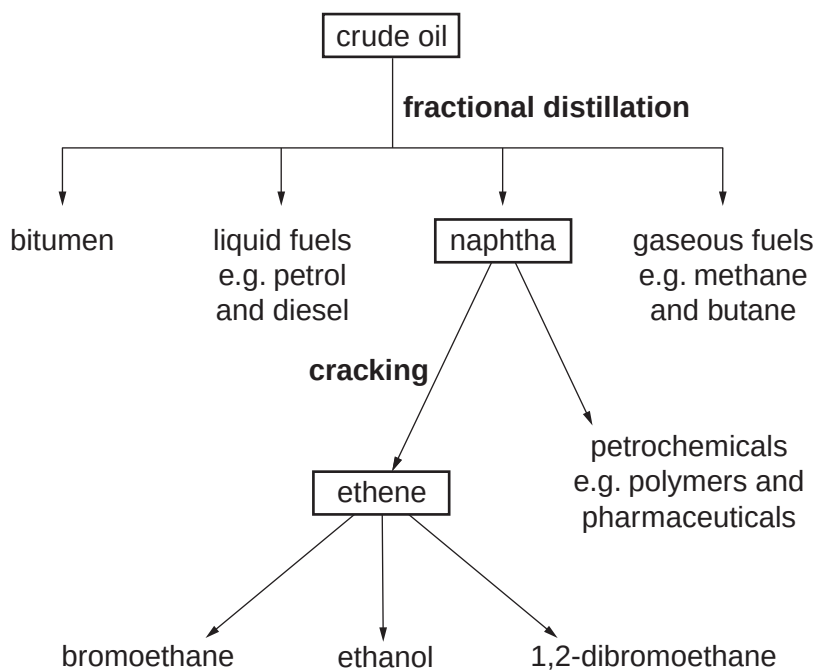


- The total number of marks for this paper is **100**.

Answer **all** the questions.

- 1 Crude oil is a source of many important petrochemicals.

The flow chart shows some of the petrochemicals that can be made and the processes used to make them.



- (a) Explain why crude oil can be separated into different fractions.

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

- (b) Many scientists believe that we should use more fuels such as biodiesel or bio-ethanol rather than petrol and diesel.

Suggest **one** reason why these scientists take this view.

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

- (i) When $C_{12}H_{26}$ is cracked, a variety of alkanes and alkenes are formed with different chain lengths.

..... [1]

- (ii) One molecule of $C_{12}H_{26}$ is cracked to produce one molecule of propane and several molecules of an alkene, **A**.

- Write the formula of the particle responsible for the peak at $m/z = 27$.
- Identify, with a reason, alkene **A**.
- Write an equation to show this cracking of $C_{12}H_{26}$ to form alkene **A**.

..... [4]

- Describe how ethene can be converted into 1,2-dibromoethane, bromoethane and ethanol.
- Name and describe the mechanism for the conversion of ethene into 1,2-dibromoethane using the 'curly arrow' model. Include any relevant dipoles.

[9]

5

- (e) Draw and explain the shape of an ethene molecule.
State the H–C–H bond angle in ethene.

.....

.....

.....

..... [3]

- (f) Addition polymers are made by the polymerisation of alkenes.

E-Pent-2-ene can be made into an addition polymer.

- (i) Draw the structure of *E*-pent-2-ene.

[1]

- (ii) Draw the structure of poly(pent-2-ene).
Include **two** repeat units.

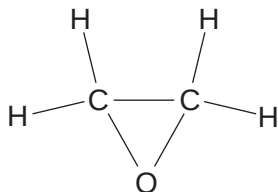
[1]

[Total: 21]

Turn over

6

- 2 Epoxyethane, C_2H_4O , is a synthetic intermediate that is used to make ethane-1,2-diol and some polymers. The structure of epoxyethane is shown below.



- (a) The controlled catalysed reaction of ethene with oxygen forms epoxyethane as the only product.

(i) Write the equation for this reaction.

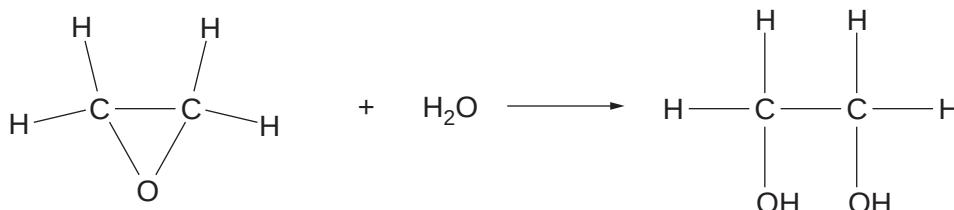
[1]

- (ii) When burnt in excess oxygen, ethene completely combusts.

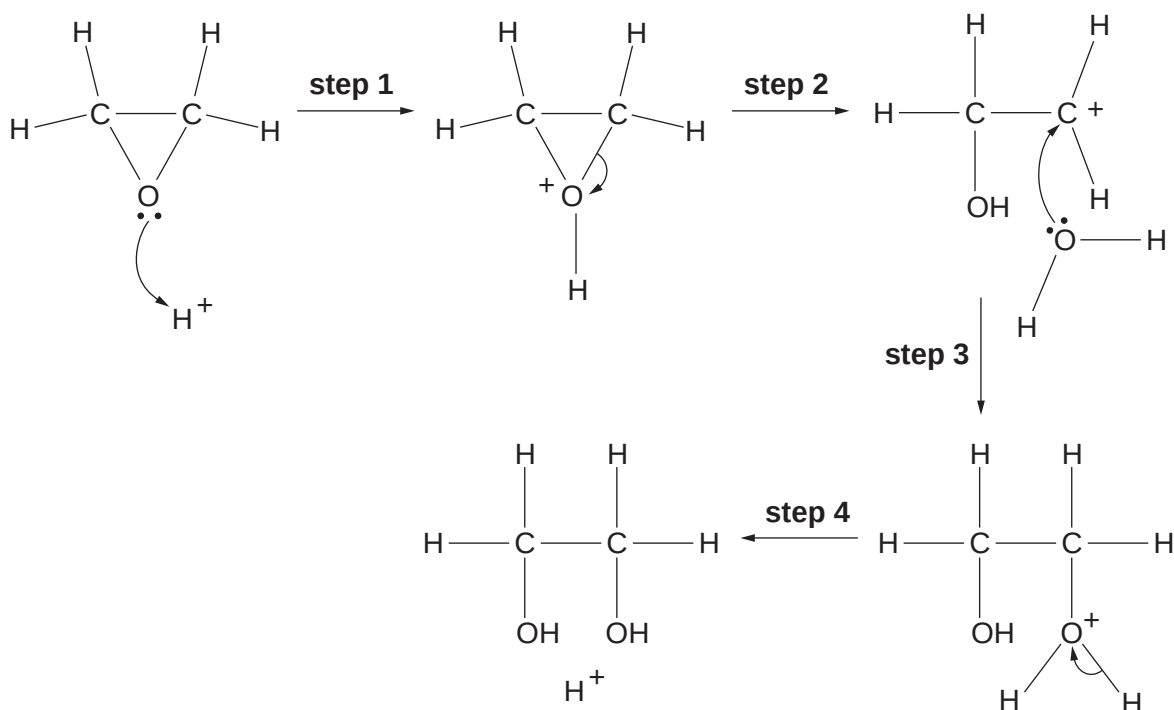
Write the equation for the complete combustion of ethene.

[1]

- (b) Epoxyethane reacts with water in the presence of an acid catalyst to form ethane-1,2-diol.

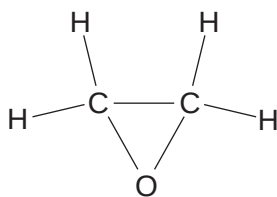


The mechanism for this reaction is shown below.



7

- (i) Draw dipoles on the carbon and oxygen atoms on the displayed formula of epoxyethane.



[1]

- (ii) The mechanism uses the 'curly arrow' model.

What does a 'curly arrow' represent?

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

- (iii) What type of bond fission occurs in **step 2**?

Explain your answer.

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

- (iv) How can you tell that water is behaving as a nucleophile in **step 3**?

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

- (v) How does the mechanism show that H^+ ions act as a catalyst in this reaction?

Refer to the steps in the mechanism in your answer.

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

- (vi) Epoxyethane reacts with methanol, CH_3OH , to form a compound with the molecular formula $C_3H_8O_2$.

Suggest the structure of this compound.

[1]

8

- (c) Ethane-1,2-diol is much less volatile than ethanol.

Suggest why.

.....

.....

.....

.....

..... [2]

- (d) Ethane-1,2-diol reacts with an excess of ethanoic acid, CH_3COOH , in the presence of an acid catalyst. A compound is formed with the molecular formula $\text{C}_6\text{H}_{10}\text{O}_4$.

Draw the structure of this compound.

[2]

- (e) Ethane-1,2-diol reacts with warm acidified potassium dichromate(VI). A number of different organic products are formed.

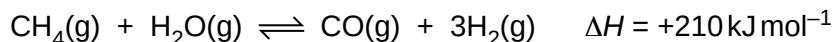
Draw the displayed formulae of **two** of these organic products.

[2]

[Total: 15]

- 3 Hydrogen has many industrial uses including making margarine and ammonia.

Hydrogen can be made by the reaction between methane and steam.



- (a) The pressure of the equilibrium mixture is **increased**.

Explain what happens to the position of the equilibrium.

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

- (b) The temperature of the equilibrium mixture is **increased**.

Explain what happens to the position of the equilibrium.

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

- (c) The reaction is actually carried out in the presence of a nickel catalyst at a pressure of 30 atmospheres.

- (i) Suggest why the manufacturer uses a pressure of 30 atmospheres.

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

10

- (ii)** The nickel catalyst increases the rate.

Use a labelled diagram of the Boltzmann distribution of molecular energies to explain why.

.....

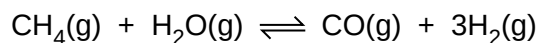
.....

.....

.....

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

- (d)** A chemical factory uses 200 tonnes of methane a day. The factory produces 68.4 tonnes of hydrogen per day by reacting methane with steam.



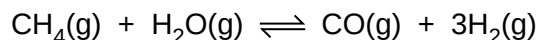
Calculate the percentage yield of hydrogen.

Give your answer to **three** significant figures. (1 tonne = 1×10^6 g)

percentage yield of hydrogen = % **[3]**

11

- (e) The carbon monoxide produced in the equation below can be reacted with hydrogen to make methanol.



- (i) Construct the equation for the reaction of carbon monoxide with hydrogen to make methanol.

..... [1]

- (ii) Suggest **two** reasons why it is important to use the carbon monoxide to make methanol.

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

- (f) Describe how hydrogen can be used in the manufacture of margarine.

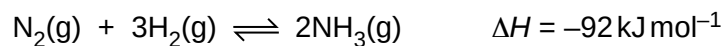
.....
.....
.....
..... [2]

[Total: 16]

12

- 4 The uses of catalysts have great economic and environmental importance. For example, catalysts are used in ammonia production and in catalytic converters.

(a) Nitrogen and hydrogen react together in the production of ammonia, NH_3 .

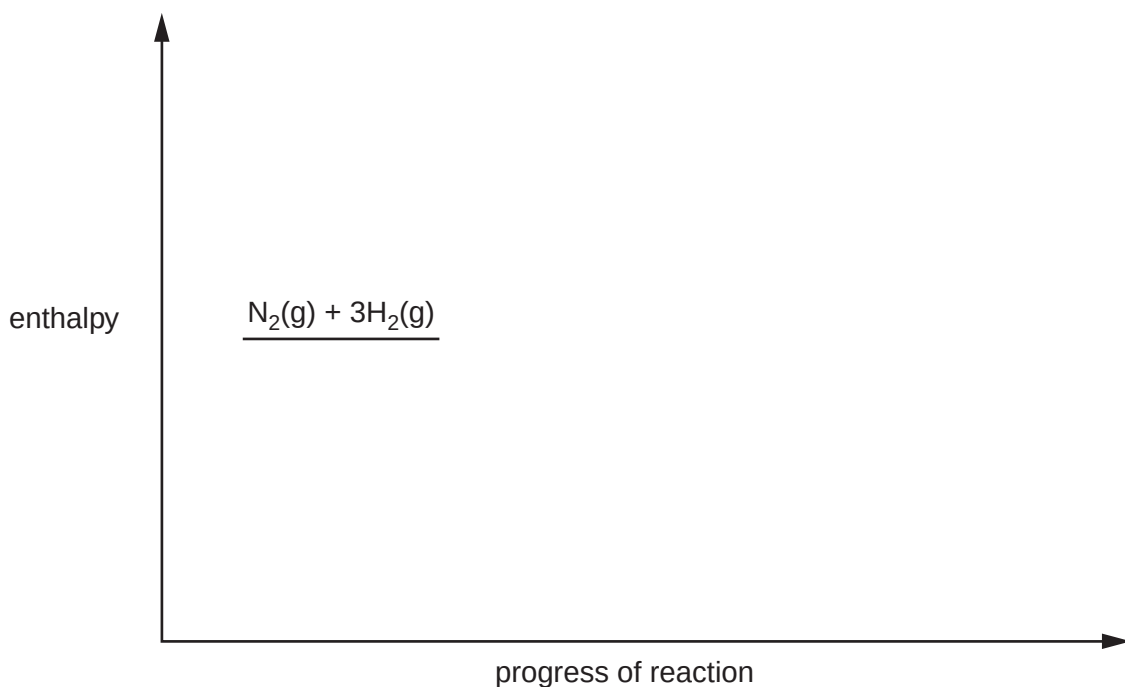


The activation energy for the forward reaction, E_a , is $+250 \text{ kJ mol}^{-1}$.

- (i) Complete the enthalpy profile diagram for this reaction between nitrogen and hydrogen.

Include the

- products
- enthalpy change of reaction, ΔH
- activation energy for the forward reaction, E_a .



[3]

- (ii) What is the value of the enthalpy change of formation of ammonia?

answer = kJ mol^{-1} [1]

- (iii) The reaction between nitrogen and hydrogen can be catalysed.

Suggest a possible value for the activation energy of the **catalysed** forward reaction.

answer = kJ mol^{-1} [1]

- (iv) What is the value of the activation energy for the uncatalysed **reverse** reaction (the decomposition of ammonia into nitrogen and hydrogen)?

answer = kJ mol^{-1} [1]

13

(b) In a catalytic converter, nitrogen monoxide reacts with carbon monoxide.

(i) Write the equation for this reaction.

..... [1]

(ii) Outline the stages that allow nitrogen monoxide and carbon monoxide to react in a catalytic converter.

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

(c) Scientists monitor pollutant gases in the atmosphere.

(i) State **two** modern analytical techniques that scientists can use to monitor environmental pollution.

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

(ii) Explain why it is important to establish **international** cooperation to reduce pollution levels.

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

14

- (d) In the stratosphere, nitrogen monoxide, NO, is linked with ozone depletion.

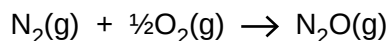
Complete the equations below that describe how NO contributes to ozone depletion.



[3]

- (e) Hess' law can be used to calculate enthalpy changes of reaction.

The equation for the reaction that gives the enthalpy change of formation, ΔH_f , of $\text{N}_2\text{O}(\text{g})$ is as follows.



- (i) It is not possible to measure the enthalpy change of formation of $\text{N}_2\text{O}(\text{g})$ directly.

Suggest why it is **not** possible.

.....

..... [1]

- (ii) The data below can be used to calculate the enthalpy change of formation, ΔH_f , of $\text{N}_2\text{O}(\text{g})$.

reaction	enthalpy change of reaction / kJ mol^{-1}
$\text{C}(\text{s}) + \text{N}_2\text{O}(\text{g}) \rightarrow \text{CO}(\text{g}) + \text{N}_2(\text{g})$	-193
$\text{C}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g})$	-111

Calculate ΔH_f for $\text{N}_2\text{O}(\text{g})$.

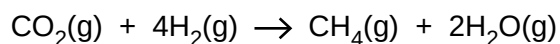
$$\Delta H_f = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

[Total: 19]

15

5 Methane and ethane are important fuels.

(a) Methane could be manufactured by the reaction between carbon dioxide and hydrogen.



Using the table of bond enthalpies, calculate the enthalpy change of reaction for this manufacture of methane.

bond	average bond enthalpy /kJ mol⁻¹
C–H	+415
H–H	+436
C=O	+805
O–H	+464

enthalpy change of reaction = kJ mol⁻¹ **[3]**

16

(b) Methane is a greenhouse gas. Scientists are concerned that the concentration of methane in the atmosphere is slowly increasing.

(i) Explain how atmospheric methane molecules can contribute to global warming.

.....

.....

.....

..... [2]

(ii) One way that scientists hope to minimise global warming is by developing Carbon Capture and Storage, CCS, techniques.

Describe **two** of these CCS techniques.

.....

.....

.....

.....

..... [2]

(i) Two of these products are bromoethane and hydrogen bromide.

Include in your answer

- the type of bond fission that occurs
- equations for each step of the reaction
- the name of each step of the reaction.



Your answer needs to be clear and well organised using the correct terminology.

..... [7]

(ii) Give **two** reasons why there are many organic products of the reaction between bromine and ethane.

..... [2]

[Total: 16]

6 A student carries out an investigation on some halogenoalkanes.

- (a) She decided to hydrolyse 1-bromopentane and 1-chloropentane using aqueous sodium hydroxide.

State and explain the difference in the rates of hydrolysis of 1-bromopentane and 1-chloropentane.

.....

.....

.....

..... [2]

- (b) A student wants to determine the structure of an unknown iodoalkane **B**.

She knows that the molecular formula of **B** is C_4H_9I .

The student heats **B** with aqueous sodium hydroxide. A reaction mixture forms containing the organic compound **C** and $I^-(aq)$.

- (i) Draw all of the possible structural isomers for **B**.

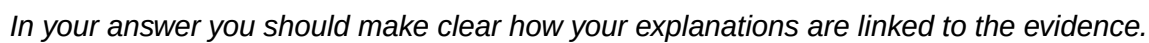
[4]

- (ii) What is the molecular formula for compound **C**?

..... [1]

- (iii) The student purifies compound **C** and splits it into two portions.

- She heats one portion of **C** with concentrated sulfuric acid. The product of this reaction is methylpropene.
- To the other portion of **C**, she adds acidified potassium dichromate(VI) and heats the mixture under reflux. The product of this reaction is compound **D**.
- The infrared spectrum for compound **D** is shown at the top of page 19.

[illegible]

[6]

END OF QUESTION PAPER