^-(aq) \rightarrow Ba(SO_4)_2(s)$

☒ **D** $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

1 mark)

12)

0.400 g of magnesium ribbon reacted with exactly 22.2 cm^3 of hydrochloric acid of concentration 1.50 mol dm^{-3}.

400 cm^3 of hydrogen gas was formed, the volume being measured at room temperature and pressure.

In the calculations that follow, use the following molar masses:

Mg = 24.0 g mol^{-1}
Cl = 35.5 g mol^{-1}

(a) Calculate the amount (in moles) of magnesium used.

(1)

(b) Calculate the amount (in moles) of hydrochloric acid used.

(1)

(c) Calculate the amount (in moles) of hydrogen produced.

[Molar volume of any gas at room temperature and pressure = 24 000 cm^3 mol^{-1}]

(1)

(e) Calculate the maximum mass of magnesium chloride that would be formed in this reaction. Give your answer to **three** significant figures.

(3)

13)

Copper(II) sulfate exists as blue hydrated crystals and white anhydrous crystals. The enthalpy changes of solution for these two substances may be represented by the following simplified equations:

$$\underset{\text{blue}}{CuSO_4.5H_2O(s)} + aq \rightarrow CuSO_4(aq) \qquad \Delta H_1 = +11.5 \text{ kJ mol}^{-1}$$

$$\underset{\text{white}}{CuSO_4(s)} + aq \rightarrow CuSO_4(aq) \qquad \Delta H_2 = -66.1 \text{ kJ mol}^{-1}$$

(a) (i) Fill in the box and add labelled arrows to complete the Hess cycle to enable you to calculate $\Delta H_{reaction}$.

(3)

$$CuSO_4.5H_2O(s) \xrightarrow{\Delta H_{reaction}} CuSO_4(s) + 5H_2O(l)$$

(ii) Calculate a value for the enthalpy change $\Delta H_{reaction}$.

(2)

(b) Suggest why it is not possible to directly measure the enthalpy change for the conversion of the blue hydrated copper(II) sulfate crystals into the white anhydrous crystals.

(1)

*(c) (i) $CuSO_4.5H_2O(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H_1 = +11.5 \text{ kJ mol}^{-1}$

Describe briefly the experimental procedure that **you** would use to obtain the data necessary to calculate ΔH_1, given a known mass of hydrated copper(II) sulfate crystals, $CuSO_4.5H_2O(s)$.

You should state the apparatus that you would use and any measurements that you would make.

You are **not** required to calculate the amounts of substances or to explain how you would use the data obtained.

(4)

(ii) The value for the enthalpy change from (c)(i) obtained by experiments in a school laboratory is likely to be significantly different from a data book value.

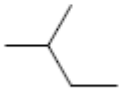
List **three** possible reasons for this which do **not** relate to the quality of the apparatus or chemicals used or possible mistakes in carrying out the procedure.

(3)

14)

This question is about alkanes.

(a) The skeletal formulae of two alkanes (**A** and **B**) are shown below.



A

B

(i) Write the general formula of the alkanes.

(1)

(ii) Compounds **A** and **B** are ..... of each other.

(1)

(iii) Draw the displayed formula of compound **A**.

(1)

(iv) Give the systematic name of compound **B**.

(1)

(b) The largest use for alkanes is as fuels. However, there are problems associated with the combustion of alkanes, whether complete or incomplete.

(i) An incomplete combustion of methane, CH_4, results in the formation of carbon monoxide and water only.

Write the equation for this reaction. State symbols are **not** required.

(2)

(ii) When does incomplete combustion occur?

(1)

(iii) State **two** problems that result from the incomplete combustion of alkane fuels.

(2)

***(iv)** State and explain the main environmental problem arising from the **complete** combustion of alkane fuels.

(3)

(c) The reactions of organic compounds, including alkanes, may be broken down into a series of steps; this is the mechanism for the reaction. The reaction between methane and chlorine may be represented by a mechanism involving three stages – **initiation**, **propagation** and **termination**.

(i) Reaction mechanisms often involve the use of 'curly arrows'. Explain the meaning of the curly arrows shown below.

(2)

Arrow I

Arrow II

Arrow I .....

.....

Arrow II .....

.....

(ii) Using the curly arrow notation, show the **initiation** step of the reaction between methane and chlorine.

(2)

(iii) Give the two **propagation** steps of the reaction between methane and chlorine.

Curly arrows are **not** required.

(2)

(iv) Suggest why a small amount of UV light can result in the formation of a large amount of product.

(1)

(v) Ethane is a trace product of this reaction. By means of an equation, show how the ethane is formed.

(1)

(d) Scientists never detect molecular hydrogen, H_2, amongst the products of the chlorination of methane.

Use the data below to suggest why this is so.

The frequency of UV light used corresponds to an energy of about 400 kJ mol^{-1}.

Bond	Bond enthalpy/ kJ mol^{-1}
C—H	435
Cl—Cl	243

(2)

15)

Carbon capture is the name given to some processes used to prevent carbon dioxide entering the atmosphere. Carbon capture is carried out because carbon dioxide is a greenhouse gas.

Flue gases in chimneys contain carbon dioxide produced from burning fossil fuels. Various different compounds can be used to react with the carbon dioxide to capture it. Alternatively, carbon dioxide can be separated from other gases by a physical process.

Many sources of natural gas contain carbon dioxide, which can be removed by freezing.

Captured carbon dioxide must then be stored to prevent it entering the atmosphere. It can be injected into depleted oil and gas formations, or into porous rocks full of salt water. These are usually over 1 km below the Earth's surface and have non-porous rocks above them. Eventually the carbon dioxide dissolves, forming carbonate ions and then new minerals.

(a) Greenhouse gases can absorb infrared radiation. Explain why carbon dioxide absorbs infrared radiation but oxygen cannot.

(2)

(b) A solution of the compound aminoethanol, $H_2NCH_2CH_2OH$, can be used to absorb carbon dioxide.

$$2H_2NCH_2CH_2OH + CO_2 + H_2O \rightleftharpoons (H_3NCH_2CH_2OH)_2CO_3$$

(i) Explain why aminoethanol is soluble in water.

(1)

(ii) The position of this equilibrium moves to the left on heating. This frees the captured carbon dioxide for storage. Use this information to decide whether the forward reaction is exothermic or endothermic. Explain your answer.

(2)

(c) The composition of a sample of natural gas and the melting temperatures of four of its components are shown below.

	Percentage	Melting temperature / K
Methane	95.2	91.1
2-methylpropane	0.8	113.7
Butane	0.9	134.7
Other hydrocarbons	2.4	
Carbon dioxide	0.7	216.5

(i) Draw a dot and cross diagram for carbon dioxide.

(2)

(ii) The London forces between molecules of carbon dioxide are stronger than the London forces between molecules of methane. Suggest a reason for this.

(1)

(iii) Use your knowledge of intermolecular forces to suggest why butane has a higher melting temperature than 2-methylpropane.

(2)

(d) When carbon dioxide dissolves, it may eventually form minerals such as magnesium carbonate and calcium carbonate.

(i) State the results of flame tests carried out on these two minerals.

(2)

Magnesium carbonate .....

Calcium carbonate .....

*(ii) Magnesium carbonate and calcium carbonate both undergo thermal decomposition, but they have different stability to heat. The difference in stability to heat can be compared in an experiment.

Suggest how this experiment could be carried out. You should indicate

- how to detect when the thermal decomposition occurs
- the measurement you would make to compare the stability to heat
- how to make the comparison fair.

You may include a diagram if you wish but it is not essential.

(4)

*(iii) State and explain which of the two carbonates is more stable to heat.

(3)