Q1.(a) Propanone can be formed when glucose comes into contact with bacteria in the absence of air.

(i) Balance the following equation for this reaction of glucose to form propanone, carbon dioxide and water.

.....$C_6H_{12}O_6$ ⟶ .....CH_3COCH_3 + ...CO_2 + ...H_2O

(1)

(ii) Deduce the role of the bacteria in this reaction.

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(1)

(b) Propanone is also formed by the oxidation of propan−2−ol.

(i) Write an equation for this reaction using [O] to represent the oxidising agent.

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(1)

(ii) State the class of alcohols to which propan−2−ol belongs.

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(1)

(c) A student determined a value for the enthalpy change when a sample of propanone was burned. The heat produced was used to warm some water in a copper calorimeter.
The student found that the temperature of 150 g of water increased by 8.0 °C when 4.50×10^{-3} mol of pure propanone was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of propanone is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

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(3)

(d) Define the term **standard enthalpy of combustion**.

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(3)

(e) Use the mean bond enthalpy data in the table and the equation given below the table to calculate a value for the standard enthalpy change when gaseous propanone is burned.

	C−H	**C−C**	**C−O**	**O−H**	**C=O**	**O=O**
Mean bond enthalpy / kJ mol^{-1}	412	348	360	463	805	496

$$CH_3COCH_3(g) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(g)$$

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(3)

(f) Suggest **two** reasons why the value obtained by the student in part (c) is different from the value calculated in part (e).

Reason 1 .....

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Reason 2 .....

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(2)

(Total 15 marks)

Q2. The table contains some bond enthalpy data.

Bond	H−H	O=O	H−O
Bond enthalpy / kJ mol^{-1}	436	496	464

(a) The value for the H−O bond enthalpy in the table is a mean bond enthalpy.

State the meaning of the term **mean bond enthalpy** for the H−O bond.

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(2)

(b) Use the bond enthalpies in the table to calculate a value for the enthalpy of formation of water in the gas phase.

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(3)

(c) The standard enthalpy of combustion of hydrogen, forming water in the gas phase, is almost the same as the correct answer to part (b).

(i) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to be the same as the answer to part (b).

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(1)

(ii) Suggest **one** reason why you would expect the standard enthalpy of combustion of hydrogen to differ slightly from the answer to part (b).

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(1)
(Total 7 marks)

Q3.(a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

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(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

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(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	$HF(g)$
$\Delta_f H^\ominus$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Standard enthalpy of formation of $C_2H_6(g)$ = ... kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C−H	C−F	H−F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F−F bond.

Is the student correct? Justify your answer with a calculation using these data.

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(4)
(Total 10 marks)

Q4. Many chemical processes release waste products into the atmosphere. Scientists are developing new solid catalysts to convert more efficiently these emissions into useful products, such as fuels. One example is a catalyst to convert these emissions into methanol. The catalyst is thought to work by breaking a H–H bond.

An equation for this formation of methanol is given below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \Delta H = -49 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are shown in the following table.

Bond	C=O	C–H	C–O	O–H
Mean bond enthalpy / kJ mol^{-1}	743	412	360	463

(a) Use the enthalpy change for the reaction and data from the table to calculate a value for the H–H bond enthalpy.

H–H bond enthalpy = ... kJ mol^{-1}

(3)

(b) A data book value for the H–H bond enthalpy is 436 kJ mol^{-1}.

Suggest **one** reason why this value is different from your answer to part (a).

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(1)

(c) Suggest **one** environmental advantage of manufacturing methanol fuel by this reaction.

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(1)

(d) Use Le Chatelier's principle to justify why the reaction is carried out at a high pressure rather than at atmospheric pressure.

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(3)

(e) Suggest why the catalyst used in this process may become less efficient if the carbon dioxide and hydrogen contain impurities.

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(1)

(f) In a laboratory experiment to investigate the reaction shown in the equation below, 1.0 mol of carbon dioxide and 3.0 mol of hydrogen were sealed into a container. After the mixture had reached equilibrium, at a pressure of 500 kPa, the yield of methanol was 0.86 mol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Calculate a value for K_p
Give your answer to the appropriate number of significant figures.
Give units with your answer.

K_p = ... Units = ...

(7)
(Total 16 marks)