4 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.

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

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

Table 2

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

0 4 . 1 Use the enthalpy change for the reaction and data from **Table 2** to calculate a value for the H–H bond enthalpy.

[3 marks]

H–H bond enthalpy = _____ kJ mol^{-1}

0 4 . 2 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 Question **4.1**.

[1 mark]

_____

_____

_____

0 4 . 3 Suggest **one** environmental advantage of manufacturing methanol fuel by this reaction.

[1 mark]

0 4 . 4 Use Le Chatelier's principle to justify why the reaction is carried out at a high pressure rather than at atmospheric pressure.

[3 marks]

0 4 . 5 Suggest why the catalyst used in this process may become less efficient if the carbon dioxide and hydrogen contain impurities.

[1 mark]

Question 4 continues on the next page

0 4 . 6 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.

[7 marks]

K_p = _____ Units = _____