

Mark schemes

Q1.

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]

Q2.

C

The rate of the reverse reaction increases.

[1]

Q3.

(a) M1 decreases yield

1

M2 So equilibrium shifts to side with more moles/molecules or more moles/molecules on LHS

Allow M2 independent of M1

1

M3 So equilibrium shifts (to left side) to oppose decrease in pressure **OR** to increase pressure

Must refer to equilibrium shifting to gain maximum marks

1

(b) M1 amount SO₂ (= 0.46 – 0.18) = 0.28 mol

1

M2 amount O₂ (= 0.25 – 0.09) = 0.16 mol

1

M3 total amount (= 0.28 + 0.16 + 0.18) = 0.62 mol

1

M4 partial pressure of SO₂ = $\frac{0.28}{0.62} \times 215 = 97(.1)$ (kPa)

$$M4 = \frac{M1}{M3} \times 215$$

1

(c) M1 $K_p = \frac{(pp \text{ SO}_3)^2}{(pp \text{ SO}_2)^2 \times pp \text{ O}_2}$

Penalise square brackets in M1

1

M2 = 1.2(0) × 10⁻²

1

M3 = kPa⁻¹

1

(d) Stays the same

1

[11]

Q4.(a) Amount Diester = $1 - \frac{x}{2}$

M1

Amount Water = $1 - x$

M2

Amount Diol = $\frac{x}{2}$

M3

(b)



Allow other versions of the structure (abbreviated or displayed)

1

(c) $K_c = \frac{0.452^2 \times 0.273}{0.971 \times (\text{amount H}_2\text{O})^2}$ or $\frac{[\text{acid}]^2 \times [\text{diol}]}{[\text{diester}] \times [\text{H}_2\text{O}]^2}$
 $(\text{Amount H}_2\text{O})^2 = \frac{0.452^2 \times 0.273}{0.161 \times 0.971}$ or $\frac{[\text{acid}]^2 \times [\text{diol}]}{[\text{diester}] \times K_c} = (0.357)$

M1

$$K_c = \frac{\left(\frac{0.452}{\cancel{v}}\right)^2 \times \left(\frac{0.273}{\cancel{v}}\right)}{\left(\frac{0.971}{\cancel{v}}\right) \left(\frac{\text{amount H}_2\text{O}}{\cancel{v}}\right)^2}$$

M2

Amount H₂O = $\sqrt{0.357} = 0.597$ mol

M3

[7]

Q5.

A

The concentrations of the reactants and products are equal.

[1]

Q6.

(a) M1 $\frac{[\text{CO}]^2 [\text{H}_2]^4}{[\text{C}_2\text{H}_5\text{OH}] [\text{H}_2\text{O}]}$

1

- M2** mol⁴ 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 x 10⁻³ scores **M1,2,3**
 7.66 x 10⁻¹⁵ scores **M1,3**
M1 can use 0.750 or 750 (or 75, 7.5, 0.075, 0.0075, etc) 1
- M2**
$$\frac{\left[\frac{0.110}{0.750}\right]^2 \left[\frac{0.220}{0.750}\right]^4}{\left[\frac{0.075}{0.750}\right] \left[\frac{0.156}{0.750}\right]}$$

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

M2 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 x 10⁻³
M3 ignore units
If moles are used in place of concentration
 penalise **M1**, but **M2** and **M3** could score for ECF

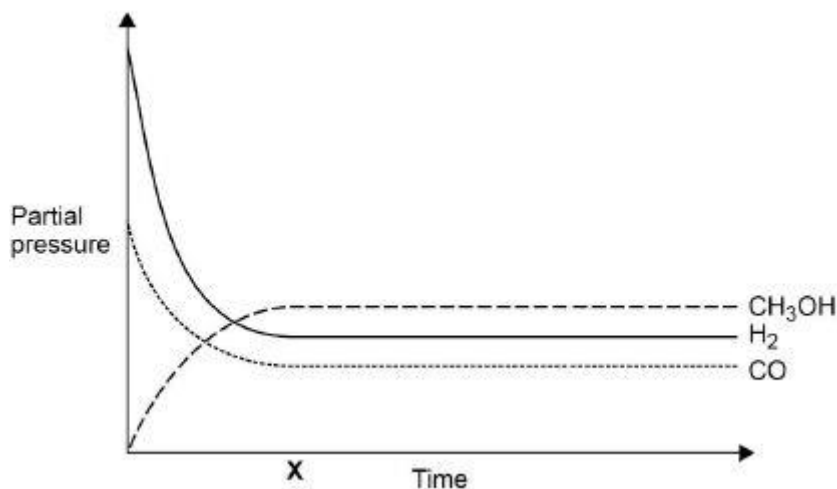
$$\frac{(0.110)^2 (0.220)^4}{(0.075) (0.156)}$$

M2 (0.075) (0.156) **M3** 2.42 x 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]

Q7.

(a)



X must be on or just below line of x axis

1

(b) **M1** Equilibrium $n(\text{H}_2) = \underline{0.24}$

1

M2 Total number of moles = 0.47

1

M3 Mole fraction of $\text{H}_2 = 0.51(1)$ or $\frac{0.24}{0.47}$

M3 Allow mole fraction of $\text{H}_2 = \frac{\text{M1}}{\text{M2}}$

1

M4 Partial pressure of hydrogen = 5310 or 5.31×10^3 kPa

M4 Allow Partial pressure of hydrogen = **M3** $\times 1.04$
 $\times 10^4$

1

(c) **M1** $K_p = \frac{pp\text{CH}_3\text{OH}}{pp\text{H}_2^2 \times pp\text{CO}}$ OR $\frac{p\text{CH}_3\text{OH}}{p\text{H}_2^2 \times p\text{CO}}$

Do not allow square brackets

1

Pa⁻² or kPa⁻²

Allow any pressure to power of ⁻²

1

(d) **M1** Increases

1

M2 No effect

1

(e) **M1** No effect 1

M2 Increases rate of forward and backward reaction equally/by the same amount OR catalyst does not affect position of equilibrium

M2 Allow Catalyst does not appear in the K_p expression

M2 Allow Only temperature affects K_p

Ignore Catalysts increase the rate of reaction or rate at which equilibrium is reached 1

1

[11]

Q8.

(a) Amount of Nitrogen monoxide = 1.15 mol

Answers to min 2sf

1

Amount of Chlorine = 0.825 mol

1

(b)

$$K_c = \frac{[\text{NOCl}]^2}{[\text{NO}]^2[\text{Cl}_2]}$$

1

(c)

$$1.32 \times 10^{-2} = \frac{[\text{NOCl}]^2}{\left[\frac{0.85}{0.800}\right]^2 \left[\frac{0.458}{0.800}\right]}$$

M1 = divides mole quantities by 0.800

1

$$[\text{NOCl}]^2 = 8.53 \times 10^{-3} \text{ mol}^2\text{dm}^{-6}$$

M2 = evaluates $[\text{NOCl}]^2$

1

$$[\text{NOCl}] = 0.0924 \text{ mol dm}^{-3}$$

M3 = $\sqrt{M2}$

1

$$n(\text{NOCl}) = 0.0924 \times 0.800 = 0.0739 \text{ mol}$$

M4 = $M3 \times 0.800$ (allow ecf on an incorrect volume used in M1)

(answer to 2sf or more)

1

If no division in M1 then max 3

$$M2 = 4.37 \times 10^{-3}$$

$$M3 = 0.0661 \text{ mol dm}^{-3}$$

$$M4 = 0.0529 \text{ mol}$$

If Kc upside down then can still score 4

M1 = divides mole quantities by 0.800

M2 = 48.96

M3 = 7.00 mol dm⁻³

M4 = 0.600 mol

Incorrect rearrangement loses M2

[7]

Q9.

A

1.5

[1]

Q10.

A

[1]

Q11.

(a) 3 minutes

M2 dependent on M1 or near miss

1

(At equilibrium, rate _{fwd} = rate _{back} so) concentrations (of O₂ and SO₃) 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) T₂ (Not worth a mark alone)

T₁, 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]

Q12.

(a) **M1** no effect (on yield)
CE = 0 if yield changes

1

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

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 equally / by the same amount

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 $\frac{250}{1000}$)

$$K_c = \frac{\frac{0.0610}{0.250}}{\left[\frac{0.240}{0.250}\right]\left[\frac{0.190}{0.250}\right]^2} \left(= \frac{0.244}{1.36 \times 0.76^2} \right)$$

M2

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 cm³*

*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 mol² dm⁻⁶

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

1

[8]**Q13.**

(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 $K_c = \text{mole ratio} \times 1/V$

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]

Q14.

C

[1]

Q15.

(a) mol R = $2x$

1

(b) $3.6 = \frac{(2x)^2}{(1-x)^2}$

M1 can be awarded for the insertion of their answer from (a) correctly

1

$\sqrt{3.6} = \frac{2x}{1-x}$ (only positive root to be used)

M2 can be awarded if their expression is expanded

1

$\sqrt{3.6} - \sqrt{3.6} x = 2x$

$1.9 = 3.9x$

$X = 0.49$

$[R] = 0.97 \text{ mol dm}^{-3}$ (allow range 0.97–.098)

M3 solve for x from their expression in M1 and use it to calculate $[R]$

1

[4]

Q16.

D

[1]

Q17.

- (a) 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. To access Level 3, statement 3a must be considered.

Answer is communicated coherently and shows a logical progression from stage 1 (including 1b) to stage 2 and stage 3

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 is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3.

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 presented in a logical order, with sensible reasoning.

Level 0 (0 marks)

Insufficient correct chemistry to gain a mark.

Indicative chemistry content**Stage 1 – Deductions from graph**

1a Yield increases as temperature increases (or converse)

1b After a certain temperature yield no longer increases

1c Yield decreases as pressure increases (or converse)

Stage 2 – Optimum temperature and explanation

2a High temperature results in high energy costs/expensive

2b (After a certain temperature) yield no longer increases therefore there is no gain in using a higher temperature

2c Optimum temperature is between 780-880oC

Stage 3 – Optimum pressure and explanation

3a Low pressure may be too slow

3b So compromise pressure required

3c Optimum pressure is 1000-2000kPa or moderate pressure used

6

- (b) Moles of carbon monoxide 17.9

Allow 17.94

1

Moles of hydrogen 19.9
Allow 19.88

1

(c)
$$K_p = \frac{pp(\text{CH}_3\text{OH})}{pp(\text{CO}) \times pp(\text{H}_2)^2}$$

ignore brackets

If K_p expression incorrect can only score M2 & M3 & M4

1

Total moles of gas = (2.76 + 4.51 + 0.36) = 7.63

If CE in M2 allow ecf for M3, M4 and M6

If no total moles calculated then can only score M1 and M6

1

$$pp(\text{CO}) = \frac{2.76}{7.63} \times 630 \text{ (kPa)} \quad (= 228 \text{ (kPa)})$$

$$pp(\text{H}_2) = \frac{4.51}{7.63} \times 630 \text{ (kPa)} \quad (= 372 \text{ (kPa)})$$

$$pp(\text{CH}_3\text{OH}) = \frac{0.36}{7.63} \times 630 \text{ (kPa)} \quad (= 29.7 \text{ (kPa)})$$

All 3 pp of CO, H₂ and CH₃OH = 2 marks

2 pp correct = 1 mark

2

$$K_p = \frac{29.7}{228 \times (372)^2} = 9.4(1) \times 10^{-7} \quad \text{or } 9.4(1) \times 10^{-13} \text{ if pp in Pa}$$

can also score M1 from this expression

Allow 9.39 to 9.50 × 10⁻⁷ (kPa⁻²)

1

kPa⁻² or **Pa⁻²** (if converted to 630 000)

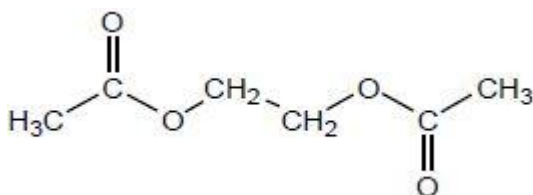
If no marks awarded allow M6 only for **kPa⁻²** or **Pa⁻²**

1

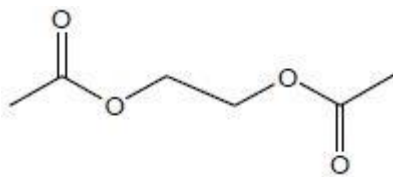
[14]

Q18.

(a)



Allow $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{OOCCH}_3$
 OR $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{OCOCH}_3$
 OR



1

(b) Mol $\text{HOCH}_2\text{CH}_2\text{OH}$ = 6.00×10^{-2} OR 0.06(00)

1

Mol $\text{C}_6\text{H}_{10}\text{O}_4$ = 1.45×10^{-1} OR 0.145

1

Mol H_2O = 2.90×10^{-1} OR 0.29(0)

1

(c)

$$(K_c =) \frac{[\text{ester}] \times [\text{H}_2\text{O}]^2}{[\text{CH}_3\text{COOH}]^2 \times [\text{HOCH}_2\text{CH}_2\text{OH}]}$$

Allow words for acid and alcohol

1

The volume cancels out (Penalise a contradictory justification from expression if the volumes do not cancel out)

OR

there are equal no of moles on each side of the equation

OR

there are equal no of molecules on each side of the equation

1

(d)

$$(\text{Mol CH}_3\text{COOH} / V)^2 = \frac{(8.02 \times 10^{-1} / V)(1.15 / V)^2}{6.45 \times (2.64 \times 10^{-1} / V)}$$

M1

$$\text{Mol CH}_3\text{COOH} = \sqrt{\frac{(8.02 \times 10^{-1}) \times (1.15)^2}{6.45 \times (2.64 \times 10^{-1})}} = \sqrt{0.623}$$

M2

Mol CH_3COOH = 0.789 (must be 3 sfs) Allow 0.788 – 0.790

M3

0.789 scores 3

Allow without V : $(n\text{CH}_3\text{COOH})^2 =$
 $\frac{(8.02 \times 10^{-1})(1.15)^2}{6.45 \times (2.64 \times 10^{-1})}$

If $(n\text{CH}_3\text{COOH})^2 = 0.623$ then award M1 and M2

If K_c is correct in (c) but incorrect rearrangement, then CE=0 except if upside down rearrangement

then M3 only awarded for 1.27

If K_c is incorrect in (c) then only M1 can be awarded for correct rearrangement.

[9]

Q19.

(a)
$$\frac{[Y][H_2O]^2}{[X][CH_3OH]^2}$$

1

(b) 0.06

1

0.32

1

0.52

1

(c)
$$\frac{0.26 \times 0.52^2}{0.06 \times 0.32^2}$$

1

= (11.44) = 11 (2 sf)

1

No units

1

(d) Increase

1

[8]

Q20.

(a) amount of X = 0.50 – 0.20 = 0.30 (mol)

1

amount of Y = 0.50 – 2 × 0.20 = 0.10 (mol)

1

(b) Axes labelled with values, units and scales that use over half of each axis

All three of values, units and scales are required for the mark

1

Curve starts at origin

1

Then flattens at 30 seconds at 0.20 mol

1

(c) Expression = $K_c = \frac{[Z]}{[X][Y]^2}$ 1

$$[Y]^2 = \frac{[Z]}{[X] K_c} \quad 1$$

$$[Y] = (0.35 / 0.40 \times 2.9)^{0.5} = 0.5493 = 0.55 \text{ (mol dm}^{-3}\text{)}$$

Answer must be to 2 significant figures

1

(d) Darkened / went more orange 1

The equilibrium moved to the right 1

To oppose the increased concentration of Y 1

(e) The orange colour would fade 1

[12]