THE SCHOOL FOR EXCELLENCE (TSFX)

UNITS 3 & 4 CHEMISTRY 2015

WRITTEN EXAMINATION – SOLUTIONS

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SECTION A – MULTIPLE CHOICE QUESTIONS

QUESTION 1   **Answer is D**

$$n\left(Na_2CO_3.10H_2O\right) = \frac{m}{M} = \frac{10.0}{286} = 0.034965 \, mol$$

$$n\left(H_2O\right) = 10 \times 0.034965 = 0.34965 \, mol$$

$$m\left(H_2O\right) = 0.34965 \times 18 = 6.29 \, g$$

**QUESTION 2**   **Answer is C**

Limiting Reaction is CO.

As the reaction is occurring at constant temperature and pressure, mole ratios may be used as volume ratios.

From mole ratios: $2 \, vols \, CO \rightarrow 2 \, vols \, CO_2$

$$\therefore 100 \, cm^3 \, CO \rightarrow 100 \, cm^3 \, CO_2$$

As only $50 \, cm^3$ of O_2 are consumed during the reaction, there will be $50 \, cm^3$ of O_2 remaining.

Final $V = 100 + 50 = 150 \, cm^3$

QUESTION 3   **Answer is C**

$$2AgNO_{3(aq)} + MgCl_{2(aq)} \rightarrow 2AgCl_{(s)} + MgNO_{3(aq)}$$
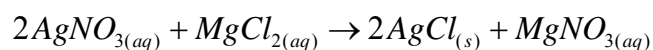
$$n(AgNO_3) = \frac{5.00}{171.9} = 0.0290867 \, mol \qquad n(MgCl_2) = \frac{10.00}{95.3} = 0.10493 \, mol$$

Therefore, $AgNO_3$ is the limiting reactant.

$n(Ag^+) = 0.0290867 \, mol$ All will react with Cl^- to produce a precipitate

$n(Cl^-) = 2 \times 0.10493 = 0.20986 \, mol$

$n(Cl^-)_{reacts \, with \, Ag} = 0.0290867 \, mol$

$n(Cl^-)_{remaining} = 0.20986 - 0.0290867 = 0.1807733 \, mol$

$n(NO_3^-) = 0.0290867 \, mol$ All will react with Mg^{2+} (product ionises)

$n(Mg^{2+}) = 0.10493 \, mol$ All Mg^{2+} will be in a form that can ionise in water

$$n(ions) = 0.1807733 + 0.0290867 + 0.10493 = 0.31479 \, mol$$

Number of ions = $0.31479 \times 6.02 \times 10^{23} = 1.89 \times 10^{23}$

QUESTION 4   **Answer is D**

A $10 \mu g L^{-1} = 0.00001 \, g L^{-1}$ (Convert $g \rightarrow mol$)

$$= \frac{0.00001}{207.2}$$

$$= 4.8 \times 10^{-8} M$$

B   Convert to number of g per 100mL to determine the concentration in % w/v

    $10 \mu g L^{-1}$ (Divide by 10 to determine $\mu g / 100mL$) $= 1 \mu g / 100mL$ (convert $\mu g \rightarrow g$)

$$= 1 \times 10^{-6} \, g / 100 \, mL$$

$$= 1 \times 10^{-6} \, \% \, w / v$$

C   Convert $\mu g \rightarrow mg$

    $1000 \, \mu g = 1 \, mg$ (Divide by 1000 to convert $\mu g \rightarrow mg$)

    $10 \mu g L^{-1} = 0.010 \, mg / L$

D ppm are equivalent to mg / L therefore, $10 \mu g L^{-1} = 0.010 \, ppm$ (not $0.10 \, ppm$)

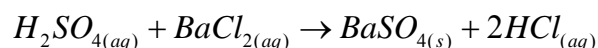**QUESTION 5**   **Answer is D**

The oxidation number of H in $LiAlH_4$ is -1.
Note: Oxidation numbers may be fractions and decimal values as well.

QUESTION 6   **Answer is D**

QUESTION 7   **Answer is A**

	C	H	O	N
m in 100 g	40.4	7.9	36	15.7
n	$\dfrac{40.4}{12} = 3.37$	$\dfrac{7.9}{1} = 7.9$	$\dfrac{36}{16} = 2.25$	$\dfrac{15.7}{14} = 1.12$
Ratio	3	7	2	1

Formula is $C_3H_7NO_2$: H$_2$N−CH−COOH
                                          |
                                          CH$_3$

QUESTION 8   **Answer is D**

$$H_2SO_{4(aq)} + BaCl_{2(aq)} \rightarrow BaSO_{4(s)} + 2HCl_{(aq)}$$

$$n(BaSO_4) = \frac{9.3}{233.4} = 0.039846 \, mol$$

$$\therefore n(H_2SO_4) = 0.039846 \, mol$$

$$\therefore c(H_2SO_4) = \frac{0.039846}{0.06} = 0.6641 \, M$$

Correct for dilution: $\therefore c(H_2SO_4) = 0.6641 \times 6 = 3.985 M$

QUESTION 9   **Answer is C**

If the mass used for the sample was smaller than it should be then the mass of the $NaCl$ will form a higher percentage of the total mass i.e. the calculated percentage will be higher.

QUESTION 10   **Answer is B**

From graph: 0.1 Abs units $= 2.5 \, mg \, / \, L$

Correct for $1:5$ dilution $= 2.5 \times 5 = mg \, / \, L$
$= 12.5 \, mg \, / \, 1000 \, mL$
$= 12.5 \, mg \, / \, 1000 \, g$ (assuming $d = 1 \, g \, / \, mL$)
$= 12.5 \times 10^{-3} g \, / \, 1000 \, g$
$= 12.5 \times 10^{-3} \times 10^3 \, g \, / \, 1,000,000 \, g = 12.5 \, ppm$

QUESTION 11   **Answer is A**

Choose the wavelength that gives maximum absorbance – but in a region where Sugar X absorbs exclusively.

QUESTION 12   **Answer is A**

Overall spin will only be observed in nuclei that have an odd number of nucleons such as ^{13}C . ^{12}C has an even number of nucleons, hence no overall spin.

QUESTION 13   **Answer is A**

AAS is used to determine the concentration of metal atoms in samples.

QUESTION 14   **Answer is D**

QUESTION 15   **Answer is A**

QUESTION 16   **Answer is C**

QUESTION 17   **Answer is C**

The mass of the ester is less than the mass of the two reactants it was made from.

$$m(ester) = m(acid) + m(carboxylic\ acid) - m(H_2O)$$

Therefore, the $\%C$ in the ester is higher than the $\%C$ in the reactants.

QUESTION 18   **Answer is A**

As this reaction is an addition polymerisation reaction – monomers need to be unsaturated (an alkene).

QUESTION 19   **Answer is D**

QUESTION 20   **Answer is A**

QUESTION 21   **Answer is B**

$$n(butane) = \frac{PV}{RT} = \frac{(1.5 \times 101.3) \times 4.0}{8.31 \times (273 + 10)} = \frac{151.95 \times 4.0}{8.31 \times 283} = 0.258\ mol$$

1 mole butane produces $2874\,kJ$ of heat. Hence 0.258 mole produces $2874 \times 0.258 = 741.5\ kJ$.

Use $E(J) = m \times c \times \Delta T$ to calculate the mass of water to heat. {Note: $\Delta T = 90$}

$$mass(H_2O) = \frac{E(J)}{4.18 \times 90} = \frac{741500}{376.2} = 1970\ mL$$

On each of the nights he can heat $986\ mL$ of H_2O .

QUESTION 22   **Answer is D**

Reverse the first equation and change the sign of the ΔH.

Double the coefficients of the first equation and its ΔH.

Then add to the second equation.

$$\Delta H = -2(-146) + 418 = 710 \, kJ$$

QUESTION 23   **Answer is B**

Reaction occurs between Cu^{2+} (in cathode) and Fe (in anode).

CH_3OH is not an electrolyte.

Ag^+ will migrate from the salt bridge to the cathode. As Ag^+ is a stronger oxidant than Cu^{2+}, it will react, interfering with cell reactions. Therefore, we cannot use $AgNO_3$.

K^+ is a very weak oxidant, therefore, it will not interfere with reactions. OH^- will move into the anode where it reacts with Fe^{2+} to form a precipitate. Therefore, KOH cannot be used.

QUESTION 24   **Answer is A**

List species in order from strongest oxidant to weakest oxidant.

From the given information:

When metal X is placed in a solution of Y^{2+} ions, Y and X^{2+} are formed.

Since X displaces Y^{2+} ions in solution, Y^{2+} must be a stronger oxidant.

When both metals are placed in an acidified solution, no reaction occurs.
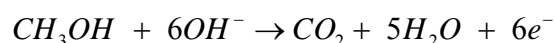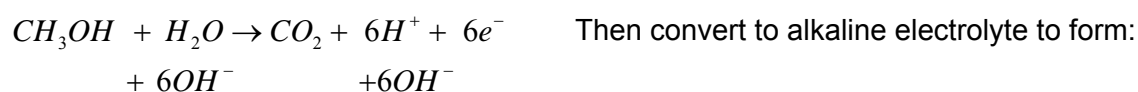
X and Y must have a higher E^o value than H^+ for the reaction to be non-spontaneous.

QUESTION 25   **Answer is B**

In the recharging process, the products are converted back to reactants. The negative electrode is the cathode where reduction takes place and the positive electrode is the anode where oxidation takes place. The oxidation state of Pb in $PbSO_4$ is $+2$, 0 in Pb and $+4$ in PbO_2. Reduction is from $PbSO_4$ to Pb, which takes place at the negatively charged cathode.

QUESTION 26   **Answer is B**

Derive a half-equation for $CH_3OH \, / \, CO_2$:

$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$ Then convert to alkaline electrolyte to form:
$$+ \, 6OH^- \qquad\qquad +6OH^-$$
\
$$CH_3OH + 6OH^- \rightarrow CO_2 + 5H_2O + 6e^-$$

QUESTION 27   **Answer is D**

Process C involves the conversion of the kinetic energy of steam to mechanical energy. Both energy forms are an example of kinetic energy, therefore, the answer is D.

QUESTION 28   **Answer is D**

$$n(methanol) = \frac{m}{M} = \frac{1.50}{32} = 0.046875\,mol$$

$$1\,mol \rightarrow -727\,kJ$$

$$0.046875\,mol \rightarrow x\,kJ$$

$$x = 34.078\,kJ$$

$$CF = \frac{E(J)}{\Delta T}$$

$$\Delta T = \frac{34078}{5410} = 6.30^0\,C$$

Final temperature is $20.50 + 6.30 = 26.80^o\,C$

QUESTION 29   **Answer is D**

QUESTION 30   **Answer is D**

As these energy profile diagrams are drawn to the same scale, visual comparisons can be made. Note, the activation energy for the forward and back reactions must be considered for both energy profiles.
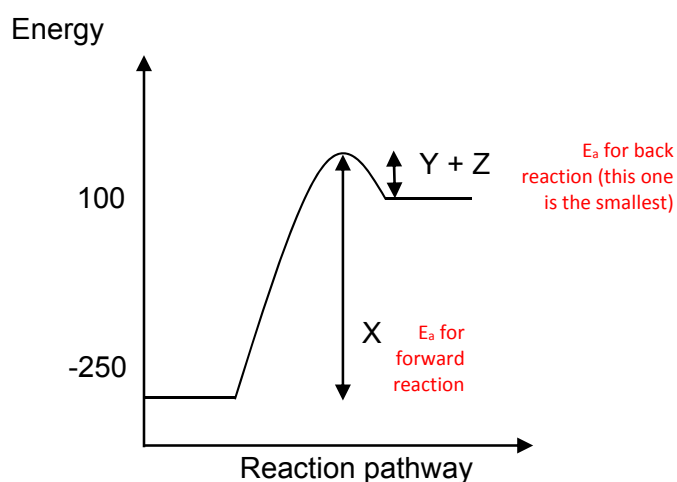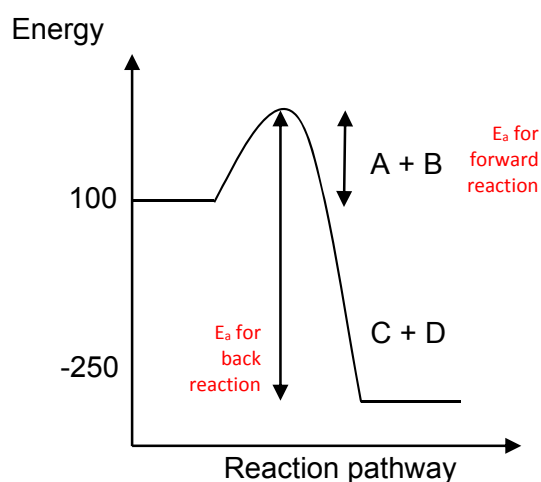
SECTION B – SHORT ANSWER QUESTIONS

QUESTION 1
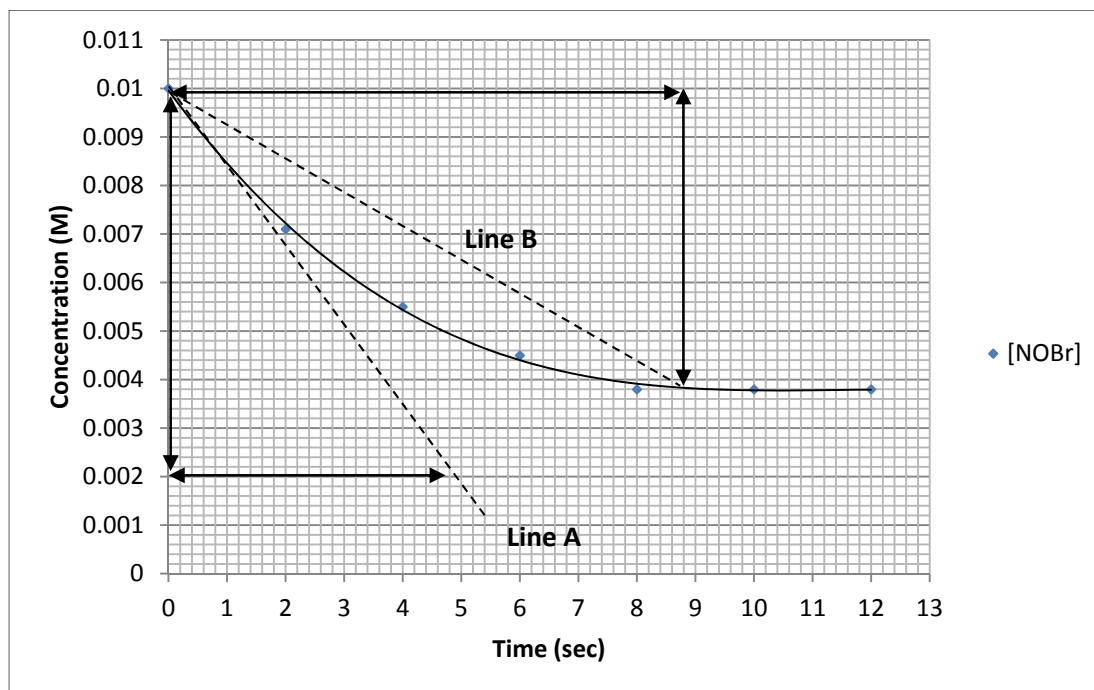
a. i.   Initial reaction rate = Gradient of line A

Gradient Line A $= \dfrac{rise}{run} = \dfrac{0.010 - 0.002}{0 - 4.8} = -1.6 \times 10^{-3} \left[NOBr \right] M.s^{-1}$

The rate is –ve since the concentration of NOBr is decreasing with time.

1 mark

ii. Average reaction rate = Gradient of line B

Gradient Line B $= \dfrac{rise}{run} = \dfrac{0.01 - 0.0038}{0 - 8.8} = -7.0 \times 10^{-4} \left[NOBr \right] M.s^{-1}$

1 mark

b. The initial rate is greater than the rate over first 8 seconds since the concentration of the reactants is higher at the start of the reaction. As the reaction proceeds, more reactants get used up, the reactant concentrations decrease, leading to fewer successful collisions.

1 mark

c.
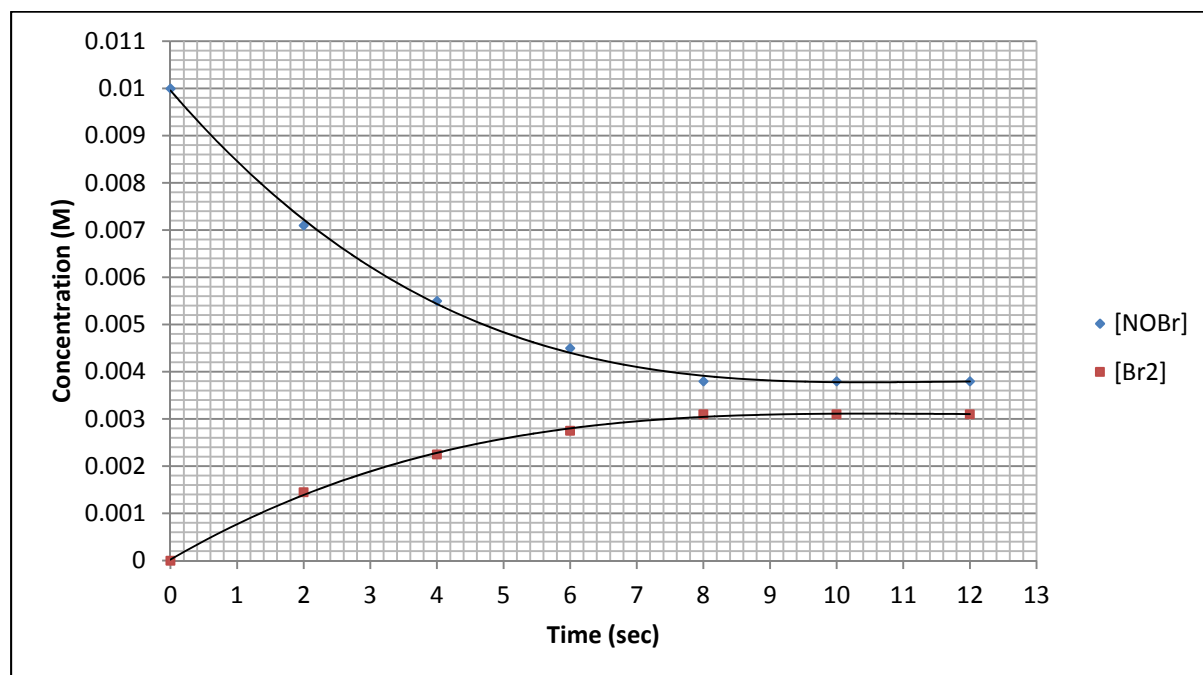
For every 2 mole $NOBr$ that reacts, only 1 mole Br_2 is produced. Therefore, $[Br_2]$ will increase at half the rate that the $[NOBr]$ decreases. (1)

To determine the $[Br_2]$ at each time interval, find the change in $[NOBr]$ then divide it by 2.

Time (s)	$[NOBr]$	$[Br_2]$
0	0.01	0
2	0.0071	0.00145
4	0.0055	0.00225
6	0.0045	0.00275
8	0.0038	0.0031
10	0.0038	0.0031
12	0.0038	0.0031

Sample calculation:

$$[Br_2] \text{ at 6 seconds } = \frac{\Delta[NOBr]}{2}$$
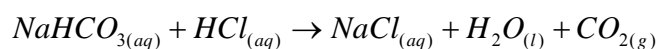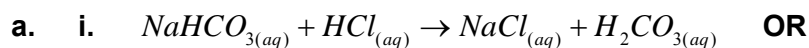
$$= \frac{(0.01 - 0.0045)}{2}$$

$$= 0.00275 \ M$$

At $t = 8$ sec, $[NOBr]$ remains stable indicating that the reaction has reached completion. At this stage the $[Br_2]$ will also remain constant. (1)

2 marks

d. Increasing the pressure by decreasing the volume is equivalent to increasing the concentration of reactants and products. (1) This results in more frequent collisions between product particles, the number of effective collisions increases, and hence the back reaction rate will also increase. (1)

2 marks

QUESTION 2

a. i. $NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2CO_{3(aq)}$ **OR**

$NaHCO_{3(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

1 mark

ii. If the baking soda is 100% pure sodium hydrogen carbonate:

$$n = \frac{m}{M} = \frac{2.06}{(23.0+1.0+12.0+3\times16.0)} = \frac{2.06}{84} = 0.0245 \; mol$$

Making this up to $250 \; mL$: $c = \frac{n}{V} = \frac{0.0245}{0.250} = 0.0981 \; M$ (1)

As the ratio of $NaHCO_3$ and HCl in the equation is $1:1$, $n(HCl)$ delivered from the burette will be equal to $n(NaHCO_3)$. As the concentration of the presumed 100% sodium hydrogen carbonate is less than the concentration of HCl being used, the volume of HCl required for the titration will be greater than the volume of $NaHCO_3$ present i.e. at least $20 \; mL$. Therefore, a $20 \; mL$ burette will not be sufficient for this titration. (1)

2 marks

b. The products at the equivalence point of this titration are acidic, meaning that an indicator which changes colour in the acidic region should be used. (1)

Phenolphthalein changes colour in the alkaline region and is therefore not a good choice for this titration. (1)

2 marks

c. i. John has included the $24.36 \; mL$ which should have been excluded as an outlier and a trial titration. (1 mark) The average titre being used is therefore higher than what it should be.

ii. $n(NaHCO_3)$ in $20 \; ml$ aliquot $= n(HCl) = 0.02404 \times 0.100 = 0.002404 \; mol$ (1)

$n(NaHCO_3)$ in $250 \; mL$ flask $= 0.002404 \times \dfrac{250}{20} = 0.03005 \; mol$ (1)

$mass(NaHCO_3) = 0.03005 \times 84 = 2.5242 \; g$

$\% \; Purity = \dfrac{(2.5242 \times 100)}{2.06} = 126\% \; (3 \; sf)$ (1)

3 marks

iii. Using a higher average titre. (1)

The wrong indicator was used for the titration (1).

The indicator used would change colour after the equivalence point of the reaction. This means that a greater volume of HCl than that required would be delivered from the burette, resulting in the $n(NaHCO_3)$ and $mass(NaHCO_3)$ calculated being higher than the true values. This would result in a higher calculated % than the true value. (1)

Using a higher average titre would have the same effect on the calculated percentage.

3 marks

QUESTION 3

a. **i.** The double bonds in unsaturated hydrocarbon molecules are broken and two atoms of bromine are added via an addition reaction. In the process, the concentration of bromine decreases. (1)

$$CH_2 = CH_{2(g)} + Br_{2(g)} \rightarrow CH_2Br - CH_2Br \quad (1)$$
$$\text{Brown} \quad \text{Colourless}$$
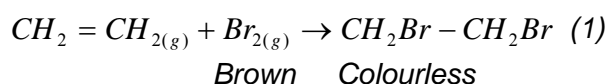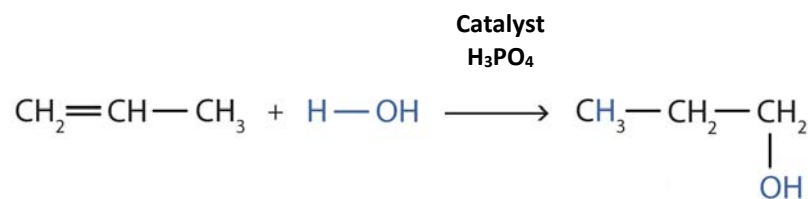
2 marks

ii. UV light.

1 mark

b. Difference in chemical properties: Reactivity differs due to the presence of the double bonds in alkenes. (1)

Similarity in physical properties: Due to similar chain length, composition and polarity. (1)
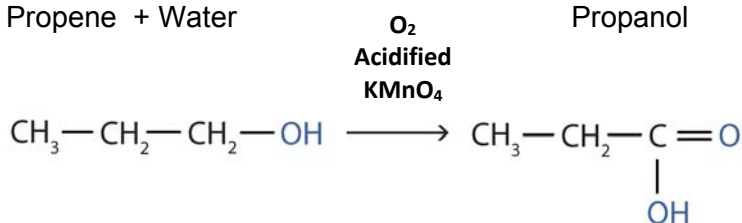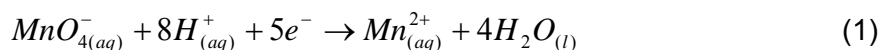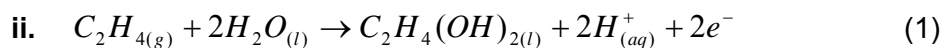
2 marks

c. **i.**

3 marks

ii. $C_2H_{4(g)} + 2H_2O_{(l)} \rightarrow C_2H_4(OH)_{2(l)} + 2H^+_{(aq)} + 2e^-$ (1)

$MnO^-_{4(aq)} + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$ (1)

Balance for electrons:

$5C_2H_{4(g)} + 10H_2O_{(l)} \rightarrow 5C_2H_4(OH)_{2(l)} + 10H^+_{(aq)} + 10e^-$

$2MnO^-_{4(aq)} + 16H^+_{(aq)} + 10e^- \rightarrow 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$

Overall equation:

$5C_2H_{4(g)} + 10H_2O_{(l)} + 2MnO^-_{4(aq)} + 16H^+_{(aq)}$
$$\rightarrow 5C_2H_4(OH)_{2(l)} + 10H^+_{(aq)} + 2Mn^{2+}_{(aq)} + 8H_2O_{(l)}$$

$5C_2H_{4(g)} + 2H_2O_{(l)} + 2MnO^-_{4(aq)} + 6H^+_{(aq)} \rightarrow 5C_2H_4(OH)_{2(l)} + 2Mn^{2+}_{(aq)}$ (1)
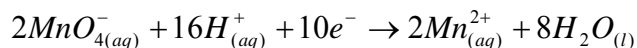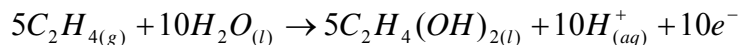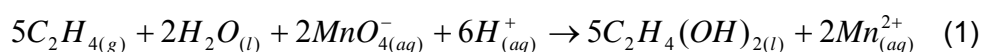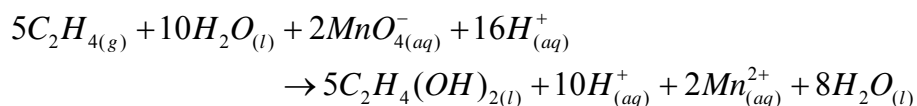
<div align="right">3 marks</div>

QUESTION 4

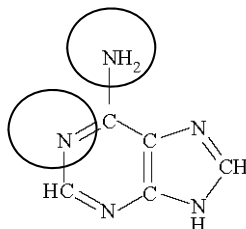**a.**   **i.**   Circle A. Proteins in the body are produced from α or 2 amino acids. (1)

     ii.   Circle E and F. Note: Molecule D is a sugar but forms the component of nucleotides rather than carbohydrates. (1)
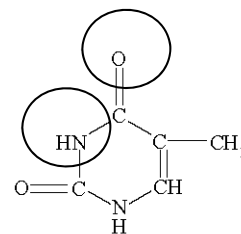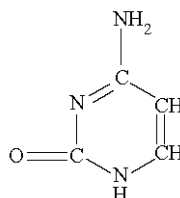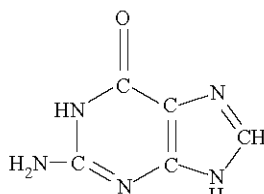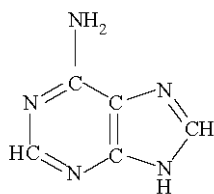
     iii.   Circle I. (1)

<div align="right">3 marks</div>

b.   **i.**

<div align="right">1 mark</div>

   ii.

adenine (A)   thymine (T)
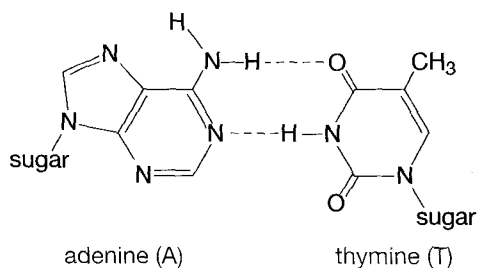
1 mark for correctly identifying the base.
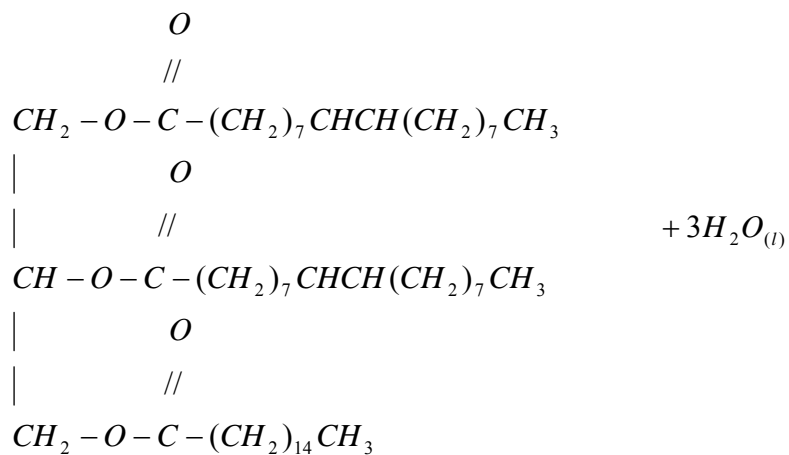1 mark for circling the components involved in maintaining the secondary structure.

2 marks

c. Molecule C is adenine which forms 2 hydrogen bonds with thymine. As it produces fewer hydrogen bonds when pairing with its complementary base as compared to the pairing bonds involved between cytosine and guanine, a strand mainly consisting of A – T would display fewer forces, hence lower temperatures would be required for melting. (1) The curve that best represents this scenario is curve A. (1)

2 marks

QUESTION 5

a.

$$
\begin{array}{l}
\quad\quad\quad\quad O \\
\quad\quad\quad\quad // \\
CH_2 - O - C - (CH_2)_7 CHCH(CH_2)_7 CH_3 \\
\quad | \quad\quad\quad\quad O \\
\quad | \quad\quad\quad\quad // \quad\quad\quad\quad\quad\quad\quad + 3H_2O_{(l)} \\
CH - O - C - (CH_2)_7 CHCH(CH_2)_7 CH_3 \\
\quad | \quad\quad\quad\quad O \\
\quad | \quad\quad\quad\quad // \\
CH_2 - O - C - (CH_2)_{14} CH_3
\end{array}
$$

$$ \downarrow $$

$$ C_3H_8O_3 + 2COOH(CH_2)_7 CHCH(CH_2)_7 CH_3 + COOH(CH_2)_{14} CH_3 $$

2 marks

b. **i.** One of two answers accepted:

$$CH_3(CH_2)_7CHCH(CH_2)_7COOH + CH_3OH_{(l)}$$
$$\rightarrow CH_3(CH_2)_7CHCH(CH_2)_7COOCH_{3(l)} + H_2O_{(l)}$$

OR

$$CH_3(CH_2)_{14}COOH_{(l)} + CH_3OH_{(l)} \rightarrow CH_3(CH_2)_{14}COOCH_{3(l)} + H_2O_{(l)}$$
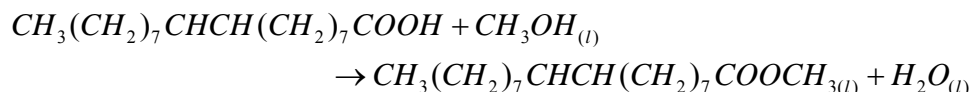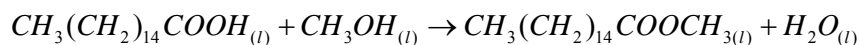
1 mark

ii. One of two answers accepted:

$$2C_{18}H_{34}O_{2(l)} + 33O_{2(g)} \rightarrow 36CO_{(g)} + 34H_2O_{(l)}$$

OR

$$C_{16}H_{32}O_{2(l)} + 15O_{2(g)} \rightarrow 16CO_{(g)} + 16H_2O_{(l)}$$
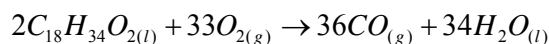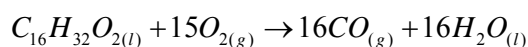
1 mark

c. **i.** Reagent A is $H_{2(g)}$. (1)

Substance B is a catalyst (platinum). (1)

ii. Answer is B. (1)

3 marks

QUESTION 6

**a.** **i.** $C_3H_6O_6^+$. Species must be positively charged to obtain the full mark.

1 mark

ii. The peak corresponding to mass/charge ratio 74 is caused by the ionised molecule of B consisting of the ^{12}C isotope. The Peak at 75 is caused by the molecular ion consisting of one ^{13}C atom.

1 mark

b. **i.** The very broad dip at about $3000\ cm^{-1}$ is due to $O-H$.

The dip at about $1700\ cm^{-1}$ is due to $C=O$.

The molecule is therefore most likely to be a carboxylic acid.

1 mark

ii. Due to differences in the energies between atoms and molecules, different environments may be created, resulting in different IR spectra.

2 marks

c. **i.** The peak areas are in the ratio $1:2:3$ (from left to right) indicating how many of each type of hydrogen atom is present in the molecule.

The shift at about $11.5\ ppm$ suggests the presence of a H atom in $R-COOH$. As the relative area is 1 – there is 1 such H atom in this environment.

The shift at about $2.6\ ppm$ suggests the presence of a H atom in $R-CH_2-COOH$. As the relative area is 2 – there are 2 such H atoms in this environment.

The shift at about $1\ ppm$ suggests the presence of a H atom in $R-CH_3$. As the relative area is 3 – there are 3 such H atoms in this environment.
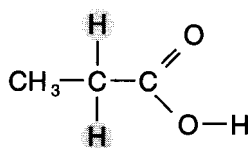
2 marks

ii. Isomers display the same number of each type of atom, However, due to different structural arrangements, different chemical environments will be produced. (1) Therefore, NMR spectra of molecules will vary amongst isomers. (1)

2 marks

QUESTION 7

a. **i.** So that sample components can be carried through the column.

1 mark

ii. Any inert (unreactive) gas such as N_2 or He.

1 mark

b. **i.** The functional group of carboxylic acids contains 3 polar covalent bonds (as opposed to 2 polar covalent bonds in the hydroxyl functional group of the alcohols). (1)

The net strength of forces between the carboxylic acids and the stationary phase will be greater, resulting in longer retention times. (1)

2 marks

ii. Propanol.

1 mark

iii. Species A.

1 mark

iv. Any two of the following:

- Increase the column length.
- Decrease the flow rate of the carrier gas.
- Change the stationary phase so that components exhibit a stronger affinity to it.
- Decrease the temperature.

1 mark

QUESTION 8

a. $K_c = \dfrac{[H_2SO_{5(l)}][H_2O_{(l)}]}{[H_2O_{2(l)}][H_2SO_{4(l)}]}$

1 mark

b.

	H_2O_2	H_2SO_4	H_2SO_5	H_2O
Initial Ratio	1	2.5	0	1.80
Mole Transferred	0.7↓	0.7↓	0.7↑	0.7↑
Eq Mole	0.30	1.80	0.70	2.50

(1+1)

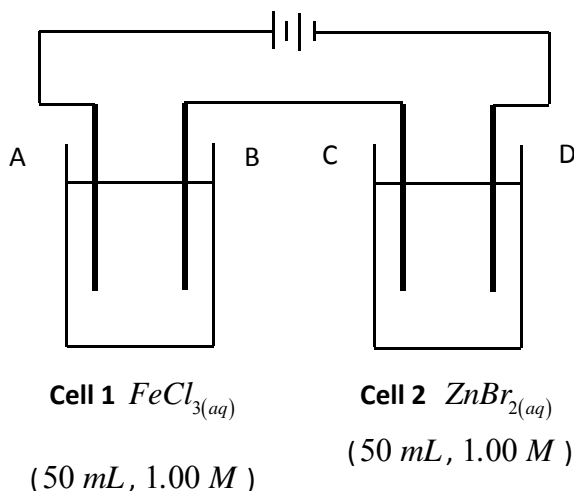$K_c = \dfrac{0.70 \times 2.50}{0.30 \times 1.80} = 3.2$ (1)

3 marks

c. **i.** Net forward reaction. (1)

ii. Decreases. (1) (Reactant concentration decreases, hence collision frequency decreases, hence forward reaction rate decreases).

iii. Lower. (1)
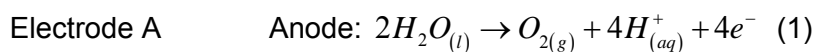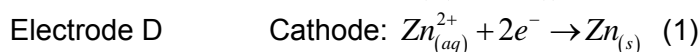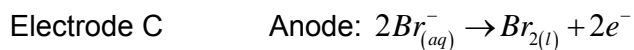
iv. Lower. (1)

4 marks

QUESTION 9

a.

Cell 1 $FeCl_{3(aq)}$

Cell 2 $ZnBr_{2(aq)}$

$(50\ mL,\ 1.00\ M)$

$(50\ mL,\ 1.00\ M)$

i. Possible reactants in Cell 1: Fe^{3+}, Cl^-

Possible reactants in Cell 2: Zn^{2+}, Br^- and water

Cell 1:

Electrode A   Anode: $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$ (1)

Electrode B   Cathode: $Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$

Cell 2:

Electrode C   Anode: $2Br^-_{(aq)} \rightarrow Br_{2(l)} + 2e^-$

Electrode D   Cathode: $Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$ (1)

2 marks

ii. $2H_2O_{(l)} + 4Fe^{3+}_{(aq)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4Fe^{2+}_{(aq)}$
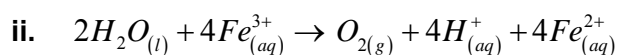
1 mark

iii. Ignoring over potentials:

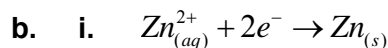Voltage for Cell 1 $= 0.77 - 1.23 = -0.46\ V$

Therefore, at least $0.46\ V$ is required. (1)

Voltage for Cell 2 $= -0.76 - 1.09 = -1.85\ V$

Therefore, at least $1.85\ V$ is required. (1)

A greater voltage is needed for Cell 2 than for Cell 1. If $1.85\ V$ is applied to both Cells, there is the potential for other reactions to occur in Cell 1 other than those predicted by the electrochemical series. (1)
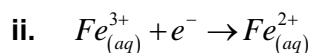
3 marks

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b. **i.** $Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$

$n(Zn) = \dfrac{1.02}{65.4} = 0.0156 \ mol$

$n(e^-) = 2 \times n(Zn) = 2 \times 0.0156 = 0.0312 \ mol$

1 mark

ii. $Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$

$n\left(Fe^{3+}_{(aq)}\right)$ reacted $= n(e^-)$

$n\left(Fe^{3+}_{(aq)}\right)$ reacted $= 0.0312 \ mol$ (1)

$n\left(Fe^{3+}_{(aq)}\right)$ left over $= \left(Fe^{3+}_{(aq)}\right)$ initial $- \left(Fe^{3+}_{(aq)}\right)$ reacted

$\qquad\qquad = (1.00 \times 0.0500) - 0.0312 = 0.0188 \ mol$ (1)

$c\left(Fe^{3+}_{(aq)}\right)$ left over $= \dfrac{0.0188}{0.05} = 0.376 \ M$ (1)

3 marks

iii. $Q = n(e^-) \times F = 0.0312 \times 96500 = 3010 \ C$ (1)

$t = \dfrac{Q}{I} = \dfrac{3010}{2.50} = 1204 \ s = 20.1 \ min$ (1)

2 marks

c. There would be no difference. (1) The extent of the reaction occurring in Cell 1 is determined by the amount current that runs through the cell, not by the chemical species in Cell 2.

1 mark

d. **i.** The rate of the reaction would increase if the surface area of the electrodes increases.
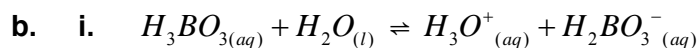
1 mark

ii. If the electrodes are placed closer together, the overall cell resistance goes down allowing for a faster reaction rate.

1 mark

QUESTION 10

a. The value of K_a for boric acid is very small, indicating that it is an extremely weak acid. Since the corrosive nature of an acid depend on the $[H_3O^+]$, this would be very low in boric acid and a dilute solution could be safely used without causing harm.

1 mark

b. **i.** $H_3BO_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{\ (aq)} + H_2BO_3^-_{\ (aq)}$

$$K_a = \frac{\left[H_3O^+\right]^2}{\left[H_3BO_3\right]} = 7.3 \times 10^{-10} \quad (1)$$

$$\therefore \left[H_3O^+\right] = \sqrt{7.3 \times 10^{-10} \times 0.5} = 1.9 \times 10^{-5} M \quad (1)$$
$$pH = -\log_{10} 1.9 \times 10^{-5} = 4.7 \quad (1)$$

3 marks

ii. The approximation can be applied because the K_a value is less than 1.0×10^{-4}.

1 mark

iii. % Hydrolysis $= \dfrac{[\text{One Product}]}{[\text{Initial Reactant}]} = \dfrac{\left[H_3O^+\right]}{\left[H_3BO_3\right]} \times 100 \quad (1)$

$$\% = \frac{1.9 \times 10^{-5}}{0.50} \times 100 = 0.0038\% \quad (1)$$

2 marks