1 (a) Propene, C_3H_6, reacts with hydrogen bromide, HBr, in an electrophilic addition reaction.

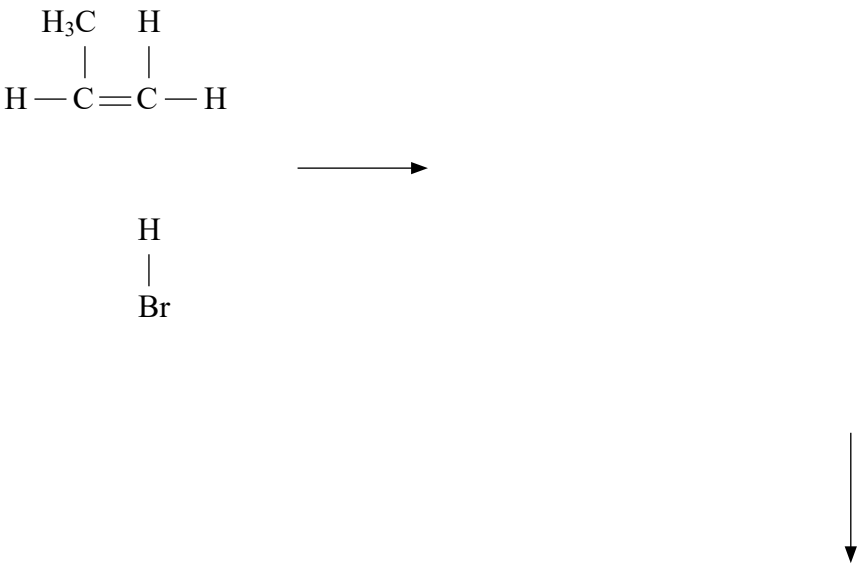
2-bromopropane is formed as the major product.

$$H_3CCH{=}CH_2 + HBr \rightarrow H_3CCH(Br)CH_3$$

(i) Complete the mechanism for the reaction, using 'curly arrows' where appropriate. Show clearly the structure of the intermediate carbocation formed.

(3)

Mechanism



(ii) Draw the structure of the alternative carbocation that can be formed in the reaction between propene and hydrogen bromide.

(1)

(b) Four isomers, each with the molecular formula $C_4H_{10}O$, are shown below.

Isomer **A**: C $_3CH_2CH_2CH_2OH$

Isomer **B**: C $_3CH_2CH(OH)CH_3$

Isomer **C**: $(C_3)_3COH$

Isomer **D**: C $_3CH(CH_3)CH_2OH$

(i) Which isomer is a secondary alcohol? Justify your answer.

(2)

(ii) Which isomer is resistant to oxidation when heated with acidified potassium dichromate(VI)? Justify your answer in terms of the structure of the isomer.

(2)

(iii) Which isomer can be oxidized to a ketone? Draw the displayed formula of the ketone produced.

(1)

(iv) Which isomers can be oxidized to an aldehyde?

(1)

(v) Phosphorus(V) chloride (phosphorus pentachloride), PCl_5, is used to test for the presence of an –OH group.

What would you expect to see when any of the above four isomers, A, B, C or D, are reacted with phosphorus(V) chloride?

(1)

(vi) Complete the equation for the reaction shown below. State symbols are **not** required.

(2)

$C_4H_9OH + PCl_5 \rightarrow$

(Total for Question = 13 marks)

2 Alkenes are unsaturated hydrocarbons which, because of their reactivity, are important industrial starting materials. Alkenes for industrial use are obtained by cracking alkanes.

(a) Write the equation for the cracking of decane ($C_{10}H_{22}$) to form 1 molecule of propene as the only alkene.

(1)

(b) The carbon–carbon double bond in alkenes consists of a σ and a π bond.

(i) Explain, using diagrams, the difference between the σ and the π bond in the carbon–carbon double bond of an alkene.

(4)

Diagrams

Explanation

(ii) State the type and mechanism involved in the typical reaction of alkenes.

(1)

*(iii) By considering the strength and structure of the π bond, explain why alkenes are more reactive than alkanes.

(2)

(c) When propene reacts with hydrogen bromide, there are two possible products.

(i) Draw a displayed formula of each of these products and label the major product.

(2)

(ii) Give the mechanism for the reaction of propene with hydrogen bromide which forms the major product.

(3)

(iii) Explain, by referring to the mechanism, why the major product is formed.

(2)

(d) The polymer poly(propene) is manufactured from propene.

(i) Write an equation for the polymerization, drawing the displayed formula of the repeat unit of poly(propene).

(3)

(ii) UV radiation causes poly(propene) to degrade. Suggest one advantage and one disadvantage of this.

(2)

Advantage

Disadvantage

(Total for Question 20 marks)

3 (a) The alkenes have the general formula C_nH_{2n}. However, a compound with this general formula is not necessarily an alkene. Suggest why this is so.

(1)

(b) Give the equation, using skeletal formulae, for the reaction of propene with each of the following.

(i) Hydrogen:

(1)

(ii) Hydrogen bromide to form the major product:

(2)

(c) Give the mechanism for the reaction of propene with hydrogen bromide, HBr, to form the major product.

(3)

(Total for Question 7 marks)

4 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)

Test:

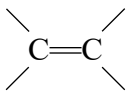
Result with hexane:

Result with hex-1-ene:

(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)

(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?

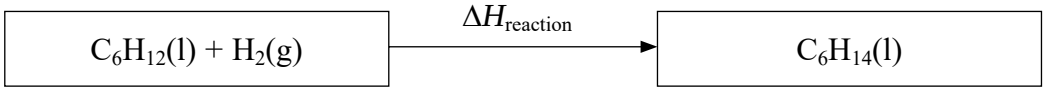
(1)

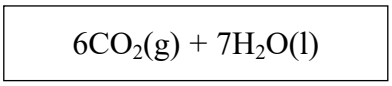
(ii) The enthalpy change of this reaction $\Delta H_{reaction}$ can be calculated from the following enthalpy changes of combustion.

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)





$\Delta H_{reaction}$ = kJ mol^{-1}

(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)

(Total for Question = 17 marks)