Chemistry

2013 Chief Assessor's Report

Government of South Australia

SACE Board of SA

CHEMISTRY

2013 CHIEF ASSESSOR’S REPORT

OVERVIEW

Chief Assessors’ reports give an overview of how students performed in their school and external assessments in relation to the learning requirements, assessment design criteria, and performance standards set out in the relevant subject outline. They provide information and advice regarding the assessment types, the application of the performance standards in school and external assessments, the quality of student performance, and any relevant statistical information.

SCHOOL ASSESSMENT

General Comments

A general improvement in the design of assessment tasks this year displayed a greater awareness that the quality of tasks is improved when performance standards are central to both the task design and the marking processes. Although subject outline specifications were generally adhered to, in a few instances use of the 2012 subject outline resulted in the assessment of specific feature AE3, which does not appear in the 2013 document.

Review of student work and confirmation of teachers’ decisions were assisted by an explicit statement of the specific features assessed in each task and some indication of how these were used to assess the student work. Inclusion of an assessment rubric facilitated the process significantly as did some evidence of the marking of the work.

The review of work in assessment groups comprising two or more classes, whether from different teachers in the same school or from classes in different schools, was challenging in some cases. Use of common tasks or of tasks of a similar nature and complexity, and marking of similar rigour, facilitated the process and the confirmation of teachers’ decisions. In such assessment groups, ongoing communication between teachers and internal moderation throughout the year is advised in order to ensure valid comparisons and fairness to all students.

Assessment Type 1: Investigations Folio

In this assessment type, use of rubrics and of marks schemes that did not align with the assessment design criteria or performance standards often led to an overall grade that was not supported by the evidence in student work. A high mark for correct responses to questions inviting ‘yes/no’, factual, or general responses does not necessarily indicate performance at a high level, particularly in the area of analysis and evaluation. Best practice was reflected by explicit reference to performance standards in the assessment of student work.

Practical Investigations

In practical investigations there were still instances where student responses were limited by:

- overly-specific instructions such as, ‘Identify two sources of systematic error’ or ‘State two improvements…’, often associated with a restricted number of marks
- restricted space in ‘fill-in’ report formats
- consistent and heavy scaffolding throughout all the investigations.

Best practice task design provided opportunities for students to demonstrate their achievement in the higher order skills of analysis and evaluation by formulating open-ended instructions for students to discuss, explain, and evaluate procedures and results.

A contraction was noted in the range of tasks used for the design investigation, with most investigations relating to factors affecting the rate of a reaction or the enthalpy of combustion of alcohols. This is not in itself a problem, but, as in previous years, it was sometimes difficult to discern student input into the design, as fairly standard procedures were documented. Best practice designs were typified by evidence of student initiative in such aspects as:

- why a particular reaction was selected for the investigation
- why and how particular factors were held constant
- why a particular range of concentrations or of temperature was studied
- calculation of quantities required for the preparation and dilution of an original solution to prepare the series of solutions used in the investigation
- what modifications were made to the original procedure and the reasons for these modifications.

The evaluation of data and procedures continues to be an area of concern, with considerable confusion evident amongst students and teachers on:

- the difference between valid experimental errors and procedural mistakes (such as the incorrect rinsing of volumetric glassware)
- the relationship between random errors, scatter, and precision, and between systematic errors and accuracy
- the advantage of repeating experiments, whether using identical or different conditions.

Teachers often awarded inflated grades when the discussion, whilst accurate, was of a non-specific nature and of limited depth. Such discussions often made general references to the solutions used to rinse volumetric glassware, errors of parallax, contamination of materials and uncalibrated equipment with no link to specific solutions, reasons for rinsing, possible reasons for — or effects of — contamination, or the possible impact of use of uncalibrated equipment. Some error analyses merely defined the terms systematic and random errors. Best practice discussions typically:

- related precision and accuracy to specific data
- linked sources of error, and their impact, to specific procedures and data
- explored ways in which such errors could be identified, minimised, or removed
- offered thoughtful reasons for suggested improvements, indicating the expected impact of a particular improvement on results and on the conclusion.

A trend towards excessive length in reports was noted; logical, critical, and insightful analysis was most often demonstrated in concise and focused discussions. It should be noted that a discussion of sources of random and systematic errors is not appropriate to an organic preparation.

Review of student work was assisted when clear evidence was provided for the grade decisions made for specific features I3 (laboratory skills) and A3 (individual and collaborative work skills). Suggestions for ways in which this evidence could be provided can be found under Support Materials on the Stage 2 Chemistry minisite.

Issues Investigation

The formulation of an appropriate question that linked a chosen aspect of chemistry to a social issue was significant in determining the achievement of students in this investigation. The formulation of questions where a research topic was addressed, rather than an issue with distinct perspectives, made it difficult for students to demonstrate skills of analysis and evaluation at a critical and perceptive level. Similarly, the choice of a question that was closely aligned and limited to material in the course work often resulted in a logical rather than a perceptive use of knowledge of chemistry to understand and explain the relevant issue.

The selection and acknowledgement of information and use of in-text references or footnotes were generally appropriate, but the evaluation of information frequently displayed a lack of critical analysis, with little substantiation provided for statements relating to bias and credibility. Also, where two or more sources were evaluated, there was often little distinction between the content and expression of the evaluations. Whilst excellent evaluations could result from a critical and insightful completion of one of the common evaluation forms, best practice evaluations often took the form of an unstructured explanation of why a source of information was considered particularly suitable for the investigation.

In a significant number of groups the 1500 word limit had not been applied when assessing the student work. In some cases no reference to the limit had been made in the task description, but in other instances the instructions indicated a misunderstanding that the limit applied only to the written report and excluded the source analyses. Teachers and students must be aware that words written after the limit has been reached are not assessable.

Assessment Type 2: Skills and Application Tasks

As in previous years, there were fewer adjustments to grades in this assessment type than in Assessment Type 1. Teachers are clearly more comfortable with the setting and assessment of SATs than of investigations, generally using or basing questions on past examination papers. Where adjustments to grades were necessary it was most commonly due to one of two reasons:

- a mark percentage was converted directly to a grade
- the questions selected restricted the opportunities for students to demonstrate achievement at a high level in the assessment design criteria.

In a well-designed set of tasks it is possible to align a mark with the appropriate grade. If questions from past examination papers are used, it is essential to select questions requiring a balanced mix of short and extended responses over a range of content and complexity. Best practice tasks, like the final examination, provided questions of developing complexity in familiar and unfamiliar contexts, allowing students to demonstrate achievement at all levels of the performance standards. This range included questions requiring simple, factual responses (typified by instructions such as ‘state’, ‘identify’, or ‘name’), simple application of mathematical formulae, straightforward chemical equations, descriptions of simple concepts, and application of such concepts in familiar contexts. However, best practice tasks also presented questions that allowed students to demonstrate insight in analysis and evaluation, depth of knowledge and understanding of a range of concepts, and an ability to apply these concepts to complex problems in unfamiliar contexts. Questions successful in this respect included:

- interpretation and analysis of unfamiliar diagrams and of sets of data presented in different forms
- use of non-formulaic and unexpected wording in questions
- extended responses that required contemporary issues, materials, or products to be related to relevant chemistry.

It was noted that student answers to well-posed extended-response questions provided evidence at a range of grade levels in several specific features.

EXTERNAL ASSESSMENT

Assessment Type 3: Examination

General Observations

The mean score for the examination was slightly lower than those of the previous two years with the means for Questions 10, 11, and 12 being the lowest. It would appear that students had sufficient time to make an attempt at all questions, since even for these questions there were few students who failed to attempt answers.

Students who used the additional pages identified questions well, showing all required details to identify the question number and part.

On the whole, legibility was satisfactory, with much of the work clear and easy to read. Although infrequent, the writing of some was so small or untidy that it was very difficult to interpret meaning and so assign marks.

Although grammar and spelling were done well by most students, for some, poor grammar and sentence structure affected the clarity of answers. There were also many instances of poor spelling, particularly of chemical terms. At this level students can be expected to know the correct spelling of such terms, e.g. flocculation, porous, disaccharide, hydrolysis, flotation, and effervescence.

Students who did not use pencil when drawing the graph, found it difficult to draw a neat, clear graph with a well-defined line of best fit. As has been mentioned in previous years, there were many poorly drawn covalent bonds. Some students who used correction fluid neglected to go back and rewrite their answers. Students who used a fluorescent highlighter to circle the hydrophilic part of the molecule found it difficult to restrict their circle to the appropriate part of the molecule.

Some students wrote concise, clear, and logical answers. Others gave far more detailed responses than required; students should take the space provided and the number of marks allocated as a guide to the length of answer required. However, some students used time and space repeating information given in the question, a practice that receives no marks.

In some questions there was clear evidence of the difficulties that many students have in reading and interpreting information and instructions. The inability to select and use data appropriately proved costly for many.

Even though students had access to calculators, poor arithmetic skills plagued a large minority.

Question 1

(a) (i) Generally answered correctly, but some students incorrectly identified the cell as galvanic, failing to recognise the presence of an external power source.

(ii) Generally answered correctly, but some students indicated the opposite direction, perhaps confused from an incorrect answer in part (i), and/or incorrectly assuming electron flow is from negative to positive. A surprising number of responses showed electron flow through the electrolyte, rather than in the wire.

(iii) Generally answered correctly, but again the cathode was labelled as the anode by some, likely carried through from incorrect answers to part (i) and/or part (ii).

(b) (i) The majority of students correctly stated d block, with the most common error being the incorrect use of capital D. A small number gave generic answers, such as ‘transition metals’.

(ii) (1) The oxidation state of Cr in $Cr_2O_7^{2-}$ was generally determined correctly, although the positive sign was omitted by some. A common incorrect answer was +12. Similarly, many students correctly gave 0 for the oxidation state of Cr (elemental form), with the most common incorrect answer being +3, indicating confusion between oxidation state and likely charge on the monatomic ion.

(2) Reduction was correctly identified by the majority of students. Students who incorrectly showed an increase in oxidation number were given credit if they recognised this as oxidation.

(iii) A correct equation was given by many students. The most common error, giving the product as $CrCl_2$, suggested that students did not relate the formula to the chromium’s +3 oxidation state in Cr_2O_3. Students with correct reactants and products generally balanced the equation correctly.

(c) (i) This was generally well answered, with the majority of students demonstrating an understanding of the concept of flocculation. The most common errors were referral to aluminium sulfate as positive, rather than aluminium ions, and omitting to explain how the clay particles are removed after flocculation. A small number of students confused flocculation and froth flotation.

(ii) (1) Many students did not address this question well, explaining how a zeolite works in terms of cation exchange, rather than stating its structural features.

(2) This part was generally poorly answered. Common errors included incorrect unit conversion from ppb to mg L^{-1} and dividing by 0.250

rather than multiplying. It was also common to see molar mass used, resulting in many confused answers. Students who showed clear working of their calculation were able to receive part marks when errors occurred; students who did not show clear working were unable to receive part marks since errors were not apparent to markers.

Question 2

(a) (i) Although most students correctly identified the crushing process, some students wrote 'increasing the surface area', which is not the name of the process. Many gave 'leaching', hence not addressing the increase in rate of reaction. Others ignored the flow chart entirely and provided answers such as 'froth flotation'.

(ii) This was poorly answered, with very few students achieving full marks. Although some correctly stated that zinc oxide reacts with sulfuric acid, few cited the formation of zincate anion as evidence for non-metallic properties. Answers that lacked clarity were common, such as 'it reacts with acid' (implying elemental zinc), rather than specifying zinc oxide. Some students assumed that it is the reaction of the element (i.e. zinc) with acid or base that demonstrates the amphoteric nature rather than the oxide. Some students provided correct evidence of metalloidal nature but made no reference to evidence from the flow chart. Very few students used the existence/formation of a Zn^{2+} cation in the hemimorphite as evidence of a metallic characteristic of zinc.

(iii) This was generally poorly answered. Although some students correctly identified carbon's role as a reducing agent, answers such as 'to remove the oxygen' were common, which did not address the question in the chemical context. 'Catalyst' was a common incorrect answer.

(b) The majority of students gave the correct, balanced equation. The most common error was omission of H_2O as a reactant. Although ideal responses included the equilibrium sign, no penalty was applied if a forward arrow was used.

(c) (i) The graph was reasonably well done, with the majority of students scoring at least 3 marks, and many scoring 4 or 5. The most common errors included incorrect assignment of variables to axes, unequal increments on the concentration (horizontal) axis by equally spacing the values given in the question), and drawing lines of best fit that did not equally distribute points above and below the line. Students who selected an awkward scale (not based on 1, 2, or 5) frequently plotted points incorrectly. Some students seemed intent on having the line pass through the origin, which is not necessarily the case.

(ii) This was well answered, with most students correctly citing scatter (or words to that effect) as the evidence for the presence of random errors. Some incorrectly answered that the line of best fit did not pass through the origin, hence confusing random and systematic errors.

(iii) This was generally well done, although a significant number of students could not accurately determine the corresponding value on the x-axis using their graph, particularly if it didn't coincide with a grid line. Omission of units was a common error.

Question 3

(a) (i) This was generally well answered although some students gave the name of a specific disaccharide.

(ii) This was generally well answered, with ‘condensation’ the most common incorrect answer.

(iii) More than half of the students answered correctly although many students, who failed to read the question carefully, gave the molecular formula of a disaccharide or polysaccharide. It would appear that these students did not recognise the cue ‘6-carbon sugar molecule’ in the question.

(b) (i) Only a small percentage of students achieved full marks for this question. A significant number of students wrote of a ‘change in structure’ without making it clear that this referred to a change in shape or spatial arrangement. Of those who correctly stated that the shape or spatial arrangement would change, few explained that this change was due to changes in secondary interactions. Many students did not make a clear link between the shape of an enzyme and its function. Some explained the effect of a change in pH or heat on an enzyme, giving a ‘learned’ answer rather than applying their knowledge to the specific question asked.

The best answers clearly made three points:

- secondary interactions in the protein being affected
- three-dimensional arrangement (tertiary structure) being changed, sometimes with reference to the active site being affected
- importance of the three-dimensional arrangement to the protein’s function as a catalyst.

(ii) This was generally well answered. A common incorrect answer was that the enzyme would now catalyse a different reaction.

(c) (i) Most students correctly identified the amide or peptide functional group. Amine and carboxylic acid were the most common incorrect answers.

(ii) Although this was reasonably well done, with the majority of students able to draw the required structure, many lost marks for careless errors. These included failure to show at least one end of the chain open, and omission of atoms, commonly H. As in previous years, some students drew bonds poorly, not clearly drawing bonds between the atoms involved.

(iii) This was well done by the better students but others included many errors. These included answers such as pent-1,5-diamine, or penta-1,5-diamine which omitted the –ane of the parent hydrocarbon. Others omitted the numbers showing the position of the functional groups or numbered the chain incorrectly, while the use of ‘di’ as a prefix and omission of the ‘di’ were not infrequent errors.

(iv) This was well answered with many students scoring full marks. The most common error was to only ionise one end. As in part (ii), some students did not clearly draw bonds between the atoms involved.

Question 4

(a) Most students correctly circled the carboxyl group, although there were some answers where circles included the adjacent carbon.

(b) Most students correctly stated that effervescence, or similar, would be observed.

(c) (i) Many students achieved one mark by correctly referring to more successful/productive collisions, but often did not explain this in terms of more reactant particles now having kinetic energy greater than or equal to the (new, lower) activation energy. Two common misconceptions were that a catalyst increases the frequency of collisions and that a catalyst gives the reactants more energy. Many students repeated information given in the question, which not only fails to gain marks but is wasteful of time and space. Many stated there would be ‘more collisions’ rather than ‘more successful collisions’. Some students gave general statements rather than addressing the question, for example ‘lower activation energy means less energy needed for the reaction’.

(ii) This question was very poorly answered, with few scoring full marks, and the majority scoring 1 or 2. Although many students explained the theory behind this question in terms of addition reactions (which was not required), they did not actually describe *how* the two acids could be distinguished (experimentally) using bromine. The expected colour change was given by most students, although some students described the brown colour of bromine solution changing to ‘clear’ rather than ‘colourless’. Some correctly stated that dihydromatricaria acid (DHMA) would require more bromine, but few referred to drop wise addition or titration with bromine, and it was rare to see mention of the requirement for equal amounts of the acids. Some students incorrectly inferred that oleic acid would not react at all. It was also common for students to state that DHMA would react more quickly with bromine, rather than requiring more bromine, when compared with oleic acid. Although students are not expected to know it, the reality is that the addition of bromine (and other addends) to alkynes occurs more slowly than to alkenes, even though the alkynes will react with a greater quantity.

(iii) The extended response was answered well, with the majority of students achieving at least half marks, and many achieving 7 or 8 marks. Many students demonstrated a good understanding of the principles of chromatography, and could apply them correctly to this specific example.

Common reasons for not receiving some of the marks included the incorrect inference that oleic acid is more non-polar because it is a larger molecule (rather than referring to the larger non-polar hydrocarbon chain), incorrectly stating that DHMA is ‘polar’ rather than *more* polar (than oleic acid), incorrectly answering in terms of a polar stationary phase (when the question clearly states a non-polar stationary phase is used), referring to distance travelled by a component (rather than retention time), and neglecting to explain retention time in terms of strength of interaction with the stationary phase. Incorrect terminology was also common, such as confusion between the terms ‘absorb’ and ‘adsorb’ and reference to a component being ‘adsorbed’ into the mobile phase. Students are encouraged to answer questions specifically, rather than giving a general account of the principles involved.

Question 5

(a) Generally well done. Errors included inversion of the expression, the use of round brackets for concentrations, and addition (rather than multiplication) of concentrations in the denominator. Although not common, a few students omitted [H_2O] from the expression.

(b) (i) (1) Generally well done, with the most common error being failure to convert moles to concentrations. Of greater concern was the number of students who could not correctly substitute the number of moles of each substance in the K_c expression. Calculation errors were common.

(2) Mostly well done, although some students wrote in general terms about the K_c value and the position of equilibrium rather than making, as instructed, a specific statement about the yield of ethanol.

(ii) Generally well done, with many students using a well-constructed table. Those who set their work out in a table generally (but not always) enjoyed greater success in the calculations. Common errors included:

- use of concentration units rather than moles
- subtraction, rather than addition, of the change in moles to the equilibrium values
- failure to recognise the 1:1:1 mole ratio of reactants and products.

(c) Most students obtained at least some marks for this and many responses were excellent. A significant number of students misinterpreted the question, explaining the effect of changing both temperature and pressure, or assuming that the change referred to an increase in temperature and pressure. Most responses were awarded 3 marks, as reference to the adjustment to the position of equilibrium to counteract stress was either overlooked or simply dismissed with ‘according to Le Châtelier’s principle’. Poorer responses included discussion of collision theory and referred to reaction rate.
Students are advised in questions such as these to check their responses for contradictory statements.

(d) Many students gave correct answers here although some were vague with regard to reactants and products. The most common wrong answer was the use of a catalyst.

(e) Most students had no problems here, although a significant number linked the temperature increase to equilibrium yield (usually incorrectly).

(f) Better students wrote good responses although quite a few students gave vague answers that were too general to warrant credit, e.g. ‘use the heat for another reaction’. The best answers referred specifically to the reaction.

Question 6

(a) (i) Well done by most students, although some students are confused about the correct use of hyphens, commas, and numbers. The hydrocarbon chain and functional group were commonly correctly identified.

(ii) Generally well done. The most common errors included:

- drawing the structure of the carboxylate ion
- reversal of the ester link
- omission of the –O– in the ester link
- incorrect number of H atoms on the glycerol backbone
- simple addition of $CH_3(CH_2)_{16}COOH$ to the –OH groups of glycerol

- too many H's on centre carbon
- poorly drawn covalent bonds.

(iii) (1) Some very clear, precise, and correct structures were drawn although many students lost marks for poor attention to the detail. Students who attempted to use the skeletal form of the carboxylate ion rarely represented the correct number of C atoms. A surprising number could not apply their knowledge to this question and did not attempt a response.

(2) This question was very poorly done. Students discussed (often at great length) the solubility of the hydrophobic tail in the oil and the attraction of the ionic head to water, but made no reference at all to the subsequent formation of micelles with a surface negative charge and resultant repulsion between micelles.

(b) (i) Most students identified the correct end of the molecule but careless drawing, often cutting through atoms and/or numerals, penalised some.

(ii) Although there were many ways to approach this question, not many students gained full marks. Again, the ability to be concise and logical was missing in many responses. The protonation in acidic solution of the carboxylate ion to form a molecule was generally recognised but often poorly articulated, with many students referring to an ionic bond forming between the carboxylate ion and the H^+. Many could not explain the effect this protonation would have on the action of the surfactant. In contrasting the behaviour of the anionic with the non-ionic surfactant, a large number of students stated that there would be no attraction at all between the molecule and H^+. A great deal of confusion was evident about dipole–dipole interactions, hydrogen-bonding, and ion–dipole interactions.
On the other hand, some responses were exceptional and showed a sure grasp of relevant concepts and great ability to apply them in an unfamiliar context.

(c) (i) Most students correctly identified the repeating unit.

(ii) Generally well done although some students drew a section of the polymer chain rather than the monomer. Correct placement of bonds was an issue for many, with lines drawn between atoms that would not be directly bonded.

Question 7

(a) Most students gave the correct molecular formula. The common errors were having the wrong number of hydrogen atoms or not having each element represented once in the formula.

(b) Not a high number of students gained full marks. States of matter, the negative sign, or the enthalpy units were frequently omitted. Incorrect states occurred in some responses (e.g. $_{(g)}$ for water or $_{(aq)}$ for cineole). The most common balancing error was failure to allow for the O in cineole.

(c) In all parts of part (c) many students demonstrated an inability to select appropriate data from the results table and/or use that data appropriately.
Very few students obtained the mark for correct use of significant figures.

(i) Students lost marks in a wide variety of ways. These included using the wrong formula, using the wrong mass of water, and incorrect substitution of values in the formula. Some students used data from Trial 2 rather than Trial 1. Some calculated the molar enthalpy of combustion rather than heat released, suggesting students may be accustomed to substituting values in formulae rather than using data in a variety of ways. Some used the mass of cineole or the initial or final mass of the burner rather than the mass of water heated. A small number of students calculated the energy released using ΔH from the thermochemical equation. Calculation errors were common and many students made no attempt to round off to an appropriate number of significant figures. Students who attempted to do so generally gave this answer to the appropriate number of significant figures. Many omitted, or used the incorrect, units.

(ii) This was reasonably well done, although some used data from the incorrect experiment. A number of students used one of the masses of the spirit burner rather than subtracting to find the mass of cineole burnt. Values were commonly rounded to three or four significant figures, as students did not appreciate that subtraction in this example led to a decrease in the number of significant figures. If a balance is accurate to the nearest 0.1 g it is unable to give a mass of 1.2 g accurate to three or four significant figures.

(iii) There were many errors here, including wrong mass, wrong temperature change, and omission of units and sign in the final answer. Although the value was given in the table, a large number of students chose to recalculate heat released using the experimental data in the table, sometimes correctly.

Question 8

(a) (i) Most students correctly identified CO as a primary pollutant.

(ii) Generally well done, although some students missed the link between more air (more oxygen) and more complete combustion.

(iii) Few students could identify an appropriate pollutant. The most common incorrect answers included hydrocarbons, NO, and various sulfur compounds.

(b) (i) Most students obtained some marks for this question and many obtained full marks. Good answers linked the energy to breaking the triple bond in nitrogen and subsequent formation of two oxides. Many students wrote about one oxide forming. Loss of marks was generally due to a failure to name, or to give the formulae of, specific oxides of nitrogen, referring only to NO_x. Non-existent oxides of nitrogen also appeared in many responses. Appropriate equations were often used to clarify responses.

(ii) Most graphs showed a positive slope and students gained the mark.

(iii) Few students were able to identify two relevant conditions, with sunlight or ultraviolet radiation being more commonly mentioned than the stationary air mass. Many students wrote vaguely about ‘light’ or ‘radiation’ being necessary and a number thought that heat was required. Many discussed the availability of gases such as NO, NO_2, or O_2. As mentioned in other comments, lack of precise use of chemical terms was evident.

(c) On a positive note, responses to this question included a number of good answers that were short and concise. On the other hand, weaker responses suggested students with weak knowledge of the enhanced greenhouse effect. Too many talked about light reflected by the Earth, ultraviolet radiation being absorbed by greenhouse gases, or clouds/atmosphere absorbing infrared energy from the sun, while a reasonable number included material on ozone depletion.
Some stronger students became embroiled in a lengthy discussion of absorption/re-radiation of energy (sometimes falling into error with terminology) and failed to adequately address the issue of human activities and link them with two specific greenhouse gases.
In describing human activities that could disrupt the thermal balance, students were often vague and used general terms such as ‘transportation’, ‘open burning’, or ‘farming’. Some activities were essentially the same, for example, driving cars, transport, and engines all rely on the burning of carbon-based fuels. The impact of deforestation was generally explained well.
Many students were unclear about which gases were greenhouse gases and mentioned a host of possibilities, including CO, NO, NO_2, SO_2, and even N_2.

Question 9

(a) This was not done as well as might have been expected, with ‘pentanal’ and ‘hexanol’ the most common errors. Most students recognised the 6-carbon chain and correctly deduced the stem *hexan*-, but few were able to complete the name successfully. Carboxylic acids, alkenes, and alcohols were not uncommon. Some students were penalised because their writing made it difficult for markers to determine whether the last two letters were *–al* or *–ol*. Students are not given the benefit of any doubt when writing is not legible.

(b) (i) This was generally well done with incorrect responses ranging from 1:2 to 1:56. Students with an incorrect ratio were given credit when they applied it correctly to part (iv) (1), which most were able to do.

(ii) Most students answered this well. Although the most common error was failure to convert the volume from mL to L, most clearly identified the volume conversion, performed it correctly, and multiplied by the correct molar mass. Some students incorrectly used NaOH.

Use of an incorrect formula was still evident, e.g. $n = c/V$.

The calculation was handled quite well and very few failed to show the appropriate units of mass.

(iii) This question was poorly done. Few students related their answers to the relative polarities of water and propan-2-ol. Many answered half the question by referring to water or propan-2-ol but not both, for example, mentioning formation of two layers with water but failing to mention the propan-2-ol. Frequently, propan-2-ol was stated to be *non-polar* rather than *less polar than water*. This was one example of poor use of chemical terminology, a problem throughout the examination.

(iv) (1) Most students were able to carry out the volume conversion and complete the first step. Those who had been successful in part (b) (ii) generally gave correct responses here. Some students were out by a factor of 10, giving answers such as 1.97 g. The correct use of units by most students was pleasing.

(2) Generally this was handled well by the better students. Many students were unsure of what to do with the 9.543 g, with failure to multiply by 100 being quite common.

(3) There was good correlation between answers to part (2) and part (3). Even when the answer for part (2) was incorrect, students were able to gain credit for correct use of the table to identify the appropriate grade of oil.

(4) A little over half of the responses correctly identified $C_{20}H_{12}O_4^{2-}$ as the coloured form. Many students failed to associate their answer with the information given with ‘purple’, ‘orange’, ‘red’, and ‘brown’ all being suggested.

Question 10

(a) (i) Overall this was not well done. Although students could correctly state the sequence of subshells, the assigning of electrons was poorly done. Incorrect notations with upper case D and subscripts for the subshells were rare. The most common errors included showing an incorrect number of electrons or having electrons in the 4s subshell, e.g. $3d^7\ 4s^2$ rather than $3d^9$.

(ii) Writing of this half-equation was not well done. Errors included incorrect balancing, showing the wrong number of electrons, having the electrons on the wrong side, and attempts to balance the O atoms with O_2 rather than H_2O. A few students recognised that the reaction occurs in alkaline conditions and wrote a correct half-equation for this. A few students wrote the half-equation $Cu^{2+} + e^- \rightarrow Cu^+$.

(b) (i) Although this was not well done a significant number were able to identify either Hg or Ag. As students are not required to learn specific metal oxides that can be reduced by hydrogen, this question required the use of the metal activity series provided in Booklet 1 to determine an answer.

(ii) This was not well done, with some suggesting that the reaction between copper oxide and hydrogen produced a blue-green gaseous product. Students are advised to spend time planning an answer to questions that require an explanation. Markers commented on poor expression and language skills which caused loss of marks. Terminology was poor with the terms ‘atom’ and ‘ion’ used interchangeably. Few students described the concept of the energy gain causing electrons to move to higher energy levels, followed by a return to a lower energy level accompanied by the emission of energy of a certain wavelength, so giving the unique colour of copper. Many answers treated the phenomenon as atomic absorption, with many stating that it was the absorption of the energy that gave rise to the colour. Many stated that the atoms were excited but made no reference to the electrons. Some also thought that only the valence shell electrons were excited.

(iii) (1) Most students calculated the number of moles successfully, although some were confused as to what mass to use. Many students had difficulty in calculating the correct mass of copper. Most students could find the molar mass of copper but some then failed to calculate the number of moles correctly.

(2) Students used a wide range of methods to determine the answer. It was pleasing to see a number of students who tackled an unfamiliar problem in innovative answers involving molar masses and mole ratios of Cu and copper oxides. Very few students used the data to determine the moles of Cu and O and then calculate the Cu:O mole ratio to determine the empirical formula.

(iv) This question, requiring students to analyse an unfamiliar practical procedure, was poorly done with few answers gaining full marks. Most students could correctly identify a source of systematic error, with an incorrectly calibrated balance commonly cited. However, this was usually followed by an incorrect explanation of its effect, although there were some exceptional explanations. Most students could not explain how their chosen systematic error would influence the data. Most students merely stated that the final calculation of the formula would be wrong or not accurate.

Question 11

(a) The majority of students who correctly chose flammability generally could describe how to minimise the hazard (usually something about flames). Many answers suggested that students did not recognise that boiling point and flammability are different properties. Rather than state how they would minimise the hazard, some described the safety equipment that should be present, e.g. fire blanket or extinguisher. Some believed that working in a fume cupboard would reduce the flammability hazard.

(b) This was poorly done, with many students failing to determine the valence shell electron arrangement prior to discussing the reason for the molecular shape. Students who explained why dimethyl sulfoxide (DMSO) was trigonal planar had failed to undertake this step and failed to read the question carefully. This was another question where poor terminology cost marks, e.g. reference to CH_3 molecules, and writing of ‘valence electrons repelling’ rather than referring to pairs of electrons. A few students drew a correct diagram, but these rarely gained full marks because the explanation was poor. The most common errors were:

- a lack of recognition of the non-bonding pair of electrons and hence the four electron regions
- writing about repulsion between atoms rather than valence shell electron pairs
- stating the valence shell electron pair repulsion (VSEPR) theory in general terms without relating the answer to the specific molecule.

(c) (i) This was generally well done although in some cases the functional group was missing or was incorrect (e.g. COO). Incorrect responses commonly had the correct carbon skeleton. A few students chose to draw a skeletal form, usually correctly.

(ii) This was poorly done, generating a wide range of marks. Again incorrect descriptions and terminology cost students marks, e.g. stating that ethyl ethanoate was non-polar or that DMSO could hydrogen bond to itself. Many responses could not relate boiling point to secondary interactions and expressed the belief that primary bonds were involved. A common error was use of the term ‘bonds’ without clarification of the nature of the bonds.

(d) (i) Although a small majority of students correctly stated that the cathode was positive, the high proportion of incorrect answers suggests that students did not recognise that, when discharging, the cell is functioning as a galvanic cell.

(ii) (1) Not well done. Relating the answer to the operation of the cell proved a challenge. Although many understood that the peroxide would coat the electrode, few could then suggest a consequence. There were many incorrect guesses made ranging from ‘it is toxic’ to ‘cell wouldn’t work’.

The question required students to apply their knowledge of electrochemical cells to a new situation; answers suggested that students did not understand the operation of electrochemical cells very well. Answers were often too general and vague.

(2) Although this was well done, a higher proportion of correct responses might have been expected, considering that students would be familiar with the rule for oxidation state of oxygen in peroxides. The most common wrong answers were –2 and +1.

Question 12

(a) (i) This was not done well. Responses included charges from +8 to –3, with +4 being quite common. It appeared that many students were unaware that in silicates the oxidation state of silicon is +4 whereas that of oxygen is –2. That some students assigned a positive charge to an anion was puzzling, suggesting that chemical definitions are not well known. Students who successfully answered this generally went on to answer part (ii) correctly.

(ii) Overall not well done although, strangely, students tended to answer this better than part (i). There were some attempts with incorrect notation, e.g. $Mg(SiO_4)Fe$. A few students wrote SO_4 rather than SiO_4.

(b) This was quite well done. The better responses recognised this as an equilibrium question and gave an appropriate equation for the cation exchange. Many students correctly identified the acidic conditions (i.e. pH < 7) although some wanted to call it ‘acid rain’, a term applied to rain with a pH < 5.6. The best answers mentioned the importance of the Mg being in a soluble form.

(c) Although most students made an attempt, this question proved difficult, generating a wide spread of marks. Many students quoted the question without providing supporting evidence. Although students could use ideas from the previous question, few did so. Some students, who had answered part (b) quite well, stated that olivine had basic properties which enabled it to neutralise acids. Some students demonstrated creativity, stating, for example, that Mg^{2+} would form MgO, which as a basic oxide would neutralise the acid. Others suggested that the formation of $MgCO_3$ would reduce the acidity. Some suggested that the silicate anion would undergo cation exchange with H^+ to reduce acidity.

Students found the second part of the question, the link to levels of CO_2 in the atmosphere, more difficult to answer. Many students believed acidification of the oceans to be due to acid rain rather than increased CO_2 concentration in the atmosphere.
Better responses generally gave an appropriate equation, commonly $CO_2 + H_2O \rightarrow H_2CO_3$, although there were many mistakes in equations, with HCO_3 common as the formula of carbonic acid.

Some students who received full marks referred to Mg^{2+} being good for plant health (from the previous question) and then created an argument based on improved plant health and a consequent increase in photosynthesis.
Full marks for literacy were rare as many students gave irrelevant information, possibly through searching for marks.

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