Access Tuition

A-Level Chemistry

Equilibrium Constant (Kc)

Mark Scheme

Time available: 67 minutes
Marks available: 59 marks

Mark schemes

1. (a)

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

1

(b) M1: dividing by volume for SO_2 and SO_3 / calculation of concentrations of SO_2 and SO_3

$$15.0 = 15.0 = \frac{(\frac{0.461}{1.80})^2}{\left(\frac{0.176}{1.80}\right)^2 [O_2]}$$

Or $[SO_2]$ = 0.0978 mol dm^{-3} and $[SO_3]$ = 0.256 mol dm^{-3}

1

M2: correct substitution into rearranged expression

$$[O_2] = \frac{(\frac{0.461}{1.80})^2}{\left(\frac{0.176}{1.80}\right)^2 (15.0)}$$

or

$$[O_2] = \frac{(0.256)^2}{(0.0978)^2(15.0)}$$

($[O_2]$ = 0.457 mol dm^{-3})

1

M3 amount of oxygen = $[O_2]$ × 1.80 = 0.823 mol

At least 2sf

1

(c) (pV = nRT)

T = pV ÷ nR

M1: rearranged expression for ideal gas equation

1

n = 0.025 + 0.049 + 0.034

n = 0.108

M2: total number of moles

1

Conversions: pressure = 255000 Pa ; volume = 0.0035 m^3

M3: unit conversions

1

$$T = \frac{255000 \times 0.0035}{8.31 \times 0.108}$$

1

M4: temperature in K

T = 994.5 K

T = 721 °C

M5: temperature in °C (allow 720 – 722)

M5 = M4 – 273

1

[9]

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 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 $\frac{(0.147)^2 (0.293)^4}{(0.100)(0.208)}$ 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 x 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 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]

3. (a) Amount of Nitrogen monoxide = 1.15 mol

Answers to min 2sf

1

Amount of Chlorine = 0.825 mol

1

(b)

$$K_c = \frac{[NOCl]^2}{[NO]^2[Cl_2]}$$

1

(c)

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

M1 = divides mole quantities by 0.800

1

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

M2 = evaluates $[NOCl]^2$

1

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

M3 = √M2

1

n(NOCl) = 0.0924 x 0.800 = 0.0739 mol

M4 = M3 x 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 = 4.37×10^{-3}

M3 = 0.0661 mol dm^{-3}

M4 = 0.0529 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]

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

Must be square brackets

Ignore state symbols

Ignore units

1

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

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

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** $\frac{1}{Answer\ to\ (c)}$ = 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 × 10^{-3} – 2x ∴ x = 1.25 × 10^{-3}

If incorrect x can score max 3

M2

B = 9.5 × 10^{-3} – x = 8.25 × 10^{-3}

Allow 2 or more sig figs

M3

C = 2.8 × 10^{-2} + 3x = 0.0318

M4

D = x = 1.25 × 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] = <u>0.17</u> (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) mol R = 2*x*

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

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

$1.9 = 3.9x$

$X = 0.49$

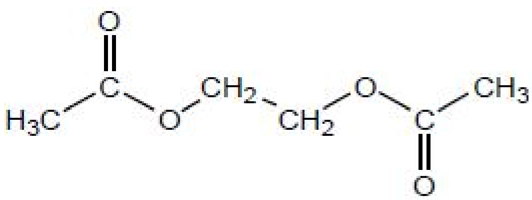
[R] = 0.97 mol dm^{-3} (allow range 0.97–.098)

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

1

[4]

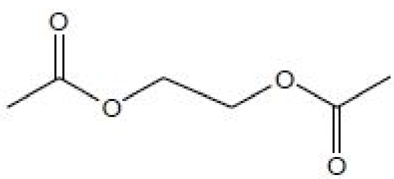
7. (a)



Allow $CH_3COOCH_2CH_2OOCCH_3$

OR $CH_3COOCH_2CH_2OCOCH_3$

OR



1

(b) Mol $HOCH_2CH_2OH$ $= 6.00 \times 10^{-2}$ OR 0.06(00)

1

Mol $C_6H_{10}O_4$ $= 1.45 \times 10^{-1}$ OR 0.145

1

Mol H_2O $= 2.90 \times 10^{-1}$ OR 0.29(0)

1

(c)

$$(K_c =) \frac{[\text{ester}] \times [H_2O]^2}{[CH_3COOH]^2 \times [HOCH_2CH_2OH]}$$

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)

$$(\text{Mol } CH_3COOH / V)^2 = \frac{(8.02 \times 10^{-1} / V)(1.15 / V)^2}{6.45 \times (2.64 \times 10^{-1} / V)}$$

M1

$$\text{Mol } CH_3COOH = \sqrt{\frac{(8.02 \times 10^{-1}) \times (1.15)^2}{6.45 \times (2.64 \times 10^{-1})}} = \sqrt{0.623}$$

M2

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

M3

0.789 scores 3

Allow without V : $(nCH_3COOH)^2 = \frac{(8.02 \times 10^{-1})(1.15)^2}{6.45 \times (2.64 \times 10^{-1})}$

If $(nCH_3COOH)^2$ *=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]