# CHEMISTRY

## Units 3 & 4 - Written examination

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## (TSSM's 2015 trial exam updated for the current study design)

## ***<u>SOLUTIONS</u>***

**SECTION A: Multiple-choice questions (1 mark each)**

**Question 1**

*Answer:* A

*Explanation:*

Bromine is a stronger oxidant than iodine. Thiosulfate is oxidised and bromine is reduced in this reaction.

**Question 2**

*Answer:* C

*Explanation:*
Option 1 cannot form a cis or trans isomer due to the fact that one of the carbons connected to the double bond has two hydrogens bonded to it.

**Question 3**

*Answer:* D

*Explanation:*

Options A and C will have splitting in the H-NMR
Option B will only have 2 C peaks
Option D will have 2 single H peaks and 3 C peaks

**Question 4**

*Answer:* C

*Explanation:*

$^1$H-NMR uses radio waves which have the longest wavelengths.

**Question 5**

*Answer:* D

*Explanation:*

n ($C_2H_5OH$) = m/M = 20.0/46.0 = 0.435 mol
E = n x $\Delta$H = 0.435 x 1372 = 597 kJ

**Question 6**

*Answer:* D

*Explanation:*
Secondary alcohols will form ketones when oxidised.
Options A and B are primary alcohols and Option C is a tertiary alcohol.

**Question 7**

*Answer:* B

*Explanation:*

The number of mole of carbon has to be used for this calculation as it is the scarce reagent in this reaction.
$n(\text{Al}) = \frac{4}{3} \times 0.72 = 0.96$ mol

**Question 8**

*Answer:* D

*Explanation:*

$n(\text{C}) = \frac{36}{12} = 3 mol \quad = n(CO_2)$

$V = n \times 24.8 = 74.4$ L

**Question 9**

*Answer:* B

*Explanation:*

Oxidation reaction: $I^- + 3H_2O \rightarrow IO_3^- + 6H^+ + 6e^-$
Reduction reaction: $MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$
Overall reaction: $6MnO_4^- + 18H^+ + 5I^- \rightarrow 6Mn^{2+} + 9H_2O + 5IO_3^-$

**Question 10**

*Answer:* A

*Explanation:*

Electrons flow from anode to cathode. Electrons are flowing from M → N, therefore M is undergoing oxidation.

**Question 11**

*Answer:* C

*Explanation:*

Catalysts decrease the activation energy.

**Question 12**

*Answer:* C

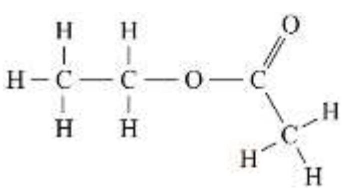
*Explanation:*

An equilibrium constant of $10^{-4}$ means that the [reactants] is much less than the [products], therefore the reaction is unfavourable and will not have very much product.

**Question 13**

*Answer:* D

*Explanation:*




Ethyl ethanoate is shown – it has four carbon atoms and each has a unique environment. There are three different hydrogen environments.

**Question 14**

*Answer:* C

*Explanation:*

Fatty acids have two oxygen atoms so the molecular formula is probably $C_{18}H_{32}O_2$. A saturated fatty acid will have the formula $C_nH_{2n+1}COOH$. In this case, the fatty acid would have 36 hydrogen atoms if it was saturated. As it has 4 less than that it must have two carbon to carbon double bonds.

**Question 15**

*Answer:* B

*Explanation:*

When the volume is decreased, the green intensity increases. The volume decrease favours the forward reaction, as there are less product molecules than reactants. This will reduce the green intensity but the net change in green intensity is still an increase over the original value.

**Question 16**

*Answer:* D

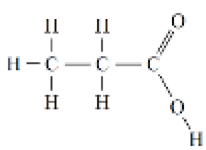
*Explanation:*

The temperature is increased and the amount of chlorine increases. As chlorine is a reactant then the temperature increase has led to a drop in the value of K. This is consistent with an exothermic reaction.

**Question 17**

*Answer:* C

*Explanation:*



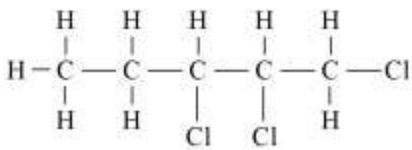

Like ethanoic acid, propanoic acid can be formed from the oxidation of the equivalent alkanol, in this case propan-1-ol. None of the other options are correct.

**Question 18**

*Answer:* A

*Explanation:*




Numbering should start from the right hand end. This will give 1,2,3- trichloropentane making A the correct answer.

**Question 19**

*Answer:* B

*Explanation:*

Options 1 and 2 have uneven number of molecules on either side of the equations.

**Question 20**

*Answer:* D

*Explanation:*

The molecule shown contains a carboxyl group on the right hand end and an amine and amide group close to each other in the middle. It does not contain an ester or a hydroxyl group.

**Question 21**

*Answer:* A

*Explanation:*

When a reaction is reversed, the sign of the value of $\Delta H$ changes (it becomes positive) and the numerical value of K becomes the reciprocal of the original value (1/5.6 = 0.18).

**Question 22**

*Answer:* A

*Explanation:*

Commercial production of electricity from nuclear sources involves nuclear fission. In nuclear fission, large nuclei are split, releasing neutrons that can further split more nuclei. Large amounts of energy are released as thermal energy in this process.

**Question 23**

*Answer:* D

*Explanation:*

$n(\text{ethanol}) = \frac{0.46}{46} = 0.01$ mol

energy released (from Data Book) = 0.01 ×1364 = 13.64 kJ = $1.36 \times 10^4$ Joule

**Question 24**

*Answer:* B

*Explanation:*

$E = shc \times mass \times \Delta T$ where shc = specific heat capacity

750 = x × 80 × 3.9

x = 750/312 = 2.40

**Question 25**

*Answer:* B

*Explanation:*

The relevant half-equations are

$I_2(s) + 2e^- \rightarrow 2I^-(aq)$
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

Iodine will react with zinc metal. The zinc will be oxidised to zinc ions at the anode which is the negative electrode.

**Question 26**

*Answer:* A

*Explanation:*

The question states that the cell is using an alkaline electrolyte, so $OH^-$ ions will be present and not $H^+$ ions. The carbon in methane will form carbon dioxide, meaning the balanced half equation will be :

$CH_4(g) + 8OH^-(aq) \rightarrow CO_2(g) + 6H_2O(g) + 8e^-$

This is oxidation, which will occur at the anode.

**Question 27**

*Answer:* D

*Explanation:*

Methane is produced from biomass from the action of anaerobic bacteria. Biomass can be obtained from sewerage, food scraps and other organic waste. Fermentation is not a correct answer as it produces ethanol. Coal as a fuel is not a sustainable resource.

**Question 28**

*Answer:* D

*Explanation:*

This is electrolysis of an aqueous solution so the relevant half equations are;

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow \underline{2H_2O(}l)$
$\underline{Ag^+}(aq) + e^- \rightarrow Ag(s)$
$\underline{2H_2O(}l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

The strongest oxidant, $Ag^+$, will react with the strongest reductant, $H_2O(l)$
The silver ions are reduced and water is oxidised to oxygen gas at the anode.
Therefore oxygen gas is produced at the positive electrode.

**Question 29**

*Answer:* C

*Explanation:*

Using the working from question 28, silver metal is produced in a reduction reaction, which will occur at the negative cathode.

**Question 30**

*Answer:* D

*Explanation:*

$Q = It = 8.4 \times 12 \times 60 = 6048$ C

$n(\text{e}) = \frac{6048}{96500}$ =0.0627 mol = $n$(Ag)

*mass*(Ag) = n × M = 0.0627 × 107.9 = 6.77 g

**SECTION B : Short-answer questions**

**Question 1** (9 marks)

**a**. $Fe (s) + H_2SO_4 (aq) \rightarrow FeSO_4 (aq) + H_2(g)$ 1 mark

**b.** Oxidation: $Fe^{2+} (aq) \rightarrow Fe^{3+} (aq) + e^-$

Reduction: $MnO_4^- (aq) + 8H^+ (aq) + 5e^- \rightarrow Mn^{2+} (aq) + 4H_2O (l)$*

Overall: $MnO_4^- (aq) + 5Fe^{2+} (aq) + 8H^+ (aq) \rightarrow Mn^{2+} (aq) + 5Fe^{3+} (aq) + 4H_2O (l)$ *

2 marks

**c.** n ($MnO4^-$) = c x v = 0.0196 x 0.0220 = 4.31 x $10^{-4}$ mol*

n ($Fe2^+$) in 25 mL = 4.31 x $10^{-4}$ x 5 = 0.00216 mol*

n ($Fe2^+$) in 250 mL = 0.00216 x 250/25 = 0.0216 mol*

m (Fe) = 0.0216 x 55.8 = 1.20 g*

m (C) = 1.27 – 1.20 = 0.07 g

% (C) = 0.07/1.27 x 100 = 5.51%*

**Question 2** (4 marks)

**a.** $C_{12}H_{22}O_{11}$ (s) + $12O_2$ (g) → $12CO_2$ (g) + $11H_2O$ (g)* ΔH = -5460 kJ/mol*

2 mark

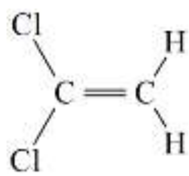
**b.** n (sucrose) = m/M = 1.00/(12x12.0 + 22.0 + 11x16.0) = 1.00/342.0 = 0.00292 mol*
E = n x ΔH = 0.00292 x 5460* = 16.0 kJ*

3 marks

**Question 3** (11 marks)

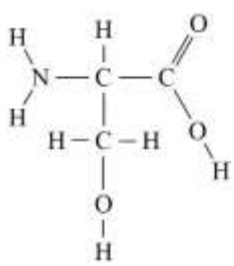
**a**.

**i**. 1 mark



**ii**. 1,1-dichloroethene 1 mark

**b**. **i**. 2 marks



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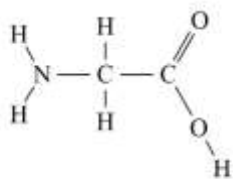

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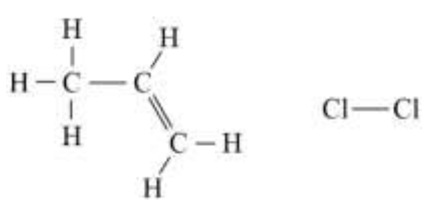
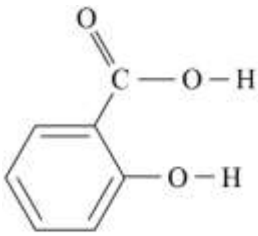
**ii**. Molecule A: serine * Molecule B: glycine * 2 marks

**c**. **i**. 2 marks



**ii**. Addition. 1 mark

**d**. 2 marks



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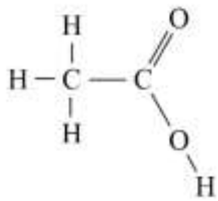

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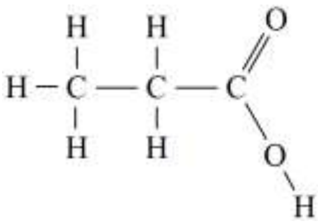
**Question 4** (11 marks)

**a**. 1 mark



**b**. **i**. $C_3H_6O_2 + e^- \rightarrow C_3H_6O_2^+ + 2e^-$ 1 mark

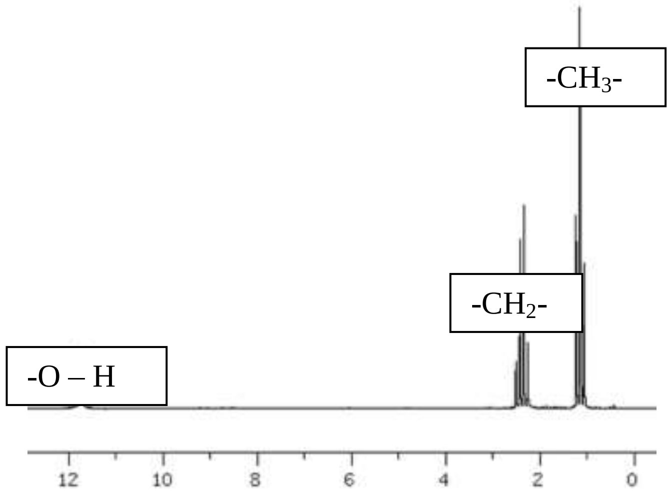
**ii.** Perhaps $COOH^+$ 1 mark

**c**. 2 marks

- Peak at 2500-3300 $cm^{-1}$ O – H (acid)
- Peak at 1680-1750 $cm^{-1}$ C = O

**d**. **i**.

3 marks




**ii**. 2.4 ppm quartet as group is beside – $CH_3$ n + 1 rule gives quartet 2 marks

1.1 ppm triplet as group is beside -$CH_2$ n+1 rule gives triplet

**iii**. 1:2:3 (from left to right) 1 mark

**Question 5** (9 marks)

**a**. **i**. Glucose will be soluble due to the presence of so many O – H bonds. These bonds are highly polar and will lead to hydrogen bonds forming between water and glucose.

1 mark

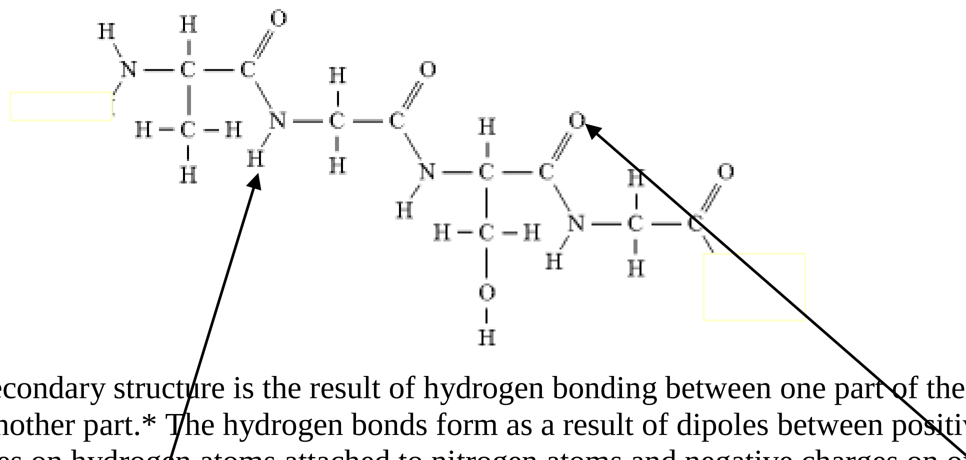
**ii**. Ether or glycosidic. 1 mark

**iii**. One of starch, cellulose or glycogen. 1 mark

**iv**. $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ 1 mark

**v**. $C_6H_{12}O_6(aq) \rightarrow 2C_2H_6O(aq) + 2CO_2(g)$ 1 mark

**b**.



**i**. The secondary structure is the result of hydrogen bonding between one part of the chain and another part.* The hydrogen bonds form as a result of dipoles between positive charges on hydrogen atoms attached to nitrogen atoms and negative charges on oxygen atoms attached to carbon atoms.*

2 marks

**ii**. The difference in the amino acids is the -R group. In glycine and alanine, the R group is an alkyl group that is non-polar and low in solubility*. In serine, a significant dipole exists, so the solubility in water will be higher*.

2 marks

**Question 6** (10 marks)

**a**. **i**. 1 mark

$K = \frac{[CO_2][H2]^4}{[CH4][H2O]^2}$

**ii**.

| | $CH_4(g)$ | + $2H_2O(g)$ | ⇄ $CO_2(g)$ | + $4H_2(g)$ |
|---|---|---|---|---|
| Initial | 1 | 1.4 | 0 | 0 |
| Equilibrium | 1-0.22<br>0.78 * | 1.4 – 0.44<br>0.96* | 0.22 | 0.88* (as 4 times $CO_2$) |

3 marks

**iii**. $K = \frac{(0.22)(0.88^4)}{(0.78)(0.96^2)}$ * $= \frac{0.132}{0.719}$ $= 0.18\ M^2$ * 2 marks

**b**. Answer True or False to each of the following. 4 marks

| **Statement** | **True or False** |
|---|---|
| If 4 mol of methane is added to steam in a reactor and the amount of methane changes to 3 mol over time, the amount of carbon dioxide formed will be 1 mol. | True (1 mol of methane will form 1 mol $CO_2$) |
| 1 mol of carbon dioxide and 1 mol of hydrogen gas are added to an empty reactor. No reaction will occur as they are both products. | False (It is a reversible reaction) |
| 1 mol of methane is added to 10 mol of steam in an empty reactor. When equilibrium is reached the methane will be all gone as it is very much the scarce reagent. | False (In a reversible reaction, some reactant will remain) |
| If 4 mol of methane and 8 mol of steam are added to an empty reactor, 4 mol of carbon dioxide will form. | False (not all the methane will react) |

**Question 7** (11 marks)

**a**. E = c x m x ΔT* = 4.18 x 450 x (35-15) = 3.8 x $10^4$ J*

2 marks

**b**. **i**. E lost by copper = E gained by water = 3.8 x $10^4$ J 1 mark

**ii**. ΔT (copper) = E/(c x m)* = 3.8 x $10^4$ J/(390 x 0.12) = 804 ºC* 2 marks

**iii**. Initial temperature of the copper = 35 + 804 = 839 ºC 1 mark

**Question 8** (8 marks)

**a**. **i**. The value of ΔT will be lower than that of a well insulated calorimeter. 1 mark

**ii**. The calibration factor will be higher than that of a well-insulated calorimeter. 1 mark

**b**. **i**. HCl(aq) + NaOH(aq) → NaCl(aq) + $H_2O$(l) 1 mark

**ii**. The number of mole of HCl must be used as it is the limiting reagent in this experiment.

1 mark

**c**. **i**. The value of $\Delta$T will be lower than it should be as more water is being heated. 1 mark

**ii**. the value of $\Delta$H will be lower than it should be as a result of the low $\Delta$T 1 mark

**d**. $n$(ethanol) = $\frac{0.552}{46}$ = 0.012 mol

$E = n \times 1364 = 0.012 \times 1364 = 16.368$ kJ = 16368 J *

$\Delta T = E/CF = 16368/684 = 23.9\ ^0$C * 2 marks

**Question 9** (8 marks)

**a**. $V^{3+}$, $V^{2+}$, $V^{5+}$ ( in $VO_2^+$), $V^{4+}$ (in $VO^{2+}$ ) ½ mark each 2 marks

**b. i**. $VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq) \rightarrow VO^{2+}(aq) + V^{3+}(aq) + H_2O(l)$ 1 mark

**ii**. 1.26 V 1 mark

**iii**. The left hand side is the negative electrode and the right hand side the positive 1 mark

**c**. **i**. $VO^{2+}(aq) + V^{3+}(aq) + H_2O(l) \rightarrow VO_2^+(aq) + 2H^+(aq) + V^{2+}(aq)$ 1 mark

**ii**. Voltage must be greater than 1.26 V for recharging to occur. 1 mark

**iii**. A secondary cell is a cell that can be recharged. A power supply can be applied that reverses the discharge equation, reforming the reactants. 1 mark

**Question 10** (9 marks)

**a**. Cell A: Molten KCl 2 marks

- the cathode: $K^+(l) + e^- \rightarrow K(l)$
- the anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

**b**. Cell B: Dilute KCl solution 2 marks

- the cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$
- the anode: $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

**c**. Cell C: 4.0 M KCl solution 2 marks

**i**.

- the cathode: $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

- the anode: $2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

**ii**. $Q = It = 3.4 \times 25 \times 60 = 5100$ C* 3 marks

$n(e) = \frac{5100}{96500}$ =0.0528 mol

$n(H_2)$ = ½ $n(e^-)$ = 0.0528 x 0.5 = 0.0264 mol*

$volume(H_2) = \frac{nRT}{P} = \frac{0.0264 \times 8.31 \times 297}{105}$ = 0.62 L

**Question 11** (8 marks)

**a.** Oxidation: $2I^-$ (aq) → $I_2$ (aq) + $2e^-$*
Reduction: $Cr_2O_7^{2-}$ (aq) + $14H^+$ (aq) + $6e^-$ → $2Cr^{3+}$ (aq) + $7H_2O$ (l)*
Overall: $Cr_2O_7^{2-}$ (aq) + $6I^-$ (aq) + $14H^+$ (aq) → $2Cr^{3+}$ (aq) + $3I_2$ (aq) + $7H_2O$ (l)*

3 marks

**b.** Oxidation: $2S_2O_3^{2-}$ (aq) → $S_4O_6^{2-}$ (aq) + $2e^-$
Reduction: $I_2$ (aq) +$2e^-$ → $2I^-$ (aq)
Overall: $2S_2O_3^{2-}$ (aq) + $I_2$ (aq) → $S_4O_6$ (aq) + $2I^-$ (aq)

3 marks

**c.** n ($S_2O_3^{2-}$) = c x v = 0.0244 x 0.102 = 0.00249 mol*
n ($I_2$) = 0.00249/2 = 0.00124 mol*
n ($Cr_2O_7^{2-}$) = 0.00124/6 = 2.07 x $10^{-4}$ mol*
c ($K_2Cr_2O_7$) = n/v = 2.07 x $10^{-4}$ /0.025 = 0.00830 mol*

4 marks