

## Mark schemes

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

*Must refer to equilibrium*

*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 equilibrium is disturbed), the (position of) equilibrium shifts / moves in a direction which tends to reduce the disturbance

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

1

- (b) (i) M1  
A substance that speeds up the reaction / alters the rate but is chemically unchanged at the end / not used up

*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 lower activation energy /  $E_a$

**OR**

lowers the activation energy /  $E_a$

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) **M1** (could be scored by a correct mathematical expression which must have all  $\Delta H_f$  symbols and the  $\Sigma$  or SUM)

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

**OR** a correct cycle of balanced equations with 1C, 3H<sub>2</sub> and 1O<sub>2</sub>

**M2**  $\Delta H_r = -201 + (-242) - (-394)$

$\Delta H_r = -201 - 242 + 394$

$\Delta H_r = -443 + 394$

(This also scores M1)

**M3** = -49 (kJ mol<sup>-1</sup>)

**(Award 1 mark ONLY for + 49)**

*Correct answer gains full marks*

*Credit 1 mark ONLY for + 49 (kJ mol<sup>-1</sup>)*

*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<sub>2</sub> and 1O<sub>2</sub> OR a clear statement of M1 which could be in words and scores only M1*

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 more moles / molecules (of gas) on the left / of reactants

**OR** fewer moles / molecules (of gas) on the right

/ products

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

**OR** (equilibrium) shifts / moves to the side with less moles / molecules

*Ignore “volumes”, “particles” “atoms” and “species” for **M2***

**M3: Can only score M3 if M2 is correct**

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

*For **M3**, not simply “to oppose the change”*

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

*(There must be a specific reference to the change that is opposed)*

3

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

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

**OR**

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

*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 if M2 is correct**

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

*For **M3**, not simply “to oppose the change”*

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

*to absorb the heat **OR***

*to cool the reaction **OR***

*to lower the temperature*

*(There must be a specific reference to the change that is opposed)*

3

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

**OR**

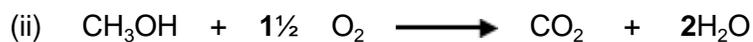
An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

**OR**

There is no change in the total amount / level of carbon dioxide /CO<sub>2</sub> carbon /greenhouse gas present in the atmosphere.

*The idea that the carbon /CO<sub>2</sub> given out equals the carbon /CO<sub>2</sub> that was taken in from the atmosphere*

1



*Ignore state symbols*

*Accept multiples*

1



*Ignore state symbols*

**OR**

*Accept multiples*



*Extra species must be crossed through*

1

- (e) **M1**  $q = m c \Delta T$   
*Award full marks for correct answer*  
*Ignore the case for each letter*

**OR**  $q = 140 \times 4.18 \times 7.5$

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

**M3** Using 0.0110 mol  
 therefore  $\Delta H = -399$  (kJmol<sup>-1</sup>)  
 OR -400

*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  $\Delta T = 280.5$ ; score  $q = m c \Delta T$  only*

*If  $c = 4.81$  (leads to 5050.5) penalise **M2** ONLY and mark on for **M3**  
 = - 459*

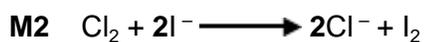
**+399 or +400 gains 2 marks**

*Ignore incorrect units*

3

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- 3** (a) (i) **M1** iodine **OR** I<sub>2</sub> OR I<sub>3</sub><sup>-</sup>  
*Ignore state symbols*  
*Credit **M1** for "iodine solution"*



**OR**



*Penalise multiples in M2 except those shown*

***M2** accept correct use of I<sub>3</sub><sup>-</sup>*

**M3** redox or reduction-oxidation or displacement

3

(ii) **M1** (the white precipitate is) silver chloride  
*M1 must be named and for this mark ignore incorrect formula*

**M2**  $\text{Ag}^+ + \text{Cl}^- \longrightarrow \text{AgCl}$   
*For M2 ignore state symbols*  
*Penalise multiples*

**M3** (white) precipitate / it dissolves

**OR** colourless solution  
*Ignore references to "clear" alone*

3

(b) (i) **M1**  $\text{H}_2\text{SO}_4 + 2\text{Cl}^- \longrightarrow 2\text{HCl} + \text{SO}_4^{2-}$   
*For M1 ignore state symbols*

**OR**  $\text{H}_2\text{SO}_4 + \text{Cl}^- \longrightarrow \text{HCl} + \text{HSO}_4^-$   
*Penalise multiples for equations and apply the list principle*

**OR**  $\text{H}^+ + \text{Cl}^- \longrightarrow \text{HCl}$

**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**  $2\text{I}^- \longrightarrow \text{I}_2 + 2\text{e}^-$

**OR**

$8\text{I}^- \longrightarrow 4\text{I}_2 + 8\text{e}^-$

*Do not penalise absence of charge on the electron*

*Credit electrons shown correctly on the other side of each equation*

**M2**  $\text{H}_2\text{SO}_4 + 8\text{H}^+ + 8\text{e}^- \longrightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O}$

**OR**

$\text{SO}_4^{2-} + 10\text{H}^+ + 8\text{e}^- \longrightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O}$

*Additional equations should not contradict*

**M3** oxidising agent / oxidises the iodide (ions)

**OR**

electron acceptor

**M4** sulfur **OR** S **OR** S<sub>2</sub> **OR** S<sub>8</sub> **OR** sulphur

4

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

**OR** a correct neutralisation equation for H<sup>+</sup> 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) equilibrium moves / shifts(from L to R)

- to replace the H<sup>+</sup> / acid / HBr that has been removed / lost
- **OR** to increase the H<sup>+</sup> / acid / HBr concentration
- **OR** to make more H<sup>+</sup> / acid / HBr / product(s)
- **OR** to oppose the loss of H<sup>+</sup> / loss of product(s)
- **OR** to oppose the decrease in concentration of product(s)  
*In M2, answers must refer to the (position of) equilibrium shifts / moves 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

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4

(a) (i) mol H<sub>2</sub> = 0.47

1

mol I<sub>2</sub> = 0.17

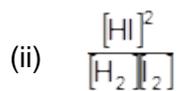
*If answers reversed, ie*

*mol H<sub>2</sub> = 0.17*

*mol I<sub>2</sub> = 0.47*

*then allow one mark (for second answer).*

1



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

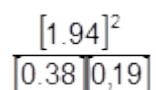
(iii) equal number of moles (on each side of equation)

**OR**

equal moles (top and bottom of  $K_c$  expression)

1

(iv)



Ignore V

*If  $K_c$  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]**

5

(a) **In either order**

*For M1 accept [ ] for concentration*

**M1** Concentrations (of reactants and products) remain or stay constant / the same

*NOT “equal concentrations” and NOT “concentration(s) is / are the same”*

**M2** Forward rate = Reverse / backward rate

*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 increase rate of / speed up both forward and reverse / backward reactions

*If M1 is given as “no effect” / “no change” then CE= 0 for clip*

**M2** increase in rate / affect on rate / speed is equal / the same

*Ignore references to “decrease in rate”*

2

(c) (i) **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 from a blank.*

**M2** There are more moles / molecules (of gas) on the left / of reactants

*Ignore “volumes”, “articles” “atoms” and “species” for M2*

**OR** fewer moles / molecules (of gas) on the right / products

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

**OR** (equilibrium) shifts / moves to the side with less moles / molecules

**M3** Can only score M3 if M2 is correct

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

*For M3, not simply “to oppose the change”*

*For M3 credit the equilibrium shifts / moves to lower / decrease the pressure*

*(There must be a specific 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 exothermic **OR** gives out / releases heat

**OR**

reverse reaction is endothermic **OR** takes in / absorbs heat

**Can only score M3 if M2 is correct**

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

*For M3, not simply "to oppose the change"*

*For M3 credit the equilibrium shifts / moves*

*to absorb the heat OR*

*to cool the reaction OR*

*to lower the temperature*

*(There must be a specific reference to the change that is opposed)*

3

(d) (i) Must be comparative

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

Higher rate of reaction

**OR** increase / speed up the rate (of reaction)

*Ignore statements about the "yield of ammonia"*

**OR** Gets to equilibrium faster/ quicker

**OR** faster or quicker rate / speed of attainment of equilibrium

1

- (ii) Less electrical pumping cost  
*Not just "less expensive" alone*

**OR**

*Not just "less energy or saves energy" alone*

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

**OR**

Uses less expensive equipment  
*Ignore references to safety*

1

[12]

**6**

- (a) (i) Mol SO<sub>3</sub> = 5.2

1

Mol SO<sub>2</sub> = 2.8

1

- (ii) 
$$\frac{[\text{SO}_2]^2 [\text{O}_2]}{[\text{SO}_3]^2}$$

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<sup>-3</sup>

*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)

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

Alternative values

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

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<sub>1</sub>

If T<sub>2</sub> CE = 0

1

**M2** (At Temp, T<sub>2</sub>, when Kc is lower) Equum/reaction moves to left or towards reagent or towards SO<sub>3</sub> OR moles SO<sub>3</sub> 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<sub>2</sub> OR moles SO<sub>2</sub> increases

**OR**

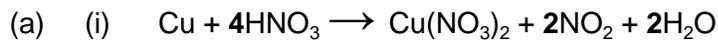
**M3** (forward) reaction is endothermic

**M2** if Temp is decreased Equm/reaction moves to left or towards reagent  
or towards SO<sub>3</sub> OR moles SO<sub>3</sub> increases

1

[12]

7



*Or multiples*

*Ignore state symbols*

1

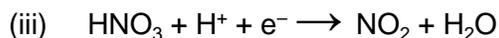


*Ignore working out*

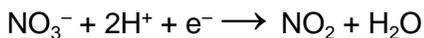
*M1 Credit (V)*

*M2 Credit (IV)*

2



OR



*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** Concentration(s) (of reactants and products)  
remain(s) constant / stay(s) the same / remain(s)  
the same / do(es) not change

**M2** Forward rate = Reverse / backward rate

*For M1 accept [ ] for concentration*

*NOT “equal concentrations” and NOT “concentration(s) is/are 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 endothermic  
or takes in / absorbs heat

OR

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

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

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

*M2 depends on a correct statement for M1*

*For M2, the equilibrium shifts/moves*

*to absorb the heat OR*

*to lower the temperature OR*

*to cool the reaction*

2

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

There are fewer moles (of gas) on the left OR more moles (of gas) on the right.

OR there is one mole (of gas) on the left and 2 moles on the right.

**M2 depends on correct M1 and must refer to pressure**

The equilibrium shifts / moves right to left to oppose the increase in pressure

*M2 depends on a correct statement for M1*

*For M2, the equilibrium shifts/moves to lower the pressure.*

2

[10]