CARIBBEAN
EXAMINATIONS
COUNCIL

CSEC® CHEMISTRY

Subject Report

May-June 2025

CARIBBEAN EXAMINATIONS COUNCIL

REPORT ON CANDIDATES' WORK IN THE CARIBBEAN SECONDARY EDUCATION CERTIFICATE® EXAMINATION

MAY-JUNE 2025

CHEMISTRY
GENERAL PROFICIENCY

St Michael, Barbados

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INTRODUCTION

This guide has been put together using candidates’ responses to the 2025 May-June examination in CSEC Chemistry.

In the 2025 examination, 59.36 per cent of candidates earned Grades I–III, compared with 64.13 per cent in 2024 and 65.47 per cent in 2023.

PAPER 01 — MULTIPLE CHOICE

This paper consisted of 60 compulsory multiple-choice items. Generally, performance on this paper was satisfactory. The maximum score obtained was 60 out of 60 marks and the mean score was 37.

PAPER 02 — STRUCTURED/EXTENDED ESSAY

Question 1

Candidates were required to define the term *electrolysis* in Part (a) (i). They were credited for the following or similar definitions.

- The chemical decomposition of an electrolyte by the passage of electric current**.**
- A chemical change caused by passing an electric current/electricity through an electrolyte**.**

While some candidates provided partially correct responses, a significant number demonstrated limited understanding of the concept. Many definitions lacked key scientific elements or were phrased too vaguely to earn full marks. For example, some candidates used the term ‘substance’ or ‘solution’ instead of *electrolyte*. In cases where candidates mentioned ionic compounds, they rarely stated that these were molten or fused.

Many responses incorrectly referenced the formation of a yellow precipitate, typically associated with the reaction of potassium iodide with lead (II) ions. This suggests that candidates may have memorized reaction outcomes without fully understanding the implications of the absence of observable changes in the context of a negative result.

In numerous instances, candidates described reactions when, in fact, no visible reaction was expected. This reflects a broader misunderstanding of how to interpret and report observations for tests yielding negative results. The absence of a yellow precipitate is a key indicator that lead (II) ions are not present and this should have guided candidates to deduce that aluminium ions were responsible for the lack of reaction.

Another common error was the misuse of terminology. Some candidates incorrectly referred to the absence of a yellow solution rather than a yellow precipitate, indicating confusion between the terms *solution* and *precipitate*. Precision in language is essential when describing chemical observations.

In Part (a) (ii), most candidates demonstrated an understanding of the difference between the cathode and anode. Some acceptable responses included the following.

- The anode is the positive electrode while the cathode is the negative electrode.
- At anode oxidation takes place/electrons lost while at the cathode reduction takes place/ electrons gained**.**
- The anode receives anions and the cathode receive cations.
- The anode attracts negatively charged ions and the cathode attracts positively charged ions.

Most candidates were able to identify at least one key distinction between the electrodes, commonly referencing the charge of the electrode or the direction of ion migration, namely, that anions move toward the anode and cations migrate toward the cathode. Some candidates, however, exhibited difficulty distinguishing between the charges associated with ions and those of the electrodes. Specifically, the charges of cations and anions were occasionally confused with the polarity of the cathode and anode. It was also noted that some candidates incorrectly referred to the electrodes as electrons, indicating a conceptual misunderstanding that should be addressed through further clarification during instruction.

In Part (a) (iii), candidates were required to determine the mass of the cathode and the mass of copper deposited. Many candidates earned full marks for successfully completing the data table by accurately recording the required values. While it was important to have correct numerical entries, candidates were also expected to identify underlying trends and patterns within the data. A significant number demonstrated the ability to recognize the trend of adding the actual mass of copper deposited to the initial mass of copper. Successfully performing this step required analytical reasoning and conceptual understanding. This aspect of electrochemistry warrants continued instructional emphasis. Targeted exercises focusing on data analysis and interpretation should be systematically incorporated into classroom practice to strengthen competence in this area.

For Part (a) (iv), candidates were required to plot five points and draw a line of best fit through them. Overall, the plotting of points was competently executed and many candidates earned full marks for this component. Nonetheless, challenges persist in interpreting and using scales especially when points fall between marked intervals. This remains an area requiring continued practice. A significant number of candidates had trouble plotting values that required understanding and applying scales involving decimal intervals, particularly at values such as 5, 15 and 25.

Regarding the construction of a best-fit straight line, most candidates attempted the task; however, several inaccurately forced the line through the origin (0,0), regardless of the data distribution. This resulted in poor alignment with the plotted points and reduced overall accuracy. In some instances, candidates drew interpolation lines or only a vertical line, indicating a partial understanding of graphical representation techniques. Graph construction remains an area where many candidates perform well; however, emphasis must be placed on developing the skill of drawing a proper best-fit line, one that passes through or near most of the data points with approximately equal distribution of points above and below the line.

In Part (a) (v), candidates were prompted to use the graph to predict the mass of copper that would be deposited after 28 minutes. A considerable number of candidates encountered difficulty accurately locating the 28-minute mark on the *x*-axis. Some candidates, despite correctly drawing the interpolation lines, misread the scale or recorded incorrect values, which ultimately led to a loss of marks.

While the interpretation of graphical data was generally satisfactory, several candidates failed to adhere to the instructions, specifically the use of dotted lines, as stipulated in the stem of the question. In numerous cases, only one guideline (typically vertical or horizontal) was drawn, resulting in the loss of marks. Candidates should be consistently encouraged to employ both horizontal and vertical guideline lines when performing interpolation or extrapolation from plotted graphs. Improvement in this area requires greater emphasis on scale interpretation, adherence to graphical conventions and careful reading of instructions. These skills should be reinforced by teachers through targeted practice and guidance.

In Part (a) (vi), candidates were required to write an ionic equation to represent the reaction at the cathode. The expected equation was $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$. A notable number of candidates had difficulty accurately constructing the ionic equation. This suggested a lack of familiarity with standard conventions for writing half-equations. Common errors included the following.

- Writing the equations in reverse order, for example, $Cu(s) + 2e^{-} \rightarrow Cu^{2+}(aq)$
- Using an incorrect number of electrons, sometimes with the incorrect copper ion, for example, $Cu^{2+}(aq) + e^{-} \rightarrow Cu(s)$ or $Cu^{+}(aq) + 2e^{-} \rightarrow Cu(s)$
- Using the incorrect sign to show reduction: $Cu^{2+}(aq) - 2e^{-}$ à $Cu(s)$.

There is a clear need for explicit instruction on the proper format of half-equations, particularly regarding correct stoichiometry and the number of moles of electrons transferred during redox processes at the electrodes. Overall, the quality of responses involving ionic equations was unsatisfactory, indicating that candidates require additional practice and reinforcement in this area. While many candidates responded correctly, a subset failed to recognize that a valid ionic equation must explicitly contain ions. This fundamental misunderstanding underscores the need for continued emphasis on the correct construction of ionic and half-equations. Furthermore, candidates should be consistently reminded that, in reduction half-equations, electrons must appear on the reactant side to reflect electron gain. The inclusion of appropriate state symbols should also be encouraged as a matter of best scientific practice.

Part (a) (vii) required candidates to calculate the quantity of electricity that passed through the copper sulfate solution when 0.2 A of current flowed for 20 minutes. The expected reponse was as follows.

$$Q = It$$
$$20 \times 60 = 1200\text{s}$$
$$Q = 0.2 \times 1200 = 240\text{ C}$$

Despite correctly applying the relationship between current (in amperes) and time, many candidates used the time value in minutes rather than converting to seconds (i.e., multiplying by 60), which led to erroneous results. This common error indicates a widespread deficiency in candidates’ understanding of unit conversions within electrochemical calculations. The ability to relate current and time to the quantity of electricity (in Coulombs) is fundamental and the use of consistent SI units is critical to obtaining accurate outcomes.

In Part (a) (viii), candidates were required to calculate the number of moles of copper that would be formed. The expected response was

$$240 \div 96500 = 0.00249$$
$$0.00249 \div 2 = 0.00124\text{ mol. Cu}$$

This calculation was generally poorly executed by candidates. In many instances, responses did not demonstrate a clear connection between the quantity of electricity (in coulombs), the number of moles of electrons involved and the amount of metal deposited. A correct solution required candidates to relate the number of moles of electrons to the number of Faradays and subsequently to the number of moles of product formed. This conceptual linkage was often missing or incorrectly applied. Most candidates failed to recognize that the deposition of one mole of copper (Cu) from the ionic equation $Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$ requires two moles of electrons, equivalent to two Faradays or 2 × 96,500C. This essential stoichiometric relationship was not consistently applied, resulting in incomplete or incorrect responses.

While some candidates correctly identified the 2:1 mole ratio between electrons and copper ions and used it to calculate the amount of copper deposited, others incorrectly assumed a 1:1 ratio. Consequently, their final answers were incorrect and they were not awarded full marks. The poor performance in this part of the question highlights a significant need for continued practice in electrochemical calculations, particularly in applying the Faraday constant and interpreting ionic equations. Emphasis should be placed on understanding the electron-to-product ratio in redox reactions as well as accurately determining the amount of substance deposited at the electrodes.

Part (a) (ix) required candidates to calculate the mass of copper that would be formed at the cathode. The expected response was $0.00124 \times 64 = 0.079$ g. This calculation was generally well executed by most candidates. These candidates demonstrated an understanding of the relationship between the number of moles and the mass of a substance and successfully applied the concept to determine the amount of copper produced. Candidates were expected to multiply the number of moles of copper, as determined in Part (a) (viii), by the molar mass of copper (64 g/mol) to obtain the correct mass. While some candidates did not provide a response, many showed a sound grasp of the relationship between the mass and mole, and were able to complete this section accurately. Notably, even in cases where the number of moles was incorrectly calculated in the preceding step, several candidates correctly performed the subsequent multiplication, applying the appropriate method despite the initial error. This indicates a reasonable level of procedural understanding, although continued reinforcement of mole-to-mass conversions is recommended.

In Part (a) (x), candidates were required to suggest a reason for the difference between the theoretical mass and the experimental mass. The expected response was that *the electrode was not completely dried or was still wet.* Most candidates provided incorrect responses to this question, indicating a widespread lack of understanding regarding factors that account for discrepancies between theoretical and experimental values in electrolysis. A few candidates correctly identified residual moisture on the copper cathode and offered insufficient drying as a plausible explanation for this. However, many gave inaccurate responses such as suggesting the presence of impurities in the deposited copper, which was not relevant in this context. Such responses suggest that candidates would benefit from more experiential learning opportunities.

In Part (b), candidates were required to complete a table by writing the observations for each test carried out on a sample of salt. The expected response is shown in the table below.

Test	**Observation**	**Inference**
A sample of Salt S is heated strongly in a dry test tube. Moist red and blue litmus is held at the mouth of the test tube.	• Gas turns blue litmus red • Brown gas evolves	Acidic gas is produced. Nitrate ions are present.
To an aqueous solution of Salt S, aqueous sodium hydroxide is added gradually until in excess.	• White precipitate forms • Soluble in excess NaOH/dissolves/no ppt/colourless soln.	Zn^{2+} are present.

While most candidates correctly recognized the acidic nature of the gas released and noted that blue litmus paper would turn red, very few mentioned the evolution of a brown gas (nitrogen dioxide) upon heating, which is characteristic of nitrates.

A moderate number of candidates observed the formation of a white precipitate upon the addition of sodium hydroxide; however, only a few recognized that the precipitate, indicative of zinc ions, is soluble in excess alkali, a key aspect of confirming the identity of the ion.

The responses indicate limited exposure to qualitative analysis procedures, particularly in identifying gases and understanding precipitate behavior. This suggests insufficient coverage of relevant syllabus content, especially concerning characteristic colour changes observed with litmus paper and specific reactions of metal ions in solution. These shortcomings highlight the need for greater emphasis on practical laboratory work related to qualitative analysis.

Recommendations

It is recommended that teachers do the following.

- Reinforce the importance of negative observations as valid scientific data, particularly in qualitative analysis.
- Provide more hands-on experiences that focus on the correct interpretation and recording of both positive and negative results.
- Emphasize the importance of using accurate scientific terminology, distinguishing clearly between solutions and precipitates.
- Encourage deeper conceptual understanding rather than rote memorization of reactions through more inquiry-based approaches.
- Strengthen students' graphing proficiency by providing continued practice in reading and applying decimal-based scales as well as constructing accurate best-fit lines.
- Offer ongoing opportunities for students to write half-equations for electrode reactions in both familiar and unfamiliar contexts to enhance conceptual understanding and application skills.
- Place greater instructional emphasis on quantitative problem-solving in electrolysis with particular attention to correct use of units in calculations involving electrical charge.
- Provide students with more experimental learning opportunities. Incorporating electrolysis as a practical activity in the classroom may help candidates develop a clearer conceptual understanding through direct observation of procedural steps and potential sources of error
- Engage students in more reflective scientific reasoning, particularly in identifying experimental limitations and sources of deviation from theoretical predictions.
- Provide students with opportunities to engage in discussions or brainstorming sessions on such topics to foster deeper analytical thinking and enhance their ability to interpret and evaluate experimental results.
- Integrate more hands-on investigations involving gas tests and reactions of metal ions with sodium hydroxide. Instruction should explicitly address visual and procedural cues that help students distinguish between soluble and insoluble precipitates.

Question 2

In Part (a) (i), candidates were asked to define the term *acid*. Many candidates described acids by their physical characteristics, for example, sour taste, corrosive nature, pH range, reactions. Candidates were not credited for such definitions. The expected responses included either the Lewis or Brønsted–Lowry definitions or a definition related to hydrogen content and its replaceability.

Part (a) (ii) required candidates to define the term *alkali*. Similar to Part (a) (i), several candidates provided physical characteristics instead of defining alkalis using the Brønsted or Lewis concepts.

In Part (a) (iii), candidates were asked to define the term *normal salt*. A common error in appropriate responses was the omission of the words *all* and *ions* when referring to the hydrogens being replaced in the normal salt; this resulted in candidates obtaining only partial marks. Candidates with partially correct responses generally recognized that the hydrogens were replaced with metal or ammonium ions.

In Part (b), candidates were required to write a balanced equation, including state symbols, to show the formation of the normal salt produced from the reaction between phosphoric acid and sodium hydroxide. Most reasonable attempts correctly wrote the chemical formulas for the reactants. However, candidates struggled mainly with determining the oxidation number of sodium in sodium phosphate and frequently used an incorrect state symbol (solid instead of aqueous) for this compound.

Part (c) (i) required candidates to state the molecular formula for an acid salt formed from the reaction. Several candidates incorrectly stated the normal salt instead of the acid salt. Among those candidates who identified the acid salt by chemical formula, many struggled to balance the oxidation state of the phosphate ion (3–) with the appropriate number of sodium or hydrogen atoms. Common incorrect formulas included 'HNa_2PO_4 and H_2NaPO_4'.

Part (c) (ii) was poorly done, as candidates often restated the chemical equation written in Part (b). Most candidates were unable to write the equation showing the formation of the acid salt because they could not correctly write its formula. However, some candidates were able to produce the correct equation once they had identified the correct formula in Part (c) (i).

Part (d) was generally well done. Candidates were provided with details about a solution, including the pH values of two acids, and were asked to state which of the two acids was stronger. Some candidates correctly referenced the lower pH as their rationale for identifying the stronger acid.

Part (e) (i) required candidates to name two acids present in orange juice. A high frequency of spelling errors related to *ascorbic acid* was noted, though candidates were not penalized for these. Greater emphasis should be placed on addressing naming errors. A few candidates incorrectly used terms such as ‘citrus’ or ‘citrus acid’. The family or category of fruits is not sufficient for credit; candidates must correctly state *citric acid*. *Vitamin C* was accepted as an alternative to *ascorbic acid*.

Part (e) (ii) was generally answered well. Some candidates incorrectly used an acid–base reaction to respond to this part, which required them to state the type of chemical reaction that occurs during the treatment of excess stomach acid.

Part (e) (iii) required candidates to state the chemical name or formula of one compound that can be used to treat excess stomach acid. Several candidates lost marks by providing brand names of antacids instead of chemical names or formulas. While candidates should be familiar with common brands, emphasis must be placed on identifying the active ingredient or compound associated with the antacid’s function. Candidates should also note that not all alkalis, particularly stronger alkalis such as $NaOH$ and $Ca(OH)_2$, are safe for ingestion.

Recommendations

Candidates are encouraged to learn and apply proper chemical terminology and reaction nomenclature when prompted.

Question 3

Part (a) required candidates to state two natural sources of hydrocarbons. Most candidates accurately identified two sources, with *crude oil* and *natural gas* being the most common correct responses, earning two easy marks. Some candidates incorrectly treated petroleum and crude oil as separate compounds and were awarded only one mark.

In Part (b), candidates had to identify the process used in the oil and gas industry to separate the components found in a natural source of hydrocarbons. Most candidates correctly identified the process as *fractional distillation*. However, many wrote only distillation, which could not be credited since there are multiple types of distillation processes.

Part (c) required candidates to name two fractions obtained from the separation process and state their uses. Most candidates were able to name two fractions and their uses. However, many of them incorrectly stated fractions in terms of carbon chain length, for example, C_1–C_4. No marks were awarded because a specific fraction name was required. In some cases, the fraction named did not align with its stated use, resulting in loss of marks.

In Part (d) (i), writing the balanced equation for the complete reaction of methane with bromine proved very challenging for most candidates. Many equations were incorrectly written. A common error was writing the equation for a monosubstituted bromine product instead of the complete reaction which requires full substitution of hydrogen atoms on methane to produce carbon tetrabromide. These candidates could not be awarded full marks. Additionally, candidates often omitted the byproduct HBr, resulting in incorrect equations. The absence of HBr was noted in most responses.

In Part (d) (ii), many candidates wrote incorrect equations and state symbols for the reaction between propene and bromine. This was largely due to errors in chemical formulas.

In Part (e), most candidates accurately drew the fully displayed isomers of pentene. However, some candidates' drawings were incorrect, with several carbon atoms showing a valency of five.

Recommendations

Teachers should provide students with ample practice regarding writing chemical equations and using appropriate state symbols to foster a deeper understanding of chemical reactions. They should also provide students with frequent opportunities to practise drawing carbon structures, emphasizing the importance of rechecking work to ensure that each carbon atom maintains a valence of four.

Question 4

Part (a) (i) required candidates to describe the type of bonds found in Element X, a metal in Group 2. Most candidates correctly identified the bonding as *metallic bonding*, explaining that metal atoms give up their valence electrons to form a lattice of metal cations surrounded by a sea of mobile or delocalized electrons.

In many responses, candidates appropriately referenced the electrostatic attraction between the metal cations and the delocalized electrons. However, several candidates provided incomplete or partially correct descriptions such as mentioning only a sea of mobile electrons without noting the electrostatic attraction to the cationic lattice.

While identification of metallic bonding was generally well done, some candidates confused the concept with ionic bonding, incorrectly describing interactions between metals and non-metals or referring to a sea of ions rather than electrons. In a few cases, candidates misidentified Element X as a non-metal and described covalent bonding; this indicated a misunderstanding of periodic trends and bonding types associated with Group 2 elements. These responses suggest that candidates would benefit from a comparative approach when learning chemical bonding. Instruction should also emphasize the distinguishing features of metallic, ionic and covalent bonding, particularly in terms of particle types and the nature of electrostatic forces involved. Using tabulated comparisons of bonding types with corresponding element examples may enhance clarity and retention. Continued confusion between metallic and ionic bonding highlights the need to reinforce foundational concepts.

Part (a) (ii) required candidates to describe the type of bonds found in the chloride of Element X. The expected response was *ionic bonds*, with an explanation such as those shown below.

- Element X gives valence electrons to chlorine, resulting in positive ions (X^{2+}) and negative ions (Cl^-).
- Complete transfer of electrons from the metal to the non-metal, leading to the formation of ions.
- Electrostatic force of attraction between the cation and anion.

A significant number of candidates correctly identified the type of bonding in the chloride of Element X as ionic, recognizing that it involves the transfer of electrons from a metal to a non-metal. However, while the identification was largely accurate, many candidates were unable to clearly or fully describe the nature of ionic bonding. Some candidates incorrectly identified the bonding as covalent, indicating a misunderstanding of bonding types based on element classification. Others confused the concepts by describing ionic bonding as the sharing of electrons rather than the transfer of electrons. It must be noted that the sharing of electrons is characteristic of covalent bonding.

Additionally, several responses offered vague justifications such as 'ionic bonding occurs because X is a metal and Cl is a non-metal.' While partially correct, such statements lack essential detail about the electron transfer process and the formation of oppositely charged ions and were therefore did not attract full credit.

Part (b) (i) required candidates to write a balanced chemical equation, including state symbols, to show the formation of the chloride of Element X. The expected response was $X(s) + Cl_2(g) \rightarrow XCl_2(s)$.

This part of the question was either poorly attempted or left unanswered by a significant number of candidates. Several common errors were observed, which prevented some candidates from receiving full marks. These included the following.

- Incorrect representation of chlorine: Several candidates wrote the formula as Cl instead of the correct diatomic form Cl_2.
- Incorrect state symbols such as (s) instead of (g) for chlorine gas and XCl_2 as aqueous (aq) instead of solid (s).
- Use of word equations instead of symbolic chemical equations.
- Inclusion of ionic charges within the formulae of compounds, for example, $X^{2+} + Cl_2^{-} \rightarrow XCl_2$.

These errors indicate that some candidates lack a clear understanding of how to properly construct molecular chemical equations. Such errors also point to gaps in foundational knowledge related to

- writing correct chemical formulae, particularly for diatomic elements
- applying solubility rules to assign appropriate state symbols
- constructing balanced chemical equations in symbolic form.

Part (c) required candidates to calculate the relative atomic mass (RAM) of Element X given that the molar mass of its chloride (XCl_2) was 159 and the relative atomic mass of chlorine was 35.5. This question was moderately done. The expected response was

$$(2 \times 35.5) = 71$$
$$159 - 71 = 88$$

While most candidates earned at least one mark by applying the correct mathematical operation, many were unsuccessful in obtaining full marks due to incorrect substitution of the relative atomic mass of chlorine or omission of necessary steps. A common error observed was the failure to multiply the RAM of chlorine by 2, as required by the chemical formula XCl_2.

In other cases, candidates substituted incorrect values for chlorine's RAM, despite having written the correct formula earlier in the question. This suggests inconsistency in applying known atomic data. Additionally, many candidates were unable to accurately deduce the RAM of Element X from the given molar mass.

Some responses showed confusion with mole-related concepts; candidates incorrectly incorporated Avogadro's number, leading to unnecessary and incorrect calculations involving multiplication or division. Overall, the quality of responses indicates a need for further reinforcement of the mole concept and improved familiarity with relative atomic masses and molecular formulas. It is recommended that students engage in targeted practice involving molar mass calculations, particularly those requiring the manipulation of known quantities to solve for an unknown. Instruction should emphasize careful reading of chemical formulas and the importance of consistent and accurate use of atomic data throughout calculations.

Part (d) required candidates to write the formula of the oxide of Element X. The expected answer was XO. Most candidates provided correct responses, demonstrating a sound understanding of basic chemical formulae. However, several candidates substituted Element X with specific elements such as calcium or magnesium despite the question referring to a generic element. This indicates a tendency among some candidates to replace symbols with familiar elements rather than working with the abstract representation provided. Additionally, several candidates wrote balanced chemical equations showing the formation of the oxide instead of the chemical formula itself. This suggests that some candidates may not clearly differentiate between a formula and a chemical equation. While responses such as XO, MgO, and CaO were accepted and credited, a few candidates provided incorrect formulas implying that Element X belonged to Group 1 rather than Group 2, as stated or implied in the question context.

Part (e) required candidates to use bonding principles to explain why graphite could be used as an inert electrode instead of Element X, a reactive metal. The expected response was that g*raphite is suitable because it conducts electricity via delocalized electrons in its structure and is unreactive, so it does not participate in the cell reaction. By contrast, Element X, although conductive due to mobile electrons, is a reactive Group 2 metal and would participate in the reaction of the cell*.

Overall, this question was poorly done. Few candidates earned the full six marks due to incomplete or incorrect explanations. While most candidates recognized that both graphite and Element X can conduct electricity, they often failed to state this clearly. Many responses lacked reference to bonding or the presence of delocalized electrons, which are fundamental to explaining conductivity. Some candidates incorrectly attributed graphite's conductivity to carbon atoms or carbon ions, while others claimed graphite does not conduct electricity at all.

In addressing the second part of the question, which required an explanation of the choice of electrode, many candidates demonstrated partial understanding by associating graphite's lack of reactivity with its use as an inert electrode. In contrast, several candidates failed to recognize that Element X, being a Group 2 reactive metal, would participate in the electrochemical reaction and therefore could not serve as an inert electrode. A notable number of candidates incorrectly stated that Element X does not conduct electricity, overlooking the earlier information identifying it as a metal. Several responses digressed into irrelevant discussions about graphite's lubricating properties, referencing weak van der Waals forces and the sliding of hexagonal layers, concepts unrelated to its role as an inert electrode in electrolysis.

In general, candidates struggled to clearly articulate the concept of inertness in relation to electrode selection. While many could define the term *inert*, they failed to explicitly apply it to graphite or contrast it appropriately with the reactivity of Element X. These errors suggest that candidates have difficulty applying bonding principles to explain physical properties and chemical reactivity.

Recommendations

To address these misconceptions and strengthen conceptual understanding, teachers should do the following.

- Emphasize that when a metal is described in isolation, that is, not bonded to a non-metal, the bonding must be metallic, including both mobile electrons and the fixed lattice of metal cations.
- Engage students in structured comparisons of ionic, covalent, and metallic bonding, linking them to element types and electron behavior. Presenting this information in tabular form with representative examples may improve clarity and retention.
- Explicitly teach electron transfer in ionic bonding and ensure that the identification of bond type is accompanied by a scientifically accurate explanation.
- Highlight the connection between bonding and properties such as conductivity and inertness through comparative reasoning exercises and principle-based questions.
- Provide students with more experiences and further reinforcement in
  - predicting chemical formulas based on group number and valency
  - distinguishing between chemical formulas and equations
  - understanding how to work with abstract element symbols in generalized chemical contexts.
- Reinforce the concept that halogens such as chlorine exist naturally as diatomic molecules, for example, Cl_2.
- Provide frequent practice in writing balanced equations with correct physical states.
- Teach students to avoid the inclusion of ionic charges in final compound formulae unless required in ionic equations.
- Give students targeted instruction on the relationship between bonding, electron mobility, and conductivity in both metals and non-metals.
- Provide regular practice in interpreting and responding to application-based questions that require comparative explanations, as well as in formula writing through exercises that involve deducing compound formulas from periodic table positions and valence considerations.
- Emphasize the importance of precision in scientific language, particularly when describing conductivity and chemical reactivity.
- Emphasize the connection between bonding and properties such as conductivity and inertness. Instruction should include comparative reasoning exercises and targeted practice with questions that require clear, principle-based explanations.

Continued practice in constructing such explanations will strengthen students’ reasoning and improve their ability to apply fundamental concepts in electrochemistry. Mastery of these foundational skills is essential for accurate representation of chemical reactions and should be regularly integrated into classroom practice.

Question 5

For Part (a), candidates were required to state four characteristics of a homologous series. A common error was that candidates used the words same and similar interchangeably. This confusion was especially evident when candidates incorrectly claimed that members of the same homologous series share the same (rather than similar) general preparation methods. Another issue was the frequent use of vague statements such as ‘physical properties vary,’ which is ambiguous and therefore could not be credited.

Part (b) required candidates to state two uses of polyesters. The most common accurate responses were *clothing* and *textiles*. Several candidates incorrectly associated polyester fibres with plastic products or gave vague responses such as ‘used in plastics’. Additionally, some candidates confused the uses of polyamides with those of polyester, notably in fishing equipment.

Part (c) required candidates to identify a test that could distinguish between two of the compounds provided, including the expected observations for each compound. Most candidates correctly used the bromine test, followed by potassium permanganate. However, a common mistake was failing to state the need for an acidified reagent for $KMnO_4$ and $K_2Cr_2O_7$ oxidation.

In Part (d), performance was generally average. More candidates were able to identify the relevant compounds (alkene and acid) from the provided molecular formula than were able to draw the fully displayed structural formulae. The most common drawing error involved placing an incorrect valence on at least one carbon atom. This was most often seen in terminal carbons (shown with a valence of three) and in carbons attached to the functional groups of the alkene and alkanoic acid (sometimes depicted with a valence of five or more, ≥ 5). A few candidates were unable to identify the compound accurately from its molecular formula; however, they correctly produced the fully displayed structural formula for the compound listed.

Recommendations

- Candidates are encouraged to specify both the type and direction of variation so they can gain full credit, for example, *physical properties increase as molar mass increases*.
- Candidates should learn specific examples of use cases, rather than broad categories, since vague answers increase the likelihood of overlapping with other polymer uses.
- Candidates are reminded that combustion is an unacceptable test for differentiating alkanes and alkenes. They should also note that bromine water and not bromine gas is the correct reagent for this test.

Question 6

In Part (a) (i), most candidates were generally able to write the correct definition of *green chemistry*. However, some candidates omitted the part of the definition that links the design of products to preventing the generation of hazardous or harmful substances. This resulted in the loss of one mark. A few candidates incorrectly associated the term *green chemistry* with plants (agriculture), organic chemistry, natural resources, a study, or pollution reduction.

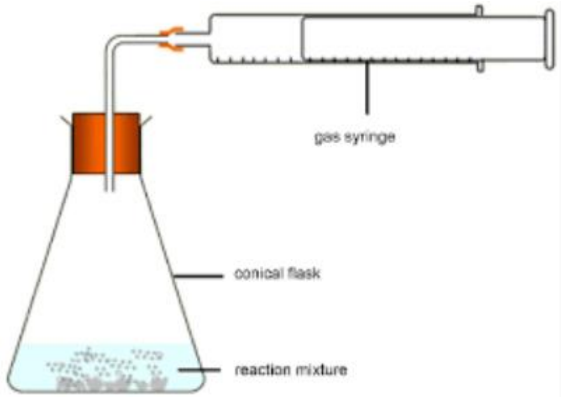
Part (a) (ii) required candidates to list any two principles of green chemistry. Generally, there were good responses for this part. Most candidates listed at least one correct principle, indicating familiarity with the topic. However, some candidates wrote only ‘prevention’ as one of the principles without providing further detail.

In Part (b) (i), candidates were required to state two pollutants that could have been emitted from the factory in the scenario provided. This part had the highest percentage of correct responses. Most candidates identified *carbon monoxide* and *carbon dioxide* as pollutants. A common mistake was listing ‘nitrogen gas’ as an air pollutant.

In Part (b) (ii), most candidates, by considering the products made by the chemical factory, were generally able to state at least two substances that can pollute waterways. This part also had a high percentage of correct responses. However, in some cases, candidates simply repeated examples given in the question stem such as ‘pesticides’, ‘fertilizers’ and ‘plastics’. As a result, marks were not awarded.

In Part (c), most candidates did not draw the appropriate diagram for the laboratory preparation of oxygen. Neither did they identify both reactants but in most cases, omitted the hydrogen peroxide in the thistle funnel. Another common error was that the system was open and downward delivery was not properly shown. In some cases, there was no passage of oxygen gas through water. Greater than 90 per cent of candidates lost the 1 UK mark because they could not identify all four labels; in many cases, only two labels were identified.

Another frequent mistake was drawing the apparatus incorrectly, as shown below.



The mean score for this part was generally two marks. These marks were awarded for correctly showing the collection flask and downward delivery and in some cases, indicating a closed system. It must be noted that many candidates did not attempt this part of the question.

Recommendations

- Candidates are encouraged to learn all the principles of green chemistry, understand their application, and know the correct definition of *green chemistry*.

- Teachers should provide demonstrations of the laboratory preparation of gases in science labatories, allowing students to draw properly labelled diagrams.

PAPER 032 — ALTERNATIVE TO THE SCHOOL-BASED ASSESSMENT (SBA)

Question 1

In Part (a) (i), most candidates were unable to accurately record thermometer readings within a margin of ±1°C of the supervisor's or industrial specialist's reference values. However, based on the candidates' recorded values, the arithmetic subtraction was performed accurately in almost all cases.

In Part (a) (ii), candidates had trouble writing the balanced chemical equation. A significant number provided incorrect formulas for the salt produced from the reaction between KOH and H_2SO_4, frequently identifying KSO_4 and SOH as products instead of the correct salt, K_2SO_4. Additionally, in some instances, when writing the chemical equation, sodium hydroxide was incorrectly used in place of potassium hydroxide.

In Part (b), candidates demonstrated difficulty in graph plotting, particularly in constructing the two lines of best fit. In many instances, the lines were drawn in an X configuration, intersecting at the midpoint between the two lines rather than at the point corresponding to the maximum temperature. In other cases, a single line or curve was drawn connecting all plotted points. Candidates also encountered challenges in plotting data points that extended beyond the provided scale; this indicated a limited understanding of how to appropriately adjust the graph to accommodate and accurately represent the data.

Both Parts (c) (i) and (ii) were poorly answered, largely due to the frequency of inaccurate best-fit lines in Part (b). As a result, many candidates were unable to obtain marks for this part. The maximum temperature rise was frequently reported as the highest recorded temperature, with minimal or no reference to the intersection point of the two lines of best fit on the plotted graph, which is the correct method for determining the temperature change.

Part (d) was generally poorly executed. Few candidates achieved full marks. Most candidates were unable to correctly identify the appropriate mass, **m,** that resulted in the reaction between the two solutions. They did not recognize that the temperature change should correspond to the value at the intersection point of the two lines of best fit. Instead, many candidates, in calculating the enthalpy change for the neutralization reaction, incorrectly used the volume of solution corresponding to the highest recorded temperature as the value for **m**.

Part (e) was generally poorly answered. Most candidates used the molar mass incorrectly in their calculations. A significant number attempted to use Avogadro's number (6×10^{23}) to perform mole calculations instead of applying the molar concentration of the solution. Candidates who attempted to use the molar mass often failed to include the volume that was calculated in Part (c) (ii).

Part (f) was also poorly answered and had the highest frequency of no responses (NRs) compared to all other subsections. In most responses, candidates omitted the negative sign required to indicate that the reaction is exothermic. Furthermore, many candidates failed to establish the connection between the calculated enthalpy change and the heat change per mole of reactant.

For Part (g), candidates should have provided sources of error that related to procedural limitations rather than those that are attributed to careless use of equipment or poor technique. For example, proper reading technique is expected to account for parallax error and is therefore not accepted as a valid source of error in this setting. In addition, there were some common vague responses that were not credited; these included ‘human error’ and ‘not reading the temperature correctly’.

In Part (h), most candidates correctly identified the use of gloves, goggles, and a lab coat (or lab apron) as appropriate safety precautions. However, in a few instances, candidates incorrectly listed sources of error as safety precautions.

Recommendations

To strengthen students’ graphing proficiency, teachers should provide continued practice in reading and applying decimal-based scales and constructing accurate lines of best fit. Teachers are encouraged to conduct multiple heat of neutralization experiments, allowing students to effectively monitor temperature changes and develop mastery of this experimental skill. Additionally, students should receive ample practice in writing balanced chemical equations with appropriate state symbols to foster a deeper understanding of chemical notation and equation construction.

Question 2

Part (a) required candidates to provide three observations related to the reaction between an ammonium salt and aqueous sodium hydroxide. The observations could have been stated as follows.

- No precipitate formed <u>or</u> it is soluble <u>or</u> there is no visible change.
- An irritating/choking/pungent gas evolved.
- The gas turned moist red litmus blue.

Candidates made a good attempt at answering Part (a). Most candidates correctly identified the change in the colour of the moist litmus paper. However, many struggled to provide the other expected observations, particularly the one that highlighted that no precipitate was formed.

Several candidates incorrectly classified the presence of ammonia as an observation rather than recognizing it as an inference. It is important to note that the presence of ammonia is inferred from sensory evidence, namely, its pungent smell. A few candidates mentioned the smell of ammonia but failed to explain how this inference was made. Furthermore, some responses included incorrect statements such as the formation of a white precipitate that was insoluble in excess sodium hydroxide; this indicated a lack of understanding of the solubility behavior of ammonium compounds.

Part (b) required candidates to describe the observations associated with the identification of chloride ions using nitric acid followed by silver nitrate solution and subsequently the effect of aqueous ammonia on the resulting precipitate. The expected responses, worth two marks, were

- formation of a white precipitate
- the white precipitate dissolving in excess aqueous ammonia.

Overall, this part was well done. Most candidates made these observations, demonstrating that overall, there was a reasonable understanding of the qualitative test for chloride ions. However, some candidates used imprecise terminology such as ‘cloudy’ or ‘cloudy white’ instead of *white precipitate*. It must be emphasized that the term ‘cloudy’ is not an acceptable substitute for a precipitate and does not carry the same scientific meaning.

A few candidates inaccurately identified the precipitate’s colour as ‘green’ or ‘brown’; this suggests possible confusion with other ions such as iron (II) or iron (III). In some responses, candidates used vague descriptions such as ‘white solution’ or omitted the solubility behavior of the precipitate entirely. Despite these shortcomings, most candidates demonstrated an awareness that a precipitate was formed and many accurately described its solubility in excess ammonia, using terms such as *dissolves*, *soluble* or *disappears*.

Part (c) assessed candidates' ability to identify the presence of aluminium, zinc, or lead ions based on their reactions with aqueous sodium hydroxide, both initially and in excess. For two marks, candidates were expected to provide the following observations.

- The formation of a white precipitate
- The dissolution of precipitate in excess sodium hydroxide

Overall, there was a good attempt at this question. Most candidates gave correct observations, demonstrating a fair understanding of the characteristic reactions of amphoteric metal ions. However, several areas of concern were noted. Some candidates failed to mention the colour of the precipitate. It must be noted that both aspects of the observation — colour and solubility — were required in order to gain full credit. Just as they did in Part (b), candidates incorrectly used the term 'cloudy' instead of *white precipitate*. It is essential for candidates to recognize that 'cloudy' is not an acceptable scientific term in this context and does not convey the same meaning as *precipitate*.

Additionally, some candidates gave incorrect colours such as 'green' or 'brown', which are characteristic of transition metal ions like iron (II) or iron (III), rather than the white precipitates associated with aluminium, zinc, or lead ions.

Part (d) assessed candidates' understanding of the reactions of aluminium and lead (II) ions with aqueous ammonia. For two marks, candidates were expected to state the following observations.

- The formation of a white precipitate
- The precipitate remaining insoluble in excess aqueous ammonia

This part of the question was not done as well as the others. While most candidates correctly stated that a white precipitate was formed, many incorrectly indicated that the precipitate was soluble in excess ammonia. This error suggests confusion between the behavior of cations in reactions with aqueous sodium hydroxide and aqueous ammonia. The dissolution of the precipitate in excess ammonia is not characteristic of aluminium or lead (II) ions in this context.

In general, candidates were more successful at identifying the initial formation of a white precipitate but struggled to accurately state its behavior in excess ammonia. A few candidates also used the imprecise term 'cloudy' instead of *white precipitate*, this should be avoided.

Part (e) assessed candidates' understanding of the reaction between aluminium ions and aqueous potassium iodide. For one mark, candidates were expected to make the observation that *no precipitate was formed.* Other ways of stating this would have been *there was no apparent reaction* or *the solution remained colourless.*

This part was challenging for many candidates. Many responses referenced the formation of a yellow or white precipitate, even though the information provided indicated that the relevant ions were absent and therefore the solution should have remained colourless with no precipitate. The reference to the formation of a yellow precipitate (commonly linked to the potassium iodide–lead (II) ion reaction) suggest reliance on memorized reactions rather than an interpretation of the given evidence. It also reflects a broader misunderstanding of how to interpret and report observations for tests yielding negative results.

The absence of a yellow precipitate is a key indicator that lead (II) ions are not present and should have guided candidates to deduce that aluminium ions were responsible for the lack of reaction.

Another common error was misuse of terminology. Some candidates incorrectly referred to the absence of a ‘yellow solution’ rather than a *yellow precipitate*, indicating confusion between the terms solution and precipitate. Precision in language is essential when describing chemical observations.

Recommendations

Several key areas for improvement should be reinforced through instruction and laboratory work. To improve performance, the following are recommended for teachers.

- Teach the distinction between observations (what can be detected with the senses) and inferences (conclusions drawn from those observations).
- Emphasize that when no precipitate forms upon the addition of sodium hydroxide, this constitutes a valid and important negative observation.
- Ensure students understand the behaviour of ammonium salts with sodium hydroxide and recognize that ammonia gas is the only alkaline gas capable of turning red litmus paper blue.
- Place greater emphasis on sequencing observations logically and aligning them with correct inferences.
- Differentiate between correct observational terms and vague or incorrect descriptors and promote the use of precise scientific terminology. Terms such as ‘cloudy’ or ‘white solution’ are unacceptable and should be avoided.
- Reinforce the definitive test for chloride ions, including the sequence of reagents used and expected outcomes.
- Stress accurate reporting of both the formation and subsequent solubility of precipitates in excess aqueous ammonia.
- Provide guided practical experiences to enhance observational accuracy, attention to detail, and the ability to describe chemical reactions using correct terminology.
- Ensure that there is accurate and complete reporting of observations, including both precipitate colour and solubility in excess reagent.
- Reinforce the behaviour of amphoteric ions in reactions with sodium hydroxide through repeated and supervised practical work.
- Highlight the importance of negative observations as valid scientific data, particularly in qualitative analysis.
- Offer hands-on practical experiences that focus on the correct interpretation and recording of both positive and negative results.
- Emphasize the importance of using accurate scientific terminology, distinguishing clearly between solutions and precipitates.
- Encourage deeper conceptual understanding rather than rote memorization of reactions.

- Differentiate the solubility behaviour of metal hydroxides in sodium hydroxide versus aqueous ammonia.
- Ensure students understand that Pb^{2+} and Al^{3+} form white precipitates with aqueous ammonia that do not dissolve in excess.

Hands-on experiences will help reinforce correct observational reporting and deepen students' understanding of qualitative analysis procedures.

Question 3

For Part (a), most candidates provided generally sound procedures but on average, one or two key steps were missing. Several responses did not include a step for recording observations. While procedural variation may sometimes occur due to resource constraints, candidates must be instructed regarding standard apparatus and methodology, as substandard variations are not accepted in an examination setting.

In Part (b), responses were generally appropriate. However, some candidates listed apparatus that were not referenced in the procedure. Arbitrary listing of apparatus is not credited if there is no clear relation to the procedure provided.

For Part (c), performance was relatively average in drawing the experimental setup. The most significant error involved drawing the solvent line above the ink dots.

Generally, Part (d) was challenging. This was likely due to the omission of a step for recording data or observations in Part (a). Other common errors included the incorrect identification of the data to be collected such as 'the distance moved by the solvent front', 'the distance moved by the ink', and 'the time taken for the ink to move'.

For Part (e), many responses were vague. For example, stating 'ink' or 'solvent' as a controlled variable is too general and not creditable. A more accurate response would be *the volume of ink or solvent*.

Recommendations

Candidates are encouraged to label all components and reagents in their diagrams and to describe experimental factors with sufficient detail.