Aga Khan University Examination Board

Notes from E-Marking Centre on HSSC-I Chemistry Examination May 2019

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 2019 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 Observations

In comparison to previous years, overall performance of the candidates has improved. However, there is still room for improvement. Mentioned below are few concepts on which teachers need to focus and give candidates more drill and practice to have a strong grip.

a. Clarity of Bronsted Lowry concept of acid and base in terms of proton that is followed by the concept of conjugate species
b. Concept of bond energy with reference to the electronegativity differences of bonded atoms, ionic characters and bond length
c. Solubility of ionic compounds in water on the basis of lattice energy and hydration energy, whereas, solubility of polar covalent compounds on the basis of weak intermolecular force of attractions
d. Causes and effects of the change in pressure on lungs during scuba diving
e. Clarity of relationship between negative exponential values and solubility products of different salts and extent of dissociation of partially soluble salts

f. Graphical representation and interpretation of thermodynamic reactions and miscible liquids in an ideal solution
g. Identification of oxidation and reduction half cells on the basis of cell equations/ or cell potentials
h. Use of formulas in different stepwise calculations for determining empirical and molecular formula of compounds
i. Calculations for the energy of electron in different orbits with reference to Bohr’s equation
j. Sequential construction of Born Haber cycle and related calculations

Detailed Comments:

Constructed Response Questions (CRQs)

Question 1a:
Describe Heisenberg's uncertainty principle.

Better responses successfully described the Heisenberg's uncertainty principle with the clarity of wave nature of electron. These responses clearly presented that there must be an inaccuracy/ uncertainty in the measurements of position or momentum of electron if both calculated at the same time.

Example:

> Heisenberg's uncertainity principle explains that, due to wave nature of electrone, it is impossible to accurately measure position and momentum of electron simultaneously.

Weaker responses failed to describe Heisenberg's uncertainty principle. Some of these responses demonstrated that there is an uncertainty in the measurement of velocity and position of electron, while some others mentioned that position and momentum of electron cannot be calculated simultaneously without any concept of uncertainty. A few of these responses described that this principle deals with the energy of electron in an orbit and their jumping from one orbit to another.

Example:

> "The electron keeps moving in its orbit without loosing its energy, as it changes its path energy is either added or released."

Question 1b:

Identify each principle/ rule of electronic configuration described in the given table

S. No.	Description	Name of Principle/ Rule
1	Electron should be filled in energy subshells in order of increasing energy values.	
2	Two electrons in the same orbital should have opposite spin.	
3	Each orbital in a sublevel is separately occupied before any orbital is doubly occupied.	

Better responses were able to identify the principle/ rules of electronic configuration with the help of description given in the question. Candidates showed knowledge about Aufbau principle which is the 'building up' principle which states that electrons occupy orbitals in order of increasing energy. Similarly, these responses showed correct identification for Pauli's Exclusion principle and Hund's rule.

Example:

S. No.	Description	Name of Principle/ Rule
1	Electron should be filled in energy subshells in order of increasing energy values.	Aufbau Principle.
2	Two electrons in the same orbital should have opposite spin.	Paulis exclusionprinciple
3	Each orbital in a sublevel is separately occupied before any orbital is doubly occupied.	H und's rule

Weaker responses depicted poor knowledge of principle/ rule related to electronic configuration. In many responses, candidates mentioned the correct name of principle/ rule but mentioned it against wrong description. It was frequently observed that candidates mentioned Heisenberg's uncertainty principle in any one out of three, since it was given in part a. In few other responses, candidates also mentioned names of different Quantum numbers and Hess's law.

Example:

S. No.	Description	Name of Principle/ Rule
1	Electron should be filled in energy subshells in order of increasing energy values.	Heinsberg uncertainity principle
2	Two electrons in the same orbital should have opposite spin.	Hund's rule
3	Each orbital in a sublevel is separately occupied before any orbital is doubly occupied.	Aufbau principle

Question 2:

Describe the concept of conjugate acids and bases using the following reactions as examples.

a. Reaction between hydrogen chloride and water

b. Reaction between ammonia and water

Better responses showed well explained conceptual knowledge of Bronsted Lowry theory of acids and bases. These responses conveyed a clear idea of proton donor and acceptor species as acid and base, whereas, the species formed after the donation or acceptance of that proton are conjugated base and conjugated acid respectively. These responses were able to describe both the reactions with the help of equation and paired-up the acids and bases with their conjugated parts using arrows.

Example:

a. Reaction between hydrogen chloride and water (2 Marks)

$HCl + H_2O \longrightarrow Cl^- + H_3O^+$

Here in this reaction HCl is an acid so Cl^- will be its conjugate base and here H_2O is base so H_3O^+ will be its conjugate acid.

b. Reaction between ammonia and water (2 Marks)

$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

Here in this reaction NH_3 is base and its conjugate acid will be NH_4^+ and here H_2O acts as an acid so its conjugate base will be OH^-

Weaker responses displayed a misconception in pairing acids and bases with their conjugated part. In these responses, a lack of understanding was shown in the concept of acid and base with reference to proton. Many of these responses depicted with the limited knowledge regarding the behaviour of water as an acid or a base in both reactions. Very few of the weaker responses successfully did part 'a' of the question, i.e. reaction between HCl and H_2O but failed to show the equation/ description/ role of water as an acid in part 'b' and ultimately their conjugated pairs could not be identified.

Example:

a. Reaction between hydrogen chloride and water (2 Marks)

Hcl + H2o ⟶ Cl⁻ + 2H2o

conjugate acid which means which oxidize itself and reduce other.

b. Reaction between ammonia and water (2 Marks)

NH3 + H2o ⟶ N + OH

in this reaction. N act as a congugate base and OH also a congugate base.

Question 3:

a. Arrange the following bonded atoms in the correct order of decreasing bond energy.

C≡C, C≡O, C≡N

b. Give a justification for your arrangement in part a.

Better responses profitably arranged the bonded atoms in descending order of bond energy in part 'a', i.e. C≡O > C≡N > C≡C, whereas in part 'b', better responses justified their arrangement with decreasing bond energy i.e. bond energy decreases with the decrease in electronegativity difference/ increase in atomic size/ increase in bond length/ decrease in ionic character.

Example:

> C≡C, C≡O, C≡N (1 Mark)
>
> C≡O, C≡N, C≡C
>
> b. Give a justification for your arrangement in part a. (2 Marks)
>
> The arrangement made in part a is according to the decreasing electron-negativity which causes low bond energy according to the increasing size of the atom.

Weaker responses failed to arrange the bonded atoms in correct order of decreasing bond energy in part ‘a’. They were rather mentioned in the opposite order, i.e. C≡O < C≡N < C≡C or random arrangement. These responses also remained unsuccessful in giving justification of the order as candidates contradicted their own statements. Like, they mentioned C≡C required minimum bond energy (correct statement) because it has two lone pairs (incorrect reason). Similarly, in many weaker responses, candidates showed incorrect arrangement with correct reasoning, i.e. C≡C possess highest bond energy (incorrect statement) because the bond length is greater as compared to C≡N and C≡O (correct reason).

Example:

> C≡C, C≡O, C≡N (1 Mark)
>
> C≡C , C≡N , C≡O
>
> b. Give a justification for your arrangement in part a. (2 Marks)
>
> The least energy to break the bond will be required by C≡C as it has no lone pairs. C≡N has one lone pair so it will require a little more bond energy whereas C≡O has 2 lone pairs so it will require maximum bond energy.

Question 4:

Give a reason why

a. ionic compounds are soluble in water but insoluble in non-aqueous solvents.

b. some covalent compounds dissolve in water.

Better responses, in part ‘a’, described the correct reasons for the solubility of ionic compounds in water. These responses mentioned about the relationship between hydration energy than and lattice energy interference to the polarity of both solute and solvent. Most of the responses explained this polarity in terms of detachment of ions in ionic compound with the attraction of polar parts of water with these ions. Whereas, there is no concept of hydration in non-aqueous solvent due to lack of polarity. In part ‘b’, candidates were able to identify weak intermolecular forces either dipole-dipole interaction or hydrogen bonding are responsible to make a covalent compound soluble in water.

Example:

a. ionic compounds are soluble in water but insoluble in non-aqueous solvents. (2 Marks)

IOnic compound are Soluble in water because when ionic substance is placed in water, Polar molecule detach cation and anion from molecule and thus ions are freed by hydration. This happens when hydration is greater then lattice energy.

b. some covalent compounds dissolve in water. (1 Mark)

Some covalent compound dissolve in water by Forming hydrogen bond in water.

Weaker responses demonstrated the concept of polarity in case of dissolution of ionic compounds in water or non-aqueous solvents in part ‘a’ but failed to explain hydration energy in comparison to lattice energy. In many weaker responses, candidates mentioned that ionic compounds break into ions/ dissociate into ions/ separate into ions but remained unsuccessful in justifying this dissociation. Furthermore, these responses didn’t mention the comparative reasoning for aqueous and non-aqueous solvents/ solute-solvent interactions. In such responses, candidates mentioned hydrogen bonding of water with ionic compounds that makes ionic compound to be soluble in water. Whereas, in part ‘b’, candidates mentioned the concept of polarity instead of the formation of weak intermolecular attractions between polar covalent compounds and polar water molecules.

Example:

a. ionic compounds are soluble in water but insoluble in non-aqueous solvents. (2 Marks)

ionic compound are soluble in water because they break their ions in water ~~the~~ their ion dissolve easily in water. ~~they have~~ they have ionic character in them

b. some covalent compounds dissolve in water. (1 Mark)

because it consist of atom, ions, molecules for this some of compounds dissolve in water

Question 5a:

State Dalton's law of partial pressure.

Better responses stated the Dalton's law of partial pressure for ideal (or non-reactive) gases. These responses also represented the mathematic expression of the law, i.e.

$P_x = P_1 + P_2 + P_3 + ….$

Example:

The total pressure of an ideal (non-reacting) gas is equal to the individual partial pressure of each gas. $P_x = P_1 + P_2 + P_3 \dots$

Weaker responses failed to state the Dalton's law of partial pressure. Few of these responses stated the law in a very generic way without taking in view the concept of ideal (or non-reactive) gases.

Example:

partial pressure means supplying pressure in certain area where pressure is required.

Question 5b:

Explain why it is dangerous for divers to hold their breath during scuba diving.

Better responses correctly explained the effects of increasing and decreasing pressure in relation to volume on the lungs of scuba diver. These responses clearly elaborated the increase in pressure and decrease in volume of lung while a diver descends. Whereas, during ascending to the surface pressure drops and lungs expand due to increase in volume and holding breath at the mean time expands lungs beyond their limit of expansion and this could be fatal.

Example:

It is dangerous for suba divers to hold their breath during scuba diving and not inhaling properly during surfacing because the compressed gas in the scuba is under high pressure (and compressed), during surfacing in water if it is not inhaled properly, the gas may expand within the body resulting in serious threatening condition called 'bends'. For this purpose, they have to spend many hours in decompression chambers. {Divers use scuba in deep water because pressure becomes x than on the surface}.

Weaker responses depicted lack of conceptual understanding of pressure during scuba diving. Candidates explained either in a very generalised way referring to the use of the effect of breathing equipment or in terms of balancing of body with the decrease and increase in pressure. Many of the weaker responses identified the process as an application of Boyle's law instead of Dalton's law of partial pressure.

Example:

It is dangeorous to hold their breath diving The scuba driving because there is high pressure and according to the Boyels law The pressure is inversly propotional to the volume So that why there is dangeorous to hold their breath during Scuba diving.

Question 6a:

Describe the role of a catalyst in a reversible reaction.

Better responses expressed the role of a catalyst in a reversible reaction specifically, i.e. it accelerates the rate of reaction reversibly/ it helps to attain equilibrium in lesser time/ it alters the path of reaction without changing itself/ it lowers the activation energy for both reactions.

Example:

> the role of a catalyst is to speed up the chemical reaction, so when a catalyst is added products are formed more quickly and from products reactants are also formed quikly, which takes less time.

Weaker responses mostly explained the role of catalyst in a generic way without relating it to the reversible reactions or equilibrium. Candidates mostly wrote that a catalyst increases the rate of forward reaction but it stops/ inhibits the backward reaction. They related the amount or concentration of catalyst to its extent of functioning.

Example:

> Catalyst alter the speed of the reaction. If the amount of catalyst is increased the reaction will moves to the forward direction. If theamount of catalyst is decrease, their will be backward reaction.

Question 6b:

Identify the salt from the given table which has the

S. No.	Salts	Ionic Product	K_{sp}
1	Ag_2CO_3	$[Ag^+]^2\ [CO_3^{2-}]$	8.1×10^{-12}
2	$AgCl$	$[Ag^+]\ [Cl^-]$	1.8×10^{-10}
3	$Fe(OH)_3$	$[Fe^{3+}]\ [OH^-]^3$	1.6×10^{-39}

i. highest tendency to dissociate.

ii. least tendency to dissociate.

Better responses identified the correct salt that has the highest dissociation tendency, i.e. AgCl because its K_{sp} value is the greatest, i.e. 8.1×10^{-10}. Whereas, the salt which has the lowest K_{sp} value, i.e. 1.6×10^{-39} has the least tendency to dissociate.

Example:

i. highest tendency to dissociate. (1 Mark)

AgCl has the greatest tendency to dissociate because higher the ksp value greater will be the dissociation.

ii. least tendency to dissociate. (1 Mark)

Fe(OH)3 has the least tendency to dissociate because lower the ksp value lesser will be the dissociation.

Weaker responses mostly swapped the salts showing lack of conceptual clarity, i.e. connection between dissociation tendency and value of K_{sp}. In few of these responses, candidates also picked Ag_2CO_3 as any one of the possibility regardless the given value of K_{sp}.

Example:

i. highest tendency to dissociate. (1 Mark)

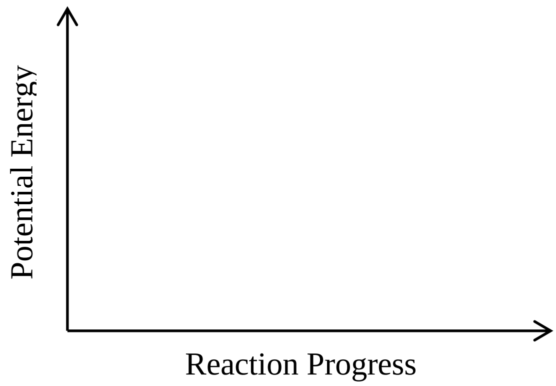
Fe(OH)3 has the highest tendency to dissociate.

ii. least tendency to dissociate. (1 Mark)

AgCl has the least tendency to dissociate.

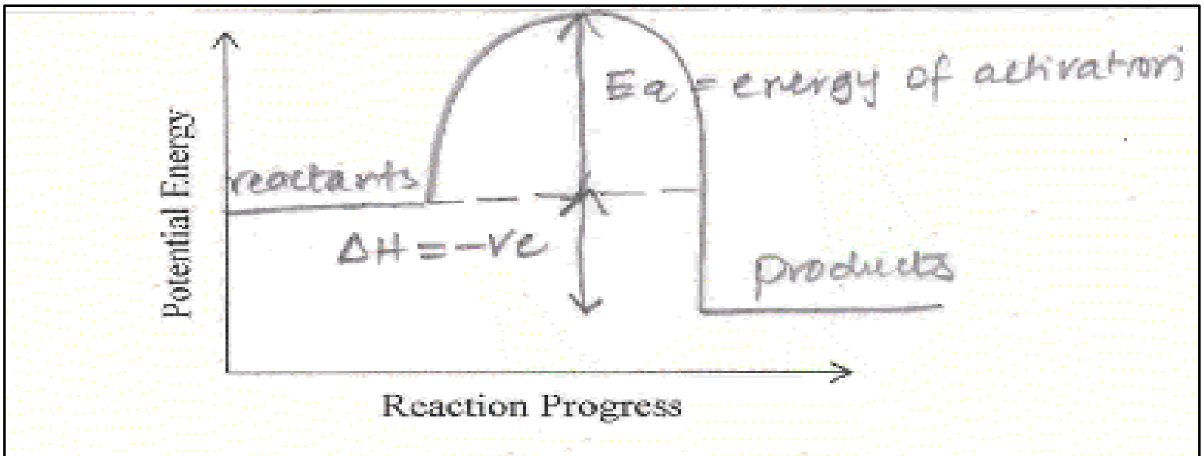
Question 7a:

Draw a labelled energy diagram for an exothermic reaction.



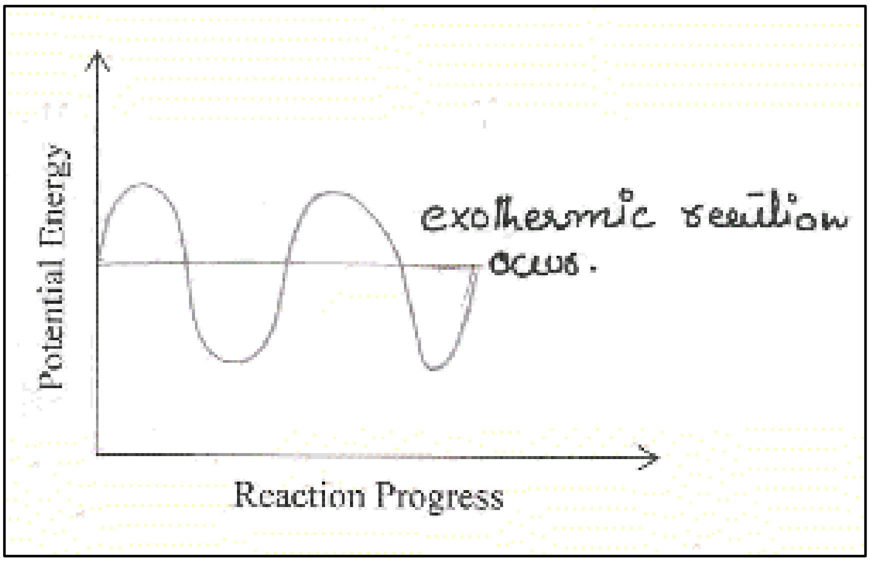
Better responses illustrated the correct position of reactant(s) and product(s) on the curve, i.e. high energy of reactant(s) and low energy of product(s). Moreover, candidates showed labelling of activation energy/ energy released/ - ΔH.

Example:

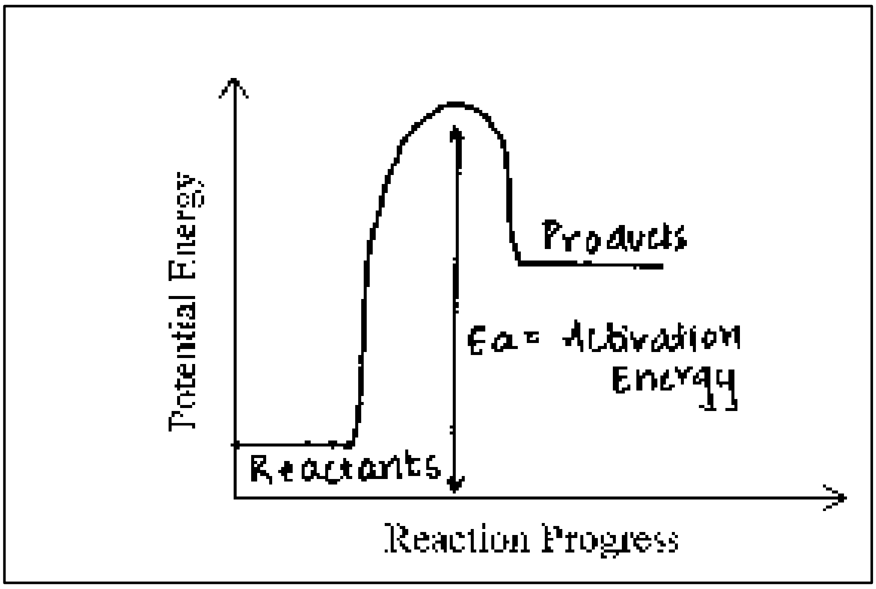


Weaker responses depicted lack of graphical understanding with respect to chemical energetics. Candidates failed to illustrate the correct components of graph in many cases. The incorrect responses showed low energy of reactant and high energy of product/ + ΔH/ for absorption of energy. It reflects the need of clarity between reactions' graphical representations of exothermic and endothermic reactions.

Examples 1:



Examples 2:



Question 7b: Describe the effective collision among molecules with reference to collision theory.

Better responses described the effective collision of molecules in light of the collision theory, i.e. it takes place only if the energy of the colliding particles is high enough to overcome the repulsion between electrons around the reacting particles/ when the colliding particles possess certain amount of energy known as activation energy. Furthermore, candidates also wrote that colliding particle must approach each other with proper orientation for effective collision.

Example:

> It is must for a reaction to proceed to have effective collision. Rate of reaction increase by increasing collisions.
> 1) Molecules of Reactants must posses activation energy.
> 2) They must be properly oriented.

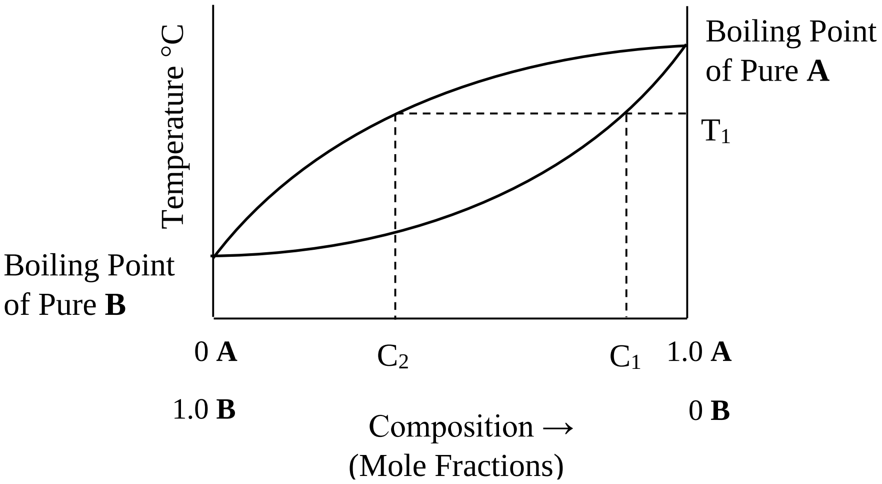
Weaker responses showed lack of understanding of the concept of effective collision. Candidates wrote that effective collision happens/ and the rate of reaction increases when the reaction proceeds rather than stating that reaction proceeds when the effective collision happens, since all collisions are not effective collisions.

Example:

> The reaction progress starts ~~effects~~ its effects of collision among molecules and the potential energy ~~to changing its~~ changes its reaction of exothermic. ~~the~~

Question 8:

Consider the composition-temperature graph of an ideal solution of two miscible liquids **A** and **B**.



a. Which liquid is more volatile, **A** or **B**? Give a reason for your identification.

b. Interpret the following parts in the given graph.

   i. Point C_1

   ii. Point C_2

Better responses, in part 'a', successfully identified that liquid B is more volatile because its boiling point is low. In part 'b', candidates successfully interpreted point C_1, in the given graph, as the composition of liquid mixture where the percentage of component A is higher than that of component B and point C_2 was explained as the composition of vapour phase where the percentage of component B is higher than that of component B.

Example:

liquid B will be more volatile. Because it will evaporate rapidly, exert more vapour pressure and hence have low boiling point.

b. Interpret the following parts in the given graph.

i. Point C_1 (1 Mark)

At C_1 the concentration of liquid A will be more as compare to concentration of liquid B in liquid phase.

ii. Point C_2 (1 Mark)

At point C_2 the concentration of liquid A will be less as compare to liquid B in gaseous state or in vapour state.

Weaker responses failed to understand the graphical representation of an ideal solution of two miscible liquids. In part 'a', candidates wrongly identified the compound with greater volatility and the reason behind that. Some of the weaker responses shown contradiction in the identification and the reason of identification, i.e. they wrongly identified compound A as a highly volatile compound but wrote the correct reason for high volatility, i.e. low boiling point. Whereas, in part 'b', candidates mentioned the interconversion of the given values of composition rather than interpreting it. Futhermore, these responses failed to interpret that C_1 represents liquid phase and C_2 vapour phase.

Example:

Liquid A is more Volatile

Because it's Boiling Point is less

b. Interpret the following parts in the given graph.

i. Point C_1 (1 Mark)

The point where A=0 is going to be A=1.0

ii. Point C_2 (1 Mark)

The point where B=0 is going to be B=1.0

Question 9:

Use the given information to answer the following questions.

$$Pt_{(s)} \left| MnO^-_{4(aq)}, H^+_{(aq)}, Mn^{2+}_{(aq)} \right\| Sn^{4+}_{(aq)}, Sn^{2+}_{(aq)} \left| Pt_{(s)} \right.$$

The half-cell reactions and potentials are:

Equation 1 $\quad MnO^-_{4(aq)} + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)} \qquad E° = +1.51\,V$

Equation 2 $\quad Sn^{4+}_{(aq)} + 2e^- \rightarrow Sn^{2+}_{(aq)} \qquad E° = +0.15\,V$

a. Which equation, 1 OR 2, is the oxidation half-cell reaction? Show the correct representation of the identified equation with its cell potential.

b. Write a balanced chemical equation for the overall cell reaction that occurs on the conduction of current.

c. Calculate the standard potential (E°) of the given electrochemical cell.

Better responses, in part 'a', distinctively identified the correct oxidation half-cell reaction, i.e. equation number 2. Since both equations are showing reduction reactions, candidates identified it with the help of reduction potential and made it correct by reversing the equation and operation sign from + to - of cell potential. In part 'b', candidates multiplied equation 1 by 2 and equation 2 by 5 to balance the number of electrons and added both the equation after balancing to get the overall cell reaction by cancelling equal number of electrons on both side. In part 'c', candidates correctly used formula to calculate standard electrode potential, i.e. $E^\circ_{cell} = E^\circ_{ox} + E^\circ_{red}$.

Example:

Oxidation half reaction:

$Sn^{+2} \longrightarrow Sn^{+4} + 2e^-$ $E^o = -0.15\,V$

b. Write a balanced chemical equation for the overall cell reaction that occurs on the conduction of current. (2 Marks)

$2MnO_4^{-1} + 16H^+ + 10e^- \longrightarrow 2Mn^{+2} + 8H_2O$

$5Sn^{+2} \longrightarrow 5Sn^{+4} + 10e^-$

overall balanced equation :-

$2MnO_4^{-1} + 16H^+ + 5Sn^{+2} \longrightarrow 2Mn^{+2} + 8H_2O + 5Sn^{+4}$

c. Calculate the standard potential (E°) of the given electrochemical cell. (1 Mark)

$E^o_{cell} = E_{ox} + E_{red}$

$= -0.15 + 1.51 = +1.36\,V$

Weaker responses, in part ‘a’, wrongly identified the oxidation half-cell reaction, i.e. equation 1. Another mistake after identification candidates made was the reversal of wrongly identified equation without reversal of operation sign from + to - or vice versa. In some responses, the correction of equation step was overall missing. Hence, candidates showed poor command on the concept of oxidation and reduction. Additionally, candidates in part ‘b’, failed to balance the number of electrons in both equations and summed up both equations as it is to get the overall reaction. In part ‘c’, some of the responses wrote incorrect formula of standard cell potential, while others placed incorrect values or signs in the correct formula that ultimately resulted in an incorrect value for standard electrode potential.

Example:

1 because Sn^{+4} gain two electrons and it will be oxidized in Sn^{+2}. and Sn has also low standard potential so it will be first oxidized.

b. Write a balanced chemical equation for the overall cell reaction that occurs on the conduction of current. (2 Marks)

by adding both Eq

$MnO_4 + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$

$MnO_4 + 8H^+ + 7e^- + Sn^{4+} \rightarrow Mn^{2+} + 4H_2O + Sn^{2+}$ Ans

c. Calculate the standard potential (E°) of the given electrochemical cell. (1 Mark)

$E^\circ = E^\circ_1 + E^\circ_2$

$= +1.51 + 0.15 = 1.66\ V$

Extended Response Questions (ERQs)

The following questions (10 and 11) offered a choice between part **a** and **b**.

Majority of the candidates attempted part ‘a’ of both questions, 10 and 11. This shows their interest and in-depth understanding of both concepts, i.e. ‘stoichiometry’ and ‘balancing of equation’. However, some responses in part ‘b’ reflected that mostly candidates lack confidence and command over the knowledge embedded in the concepts of ‘Bohr’s equation’ and ‘Born-Haber cycle’.

Question 10a:

The combustion analysis of an organic compound with relative molar mass 99 g shows that it contains 4.04% hydrogen, 24.24% carbon and 71.72% chlorine.

(**Note**: Atomic mass of H = 1 amu, C = 12 amu and Cl = 35.5 amu)

What are the ‘i’ empirical formula and (ii) molecular formula of the given compound? Show the steps of working clearly.

Better responses clearly mentioned all the steps required to calculate empirical formula in part ‘i’. First of all, candidates used given elemental percentages for the calculation of correct number of moles. After that candidates used calculated number of moles to find the simplest elemental ratio and incorporated it to formulate the empirical formula of the given organic compound. While proceeding to part ‘ii’, candidates calculated empirical formula mass by using empirical formula determined previously. This empirical formula mass was then used to calculate the value of ‘n’ followed by molecular formula of the compound.

Example:

a) Solution

% of hydrogen = 4.04 %

% of carbon = 24.24 %

% of Chlorine = 71.72

Step II

Hydrogen = $\frac{4.04}{1}$ = 4.04

carbon = $\frac{24.24}{12}$ = 2.02

Chlorine = $\frac{71.72}{35.5}$ = 2.02

Step III

H = $\frac{4.04}{2.02}$ = 2

C = $\frac{2.02}{2.02}$ = 1

Cl = $\frac{2.02}{2.02}$ = 1

Emperical formula = CH_2Cl

n = $\frac{99}{49.5}$ = 2

molecular formula = $2(CH_2Cl)$

$C_2H_4Cl_2$

Weaker responses, in part ‘i’, failed to perform step-wise calculation to calculate empirical formula. These responses showed inability of candidates to use elemental percentages in calculating the mole ratios. In many responses, candidates directly used percentages to find the simplest elemental ratio/ used wrong method to find number of mole/ used multiplication or division by 100 in the calculation for the number of moles. Since wrong number of moles had calculated. Therefore, candidates failed to determine the correct empirical formula and ultimately its mass. Besides that, in part ‘ii’, candidates remained unsuccessful in finding the correct value of ‘n’ for further determining the empirical formula.

Example 1:

Molar mass = 99g

Hydrogen% = 4.4%

Carbon% = 24.24%

Chlorine% = 71.72%

Emperical formula = ?

Molecular formula = ?

Emperical formula = $\frac{4.04\% + 24.24\% + 71.72\%}{99g}$

Emperical formula = $\frac{35.74\%}{99g}$ = 0.36g%

Molecular formula = $\frac{1amu + 12amu + 35.5 amu}{99g}$

Molecular formula = $\frac{48.5 amu}{99g}$ = 0.489 amu

Example 2:

Emperical formula of H = $\frac{1 \times 4.04\%}{99g}$ = 0.04g

Emperical formula of C = $\frac{12 \times 24.24\%}{99g}$ = 2.93g

Emperical formula of Cl = $\frac{35.5 \times 71.72\%}{99g}$ = 25.7g.

Molecular formula of H = 99g * 4.04% = 103

Molecular formula of C = 99g + 24.24% = 123

Molecular formula of Cl = 99g + 71.72% = 170

Question 10b:

Bohr's equation for the calculation of energy associated with electron in the n^{th} orbit of hydrogen atom is $E_n = \frac{-me^4}{8\varepsilon_o^2 n^2 h^2}$ where $\frac{-me^4}{8\varepsilon_o^2 h^2} = -2.18 \times 10^{-18}$ J.

Justify that the energy difference $E_3 - E_2 > E_4 - E_3$. Show the steps of working and determine the number of times $E_3 - E_2$ is greater than $E_4 - E_3$.

(**Note**: Write answers up to two decimal places.)

Better responses accurately used the given Bohr's formula for finding the values of energy associated with electron in the 2^{nd}, 3^{rd}, and 4^{th} orbit. After that candidates successfully calculated the difference between $E_3 - E_2$ and $E_4 - E_3$ by using the values calculated in the previous step. In next step, candidates justified that $E_3 - E_2 > E_4 - E_3$, along with the interpretation of values, these responses showed the correct ratio of the energy difference, i.e. 2.85.

Example:

The formula for calculating energy of any orbit of hydrogen according to Bohr is $= -2.18 \times 10^{-18} \left[\frac{1}{n^2}\right] J$

So,

for 2^{nd} orbit $= -2.18 \times 10^{-18} \left[\frac{1}{2^2}\right] J$

$= -5.45 \times 10^{-19} J$

for 3^{rd} orbit $= -2.18 \times 10^{-18} \left[\frac{1}{(3)^2}\right] J$

$= -2.42 \times 10^{-19} J$

for 4^{th} orbit $= -2.18 \times 10^{-18} \left[\frac{1}{(4)^2}\right] J$

$= -1.36 \times 10^{-19} J$

Energy differences

$E_3 - E_2 = (-2.42 \times 10^{-19}) - (-5.45 \times 10^{-19}) = 3.03 \times 10^{-19} J$

$E_4 - E_3 = (-1.36 \times 10^{-19}) - (-2.42 \times 10^{-19}) = 1.06 \times 10^{-19} J$

This shows that $E_3 - E_2 > E_4 - E_3$

$$\frac{E_3 - E_2}{E_4 - E_3} = \frac{3.03 \times 10^{-19}}{1.06 \times 10^{-19}} = 2.85$$

$E_3 - E_2$ is 2.85 times greater than $E_4 - E_3$.

Energy decreases when electron is in lower orbit. Here, 2nd orbit has the lowest energy that's why the difference of energy between 3rd and 2nd orbit is more than the difference of energy between 4^{th} and 3rd orbit.

Weaker responses, in part 'b', demonstrated limited understanding of Bohr's formula for finding E_n. Most of these responses used wrong formula for calculating energies associated with electron in 2nd, 3rd, and 4th orbits. Candidates used incorrect values of constants/ incorrect values of 'n'/ unable to square the value of 'n'/ incorrect arithmetic methods for calculations/ wrong manipulation of formula. A few of the candidates used incorrect values of exponents. Furthermore, the sign conventions (negative and positive) were ignored. Candidates failed to calculate the difference between energies related to different orbits and their ratio.

Example:

(b)

$E_n = \frac{-me^4}{8\varepsilon_0^2 n^2 h^2}$ where, $\frac{-me^4}{8\varepsilon_0^2 h^2} = 2.18 \times 10^{-8}$ J

Difference,

$E_3 - E_2 > E_4 - E_3$ and show that $E_3 - E_2$ is greater than $E_4 - E_3$

$E_3 - E_2 > E_4 - E_3$

$E_{+1} > E_{+1}$

They equal in reaction but opposite in direction.

BOHR's equation for the calculation with electron in the nth orbit of hydrogen atom is $E_n = \frac{-me^4}{8\varepsilon_0^2 n^2 h^2}$ where, $\frac{-me^4}{8\varepsilon_0 h^2} = 2.18 \times 10^{-19}$

Hence $E_3 - E_2$ is greater than $E_4 - E_3$

Question 11a:

The given reaction takes place in an acidic medium.

$$PbO_{2(s)} + I^{-}_{(aq)} \rightarrow Pb^{2+}_{(aq)} + I_{2(g)}$$

Balance the given equation using the half-reaction method.

(**Note**: Show all the steps of balancing in sequence.)

Better responses correctly balanced the given ionic equation using half-reaction method in a step-wise manner. First of all, candidates identified oxidation and reduction half-reaction and mentioned these reactions in two separate equations. Candidates balanced each equation accordingly. Candidates successively mentioned balancing of iodine with same number of atoms in oxidation half-reaction. In reduction half-reaction, balancing of oxygen by adding water on product side and balancing of hydrogen by adding H^{+} ion on reactant side was carried out correctly. Beside that, addition of 2 electrons in both equations on the correct position was mentioned. Moreover, candidates summed up these two half-reactions by generating the overall balanced equation.

Example:

Step1: Showing oxidation number of compound & Ions.

$\overset{+4}{Pb}\overset{(-2)2}{O_2} + I^{-} \longrightarrow Pb^{2+} + I_2^{0}$

Step2:, Seperating the oxidation & reduction reactions

Reduction: $PbO_2 \longrightarrow Pb^{2+}$

Oxidation: $I^{-} \longrightarrow I_2^{0}$

Step 3: Balancing the equation by balancing atoms and charges by adding H^{+} & H_2O.

Reduction: $PbO_2 \rightarrow Pb^{2+}$

$4H^{+} + PbO_2 \longrightarrow Pb^{2+} + 2H_2O$.

Example:

$4H^{+} + PbO_2 + 2e^{-} \longrightarrow Pb^{2+} + 2H_2O$

Oxidation :, $I^{-} \longrightarrow I_2^{0}$

$2I^{-} \longrightarrow I_2^{0} + 2e^{-}$

Step4 :, Now, adding both reactions & cancelling same species.

$4H^{+} + PbO_2 + \cancel{2e^{-}} \longrightarrow Pb^{2+} + 2H_2O.$

$2I^{-} \longrightarrow I_2^{0} + \cancel{2e^{-}}$

$4H^{+} + PbO_2 + 2I^{-} \longrightarrow Pb^{2+} + I_2^{0} + 2H_2O.$

Now comparing both sides:

	Left		Right
H =	4	=	4
Pb =	1	=	1
O =	2	=	2
I =	2	=	2

Since both sides are equal

Thus equation is balanced.

Weaker responses wrongly identified the oxidation and reduction half-reactions. In many of these weaker responses, candidates were able to balance atoms of iodine in oxidation half-reaction but failed to balance oxygen in reduction half-reaction. Similarly, in few responses, candidates either added the correct number of electrons but showed wrong placement or added wrong number of atoms with correct placement. Because of errors, candidates remained unsuccessful in determining the overall balanced chemical equation.

Example:

$PbO_2 + I^- \longrightarrow Pb^{2+} + I_2$

half Reaction

① $PbO_2 \longrightarrow Pb^{+2}$

② $I^{-1} \longrightarrow I_2$

① $PbO_2^{-2} \longrightarrow Pb^{+2}$ so, $x + (-2)_2 = -2$

$x + (-4) = -2$

$Pb^{+2}O_2^{-2} \longrightarrow Pb^{+2} + 2H_2O$ (adding water) $x = -2 + 4$

(adding H^+) $4H_2 + \overset{+2}{Pb}\overset{-2}{O_2} \longrightarrow Pb^{+2} + 2H_2O$ $x = +2$

$4H_2 + \overset{+2}{Pb}\overset{-2}{O_2} \rightarrow Pb^{+2} + 2H_2O + 4e^-$

② $I^{-1} \longrightarrow I_2$

$I^- \longrightarrow I_2^{+1}$

$2I^{-1} \longrightarrow I_2^{+1} + e^-$

$1\times(4H_2 + Pb^{+2}O_2^{-2} \longrightarrow Pb^{+2} + 2H_2O + 4e^-)$

$4\times(2I^{-1} \longrightarrow I_2^{+1} + e^-)$

then,

$4H_2 + \overset{+2}{Pb}\overset{-2}{O_2} \rightarrow Pb^{+2} + 2H_2O + \cancel{4e^-}$

$8I^{-1} \longrightarrow 4I_2^{+1} + \cancel{4e^-}$

final equation:

$\overset{+2}{Pb}\overset{-2}{O_2} + 8I^{-1} + 4H_2 \longrightarrow Pb^{+2} + 4I_2^{+1} + 2H_2O$.

Answer.

Question 11b:

Change in Standard Enthalpy	Value/ $kJmol^{-1}$
ΔH°_{at} Heat of atomisation of $Ca_{(s)}$	+ 179
ΔH°_{BDE} Bond dissociation enthalpy of $F_{2(g)}$	+ 158
ΔH°_{i} First ionisation energy of $Ca_{(g)}$	+ 590
ΔH°_{i} Second ionisation energy of $Ca^{+}_{(g)}$	+ 1,150
ΔH°_{ea} First electron affinity of $F_{(g)}$	−328
ΔH°_{f} Heat of formation of $CaF_{2(s)}$	−1,220

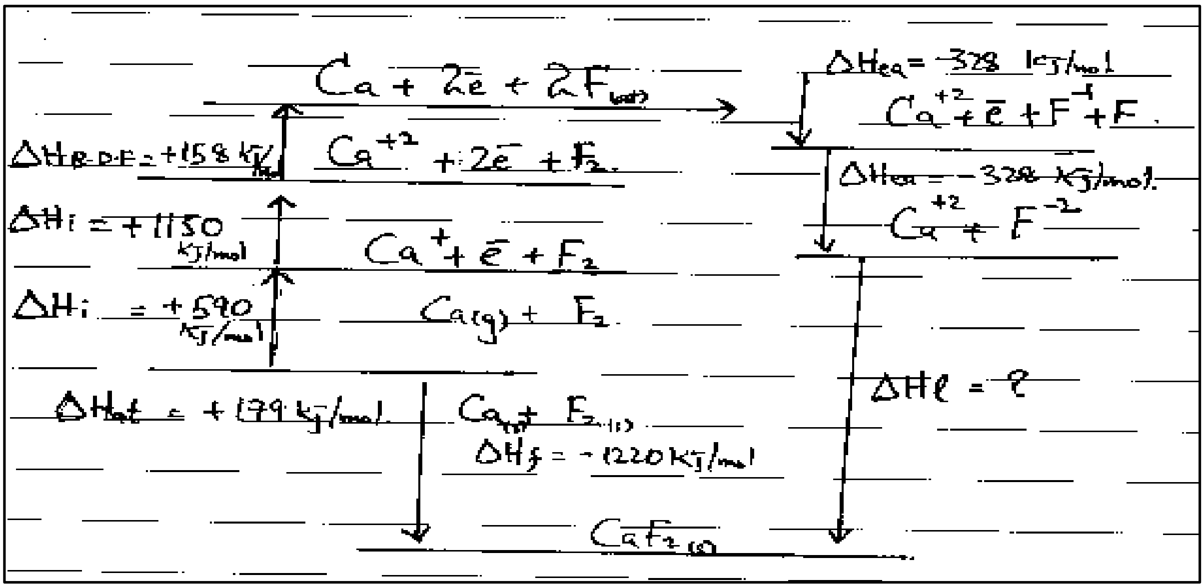
Using the given data,

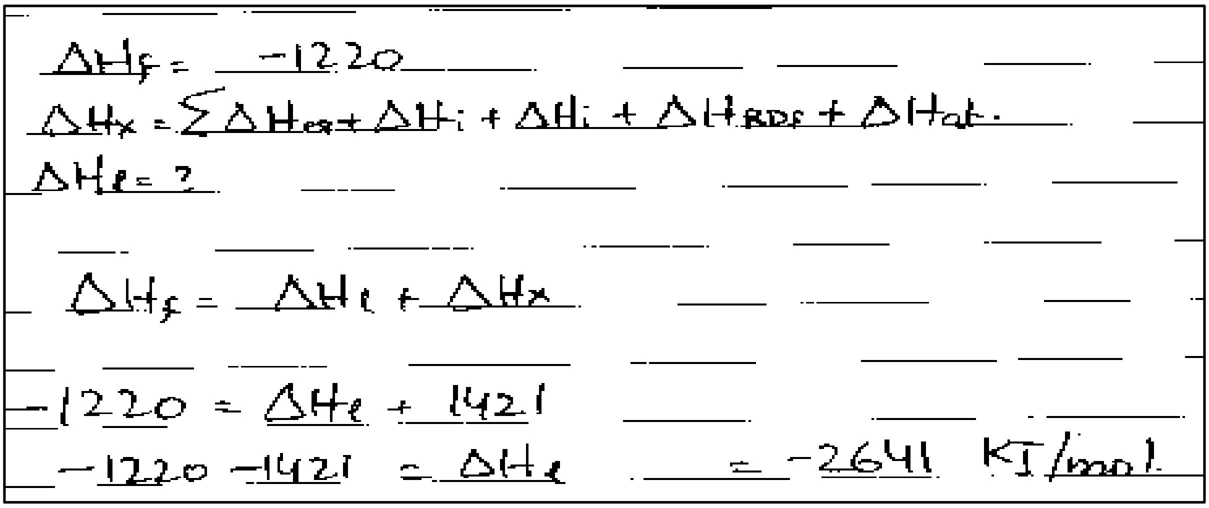
i. construct a labelled Born-Haber cycle for calcium fluoride (CaF_2).

ii. calculate the lattice enthalpy of CaF_2.

Better responses, in part ‘i’, distinctively constructed a well labelled Born-Haber cycle by showing the change in standard state of substances at each stage as given in the table. This indicates that candidates had sound clarity of the concept of Born-Haber cycle. Furthermore, these responses showed the correct direction of arrows for absorption and emission of heat in each step. In part ‘ii’, candidates showed the correct substitution of values and operation sign in the formula of lattice enthalpy and deduced the final value of lattice enthalpy for CaF_2.

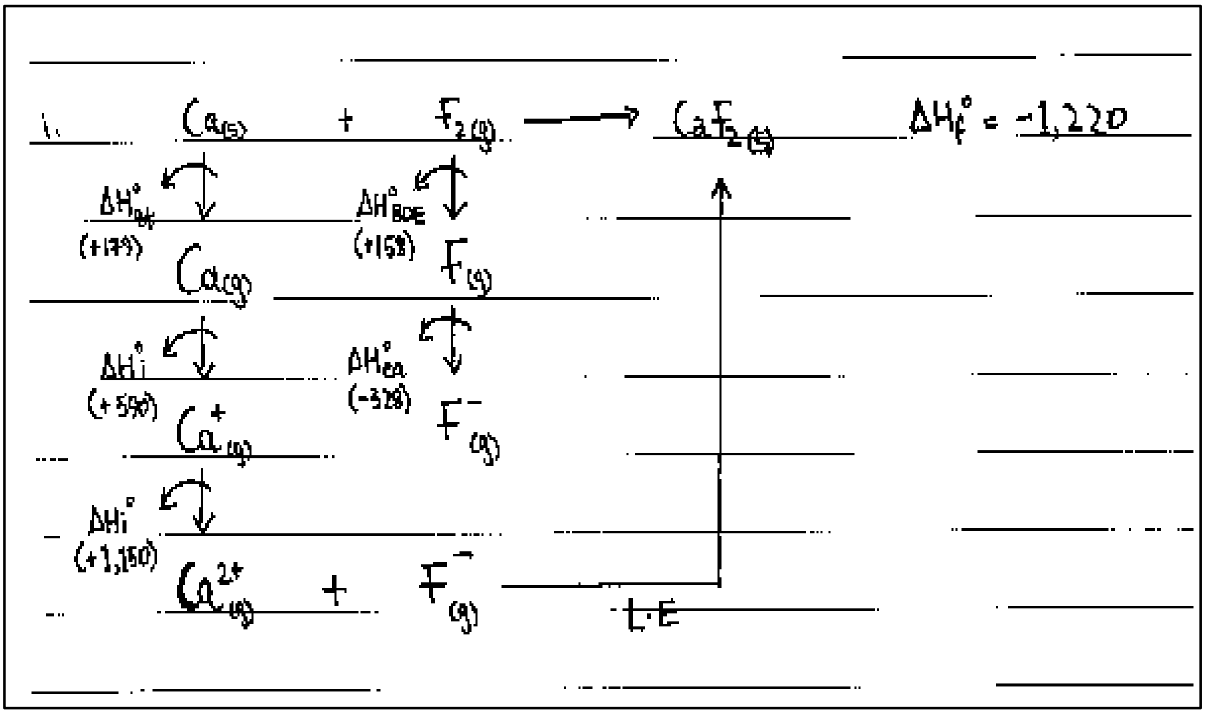
Example:





Weaker responses, in part ‘i’, showed incorrect order of events occuring in the formation of CaF_2. Step-wise arrangement of changes in enthalpy were wrongly displayed/ direction of arrows for heat absorption and emission were incorrect/ incomplete cycle was mentioned. In many responses to part ‘ii’, candidates ignored the operation signs with heat enthalpies and substituted wrong values or applied wrong formula to calculate lattice enthalpy of CaF_2. The major mistake observed in this part was that candidates did not multiply electron affinity of fluoride by 2 which led them to the incorrect value of lattice enthalpy.

Example:



ii.

$\Delta H_f = \Delta H_{at} + \Delta H_i + \Delta H_i + \Delta H_{BDE} + \Delta H_{ea} + L \cdot E$

$-1220 = +179 + 590 + 1150 + 158 + (-328) + (-L \cdot E)$

$L \cdot E = +179 + 590 + 1150 + 158 - 328 + 1220$

$L \cdot E = 2969$ ← lattice enthalpy of CaF_2.