# CHEMISTRY

## Standard Level Paper 1

### Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-7 | 8-12 | 13-17 | 18-19 | 20-22 | 23-24 | 25-30 |

### General comments

This paper consisted of 30 questions on the Subject Specific Core (SSC) and was to be completed without a calculator or Data Booklet. Each question had four possible responses, with credit awarded for correct answers and no credit deducted for incorrect answers. The mean mark was slightly higher than last November.

Teachers' impressions of this paper were conveyed by the 22 G2 forms that were returned. In the comparison with last year's paper, the great majority of respondents felt it was of a similar standard, with slightly more considering it a little more difficult than those who thought it a little easier. Nearly all thought the level of difficulty was appropriate. Syllabus coverage was considered good by about a third and satisfactory by over a half. Clarity of wording was considered good by nearly a half and satisfactory by nearly a half. The presentation of the paper was considered good by over a half and satisfactory by nearly a half.

### Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 86% to 16% and the discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.60 to 0.08.

The following comments are made on individual questions.

5 A was a popular incorrect response, suggesting that some candidates had based their choice on the molar concentration and had ignored the volume.

8 D was the most common response, indicating a belief that melting points increase down the group for alkali metals.

9 C was a popular incorrect response. Perhaps some candidates were unable to distinguish between the reactivities of halogens and halide ions.

14 B was a popular incorrect response, indicating the common belief that a change of state for the halogens involves the breaking of covalent bonds.

19 Response A attracted a large number of candidates, indicating a confusion between volume of gas collected and rate of reaction.

22 Nearly half of the candidates correctly answered this question, which demanded considerable knowledge of the reactions of acids.

 

24 This was the most difficult question on the paper, with most candidates choosing responses A or D, reflecting the popular belief that equal amounts of strong and weak acids require different amounts of alkali for neutralization.

30 B was the most common response, suggesting unfamiliarity with the addition of bromine to ethene.

# Standard Level Paper 2

## Component grade boundaries

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **Mark range**: | 0-6 | 7-12 | 13-16 | 17-20 | 21-25 | 26-29 | 30-40 |

## General comments

The mean mark on this paper was a little higher than last November. All but the weakest candidates attempted most parts of most questions, and almost none infringed the rubric by answering more than one question in Section B. More detailed comments are given in the sections below.

Teachers' impressions of this paper were conveyed by the 22 G2 forms that were returned. In comparison with last year's paper, more than half thought it a little easier, with the remainder considering it to be of a similar standard. All thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by over two-thirds and good by nearly a quarter. Clarity of wording was considered satisfactory by a half and good by nearly the same number. The presentation of the paper was considered satisfactory by nearly a half and good by the remainder.

## Difficulties for candidates

The main areas in which candidates scored poorly included bond enthalpy calculations, oxidation numbers, explanations using Le Chatelier's Principle and the influence of molecular shape on boiling point.

## Levels of knowledge, understanding and skill demonstrated

The following areas were relatively well done: the Brønsted-Lowry theory, shapes of molecules and ions.

## Strengths and weaknesses in individual questions

### Section A

**QUESTION 1**

Most candidates received some credit in (a), although there were relatively few completely correct answers. Some omitted the unit and others the sign, but the commonest error was the incorrect counting of the bonds being broken or formed. Many candidates were not helped by the poor organization of their answers, and typical responses started with a statement such as "H = products – reactants" followed by a jumble of numbers. Many candidates scored by consequential marking in (b), although a number attempted a new calculation instead of using their answer in (a).

**QUESTION 2**

The better candidates had no difficulty with the calculations in (a) and (b), but others obtained answers that were sometimes correct but with working that was hard to follow. Again in (c) the better candidates correctly drew the alkanoic acid and ester structures, with quite a number receiving credit for $CH_2OHCHO$ and other theoretically possible structures. However, a substantial number drew structures that did not match their molecular formula or structures with incorrect valencies for carbon and oxygen. Part (d) was usually low-scoring because so many candidates gave chemical, rather than physical, tests.

**QUESTION 3**

Oxidation numbers were determined correctly in (a) by a minority of candidates, with several cases of missing or incorrect signs. The answer expected in (b) was $Cu^{2+}$, but many candidates wrote Cu or $CuSO_4$. This could have been carelessness or a lack of understanding of the distinction between atoms and ions when describing redox behaviour. Most candidates correctly positioned titanium in the activity series but few referred to reducing ability in their explanations and used the terms reactivity or displacement instead.

## Section B

**QUESTION 4**

This was the most popular question on the paper, and some high scores were achieved by the best candidates. Part (a)(i) was well answered, although weaker candidates had difficulty with the term *conjugate* in (ii) – even those who chose a correct example often could not express the idea in words. There were some lengthy answers to (iii), for which "both" would have earned the mark, with a great variety of incorrect equations, while (iv) was rarely correct. The better candidates had no difficulty in achieving full marks in (b), although a common wrong answer was to compare the amounts of alkali needed to neutralize the two acids. In (c) the order of the bases was often correct, but in spite of the term "Estimate" in the question, a number of candidates attempted a calculation based on $K_c$.

**QUESTION 5**

High scores were rare for this question. In (a)(i) few equations were correct, with many suggesting the formation of hydrogen and oxygen gases. Although in (ii) many candidates correctly identified the reaction as being endothermic, few could relate this to the breaking of bonds. In (iii) some candidates referred by name to Le Chatelier's Principle as though it was sufficient as an explanation. Part (b) proved challenging for many candidates. In (i) the term *homogeneous* was not often known, in (ii) many suggestions were not observable evidence ("the forward and reaction rates are equal"), while in (iv) and (v) there was some confusion between rate of reaction and position of equilibrium. Many of those who correctly stated that the pressure increase would cause no change in the position of equilibrium, failed to refer to **gases** when stating that the numbers of moles were equal. Very few correct answers were seen to (c), as many candidates thought this question to be a calculation involving $K_c$ rather than stoichiometry.

 

**QUESTION 6**

Some lengthy answers were seen in (a), and although most candidates scored some marks, their answers often contained glaring errors. Neon atoms were often described as having metallic or covalent bonding, while the idea of electrostatic attraction was often missing from the bonding in sodium chloride. Part (b) was reasonably well done, with shapes and bond angles well known, although the Lewis structures often lacked relevant charges and the lone pair of electrons on P was sometimes missing. Part (c) was sometimes left unanswered, and the minority of candidates who had the isomers in the correct order rarely gave a correct explanation.

## Assistance and guidance for future candidates

In addition to the usual advice such as reading the question carefully, noting the mark allocations and considering the meaning of the action verbs, the following points are made:

- Practice setting out calculations clearly, with a few words quoted or a formula given, followed by the use of values from the question or Data Booklet
- Check that organic structures show atoms with the correct number of bonds
- Distinguish between key words such as **physical** and **chemical**
- Avoid contradictions within an answer, such as descriptions of ionic bonding as the attraction between oppositely charged molecules

# Standard Level Paper 3

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-7 | 8-15 | 16-19 | 20-24 | 25-28 | 29-33 | 34-45 |

## General comments

The mean mark on this paper was significantly lower than in November 2000. All but the weakest candidates attempted most parts of most questions, and almost none infringed the rubric by answering questions from more than three Options. More detailed comments are given in the sections below.

Teachers' impressions of this paper are conveyed by the 22 G2 forms that were returned. In comparison with last year's paper, three-quarters thought it of a similar standard, with more of the remainder considering it more difficult than easier. The vast majority thought the level of difficulty to be appropriate, with a small minority considering it too difficult. Syllabus coverage was considered satisfactory by three-quarters. Clarity of wording was considered satisfactory by over a half and good by most of the rest. The presentation of the paper was considered satisfactory by a half and good by a half.

## Difficulties for candidates

It is not easy to generalize on the difficulties found, although candidates that chose Option A tended to do poorly, and showed little understanding of reaction mechanisms and the correct way to write them. Also, very few candidates were able to correctly draw the structural formulas of biochemicals in Option C. Many were also unable to correctly state the units after they had completed a calculation

## Levels of knowledge, understanding and skill demonstrated

Many candidates who attempted Option B attained some excellent scores, and showed they had a thorough understanding of thermodynamics and kinetics. Also, candidates were generally able to calculate the enthalpy of combustion of a peanut. Those who answered Option E also displayed good understanding of the extraction of iron.

## Strengths and weaknesses in individual questions

### Option A – Higher organic chemistry

#### QUESTION A1

Performance in this question was quite erratic and only a small minority were able to attain full marks. Very few were able to correctly state the shapes of all the molecules, and many candidates lost marks for using imprecise terminology, eg stating "pyramidal" instead of "trigonal pyramidal".

#### QUESTION A2

This question was quite poorly done and many candidates were unable to correctly identify the reaction mechanisms – $S_N1$ and $S_N2$. Those that did identify them frequently lost marks for the mechanisms they wrote, as they were too imprecise. Candidates missed out curly arrows or did not clearly show their point of origin or destination.

### Option B – Higher physical chemistry

#### QUESTION B1

The understanding of entropy was generally good although weaker candidates did confuse it with enthalpy. The use of the Gibbs free energy equation was good although the most common error was to not convert the entropy value to kilojoules. Disappointingly few candidates realized that even spontaneous reactions need to be heated to overcome the activation energy.

#### QUESTION B2

The calculation of order of reaction was well done, and in (a) the only real problem for the majority of the candidates was the calculation of the rate constant. In (b) a number of candidates could not identify the slow step, and for most of those that managed it, the explanation was too difficult.

### Option C – Human biochemistry

#### QUESTION C1

The calculation of the heat gained by the water and the enthalpy of combustion of the peanut oil was generally well done, although a common error was using the incorrect mass of substance heated. Unfortunately, relatively few candidates were able to correctly draw the structure of the oil in (c). In (d) and (e) some good answers were found, such as incomplete combustion of the peanut, heat loss and a corresponding improvement such as burning in oxygen and insulating the apparatus. However a number of candidates made rather trivial suggestions about measuring the values wrongly and repeating the experiment to improve it.

### QUESTION C2

Most candidates could correctly state the empirical formula of a monosaccharide, but surprisingly few were able to state that it also contained a carbonyl group and at least two hydroxyl groups. The structural formula of glucose was often not known and many candidates incorrectly orientated the hydroxyl groups, perhaps not realizing that the orientation is important. Also, some candidates drew the ring structure even though the question clearly asked for the straight chain formula. The calculation in (c) was well done by all but the very weakest candidates. However, (d) proved very challenging and few could correctly explain why oils could be oxidized to a far greater extent than glucose.

## Option D – Environmental chemistry

### QUESTION D1

In this question about global warming, candidates displayed a good general understanding of the causes of and the problems created by the greenhouse effect. Unfortunately though, many showed their knowledge to be of a rather trivial nature. Very few candidates were able to explain how carbon dioxide contributes to global warming in terms of the wavelength of radiation that it absorbs. Many answers lacked scientific detail and used journalistic language such as "the heat from the Earth bounces back off the carbon dioxide in the air". Also, a number of candidates believed that particulates warm up the Earth by trapping heat, rather than cooling it by reflecting light into space, while others confused the greenhouse effect with damage to the ozone layer.

### QUESTION D2

This question was generally less well done than D1 although there were some excellent responses. Many candidates were unable to state the metal used as the catalyst, or how nitrogen monoxide reacts in the catalytic converter. Part (c) asked for the primary pollutant that causes acid rain. The expected response was sulfur dioxide, although many candidates did not seem to understand the meaning of the term *primary pollutant*, and suggested sulfur trioxide or carbon dioxide. Surprisingly few candidates were able to write a balanced equation for the reaction between nitric acid and limestone.

## Option E – Chemical industries

### QUESTION E1

This was not a popular Option and candidate performance on it was very mixed, so it is difficult to generalize. There were a few excellent responses, although many candidates showed little knowledge in this area.

### QUESTION E2

The making of steel produced a mixture of attainment from excellent to poor, as candidates either knew the process or had little idea about it.

 

### Option F – Fuels and energy

#### QUESTION F1

In this question candidates were expected to write a number of equations and many had difficulty with this, including the first rather straightforward equation, for the cracking of a hydrocarbon. Surprisingly few candidates were aware that the other product of the cracking was an alkene, which could be used as a monomer in the plastics industry. In the other equations candidates frequently made errors in balancing. The calculations were generally carried out well, although lack of units or incorrect units was a problem for some.

#### QUESTION F2

This question was somewhat less well done, although candidates could usually give at least one reason for converting coal to a gaseous or liquid fuel. However, the manufacture of coke was generally not well known and few candidates correctly stated how coke was obtained by heating in the absence of air, or how coke was converted to gas by high temperature and steam. The last part was correctly answered by only a handful of candidates.

## Assistance and guidance for future candidates

- Answers need to be far more precise, eg structural formulas and mechanisms do not score marks unless the bonding and curly arrows are correct.
- Candidates should learn definitions and use correct scientific language, avoiding trivial or journalistic explanations.
- Candidates need more practice writing and balancing equations.
- Candidates should always state the units after a calculation and check that they are consistent with the information they have been given.

# Higher Level Paper 1

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-10 | 11-15 | 16-20 | 21-24 | 25-29 | 30-33 | 34-39 |

## General comments

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) material and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and no credit deducted for incorrect answers. The mean mark was almost identical to that of last November.

Teachers' impressions of this paper were conveyed by the 19 G2 forms that were returned. In comparison with last year's paper, the vast majority felt that it was of a similar standard, with small but equal numbers suggesting that it was a little easier or a little more difficult. Most respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by nearly two-thirds and good by a third. Clarity of wording was thought satisfactory by over a half and good by over a third, while the presentation of the paper was considered satisfactory by over a third and good by nearly two-thirds.

## Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 95% to 34% and the discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.65 to 0.07.

The following comments are made on individual questions.

6 B was a popular choice. Perhaps candidates matched the total number of electrons with the atomic number in the Periodic Table without considering that $Co^{2+}$ would also have 25 electrons.

10 D attracted many candidates; perhaps there was confusion between $SO_3^{2-}$ and $SO_3$.

28 Most candidates chose B, presumably just using the given pH value and ignoring the molar concentration. This question had the highest discrimination index.

29 Response B attracted nearly as many candidates as the correct response.

30 Almost as many candidates chose C as chose B – the belief that a weak acid needs less alkali than an equal amount of a strong acid for neutralization.

30 Surprisingly, nearly as many candidates chose A as chose D.

38 Response B was a popular choice – presumably these candidates ignored either the OH group or the TMS label on the spectrum.

# Higher Level Paper 2

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-14 | 15-28 | 29-36 | 37-46 | 47-55 | 56-65 | 66-90 |

## General comments

The mean mark on this paper was considerably higher than last November. All but the weakest candidates attempted most parts of most questions. More detailed comments are given in the sections below.

Teachers' impressions of this paper were conveyed by the 19 G2 forms that were returned. In comparison with last year's paper, about three-quarters thought it to be of a similar standard, with the remainder equally divided between those who thought it a little more difficult and much more difficult. The vast majority thought the level of difficulty appropriate, but with a significant number considering it too difficult. Syllabus coverage was considered satisfactory by over half and good by over a quarter. Clarity of wording was considered satisfactory by nearly two-thirds and good by nearly a quarter. The presentation of the paper was considered satisfactory by over half and good by the remainder.

## Difficulties for candidates

The main areas in which candidates scored poorly, or which were attempted only briefly, included the energy changes associated with physical changes such as evaporation, equilibrium and vapour pressures, detailed explanations of comparisons of ionisation energies, delocalisation and the significance of conjugated double bonds, the appearance of the hydrogen emission spectrum, and the difference between rate of reaction and position of equilibrium in reversible reactions.

## Levels of knowledge, understanding and skill demonstrated

Interpretation of data was very well done and calculations, on the whole, were well set out and correctly done. The determination of empirical and molecular formulas was very good. The application of the valence shell electron pair repulsion (VSEPR) theory and the writing of correct structures for organic compounds were well attempted. Candidates expressed themselves clearly using a range of techniques such as sketch diagrams and graphs to illustrate their answers.

## Strengths and weaknesses in individual questions

### Section A

**QUESTION 1**

In (a) most candidates were able to correctly give the relative molecular mass of pentan-1-ol and to determine the enthalpy of combustion from the graph, but the explanation of why the isomeric alkanol would have about the same value of $\Delta H_c{}^\circ$ was not good. The idea of activation energy was generally well understood in (b). Many good attempts were seen in (c) in the calculation of enthalpy changes, although the use of 10 or 100 g, rather than 110 g, in $\mathrm{Q} = \mathrm{ms}\Delta T$ was common. The conversion to molar enthalpy change in (c)(ii) was less well done, but full marks were common in (c)(iii) for heat loss to the surroundings and the improvements in insulation.

**QUESTION 2**

This carefully structured question on formula calculation produced fewer completely correct answers than expected, although it was generally well done. However, the calculations were often very untidily set out. One common problem was working to too few significant figures in intermediate answers, giving a variety of ratios close to the correct one for the empirical formula. The use of the fraction $\frac{1}{18}$ rather than $\frac{2}{18}$ in calculating the mass of hydrogen caused some to lose marks, and in (b) others overlooked the fact that oxygen was also present.

**QUESTION 3**

In (a) the expression pV = nRT was quite well known, as was its use with $n = \frac{m}{M_r}$, and most candidates identified the correct variables. However, the meaning of the term R was often missing from answers. The better candidates were able to score well in (b), about evaporation causing cooling. Very few candidates recognized that all three vapour pressures would be the same in (c) and so found it difficult to score any marks at all. Many candidates attempted to apply Boyle's Law to the problem and thought that the first two containers would have the same pressure whereas the pressure of the third would be double.

**QUESTION 4**

This question was generally not well done. Although many equations in (a) contained state symbols as asked for, some appeared at the wrong electrodes, and the equation in (c) was less well known. Parts (b) and (d) were often incorrectly done, and the equations and the processes occurring were given correctly by only the most able candidates. Many scored the first mark in the calculation of charge in (e) given the current and time, but the need to take into account the 2:1 ratio was less well known. It was interesting to see a few candidates carry out the calculation correctly without using the Faraday constant; their calculations involved the charge on the electron and Avogadro's constant.

## Section B

**QUESTION 5**

This was a popular question with most candidates able to correctly calculate the relative atomic mass of sulfur given the naturally occurring percentages of the isotopes in (a), and to determine the number of neutrons in sulfur-36. A few lost a mark for not quoting the relative atomic mass to three significant figures as requested.

In (b), although most candidates knew that successive ionization energies increase for aluminium, few recognized the greater increase for the 4th ionization energy. It was a pity that some candidates did not follow the advice given to sketch a graph for the first four ionization energies of aluminium. Some of those who did showed a decrease from the second to the third energies, apparently confusing the graph with that showing the change of ionization energy across a period. The electronic configurations of Al, B and Mg were given correctly by the great majority of candidates. Explanations for the differences were generally good, although the explanations were sometimes confused and some candidates wrote about successive ionization energies here as well.

In (c), some excellent sketches of the hydrogen emission spectrum were produced with some very complete explanations. However, some candidates did not draw a diagram of the spectrum sufficiently well (for example by showing only one line, or not showing the convergence of the lines) to score full marks.

High scores in (d) were rare. Although most candidates referred to melting points, they tended to describe or explain the trend down the group without stating that the values were low, and few mentioned ionization energies other than the first one. Even though the question asked for a description, few candidates gave observations that could have been made and as a result there was a lack of detail about the reactions with water and chlorine. It was especially disappointing to see many unbalanced equations.

**QUESTION 6**

This was another popular question. In (a), Lewis structures were generally well done although it was common for the non-bonding electrons to be omitted. Electron pair repulsion theory was intelligently applied, but it was common to describe the $NF_3$ structure as tetrahedral. Although the explanation of hybridization was less well done (and was sometimes confused with sigma and pi bond formation), students were able to correctly state the type of hybridization in $BF_3$ and $NF_3$.

Candidates demonstrated an understanding of bond and molecular polarity but the explanations were often not precise enough and reference to the term electronegativity was often omitted. Sigma and pi bonds were not always clearly explained through lack of the appropriate language to describe the two methods of overlapping of atomic orbitals; however some answers were given using excellent diagrams. Attempts to explain delocalization were generally not successful. The final part of this question on the addition reactions of the three alkenes was poorly answered, displaying a lack of understanding of the concepts involved. Very few correct enthalpy diagrams were drawn, and the connection between delocalization and stability was rarely made.

**QUESTION 7**

This was not a popular question. Part (a) on the conditions and the starting materials for the preparation of methyl methanoate was successfully tackled by many candidates and some high scores were achieved. However, some answers about the differences between the ester and the acid were, on the whole, incomplete. Part (b) on condensation was less well answered, and the distinction between condensation and addition polymerization was rarely clearly expressed. There were many failed attempts at writing the equation for the reaction leading to the formation of terylene.

In (c) the structures of 2-chloropropanoic acid and 2-hydroxypropanoic acid were well drawn and the nucleophile needed for the conversion was identified by a number of candidates. Many definitions of nucleophile lacked mention of the lone electron pair. The concept of chirality was well understood and although some candidates correctly gave the $S_N1$ mechanism, almost none managed to include the reference to the planar carbocation.

**QUESTION 8**

Although part (a) on writing the equilibrium expression was generally well done, some candidates included [C(s)] in the $K_c$ expression. The identification of the reaction as endothermic was gratifyingly common.

Part (b) proved a challenge to many candidates, with very few scoring high marks. The commonest problem was the confusion between rate of reaction and position of equilibrium, with some candidates stating that the increase in pressure would decrease the rate of the forward reaction. Many referred to Le Chatelier's Principle, rather than collision theory, when explaining the effect of temperature on rate. In (b)(ii), although some argued correctly about the shift in equilibrium position, few went on to actually answer the question that was asked, about the $[H_2O]$:$[H_2]$ ratio. Candidates must recognize that a statement such as “due to Le Chatelier's Principle” is not the same as providing the explanation asked for in the question. In (iii), some candidates indicated that the value of the equilibrium constant would change when the pressure was changed.

Part (c) was very well attempted; the main cause of lost marks was in not showing clearly the activation energy on the diagram. A few candidates labelled this as a horizontal level rather than as a vertical distance.

 

## Assistance and guidance for future candidates

- Careful practice in tackling empirical formula calculations, with particular regard to the use of significant figures; the method used and the steps involved in arriving at the answer must be shown clearly
- A full explanation of changes of state, in terms of energy changes and the overcoming of intermolecular forces
- The distinction between first and successive ionization energies and the significance of both
- Practice in writing balanced chemical equations
- Practice in writing organic reactions
- Poor time management was a problem for some candidates – some wrote 4 to 6 pages to answer the first question in Section B, and then ran out of time for the next one
- A compare-and-contrast treatment of the effect of factors such as temperature on reaction rate and equilibrium position; the candidates' understanding of the effects on rates of reaction and the position of equilibrium needs to be stressed.

# Higher Level Paper 3

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-6 | 7-13 | 14-20 | 21-25 | 26-31 | 32-36 | 37-50 |

## General comments

The mean mark on this paper was very similar to that of last November. All but the weakest candidates attempted most parts of most questions, and almost none infringed the rubric by answering questions from more than two Options. More detailed comments are given in the sections below.

Teachers' impressions of this paper were conveyed by the 19 G2 forms that were returned. In comparison with last year's paper, three-quarters thought it of a similar standard, with the remainder considering it more difficult. Over three-quarters thought the level of difficulty to be appropriate, with more of the remainder considering it too difficult than considering it too easy. Syllabus coverage was considered satisfactory by nearly two-thirds and good by nearly a quarter. Clarity of wording was considered satisfactory by nearly a half and good by a third. The presentation of the paper was considered satisfactory by nearly a half and good by the remainder.

Candidates were required to answer all of the questions from any two of the six Options. No candidate answered more than the required number of questions and the vast majority indicated clearly on the cover sheet which two Options had been attempted. Usually all of the candidates from one school answered the same two Options reflecting the two they had been taught. However candidates from some schools answered a range of combinations of Options. This session proved no exception to the general observation that candidates from schools where all the candidates answer the same two Options tend to score higher marks than those where there is a range of Options covered.

Within the total entry all possible combinations of the two Options were covered with each Option being answered by a sizeable number of candidates. The answers to each Option showed a good spread of marks and no one Option appeared significantly harder or easier to score marks on than the others. All candidates appeared to have finished the paper in the time allocated. The overall performance on the paper showed a very good spread of marks and differentiated well between candidates.

## Difficulties for candidates

Some candidates appeared to have difficulty with questions that required longer responses, such as D3, E3 and F3. In many cases they were unable to structure their answers in such a way as to cover all the material required, and there was a tendency to include irrelevant information. Some candidates are still unable to use curly arrows correctly when describing organic mechanisms and many are unable to draw the structures of two enantiomers of the same compound to show clearly that they are mirror images of each other. Descriptions of experiments were also generally inadequate. In particular, very few candidates were able to describe how to determine the concentration of a coloured solution using a visible spectrometer.

## Levels of knowledge, understanding and skill demonstrated

Those aspects of chemistry that were generally well known and understood included the formation and structure of proteins, the action of enzymes, air pollution, the Haber process and the fractional distillation of crude oil. The use of IR and $^{1}H$ NMR spectroscopy and the ability to write nuclear equations was also generally well understood.

## Strengths and weaknesses in individual questions

### Option C – Human biochemistry

This was among the most popular choice of Options. Most candidates answered C1 (a) and (b) on fats satisfactorily but were less precise with their answer to (c). Many candidates stated that saturated fats contain no double bonds. This is not true - it is important to state that they contain no C=C double bonds. This question then asked them to explain how the degree of unsaturation could be determined experimentally. Very few stated that iodine adds across the double bond with a 1:1 stoichiometry or mentioned that a fixed amount of the fat (usually 100 g) needs to be taken. The amine group in C2 (a) was usually identified correctly, but many candidates were unable to show clearly the structure of the amide or peptide linkage in (b). In C2 (c) some candidates omitted to state that the protein must first be hydrolyzed with hydrochloric acid before the separate amino acids can be identified by chromatography or electrophoresis. The structure and bonding in proteins for (d) and (e) were generally well known. Candidates were able to explain the action of enzymes and the effects of both competitive and non-competitive inhibitors well in (a) but were less clear about how $V_{max}$ and $K_m$ would be affected in (b).

### Option D – Environmental chemistry

This was also a popular Option and it was refreshing to read many correctly balanced equations for the reactions involving catalytic converters, alkaline scrubbing and the formation of acid rain. There were however some common mistakes with some candidates giving carbon and nitrogen dioxide as the product of catalytic conversion. D2 (a) asked what the letters PCB stand for. This is clearly mentioned on the syllabus but it was obviously something that many teachers had not taught. Candidates' imagination was given free rein and there were some very creative guesses ranging from "poisonous chemical biodegradables" and "pathological chemical bacteria" to "products from coal burning" and "pest controlling bases". Part (b) was often well attempted, but the meaning of maximum daily tolerance value was less precisely expressed than $LD_{50}$. Many candidates suggested the lack of serious health problems or even "without causing death" rather than no discernible effect. In (c) the symptoms of mercury poisoning were generally better known than the source or explanation. D3, which was concerned with fresh water, produced a very wide range of answers. Some candidates failed to mention the polar nature of water and its ability to hydrogen bond. A surprising number did not know that only a very small percentage of the water in the world is fresh water and of this, most is unavailable as it is locked up in glaciers. Reverse osmosis was generally known quite well but ion exchange was less well explained. Several candidates talked about replacing the hard ions in seawater with $Na^+$ and $Cl^-$ ions to make it soft.

## Option E – Chemical industries

Most candidates knew the sources of nitrogen and hydrogen used in the Haber process. In (b) most realised that high pressure is used to move the position of equilibrium to the right (to give more ammonia) but did not realise that there is also a kinetic effect. Increasing the pressure will have the effect of increasing the concentration of the reactants so that they will react more quickly. Some candidates stated that increasing the pressure will decrease the volume but this is not true as the reactor vessel will remain the same size. Most made a reasonable attempt to explain the free radical mechanism for the production of low density polythene in E2, although some then went on to write the termination equation in (b). Part (e) caused the most problems. This was very much testing objective 3. Students know that -COOH and $-NH_2$ groups react together to form the polyamide linkage -CO-NH-. However they were asked to state the groups required to form polyurethanes with the -O-CO-NH- linkage. Very few realised that the groups needed would be O-COOH and $-NH_2$ (or -OH and HO-CO-NH-). Question E3 on thermal and catalytic cracking elicited some very varied responses, with some very complete answers and some very poor attempts.

## Option F – Fuels and energy

Some candidates failed to read question F1 properly and gave nickel and cadmium as the electrodes for the Leclanche cell. Most gave the correct answer but were less successful when it came to writing equations for the reactions taking place at the two electrodes. The rest of F1 was generally answered well, although some candidates could not explain why increasing the surface area of the electrodes has no effect on the voltage in (d). The nuclear equation in F2 was usually written correctly and many were also able to answer correctly the two calculations on nuclear energy and half-life in (a)(ii) and (b), although some had problems with powers of ten. The fractional distillation of oil was usually described well for F3, although many candidates lost marks because they did not state that each fraction contains a range of compounds, nor did they state clearly the number of carbon atoms per molecule in their three chosen fractions. Surprisingly, quite a few candidates were unable to write a correct equation for the cracking of $C_{12}H_{26}$ in (b).

## Option G – Modern analytical chemistry

Candidates who chose to answer the questions on this Option tended to either do very well or very badly. The better candidates were able to interpret the three spectra (mass spectrum, IR spectrum and $^1H$ NMR spectrum) in G1 well. However even the good candidates tended to do less well on G2 (b). Having explained why transition metals are coloured in (a) they seemed unable to describe how to use a visible spectrometer. Common omissions were to not dilute the standard solution to make up a series of more dilute solutions with known concentrations and not mentioning that a calibration curve needs to be plotted.

## Option H – Further organic chemistry

This was another popular Option and produced some good responses. Most candidates correctly gave the equation for the reaction of benzene with bromine in H1 (a), and also stated that a halogen carrier was needed, but omitted to state that heat is also required in (b). Many candidates identified $Br^+$ correctly as the electrophile and it was pleasing to see that many could show its origin and give the correct mechanism for electrophilic substitution in (d). The reaction of phenol with bromine was less well known. Several stated that phenol is more reactive than benzene but very few could correctly state why and also give 2,4,6-tribromophenol as the major product. Candidates gave imprecise answers to explain why but-2-ene can exist as geometric isomers whereas but-1-ene cannot. The most common mistake was to omit the fact that the pi bond cannot rotate. Candidates also need to be given practice in correctly drawing two enantiomers to show that they are mirror images. Those who did identify the isomers as enantiomers in H2 (b) usually then went on to state correctly the difference in their chemical properties and to identify the chiral (or asymmetric) carbon atom. The explanation for Markovnikov addition in H3 was done well by the better candidates, although some still experience difficulties with the correct use of curly arrows.

## Assistance and guidance for future candidates

1. It was evident, as it has been in previous years, that when all candidates from a school answered the same two Options they performed better. Teachers can help their students by preparing them thoroughly for two Options. It is better to teach the minimum number of Options well than to teach them all less comprehensively. Students should be told that if they answer questions on Options they have not been taught they are unlikely to perform well.

2. Teachers owe it to their students to ensure that the syllabus is thoroughly covered and it may be helpful to provide students with copies of the relevant Options. The fact that many candidates did not know what PCB stands for in the Option on Environmental chemistry is surprising.

3. Some candidates need more practice in tackling the longer, more discursive questions. It is important that candidates learn to read the questions carefully, particularly the action verbs, and address the questions actually asked. Descriptions of practical work and processes need more detail. Candidates should be encouraged to use diagrams where appropriate.

4. Particular areas of the programme where more attention needs to be given are:
   - use of curly arrows in organic mechanisms
   - drawing of enantiomers to show mirror images
   - details of conversion processes in oil refining
   - quantitative measurement of the degree of unsaturation of fats
   - writing the correct redox half-equations for cells

# Internal Assessment

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-4 | 5-7 | 8-10 | 11-13 | 14-15 | 16-18 | 19-24 |

 

## The range and suitability of the work submitted

A broad range of practical investigations were submitted and most schools had interesting practical schemes of work for both the HL and the SL programmes. The majority of the schools covered all the areas of the syllabus with suitable experiments. Most of the practical work undertaken was of a suitable level for the IB programme. There were only a very small number of schools whose practical schemes of work was a long way short of the recommended number of hours. The Options in both SL and HL were better done compared to last year with some excellent practicals that were included for moderation. It is clear that teachers are becoming more familiar with the criteria and are applying them more consistently and effectively. Most schools submitted evidence for participation in the Group 4 Project for each of the candidates in the sample, but some did not and a special request had to be made for the submission of such evidence.

## Candidate performance against each criterion

### Planning (a)

Candidates continue to have some trouble with Planning (a), and it was poorly done in some cases. Many clearly stated a focused research question and stated a hypothesis, but did not explain their reasons for it. Others listed a hypothesis whose explanation was very superficial. This clearly needs to be built more firmly into the structure of the investigation write-up. In many cases variables were not mentioned or inferred in Planning (b) rather than specifically identified. Note that not all investigations are susceptible to a hypothesis and such practicals are not appropriate for Planning (a).

### Planning (b)

On the whole this was well done and students selected suitable equipment and devised appropriate strategies for carrying out their investigations. However, sometimes the control of variables was not always explicitly identified. Students sometimes took too large amounts of materials when the same investigation could have been carried out on the micro scale. The problem of teachers supplying students with the procedure or too much information was still present, although not to the same extent as last year. It is important to understand that Planning (b) **cannot** be assessed if students have been provided with the procedure.

### Data Collection

This criterion was carried out well generally and almost all investigations were suitable for the collection of data. Overall, students demonstrated good skills in observing and recording raw data. However, candidates still miss the opportunity to record qualitative data when it is clearly present in those investigations (for example the colour of the indicator at the end point). Similarly, uncertainties are most often left out. Note that the second aspect of the criterion, organising and presenting raw data, **cannot** be assessed if data tables have been provided by the teacher. Also, some candidates do not seem to present raw data, but rather data that has been recopied after the investigation has been carried out. The two aspects of data collection specifically refer to recording and presentation of (appropriate) raw data.

### Data Analysis

Students were generally able to perform satisfactorily on this criterion and most investigations were suitable for Data Analysis. However, many candidates missed the opportunity to take uncertainties into account and carry out error analysis even when this was clearly possible. Some candidates, however, were unable to decide when to draw a straight line, when to draw a curve and when to join points.

### Evaluation

This is still an area where candidates score poorly as they do not follow the requirements of the three aspects of the criterion. For example, it is still not common for students to compare their results to literature values where appropriate. This criterion also requires valid a conclusion with an explanation that is based on the correct interpretation of the results – this is often missing. Similarly, marks are still lost through students failing to evaluate the procedure, listing possible sources of error and suggestions to improve the investigation following the identification of weakness(es).

## Recommendations for the teaching of future candidates

There is no doubt that some great work of extremely high standard is being produced. Generally these teachers have given their students meaningful feedback on the investigations leading to much improvement. However, this did not always happen and it seems the criteria are not always clear to the students. A small number of students made reference to ethics, safety and environmental issues and that is always pleasing to see. Overall, there were improvements compared to last year – this can only be a positive aspect of IB Chemistry that needs to be continually monitored and reinforced.

The following recommendations are made for the teaching of future candidates:

- Students may find sub-headings for each criterion useful (e.g., for Planning (a), this might include: Problem/Research Question, Hypothesis/Prediction and Explanation and Variables).
- Full portfolios are no longer required and should not be submitted unless specifically asked for.
- Evidence for participation in the Group 4 Project by **each** candidate in the sample should be submitted with the sample for moderation.
- Teachers must not provide too much information for the Planning (a), Planning (b) and Data Collection criteria.
- Candidates need practice at proposing an hypothesis that is directly related to the research question and that is explained.
- Candidates must record qualitative as well as quantitative **raw** data where appropriate, including units and uncertainties where necessary.
- Teachers must provide all written as well as any verbal instructions for investigations in the moderation sample.
- Candidates should compare their results to literature values where appropriate.
- When assessing the Evaluation criterion, require students to evaluate the procedure, list possible sources of errors, and provide suggestions to improve the investigation following the identification of weakness(es).
- Teachers are **strongly** urged to use the c, p, n notation in the assessment of the investigations and in giving feedback to the candidates (note that not all investigations need be assessed).
- Do not assess for a particular criterion if an investigation clearly does not meet all aspects of the chosen criterion.

 