1)

In an experiment to determine the enthalpy change of combustion of an alcohol, a spirit burner containing the alcohol was weighed, lit and placed under a copper can containing a known volume of water. The temperature rise of the water was measured and the burner re-weighed. The enthalpy change calculated from the results was much less exothermic than the value reported in the literature.
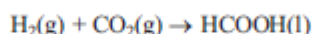
Which of the following factors is **most** likely to be the cause of this error?

☒ **A** Heat loss around the side of the copper can.

☐ **B** The use of a thermometer with a range of $0 - 110\ °C$ rather than $0 - 50\ °C$.

☐ **C** The use of a measuring cylinder for measuring the water rather than a pipette.

☐ **D** Evaporation of the alcohol during the weighing. **1 mark)**

2)

The standard enthalpy changes of formation of carbon dioxide and of methanoic acid are $-394\ kJ\ mol^{-1}$ and $-409\ kJ\ mol^{-1}$ respectively. Calculate the enthalpy change for the reaction

$$H_2(g) + CO_2(g) \rightarrow HCOOH(l)$$

☐ **A** $-803\ kJ\ mol^{-1}$

☐ **B** $-15\ kJ\ mol^{-1}$

1 mark)

☐ **C** $+803\ kJ\ mol^{-1}$

☐ **D** $+15\ kJ\ mol^{-1}$

3)

For which of the following changes is the value of ΔH negative?

☐ **A** $K(g) \rightarrow K^+(g) + e^-$

☐ **B** $K^+Cl^-(s) \rightarrow K^+(g) + Cl^-(g)$

☐ **C** $Cl(g) + e^- \rightarrow Cl^-(g)$
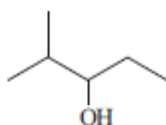
▪ **1 mark)**

☐ **D** $Cl_2(g) \rightarrow 2Cl(g)$

4)

Which of the following represents the process occurring when the enthalpy change of atomization of bromine is measured?

☐ **A** $\frac{1}{2}Br_2(l) \rightarrow Br(g)$

☐ **B** $\frac{1}{2}Br_2(g) \rightarrow Br(g)$

☐ **C** $Br_2(l) \rightarrow Br^+(g) + Br^-(g)$

1 mark)

☐ **D** $Br_2(g) \rightarrow Br^+(g) + Br^-(g)$

5)
An organic compound is represented by the skeletal formula shown below.

OH

The compound is

☐ A $CH_3CH_2CH_2CH(OH)CH_2CH_3$

☐ B $(CH_3)_2CHC(OH)(CH_3)_2$

☐ C $(CH_3)_2CHCH_2CH(OH)CH_3$

☐ D $(CH_3)_2CHCH(OH)CH_2CH_3$

1 mark)

6)
How many structural isomers does the alkane C_5H_{12} have?

☐ A 4

☐ B 3

☐ C 2

☐ D 1

1 mark)

7)
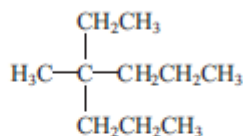When methane reacts with chlorine, a mixture of products forms. Which product provides the strongest evidence for a free radical mechanism?

☐ A C_2H_6

☐ B CH_3Cl

☐ C HCl

☐ D $CHCl_3$

1 mark)

8)
What is the IUPAC name of the compound shown below?

☐ A 2-ethyl-2-propylpentane

☐ B 3-methyl-3-propylhexane

☐ C 4-methyl-4-propylhexane

☐ D 4-ethyl-4-methylheptane

1 mark)

9)
The reaction of bromine with propene is an example of

☐ A electrophilic substitution.

☐ B free radical substitution.

☐ C electrophilic addition.

☐ D free radical addition.

1 mark)

10)

A compound **Z** contains, by mass, 26.7% carbon, 2.2% hydrogen, and 71.1% oxygen. The empirical formula of **Z** is

☐ **A** CHO_2

☐ **B** $C_2H_2O_4$

1 mark)

☐ **C** CHO

☐ **D** $C_2H_2O_2$

11)

If **X** represents the element of atomic number 9 and **Y** the element of atomic number 20, the compound formed between these two elements is

☐ **A** covalent, YX_2.

☐ **B** ionic, YX_2.

☐ **C** covalent, **YX**.

▪ 1 mark)

☐ **D** ionic, **YX**.

12)

(a) State Hess's Law.

(1)

(b) Methane burns in a limited supply of oxygen to give carbon monoxide and water.

$$CH_4(g) + 1\frac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(l)$$

The enthalpy change for this reaction cannot be determined directly, but can be found using the standard enthalpy changes of combustion of methane and carbon monoxide, together with Hess's Law.

The standard enthalpy changes of combustion needed are for CH_4, -890 kJ mol^{-1}, and for CO, -283 kJ mol^{-1}.

(i) Draw a Hess's Law diagram which would enable you to calculate the enthalpy change for the combustion of methane to carbon monoxide.

$$CH_4(g) + 1\frac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(l)$$

(2)

(ii) Calculate the enthalpy change for this reaction, in kJ mol^{-1}.

(2)

(iii) Explain why the enthalpy change for this reaction cannot be determined directly.

(1)

(c) Explain why the calculation in part (b)(ii) would give an incorrect result for the enthalpy change for the reaction below.

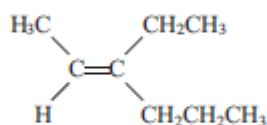$$CH_4(g) + 1\frac{1}{2}O_2(g) \rightarrow CO(g) + 2H_2O(g)$$

(2)

13)

(a) Give the general formula for the homologous series of **alkenes**.

(1)

(b) What is meant by the term **unsaturated** as applied to alkenes?

(1)

c) (i) Name the alkene below using *E-Z* nomenclature.

$$H_3C \diagdown \qquad \diagup CH_2CH_3$$
$$C{=}C$$
$$H \diagup \qquad \diagdown CH_2CH_2CH_3$$

(2)

   (ii) Suggest why this alkene cannot be named using the *cis-trans* naming system.

(1)

(d) Give the structural formula of the organic product of the reaction of ethene, $CH_2{=}CH_2$, with

   (i) hydrogen.

(1)

   (ii) chlorine.

(1)

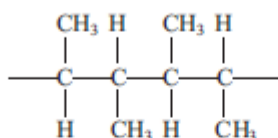   (iii) acidified aqueous potassium manganate(VII).

(1)

   (iv) bromine **water**.

(1)

(e) Draw the mechanism for the reaction of **propene** with hydrogen bromide to give the major product.

(4)

(f) The structure below shows **two** repeat units of a polymer.

$$
\begin{array}{ccccc}
 & CH_3 & H & CH_3 & H \\
 & | & | & | & | \\
{-}C & {-}C & {-}C & {-}C{-} \\
 & | & | & | & | \\
 & H & CH_3 & H & CH_3 \\
\end{array}
$$

   (i) Give the displayed formulae of **two** isomeric alkenes, either of which could have given rise to this polymer.

(2)

   (ii) State why the empirical formula of a poly(alkene) is the same as that of the monomer from which it is produced.

(1)

   (iii) State, with a reason, the atom economy for the production of a poly(alkene) from an alkene.

(1)

4

14)

Sodium burns in oxygen to give a pale yellow solid **X**.

(a) (i) 1.73 g of sodium reacts with 1.20 g of oxygen.

Calculate the empirical formula of **X**.

(2)

(ii) The molar mass of **X** is 78 g mol⁻¹. Give the molecular formula of **X**.

(1)

(iii) Write the equation, including state symbols, for the reaction of sodium with oxygen to produce **X**.

(2)

(iv) Calculate the volume of oxygen in dm^3 (at room temperature and pressure) which reacts with 1.73 g of sodium. (The molar volume of any gas at room temperature and pressure is 24 dm^3 mol⁻¹.)

(2)

(v) Calculate the number of oxygen **molecules** that react with 1.73 g of sodium. (The Avogadro constant = 6.02×10^{23} mol⁻¹.)

(1)

(b) If sodium is burnt in **air**, compound **X** is not the only product. Suggest why this is so.

(1)

15)

This question is about hexane, C_6H_{14}, and hex-1-ene, C_6H_{12}.

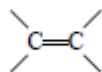(a) What test would you use to distinguish between hexane and hex-1-ene? Give the results of the test for each substance.

(2)

(b) Hex-1-ene has a number of isomers, including two stereoisomers of hex-2-ene.

(i) Complete the formula to show the structure of *E*-hex-2-ene.

(1)

*(ii) Explain why stereoisomerism can occur in alkenes, and why hex-2-ene has stereoisomers but hex-1-ene does not.

(2)

5

(c) The enthalpy change of combustion of hexane was measured using a spirit burner to heat a known mass of water in a calorimeter. The temperature rise of the water was measured. The results of the experiment are shown below.

Mass of hexane burnt	0.32 g
Mass of water in calorimeter	50 g
Initial temperature of water	22 °C
Final temperature of water	68 °C

The specific heat capacity of water is $4.18 \, J \, g^{-1} \, °C^{-1}$.

(i) Calculate the energy in joules produced by burning the hexane. Use the expression

energy transferred = mass × specific heat capacity × temperature change.

(1)

(ii) Calculate the enthalpy change of combustion of hexane. The mass of 1 mole of hexane is 86 g.

Give your answer to TWO significant figures. Include a sign and units in your answer.

(3)

(iii) The value for the enthalpy change of combustion in this experiment is different from the value given in data books. Suggest TWO reasons for this difference.

(2)

(iv) A student suggested that the results would be more accurate if a thermometer which read to 0.1°C was used. Explain why this would **not** improve the accuracy of the result. A calculation is **not** required.

(1)

d) Hex-1-ene can be converted to hexane in the following reaction.

$$C_6H_{12}(l) + H_2(g) \rightarrow C_6H_{14}(l)$$

(i) What catalyst is used in this reaction?

(1)

(ii) The enthalpy change of this reaction $\Delta H_{reaction}$ can be calculated from the following enthalpy changes of combustion.
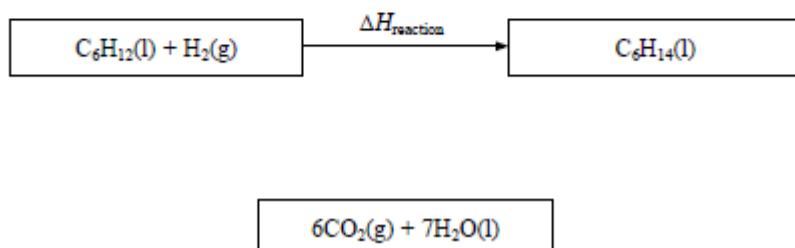
Substance	Enthalpy change of combustion /kJ mol^{-1}
Hex-1-ene, C_6H_{12}	-4003
Hydrogen, H_2	-286
Hexane, C_6H_{14}	-4163

Complete the Hess cycle by adding labelled arrows. Use your cycle to calculate the enthalpy change $\Delta H_{reaction}$.

(3)

$$C_6H_{12}(l) + H_2(g) \xrightarrow{\Delta H_{reaction}} C_6H_{14}(l)$$

$$6CO_2(g) + 7H_2O(l)$$

(iii) The enthalpy change for the reaction of some other alkenes with hydrogen is shown below.

Reaction	Standard enthalpy change / kJ mol^{-1}
$C_3H_6 + H_2 \rightarrow C_3H_8$	-125
$C_4H_8 + H_2 \rightarrow C_4H_{10}$	-126
$C_5H_{10} + H_2 \rightarrow C_5H_{12}$	-126

Explain why the values are so similar.

(1)

16)

Chloroethane, C_2H_5Cl, can be made from either ethane or ethene.

(a) (i) What reagent and condition would be used to make chloroethane from **ethane**?

(2)

Reagent.

Condition.

(ii) State the type of reaction and mechanism by which this reaction occurs.

(2)

(b) (i) What reagent would be used to make chloroethane from **ethene**?

(1)

(ii) Show, in full, the mechanism for this reaction in which **ethene** is converted to chloroethane.

(3)

(c) Which method of making chloroethane has

(3)

- a higher atom economy? ....

- a higher percentage yield? ....

Explain your answers.

Higher atom economy ....

....

Higher percentage yield ....

....

(d) The compound chloroethene, CH_2=$CHCl$, forms an addition polymer.

    (i)   Draw a diagram, using dots or crosses, to show the arrangement of electrons in chloroethene. Only the outer shell electrons need be shown.

(2)

    (ii) Chloroethene can form an addition polymer. Write the displayed formula of poly(chloroethene) showing two repeat units.

(1)

*(iii) Poly(chloroethene) is commonly known as PVC. Almost a quarter of the PVC which is manufactured is used to make water pipes, which were formerly made of metal.

Give TWO factors which have to be considered when deciding which material, PVC or metal, contributes to more sustainable uses of resources in the long term.

(2)