A-Level Chemistry

Equilibria and Le Chatelier's Principle

Mark Scheme

Time available: 62 minutes
Marks available: 54 marks

1.

This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.	
Level 3 **5-6 Marks**	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 Marks**	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer shows some attempt at structure. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms.
Level 1 **1-2 Marks**	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order or show some confusion. Answer may contain valid points which are not clearly linked to an argument structure. Errors in the use of technical terms.
Level 0	Insufficient correct chemistry to gain a mark.

Indicative chemistry content

Stage 1: Temperature
1a. The reaction is endothermic (so equilibrium shifts to RHS to reduce the temperature)
1b. So, higher temperature increases the yield **1c.** High temperatures are costly (so compromise temperature used)

Stage 2: Pressure
2a. More moles of gas on the right hand side, (so equilibrium shifts to RHS to increase the yield)
2b. So, lower pressure increases the yield
2c. A low pressure means a low cost

Stage 3: Catalyst
3a. Catalyst has no effect on yield
3b. Adding a catalyst allows a lower temperature to be used
3c. So, this lowers the cost

[6]

2. (a) **M1** $\frac{[CO]^2\,[H_2]^4}{[C_2H_5OH]\,[H_2O]}$

1

M2 $mol^4\ dm^{-12}$

M2** allow for units that are consequential on **M1

1

(b) **M1** clear attempt made to divide moles by volume to find concentrations

*7.66×10^{-3} scores **M1,2,3***

*7.66×10^{-15} scores **M1,3***

***M1** can use 0.750 or 750 (or 75, 7.5, 0.075, 0.0075, etc)*

1

M2 $\frac{[\frac{0.110}{0.750}]^2\,[\frac{0.220}{0.750}]^4}{[\frac{0.075}{0.750}]\,[\frac{0.156}{0.750}]}$

M2 $\frac{(0.147)^2\,(0.293)^4}{(0.100)\,(0.208)}$ or $\frac{(0.0215)\,(0.00740)}{(0.100)\,(0.208)}$

*for **M2** volume used must be 0.750 or 750 (if use V at this stage, then must be one of these values of V used later on)*

1

M3 7.66×10^{-3}

***M3** ignore units*

If moles are used in place of concentration

*penalise **M1**, but **M2** and **M3** could score for ECF*

M2 $\frac{(0.110)^2\,(0.220)^4}{(0.075)\,(0.156)}$ *M3 2.42×10^{-3}*

Allow ECF if incorrect expression for K_c is used

1

(c) **M1** yield would decrease

mark each point independently

1

M2 equilibrium (position) moves left / shifts left / in direction of reverse reaction

to oppose increase in pressure / to reduce pressure

***M2** need both parts; ignore favours reverse reaction for the first part*

1

M3 fewer moles/molecules of gas on left hand side / fewer moles/molecules of gaseous reactants

***M3** 2 moles/molecules (of gas) on left hand side v 6 moles/molecules (of gas) on right hand side*

1

M4 no effect on K_c

1

[9]

3. (a) 3 minutes

M2 dependent on M1 or near miss

1

(At equilibrium, $rate_{fwd} = rate_{back}$ so) concentrations (of O_2 and SO_3) remain constant

Not concentrations are the same/equal

Allow (after this point) gradient is zero / curve flattens out

1

(b) Sketch begins at origin and goes up until 3 mins

1

Levels off at 0.3 mol dm^{-3}

Mark Independently

1

(c) T_2 (Not worth a mark alone)

T_1, CE=0

Equilibrium has moved / shifted to RHS/forward in endothermic direction

Both RHS / forward and endothermic needed

1

Equilibrium has opposed the increase in T / Equilibrium moves to decrease the T

Not just to oppose the change

1

[6]

4.

(a) **M1** no effect (on yield)

CE = 0 if yield changes

1

M2 increases rate / speed of both / forward and reverse reactions <u>equally / by the same amount</u>

*If no reference to effect on yield, could still score **M2***

Ignore reference to no change in position of equilibrium, and reference to lowering activation energies

***M2** allow changes rate of both / forward and reverse reactions <u>equally / by the same amount</u>*

1

(b) $(K_c =) \frac{[CH_3OH]}{[CO][H_2]^2}$

Must be square brackets

Ignore state symbols

Ignore units

1

(c) **M1** divides moles by volume (0.250 or $\frac{250}{1000}$)

M2 $K_c = \frac{\frac{0.0610}{0.250}}{\left[\frac{0.340}{0.250}\right]\left[\frac{0.190}{0.250}\right]^2} \left(= \frac{0.244}{1.36 \times 0.76^2}\right)$

1

M3 0.311

1

*Correct answer scores 3; **M3** to at least 2sf (0.3106159 …); ignore units*

*Allow ECF from **M1** to **M2** if an attempt to calculate concentration has been made by dividing by some factor of 250 cm^3*

*Allow ECF from **M2** to M3 for use of an expression containing each reagent in a correctly substituted K_c expression*

If volume not used, then allow M3 only for 4.97 (4.96985 … to at least 2sf)

1

(d) **M1** $\frac{1}{\text{Answer to (c)}} = 3.22$

M1 *to at least 2sf (0.31 gives 3.2(258))*

M1 *= 1.21 if alternative answer to 8.3 used*

If an error was made in 8.3, but the candidate produced an answer in 8.4 that did fit the inverted calculation from 8.3, then candidate could score ***M1***

1

M2 $mol^2\ dm^{-6}$

(if volumes are not used, then candidate would get 0.20(12.)

1

[8]

5. (a) Initial amount of A = 6.4×10^{-3}

If M1 wrong can score max 3

M1

Equ A = $6.4 \times 10^{-3} - 2x \therefore x = 1.25 \times 10^{-3}$

If incorrect x can score max 3

M2

B = $9.5 \times 10^{-3} - x = 8.25 \times 10^{-3}$

Allow 2 or more sig figs

M3

C = $2.8 \times 10^{-2} + 3x = 0.0318$

M4

D = $x = 1.25 \times 10^{-3}$

M5

(b) $K_c = \frac{[C]^3[D]}{[A]^2[B]}$

Penalise ( ) but mark on in (b) & (c)

1

Units = $mol\ dm^{-3}$

If K_c *wrong no mark for units*

1

(c) M1 for correct rearrangement $[A]^2 = \frac{[C]^3[D]}{K_c[B]}$ or $[A] = \sqrt{\frac{[C]^3[D]}{K_c[B]}}$

If K_c wrong in (b) can score 1 for dividing by correct volume

M1

M2 for division of mol of B, C and D by correct volume

If K_c correct but incorrect rearrangement can score 1 for dividing by correct volume

M2

$$[A]^2 = \frac{[{}^{1.05}/_{0.5}]^3[{}^{0.076}/_{0.5}]}{116 \times [{}^{0.21}/_{0.5}]}$$

M3 for final answer: [A] = 0.17 (must be 2 sfs)

M3

(d) (All) conc fall: (ignore dilution)

OR K_c = mole ratio × 1/V

1

Equm moves to side with more moles

If vol increases, mole ratio must increase

1

To oppose the decrease in conc

To keep K_c constant

If only conc of A falls CE=0

If pressure falls CE=0

1

[13]

6. (a) Decrease

1

Increasing pressure moves equilibrium to the side of least moles i.e. backward reaction

1

To oppose the increase in pressure or to decrease the pressure

1

(b) A catalyst speeds up the rate of the forward and backward reaction

1

By the same amount

1

(c) $\Delta H = -111 - (-75 - 242)$

1

206 (kJ mol^{-1})

1

(d) $\Delta S = 3 \times 131 + 198 - (186 + 189) = 216 \text{ J K}^{-1} \text{ mol}^{-1}$

1

$\Delta G = \Delta H - T\Delta S$

1

$0 = 206 - T \frac{216}{1000}$

1

T = 953.7 or 954 K

1

T = 681 (°C)

If the value given in the question is used then the answer is 283 (°C)

1

[12]