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Question 1

- 1.1 D
- 1.2 D
- 1.3 C
- 1.4 C
- 1.5 D
- 1.6 C
- 1.7 B
- 1.8 B
- 1.9 B
- 1.10 D

Question 2

2.1.1 Ne✓ (1)

2.1.2 N₂✓ (1)

2.1.3 diamond✓ (1)

2.1.4 NH₃✓ (1)

2.1.5 NaCl✓ (1)

2.1.6 NH₃✓ (1)

2.1.7 N₂ or diamond✓ (1)

2.2.1 Water or H₂O✓ (1)

2.2.2 Ion✓-dipole✓ force (2)

2.2.3 Mg(NO₃)₂(s) → Mg²⁺✓ (aq) + 2✓NO₃²⁻ ✓ (aq) ; phase indicators✓ (4)

2.2.4 $n = c.V$
 $= 0,15 \times 0,2$ ✓ (conversion)
 $= 0,03$ ✓(✓) mol of Mg(NO₃)₂
 $n = 2 \times 0,03 = 0,06$ ✓ mol of NO₃⁻ (coe from 2.2.3) (3)

2.2.5 $n = c.V$
 $= 0,5 \times 0,2$
 $= 0,1$ mol of NO₃⁻ ions in total
 $n = (0,1 - 0,06) = 0,04$ mol of NO₃⁻ ions added from sodium nitrate.
(coe from Q2.2.4)

$M = n \times M$
 $= 0,04 \times 85$
 $= 3,4$ g of NaNO₃ (5)

Marks the following skills:

- ✓✓ Method to work of total mols of NO₃⁻ including conversion
- ✓ Subtraction to get NO₃⁻ ions added from sodium nitrate
- ✓ Molar mass 85
- ✓ Mass of NaNO₃

OR

$[\text{NO}_3^-] = 2 \times 0,15 = 0,3 \text{ mol.dm}^{-3}$ from magnesium nitrate

Added $[\text{NO}_3^-] = 0,5 - 0,3 = 0,2 \text{ mol.dm}^{-3}$

Since NaNO_3 is 1:1

Therefore $[\text{NaNO}_3] = 0,2 \text{ mol.dm}^{-3}$

$$\begin{aligned} n &= cV \\ &= 0,2 \times 0,2 \\ &= 0,04 \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{And } m &= nM \\ &= 0,04 \times 85 \\ &= 3,4\text{g} \end{aligned}$$

[22]

Question 3

- 3.1.1 Heat of reaction is the net✓ change of chemical potential energy✓ of the system. (2)
- 3.1.2 The activated complex is a temporary transition state✓ between the reactants and the products. ✓ (2)
- 3.2 The colliding particles must have **enough kinetic energy greater than or equal to the activation energy.** ✓✓
The colliding particles must have the **correct orientation.** ✓✓ (4)
- 3.3.1 $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ (3)
reactants✓ products✓ bal✓
- 3.3.2 Use powdered or granulated zinc✓✓ (increase surface area 1 mark only)
Use concentrated hydrochloric acid✓✓ (increase [] 1 mark only)
Heat the test-tube of reactants✓✓ (6)
- 3.3.3 It interacts with the reactants in such a way that the reaction follows an **alternative path**✓ of **lower activation energy**✓. (2)
- 3.4.1 C (1)
- 3.4.2 D (1)
- [21]**

Question 4

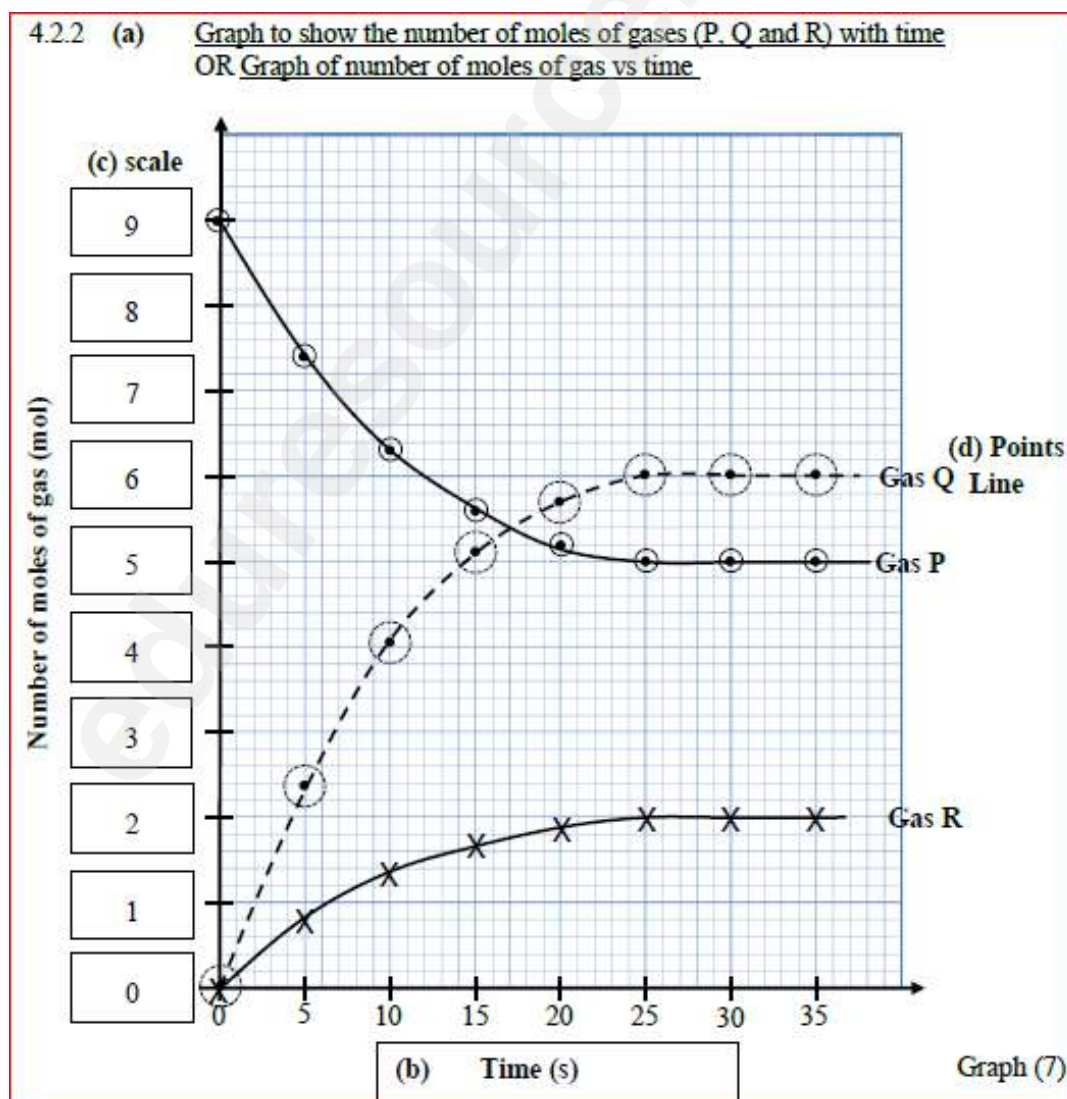
4.1.1 When an external stress is applied to a system in chemical equilibrium✓, the equilibrium point will change in such a way as to counteract the stress✓. (2)

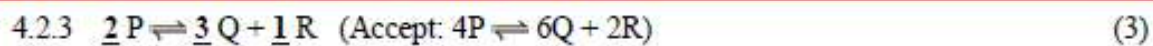
4.1.2 A measure of the extent of a reaction✓, generally measured by comparing the amount of product against the amount of product that is possible. ✓ (2)

4.1.3 Decrease volume of the container✓
This will increase the pressure✓ which will favour the forward reaction✓ which produces less moles of gas✓ (and therefore relieves the stress of high pressure. (4)

4.2.1 (a) DCE is reached when the rate of the forward reaction is equal to the rate of the reverse reaction. (1)

(b) There is no change in the number of moles (and hence concentration) of any of the gases after 25 s as shown by the data. (1)





4.2.4 $K_c = \frac{[Q]^3 \cdot [R]}{[P]^2}$ c.o.e. from Question 4.2.3 (2)

4.2.5 $K_c = \frac{\left[\frac{6}{5}\right]^3 \cdot \left[\frac{2}{5}\right]}{\left[\frac{5}{5}\right]^2}$ Marks $n_P = 5 \text{ mol}$ c.o.e. from Question 4.2.4
 $n_Q = 6 \text{ mol}$
 $n_R = 2 \text{ mol}$
 Divide by volume (5 dm^3)

$K_c = 0,69$

OR

$K_c = \frac{(1,2)^3 \cdot (0,4)}{(1)^2}$
 $K_c = 0,69$ (5)

4.2.6 Low yield c.o.e. from Question 4.2.5 (1)

[28]

Question 5

5.1 A strong acid ionises almost completely✓ in an aqueous solution, e.g. HY✓
A weak acid ionises partially in an aqueous solution, e.g. H₂X or HZ. (4)

5.2 A monoprotic acid is only able to donate one✓ proton, e.g. HY or HZ. ✓
A polyprotic acid is able to donate more than one proton, e.g. H₂X. (4)

5.3 HY✓ since it has the highest K_a✓ which means it is the strongest acid and would have the highest concentration of H₃O⁺ ions. (3)

5.4
$$\text{H}_2\text{X} + 2\text{H}_2\text{O} \rightleftharpoons 2\text{H}_3\text{O}^+ + \text{X}^{2-} \quad \text{ions balanced}$$

Or
$$\text{H}_2\text{X} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{HX}^- \quad \text{ions balanced}$$
 (3)

5.5.1
$$\text{HZ} + \text{NaOH} \rightarrow \text{NaZ} + \text{H}_2\text{O} \quad (-1 \text{ per error})$$
 (3)

5.5.2
$$n = c \times V$$

$$= 0,1 \times 0,0324$$

$$= 0,00324 \text{ mol or } 3,24 \times 10^{-3} \text{ mol}$$
 ✓✓
✓ (3)

5.5.3
$$c = n/V$$

$$= \frac{0,00324}{0,025}$$

$$= 0,13 \text{ mol.dm}^{-3}$$

Alternative (not recommended but will be accepted)
$$\frac{C_A V_A}{C_B V_B} = \frac{n_A}{n_B}$$

$$\frac{C_A \times 25,0}{0,1 \times 32,4} = \frac{1}{1}$$

$$C_A = 0,13 \text{ mol.dm}^{-3}$$
 (3)

5.5.4 Greater than 7✓ Na⁺ and OH⁻ form the strong base NaOH which remains fully dissociated. ✓ Z⁻ will undergo hydrolysis✓ and accept protons from water✓ leading to an excess of OH⁻ ions. ✓ (5)

5.5.5 (a) Phenolphthalein. (1)

(b) The indicator will change to the end-point or equivalence point colour over the pH range given✓, therefore the final pH of the solution (in this case >7) must fall within the pH range of the indicator✓ (2)

[31]

Question 6

6.1 (3)

Electrolyte concentration = $1 \text{ mol} \cdot \text{dm}^{-3}$
 Temperature = 25°C
 Pressure = 1 atmosphere / 101 kPa / $1,01 \times 10^5 \text{ Pa}$

6.2 $\text{CuSO}_4 / \text{Cu}(\text{NO}_3)_2 / \text{CuCl}_2$ (2)

6.3.1 $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$ (2)

6.3.2 $\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$ (2)

6.3.3 $\text{Cu} + \text{Cl}_2 \rightarrow \text{Cu}^{2+} + 2\text{Cl}^-$ (-1 for any error) (2)

6.4 (4)

$E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$ ✓
 $= 1,36 - 0,34$ ✓✓
 $= 1,02\text{V}$ ✓

6.5 (4)

$\text{Cu}/\text{Cu}^{2+} (1 \text{ mol} \cdot \text{dm}^{-3}) // \text{Cl}_2 / \text{Cl}^- (1 \text{ mol} \cdot \text{dm}^{-3}) / \text{Pt}$

✓anode

✓salt bridge

✓cathode

✓Pt

6.6

- Pt is an inert metal (must not react electrochemically in the cell)
- Pt is a good conductor of electricity. (2)

6.7 Potassium chloride/Sodium nitrate (etc.) (2)

6.8

- Anode – increase in concentration of cations.
- Cathode- decrease in concentration of cations } ✓
- Ionic imbalance✓
- Cations move into cathode half- cell and anions move into anode half cell✓✓
- OR ions from salt bridge move to each half cell to maintain ionic balance. (4)

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Question 7

7.1 Brine (1)

7.2 To act as an ion-selective✓ membrane which only allows Na⁺ ions to pass through into the cathode. ✓ (2)

7.3 $2\text{H}_2\text{O} + 2e^- \rightarrow \text{H}_2 + 2\text{OH}^-$ (2)

7.4 H₂O is a stronger oxidising agent than ✓ Na⁺ (aq) ✓ (2)

7.5 Skills to be marked:

- Minutes to seconds (150s) ✓
- Calculating Q✓
- **Method 1**
 - Mol of e⁻✓
 - Mol ratio 1:2✓
 - Mol of Cl₂✓
 - Calculating Volume✓✓
- **Method 2**
 - No. of e⁻ ✓
 - Calculating mol of e⁻✓
 - Mol ratio 1:2✓
 - Calculating volume✓✓

(7)

$$\begin{aligned}
 Q &= It \\
 &= 4\,000 \times 150 \\
 Q &= 600\,000\text{ C} \\
 2\text{Cl}^- &\rightarrow \text{Cl}_2 + 2e^- \\
 \textbf{Method 1} \\
 1\text{ mol of } e^- &= 96\,500\text{ C} \\
 \therefore n(e^-) &= \frac{600\,000}{96\,500} \\
 \therefore n(e^-) &= 6,22\text{ mol of } e^- \\
 \text{Cl}_2 : e^- \\
 1 : 2 \\
 n(\text{Cl}_2) &= \frac{6,22}{2} \\
 \therefore n(\text{Cl}_2) &= 3,11\text{ mol of Cl}_2 \\
 n &= \frac{V}{V_m} \\
 V &= nV_m \\
 &= 3,11 \times 22,4 \\
 V &= 69,66\text{ dm}^3\text{ of Cl}_2
 \end{aligned}$$

$$\begin{aligned}
 \textbf{Method 2} \\
 1e^- &= 1,6 \times 10^{-19}\text{ C} \\
 \therefore \text{no of } e^- &= \frac{600\,000}{1,6 \times 10^{-19}} \\
 n(e^-) &= 3,75 \times 10^{24} e^- \\
 n &= \frac{N}{N_A} \\
 &= \frac{3,75 \times 10^{24} e^-}{6,02 \times 10^{23}} \\
 n &= 6,23\text{ mol} \\
 \text{Cl}_2 : e^- \\
 1 : 2 \\
 n(\text{Cl}_2) &= \frac{6,23}{2} \\
 &= 3,12 \\
 n &= \frac{V}{V_m} \\
 V &= nV_m \\
 &= 3,12 \times 22,4 \\
 V &= 69,89\text{ dm}^3\text{ of Cl}_2
 \end{aligned}$$

[14]

Question 8

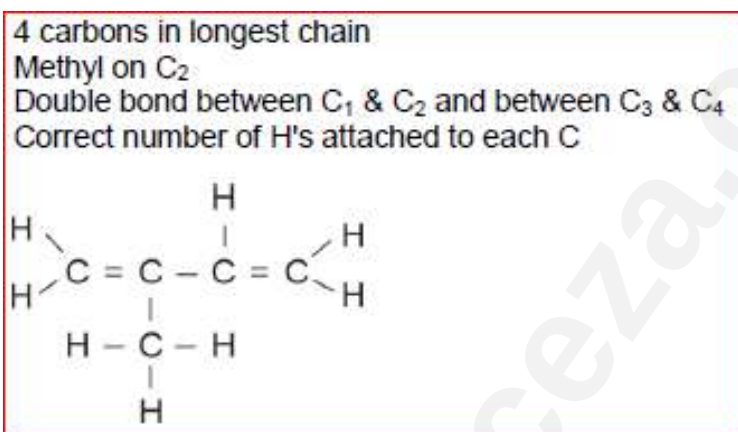
8.1.1 B (1)

8.1.2 A and F (2)

8.1.3 C and H (must have both, no part marks) (2)

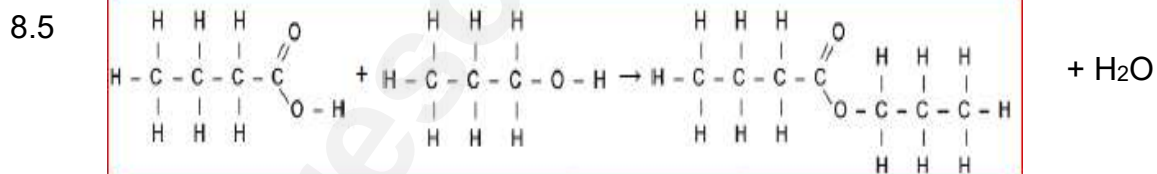
8.2 alcohol (1)

8.3 (4)



8.4 2-bromo-3-ethylhexane (4)

(2-bromo) ✓ -(3-ethyl) ✓ hex ✓ ane ✓



Ester linkage ✓

Either side of ester linkage ✓ ✓

Reactants ✓ ✓

water ✓

(6)

8.6

ONE of the following:

(4)

Structural formula (2 marks each)	IUPAC name (2 marks each)
<pre> H H-C-H H C H H H H-C - C - C - C-H H H H H </pre>	2-methylbutane (2 is redundant: don't penalise if missing)
<pre> H H-C-H H C H H H H-C - C - C - C-H H H C H H </pre>	2,2-dimethylpropane (2,2- is redundant: don't penalise if missing)

8.7 Ethanoic acid is able to form **TWO hydrogen bonds**✓ with another ethanoic acid molecule.

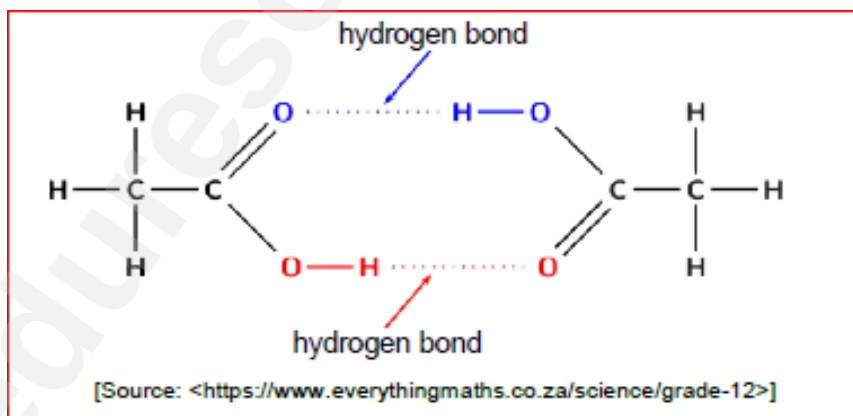
Propan-1-ol can only form **ONE** hydrogen✓ bond with another propan-1-ol molecule.

TWO hydrogen bonds per molecule are collectively **stronger** than ONE✓

More energy is needed to overcome two H-bonds compared with one H-bond therefore, ethanoic acid has a higher boiling point.

(4)

[28]



Question 9

9.1 X = methanol Y = hex-1-ene Z= ethanoic acid (3)

9.2 $\text{CH}_2\text{CHCH}_3 + \text{Br}_2 \longrightarrow \text{CH}_2\text{BrCHBrCH}_3$ (3)
Each reactant Product

9.3 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \longrightarrow \text{CH}_3\text{CH}_2\text{CHCH}_2 + \text{H}_2\text{O}$ (3)
Reactant both Products

[9]