2022 NCEA Assessment Report

Subject: Chemistry

Level: 3

Standards: 91390, 91391, 91392

Part A: Commentary

Candidates who achieved Excellence provided concise and specific explanations, supported by Chemistry vocabulary, calculations, correct formulae, correct units, and appropriate use of significant figures. Candidates were encouraged to focus on understanding processes, rather than memorising steps of a calculation or lists of reactions. This assisted candidates with problem-solving style questions. For calculation questions, candidates were expected to explain the significance of the numerical answer.

Part B: Report on standards

91390: Demonstrate understanding of thermochemical principles and the properties of particles and substances

Examination

The examination included three questions of which candidates were required to respond to all three. Question One required candidates to explain the shape and polarity of a molecule, and determine the final temperature in a calorimetry calculation. Question Two assessed the ability of candidates to explain the changes occurring during a heating curve, use enthalpy of formation data to calculate an enthalpy change, and justify the spontaneity of a chemical reaction in terms of the entropy changes of the system and surroundings. Question Three required candidates to explain the difference in atomic and ionic radii, justify trends in the periodic table, and justify the boiling points of three selected substances by comparing the relative strength of their attractive forces.

The questions covered the requirements of the 2022 assessment specifications to demonstrate understanding of thermochemical principles and the properties of particles and substances.

Observations

Many candidates were confused about the difference between enthalpy and entropy changes, and how these affected the spontaneity of a process.

Very few candidates could fully explain the factors affecting periodic trends. In particular, the effect of repulsion between energy levels (shielding) was frequently omitted or poorly described.

Candidates regularly used the term “electronegativity” incorrectly, such as referring to “regions of electronegativity” rather than “regions of electron density”.

Many candidates mistakenly referred to covalent bonds breaking when a molecule changes state. Overall, intermolecular forces were poorly explained, particularly hydrogen bonding. It was imperative that candidates made it clear that intermolecular forces existed between molecules, rather than within the molecule. Furthermore, when comparing the strength of temporary dipole forces, candidates needed to link the strength to the size of the electron cloud.

Grade awarding

Candidates who were awarded **Achievement** commonly:

- drew Lewis structures
- named molecular shapes
- recognised the number of regions of electron density around an atom
- identified bond polarity based on electronegativity differences
- performed one step calculations correctly
- wrote electron configurations using s, p, d notation
- described some aspects of a heating curve
- recognised entropy increases with an increase in disorder.

Candidates who were awarded **Not Achieved** commonly:

- could not draw Lewis structures or name shapes
- could not describe any factors affecting shape or polarity of a molecule
- were confused about what was occurring in the different parts of a heating curve
- did not know that the enthalpy of formation of an element is zero
- did not know the difference between entropy and enthalpy changes
- recognised no relevant factors affecting periodic trends
- could not identify specific intermolecular forces between molecules.

Candidates who were awarded **Achievement with Merit** commonly:

- explained the shape and / or polarity of a molecule
- linked stages of a heating curve to changes in particle movement and intermolecular forces
- calculated an enthalpy change given enthalpy of formation data
- explained the entropy changes in the system and / or surroundings
- explained the difference in radii of a non-metal atom and its anion
- explained a periodic trend in terms of increasing number of protons and strength of electrostatic attraction
- linked the non-polar nature of BF_3 to the presence of only weak temporary dipole forces between molecules
- recognised that the presence of an N-H bond causes hydrogen bonding.

Candidates who were awarded **Achievement with Excellence** commonly:

- fully explained the shape and polarity of a molecule

- calculated the final temperature in a calorimetry calculation
- justified the spontaneity of a reaction based on the entropy changes of the system and the surroundings
- justified boiling points of different molecules by comparing the strength of their intermolecular forces
- fully explained changes in particle movement, kinetic energy, and intermolecular forces during phase changes
- fully justified periodic trends in terms of number of energy levels, nuclear charge, repulsion from inner energy levels, and electrostatic attraction between the nucleus and bonding or valence electrons.

91391: Demonstrate understanding of the properties of organic compounds

Examination

The examination included three questions. Candidates were required to respond to all three. Question One required candidates to develop a valid procedure to distinguish between organic molecules using chemical tests, and to demonstrate knowledge of reaction types and reagents to complete a reaction scheme. Question Two assessed the ability of candidates to synthesize a specified organic molecule in several steps from a starting organic molecule, and hydrolyse a dipeptide under acidic and basic conditions. Question Three required candidates to use observations from physical properties and chemical reactions to derive the structural formula of an unknown organic molecule from its molecular formula, as well as the structural formulae of its organic reaction products. Candidates were also assessed on their understanding of condensation reactions in the context of a polyamide.

The questions covered the requirements of the 2022 assessment specifications to demonstrate understanding of the properties of organic compounds.

Observations

It was important that all candidates appreciated that the assessment specifications stated that knowledge of the principles of organic chemistry covered in Level 2 AS91165 would be assumed.

Candidates should have carefully considered how atoms are bonded to each other when drawing structural formulae of organic molecules. For example, a carbon atom should be directly bonded to the N of an $–NH_2$ functional group. Furthermore, all atoms should be shown in the structural formula. In addition, many candidates did not understand the difference between branched- and straight-chain organic molecules.

Many candidates struggled with the process of dipeptide hydrolysis, and could not draw structural formulae of the organic products. Since hydrolysis uses water to break the amide bond, candidates should have focused on adding –OH and –H to produce the carboxylic acid and amine functional groups, and then considered how each of these groups was affected by acidic and basic conditions.

A significant proportion of the standard focuses on chemical reactions of organic molecules. To demonstrate an understanding of the standard, candidates therefore needed to be able to select appropriate reagents and conditions to change one functional group to another in multi-step reaction pathways. It was not sufficient to simply memorise a summary reaction scheme; candidates needed to be able to apply knowledge from such a scheme to answer specific questions. Furthermore, candidates should have focused on the type of reaction occurring to change the functional group, rather than just memorise lists of reactions.

Practical organic chemistry was encouraged wherever possible. Candidates were expected to provide both the initial and final colour of solutions. If asked for a procedure, candidates needed to carefully consider the order of steps, and ensure that all organic molecules were identified with a positive chemical test, rather than by process of elimination.

Grade awarding

Candidates who were awarded **Achievement** commonly:

- named and drew structural formulae of organic molecules
- described expected observations to distinguish organic molecules
- identified reaction types
- drew enantiomers to show a tetrahedral arrangement, and described an asymmetric carbon atom
- recognised a peptide bond
- completed one step of a reaction pathway
- identified reagents and organic molecules as part of a reaction scheme
- described a hydrolysis reaction
- identified a condensation reaction.

Candidates who were awarded **Not Achieved** commonly:

- provided incorrect observations
- confused a condensation reaction with a polymerisation reaction
- could not complete a reaction scheme or create a reaction pathway.

Candidates who were awarded **Achievement with Merit** commonly:

- linked correct observations to reaction types and / or structural formulae of organic products
- completed several steps of a reaction pathway
- explained an organic reaction and could draw the correct products
- explained hydrolysis, and drew some of the products from the acidic and basic hydrolysis of a dipeptide.

Candidates who were awarded **Achievement with Excellence** commonly:

- completed a reaction pathway with reagents and conditions
- drew structural formulae of all products of hydrolysis, and explained all aspects of a hydrolysis reaction
- wrote a valid procedure to identify unknown liquids linked to reaction type and structural formulae

- used information to determine the structural formula of an organic molecule and its subsequent organic products
- drew repeating units of a polymer with open ends and thoroughly explained a condensation reaction.

91392: Demonstrate understanding of equilibrium principles in aqueous systems

Examination

The examination included three questions of which candidates were required to respond to all three. Question One focused on solubility equilibria, including predicting precipitation, and the effect of a common ion and complex ion formation on solubility. Question Two covered properties such as pH and electrical conductivity, how a buffer functions, and a weak acid calculation. Question Three was set in the context of a titration curve, and included an evaluation of buffer effectiveness, a weak base calculation, and a comparison of pH values from two similar titrations. All questions required both an explanation and a calculation to gain Excellence.

The questions covered the requirements of the 2022 assessment specifications to demonstrate understanding of equilibrium principles in aqueous systems.

Observations

Most candidates demonstrated a sound understanding of solubility equilibria. However, many candidates did not recognise that the chloride ion concentration needed to be doubled due to twice as many chloride ions being provided by the calcium chloride solution.

Many candidates struggled to explain how a buffer functions, with reference to the provided equation showing the basic component of a buffer removing added strong acid. Many candidates mistakenly indicated it was the OH^- ions neutralising the added acid. Furthermore, rather than calculating the pH of a buffer using the K_a method, many candidates incorrectly substituted into the Henderson-Hasselbalch equation.

Of significance for those candidates aiming for Excellence, many did not recognise HF as a weak acid, despite it being included in the assessment specifications. This affected their comparison of pH values for three different solutions.

Most candidates found questions in the context of a titration curve to be challenging. It is expected that an evaluation of the effectiveness of a buffer would include an explanation of whether the buffer would be more effective against added acid or base, rather than referring only to the pH range over which the solution would function as a buffer. The comparison of initial pH and equivalence point pH values for two titrations with the same strong acid, but differing weak bases, proved the most difficult. Most candidates struggled to relate the K_a values to the strength of the conjugate bases. Furthermore, many candidates did not recognise that the species present at the equivalence point was the weak acid.

Grade awarding

Candidates who were awarded **Achievement** commonly:

- identified the effect of a common ion on solubility

- recognised the formation of a complex ion
- compared the ionic product with the solubility product to predict precipitation
- calculated the concentration of a weak acid from its pH
- recognised a solution requires ions for electrical conductivity
- linked the relative pH of a solution to its $[H_3O^+]$
- calculated the pH of a weak base
- recognised pH equals the pK_a halfway to the equivalence point.

Candidates who were awarded **Not Achieved** commonly:

- wrote the incorrect charges on ions in equilibrium equation and K_s expression
- substituted the solubility provided as the K_s value in the expression
- referred to Ag rather than Ag^+ ions in descriptions of common ion and complex ion formation.
- could calculate $[H_3O^+]$ from pH
- referred only to charged particles, rather than ions in their description of electrical conductivity
- could not relate the relative $[H_3O^+]$ to differences in pH
- could not calculate the pH of buffer solution, or explain its function with reference to species reacting.

Candidates who were awarded **Achievement with Merit** commonly:

- calculated the solubility product given the solubility
- used equilibrium principles to explain the effect of a common ion and the formation of a complex ion on the solubility of a sparing soluble solid
- used the correct process to determine whether a precipitate would form when two solutions were added together
- linked the degree of dissociation to the concentration of ions in solution to compare the electrical conductivity of two solutions
- explained the function of a buffer upon addition of a small volume of strong acid
- linked the pH of a solution to its degree of dissociation and the relative $[H_3O^+]$ / $[OH^-]$
- calculated the pH of a buffer solution, and evaluated its effectiveness.

Candidates who were awarded **Achievement with Excellence** commonly:

- showed, by calculation, that a precipitate would form when two solutions were added together
- justified the relative pH values of three solutions, based upon the degree of dissociation and the relative $[H_3O^+]$
- explained the significance of the pH in the conical flask at the half equivalence point
- used K_a values to compare the expected pH values for two different weak acids and their conjugate bases.