**1** Petroleum is a source of many important chemicals.

**(a)** Name **two** industrial processes which must take place to produce alkenes from petroleum.

.................................................................................................................................................

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

**(b)** Ethene, $CH_2=CH_2$, and propene, $CH_2=CHCH_3$, can both be converted into polymers.

**(i)** What type of polymerisation takes place when ethene forms a polymer?

................................................................................................................................. [1]

**(ii)** What is the empirical formula of the polymer formed from ethene?

................................................................................................................................. [1]

**(iii)** Propene has the structural formula $CH_2=CHCH_3$.

Draw **two** repeat units of the polymer made from propene.

[2]

**(c)** Ethene will react with steam to form ethanol.

Propene will react with steam to form two isomers, both of which are alcohols.

Suggest the structures of these alcohols.

**(d)** Esters are organic chemicals noted for their characteristic smells. Ethanoic acid and methanol will react to form an ester.

**(i)** Name the catalyst needed to form an ester from ethanoic acid and methanol.

.................................................................................................................................. [1]

**(ii)** Name the ester formed when ethanoic acid reacts with methanol.

.................................................................................................................................. [1]

**(iii)** Draw the structure of the ester formed when ethanoic acid reacts with methanol. Show all bonds.

[2]

**(iv)** Give the name of a polyester.

.................................................................................................................................. [1]

[Total: 13]

**2** Alkanes and alkenes are both series of hydrocarbons.

**(a) (i)** Explain the term *hydrocarbon*.

.......................................................................................................................................

................................................................................................................................ [1]

**(ii)** What is the difference between these two series of hydrocarbons?

.......................................................................................................................................

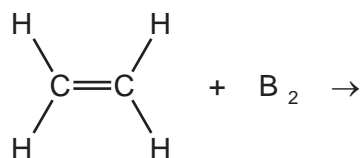................................................................................................................................ [2]

**(b)** Alkenes and simpler alkanes are made from long-chain alkanes by cracking.
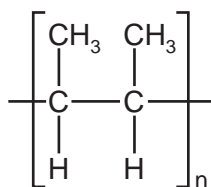Complete the following equation for the cracking of the alkane $C_{20}H_{42}$.

$$C_{20}H_{42} \rightarrow 2C_4H_8 + 2C_2H_4 + \text{...............}$$ [1]

**(c)** Alkenes such as butene and ethene are more reactive than alkanes.
Alkenes are used in the petrochemical industry to make a range of products, which includes polymers and alcohols.

**(i)** Dibromoethane is used as a pesticide. Complete the equation for its preparation from ethene.

$$\begin{array}{c} H \\ \diagdown \end{array} C = C \begin{array}{c} H \\ \diagup \end{array} \quad + \quad B_2 \quad \rightarrow$$

(ethene structure: H and H on left carbon, H and H on right carbon, C=C double bond)

[1]

**(ii)** The structural formula of a poly(alkene) is given below.

$$\left[ \begin{array}{cc} CH_3 & CH_3 \\ | & | \\ -C & -C- \\ | & | \\ H & H \end{array} \right]_n$$

Deduce the structural formula of its monomer.

[2]

**(iii)** How is butanol made from butene, $CH_3-CH_2-CH=CH_2$? Include an equation in your answer.

...............................................................................................................................

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

**(iv)** Cracking changes alkanes into alkenes. How could an alkene be converted into an alkane? Include an equation in your answer.

...............................................................................................................................

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

**(d)** 20 cm³ of a hydrocarbon was burnt in 175 cm³ of oxygen. After cooling, the volume of the remaining gases was 125 cm³. The addition of aqueous sodium hydroxide removed carbon dioxide leaving 25 cm³ of unreacted oxygen.

  **(i)** volume of oxygen used = .......... cm³              [1]
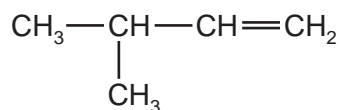
  **(ii)** volume of carbon dioxide formed = .......... cm³       [1]

  **(iii)** Deduce the formula of the hydrocarbon and the balanced equation for the reaction.

...................................................................................................................................

...................................................................................................................................

...................................................................................................................................

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

[Total: 15]

**3** The alkenes are unsaturated hydrocarbons. They form a homologous series, the members of which have the same chemical properties.
They undergo addition reactions and are easily oxidised.

**(a)** The following hydrocarbons are isomers.

$$CH_3—CH—CH=CH_2 \qquad\qquad CH_3—CH_2—CH_2—CH=CH_2$$
$$\;\;\;\;\;\;\;\;\;\;|$$
$$\;\;\;\;\;\;\;\;\;CH_3$$

**(i)** Explain why these two hydrocarbons are isomers.

...................................................................................................................................

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

**(ii)** Give the structural formula of another hydrocarbon which is isomeric with the above.

[1]

**(b)** Give the structural formula and name of each of the products of the following addition reactions.

**(i)** ethene and bromine

structural formula of product


name of product ............................................................................................... [2]

**(ii)** propene and hydrogen

structural formula of product


name of product ............................................................................................... [2]

**(iii)** but-1-ene and water

structural formula of product


name of product ............................................................................................... [2]

**(c)** Alkenes can be oxidised to carboxylic acids.

   **(i)** For example, propene, $CH_3-CH=CH_2$, would produce ethanoic acid, $CH_3-COOH$, and methanoic acid, $H-COOH$. Deduce the formulae of the alkenes which would form the following carboxylic acids when oxidised.

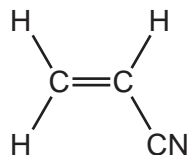     ethanoic acid and propanoic acid

     only ethanoic acid

                                                           [2]

  **(ii)** Describe the colour change you would observe when an alkene is oxidised with acidified potassium manganate(VII).

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

**(d)** Alkenes polymerise to form addition polymers.
Draw the structural formula of poly(cyanoethene), include at least **two** monomer units.
The structural formula of the monomer, cyanoethene, is given below.



                                                            [3]

                                                            [Total: 16]

**4** The alkenes are unsaturated hydrocarbons. They form a homologous series, the members of which have similar chemical properties:

- easily oxidised
- addition reactions
- polymerisation
- combustion.

**(a)** All the alkenes have the same empirical formula.

**(i)** State their empirical formula.

..................................................................................................................... [1]

**(ii)** Why is the empirical formula the same for all alkenes?

..................................................................................................................... [1]

**(b)** Alkenes can be oxidised to carboxylic acids by boiling with aqueous potassium manganate(VII).

**(i)** Pent-2-ene, $CH_3–CH_2–CH=CH–CH_3$, oxidises to $CH_3–CH_2–COOH$ and $CH_3COOH$. Name these two acids.

$CH_3–CH_2–COOH$ ......................................................................................................

$CH_3COOH$ ................................................................................................. [2]

**(ii)** Most alkenes oxidise to two carboxylic acids. Deduce the formula of an alkene which forms only one carboxylic acid.

[1]

**(c)** Complete the following equations for the addition reactions of propene.

**(i)** $CH_3–CH=CH_2 + Br_2 \rightarrow$ ..................................... [1]

**(ii)** $CH_3–CH=CH_2 + H_2O \rightarrow$ ..................................... [1]

**(d)** Draw the structural formula of poly(propene)

**(e)** 0.01 moles of an alkene needed 2.4 g of oxygen for complete combustion. 2.2 g of carbon dioxide were formed. Determine the following mole ratio.

moles of alkene **:** moles of $O_2$ **:** moles of $CO_2$

From this ratio determine the formula of the alkene.

.................................................................................................................................................... [3]

Write an equation for the complete combustion of this alkene.

.................................................................................................................................................... [1]
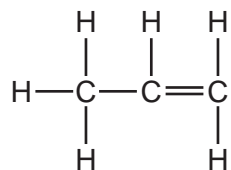
[Total: 13]

**5** The alkenes are a series of unsaturated hydrocarbons. They have the general molecular formula $C_nH_{2n}$.

**(a)** Deduce the molecular formula of an alkene which has a relative molecular mass of 126. Show your working.

.............................................................................................................................................

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

**(b)** The structural formula of propene is drawn below.

$$H-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}-\overset{\displaystyle H}{\underset{\displaystyle H}{C}}=\overset{\displaystyle H}{C}$$

**(i)** Draw a diagram showing the arrangement of the valency electrons in one molecule of this covalent compound.
Use x to represent an electron from an atom of carbon.
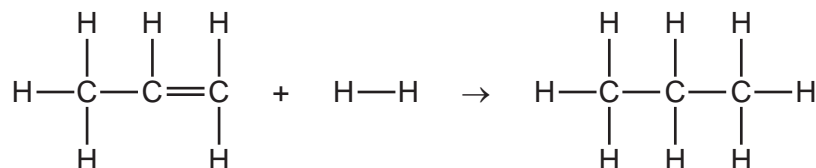Use o to represent an electron from an atom of hydrogen.

[3]

**(ii)** Draw the structure of the polymer formed from propene

[2]

**(iii)** Bond energy is the amount of energy, in kJ, which must be supplied to break one mole of the bond.

| bond | bond energy in kJ/mol |
|------|------------------------|
| H—H | +436 |
| C=C | +610 |
| C—C | +346 |
| C—H | +415 |

Use the data in the table to show that the following reaction is exothermic.

$$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}=\overset{\overset{H}{|}}{C} \quad + \quad H-H \quad \rightarrow \quad H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H$$

.................................................................................................................................

.................................................................................................................................

............................................................................................................... [3]

**(c)** This question is concerned with some of the addition reactions of but-1-ene.

**(i)** Name the product formed when but-1-ene reacts with water.

............................................................................................................... [1]

**(ii)** Complete the equation.

$CH_3-CH_2-CH=CH_2 + Br_2 \rightarrow$ ................................................................... [2]

**(iii)** Deduce the formula of the compound which reacts with but-1-ene to form 1-iodobutane.

............................................................................................................... [1]

[Total: 14]