1 Hydrogen gas is used in the chemical industry.

1 (a) Tungsten is extracted by passing hydrogen over heated tungsten oxide (WO_3).

1 (a) (i) State the role of the hydrogen in this reaction.

.....

(1 mark)

1 (a) (ii) Write an equation for this reaction.

.....

(1 mark)

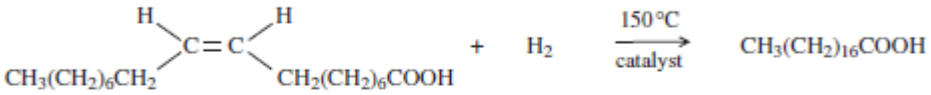
1 (a) (iii) State **one** risk of using hydrogen gas in metal extractions.

.....

.....

(1 mark)

1 (b) Hydrogen is used to convert oleic acid into stearic acid as shown by the following equation.



oleic acid stearic acid

1 (b) (i) Use your knowledge of the chemistry of alkenes to deduce the type of reaction that has occurred in this conversion.

.....

(1 mark)

1 (b) (ii) State the type of stereoisomerism shown by oleic acid.

.....

(1 mark)

2 For each of the following reactions, select from the list below, the **formula** of a sodium halide that would react as described.

NaF NaCl NaBr NaI

Each **formula** may be selected once, more than once or not at all.

(a) This sodium halide is a white solid that reacts with concentrated sulfuric acid to give a brown gas.

Formula of sodium halide .....

(1 mark)

(b) When a solution of this sodium halide is mixed with silver nitrate solution, no precipitate is formed.

Formula of sodium halide .....

(1 mark)

(c) When this solid sodium halide reacts with concentrated sulfuric acid, the reaction mixture remains white and steamy fumes are given off.

Formula of sodium halide .....

(1 mark)

(d) A colourless aqueous solution of this sodium halide reacts with orange bromine water to give a dark brown solution.

Formula of sodium halide .....

(1 mark)

3 Group 2 metals and their compounds are used commercially in a variety of processes and applications.

(a) State a use of magnesium hydroxide in medicine.

.....

(1 mark)

(b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

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.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

(c) Strontium metal is used in the manufacture of alloys.

(c) (i) Explain why strontium has a higher melting point than barium.

.....

.....

.....

.....

(2 marks)

(c) (ii) Write an equation for the reaction of strontium with water.

.....

(1 mark)

(d) Magnesium can be used in the extraction of titanium.

(d) (i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

.....

(1 mark)

(d) (ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

.....

.....

.....

(1 mark)

4 Nitric acid is manufactured from ammonia in a process that involves several stages.

(a) In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905\,kJ\,mol^{-1}$$

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

(a) (i) In terms of redox, state what happens to the ammonia in the forward reaction.

.....

(1 mark)

(a) (ii) Suggest a reason why the catalyst must be hot.

.....

(1 mark)

(a) (iii) Suggest a reason why the catalyst remains hot during the reaction.

.....

(1 mark)

(a) (iv) State how a catalyst increases the rate of a reaction.

.....

.....

.....

.....

(2 marks)

(b) In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113\,kJ\,mol^{-1}$$

Explain why the equilibrium mixture is cooled during this stage of the process.

.....

.....

.....

.....

(2 marks)

(c) In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

$$2NO_2(g) + H_2O(l) \longrightarrow H^+(aq) + NO_3^-(aq) + HNO_2(aq)$$

Give the oxidation state of nitrogen in each of the following.

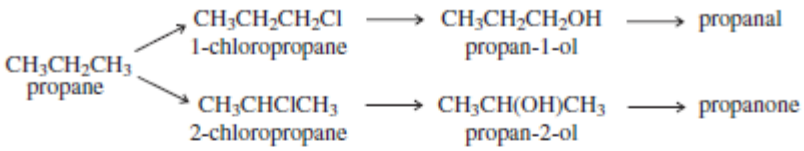
NO_2 .....

NO_3^- .....

HNO_2 .....

(3 marks)

5 Consider the following scheme of reactions.



(a) State the type of structural isomerism shown by propanal and propanone.

.....

(1 mark)

(b) A chemical test can be used to distinguish between separate samples of propanal and propanone.

Identify a suitable reagent for the test.
State what you would observe with propanal and with propanone.

Test reagent .....

Observation with propanal .....

Observation with propanone .....

(3 marks)

(c) State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately 1720 cm^{-1}.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

(1 mark)

(d) The reaction of chlorine with propane is similar to the reaction of chlorine with methane.

(d) (i) Name the type of mechanism in the reaction of chlorine with methane.

.....

(1 mark)

(d) (ii) Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form 1-chloropropane ($CH_3CH_2CH_2Cl$).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step to form a molecule with the empirical formula C_3H_7

.....

(4 marks)

(e) High resolution mass spectrometry of a sample of propane indicated that it was contaminated with traces of carbon dioxide.

Use the data in the table to show how precise M_r values can be used to prove that the sample contains both of these gases.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

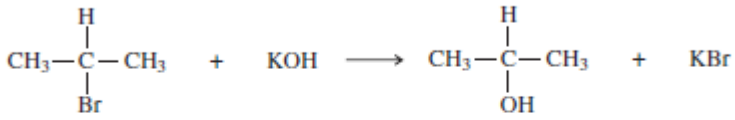
.....

.....

.....

(2 marks)

6 (a) Consider the following reaction.



(a) (i) Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(3 marks)

(a) (ii) Name the haloalkane in this reaction.

.....

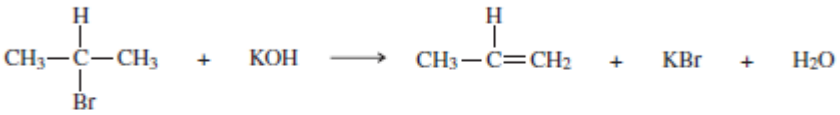
(1 mark)

(a) (iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

.....

(1 mark)

(b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(4 marks)

(c) Give **one** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

.....

(1 mark)

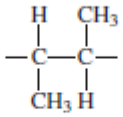
(d) Alkenes can be polymerised to produce poly(alkenes).

(d) (i) State the type of polymerisation that alkenes undergo.

.....

(1 mark)

(d) (ii) Name the alkene that gives a polymer with the repeating unit shown below.



Name of alkene .....

(1 mark)

7 Ethanol is an important industrial compound.

(a) Ethanol can be produced by the hydration of ethene.
The equation for the equilibrium that is established is

$$H_2C{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -42\ kJ\ mol^{-1}$$

The operating conditions for the process are a temperature of 300 °C and a pressure of 7 MPa.
Under these conditions, the conversion of ethene into ethanol is 5%.

(a) (i) Identify the catalyst used in this process.
Deduce how an overall yield of 95% is achieved in this process without changing the operating conditions.

.....

.....

.....

.....

(2 marks)

(a) (ii) Use your knowledge of equilibrium reactions to explain why a manufacturer might consider using an excess of steam in this process, under the same operating conditions.

.....

.....

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.....

.....

.....

.....

(3 marks)

(a) (iii) At pressures higher than 7 MPa, some of the ethene reacts to form a solid with a relative molecular mass greater than 5000

Deduce the identity of this solid.

Give **one** other reason for **not** operating this process at pressures higher than 7 MPa. Do **not** include safety reasons.

.....

.....

.....

(2 marks)

(b) Write an equation for the reaction that has an enthalpy change that is the standard enthalpy of formation of ethanol.

.....

(2 marks)

(c) When ethanol is used as a fuel, it undergoes combustion.

(c) (i) Define the term *standard enthalpy of combustion.*

.....

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.....

.....

.....

.....

(3 marks)

(c) (ii) Consider these bond enthalpy data.

	C—H	C—C	C—O	O=O	C=O	O—H
Bond enthalpy / kJ mol^{-1}	412	348	360	496	805	463

Use these data and the equation to calculate a value for the enthalpy of combustion of gaseous ethanol.

$$CH_3CH_2OH(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$$

.....

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.....

.....

.....

.....

(3 marks)

(d) Gaseous ethanol can be used to convert hot copper(II) oxide into copper.

(d) (i) Deduce the role of ethanol in this reaction.

.....

(1 mark)

(d) (ii) Draw the structure of the organic compound with M_r = 60 that is produced in this reaction.