



## 3.2.3 Equilibria

*Dynamic nature*

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99 minutes



98 marks

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- M1.** (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]

**M2.** (a) (i) **M1** (could be scored by a correct mathematical expression which must have

all  $\Delta H$  symbols and the  $\Sigma$  or SUM)

$$\mathbf{M1} \quad \underline{\Delta H}_r = \Sigma \Delta H_f(\text{products}) - \Sigma \Delta H_f(\text{reactants})$$

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

$$\mathbf{M2} \quad \underline{\Delta H}_r = -201 + (-242) - (-394)$$

$$\underline{\Delta H}_r = -201 - 242 + 394$$

$$\underline{\Delta H}_r = -443 + 394$$

(This also scores M1)

$$\mathbf{M3} = -49 \text{ (kJ mol}^{-1}\text{)}$$

**(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**

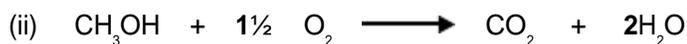
An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere.

**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*

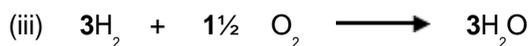
1



*Ignore state symbols*

*Accept multiples*

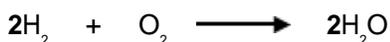
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*Ignore state symbols*

**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

[16]

**M3.** (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]

- M4.** (a) (i) chlorotrifluoromethane  
*Spelling must be correct but do not penalise “flouro”*  
*Ignore use of 1-*

1

- (ii)  $\text{CF}_3\cdot$

*May be drawn out with dot on C*

*OR if as shown dot may be anywhere*

1

- (iii) An unpaired/non-bonded/unbonded/free/a single/one/lone electron

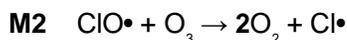
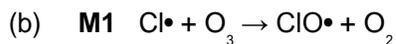
*NOT “bonded electron” and NOT “paired electron”*

*NOT “pair of electrons”*

*NOT “electrons”*

*Ignore “(free) radical”*

1



*Mark independently*

*Equations could gain credit in either position*

*The dot can be anywhere on either radical*

*Penalise the absence of a dot on the first occasion that it is seen and then mark on. Do not make the same penalty in the next equation, but penalise the absence of a dot on the other radical.*

*Apply the list principle for additional equations*

2

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

**OR**

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

*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.*

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

1

- (ii) **M1** The (forward) reaction/to the right is endothermic or takes in heat

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

**M2** The equilibrium moves/shifts to oppose the increase in temperature

*M2 depends on a correct statement for M1*

*For M2 accept*

*The equilibrium moves/shifts*

- to take in heat/lower the temperature*
- to promote the endothermic reaction and take in heat/ lower the temperature*
- to oppose the change and take in heat/lower the temperature*

*(leading to the formation of more ozone)*

2

(d) Any one of

- Pentane does not contain chlorine OR C–Cl (bond)
- Pentane is chlorine-free
- Pentane does not release chlorine (atoms/radicals)  
*Ignore reference to F OR C–F OR halogen*  
*Ignore “Pentane is not a CFC”*  
*Ignore “Pentane is a hydrocarbon”*  
*Ignore “Pentane only contains C and H”*  
*Ignore “Pentane is C<sub>5</sub>H<sub>12</sub>”*

1

[9]

**M5.** (a) **M1** Concentrations of reactants and products remain constant

*For M1*  
*NOT “equal concentrations”*  
*NOT “amount”*

1

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

*Credit the use of [ ] for concentration*  
*Ignore dynamic, ignore closed system*

1

(b) **M1** The (forward) reaction / to the right is exothermic or releases heat OR converse for reverse reaction.

1

**M2** The equilibrium responds by absorbing heat / lowering temperature  
**OR**

Promotes the endothermic reaction by absorbing heat / lowering temperature

**OR**

Temperature increase is opposed (by shift to the left)

**OR**

Change is opposed by absorbing heat / lowering temperature.

1

(c) (i) A substance that speeds up / alters the rate but is unchanged at the end / not used up.

*Both ideas needed*

*Ignore references to activation energy and alternative route.*

1

(ii) None OR no change OR no effect OR nothing OR Does not affect it / the position (of equilibrium) OR (The position is) the same or unchanged.

1

(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**

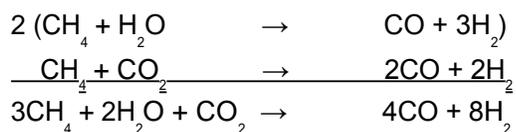
There is no change in the total amount of carbon dioxide / carbon / greenhouse gas present in the atmosphere.

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

*Ignore carbon monoxide*

1

(ii) A method which shows (see below) OR states in words that two times the first equation + the second equation gives the correct ratio.



Ratio = 1 : 2

1

[8]

**M6.** (a) Rate forward reaction = rate backward reaction (1)

Concentrations of reactants and products are constant (1)

2

(b) System opposes change (1)

Moves to the side with fewer moles (1)

In this case NH<sub>3</sub> (2 moles) on right side < N<sub>2</sub> + H<sub>2</sub> together (4 moles) on left side of equation (1)

3

(c) Too expensive to generate etc (1)

1

- (d) (i) Yield of ammonia increases (1)  
 Exothermic reaction favoured (1)  
 System moves to raise temp / or oppose decrease in temp (1) 3
- (ii) Faster reaction (1) 1
- (iii) Balance between rate and yield (1) 1
- [11]**

- M7.** (a) mark labelled **X** on curve **A** where curve **C** joins **A**; 1
- (b) equilibrium opposes a change;  
*(Q of L mark)* 1
- (c) **B** 1
- more ammonia is produced (or yield increases); 1
- fewer moles (of gas) on right ( or 4 mol goes to 2 mol); 1
- equilibrium moves to oppose increase in pressure (or oppose change); 1
- (d) **C** 1
- amount of ammonia (or yield or equilibrium) unchanged; 1
- reaction is faster; 1

**[9]**

<b>M8.</b>	(a)	Same	1	
	(b)	(i)	Decreases	1
			More moles on left hand side	1
			Equilibrium moves to increase the pressure <i>(Or to oppose the change or to compensate for low pressure)</i>	1
		(ii)	Cost of producing high pressure <b>(1)</b> Cost of plant to resist high pressure <b>(1)</b> Correct safety factor with reason <b>(1)</b>	<b>max 2</b>
	(c)	No change	1	
			Catalyst has no effect on equilibrium position <i>(Or catalyst affects rate of forward and backwards reactions equally)</i>	1
	(d)	Negative	1	
			Reaction <i>(or equilibrium)</i> moves in the exothermic direction <i>(or to the right)</i>	1
			In order to oppose the change <i>(or to raise the temperature)</i>	1
	(e)	Recycled <i>(or re-used or 'put back in')</i>	1	

[12]

<b>M9.</b>	(a)	<u>rate</u> forward reaction = <u>rate</u> backward reaction <b>(1)</b> concentration remains constant <b>(1)</b> <i>NOT 'Equal', Allow 'The same' if clear that means constant</i>	2
	(b)	fewer moles (of gas) on R.H.S <b>(1)</b> <b>(or converse)</b> (methanol favoured) by reducing applied pressure <b>(1)</b> <i>Or removing constraint</i>	2

- (c) Power / energy required to provide high pressure / pumping **(1)**  
Strong pressure vessel / or equipment **(1)**

*High maintenance costs (1)*

*High insurance costs (1)*

*Any two*

2

- (d) Effect: decreases **(1)**

Explanation: reaction exothermic (or reverse reaction endothermic) **(1)**

system tries to lower T or remove constraint or

oppose the change

or endothermic reaction favoured

3

- (e) to speed up reaction **(1)**

*or otherwise to slow*

*or takes too long*

*or to give more molecules  $E > E_A$*

1

**[10]**

