CARIBBEAN EXAMINATIONS COUNCIL

CAPE® CHEMISTRY

Unit 1 and Unit 2

Subject Report with Exemplars

June/July 2022

CARIBBEAN EXAMINATIONS COUNCIL

REPORT ON CANDIDATES' WORK IN THE
CARIBBEAN ADVANCED PROFICIENCY EXAMINATION

JUNE/JULY 2022

CHEMISTRY
Unit 1 and Unit 2

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INTRODUCTION

CAPE Chemistry comprises two units, consisting of three modules per unit. The units and their respective modules are listed below.

Unit 1
- Module 1 — Fundamentals in Chemistry
- Module 2 — Kinetics and Equilibria
- Module 3 — Chemistry of the Elements

Unit 2
- Module 1 — The Chemistry of Carbon Compounds
- Module 2 — Analytical Methods and Separation Techniques
- Module 3 — Industry and the Environment

Candidates' knowledge of the two units is examined using three papers per unit. Paper 01 and 02 are examined externally. Paper 031, the School Based Assessment (SBA), is examined internally by teachers and moderated by CXC. Private candidates write Paper 032 which is an alternative to the SBA.

Paper 01 consists of 45 compulsory multiple-choice items, consisting of 15 items per module. The paper is worth a total of 90 marks, which accounts for 40 per cent of the overall score for the unit.

Paper 02 comprises three compulsory questions, consisting of one question per module. Each question is worth 30 marks. The paper is worth 40 per cent of the overall score for the unit.

Paper 031 comprises laboratory exercises and is worth 20 per cent of the overall score for the unit. Paper 032 comprises three compulsory questions which test candidates' laboratory skills.

In 2022, the number of candidates taking Unit 1 was 3453 while 2776 took Unit 2. Ninety-one per cent of candidates earned acceptable grades (Grades I–V) for Unit 1 and 95 per cent earned acceptable grades in Unit 2.

The overall performance of candidates in Unit 1 was consistent with 2021 and there was an improvement in the performance of candidates when compared with 2020. For Unit 2, the overall performance of candidates was consistent with 2021 but slightly higher than 2020.

Candidates continued to perform poorly on Paper 02. Their performance on some modules demonstrated that they did not have the expected knowledge, skills and abilities. Some candidates had challenges answering questions in which they had to apply, analyse or synthesize information. Several candidates demonstrated limited experimental knowledge and skills on questions which required them to demonstrate their practical knowledge and experience.

UNIT 1

PAPER 01 — MULTIPLE CHOICE

Paper 01 consisted of 45 multiple-choice items. It was designed to test the syllabus content extensively. The items were based on the three modules of the syllabus. Approximately 92 per cent of candidates earned acceptable grades. The mean score was 62.40 out of 90 marks and the standard deviation 15.70.

Module 1: Fundamentals in Chemistry

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Question 1

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This question was based on Syllabus Objectives 1.1–1.3, 2.4, 2.6, 2.10, 6.4 and 6.9. The mean was 11.93 and the standard deviation 4.99.

Candidates were tested on their knowledge and understanding of the
- properties of simple subatomic particles
- postulate of Dalton's Atomic Theory
- evidence used to prove the invalidity of the postulate and the modification to the postulate
- term *relative atomic mass* and how to calculate the relative atomic mass of neon
- electronic configuration of oxygen in terms of s and p
- overlap of the atomic orbitals to form the double covalent bond in the oxygen molecule
- effect of hydrogen bonds in water and in ice in relation to the physical properties
- term *bond energy* and use of bond energy data to determine the enthalpy of reaction
- description of an experiment to determine the heat of neutralization.

Examiner's Comment

Overall, the performance of candidates was fair. Many candidates were able to provide the correct properties of the subatomic particles in Part (a) (i) to Part (a) (iv).

For Part (b), candidates were able to state the evidence used to disprove the postulate of Dalton's Theory given but were not able to provide the modifications made to the postulate.

Generally, candidates' performance on Part (c) (i) and Part (c) (ii) was fair. A few candidates exhibited limited knowledge of the definition of the term *relative atomic* mass and how to calculate the relative atomic mass of neon.

In Part (d) (i), a few candidates wrote the incorrect *s, p* electronic configuration of the oxygen atom in its ground state. In Part (d) (ii), only a few candidates were able to explain how the atomic orbitals in the oxygen atom overlap to form the double covalent bond in the oxygen molecule. Candidates used the electronic arrangement in the formation of the double covalent bond to provide an explanation. For Part (d) (iii), many candidates were able to identify that hydrogen bonds are present in water and in ice. However, only a few candidates stated the reason why the hydrogen bonds were present. These candidates were also able to state the effect that the bonds have on the structure of the molecules and therefore on the properties of water and ice.

In Part (e) (i), candidates were unable to define the term *bond energy*. However, some candidates correctly calculated the enthalpy change for the reaction between methane and oxygen to produce carbon dioxide and water.

Candidates' performance in Part (f) was very poor. They were unable to outline the experimental steps involved in obtaining an accurate value for the enthalpy of neuralization reaction between sodium hydroxide and hydrochloric acid.

Recommendations

In addition to doing experiments, teachers need to ensure that students write reports on these activities. Teachers should assess the reports for how candidates use language and for accuracy.

Module 2: Kinetics and Equilibria
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Question 2
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This question was based on Syllabus Objectives 1.1, 1.2, 3.2, 3.3–3.6, 6.1 and 6.3. The mean was 11.04 and the standard deviation 7.48.

Candidates were tested on their knowledge and understanding of
- pH and how to calculate the hydrogen ion concentration of a liquid extracted from ants
- the required sketch of the titration curve of the reaction between a weak acid and strong base
- the pH range of three given indicator
- the definition of rate of reaction
- the factors which affect the rate of reaction (catalyst and surface area)
- how to determine the order of reaction
- how to determine the rate law
- the definition of the standard electrode potential of a half cell
- how to draw the required labelled diagram to show how the standard electrode potential of a given half-cell is determined.

Examiner's Comment

Generally, candidates performed fairly well. Many candidates were able to define the term *pH* in Part (a) (i) and calculate the hydrogen ion concentration correctly in Part (a) (ii). However, in Part (a) (iii), only a few candidates were able to sketch the correct, labelled titration curve for the titration between the weak acidic solution and the strong base. In Part (a) (iv), many candidates selected the correct indicator for the titration but the reasons provided for its selection were not acceptable.

In Part (b) (i), only a few candidates were able to define the term *rate of reaction* but in Part (b) (ii), most candidates were able to explain the effect of the catalyst and the surface area on the rate of reaction.

Candidates performed well on Part (c). In Part (c) (i), they provided the correct order of reaction based on the experimental data given and in Part (c) (ii), they stated the overall order of reaction. Finally, in Part (c) (iii), they wrote the correct rate law.

Part (d) proved to be challenging for many candidates. In Part (d) (i), only a few candidates gave the correct definition for the term *standard electrode potential of a half-cell*. In Part (d) (ii), only a few candidates drew the correct, labelled diagram to show how the standard electrode potential of the $Fe^{3+}aq/Fe^{2+}aq$ half-cell could be determined.

Module 3: Chemistry of the Elements

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Question 3

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This question tested Syllabus Objectives 4.1, 4.2, 4.5, 5.3–5.6, 6.4 and 6.5. The mean was 6.70 and the standard deviation 5.85.

This question assessed candidates'
- knowledge and understanding of how boiling point and oxidizing power change the properties of halogens going down the group
- knowledge of and ability to write balanced chemical equations for the reactions of the halide ions and concentrated sulfuric acid
- experimental knowledge of the reaction of aqueous silver nitrate and aqueous ammonia with
  – sodium chloride
  – sodium bromide.

Candidates were provided with the physical properties (melting point, density and atomic radii) of calcium and iron and asked to relate the given values to the structure and bonding of these elements. Candidates' knowledge of the electronic configuration of a few atoms and ions of transition elements was also assessed. Candidates were asked to express their understanding of the fact that copper (I) compounds were colourless but copper (II) compounds were coloured, given their electronic configuration.

Examiner's Comment

A few candidates performed fairly well in Part (a) but the performance of most candidates was weak. Many candidates were unable to provide the correct or acceptable explanation of the trend of boiling point and oxidizing power of the halogens when proceeding down the group.

Part (b) was very challenging for many candidates. They had to write balanced chemical equations for the reactions between the halide ion and concentrated sulfuric acid. Most candidates were unable to write balanced equations with the appropriate state symbols. Many candidates showed that they had limited or no knowledge of the correct products.

Candidates did not answer Part (c) well. They were required to complete a table to show how aqueous silver nitrate and aqueous ammonia can be used to distinguish between solutions of sodium chloride and sodium bromide. Many candidates had some knowledge of what the result of the reactions should be but the observations they gave were sometimes unacceptable.

In Part (d), a few candidates were able to discuss how the values of the physical properties (melting point, density, and atomic radius) of calcium and iron relate to their structure and bonding.

Completing the electronic configuration of the transition elements' atoms and ions in Part (e) (i) proved to be difficult for many candidates. Additionally, many candidates lacked the knowledge and understanding to provide acceptable responses for Part (e) (ii). Only a few candidates were able to write acceptable explanations of the colourless compounds of copper (I) compared to the coloured compounds of copper (II).

Recommendations

Teachers are reminded of the need to
- link the observed characteristics of the groups and periods with the physical or chemical or structural properties of the elements
- encourage students to practise writing full and ionic equations with state symbols for the chemical reactions discussed
- develop students' ability to explain the trends and patterns in groups and periods
- expose students to suitable practical exercises for the various topics.

PAPER 032 — ALTERNATIVE TO THE SCHOOL BASED ASSESSMENT

This question tested the following modules and Syllabus Objectives
- Module 1: 3.8–3.9
- Module 2: 1–1.4
- Module 3: 4.2.

Overall, the performance of candidates was poor. The maximum mark available was 45. The mean score was 15.38 and the standard deviation of 7.09.

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Question 1
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Candidates were asked to carry out a titration experiment to determine the concentration of the iodine solution provided. They were provided with a sample of iodine solution, a standard sodium thiosulphate solution and starch solution.

Common errors observed included
- incorrect recording of titration volumes (They did not use two decimal places.)
- poor choice of titre values in the calculations (Candidates selected values that were greater than ± 0.1 cm^3 difference.)
- incorrect calculation of the average titre value which was to be used in the subsequent calculations.

Candidates were required to perform molar calculations based on given stoichiometric equations. Candidates experienced difficulty in deducing the overall reaction equation from one of the two half equations provided in Part (f) and carrying out the required calculations in Part (g). Performing titrations, taking the required recordings and calculating values correctly were areas of weakness for most candidates.

Recommendations

Instructors need to emphasize to candidates, the importance of recording titre values accurately and the need for repeating titrations until subsequent volume readings differ by no more than 0.1cm^3. Additionally, candidates need to be properly instructed on how to perform molar calculations.

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Question 2

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This question utilized the data analysis format to investigate the effect of concentration on the rate of reaction between methanoic acid and aqueous bromine. Candidates were asked to

- construct a table to show the values of reaction rate corresponding to different bromine concentrations at different times
- plot a graph of reaction rate against the bromine concentration
- suggest a reason for the shape of the graph
- describe a method which can be used to determine the changes in the bromine concentration
- determine, from the graph, the relationship between the reaction rate and bromine concentration, and the order of the reaction and the rate law.

Many candidates presented the correct tabular representation of the data provided and plotted an acceptable graph. Errors made by candidates in plotting the graph included the incorrect labelling of the axes, poor choice of scale and incorrect choice of axes to represent the data.

Candidates were generally unable to explain the shape of the graph and thereby gave the incorrect conclusion as to the effect of time on the rate of the reaction. Determining the reaction rate proved to be very difficult for most candidates who failed to recognize the need to determine the gradient of the graph at the times indicated.

Question 3

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This question assessed candidates' level of competence in the skills associated with the planning and design (PD) of practical investigations. Candidates were asked to design an experiment to determine the relative reactivities of the aqueous solutions of iodine, chlorine and bromine.

Overall, the performance of candidates was very weak. Many candidates were unable to formulate appropriate hypotheses and construct aims that would unambiguously indicate the relative reactivities of the halide solutions. The qualitative tests presented were almost always incomplete as many candidates failed to indicate that the same halide solution was to be used in each testing procedure.

UNIT 2

PAPER 01 – MULTIPLE CHOICE

Paper 01 consisted of 45 multiple-choice items. Approximately 96 per cent of the candidates earned acceptable grades. The mean score was 66.99 out of 90 marks and the standard deviation 13.40.

Module 1: The Chemistry of Carbon Compounds
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Question 1
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This question tested Syllabus Objectives 2.9–2.11, 3.1–3.3 and 4.1–4.5. The mean was 9.58 and the standard deviation 7.03.

Candidates were tested on their knowledge and understanding of the following.
- Selected reactions of some carbonyl compounds
- The structures of some carbonyl compounds
- The expression required for the K_a of chloroethanoic acid
- The pK_a value associated with the K_a of chloroethanoic acid
- The difference in pK_a values for phenylamine and ethylamine
- The monomers associated with given polymers
- The required structures of monomers associated with a given polymer
- The laboratory reaction necessary to break a given polymer

Candidates' performance was fair in some subparts. A few candidates performed well on Part (a) while some candidates' performance on Part (b) was fair.

In Part (c) (i), candidates were able to insert the pK_a values into the correct spaces. However, in Part (c) (ii), they were unable to explain why they assigned the values to the particular spaces. The reasons given demonstrated that candidates did not understand the concepts associated with assigning pK_a values.

Providing suitable responses to explain the differences in the pK_a values of ethylamine and phenylamine in Part (d) proved challenging for candidates.

Part (e) tested candidates' knowledge of polymerization. Many candidates were able to provide correct responses.

Module 2: Kinetics and Equilibria
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Question 2
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This question tested Syllabus Objectives 7.1–7.3, 8.1–8.3 and 9.4–9.5. The mean was 8.13 and the standard deviation 5.56.

This question examined candidates' knowledge and understanding of
- the workings of a mass spectrometer
- the m/z ratio of M^+ and M+2 peaks of a given mass spectrum
- the formulas of fragments at particular m/z ratios
- the formulas of the M^+ and M+2 molecular ion species
- the process in thin layer chromatography, TLC
- the use of a TLC chromatogram to analyse and identify alpha-amino acids
- the use of TLC in analysing mixtures of alpha-amino acids
- the experimental steps for the separation of benzoic acid and 1, 4 – dimethoxybenzene by solvent extraction
- the definition of partition coefficient
- calculating the partition coefficient
- the application of the concept of partition coefficient to determine the concentration of iodine in the organic solvent which is in equilibrium with iodine in the aqueous layer.

Generally, the performance of candidates was weak. However, Part (a) was done well by many candidates.

Many candidates were able to provide the m/z ratios of the M^+ and M+2 peaks correctly for Part (b) (i). A few candidates were able to write the correct formulas for the fragments at m/z ratios, 43, 107 and 109 for Part (b) (ii). However, many candidates did not put the required charges on the formulas of the fragments. Part (b) (iii) proved to be difficult for many candidates. The M^+ and M+2 molecular ion species were usually incorrect and this resulted in candidates giving an incorrect name for the haloalkane.

A few candidates were able to name the correct process in the TLC separation of alpha-amino acids in Part (c) (i). Part (c) (ii) also was done fairly well by many candidates. However, Part (c) (iii) was challenging for many candidates.

Part (d) (i) was very challenging for many candidates. It was obvious that they had not been exposed to this type of experimental procedure. Only a few candidates defined the partition coefficient correctly in Part (d) (ii) and calculated the partition coefficient correctly in Part (d) (iii). Part (d) (iv) also proved to be challenging for many candidates. They experienced difficulty determining the concentration of iodine in the organic solvent in the process of solvent extraction.

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Module 3: Chemistry of the Elements
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Question 3
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This question tested Syllabus Objectives 3.1–3.3, 6.1 and 10.1–10.3. The mean score was 12.08 and the standard deviation 5.14.

Candidates were asked to
- insert the missing information concerning the fractions, boiling range, number of carbon atoms and uses of the crude oil fractions
- define the term *catalytic cracking*
- write a balanced equation to show the products of the cracking of decane
- explain the principles involved in the fractional distillation of crude oil
- explain the adverse effect of the petroleum industry and its impact on the environment
- define the terms *reuse, recycle and reduce*
- apply the concepts of reuse, recycle and reduce to glass waste
- describe the chemical processes involved in the production of chlorine and sodium hydroxide using the diaphragm cell
- describe the chemical changes involved in the chlor-alkali industry to produce hydrochloric acid and sodium hypochlorite
- indicate two modifications to be made to the structure of the diaphragm cell to ensure that sodium hypochlorite is not formed.

Overall, candidates performed fairly well. The performance of many candidates on Part (a) was good.

Candidates' performance on Part (b) (i) and Part (b) (ii) was also good. However, in Part (b) (iii), candidates' discussions on the principles of fractional distillation of crude oil were very vague. This showed that they did not have the expected understanding. In Part (b) (iv), candidates gave a variety of adverse effects of the petroleum industry which were correct.

In Part (c) (i), some candidates gave correct definitions of the terms *reuse*, *recycle* and *reduce.* However, in Part (c) (ii), their application of these terms to glass waste was vague and mainly incorrect.

Candidates demonstrated that they possessed the correct knowledge and understanding of the chemical processes involved in the production of chlorine and sodium hydroxide in Part (d) (i). However, candidates lost marks because they did not include the physical states in the chemical equations.

Parts (e) (i) and (e) (ii) were challenging for some candidates who could not report on the chemical changes with equations in the chlor-alkali industry.

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Finally, in Part (e) (iii), many candidates were able to provide one correct modification that could be made to the structure of the diaphragm cell to ensure that sodium hypochlorite was not formed.

PAPER 032 – ALTERNATIVE TO THE SCHOOL BASED ASSESSMENT

This question tested the following modules and Syllabus Objectives.
- Module 1: 2.4, 2.9
- Module 2: 3.3–3.4
- Module 3: 8.4–8.5

Overall, the performance of candidates was weak. The maximum mark available was 45. The mean score was 19.93 and the standard deviation 5.99.

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Question 1

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Candidates were required to test organic compounds to differentiate between and identify the unknown liquids as an aldehyde, a ketone or an alkene. Many candidates appeared to have difficulty observing the chemical reactions and recording the appropriate changes in colour and/or appearances of precipitates. Consequently, candidates were unable to correctly identify the organic liquids and give justification for their choices.

Question 2

This question assessed candidates' ability to

- provide a tabular representation of data on the gravimetric analysis of a hydrated salt
- describe the experimental steps in the analysis
- state precautions which must be observed during the experimental procedure
- determine the number of moles of water attached to the anhydrous salt.

Many candidates were able to give an acceptable tabular representation of the data provided, including the appropriate units. However, candidates were not able to describe the correct experimental procedure for conducting the analysis. Very few students were able to provide at least one correct precaution which must be observed during the experimental procedure. Only a few candidates were able to carry out the series of calculations required to determine the moles of water contained in one mole of the anhydrous salt. Performing molar calculations continues to be an area of weakness for many candidates.

Question 3

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This question tested candidates' ability to plan and design an experiment to determine if the agricultural run-off in the drains of a large commercial farm contains dissolved nitrates and phosphates due to the use of fertilizers.

While many candidates were able to formulate accurate hypotheses and aims, these first tasks in experimental planning and design were challenging for some candidates. Errors made by candidates included writing incorrect hypotheses and aims, and formulating hypotheses and aims that were not properly linked.

Many candidates struggled to present an appropriate and credible method for testing their hypotheses. Listing the reagents and apparatus, and the experimental procedure proved to be challenging for some candidates. They presented methods which were either incomplete or inaccurate. Candidates also experienced difficulty providing variables, expected results and precautions.

The responses given demonstrated that candidates lacked experimental knowledge. Therefore, teachers need to strengthen students' knowledge of experimental planning and design.