Mark schemes

1 (a) (If any factor is changed which affects an <u>equilibrium</u>), the (position of) <u>equilibrium</u> will <u>shift /</u> <u>move</u> so as to <u>oppose</u> / <u>counteract the change</u>.

> *Must refer to <u>equilibrium</u>*
>
> *Ignore reference to "system" alone*
>
> *A variety of wording will be seen here and the key part is the last phrase*

OR

(When a system / reaction in <u>equilibrium</u> is disturbed), the (position of) <u>equilibrium</u> shifts / moves in a direction which tends to <u>reduce the disturbance</u>

> *An alternative to shift / move would be the idea of <u>changing /</u> <u>altering the position</u> of equilibrium*

1

(b) (i) M1

A substance that <u>speeds up the reaction / alters the rate</u> but is <u>chemically unchanged at the end / not used up</u>

> *Both ideas needed for **M1***
>
> *Credit can score for **M1**, **M2** and **M3** from anywhere within the answer*

M2
Catalysts provide an alternative route / alternative pathway / different mechanism

M3
that has a <u>lower activation energy / E_a</u>

OR
<u>lowers the activation energy / E_a</u>

3

(ii) (Time is) less / shorter / decreases / reduces

> *Credit "faster", "speeds up", "quicker" or words to this effect*

1

(iii) None

1

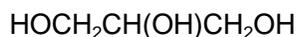(c) (i) R

1

(ii) T

1

(iii) R

1

(iv) P

1

(v) Q

1
[11]

2 (a) (i) <u>3</u>CH$_3$OH

Not molecular formula

1

HOCH$_2$CH(OH)CH$_2$OH

1

(ii)   → 19CO$_2$ + 19H$_2$O

Or doubled

1

C$_{17}$H$_{35}$COOCH$_3$ + 27½ or 55/2 O$_2$
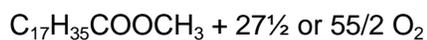
Consequential on correct right-hand side

1

(b) (i) A   0.7

1

Ethanol   6.4

1

Water   3.6

1

(ii) No effect

If wrong, CE= 0

1

Equal moles on each side of equation **OR** V cancels

Ignore moles of gas

1

(iii) M1 $K_c = \dfrac{[\,\text{DEM}\,][\text{H}_2\text{O}]^2}{[\text{A}][\text{C}_2\text{H}_5\,\text{OH}]^2}$

Must have all brackets but allow ( )

1

(iv) M2 $\dfrac{2.1 \times (3.4)^2}{0.85 \times (7.2)^2}$

*If K$_c$ wrong can only score M4 for units consequential to their K$_c$
working in (b)(iv)*

1

M3 0.55 (min 2dp)

1

M4 No units

1

[13]

3   (a)   (i)   **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> ΔH symbols and the $\sum$ or SUM)**

M1 $\underline{\Delta H_r} = \Sigma \Delta H_f$ **(products)** - $\Sigma \Delta H_f$ **(reactants)**

OR   a <u>correct cycle of balanced equations with 1C, 3H$_2$ and 1O$_2$</u>

M2 $\underline{\Delta H_r} = -201 + (-242) - (-394)$
$\underline{\Delta H_r} = -201 - 242 + 394$
$\underline{\Delta H_r} = -443 + 394$
(This also scores M1)

M3 $= -$ **49** (kJ mol^{-1})
(Award 1 mark ONLY for + 49)
Correct answer gains full marks

Credit 1 mark ONLY for + 49 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*

- *If no AE, check for a correct method; this requires either correct cycle of balanced equations with 1C, 3H$_2$ and 1O$_2$*

   *OR a clear statement of **M1** which could be in words and scores <u>only **M1**</u>*

3

(ii)   It is an element / elemental
     Ignore reference to "standard state"

OR

By definition

1

(b)   **M1** (The yield) increases / goes up / gets more

If M1 is given as "decreases" / "no effect" / "no change" then CE= 0
*for clip, but mark on only **M2** and **M3** from a blank M1*

M2   There are <u>more moles / molecules</u> (of gas) on the <u>left</u> / of reactants
OR <u>fewer moles / molecules</u> (of gas) on the <u>right</u>
/ products
OR there are <u>4 moles /molecules</u> (of gas) on the left <u>and 2 moles / molecules</u> on the right.
OR (equilibrium) shifts / moves <u>to the side with less moles / molecules</u>

Ignore "volumes", "particles" "atoms" and "species" for **M2**

M3: Can only score M3 if <u>M2 is correct</u>

The (position of) <u>equilibrium shifts / moves</u> (from left to right) to <u>oppose the increase</u>
<u>in pressure</u>

*For **M3**, <u>not</u> simply "to oppose the change"*

*For **M3** credit the <u>equilibrium shifts / moves</u> (to right) to <u>lower /</u>*
<u>*decrease the pressure*</u>

(There must be a <u>specific</u> reference to the change that is opposed)

3

(c)   **M1**   Yield increases goes up

M2   The (forward) reaction / to the right is <u>endothermic</u> OR <u>takes in/ absorbs</u>
<u>heat</u>

   OR

The reverse reaction / to the left is <u>exothermic</u> OR <u>gives out / releases heat</u>

If M1 is given as "decrease" / "no effect" / "no change" then CE= 0
*for clip, but mark on only **M2** and **M3** from a blank **M1***

Can only score M3 <u>if M2 is correct</u>

M3 The (position of) <u>equilibrium shifts / moves</u> (from left to right) <u>to oppose the increase</u>
<u>in temperature</u> **(QoL)**

*For **M3**, <u>not</u> simply "to oppose the change"*

*For **M3**, credit the (position of) <u>equilibrium shifts / moves</u> **(QoL)***

*to <u>absorb the heat</u> **OR***

*to <u>cool the reaction</u> **OR***

to <u>lower the temperature</u>

(There must be a <u>specific</u> reference to the change that is opposed)

3

(d) (i)   An activity which has no <u>net / overall</u> (annual) carbon emissions <u>to the atmosphere</u>

        OR

An activity which has no <u>net / overall</u> (annual) greenhouse gas emissions <u>to the atmosphere</u>.

        OR

There is no change in the <u>total amount / level</u> of carbon dioxide /CO_2 carbon /greenhouse gas present <u>in the atmosphere</u>.

> *The idea that the carbon /CO_2 given out equals the carbon /CO_2 that was taken in from <u>the atmosphere</u>*

1

(ii) CH_3OH + **1½** O_2 ⟶ CO_2 + **2**H_2O
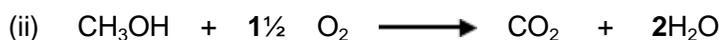
> *Ignore state symbols*
> *Accept multiples*

1

(iii) **3**H_2 + **1½** O_2 ⟶ **3**H_2O

> *Ignore state symbols*

        OR

> *Accept multiples*

2H_2 + O_2 ⟶ **2**H_2O

> *Extra species must be crossed through*

1

(e) **M1** q = m c ΔT

> *Award full marks for <u>correct answer</u>*
> *Ignore the case for each letter*

OR q = 140 × 4.18 × 7.5

M2 = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ)(also scores **M1**)

M3 Using 0.0110 mol
therefore ΔH = <u>**– 399**</u> (kJmol^{-1})
OR <u>**– 400**</u>

> *Penalise **M3** ONLY if correct numerical answer but sign is incorrect;*
> *+399 **gains 2 marks***
> *Penalise **M2** for arithmetic error and mark on*
> *In **M1**, do not penalise incorrect cases in the formula*
> *If ΔT = 280.5; score q = m c ΔT only*
> *If c = 4.81 (leads to 5050.5) penalise **M2** ONLY and mark on for **M3** = – 459*
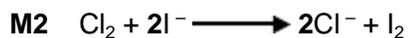
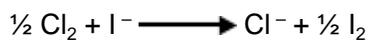**+399 or +400 gains 2 marks**

> *Ignore incorrect units*

3

[16]

4 (a) (i) **M1** iodine *OR* I_2 OR I_3^-

Ignore state symbols

*Credit **M1** for "iodine solution"*

M2 $Cl_2 + 2I^- \longrightarrow 2Cl^- + I_2$
OR
$\frac{1}{2} Cl_2 + I^- \longrightarrow Cl^- + \frac{1}{2} I_2$
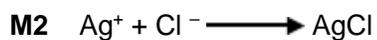
Penalise multiples in M2 except those shown

***M2** accept correct use of I_3^-*

M3 redox or reduction-oxidation or displacement

3

(ii) **M1** (the white precipitate is) <u>silver chloride</u>

***M1** <u>must be named</u> and for <u>this mark</u> ignore incorrect formula*

M2 $Ag^+ + Cl^- \longrightarrow AgCl$

*For **M2** ignore state symbols*

Penalise multiples

M3 (white) precipitate / <u>it dissolves</u>

OR <u>colourless solution</u>
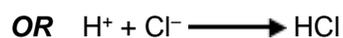
Ignore references to "clear" alone

3

(b) (i) **M1** $H_2SO_4 + 2Cl^- \longrightarrow 2HCl + SO_4^{2-}$

*For **M1** ignore state symbols*

OR $H_2SO_4 + Cl^- \longrightarrow HCl + HSO_4^-$

Penalise multiples for equations and apply the list principle

OR $H^+ + Cl^- \longrightarrow HCl$

M2 hydrogen chloride *OR* HCl *OR* hydrochloric acid

2

(ii)   **M1 and M2 in either order**

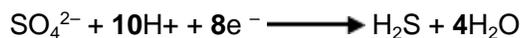   *For **M1** and **M2**, ignore state symbols and credit multiples*

M1 $2I^- \longrightarrow I_2 + 2e^-$

OR

      $8I^- \longrightarrow 4I_2 + 8e-$
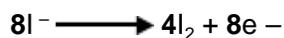
      Do not penalise absence of charge on the electron
      Credit electrons shown correctly on the other side of each equation

M2 $H_2SO_4 + 8H^+ + 8e^- \longrightarrow H_2S + 4H_2O$

OR

$SO_4^{2-} + 10H+ + 8e^- \longrightarrow H_2S + 4H_2O$

      Additional equations should not contradict

M3   <u>oxidising agent</u> / <u>oxidises the iodide</u> (ions)

OR

<u>electron acceptor</u>

M4   sulfur ***OR*** S ***OR*** S_2 ***OR*** S_8 ***OR*** sulphur

                                                 4

(iii) **M1** The <u>NaOH / OH⁻ / (sodium) hydroxide reacts with / neutralises the H⁺ / acid / HBr</u> (lowering its concentration)

OR a correct neutralisation equation for H⁺ or HBr with NaOH or with hydroxide ion
Ignore reference to NaOH reacting with bromide ions
Ignore reference to NaOH reacting with HBrO alone

M2 **Requires a correct statement for M1**

The (position of) <u>equilibrium moves / shifts</u>(from L to R)

- to <u>replace the H⁺ / acid / HBr that has been removed / lost</u>

- **OR** to <u>increase the H⁺ / acid / HBr concentration</u>

- **OR** to <u>make more H⁺ / acid / HBr / product(s)</u>

- **OR** to <u>oppose the loss of H⁺ / loss of product(s)</u>

- **OR** to <u>oppose the decrease in concentration</u> of product(s)
  *In **M2**, answers must refer to the (position of) <u>equilibrium shifts / moves</u> and is not enough to state simply that it / the system / the reaction shifts to oppose the change.*

M3 The (health) benefit outweighs the risk or wtte

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses
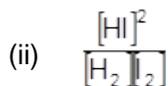
3

[15]

5 (a) (i) mol H_2 = 0.47

1

mol I_2 = 0.17
If answers reversed, ie
mol H_2 = 0.17
mol I_2 = 0.47
then allow one mark (for second answer).

1

(ii) $$\dfrac{[HI]^2}{[H_2][I_2]}$$

Penalise expression containing V
But mark on in (a)(iv)

Penalise missing square brackets _in this part_
(and not elsewhere in paper) but mark on in (a)(iv)

1

(iii)   equal number of <u>moles</u> (on each side of equation)

OR

equal <u>moles</u> (top and bottom of *Kc* expression)

1

(iv)

$$\dfrac{[1.94]^2}{[0.38][0.19]}$$
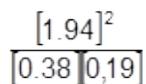
Ignore V

If Kc wrong in (a)(ii) (wrong powers or upside down etc) no marks
here

1

= 52(.1)

1

(b)   (i)   **D**

1

(ii)   **B**

1

(iii)   **A**

1

(iv)   **C**

1

[10]

6 (a) **In either order**

For M1 accept [ ] for concentration

M1 <u>Concentrations</u> (of reactants and products) <u>remain or stay constant / the same</u>

NOT "equal concentrations" and NOT "concentration(s) <u>is / are</u> the same"

M2 <u>Forward rate</u> = <u>Reverse / backward rate</u>

NOT "amount"

Ignore "dynamic" and ignore "speed"

Ignore "closed system"

It is possible to score both marks under the heading of a single feature

2

(b) **M1** Catalysts <u>increase rate of / speed up</u> both <u>forward and reverse / backward reactions</u>

If M1 is given as "no effect" / "no change" then CE= 0 for clip

M2 increase in <u>rate</u> / affect on <u>rate / speed</u> is <u>equal / the same</u>

Ignore references to "decrease in rate"

2

(c) (i) **M1** (The yield) <u>increases / goes up / gets more</u>

If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank.

M2 There are <u>more moles / molecules</u> (of gas) on the <u>left / of reactants</u>

Ignore "volumes", "articles" "atoms" and "species" for M2

OR <u>fewer moles / molecules</u> (of gas) on the <u>right / products</u>

OR there are <u>4 moles / molecules</u> (of gas) on the left <u>and 2 moles / molecules</u> on the right.

OR (equilibrium) shifts / moves <u>to the side with less moles / molecules</u>

M3 Can only score M3 <u>if M2 is correct</u>

The <u>equilibrium shifts / moves</u> (from left to right) to <u>oppose the increase in pressure</u>

For M3, <u>not</u> simply "to oppose the change"

For M3 credit the <u>equilibrium</u> <u>shifts / moves</u> to <u>lower / decrease</u> the <u>pressure</u>

(There must be a <u>specific</u> reference to the change that is opposed)

3

(ii) **M1** The yield decreases / goes down / gets less

If M1 is given as "increase" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank.

M2 (Forward) reaction is <u>exothermic</u> **OR** <u>gives out / releases heat</u>

OR

reverse reaction is <u>endothermic</u> **OR** <u>takes in / absorbs heat</u>

Can only score M3 <u>if M2 is correct</u>

The <u>equilibrium shifts / moves</u> (from right to left) to <u>oppose the increase in temperature</u>

For M3, <u>not</u> simply "to oppose the change"
For M3 credit the <u>equilibrium shifts / moves</u>
to <u>absorb the heat</u> OR
to <u>cool the reaction</u> OR
to <u>lower the temperature</u>
(There must be a <u>specific</u> reference to the change that is opposed)

3

(d) (i) Must be comparative

Credit correct reference to rate being <u>too (s)low / (s)lower</u> at temperatures less than 600 K

<u>Higher rate</u> of reaction

OR <u>increase / speed up the rate</u> (of reaction)
Ignore statements about the "yield of ammonia"

OR Gets to equilibrium <u>faster/ quicker</u>

OR <u>faster or quicker rate / speed</u> of attainment of equilibrium

1

(ii) <u>Less</u> electrical <u>pumping cost</u>
Not just "less expensive" alone

OR

Not just "less energy or saves energy" alone

Use lower pressure <u>equipment / valves / gaskets / piping</u> etc.
Credit correct <u>qualified</u> references to higher pressures

OR

Uses less expensive <u>equipment</u>
Ignore references to safety

1

[12]

7 (a) (i) Mol SO_3 = 5.2

1

Mol SO_2 = 2.8

1

(ii) $$\dfrac{[SO_2]^2[O_2]}{[SO_3]^2}$$

Penalise expression containing numbers or V

Allow ( ) but must have all brackets. If brackets missing but otherwise correct, penalise here but mark on

Ignore subsequent correct working

If Kc wrong (wrong powers or upside down etc) can only score M1 in (a)(iv)

1

(iii) mol dm^{-3}

Allow conseq to their wrong Kc

1

(iv) *If Kc wrong in (a)(iv) (wrong powers or upside down etc) can only score M1*

Values from (a)(i)

$$\dfrac{[2.8/12]^2[1.4/12]}{[5.2/12]^2} \quad \text{or} \quad \dfrac{[0.233]^2[0.117]}{[0.433]^2}$$

Alternative values

$$\dfrac{[2.1/12]^2[1.4/12]}{[5.8/12]^2}$$

1

M1 *For dividing all three by volume – if volume missed or used wrongly, lose M1 & M2 but can score M3 conseq*

M2 *insertion of values (allow conseq use of their wrong values from (a)(i))*
AE (−1) for copying numbers wrongly or swapping two numbers

1

Values from (a)(i)

M3 = 0.0338 or 0.034

(allow 0.03376 to 0.035)

Min 2 sfs

Ignore units in (a)(iv)

If vol missed score only M3

Values from (a)(i)

0.406 - allow values between 0.40 (if correctly rounded) and 0.41

Alternative values

M3 0.0153 or 0.015

(allow 0.015 to 0.017)

Min 2 sfs

Ignore units in (a)(iv)

from alternative values allow 0.18 to 0.184

1

(b) (i) Increase or more moles (of oxygen) or higher

1

(ii) No change or no effect or none or (remains) same

1

(c) **M1** T_1

If T_2 CE = 0

1

M2 (At Temp,T2, when Kc is lower) Equm/reaction moves to left or towards reagent or towards SO_3 OR moles SO_3 increases

1

M3 This reverse reaction is exothermic,

OR

M3 (forward) reaction is endothermic

M2 if Temp is increased Equm/reaction moves to right or towards product or towards SO_2 OR moles SO_2 increases
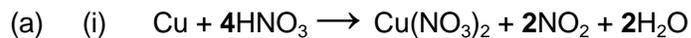
OR

M3 (forward) reaction is endothermic

M2 if Temp is decreased Equm/reaction moves to left or towards reagent or towards SO_3 OR moles SO_3 increases
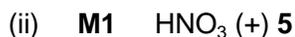
1

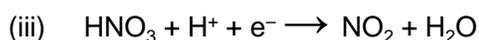**[12]**

8 (a) (i) $Cu + \mathbf{4}HNO_3 \longrightarrow Cu(NO_3)_2 + \mathbf{2}NO_2 + \mathbf{2}H_2O$

Or multiples
Ignore state symbols

1

(ii) **M1** HNO_3 (+) **5**

M2 NO_2 (+) **4**
Ignore working out
M1 Credit (V)
M2 Credit (IV)

2

(iii) $HNO_3 + H^+ + e^- \longrightarrow NO_2 + H_2O$

OR
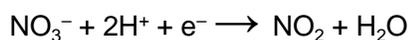
$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$
Or multiples
Ignore state symbols
Ignore charge on the electron unless incorrect and accept loss of electron on the RHS

1

(b) (i) **In either order**

M1 <u>Concentration(s)</u> (of reactants and products)
<u>remain(s) constant / stay(s) the same / remain(s)</u>
<u>the same / do(es) not change</u>

M2 <u>Forward rate = Reverse / backward rate</u>
For M1 accept [ ] for concentration
NOT "equal concentrations" and NOT "concentration(s) <u>is/are</u> the same"
NOT "amount"
Ignore "dynamic" and ignore "speed"
Ignore "closed system"
It is possible to score both marks under the heading of a single feature

2

(ii) **M1**

The (forward) reaction / to the right is <u>endothermic</u>
or <u>takes in / absorbs heat</u>

OR

The reverse reaction / to the left is <u>exothermic</u> or <u>gives</u>
<u>out / releases heat</u>

M2 depends on correct M1 and must refer to temperature/heat

The <u>equilibrium shifts / moves</u> left to right to <u>oppose the increase in</u> <u>temperature</u>

M2 depends on a correct statement for M1
For M2, the <u>equilibrium shifts/moves</u>
to <u>absorb the heat</u> OR
to <u>lower the temperature</u> OR
to <u>cool the reaction</u>

2

(iii) **M1 refers to number of moles**

There are <u>fewer moles</u> (of gas) on the left OR <u>more</u>
<u>moles</u> (of gas) on the right.
OR there is <u>one mole</u> (of gas) on the left <u>and 2 moles</u>
on the right.

M2 depends on correct M1 and must refer to pressure
The <u>equilibrium shifts / moves</u> right to left to <u>oppose the</u>
<u>increase in pressure</u>

M2 depends on a correct statement for M1
For M2, the <u>equilibrium shifts/moves</u> to <u>lower the pressure.</u>

2

[10]

9 (a) Forward and backward reactions proceeding at equal rate

1

Amount (Conc or moles or proportion) of reactants and
products remain constant
Not "reactants and products have equal conc"

1

(b) **M1** $\dfrac{[R]^2}{[P][Q]^2}$

Allow ( ) but must have all brackets
*If Kc wrong can only score **M3** (process mark)*
for dividing both R and P by volume)

1

(c) **M2** $[Q]^2 = \dfrac{[R]^2}{k_c[P]}$

          Rearrangement of correct Kc expression

          *If wrong Kc used can only score **M3** for correct use of vol*

          *If wrong rearrangement can only score max 2 for **M3** and **M5** for correct √*

                                                                               1

    M3 $[Q]^2 = \dfrac{(5.24/10)^2}{68.0 \times (3.82/10)}$

          Process mark for dividing both R and P by volume even in incorrect expression

          *If vol missed can only score max 2 for **M2** and M5 for correct √*

          *If vol used but then wrong maths can score **M2 M3** and **M5** for correct √*

          If moles used wrongly, eg (2×5.24) or $(5.24 \times 10/10^3)$

          *can only score **M2** and **M5***

                                                                                    1

    M4 $[Q]^2 = 0.0106$

          Correct calculation of Q^2

                                                                                1

    M5 $[Q] = 0.10(3)$

          Correct taking of √

                                                                                1

(c) cont.

Wrong rearrangement and no use of volume

                                                                                    0

Wrong rearrangement

          *For Correct use of volume **M3** and Correct taking of square root **M5***

                                                                                 2 max

No use of volume

          2 max

          answer = 0.325

          Ignore subsequent multiplying or dividing by 10.

          0.0325 or 3.25 *still score max 2*

          *For Correct rearrangement **M2** and*

          *Correct taking of square root **M5***

                                                                                2 max

Use of volume but maths error e.g. using $(5.24)^2/10$
when should be $(5.24/10)^2$

> *Scores 3*
> ***also giving answer 0.325***
> *for **M2, M3** and **M5***

3

Use of volume but Q/10 also used
or Q multiplied by 10 at end
(i.e.muddling moles with concentration)

> ***Gives answer 1.03***
> *For Correct rearrangement **M2** and*
> *Correct taking of square root **M5***

2 max

Wrong use of moles, e.g (5.24×2) or $(5.24 \times 10/10^3)$

> *For Correct rearrangement **M2** and*
> *Correct taking of square root **M5***

2 max

Wrong Kc used, e.g. missing powers

> *For Correct use of volume **M3***

1 max

(d)   Increase or more or larger

> *Allow moves to left*

1

(e)   Increase or more or larger

> *Allow moves to left*

1

(f)   Decrease or less or smaller

> *NOT allow moves left*

1

(g)   No effect or unchanged or none

1

(h)   0.0147 or 0.0148 or 1.47×10^{-2} or 1.48×10^{-2}

Allow 0.015 or 1.5×10^{-2}

If not 0.0147, look at (c) for conseq correct use
of their [Q] in new Kc = $1.39 \times [Q]^2$

> *Not allow just 1/68.0*
> *ignore units*

1

[24]

10 (a) = (0.0745) × (0.0813) / (0.0424) × (0.0525)
= 2.72

Allow answer only without working if correct.

Lose this mark if the wrong K_c expression is used.

1

Answer, whether or not correct, given to three significant figs

Do not expect conversion from moles to concentration but allow if shown.

1

(b) Less acid is present (so less NaOH needed)

1

Equilibrium would shift to right (side with more ester / less acid)

1

[4]