1. Chloroethene, $CH_2{=}CHCl$, is prepared in the presence of a solid catalyst using the equilibrium reaction below.

$$CH_2ClCH_2Cl(g) \rightleftharpoons CH_2{=}CHCl(g) + HCl(g) \qquad \Delta H = +51\ \text{kJ mol}^{-1}$$

Which change would result in an increased equilibrium yield of chloroethene?

A increasing the pressure

B increasing the surface area of the catalyst

C increasing the temperature

D use of a homogeneous catalyst

Your answer ☐

[1]

2. Which statement(s) is/are correct when a catalyst is added to a system in dynamic equilibrium?

1 The rates of the forward and reverse reactions increase by the same amount.

2 The concentrations of the reactants and products do not change.

3 The value of K_c increases.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer [ ] **[1]**

3. Methanol, CH_3OH, can be made industrially by the reaction of carbon monoxide with hydrogen, as shown in **equilibrium 1**.

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ $\Delta H = -91\,kJ\,mol^{-1}$ **Equilibrium 1**

(a) Predict the conditions of pressure and temperature that would give the maximum equilibrium yield of CH_3OH in **equilibrium 1**.

Explain your answer.

....

....

....

....

.... **[3]**

(b) A catalyst is used in the production of methanol in **equilibrium 1**.

State **two** ways that the use of catalysts helps chemical companies to make their processes more sustainable and less harmful to the environment.

1 ....

....

2 ....

....
[2]

(c) Standard entropy values are given below.

Substance	CO(g)	H_2(g)	CH_3OH(g)
$S^{\ominus}$ / J K^{-1} mol^{-1}	198	131	238

A chemist proposed producing methanol at 525 K using **equilibrium 1**.

Explain, with a calculation, whether the production of methanol is feasible at 525 K.

....

....

....

....

....

....

....

....

....

.... **[5]**

(d) At 298 K, the free energy change, ΔG, for the production of methanol in **equilibrium 1** is -2.48×10^4 J mol^{-1}.

ΔG is linked to K_p by the relationship: $\Delta G = -RT \ln K_p$.

R = gas constant
T = temperature in K.

Calculate K_p for **equilibrium 1** at 298 K.

Give your answer to **3** significant figures.

K_p = ... units .... **[3]**

4. The equilibrium constant K_p and temperature T (in K) are linked by the mathematical relationship shown in **equation 5.1** (R = Gas constant in $J\,mol^{-1}\,K^{-1}$ and ΔH is enthalpy change in $J\,mol^{-1}$).

$$\ln K_p = -\frac{\Delta H}{R} \times \frac{1}{T} + \frac{\Delta S}{R}$$ **Equation 5.1**

(a) The table shows the values of K_p at different temperatures for an equilibrium.

Complete the table by adding the missing values of $\frac{1}{T}$ and $\ln K_p$.

Temperature, T/K	400	500	600	700	800
K_p	3.00×10^{58}	5.86×10^{45}	1.83×10^{37}	1.46×10^{31}	1.14×10^{26}
$\frac{1}{T}$ / K^{-1}	2.50×10^{-3}	....	....	....	....
$\ln K_p$	135	....	....	....	....

[2]

(b) State and explain how increasing the temperature affects the position of this equilibrium and whether the forward reaction is exothermic or endothermic.

....

....

.... **[1]**

(c) Plot a graph of $\ln K_p$ against $\frac{1}{T}$ using the axes provided on the opposite page.

Use your graph and **equation 5.1** to determine ΔH, in $kJ\,mol^{-1}$, for this equilibrium.

Give your answer to **3** significant figures.

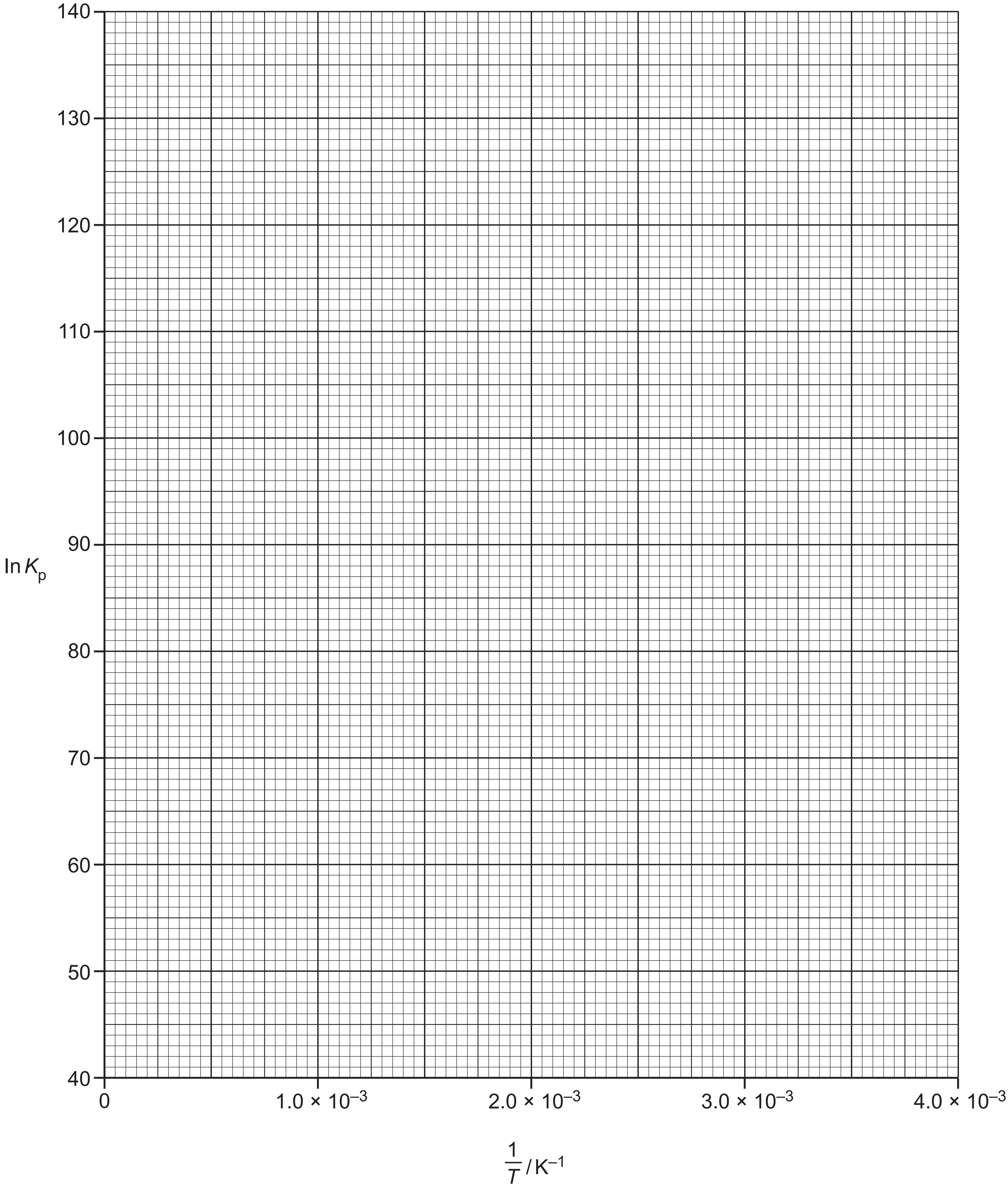
ΔH = ... $kJ\,mol^{-1}$ **[4]**

(d) Explain how ΔS could be calculated from a graph of $\ln K_p$ against $\frac{1}{T}$.

....

....

.... **[2]**


140
130
120
110
100
90
80
70
60
50
40
ln K_p
0
1.0 × 10^{-3}
2.0 × 10^{-3}
3.0 × 10^{-3}
4.0 × 10^{-3}
$\frac{1}{T}$ / K^{-1}