

## Aga Khan University Examination Board

### Notes from E-Marking Centre on HSSC-I Chemistry Examination May 2018

#### **Introduction:**

This document has been produced for the teachers and candidates of Higher Secondary School Certificate (HSSC) Part I Chemistry. It contains comments on candidates' responses to the 2018 HSSC-I Examination, indicating the quality of the responses and highlighting their relative strengths and weaknesses.

#### **E-Marking Notes:**

This includes overall comments on candidates' performance on every question and *some* specific examples of candidates' responses which support the mentioned comments. Please note that the descriptive comments represent an overall perception of the better and weaker responses as gathered from the e-marking session. However, the candidates' responses shared in this document represent some specific example(s) of the mentioned comments.

Teachers and candidates should be aware that examiners may ask questions that address the Student Learning Outcomes (SLOs) in a manner that requires candidates to respond by integrating knowledge, understanding and application skills they have developed during the course of study. Candidates are advised to read and comprehend each question carefully before writing the response to fulfil the demand of the question.

Candidates need to be aware that the marks allocated to the questions are related to the answer space provided on the examination paper as a guide to the length of the required response. A longer response will not in itself lead to higher marks. Candidates need to be familiar with the command words in the SLOs which contain terms commonly used in examination questions. However, candidates should also be aware that not all questions will start with or contain one of the command words. Words such as 'how', 'why' or 'what' may also be used.

#### **General Comments:**

In Constructed Response Questions (CRQs), the candidates showed better understanding of the concepts such as quantum number and its types, sigma and pi bonds, ideal gas constant ( $R$ ), properties of liquids, application of Le-Chatelier's principle, and heat capacity. However, a little more focus and efforts are required towards the concepts of percentage composition, types of orbital overlapping, order of reaction and different concentration units of solutions.

In extended response questions (ERQs), candidates found difficulties to describe hydration and the types of salt which undergo hydrolysis and were unable to provide related examples, whereas they were more confident to describe Bohr's atomic theory. Similarly, candidates displayed weak understanding while explaining working of a bomb calorimeter, but showed better progress to explain the structure of fuel cell.

**Detailed Comments:**

**Constructed Response Questions (CRQs)**

**Question 1:**

If the combustion analysis of 0.80 g of an unknown organic compound yields 1.63 g of CO<sub>2</sub> and 0.97 g of H<sub>2</sub>O, then what will be the percentages of carbon, hydrogen and oxygen present in the organic compound?

(Note: Atomic mass of H = 1 amu, C = 12 amu, O = 16 amu)

*Better responses* correctly calculated the percentage of carbon, hydrogen and oxygen present in the organic compound. Some of the candidates calculated percentage of carbon or the percentage of hydrogen in one single step using a combined formula which involved calculation of mass of carbon or hydrogen and their percentages, while other candidates first calculated the amount of carbon present in 1.63 g of CO<sub>2</sub> or the amount of hydrogen present in 0.97 g of H<sub>2</sub>O and then, calculated their percentages in organic compound. Finally, they were able to calculate percentage of oxygen by adding percentage of carbon and hydrogen and then, subtracting the total from 100.

**Example:**

Data: mass of compound = 0.8g	% of H = $\frac{\text{mass of H}_2\text{O}}{\text{mass of compound}} \times 2.016 \times 100$
mass of CO <sub>2</sub> = 1.63g	
mass of H <sub>2</sub> O = 0.97g	% of H = $\frac{0.97}{0.8} \times \frac{2.016}{18} \times 100$
Calculation:	
% of C = $\frac{\text{mass of CO}_2}{\text{mass of compound}} \times \frac{12}{44} \times 100$	% of H = 13.58%
% of C = $\frac{1.63}{0.8} \times \frac{12}{44} \times 100$	% of O = 100% - (% of C + % of H)
% of C = 55.57%	% of O = 100% - (55.57% + 13.58%)
	% of O = 100% - 69.15%
	% of O = 30.85%

*Weaker responses* exhibited lack of understanding of the concept of formulae and percentage composition and rather calculating the percentage of carbon and hydrogen in the given mass of organic compound, they calculated the percentage of carbon and hydrogen in one mole of CO<sub>2</sub> and H<sub>2</sub>O by dividing the atomic mass of carbon with molecular mass of CO<sub>2</sub> or by dividing the atomic mass of hydrogen with molecular mass of water. Some of the candidates wrongly calculated the percentage of carbon or hydrogen by dividing the given mass of CO<sub>2</sub> or H<sub>2</sub>O with atomic mass of carbon or hydrogen respectively. Furthermore, they calculated percentage of oxygen in negative by subtracting 100 from the sum of percentage of carbon and hydrogen.

**Example:**

$$\text{Percentage of Carbon} = \frac{1.63}{12} \times 100 = 13.5\%$$

$$\text{Percentage of Hydrogen} = \frac{0.97}{1} \times 100 = 97\%$$

$$\text{Percentage of Oxygen} = (\% \text{ of Carbon} + \% \text{ of Hydrogen}) - 100$$

$$= (13.5\% + 97\%) - 100$$

$$= -92.8\%$$

Percentage of Oxygen = -92.8%.

Hence percentage of Carbon, Hydrogen and Oxygen are 13.5, 97, -92.8 respectively.

**Question 2a:**

Complete the following table with the type of information that each of the given quantum numbers specify.

S. No.	Quantum Number	Type of Information
1	Principal quantum number	
2	Azimuthal quantum number	
3	Magnetic quantum number	

*Better responses* were able to clearly relate the different types of quantum number with the type of information they provide such as principal quantum number gives information about the size of orbital, azimuthal quantum number provides information about the shape of an orbital and magnetic quantum number describes the orientation of an orbital. Some of the candidates also used other terms in their description like principal quantum number is related to size of energy level or shell (K, L or M), similarly, they mentioned that azimuthal quantum number deals with sub-shells (s, p, d and f).

**Example:**

S. No.	Quantum Number	Type of Information
1	Principal quantum number	Principle quantum number gives number of shells or also tell us the size e.g:-K,L,M = 1,2,3
2	Azimuthal quantum number	Azimuthal quantum number gives us information of subshells and their shape e.g:- s,p,d,f = 0,1,2,3
3	Magnetic quantum number	Magnetic quantum number gives us information of <sup>orientation in</sup> magnetic field.

Weaker responses showed poor understanding of different types of quantum numbers like principal quantum number, azimuthal quantum number and magnetic quantum number. Rather providing the type of information each quantum number specify, they mentioned number of electrons that each shell can have and represented formulae or the symbols through which these quantum numbers are denoted.

**Example:**

S. No.	Quantum Number	Type of Information
1	Principal quantum number	$K = 2$ $M = 18$ $L = 8$ $N = 32$
2	Azimuthal quantum number	$L = n - 1$ $n = 1, l = 0 = s$ $n = 3, l = 2$ $n = 2, l = 1$ $n = 4, l = 3$
3	Magnetic quantum number	$m = \pm l$ $n = 1, l = 0, m = 0, -1$ $n = 3 = l = 0, m = 3, 2, 1, 0, -1, -2, -3$ $n = 2, l = 0, m = 2, 1, 0, -1, -2$

**Question 2b:**

Complete the given table by mentioning the quantum numbers for each orbital.

Quantum Number	Orbital	
	2p	3d
Azimuthal quantum number		
Magnetic quantum number		

*Better responses* showed good understanding towards the calculation of numerical value of azimuthal and magnetic quantum number. They used appropriate formula to calculate the value of azimuthal and magnetic quantum numbers. They calculated the value of azimuthal quantum number for each given orbital using formula  $l = n - 1$  and putting correct values of  $n$ . Further considering the values of azimuthal quantum number, they represented the correct values of magnetic quantum number for each orbital.

**Example:**

Quantum Number	Orbital	
	2p	3d
Azimuthal quantum number	$l = n - 1 \Rightarrow 2 - 1$ $\Rightarrow$ <span style="border: 1px solid black; padding: 2px;">1</span>	$l = n - 1 \Rightarrow 3 - 1$ $\Rightarrow$ <span style="border: 1px solid black; padding: 2px;">2</span>
Magnetic quantum number	$m = +l \Rightarrow +1$ $\therefore m = -1, 0, +1$	$m = +l \Rightarrow +2$ $\therefore m = -2, -1, 0, +1, +2$

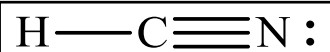
*Weaker responses* were unable to calculate correct values of each given quantum number. Instead of calculating the values of quantum number, they just mentioned all the general possible values of azimuthal quantum number. Moreover, they wrongly represented the magnetic quantum number values of both the orbitals.

**Example:**

Quantum Number	Orbital	
	2p	3d
Azimuthal quantum number	0, 1	0, 1, 2
Magnetic quantum number	0, $\pm 1, \pm 2$	0, $\pm 1, \pm 2, \pm 3$

**Question 3:**

Given below is the linear structure of hydrogen cyanide molecule.



- What is the hybridization of carbon atom in hydrogen cyanide molecule?
- How many  $\sigma$  and  $\pi$  bonds are observed in the given molecule?

*Better responses* depicted in-depth understanding of the concept of hybridisation and types of covalent bonds. They identified the type of hybridization in hydrogen cyanide molecule and mentioned that the carbon atom in hydrogen cyanide molecule undergo  $sp$  hybridisation. In part **b**, these candidate were able to correctly recognise the number of sigma and pi bonds in the given molecule.

**Example:**

a.	What is the hybridization of carbon atom in hydrogen cyanide molecule?	(1 Mark)
<u>sp hybridization</u>		
b.	How many $\sigma$ and $\pi$ bonds are observed in the given molecule?	(2 Marks)
<u>2 <math>\sigma</math> and 2 <math>\pi</math> bonds are observed</u>		

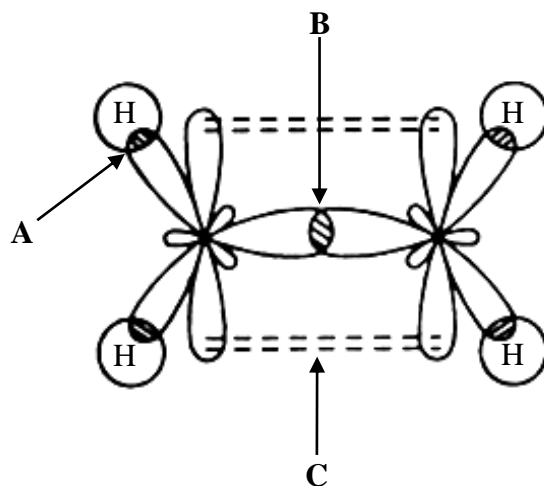
*Weaker responses* showed poor understanding of the concept of hybridization and types of covalent bonds. They were not able to relate the concept of hybridisation with the given structure of hydrogen cyanide molecule. These candidates counted the total number of bonds between carbon and nitrogen atom and wrongly suggested the hybridisation of carbon atom as  $sp^3$ . In addition to that in part **b**, majority of these candidates considered the bond between hydrogen and carbon as sigma only, while they identified the three covalent bonds between carbon and nitrogen atom as pi bonds.

**Example:**

a.	What is the hybridization of carbon atom in hydrogen cyanide molecule?	(1 Mark)
<u>SP<sub>3</sub></u>		
b.	How many $\sigma$ and $\pi$ bonds are observed in the given molecule?	(2 Marks)
<u>one sigma bond and 3 <math>\pi</math> bonds</u>		

**Question 4:**

Identify the type of orbital overlap at **A**, **B** and **C** in the given structure of ethene.



*Better responses* demonstrated good knowledge towards the type of orbital overlap in the structure of ethene and identified correctly each given type of orbital overlap including hybridised and unhybridised orbitals. They mentioned **A** as  $sp^2$ -s overlap, **B** as  $sp^2$ - $sp^2$  overlap and **C** as sideways overlap. These candidates further recognised the hybrid atoms associated with each hybridised or unhybridised orbital such as in  $sp^2$ -s overlap,  $sp^2$  hybrid orbital of carbon and s orbital of hydrogen are involved.

**Example:**

A:  $sp^2$ -s overlap between ' $sp^2$ ' of C and 's' of H  
B:  $sp^2$ - $sp^2$  overlap  
C:  $2p_z$ - $2p_z$  (sideways overlap of p orbitals)

*Weaker responses* exhibited weak concepts of type of orbital overlapping involved in the structure of ethene molecule. They were at least able to identify s orbital of hydrogen atom but mentioned the wrong type of orbital overlap as s-p instead of  $sp^2$ -s. Similarly, they were not able to recognise hybridised and unhybridised orbital on carbon atoms and mentioned p-p overlap instead of  $sp^2$ - $sp^2$ . Some of these candidates were not specific and generally identified the type of overlap as head to head or head on overlapping.

**Example:**

A: s-p overlapping.  
B: p-p (head on approach) overlapping - ~~for~~  
C: p-p (side-way) overlapping.

**Question 5:**

If 0.25 moles of water vapours occupy a volume of 2.46 dm<sup>3</sup> at 27°C and 2.5 atmospheric pressure, then calculate the value of ideal gas constant (R).

*Better responses* showed good understanding of ideal gas equation and represented stepwise calculation of ideal gas constant using the information provided. They first converted temperature from Celsius to Kelvin and then, used ideal gas equation to substitute all the given values and calculated correct value of ideal gas constant. These candidates further mentioned the correct unit of the ideal gas constant.

**Example:**

<u>Data:-</u>	<u>Solution:-</u> $PV = nRT$
$n = 0.25 \text{ mol}$	$\frac{2.5 \times 2.46}{0.25 \times 300} = R$
$V = 2.46 \text{ dm}^3$	
$T = 27^\circ\text{C}$ or $27 + 273 = 300\text{K}$	$\frac{6.15}{75} = R$
$P = 2.5 \text{ ATM}$	
$R = ??$	$0.0821 \text{ atm} \cdot \text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$

*Weaker responses* struggled to find correct value of ideal gas constant due to lack of understanding of the concept. Majority of these candidates did not change temperature from Celsius to Kelvin and calculated wrong answer. Some of these candidates tried to change unit but used inappropriate values for conversion. Similarly, these candidates were not able to use ideal gas equation correctly to find out the right answer. These candidates further did not mention unit of final answer.

**Example:**

$PV = nRT$	}	$R = \frac{6.15}{6.75}$
$R = \frac{PV}{nT}$		
		$R = 0.911$
$R = \frac{2.5 \text{ atm} \times 2.46 \text{ dm}^3}{0.25 \text{ mol} \times 27^\circ\text{C}}$		

**Question 6a:**

Give reasons for the following observations.

- i. Water occupies more space when it freezes.
- ii. Ice floats on the surface of water.

*Better responses* clearly relates the concept of anomalous behaviour of water with the expansion of structure during freezing of water. They discussed that as the temperature of water is decreased and ice is formed, then the molecules become more regular and this regularity extends throughout the whole structure. At low temperature, water molecules come closer, with same charges come in front of each other and repel, thus they set themselves accordingly to particular geometry which have extra spaces. In part **ii**, they provided simple answer that ice floats on the surface of water because it has low density compared to water.

**Example:**

When water freezes into ice, due to its anomalous nature, <sup>(at 0°C)</sup> the structure of it (ice) becomes orderly arranged with empty spaces in between. This increases the volume <sup>and hence</sup> a space of water.

ii. Ice floats on the surface of water. (1 Mark)

Because at 0° (when ice is formed) the density of this ice is least due empty spaces in its molecules, thus is less denser, while water <sup>(at 4°C)</sup> has maximum density thus it settles down while ice floats.

*Weaker responses* depicted poor understanding of the properties of water like anomalous behaviour of water and its density. These candidates were not able to provide correct reason mentioning regularity in the structure of water when it freezes or the empty spaces created due to repulsion of molecules. Instead of giving correct reason, they just wrote that it is due to anomalous behaviour of water. Some of these candidates wrongly described that as temperature decreased intermolecular forces increased which creates empty spaces and water occupies more spaces. Furthermore, in part **ii**, these candidates mentioned that ice is a solid with higher density compared to water and due to which it floats on the surface of water.

**Example:**

when water freezes their intermolecular forces become strong because particles are brought closer and they become solid which occupy more space.

ii. Ice floats on the surface of water. (1 Mark)

Ice is a solid and solids have higher densities than that of liquids that is why it floats on the surface of water.

**Question 6b:**

Give a reason why the surface tension of

- i. water is higher than that of ethers.
- ii. liquids decrease with the increase in temperature.

*Better responses* provided correct reason about the higher surface tension of water compared to ether or the effect of temperature on surface tension of liquids. They clearly mentioned that water possess strong intermolecular forces i.e., hydrogen bonding, which is absent in case of ether due to which water has higher surface tension than ether. In part **ii**, they further depicted in-depth understanding of surface tension by describing that at higher temperature intermolecular forces become weak so the surface tension of liquids decreases.

**Example:**

i. water is higher than that of ethers.	(1 Mark)
Because water molecule on surface is attracted by other molecule due to hydrogen bonding & IMF while ethers do not have hydrogen bonding.	
ii. liquids decrease with the increase in temperature.	(1 Mark)
Due to increase in temperature kinetic energy of molecules increases which cause to break IMF forces & hydrogen bonding & surface tension reduces.	

*Weaker responses* displayed lack of knowledge of surface tension and the factors that can affect surface tension of liquids. They provided irrelevant answer or illogical reasoning such as mentioning the boiling point of water and ether. Similarly, in part **ii**, these candidates were not able to provide correct reason mentioning the effect of temperature on surface tension of liquids. Majority of these candidates were not able to comprehend that question correctly, and discussed about evaporation of water. Instead of writing the effect of temperature on surface tension of liquids, they generally discussed that as the temperature increase liquids evaporate and the quantity of liquids decreases.

**Example:**

i. water is higher than that of ethers.	(1 Mark)
Because of that, that ethers have high boiling point.	
ii. liquids decrease with the increase in temperature.	(1 Mark)
Because in temperature cause increase in kinetic energy which increase evaporation rate.	

**Question 7:**

Calculate the solubility product ( $K_{sp}$ ) of AgCl, if the solubility of AgCl is  $1.2 \times 10^{-3} \text{ g dm}^{-3}$  at  $25^\circ\text{C}$ .

(Note: Atomic mass of Ag = 107.86 amu and Cl = 35.5 amu)

*Better responses* correctly calculated solubility product of AgCl showing all the required steps. They first used information provided in the question and calculated correct number of moles of AgCl. Then, they represented correct ionic equation of AgCl and derived appropriate formula of  $K_{sp}$  to calculate solubility product of AgCl.

**Example:**

• <u>Data:</u>	$\text{AgCl} \rightleftharpoons \text{Ag}^+ + \text{Cl}^-$	
Solubility of AgCl = $1.2 \times 10^{-3} \text{ g/dm}^3$	AgCl : Ag <sup>+</sup>	AgCl : Cl <sup>-</sup>
[AgCl] = ?	1 : 1	1 : 1
$K_{sp}$ of AgCl = ?	$8.37 \times 10^{-6} \text{ M} : 8.37 \times 10^{-6}$	$8.37 \times 10^{-6} : 8.37 \times 10^{-6}$
• <u>Solution:</u>	$K_c = \frac{[\text{Ag}][\text{Cl}]}{[\text{AgCl}]}$	
AgCl's Molecular mass = 107.86 + 35.5	$K_{sp} = [\text{Ag}][\text{Cl}]$	
Mr of AgCl = 143.36 g/mol	$K_{sp} = [8.37 \times 10^{-6}] [8.37 \times 10^{-6}]$	
$[\text{AgCl}] = \frac{1.2 \times 10^{-3} \text{ g/dm}^3}{143.36 \text{ g/mol}}$	$K_{sp} = 7.00569 \times 10^{-11} \text{ mol}^2/\text{dm}^6$	
$[\text{AgCl}] = 8.37 \times 10^{-6} \text{ mol/dm}^3$	<u>Ans.</u>	

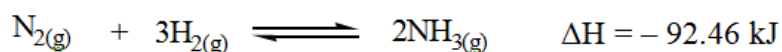
*Weaker responses* demonstrated poor understanding of the concept of solubility product. Rather calculating the moles of AgCl they directly used the given value of solubility to find out the solubility product of AgCl. They did not mention any ionic equation which represents the dissociation of AgCl. In addition, they used wrong formula to calculate solubility product of AgCl which involved the given temperature value.

**Example:**

Data:-
$T = 25^{\circ}\text{C}$
solubility = $1.2 \times 10^{-3} \text{ g m dm}^{-3}$
$K_{sp} = ?$
Formula:-
$K_{sp} = \frac{K_P \times \text{molar mass}}{T}$
$K_{sp} = \frac{(1.2 \times 10^{-3})(143.36)}{25}$
$= \frac{0.172}{25} = 6.881 \times 10^{-3}$

**Question 8:**

- State Le-Chatelier's principle.
- Mention THREE conditions which, when applied can increase the yield of ammonia in the following reaction.



*Better responses* clearly defined the Le-Chatelier's principle mentioning that when stress is applied to a system at equilibrium, the system acts in such a way so as to nullify the effect of that stress. In part **b**, they further showed understanding towards the effector of different factors such as concentration, pressure and temperature on equilibria. They correctly mentioned three different conditions like high pressure, low temperature and continuous removal of ammonia from the reaction mixture to increase the yield of ammonia.

### Example:

a. State Le-Chatelier's principle. (1 Mark)  
If the equilibrium of any system is disturbed, the system will tend to react in such a way as to reestablish the equilibrium.

b. Mention THREE conditions which, when applied can increase the yield of ammonia in the following reaction. (3 Marks)

$$\text{N}_{2(g)} + 3\text{H}_{2(g)} \rightleftharpoons 2\text{NH}_{3(g)} \quad \Delta H = -92.46 \text{ kJ}$$

1- continual withdrawal of Ammonia is necessary for the reaction to move in forward direction.

2- high pressure is applied for the forward reaction to increase the volume at product side and for more yield of Ammonia.

3- Low temperature favours more yield as the react is exothermic that's why increasing temperature can reverse the reaction.

Weaker responses depicted poor understanding of the reversible reactions, Le-Chatelier's principle and its application in different situations. Majority of these candidates provided incomplete definition of Le-Chatelier's principle without mentioning the terms like reversibility or equilibrium. Similarly, in part b, rather mentioning the three conditions which can be used industrially to increase the yield of ammonia such as high pressure, low temperature and continuous removal of ammonia, they provided general answer such as addition of catalyst to speed up reaction or increasing the concentration of reactants.

### Example:

a. State Le-Chatelier's principle. (1 Mark)  
When a stress is applied to a system the system tends to nullify the effect of stress.

b. Mention THREE conditions which, when applied can increase the yield of ammonia in the following reaction. (3 Marks)

$$\text{N}_{2(g)} + 3\text{H}_{2(g)} \rightleftharpoons 2\text{NH}_{3(g)} \quad \Delta H = -92.46 \text{ kJ}$$

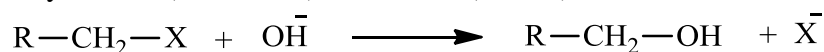
(1) Catalyst can be added for speeding up the reaction.

(2) Increase the concentration of  $\text{N}_2$  so to balance the effect the reaction will proceed in forward direction.

(3) Increase pressure on Reactant side so to nullify the effect it will move in forward direction.

**Question 9:**

Following results are obtained for the given nucleophilic substitution reaction between alkyl halide ( $\text{R-CH}_2\text{-X}$ ) and a base ( $\text{NaOH}$ ).



Experiment	$[\text{R-CH}_2\text{-X}]$	$[\text{NaOH}]$	Initial Rate
1	0.030	0.2	1.5
2	0.045	0.2	2.25
3	0.040	0.4	3.75

- What is the order of reaction with respect to alkyl halide and base.
- Give reasons to support your answer in part a.
- Write an overall rate equation for the given reaction.

*Better responses* were able to analyse the given situation properly and deduced the order of reaction with respect to alkyl halide and base. In part **b**, they gave correct reason to support their answer in part **a** such as they mentioned that as the concentration of base or the concentration of alkyl halide increases the rate also increased. Finally, they clearly showed the overall rate equation for the given reaction including base and alkyl halide.

**Example:**

- a. What is the order of reaction with respect to alkyl halide and base. (1 Mark)

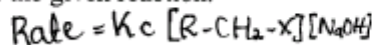
w.r.t alkyl halide: 1<sup>st</sup> order

w.r.t to base: 1<sup>st</sup> order

- b. Give reasons to support your answer in part a. (2 Marks)

As we can see that if the concentration of either alkyl halide or a base is increased the rate of reaction also increased by the power of one, directly proportional to the concentration of reactants (both).

- c. Write an overall rate equation for the given reaction. (1 Mark)



Weaker responses were failed to demonstrate understanding of the concept of chemical kinetics to deduce order of reaction using the method of initial rate. They wrongly identified third order reaction. In part b, these candidates did not relate information provided in the table and gave illogical explanation to support their answer. Furthermore, they were not able to correctly write overall rate equation for the given reaction. Majority of these candidates tried to write the overall rate equation in term of equilibrium constant expression mentioning the concentration of product and leaving halide group in numerator and the concentration of both reactants i.e., alkyl halide and base, in denominator.

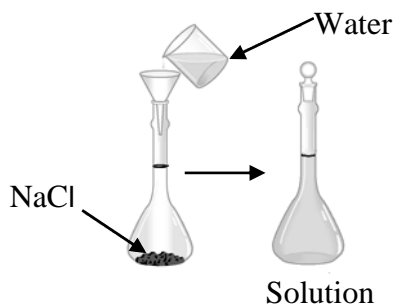
**Example:**

a.	What is the order of reaction with respect to alkyl halide and base.	(1 Mark)
	The reaction is of <del>first</del> <sup>third</sup> order.	
b.	Give reasons to support your answer in part a.	(2 Marks)
	The reaction is of <del>first</del> <sup>third</sup> order because the formation of the products is taking place in three steps. That means that R-CH <sub>2</sub> -OH and $\bar{x}$ are not formed directly by the reactants but it <del>took steps</del> <sup>includes</sup> intermediate products too.	
c.	Write an overall rate equation for the given reaction.	(1 Mark)
	$R = \frac{[R-CH_2-OH][\bar{x}]}{[R-CH_2-X][OH]^-}$	

**Question 10:**

A solution is prepared by dissolving 1250 mg of NaCl in 1000 mL of water. Calculate the concentration of prepared solution in ppm.

(Note: Atomic mass of Na = 23 amu and Cl = 35.5 amu)



*Better responses* exhibited complete understanding and used appropriate formula to solve the given numerical. Majority of these candidates first converted given mass of NaCl from mg to g and divided it by the given mass of solvent and multiplied the final answer with  $10^6$  to get the concentration in ppm. Some of the candidates used other method where they first changed unit from 1000 mL to 1 litre and divided the given mg of NaCl with 1 litre of water to get the final concentration in ppm.

**Example:**

$$\begin{aligned} \text{Mass of NaCl} &= 1250 \text{ mg} \approx 1.25 \text{ g} \quad \text{ppm} = 1250 \\ \text{Mass of water} &= 1000 \text{ mL} \text{ or } 1000 \text{ cm}^3 \\ \text{ppm (conc)} &= ? \\ \text{ppm} &= \frac{\text{mass of solute} \times 10^6}{\text{Mass of solvent}} \\ &= \frac{1.25}{1000} \times 10^6 \end{aligned}$$

*Weaker responses* represented lack of grip to solve the numericals based on ppm concentration. Majority of these candidates used wrong formula to calculate concentration in ppm. They added amount of NaCl and water and then divided the amount of NaCl with total to get the wrong answer. Some of these candidates used correct formula but did not show any unit conversion and obtained wrong answer.

**Example:**

$$\begin{aligned} \text{Data} &= \text{solute} = 1250 \text{ mg of NaCl} \\ \text{solution} &= 1 \text{ soln. Solvent} = 1000 \text{ mL} \\ \text{solution} &= 1250 + 1000 = 2250 \\ &= \frac{\text{mass of solute}}{\text{solution}} = \frac{1250}{2250} = 0.55555 \\ &= 5 \times 10^{-6} \text{ ppm} \end{aligned}$$

**Question 11:**

- a. Define the following terms.
  - i. Heat capacity
  - ii. Molar heat capacity
- b. Write the formula for molar heat capacity.

*Better responses* clearly defined the given terms such as heat capacity as the amount of heat required to raise the temperature of given amount of a substance by one degree Kelvin. Few of these candidates mentioned that it is the amount of heat required to raise the temperature by one degree Celsius. Similarly, they provided correct definition of molar heat capacity including the description of one mole of a substance and wrote correct formula of molar heat capacity.

**Example:**

a. Define the following terms. (1 Mark)

- i. Heat capacity  
Amount of heat required to raise the temperature of any substance upto 1K it is known as Heat capacity.
- ii. Molar heat capacity (1 Mark)  
Amount of heat required to raise the temperature of one mole of any substance is known as Heat capacity.

b. Write the formula for molar heat capacity. (1 Mark)

$$C = \frac{Q}{n\Delta T} \text{ OR } Q = nC\Delta T$$

Weaker responses were not able to provide correct definition of heat capacity and molar heat capacity and gave wrong formula of molar heat capacity. They defined heat capacity as the capacity of any substance to absorb one degree kelvin heat. Similarly, they gave incorrect definition of molar heat capacity and mentioned that it is the capacity of one mole of substance to absorb heat. Finally, they wrote completely wrong formula to express molar heat capacity involving sum of heat divided by number of moles.

**Example:**

i. Heat capacity	
Heat capacity is the capacity of any substance to absorb heat by 1 K.	
ii. Molar heat capacity	(1 Mark)
Molar heat capacity is heat capacity of 1m of a substance to absorb heat.	
b. Write the formula for molar heat capacity.	(1 Mark)
$\text{molar heat capacity} = \frac{m + Q_1 + Q_2 + T_1 + T_2}{\text{no. of moles}}$	

## Extended Response Questions (ERQs)

These questions offered a choice between part **a** and **b**

Most of the candidates attempted **12a** and performed better compared to **12b**.

### Question 12a:

- i. Describe the main points of Bohr's atomic theory.
- ii. Calculate the radius of the 3rd orbit of an electron in a hydrogen atom.

(Note:  $a^{\circ} = \frac{\epsilon_0 h^2}{\pi m e^2} = 0.529A^{\circ}$ )

*Better responses* clearly stated the main points of Bohr's atomic theory mentioning that the electron revolves in one of the circular orbits outside the nucleus and they neither emits nor absorbs energy while moving in the same fixed orbits. The energy is emitted or absorbed only when an electron jumps from one orbit to another. They mentioned that energy change  $\Delta E$  is given by the Planck's equation  $\Delta E = E_2 - E_1 = h\nu$ . Furthermore, they described that electron can revolve only in those orbits having a fixed angular momentum ( $mvr$ ), which is represented by  $mvr = nh/2\pi$ . In part **b**, they correctly calculated the radius of the 3<sup>rd</sup> orbit of an electron in a hydrogen atom using appropriate formula.

### Example:

#### 1) Bohr's Atomic Theory:

The main points of the Bohr's atomic theory are as follows:

1) The hydrogen atom consists of a tiny nucleus and the electrons are revolving in one of the circular orbits of radius  $r$  around the nucleus

2) Each orbit has a fixed energy that is quantized.

3) The electrons revolves in the fixed circular paths called energy levels or orbits.

4) As long as an electron remains in a particular orbit, it does not emit or absorb energy. The energy is absorbed or radiated only when an electron jumps from a higher one orbit to another orbit.

5) When an electron jumps from higher orbit to lower orbit, it radiates energy and whenever an electron jumps from lower orbit to higher orbit, it absorbs energy. This change in energy  $\Delta E$ , is given by the following

Planck's equation:  $\Delta E = E_2 - E_1 = h\nu$

where  $h$  is the Planck's constant which is equal to  $6.625 \times 10^{-34} \text{ Js}$  and  $\nu$  is the frequency of light.

b) Electrons revolve in orbits of fixed angular momentum  $mvr$ , given as

$$mvr = \frac{nh}{2\pi}$$

where  $n$  is the quantum number or the orbit number having values 1, 2, 3 and so on.

The defect in the Bohr's atomic model is that he introduced the concept of circular orbits and that the atom is flat but it is not true. In actual, there are orbitals s, p, d and f which were introduced by the Heisenberg's uncertainty principle.

(ii)  $n = 3$ ,  $\lambda = 1$

$$r = 0.529 \left( \frac{n^2}{\lambda} \right) \text{ \AA}$$

$$r = 0.529 \left( \frac{3^2}{1} \right) \text{ \AA}$$

$$\boxed{r = 4.761 \text{ \AA}} \text{ OR } \boxed{r = 4.761 \times 10^{-10} \text{ m}} \Rightarrow \text{Answer.}$$

$\downarrow$   
Answer

Weaker responses depicted lack of understanding of Bohr's atomic theory. Instead of writing the main points of Bohr's atomic theory, they generally tried to discuss the structure of atom. They explained that protons and neutrons are present in nucleus. Rather mentioning electrons movement in circular orbits and their fixed energy, they just simply described that electrons revolve around nucleus. Instead of writing that energy is emitted or absorbed only when an electron jumps from one orbit to another, they mentioned that energy is released continuously while movement of electron. Furthermore, these candidates did not discuss about Planck's equation  $\Delta E = E_2 - E_1 = h\nu$  and angular momentum ( $mvr = nh/2\pi$ ) of an orbit. In part ii, majority of these candidates used wrong formulae to calculate the radius of the 3<sup>rd</sup> orbit of an electron in a hydrogen atom. Some of these candidates used correct formula but forgot to take square of value for  $n$  and directly multiplied 3 with 0.529 to and obtained wrong answer.

**Example:**

Bohr's atomic theory:-

- Bohr's atomic theory explained that electrons are in continuous motion in 2 dimension.
- Electron revolve around the nucleus with a specific energy level which decreases gradually.
- if the energy of electrons becomes very low then there are possibilities that electrons will fall into nucleus
- Electrons can possibly be found in the orbital which he explained is the path of movement of electrons.
- There is <sup>some</sup> force of nucleus which is continuously holding electrons towards it self.
- if electrons are energized they jump from one orbital to upper orbital

radius of 3<sup>rd</sup> orbit of hydrogen

$$r = \frac{1}{a_0} \times n$$

$$r = \frac{1}{\frac{E_0 h^2}{4\pi m e^2}} \times n$$

$$r = \frac{1}{a_0} n$$

$$r = \frac{1}{a_0} n$$

we know that  $a_0 = 0.529$  | Hence radius of 3 orbit of hydrogen is 3.5

So

$$\frac{1}{0.529} \times 3 = 5.5$$

### Question 12b

- Define the term 'hydration'.
- Describe THREE types of salt which undergo hydrolysis. Give ONE example of each type.

*Better responses* gave correct definition of hydration mentioning that it is a process in which water molecule adds up to a substance without bond breakage. They identified three different types of salt which undergo hydrolysis and provided related examples in each case. They described that salt of weak acids and strong bases hydrolyse to produce basic solutions ( $\text{pH} > 7$ ) and identified  $\text{CH}_3\text{COONa}$  as most common example. On the other hand, they demonstrated that salt of strong acids and weak bases hydrolyse to produce acidic solutions ( $\text{pH} < 7$ ) and mentioned  $\text{NH}_4\text{Cl}$  as an example. Finally, they recognised salt of weak acids and weak bases which can hydrolyse and provided appropriate example.

#### Example:

- Hydration: The process in which water molecules surround and interact with solute molecules or ions is called hydration.
- A salt of strong Acid and weak base (Acidic salt): These salts when mixed with water produces slightly acidic solution due to "cationic hydrolysis". For example salt  $\text{NH}_4\text{Cl}$  is derived from strong acid  $\text{HCl}$  and weak base  $\text{NH}_4\text{OH}$  due to which  $\text{NH}_4^+$  being strong conjugate acid reacts with  $\text{OH}^-$  part of the water (hydrolysis) and releases  $\text{H}^+$  thus making solution slightly acidic.
- A salt of strong base and weak acid (Basic salts): These salts when dissolved in water produces slightly basic solution due to "anionic hydrolysis". For example salt  $\text{CH}_3\text{COONa}$  is produced from weak acid  $\text{CH}_3\text{COOH}$  and strong base  $\text{NaOH}$  due to which  $\text{CH}_3\text{COO}^-$  being strong conjugate base of  $\text{CH}_3\text{COOH}$  reacts with  $\text{H}^+$  part of water (hydrolysis) and releases  $\text{OH}^-$  ions thus making solution slightly basic.

3) A salt of weak acid and weak base These salts when dissolved in water can produce slightly acid, slightly basic or neutral solutions. This is because both type of hydrolysis can take place (anionic and cationic). ~~The reason behind this is~~ For example, salt  $\text{CH}_3\text{COONH}_4$  which is produced from weak acid  $\text{CH}_3\text{COOH}$  and weak base  $\text{NH}_4\text{OH}$  can do both type of hydrolysis because the conjugate base  $\text{CH}_3\text{COO}^-$  of  $\text{CH}_3\text{COOH}$  is strong as well as conjugate ~~base~~ acid of  $\text{NH}_4^+$  of  $\text{NH}_4\text{OH}$  is strong too. So, both have the tendency to hydrolyse water and produce acidic, basic or neutral solutions depending upon the favoured conditions such as concentration, temperature etc.

In most of the *weaker responses*, candidates were unable to provide correct definition of the term hydration. Majority of these candidates were confused to define hydration and provided description related to hydrolysis and used irrelevant terms; like, bond cleavage or water reacts chemically with substance. In part **ii**, these candidates showed lack of understanding to describe different types of salt on the basis of hydrolysis and were unable to mention any related example. Most of the candidates just only identified acidic and basic salt but could not describe the composition of these salts; like, weak/ strong acid or base. Instead of giving example of type of salts, some of the candidates gave name of strong/ weak acid or base. Significant number of these candidates wrongly identified salt of strong acid and strong bases which does not hydrolyse, and provided example of NaCl. Furthermore, these candidates also showed ionization reactions of acid or bases which was not the demand of that question.

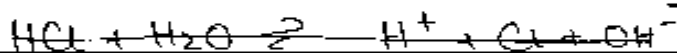
Example:

### HYDRATION

The attachment of molecules to one another by the addition of water. The salts undergo a reaction when water is added to them.

#### TYPES

(1) ACIDIC SALTS :- salts which produce hydrogen ions ( $H^+$ ) in a reaction e.g. ~~HCl~~ or  $H_2SO_4$ .



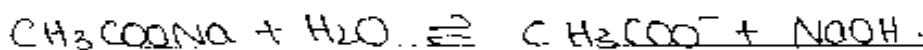
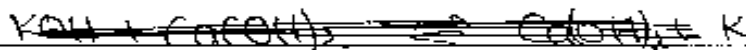
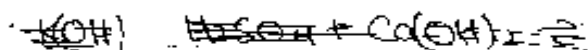
So it is acidic solution because  $H^+$  are produced and present in the solution freely.

(2) BASIC SALTS :- salts which produces hydroxyl ion in a reaction. They produces  $OH^-$  ions in a solution e.g. NaOH.



so  $OH^-$  is present in solution freely.

Neutral Salts :- salts of both acid and bases are present in a solution.

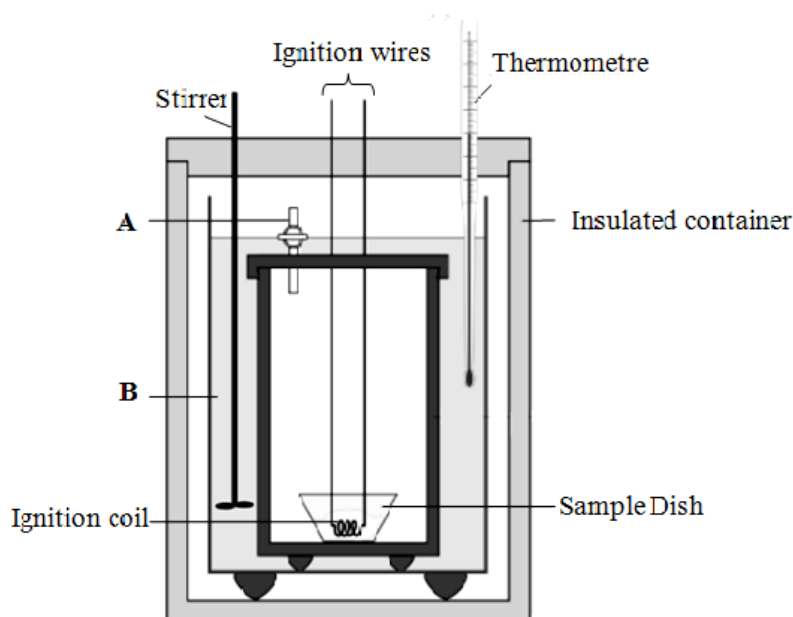


Both are weak acid and base and make neutral solution.

Most of the candidate attempted **13b** and performed better compared to part **13a**.

**Question 13a:**

Given is the diagram of bomb calorimetre.



- i. Identify the labelled components, **A** and **B** in the given diagram.
- ii. Write the steps that will need to be followed in order to determine the heat of combustion of 1g of food sample using bomb calorimetre.

*Better responses* correctly labelled component A and B of the bomb calorimetre as oxygen inlet and water respectively. They showed good understanding of working of bomb calorimeter and mentioned all the necessary steps required to determine the heat of combustion of 1g of food sample. They described that sample is placed in a crucible inside the bomb and oxygen is provided in through a valve until the pressure inside is maintained. They further discussed that initial temperature is measured and then, the test substance is ignited, electrically by passing the current through ignition coil and the temperature of water is recorded at 30 sec intervals. Finally, they showed correct formula to calculate enthalpy of combustion i.e.  $q = c \times \Delta T$ .

### Example:

Labelled part a is the pump used to introduce  $O_2$  in the calorim-<sup>eter</sup>.  
Labelled part b is water which acts as an insulator.

Bomb calorimeter is used to measure the enthalpy of food, fuel and other compounds. It consists of a steel vessel lined with enamel layer. A platinum crucible is present inside the vessel. It contains the ignition coil. A stirrer and a thermometer are also a part of this system.

To calculate the enthalpy, 1 g of the substance will be

placed in the platinum crucible. The vessel is then immersed in a known mass of water. A oxygen at 1 atm is supplied to the system through the pump at an interval of 30 seconds. The crucible is electrically heated with the help of ignition coil. Before heating, the initial temperature of the water is noted. During heating, water is gently stirred to ensure the uniform heating of ~~substance~~ system. Temperature changes are noted after every thirty seconds.

The change in the temperature of water is due to either the heat released or the heat absorbed by the test substance.

The enthalpy can then be calculated using the formula  $q = c \Delta T$  where  $q$  is the heat,  $c$  is the specific heat capacity and  $\Delta T$  is the change in temperature. The mass is not mentioned as it is 1 g. ~~end~~

*Weaker responses* were unable to illustrate the given diagram of bomb calorimetre and wrongly identified both components A and B as lid and mixture respectively. Some of these candidates tried to identify label part A as outlet of hydrogen or water. Similarly, they recognised part B as solvents or different types of gases present in the bomb calorimetre. In part **ii**, these candidates showed lack of understanding to explain the working of bomb calorimetre or to mention all the necessary steps need to follow to determine the heat of combustion of 1g of food sample. Majority of these candidates missed the sequence in writing different steps of working and showed illogical order of working. For example, change of initial and final temperature was discussed before the placement of sample in a crucible inside the bomb. Similarly, record of final temperature was discussed before mentioning about heating through ignition coil. Most of the candidates did not mention that calorimetre is immersed in a known mass of water in a well-insulated calorimetre and allowed to attain steady temperature. Some of these candidates also did not provide description about heating through ignition coil or the record of temperature of water at 30 sec intervals. Moreover, they were unable to represent correct formula required to calculate enthalpy of combustion i.e.,  $q = c \times \Delta T$ , where,  $\Delta T$  is increase of temperature,  $c$  is heat capacity in  $\text{kJK}^{-1}$  of bomb calorimetre.

**Example:**

a. (i) A = lid.

B = mixture

(ii) → Firstly the metal box of calorimeter will be fixed inside the wooden box in which thermometer must be placed.

if → We'll weight the calorimeter first then we'll pour the mixture and weight it again.

→ The temperature of the mixture would be found out through thermometer which is placed in it.

→ The mixture or the food sample should be mixed continuously with the help of a stirrer.

→ when the bomb calorimeter which is placed in an insulated container put into heat its temperature will rise and would be observed on thermometer.

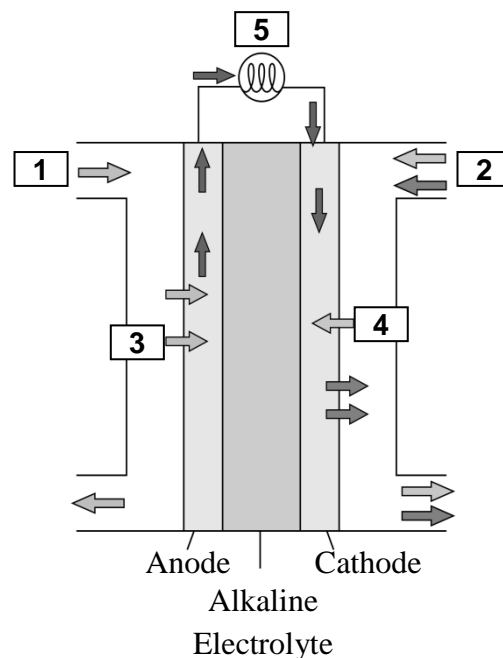
→ The ignition coil & ignition wires will help the food sample or mixture to heat through combustion

→ During this process the lid will kept closed and after the process the lid will allowed to open.

→ The fumes will come out through the small opening as combustion had occur.

### Question 13b

An alkaline, hydrogen-oxygen fuel cell is shown below.



- Name the type of electrodes and electrolyte used in this cell.
- Identifying the steps labelled as 1 to 5 in the above diagram, describe the process of conversion of chemical energy into electrical energy by the fuel cell. Write equations for the chemical reactions to support your answer.

Better responses identified electrodes as hollow tubes made of porous compressed carbon filled with platinum/ nickel, which acts as a catalyst, and KOH as electrolyte used in this cell. These candidates were able to correctly recognise all the steps labelled as 1 to 5 in the diagram. These candidates mentioned the parts of fuel cell where the oxidation and reduction taking place and provided correct equation for each oxidation and reduction reactions. Finally, they further indicated that electrons flow through an external circuit from anode to cathode.

**Example:**

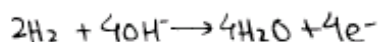
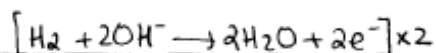
b. i. Both electrodes are made of compressed carbon that is impregnated with Platinum. The anode is ~~posit~~ negatively charged and the cathode is positively charged due to the cell being galvanic. The electrolyte used in this cell is KOH

ii. Step 1 indicates the entrance of hydrogen gas through inlet while Step 2 shows entrance of oxygen gas through inlet. Both gases are used as fuel in the cell and ~~react~~ are efficient (75%) and result in the fuel cell not causing pollution by forming pure water as product.

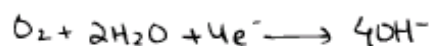
Step 3 shows the oxidation reaction occurring at anode where

H<sub>2</sub> react with OH<sup>-</sup> from electrolyte to produce water (and lose e<sup>-</sup>) while step 4 shows reduction at cathode of O<sub>2</sub> where it react with water molecules and gains electrons

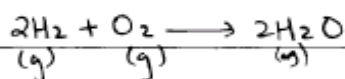
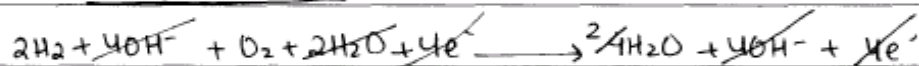
At Anode:



At Cathode:



Overall Reaction:



Step 5 shows the generation of electrical energy from chemical energy as electrons transferred towards cathode through external circuit.

Fuel cells are used in space vehicles as they do not produce pollution and the water can be condensed to use as drinking water

Weaker responses showed candidates' misconception and lack of understanding about reduction/ oxidation and fuel cells. They mixed the concept of fuel cell with lead storage battery and wrongly identified the metallic lead (Pb) as anode, lead oxide (PbO<sub>2</sub>) as cathode and H<sub>2</sub>SO<sub>4</sub> as electrolyte. Rather identifying stream of hydrogen enters at 1 and stream of oxygen enters at 2, some of these candidates mentioned hydrogen and oxygen as cathode and anode electrodes respectively and recognised water as electrolyte. Moreover, they provided irrelevant details regarding oxidation and reduction reaction with incorrect equations, and provided wrong description about flow of electron.

**Example:**

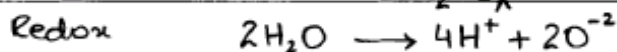
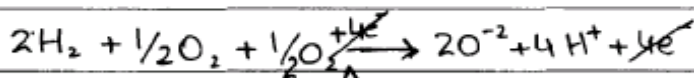
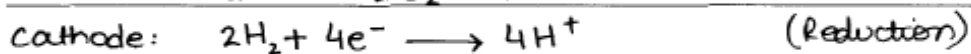
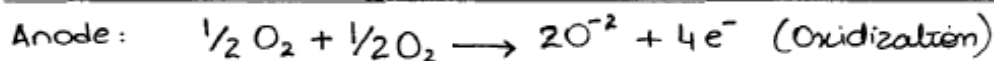
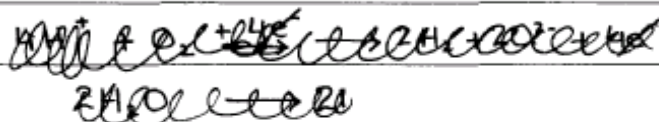
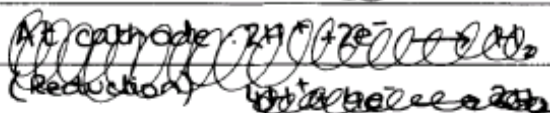
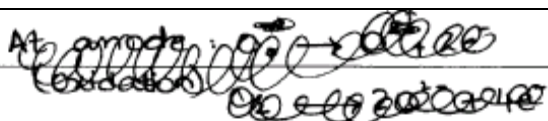
The electrodes used in this cell are :

~~Copper~~ Hydrogen is the cathode.

Oxygen is the anode.

The electrolyte used is  $H_2O$ .

The hydrogen gas is provided from point 2 whereas oxygen gas is provided from point 1. These gases are provided at high temperature therefore the electrodes are combusted without flames. Therefore, the gases leave from the other opening. But their arrival excited the electron and they travel from the anode to the battery to the cathode, the flow of electrons being the electric current and the cathode is reduced when it receives the electrons. (Reactions on next page)



Reaction: