CARIBBEAN EXAMINATIONS COUNCIL

CAPE® CHEMISTRY UNIT 1

Subject Report with Exemplars

June/July 2021

CARIBBEAN EXAMINATIONS COUNCIL

REPORT ON CANDIDATES' WORK IN THE CARIBBEAN ADVANCED PROFICIENCY EXAMINATION

JUNE/JULY 2021

CHEMISTRY
UNIT 1

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INTRODUCTION

Unit 1: Chemical Principles and Applications I is divided into three modules. These modules are

- Module 1: Fundamentals in Chemistry
- Module 2: Kinetics and Equilibria
- Module 3: Chemistry of the Elements.

Candidates' knowledge of this unit is examined through the following papers.

- Paper 01 — Multiple Choice
- Paper 02 — Structured Essay
- Paper 031 — School-Based Assessment (SBA)
- Paper 032 — Alternative to the School-Based Assessment

Paper 01 comprises 45 compulsory multiple-choice items, which consist of 15 items per module. The paper is worth a total of 90 marks, representing 40 per cent of the total mark for the unit.

Paper 02 comprises three compulsory questions. Each module is the basis of one question. The paper is worth a total of 90 marks, representing 40 per cent of the total mark for the unit.

For Paper 031, candidates must complete laboratory exercises. This component of the exam contributes 20 per cent of the total mark for the unit.

Paper 032 is taken by private candidates. It comprises three compulsory questions which assess candidates' experimental skills.

There was an improvement in the overall performance of candidates in 2021 when compared with 2019 and 2020. Ninety-one per cent of the 3930 candidates who wrote the examination earned Grades I–V. There was also an increase by approximately ten per cent in candidates earning Grade 1.

It is encouraging to see an improvement in the performance of candidates on Paper 01 and Paper 02. However, candidates are underperforming on certain topics and so we are encouraging teachers to teach students about all topics in each unit in detail.

PAPER 01 — MULTIPLE CHOICE

Paper 01 consisted of 45 multiple-choice items. The paper was designed to test the Unit 1 modules extensively. Approximately 92 per cent of candidates earned acceptable grades. The mean score was 34 out of 45 marks.

PAPER 02 — STRUCTURED ESSAY

Question 1

This question tested syllabus objectives 1.4–1.6, 3.3–3.9 and 4.1–4.4 from Module 1: Fundamentals in Chemistry. The mean was 12.35 and the standard deviation 6.29.

Candidate's Response to Part (a) (i)

(i) Define the term 'radioactive isotope'.

A radioactive isotope is an isotope which nuclei breaks down spontaneously by emitting radioactive particles or waves.

[1 mark]

> **Examiner's Comments**
>
> The candidate accurately defined the term *radioactive isotope*. In many cases, candidates did not include the critical component of the definition which was the spontaneous breakdown of the nuclei.

Candidate's Response to Part (a) (ii)

(ii) Give the names and symbols for TWO other forms of radioactive emissions.

1. Beta particle (name) & β (symbol)
2. gamma rays/radiation (name) & γ (symbol)

[2 marks]

> **Examiner's Comments**
>
> The candidate was able to give the names and symbols of two other forms of radioactive emissions. Many candidates were able to give the names for these types of emissions but they did not provide the correct symbols.

Candidate's Response to Part (a) (iii)

(iii) List THREE uses of radioactive isotopes.

1. C-14 (Carbon 14) : used to date ancient organic matter

2. ^{233}U (Uranium 233) : energy generation

3. ^{131}I (Iodine 131) : used as tracers to determine thyroid gland problems.

[3 marks]

Examiner's Comments

Generally, candidates were able to list uses of radioactive isotopes. In addition to the uses provided by the candidate in the exemplar, it must be noted that radioactive isotopes are also used for monitoring and controlling sheet material in a rolling mill.

Candidate's Response to Part (a) (iv)

(iv) Determine the value of A and Z in the following equation.

$$^{241}_{95}Am \rightarrow \, ^{A}_{Z}Np + \, ^{4}_{2}He + energy$$

$A = 241 - 4$
$= 237$

$Z = 95 - 2$
$= 93$

[2 marks]

Examiner's Comments

The candidate was able to determine the value of A and Z. Generally, candidates answered Part (a) (iv) correctly.

Candidate's Response to Part (b)

(b) The element rhenium consists of two isotopes ^{185}Re and ^{187}Re, in the atomic ratio of 2:3. Calculate the relative atomic mass of rhenium to three significant figures.

$$A_r = \left(\frac{2}{5} \times 185\right) + \left(\frac{3}{5} \times 187\right)$$

$$= 74 + 112.2$$

$$= 186.2$$

$$\approx 186 \text{ (to 3 significant figures)}$$

[2 marks]

> **Examiner's Comments**
> The candidate was able to calculate the relative atomic mass of rhenium to three significant figures. There were some candidates who calculated the answer correctly but did not give the final answer as three significant figures. Other candidates were unable to calculate the correct answer.

Candidate's Response to Part (c) (i)

(i) List TWO chemicals and ONE piece of apparatus that the student may use to carry out the investigation.

Chemicals ..... Cl_2 (aq) – Chlorine water ✓

..... KI (aq) — Potassium Iodide solution ✓

Apparatus ..... 50 cm^3 beaker ✗

.....

[3 marks]

> **Examiner's Comments**
> The candidate was able to list the chemicals needed to conduct the investigation but failed to list one correct piece of apparatus. Generally, many candidates were unable to list the reagents for this investigation.

Candidate's Response to Part (c) (ii)

(ii) Describe ONE physical change that the student may observe while carrying out the investigation.

The colour of the solution ~~with~~ ($KI_{(aq)}$) will transition from colourless to Brown when the $Cl_{2 (aq)}$ is added.

[1 mark]

Examiner's Comments

The candidate accurately described the colour transition that would occur during the investigation. However, many candidates were unable to do so because they answered Part (c) (i) incorrectly.

Candidate's Response to Part (c) (iii)

(iii) Identify the oxidizing agent that the student may use while conducting the investigation.

Oxidizing Agent = $Cl_{2 (aq)}$.

[1 mark]

Examiner's Comments

The candidate's response was correct. However, many candidates were unable to identify the oxidizing agent that the student could use because they answered Part (c) (ii) incorrectly.

Candidate's Response to Part (c) (iv)

(iv) Write relevant half equations to illustrate the chemical changes that occur with EACH element used to carry out the investigation.

$2e^- + Cl_{2 (aq)} \longrightarrow 2Cl^-_{(aq)}$

eq ①: $Cl_{2 (aq)} + 2e^- \rightarrow 2Cl^-_{(aq)}$

$2I^-_{(aq)} \longrightarrow I_{2 (aq)} + 2e^-$

eq ②: $2I^-_{(aq)} \rightarrow I_{2 (aq)} + 2e^-$

[2 marks]

Examiner's Comments

The candidate provided the relevant half equations. However, many candidates were unable to do so because they answered Part (c) (iii) incorrectly.

Candidate's Response to Part (d)

(d) Define EACH of the following terms.

(i) Molar mass this is the mass of 1 mole of a chemical substance expressed in grams units: $g\,mol^{-1}$.

(ii) Mole The amount of substance that has the same number of elementary entities as their are atoms in 12.00 grams of C-12.

[2 marks]

decrease in oxidation state
reduced

Examiner's Comments

The candidate was able to define both terms. Generally, most candidates were able to define molar mass; however, some candidates were unable to define the term *mole.*

Candidate's Response to Part (e) (i)

(i) Calculate the original number of moles of NaOH in 100 cm^3 of 0.500 mol dm^{-3} aqueous sodium hydroxide.

$1000\ cm^3 \xrightarrow{\text{contains}} 0.500$ moles of $NaOH_{(aq)}$

$1\ cm^3 \xrightarrow{\text{contains}} \frac{0.500}{1000}$ moles

$\therefore 100\ cm^3 \xrightarrow{\text{contains}} \frac{0.500}{1000} \times 100$ moles

$= 0.05$ moles ✔

[2 marks]

Candidate's Response to Part (e) (ii)

(ii) Calculate the number of moles of HCl in 27.3 cm^3 of 0.600 mol dm^{-3} hydrochloric acid.

$1000\ cm^3 \xrightarrow{\text{contains}} 0.600$ moles of $HCl_{(aq)}$

$1\ cm^3 \xrightarrow{\text{contains}} \frac{0.600}{1000}$ moles of $HCl_{(aq)}$

$\therefore 27.3\ cm^3 \xrightarrow{\text{contains}} \left(\frac{0.600}{1000} \times 27.3\right)$ moles of $HCl_{(aq)}$ ✔

$= 0.01638$ moles

≈ 0.016 (to 3 sig. figs.)

[2 marks]

Examiner's Comments

The candidate presented the steps required to calculate the answers for Part (e) (i) and Part (e) (ii) clearly and logically.

Candidate's Response to Part (e) (iii)

(iii) Deduce the number of moles of the unreacted NaOH neutralized by the hydrochloric acid.

Moles of unreacted NaOH ....0.01638 moles of NaOH....

[1 mark]

NaOH : HCl
1 : 1

> **Examiner's Comments**
> Candidates were required to deduce the mole ratio between the NaOH and HCl to provide the correct answer. However, several candidates were unable to do so.

Candidate's Response to Part (e) (iv)

(iv) Calculate the number of moles of NaOH which reacted with the ammonium sulfate.

no. of moles reacted = initial no. of moles − excess no. of moles

= (0.05 − 0.01638) moles

= 0.03362 moles ≈ 0.034 moles

Moles of NaoH ....0.034 moles....

[2 marks]

Candidate's Response to Part (e) (v)

(v) Use your answer in (e) (iv) to calculate the number of moles and the mass of ammonium sulfate in the sample.

$(NH_4)_2SO_4 : NaOH$

1 : 2

$\frac{0.03362}{2}$: 0.03362

= 0.01681

molar mass of $(NH_4)_2SO_4$:

= 2(14) + 8(1) + 32.1 + 4(16)

= 28 + 8 + 32.1 + 64

= 132.1 grams..

Moles of ammonium sulfate ....0.01681 moles....

Mass of ammonium sulfate ....(0.01681 × 132.1) grams

= 2.22 grams **[3 marks]**

Examiner's Comments
The candidate calculated the answers to Part (e) (iv) and Part (e) (v) in a clear and logical manner.

Candidate's Response to Part (e) (vi)

(vi) Write the ionic equation, including physical states, for the reaction between ammonium sulfate and aqueous sodium hydroxide.

$2NH_4^+{}_{(aq)} + 2OH^-{}_{(aq)} \rightarrow 2NH_{3(g)} + 2H_2O_{(l)}$

[1 mark]

Examiner's Comments
Many candidates were unable to provide the correct equation.

Question 2

This question tested syllabus objectives 1.4–1.8, 4.1–4.4 and 2.3–2.7 from Module 2: Kinetics and Equilibria. The mean was 11.65 and the standard deviation 7.52.

Candidate's Response to Part (a) (i)

(i) Using the data from Experiment 1, calculate a value for the rate constant, *k*, and state its units.

rate = $k[Q][R]^2$

$\therefore k = \frac{\text{rate}}{[Q] \times [R]^2}$

using expm't 1:

$k = \frac{1.2 \times 10^{-4}}{(0.020) \times (0.020)^2}$

$= 15$

units: $\frac{\text{mol dm}^{-3}\ s^{-1}}{\text{mol dm}^{-3} \times \text{mol}^2\,\text{dm}^{-6}} = \text{mol}^{-2}\,\text{dm}^6\,s^{-1}$

Rate constant, *k* ....15 $\text{mol}^{-2}\,\text{dm}^6\,s^{-1}$....

[3 marks]

Examiner's Comments
The candidate calculated the correct value for the rate constant, k, and stated its units.

Candidate's Response to Part (a) (ii)

Experiment	Initial [Q]/mol dm^{-3}	Initial [R]/mol dm^{-3}	Initial Rate/mol dm^{-3} s^{-1}
1	0.020	0.020	1.2×10^{-4}
2	0.040	0.040	9.6×10^{-4}
3	0.010	0.040	2.4×10^{-4}
4	0.060	0.030	8.1×10^{-4}
5	0.040	0.035 ≈ 0.04 to 2 sig. figs.	7.2×10^{-4}

Examiner's Comments

The candidate completed the table accurately.

Candidate's Response to Part (a) (iii)

(iii) The order of the reaction with respect to R is 2. State the meaning of the term 'order of reaction' with respect to R.

This is the relationship between R's rate of reaction and and the concentration of R.

[1 mark]

[redacted]

Examiner's Comments

The candidate's definition of the term *order of reaction* with respect to R is incorrect. The candidate should have stated that the order of reaction is the power to which the concentration of a particular reactant is raised in the rate equation.

Candidate's Response to Part (a) (iv)

(iv) Deduce the overall order of the reaction between Q and R.

Overal order = order w.r.t Q + order w.r.t R

= 1 + 2 = (3) ← overal order **[1 mark]**

Examiner's Comments

The candidate's deduction was correct.

Candidate's Response to Part (b)

(b) A fixed mass of marble lumps is reacted with dilute hydrochloric acid at a constant temperature. Outline why the rate of the reaction would increase if the lumps of marble are reduced in size.

The surface area to volume ratio would increase, causing more collisions per unit time, increasing the liklihood for effective collisions, ultimately leading to more product formed per unit time (faster rate) **[2 marks]**

Examiner's Comments

The candidate accurately outlined why the rate of the reaction would increase if the size of the lumps of marble is reduced.

Candidate's Response to Part (c) (i)

(i) Calculate the number of moles of iodine and the number of moles of hydrogen iodide in the equilibrium mixture.

$2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$

initial no. of moles: 0.218   0   0

change in no. of moles: $-2x$ $+x$ $+x$

Number of moles of iodine 0.023 moles

[1 mark]

no. of moles of $HI_{(g)} = 0.218 - 2x$

$= 0.218 - 2(0.023)$

$= 0.172$ moles

Number of moles of hydrogen iodide 0.172 moles

[2 marks]

Examiner's Comments

The candidate calculated the number of moles of iodine correctly. However, the candidate made an error when calculating of the number of moles of hydrogen iodide and hence arrived at 0.172 instead of 0.195.

The correct calculation is *0.218 mol – 0.023 mol = 0.195 mol.*

Candidate's Response to Part (c) (ii)

(ii) Write an expression for K_c for the equilibrium.

$$K_c = \frac{[H_{2(g)}] \times [I_{2(g)}]}{[HI_{(g)}]^2}$$

[1 mark]

Examiner's Comments

The candidate wrote an accurate expression for K_c for the equilibrium.

Candidate's Response to Part (c) (iii)

(iii) Calculate the value of K_c at 700 K.

$$K_c = \frac{(0.023)(0.023)}{(0.172)^2}$$

$$= 0.01788$$

$$\approx 0.018 \text{ (to 3 significant figures)}$$

[2 marks]

> **Examiner's Comments**
> The candidate's answer was incorrect because of the error brought forward from the calculation for Part (c) (i). However, the formula and the resulting calculation were correct. Hence, the candidate received two marks.

Candidate's Response to Part (c) (iv)

(iv) Calculate the value of K_c at 700 K for the equilibrium of the reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

$$K_c = \frac{1}{0.018} = 55.56 \approx 55.6$$

$$K_c = \frac{1}{0.01788} = 55.9$$ more accurate value

[1 mark]

> **Examiner's Comments**
> The candidate used the correct method to calculate the answer. However, the answer was incorrect because of the error brought forward from the previous parts.

Candidate's Response to Part (d) (i)

(i) State the meaning of the term 'buffer solution'.

A buffer solution is a solution which resists changes in pH upon the adition of small volumes of acid ($H^+_{(aq)}$) or alkalis ($OH^-_{(aq)}$).

[2 marks]

> **Examiner's Comments**
> The candidate provided a clear and concise definition of the term *buffer solution*.

Candidate's Response to Part (d) (ii)

(ii) Identify a reagent which could be added to a solution of ammonia in order to form a buffer solution.

$NH_4Cl_{(s)}$ → salt of weak base

[1 mark]

> **Examiner's Comments**
> The candidate was able to correctly identify a reagent which could be added to a solution of ammonia to form a buffer solution. The candidate demonstrated good experimental skills in providing the answer.

Candidate's Response to Part (d) (iii)

(iii) Consider the following equation which represents a buffer solution consisting of a weak acid and its conjugate base in water.

$$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + A^-_{(aq)}$$

(conjugate base)

Explain the effect on the buffer solution if the concentrations of hydrogen ions [H⁺] and hydroxide ions [OH⁻] are increased separately.

$[H^+_{(aq)}]$: increase will cause the equilibrium position to the left in accordance with Le Chatelier's principle, resulting in the formation of HA (aq). i.e. $H^+_{(aq)} + A^-_{(aq)} \rightarrow HA_{(aq)}$

$[OH^-_{(aq)}]$: increase will cause the equilibrium position of the rxn above to shift to the right in accordance with Le Chatelier's principle, leading to the dissociation of HA (aq).

[2 marks]

> **Examiner's Comments**
> The candidate offered an adequate explanation for the effect that the increased concentration of each ion would have on the buffer solution.

Candidate's Response to Part (d) (iv)

(iv) Explain how the molecular structure of amino acids relates to their function as buffers in human blood.

- Amino acids are a biological buffer.
- They are capable of liberating an H^+ ion when alkaline solution is added as they possess an acidic carboxylic acid group (COOH) forming COO^-.
- They are capable of accepting an H^+ ion, when acidic solution is added, since they possess an alkaline amino group (NH_2) forming NH_3^+ which accepts the $H^+_{(aq)}$ in its structure. This is how amino acids act as buffers.

Equation - $HP_{(aq)} \rightleftharpoons H^+_{(aq)} + P^-_{(aq)}$ (amino acid → conjugate base)

[3 marks]

Examiner's Comments

The candidate adequately explained how the molecular structure of amino acids relates to their function as buffers in the human body.

Candidate's Response to Part (e) (i)

(i) Identify TWO relevant pieces of apparatus and/or materials that may have been used by the students to carry out the experiment.

① pH meter ✓

② 250 ml beaker ✓

[2 marks]

Examiner's Comments

The candidate was able to identify two relevant pieces of apparatus and/or materials that may have been used by the students to carry out the experiment. In doing so, the candidate demonstrated good experimental skills.

Candidate's Response to Part (e) (ii)

(ii) Identify TWO relevant experimental steps that may have been taken by the students to determine the pH of the buffer.

① Cleaning the pH meter and beaker with distilled water to remove ✓ contaminants to attain accurate readings.

② Calibrating the pH meter to read pH values accurately. ✓

[2 marks]

Examiner's Comments

The candidate correctly identified two relevant experimental steps that may have been taken by the students to determine the pH of the buffer.

Question 3

This question tested syllabus objectives 2.1–2.2, 2.4 and 5.7–5.10 from Module 3: Chemistry of the Elements. The mean was 8.31 and the standard deviation 6.44.

Candidate's Response to Part (a) (i)

Element	1st IE (kJ mol^{-1})	AR (nm)	ES	OS
Magnesium	763	0.160	$1s^2, 2s^2, 2p^6, 3s^2$	+2
Calcium	590	0.197	$[Ar]\ 4s^2$	+2
Strontium	548	0.215	$[Kr]\ 5s^2$	+2
Vanadium	650	0.122	$[Ar]\ 3d^3 4s^2$	+5, +4, +3, +2
Chromium	653	0.117	$[Ar]\ 3d^5 4s^1$	+6, +3
Manganese	717	0.117	$[Ar]3d^5 4s^2$	+7, +4, +2
Iron	759	0.116	$[Ar]\ 3d^6 4s^2$	+2, +3
Cobalt	758	0.116	$[Ar]\ 3d^7 4s^2$	+2, +3

Examiner's Comments
The candidate completed the table accurately by inserting the electronic structure and the oxidation state for each of the listed elements.

Candidate's Response to Part (a) (ii)

(ii) Explain the difference between the trend of the first ionization energy for the Group II elements and the first row transition elements.

The first (IE) ionisation energy of the Group 2 elements ~~increase~~ decrease down the group while the 1st IE for transition elements increase from left to right. For Group 2, as the group is descended, the number of electrons and thus shells increase. This makes the distance from the valance shell to the nucleus (containing protons) increase. With the longer distance, the attraction between protons and valance electrons decreases, making it easier to lose the electron. With the increasing number of shells, the shielding effect also increases down the group, shielding the outermost electrons from the protons, making it easier to lose the electrons and thus, decreasing the 1st ionisation energy (energy needed to lose electrons). For the transition elements, as the number of electrons increase across the period, the nuclear charge also increases. This causes the attraction between valance electrons and the protons to increase from left to right making it more difficult to lose electrons. Due to the attraction, the atomic radius also decreases across the group. This decreases the distance between valance electrons

[4 marks]

Examiner's Comments

The candidate used four key points to explain the difference between the trend of the first ionization energy for the Group II elements and the first-row transition elements.

Candidate's Response to Part (b) (i)

(b) (i) Account for the difference in oxidation state between vanadium and calcium.

Vanadium has four oxidation states (+5, +4, +3, +2) while Calcium has only one +2. Vanadium is able to lose elections from both it's 3d and 4s orbital while Ca can only lose from 4s. This is because the valance shell of Ca only contains 2 elections and losing elections from inner shells would require a lot of energy. Thus, it is only able to lose 2 electrones, making its oxidation state +2 only. Vanadium has a 3d orbital and 4s orbital. Because these 2 orbitals often overlap, elections can be lost easily from both, but first from the 4s orbital. The total number of elections in the 3d and 4s orbital of vanadium is 5 and so it can lose up to 5 elections easily. ~~The oxidation state is the number of elections~~ The oxidation state is the number of elections lost or gained in an atom.

[4 marks]

Examiner's Comments
The candidate accurately accounted for the difference in oxidation state between the Group II elements.

Candidate's Response to Part (b) (ii)

Calcium carbonate is more thermally stable than magnesium carbonate.

This is because the calcium ion has a ~~higher~~ longer atomic radius, and thus ~~h~~ lower polarising power and lower charge density. it is not easily able to pull the CO_3^- ion close to it and so requires a lot of heat (energy) ~~for~~ to bond. Since it can take up this much heat, it ~~has~~ is more thermally stable.

[2 marks]

Examiner’s Comments
The candidate demonstrated good knowledge of the Group II carbonates by explaining why calcium carbonate is more thermally stable than magnesium carbonate.

Candidate’s Response to Part (c) (i)

When concentrated HCl is added to a pink solution of cobalt (II) chloride, the solution turns blue.

$[Co(H_2O)_6]^{2+}_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons [CoCl_4]^{2-}_{(aq)} + 6H_2O_{(l)}$

This is a ligand displacement reaction. Because the product formed $[CoCl_4]^{2-}$ is more stable than the reactant $[Co(H_2O)_6]^{2+}$, ~~it is the product~~ the Cl^- ligand is able to displace the H_2O ligand. $[Co(H_2O)_6]^{2+}$ is pink while $[CoCl_4]^{2-}$ is blue.

[3 marks]

Examiner’s Comments
The candidate demonstrated knowledge and understanding of the term *stability constant*.

Candidate’s Response to Part (c) (ii)

(ii) Write a balanced equation for the reaction in (c) (i).

$[Co(H_2O)_6]^{2+}_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons [CoCl_4]^{2-}_{(aq)} + 6H_2O_{(l)}$

pink ~~blue~~ blue

[2 marks]

Examiner’s Comments
The candidate wrote the correct equation for the reaction in Part (c) (i).

Candidate's Response to Part (d) (i)

Test	Observation
• A few cm^3 of 3M NaOH is added to a small amount of solid NH_4VO_3, followed by a few cm^3 of 3M H_2SO_4.	Colour formed ....yellow.....................
• A few pieces of granulated zinc are then added to the solution above.	Colour changes to ......green.......... then to ......blue.......... then to ......green.......... and finally ......violet..........

[5 marks]

Examiner's Comments
The candidate completed the table accurately by providing the correct colour changes which would be observed after the given tests.

Candidate's Response to Part (d) (ii)

Colour	Formula of Species
yellow	VO_2^+
green	VO_2^+ and VO^{2+} mixture
blue	VO^{2+}
green	V^{3+}
violet	V^{2+}

[5 marks]

Examiner's Comments The candidate completed the table accurately by writing the correct formula of the species formed which was responsible for each of the colours observed in Part (d) (i).

PAPER 032 — ALTERNATIVE TO THE SCHOOL-BASED ASSESSMENT

Paper 032, Alternative to the School-Based Assessment, tested candidates' knowledge of syllabus objectives 3.8 from Module 1: Fundamentals in Chemistry, 1.2–1.5 from Module 2: Kinetics and Equilibria, and 6.2 from Module 3: Chemistry of Elements.

Overall, the performance of candidates was poor. The maximum mark was 45. The mean score was 15.45 and the standard deviation 7.80.

Question 1

Candidates were asked to carry out a titration experiment to determine the percentage purity of the sample of contaminated sodium carbonate.

Candidate's Response to Part (a) (i)

(i) **TABLE 1: DILUTION DATA**

Volume of Solution P used for dilution =	....13.30.................. cm^3

[1 mark]

Examiner's Comments
The candidate measured a volume within the stipulated range. Generally, most candidates did not express the volume used to two decimal points as required.

Candidate's Response to Part (a) (ii)

(ii) **TABLE 2: DATA FOR TITRATION**

Volume of 0.100 M HCl	**Readings**		
	1	**2**	**3**
Final burette reading	23.10 cm^3	45.10 cm^3	21.90 cm^3
Initial burette reading	0.00 cm^3	23.10 cm^3	0.00 cm^3
Volume of 0.100 M HCl	23.10 cm^3	22.00 cm^3	21.90 cm^3

[7 marks]

Examiner's Comments

The candidate demonstrated the skills required to record titration data.

Candidate's Response to Part (a) (iii)

(iii) State the expected colour at the end-point of this titration.

red

[1 mark]

Examiner's Comments

Some candidates were unable to state the colour expected at the end-point of the titration. The expected colour was pale orange. Candidates were also awarded a mark for stating the colour pink.

Candidate's Response to Part (b) to Part (g)

(b) The equation for the reaction is:

$2\,HCl\,(aq) + Na_2CO_3\,(aq) \rightarrow 2\,NaCl\,(aq) + H_2O\,(l) + CO_2\,(g).$

Determine the volume of 0.100 M HCl to be used in your calculations.

average HCl = $(15.4\,cm^3 + 15.3\,cm^3 + 15.3\,cm^3)/3$

= $15.33\,cm^3$

(c) Calculate the number of moles of 0.100 M HCl used in the titration.

0.1 M → $1000\,cm^3$

~~15.33 cm~~ x M → $15.33\,cm^3$

$x = 1.533 \times 10^{-3}$ ~~moles~~ mol

[1 mark]

(d) Calculate the number of moles of sodium carbonate, Na_2CO_3, present in 25 cm³ of Q.

m.m Na_2CO_3 = 106 ~~126 + 106 = 118~~

mole ratio

2 : 1

1.533×10^{-3} x

$x = 7.66 \times 10^{-4}$ moles

[1 mark]

(e) Calculate the concentration, in mol dm^{-3}, of sodium carbonate in Q.

$7.66 \times 10^{-4} \rightarrow 25 cm^3$

$x \rightarrow 1000 cm^3$

$x = 0.031 mol dm^{-3}$

Na_2CO_3

[1 mark]

(f) Calculate the concentration, in mol dm^{-3}, of sodium carbonate in P.

$0.031 mol \rightarrow 1 dm^3$

$x mol \rightarrow 250 cm^3$

$x = 7.75 \times 10^{-3} mol Na_2CO_3$

$7.75 \times 10^{-3} mol \rightarrow 13.2 cm^3$

$x mol \rightarrow 1000 cm^3$

$x = 0.58 mol dm^{-3}$

[1 mark]

(g) Calculate the percentage purity by mass of the sodium carbonate in the contaminated sample used to prepare Solution P.

$1 mol \rightarrow 106 g$

$0.58 mol \rightarrow 126 g$

$0.58 \times 106 = 61.48 g$

$61.48 g Na_2CO_3$

$\frac{61.48}{126} \times 100 = 48.79\%$

[1 mark]

Examiner's Comments

The candidate showed an excellent progression of the calculations required to answer these subparts correctly. Many candidates struggled to perform the calculations correctly.

Question 2

Candidates were required to utilize the data analysis format to investigate the rate of reaction between hydrogen peroxide solution with iodide ions in aqueous acid.

Candidate's Response to Part (a)

(a) Construct a table in the space provided below to record the information above regarding experiment number, initial concentration of reactants and initial rate of formation of I_2.

~~Experiment~~ ~~Initial Concentration of H2O2~~ ~~Initial concentration of I⁻~~

TABLE SHOWING ~~HOW~~ CONENTRATIONS AND RATES FOR FORMATION OF I_2(aq)

Experiment	Initial [H_2O_2(aq)]	Initial [I^-(aq)]	Initial [H^+(aq)]	Inital Rate ($mol dm^{-3} s^{-1}$)
1	0·01 $mol dm^{-3}$	0·01 $mol dm^{-3}$	0·10 $mol dm^{-3}$	$1·75 \times 10^{-6}$
2	0·02 $mol dm^{-3}$	0·01 $mol dm^{-3}$	0·10 $mol dm^{-3}$	$3,5 \times 10^{-6}$
3	0·03 $mol dm^{-3}$	0·01 $mol dm^{-3}$	0·10 $mol dm^{-3}$	$5,25 \times 10^{-6}$
4	0·03 $mol dm^{-3}$	0·02 $mol dm^{-3}$	0·10 $mol dm^{-3}$	$1·05 \times 10^{-5}$
5	0·03 $mol dm^{-3}$	0·02 $mol dm^{-3}$	0·20 $mol dm^{-3}$	$1·05 \times 10^{-5}$

Examiner's Comments

The candidate was able to construct the table and provide the required information. Several candidates were able to construct the table accurately. However, some candidates were unable to determine the concentration values from the information provided.

Candidate's Response to Parts (b) to (d)

(b) Deduce the order of the reaction with respect to EACH of the reactants below, explaining how you arrived at your answer.

(i) H_2O_2 (aq) using exp 1 and 2 since [H+] and [I-] are constant finding ratio of [H2O2] to Rate

[H2O2] : $\frac{0.02}{0.01} = 2$ Rate = $\frac{3.5 \times 10^{-6}}{1.75 \times 10^{-6}}$

ratio is 2:2 so as concentration doubles, rate doubles so order wrt H2O2 is one, 1

[2 marks]

(ii) I^-(aq) using exp 3 and 4 since [H2O2] and [H+] are constant

[I-] = $\frac{0.02}{0.01}$ Rate: $\frac{1.05 \times 10^{-5}}{5.25 \times 10^{-6}}$ ratio is 2:2

= 2 = 2 so as [I-] doubles rate doubles so order is one, 1

[2 marks]

(iii) H^+(aq) using exp 4 and 5 as concs for H2O2 and I- are the same

ratio:

[H+] = $\frac{0.20}{0.10}$ Rate = $\frac{1.05 \times 10^{-5}}{1.05 \times 10^{-5}}$

= 2 = 1

ratio is 2:1 so as [H+] doubles rate is constant so order wrt [H+] is zero, 0 **[1 mark]**

(c) Write the rate equation for the reaction.

Rate = K [H2O2 (aq)][I- (aq)]

[1 mark]

(d) Using your rate equation from (c) and values from your table, calculate the value of the rate constant k. State the units.

Experiment number used ...5...

Calculations

Rate = $K[H_2O_2][I^-]$

$1.05 \times 10^{-5} = K(0.03)(0.02)$

$K = \frac{1.05 \times 10^{-5}}{(0.03)(0.02)}$

$= 0.0175\ mol^{-1} dm^3 s^{-1}$

Units:

$\frac{mol\ dm^{-3} s^{-1}}{mol^2\ dm^{-6}}$

$mol^{-1} dm^3 s^{-1}$

Rate constant k = ...0.0175... Units ...$mol^{-1} dm^3 s^{-1}$...

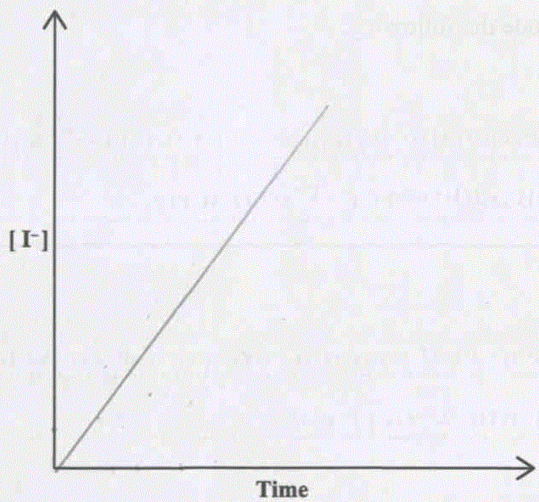
[2 marks]

Examiner's Comments
The candidate answered all parts in an exemplary manner, giving observations and inferences where required. The candidate's calculations were clear and correct, and the units were properly retained.

Candidate's Response to Parts (e) (i) and (e) (ii)

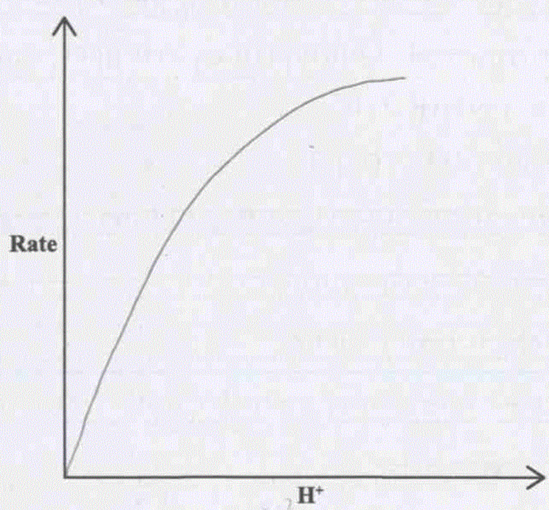
(e) Sketch in the space below the shapes of the graph expected for the plots of EACH of the following. (Do NOT use actual values).

(i) [I^-] versus time



[1 mark]

(ii) Rate of reaction vs [H^+]



[1 mark]

Examiner's Comments
The candidate did not sketch the expected shapes of the graphs. Only a few candidates were able to do so correctly.

Question 3

This question assessed candidates' level of competence in the skills associated with the planning and design of practical investigations.

Overall, the performance of candidates was very weak.

Candidate's Response to Part (a)

3. A homeowner recently purchased a home and suspects that the pipes in the home contain lead.

Plan and design an experiment that would help the homeowner to determine whether the water flowing through the existing pipes in the home contain lead.

Your answer should include the following:

(a) Hypothesis

The water flowing through pipes contain Pb^{2+} (aq) and will test positive with addition of I^- (aq) ions.

[1 mark]

Examiner's Comments
Generally, candidates were able to provide a hypothesis for the experiment.

Candidate's Response to Part (b)

(b) Aim

to determine if Pb^{2+} (aq) ions are present in water sample from pipes using I^- (aq) ions

[1 mark]

Examiner's Comments
Generally, candidates were able to provide an aim for the experiment.

Candidate's Response to Part (c)

(c) Apparatus and materials ·

sample of water from pipes, aqueous KI (aq) solution, ~~beer~~ ~~250~~ 100 ml beaker, ~~10cm3 measuring cylinder~~, ~~25~~ ~~50~~ ~~cm3 measuring cylinder, stirring rod~~ boiling tubes, dropper, sample of water from other source, white tile **[3 marks]**

Examiner's Comments

The candidate provided an appropriate list of apparatus and materials needed to conduct the experiment.

Generally, many candidates were unable to provide the required information. Some of the lists provided by candidates were unsuitable or irrelevant for conducting the experiment based on the aim they stated in Part (b).

Candidate's Response to Part (d)

d) Procedure

1. Place 2cm3 of water sample from pipe into boiling tube labelled A
2. Using a dropper add 3-4 drops of KI (aq) into boiling tube with water and shake thoroughly
3. Observe any colour change or formation of ppt.
4. Repeat steps 1-3 using another boiling tube with 2cm3 of water that is not from same source ie distilled water

Examiner's Comments

The candidate provided an acceptable experimental procedure. Generally, many candidates struggled to provide an appropriate procedure.

Candidate's Response to Part (e)

(e) Variables

- Manipulated

  type of water used

  [1 mark]

- Responding

  colour of precipitate formed

  [1 mark]

- Controlled

  volume of water used, volume of KI(aq) used, amount of shaking

  [1 mark]

> **Examiner's Comments**
> The candidate provided variables which were appropriate for the experiment. Generally, candidates did not answer this part well.

Candidate's Response to Part (f)

(f) Expected results

If Pb^{2+} ions are present in sample of water from pipe, a bright yellow precipitate would form ie $PbI_2(s)$

If Pb^{2+} ions are not present, there will be no colour change and no precipitate formation.

In sample of distilled water, no colour change is expected to occur as no $PbI_2(s)$ will be formed

[2 marks]

> **Examiner's Comments**
> The expected results provided by the candidate were suitable for the experiment. Generally, candidates were unable to determine the correct expected results.

Candidate's Response to Part (g)

(g) ONE possible source of error

boiling tube had contaminants present prior to start of experiment due to improper cleaning of apparatus. this could affect reaction and products formed may differ from what is expected.

[1 mark]

Examiner's Comments The candidate provided an acceptable source of error. Many candidates could not provide a reasonable source of error.

Candidate's Response to Part (h)

(h) ONE precaution

colour change was observed in front a white tile or white sheet of paper to gain most accurate reading

[1 mark]

Total 15 marks

Examiner's Comments The candidate did not provide an appropriate precaution. Generally, candidates were able to provide acceptable precautions to take when carrying out the investigation.