1 Crude oil is a source of hydrocarbons which can be used as fuels or for processing into petrochemicals.

Octane, C_8H_{18}, is one of the alkanes present in petrol.

Carbon dioxide is formed during the complete combustion of octane.

$$C_8H_{18} + 12½O_2 \rightarrow 8CO_2 + 9H_2O$$

(a) What is the general formula for an alkane?

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

(b) Carbon monoxide, CO, is formed during the incomplete combustion of octane.

(i) Write an equation for the incomplete combustion of octane, forming carbon monoxide and water.

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

(ii) Why does incomplete combustion sometimes take place?

.....

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

(c) In cars fitted with a catalytic converter, two toxic gases, CO and NO, react together to form two non-toxic gases.

(i) Write an equation for the reaction between CO and NO in a catalytic converter.

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

(ii) Outline the stages that take place in a catalytic converter to allow CO to react with NO.

.....

.....

.....

.....

.....

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

(d) Oil companies process hydrocarbons, such as octane, into branched and cyclic hydrocarbons that promote efficient combustion in petrol.

Draw the skeletal formulae of a branched hydrocarbon and a cyclic hydrocarbon, each containing eight carbon atoms.

[2]

(e) Some scientists believe that increased CO_2 levels arising from the combustion of hydrocarbons lead to global warming because CO_2 is a greenhouse gas. Carbon capture and storage, CCS, is being developed as a method for removing CO_2 produced by combustion.

(i) Different gases have different contributions to global warming.

State **two** factors that affect the contribution of a greenhouse gas to global warming.

.....

.....

.....

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

(ii) Outline **two** methods that could be developed to achieve carbon capture and storage, CCS.

.....

.....

.....

.....

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

[Total: 13]

2 Catalysts speed up the rate of a reaction without being consumed by the overall reaction.

(a) Chlorine radicals in the stratosphere act as a catalyst for ozone depletion.

(i) Research chemists have proposed possible reaction mechanisms for ozone depletion. The equations below represent part of such a mechanism.

Complete the equations.

$Cl + O_3 \longrightarrow$ ..... + ...

ClO + ... $\longrightarrow$ ..... + O_2 **[2]**

(ii) Write an equation for the overall reaction in **(i)**.

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

(b) One of the catalysed reactions that takes place in a catalytic converter is shown below.

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

The catalyst used is platinum/rhodium attached to a ceramic surface.

Outline the stages that take place in a catalytic converter to allow CO to react with NO.

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

(c) Explain, using an enthalpy profile diagram and a Boltzmann distribution, how the presence of a catalyst increases the rate of reaction.

In your answer you should organise your answer and use the correct technical terms.

[7]

(d) Explain why many industrial manufacturing processes use catalysts.

Include in your answer ideas about sustainability, economics and pollution control.

.....

.....

.....

.....

.....

.....

.....

.....

..... **[4]**

[Total: 18]

3 Biofuels such as bioethanol and biodiesel are increasingly being used as an alternative to fossil fuels to provide energy.

(a) Describe, with the aid of an equation, how bioethanol is manufactured by fermentation.

.....

.....

.....

.....

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

(b) Biodiesel is obtained from plant oils. The manufacture involves several stages, all of which have a high energy requirement.

Biodiesel is often described as being 'carbon-neutral' because:

- plants convert atmospheric carbon dioxide into carbon compounds
- on burning biodiesel this carbon dioxide is returned to the atmosphere.

(i) Construct an equation to show the complete combustion of biodiesel.

Assume that the molecular formula of the biodiesel is $C_{15}H_{30}O_2$.

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

(ii) Suggest why biodiesel is **not** completely carbon-neutral.

.....

.....

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

(c) Many scientists suggest that society should use more biofuels rather than fossil fuels to provide energy. Other scientists are worried that biofuels will need large areas of land to grow suitable crops.

Suggest **disadvantages** or **advantages**, other than being carbon-neutral, of using more biofuels.

.....

.....

.....

.....

.....

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

(d) Unsaturated compounds in plant oils can also be used to make margarine.

Describe how.

.....

.....

.....

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

(e) Part of the structure of an unsaturated compound in plant oils is shown below:

$$-CH_2CH_2CH=CHCH_2CH_2-$$

(i) Draw the displayed formula of the *Z* isomer of this part of the structure.

[1]

(ii) Explain why this part of the structure can have an *E* and a *Z* isomer.

.....

.....

.....

.....

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

[Total: 14]

4 Alkenes are a very useful series of hydrocarbons used widely in synthesis. Alkenes are more reactive than alkanes.

(a) What is the name of the process used to convert long chain alkanes into more useful shorter chain alkenes?

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

(b) Ethene and steam can be converted into ethanol.
The equilibrium is shown below.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46 \text{ kJ mol}^{-1}$$

le Chatelier's principle can be used to predict the effect of changing conditions on the position of equilibrium.

(i) Name the catalyst used in this reaction.

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

(ii) State le Chatelier's principle.

.....

.....

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

(iii) Using le Chatelier's principle, predict and explain the conditions that would give the maximum equilibrium yield of ethanol from ethene and steam.

.....

.....

.....

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

(iv) The actual conditions used are 60 atmospheres pressure at 300 °C in the presence of a catalyst. Compare these conditions with your answer to **(iii)** and comment on why these conditions are used.

.....

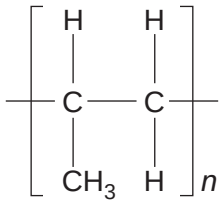
.....

.....

.....

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

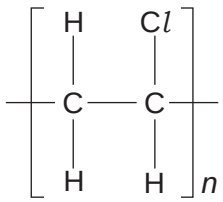
(c) Alkenes are used to make addition polymers.
The repeat unit for an addition polymer is shown below.



What is the name of the monomer used to make this polymer?

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

(d) Poly(chloroethene) has the repeat unit below.



This repeat unit can be written as —CH_2CHCl— .

One way to dispose of poly(chloroethene) is to react it with oxygen at high temperature. This is called incineration.

(i) Complete the following equation that shows the reaction taking place during incineration.

—CH_2CHCl— + ... O_2 → ..... CO_2 + ... H_2O + ... HCl **[1]**

(ii) Research chemists have reduced the environmental impact of incineration by removing the HCl formed from the waste gases.

Suggest a type of reactant that could be used to remove the HCl.

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

(e) The disposal of polymers causes environmental damage.
Research chemists are developing polymers that will reduce this environmental damage and increase sustainability.

Describe **two** ways in which chemists can reduce this environmental damage.

.....

.....

[Total: 14]

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