CHEMISTRY

Overall grade boundaries

Higher Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-31	32-43	44-54	55-65	66-76	77-100

Standard Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-33	34-47	48-58	59-67	68-78	79-100

Standard Level

Paper 1

Component Grade Boundaries:

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-12	13-18	19-21	22-23	24-26	27-30

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, with many more candidates scoring high marks.

Teachers' impressions of this paper were conveyed by the 29 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 easier than those who thought it a little more difficult. Nearly all thought the level of difficulty was appropriate. Syllabus coverage was considered good by nearly a half and satisfactory by over a half. Clarity of wording was considered good by over a half and satisfactory by over a third. 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 87% to 29% and the discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.61 to 0.19.

The following comments are made on individual questions.

Question 1

Although this first question required some mental arithmetic from the candidates nearly three-quarters got it right.

Question 5

This was the question with the lowest difficulty index, with D being the most common response. The problem did not seem to be with the straightforward mental arithmetic but rather with the use of an incorrect mole ratio.

Question 6

This was the question with the highest difficulty index.

Question 11

This question discriminated well. A substantial number of candidates chose response A, presumably through not reading or not understanding the significance of the term *intermolecular*.

Question 13

Response D attracted a substantial number of candidates, although more than half got the question right, indicating a knowledge of the very high strength of hydrogen bonding in water.

Question 21

Nearly half of the candidates correctly answered this question, although significant numbers chose responses A and C. The question discriminated very well.

Question 30

This was the question with the highest discrimination index. Response D attracted substantial numbers of candidates, perhaps because one of the methyl groups was shown as H_3C instead of CH_3.

Standard Level

Paper 2

Component Grade Boundaries:

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-18	19-22	23-27	28-31	32-40

General Comments

The mean mark on this paper was higher than last November, with fewer candidates scoring very low marks. 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 below.

Teachers' impressions of this paper are conveyed by the 28 G2 forms that were returned. In comparison with last year's paper, more than three-quarters thought it to be of a similar standard, with the remainder considering it a little easier. All thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by over two-thirds and good by the remainder. Clarity of wording was considered good by over a half and satisfactory by most of the remainder. The presentation of the paper was considered good by over a half and satisfactory by the remainder.

Difficulties for candidates

The main areas in which candidates scored poorly included the application of collision theory and understanding the different types of bonding.

Levels of knowledge, understanding and skill demonstrated

This is the last of the ten papers set on the current course, and the best candidates, who were well prepared, obtained high scores. Parts of the syllabus that were generally well attempted include atomic structure, the application of Le Chatelier's principle and strong and weak acids.

Strengths and weaknesses in individual questions

Section A

Question 1

In (a) the gas was correctly named by most candidates, although hydrogen was frequently mentioned, along with a range of answers from weaker candidates, such as hydrogen carbonate and copper chloride. The better candidates managed the equation, although quite a number used Ca instead of Cu.
In (b), most could correctly read the two values from the graph, although with a time of five minutes being a common error.
Part (c) was not well done by most candidates, with substantial numbers scoring no marks. In (c)(i), many compared the two curves, while others misinterpreted the graph as being about rate against time and wrote about the number of collisions increasing. Most of those who referred to a decrease in collisions did so without any reference to time or frequency. In (c)(ii), differences in temperature, gas pressure and the state of subdivision of the copper(II) carbonate featured in many answers.
The line in (d) was generally correct, although more scored the mark for the steeper gradient than for the same final gas volume.

Question 2

The vast majority of candidates scored full marks here, with zero being the next most frequent score.

Question 3

In (a), most candidates were able to select the correct values from the table, although a minority just answered "low temperature and high pressure".
In (b), many candidates knew how to apply Le Chatelier's principle, but large numbers did not answer the actual question, and made no reference to the yield or amount of ammonia. A common omission in the explanation in (b)(i) was gas moles or volumes.

Most candidates scored one mark in (c), but few managed both. Many answers were too vague for the mark to be awarded, such as "greater cost" without any reference to high pressure.

Section B

Question 4

This was the most popular question in Section B, and some high scores were achieved by the best candidates.
In (a)(i), although most candidates had some idea of ionization, few scored the mark because their answers were too vague, with most omitting the reference to the gaseous state. In (a)(ii) and (iii) the trends were correctly described by most candidates, although some merely quoted the values from the Data Booklet, and most scored at least one mark for the explanations.
Very few got all the formulas correct in (b), and a disappointing number managed only one or two. Even fewer offered a correct comment on the acid-base nature; some had the trend reversed, while others referred to the elements or their hydroxides. A minority misread the question and answered only about sodium and sulfur. The amphoteric nature of Al_2O_3 was not well known.
There were many vague answers in (c)(i), with few references to electron pairs or covalent bonds, and many statements about gaining electrons would have been correct descriptions of oxidizing agents. Covalent and metallic bonding were seen in answers to (c)(ii), and several candidates merely quoted electronegativity values from the Data Booklet without comment.
In (d)(i) the majority mentioned metallic bonding, and some even referred to delocalized electrons, but few mentioned that magnesium had more than sodium. A minority, mostly those answering in Spanish, thought that the question was referring to a compound formed between sodium and magnesium. In (d)(ii) there were many references to the breaking of covalent bonds in chlorine, with others writing about a compound formed between the two.

Question 5

This was the second most popular question in Section B and there were several high-scoring answers seen.
Part (a) was well done by most candidates, the most common error being the omission of a reversible arrow in the weak acid equation. The majority of equations did not include water as a reagent (correct equations with and without water were accepted).
Several good answers were seen in (b), although weaker candidates lost marks in a variety of ways, such as stating a method and not giving the expected results or giving the results but not making it clear which was for which acid. Perhaps the commonest error was to state that more alkali would be needed to neutralize the strong acid.
Part (c) proved difficult for many candidates. Incorrect use of powers of ten was the commonest error.
Part (d) was invariably well done.
Part (e) was surprisingly poorly answered.
The equation in part (f) usually began with the correct acid and alkali formulas, and a pleasing number of candidates scored both marks, the commonest errors being incorrect products (such as $NaCO_3$) or products with incorrect or incomplete charges (such as $NH_4^+CO_3^-$).
Part (g) was often completely correct.

Question 6

Comments here are brief because very few candidates attempted this question, although a wide range of marks was seen. Full marks were rare in (a), although most knew something about the two terms. In part (e), although potassium dichromate(VI) was often the chosen oxidizing agent, the need for acidification was often missing and the colour change was not always correct.

Assistance and guidance for future candidates

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

- use correct technical language in definitions (such as *ionization energy* and *electronegativity*)
- compare and contrast the different types of bonding and understand their relevance in explaining physical properties (such as melting point)

Standard Level

Paper 3

Component grade boundaries:

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-20	21-25	26-29	30-34	35-45

General comments

The mean mark on this paper was considerably higher than last November. There were far fewer candidates with very low scores and there were several scripts with marks higher than last November's highest-scoring script. 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 27 G2 forms that were returned. In comparison with last year's paper, nearly two-thirds thought it of a similar standard, with the remainder equally divided between those considering it a little easier and a little more difficult. Almost all thought the level of difficulty to be appropriate. Syllabus coverage was considered satisfactory by nearly three-quarters, with slightly more of the remainder considering it poor rather than good. Clarity of wording was considered satisfactory by over a half and good by most of the rest. The presentation of the paper was considered good by more than half and satisfactory by most of the rest.

Difficulties for candidates

The paper was generally well answered and it was the options perceived as ‘easy,’ such as options D and F, in which candidates failed to obtain good marks. Briefly, the main areas in which candidates scored poorly, or which were attempted only briefly, included the working out of molecular shapes and bond angles, the distinction between different types of spectra, different types of water treatment and buffer solution calculations.

Levels of knowledge, understanding and skill demonstrated

Again Option B was answered excellently by some candidates and Option C was done very well by the better candidates. Option E continues to be unpopular but was well answered by those who attempted it. Those aspects of chemistry that were generally well known and understood included many aspects of chemical kinetics, hormones, ozone in the atmosphere, the formation of coal and reactions involving glucose.

Strengths and weaknesses in individual questions

Option A – Higher Organic Chemistry

Question A1

Performance in this question was mixed. In (a), many candidates did not know that alkanes were unreactive due to a non-polar structure and strong bonds. Although in (b) more were familiar with homolytic fission, many referred only to the radical's method of formation. In (c) nearly all candidates could successfully draw the hydrocarbon, although fewer seemed to know the effects of different structures on octane ratings - very few candidates scored both available marks. Part (d) was not well answered, with candidates failing to read the question correctly. It clearly asked about the bonds in methanol, but many candidates talked about the bonds in isolation from a molecule and many thought that the H-C-H bond angle would be 180°. In (d)(ii) most candidates seemed to confuse NMR with infrared or mass spectra.

Option B – Higher Physical Chemistry

Question B1

This question on kinetics was generally well answered. In (a) most candidates could correctly deduce the order of reaction, and in (b) identify the rate-determining step, although only the best candidates could relate it to the specific reaction. It is regretted that due to a typographical error in (c), candidates were asked to identify three graphs. Those who gave the correct two and any other one were not penalized; however, few candidates chose both of the correct graphs and many candidates chose neither. In (d) a surprising number of candidates did not realise the temperature dependence of k.

Question B2

This question on buffers was more challenging for many of the candidates. In (a)(i) nearly all knew that a buffer resisted change, but not that it only worked with the addition of small amounts of acid or base. Calculating the pH of the buffer in (a)(ii) was well done by the better candidates, with a number of them using the Henderson-Hasselbalch equation (which is not part of the IB syllabus). Weaker candidates stated that $[CH_3COO^-] = [H^+]$. In (a)(iii) describing the action of the base on the buffer was well done by some, although many candidates wrote about the addition of acid instead of alkali. In (b) many correctly quoted a suitable ammonium salt or hydrochloric acid to form a buffer.

Option C – Human Biochemistry

Question C1

This was a straightforward question, generally well answered although some candidates were confused between the locations of control and production.

Question C2

In (a), the correct answer of glycerol was well known, although many candidates gave water instead. In (b)(i) unsaturated was a familiar but poorly explained term - there were many references to double bonds that did not mention carbon atoms. Part (b)(ii) required candidates to think carefully, and a pleasantly surprising number managed the correct answer. In (b)(iii) several candidates named more than one force, often including covalent bonds. In (b)(iv) the best candidates scored full marks, although the commonest error was to mention the breaking of covalent bonds. In (c), the commonest error was to use the A_r value for iodine instead of the M_r value; even so, many who calculated the number of moles of iodine did not then make a statement about the number of double bonds in the oil.

Option D – Environmental Chemistry

Question D1

Part (a) was often well done, although some candidates confused ozone formation with depletion and others wrote equations involving pollutants such as chlorine, in spite of the word "natural" in the question. In (b) there were many all-correct answers to (i) and (ii), although (iii) was less well answered – the commonest error was to suggest that butane's contribution to the greenhouse effect was through its combustion to give carbon dioxide, and few referred to its flammability.

Question D2

The better candidates had no difficulty in scoring well here, although the weaker ones wrote extensively about primary and/or tertiary treatment, or their answers lacked structure.

Option E – Chemical Industries

Question E1

Most candidates who attempted this option scored quite well here, although the commonest error was, in (a), to omit the removal of water and carbon dioxide before liquefying air.

Question E2

This part of the option was less well known, although there were many good answers. In (a), the commonest error was not to attempt the explanation in (iii). There were several reactions attempted in (b) that did not produce benzene.

Option F – Fuels and Energy

Question F1

In (a) the formation of coal was generally well known, although many answers lacked structure and it was rare for full marks to be awarded. Part (b) was poorly done as candidates did not organize their answers and compare the fuels; several wrote about the greenhouse effect, even though this is a disadvantage of both fuels. Pollution with no further detail featured in several answers, and many candidates stated that coal was cheaper or that oil was more expensive to obtain without stating why.

Question F2

The best candidates scored full marks here, but the weaker ones made errors such as omitting O_2 as a product from the first equation or including it as a reagent in the second one. Photosynthesis was generally better known than fermentation.

Assistance and guidance for future candidates

General:

- Candidates need to be far more precise in their answers – they should be syllabus-specific rather than just general knowledge.
- Longer answers should be structured and planned if they are to gain the marks available.
- Candidates should read the questions carefully they are clear about what they are being asked.
- Practice before the examination with past papers and markschemes to ensure that candidates understand the level they need to be working at.

The specific points in this paper are:

- understanding key terms such as free radical, homolytic fission
- distinguishing between the three different types of spectra
- practice in calculations involving buffer solutions and the addition of iodine to carbon-to-carbon double bonds to determine the degree of unsaturation
- making a clear distinction between primary, secondary and tertiary water treatments

Higher Level

Paper 1

Component Grade Boundaries:

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-14	15-19	20-23	24-28	29-32	33-40

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 identical to that of last November.

Teachers' impressions of this paper were conveyed by the 25 G2 forms that were returned. In comparison with last year's paper, the majority felt that it was of a similar standard, but with rather more suggesting that it was a little more difficult, compared to those who thought it easier. Most respondents thought the level of difficulty was appropriate, but one-fifth considered it too difficult. Syllabus coverage was considered good by over two-thirds and satisfactory by the remainder. Clarity of wording was thought good by nearly two-thirds and satisfactory by nearly one-third, while the presentation of the paper was considered good by the vast majority.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 93% to 24% and the discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.62 to 0.11.

The following comments are made on individual questions.

Question 1

This was a difficult opening question; although nearly half the candidates got it right, response C attracted almost as many candidates as B.

Question 10

Although there was a comment that candidates found this question difficult, more than half got it right, with the distractors attracting roughly equal numbers.

Question 12

Although nearly half got this question right, response B was chosen by a substantial number of candidates.

Question 16

Although nearly half got this question right, response A was a popular choice.

Question 21

This was the question with the highest difficulty index.

Question 25

This was the one of only two questions on the paper in which one of the distractors (in this case, C) attracted more candidates than the correct response (D).

Question 28

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

Question 29

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

Question 30

Although nearly half got this question right, response D attracted a substantial number of candidates.

Question 36

This was the question with the highest discrimination index. Response D was chosen by substantial numbers of candidates, perhaps because one of the methyl groups was shown as H_3C instead of CH_3.

Question 37

This was the other question on the paper in which one of the distractors (in this case, A) attracted more candidates than the correct response (B); it also had the lowest discrimination index.

Question 39

This question discriminated well, and was answered correctly by nearly half the candidates, but response C was a popular choice.

Question 40

Response A attracted almost as many candidates as the correct answer.

Higher Level

Paper Two

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-28	29-39	40-49	50-58	59-68	69-90

General comments

This was a paper that provided good candidates with the opportunity to show what they could do whilst poorer candidates could make some headway with all of the questions. In general, candidates must pay particular attention to the number of marks allocated to a particular question and tailor their answers accordingly. Calculations must be shown clearly and should be checked for accuracy, significant figures and units where appropriate.

The areas of the programme which proved difficult for the candidates:

- definitions (e.g., enthalpy of formation, lattice enthalpy)
- Born-Haber cycle
- identifying the parts of a mass spectrometer
- function of salt bridge in a voltaic cell
- determination of empirical formula
- drawing complete Lewis structures
- explaining the term hybridization
- understanding delocalization
- pH titration curves

- calculation involving buffer solutions

The levels of knowledge, understanding and skills demonstrated:

- signs for enthalpy changes
- dependence of deflection on mass to charge ratio
- isotopes and calculation of A_r
- kinetic theory
- balancing equations
- shapes and bond angles
- types of hybridization
- equilibrium
- organic reactions

The strengths and weaknesses of candidates in the treatment of individual questions:

Section A

Question 1

Part (a) on the signs of enthalpy values was well done by most candidates, but in (b) marks were lost through omitting state symbols or electrons, or writing equations involving other species such as water. Although many knew something about lattice energy, few included the key words ionic and gaseous and so did not score the mark. A minority correctly attempted a Born-Haber cycle showing the species in the correct endothermic and exothermic relationships. Some students ignored state symbols in writing equations for the enthalpy changes given. Even without being able to construct a Born-Haber cycle, the question was designed to allow candidates to score two thirds of the marks based on understanding the enthalpy changes given, but even this proved to be a challenge for some. Candidates found it difficult to explain exactly what they meant; these definitions are worth learning. Candidates should be advised to show clearly the method used and the steps involved in arriving at their answer, rather than just present the examiner with a bare answer.

Question 2

Question 2 (a) on the mass spectrometer was generally not done well as candidates listed the function of the parts (e.g., acceleration) rather than answering the question which asked for the identification of the part (e.g., charged plates or an electric field). On the other hand, many students had a very good sense of the smallest mass to charge ratio being responsible for the greatest deflection in a mass spectrometer. An understanding of the presence of more than one peak in the mass spectrum of an element due to isotopes and the calculation of the relative atomic mass of an element was very well done.

Question 3

Question 3 was straightforward and there were many candidates who achieved high marks. Use of the ideal gas equation and application of kinetic molecular theory was extremely well done by many candidates. Some, however, forgot to convert the temperature from the centigrade to the Kelvin scale, a typical situation experienced in most questions of this nature. It proved difficult for some candidates to score two marks in part (b), which required a mention of increased energy or movement and more frequent or energetic collisions; some referred to activation energy or reaction rates.

Question 4

The question on redox chemistry was not done well, with gaps in knowledge and understanding in key areas. It was common for students to incorrectly suggest that the function of the salt bridge is the movement of electrons rather the movement of ions. Candidates were typically able to write the half-equation for the reaction between Fe(s) and Fe^{2+}(aq), and between Fe^{2+}(aq) and Fe^{3+}(aq). Some candidates did not recognize the role of platinum as an electrode and wrote equations containing Pt, and a variety of iron ions. Generally, candidates were able to calculate the standard cell potential but some had no idea how to proceed. Similarly, some had problems writing the correct oxidation and reduction half-reactions at each of the two electrodes. If the two reactions were interchanged, it was still possible to score a mark for the direction of the electron flow as long as it was consistent with the equations written.

Question 5

Although many candidates were able to write a balanced chemical equation for the reaction of an element X with oxygen to form the oxide X_2O_3, some used atomic oxygen to balance the equation instead of molecular oxygen, and others used X^{3+} instead of X. Given the mass of the oxide and the element X, some students were not able to determine the atomic mass of X and identify the element. Some simply wrote Al as the incorrect answer. Still more surprising was the fact that, given the percentage of nitrogen and oxygen in an oxide of nitrogen, some students answered the question by trial and error by using formulas such as NO, NO_2, NO_3, etc. rather than doing it logically. Others changed a mole ratio of 1:2.5 into 1: 2 or 1:3, rather than into the correct whole number ratio of 2:5.

Section B

As a broad generalization, the more able candidates tended to choose questions 8 and 9 whilst the others opted for questions 6 and 7. In answering questions in Section B, candidates should look at the number of marks available – this will give them a good idea of the length of the answer expected.

Question 6

This was the second most popular question out of the four, and the standard achieved was rather mixed. It was disappointing in part (a) to see many errors in the drawing of the Lewis structures, such as omitting non-bonding electrons and charges and including a non-bonding pair on boron in BF_4^-. Although the prediction of the shape and bond angles of the species was generally correctly done, explanations based on VSPER theory were often lacking. Candidates were expected to identify the number of negative charge centers around the central atom, and to explain the angle.

In part (c) many candidates lost the hybridization mark through lack of precision – there were few references to atomic orbitals. Although many could not explain the term *hybridization,* a good number were able to state the type of hybridization typically in BF_4^- and H_2CO than in the other two species. The errors in answers were based on not recognizing that where as a π bond does not participate in hybridization, the lone electron pair(s) do. Very few candidates mentioned covalent bonding or electron sharing while trying to explain bonding between carbon and oxygen. There were some vague descriptions of sigma and pi bond formation and many were not able to explain either the end-on (axial) overlap of orbitals in the formation of a σ bond compared to sideways overlap of parallel p orbitals to form a π bond. A common error was to confuse the strength of the pi bond with that of the double bond; some who correctly stated that the pi bond was weaker than the sigma bond went on to say that the double bond was weaker than the single bond. Part (e) was generally well done. Some were unable to predict a value for the bond length of the carbon to oxygen bond in the ethanoate ion; others incorrectly used values for C-C and C=C bonds rather than averaging or suggesting a value in-between those for C-O and C=O bonds.

Question 7

This was by far the most popular question. Although the question clearly specified the dissociation of hydrogen iodide into its elements, many candidates wrote the formation of H^+ and I^- ions in the balanced equation. Some wrote solid or liquid as a state in the balanced equation, but then proceeded to incorrectly include the concentration terms for such species in the equilibrium equation (since the concentration of a solid or a pure liquid is a constant, such terms do not appear in the equilibrium expression). Part (b) was well attempted, the commonest calculation error being the failure to halve the 0.22 mol of HI reacted to find the amounts of I_2 and H_2.

Prediction of the effect of increase in K_c value with increasing temperature was very well done; however, the explanation was at times incomplete. Saying "due to Le Chaterlier's principle" is not providing an explanation. The part on the weaker dissociation of HCl (g) and HBr (g) compared to HI (g) based on their K_c values was very well done, as was the question on heterogeneous catalysis. Sketching and explaning of the effect of a catalyst on the activation energy was straight forward and well done.

Question 8

This question was third in order of popularity but few candidates did well. It is regretted that the positioning of the line on the graph in part (b) was not accurate, although it posed few problems for candidates. Most realized that half-neutralization would occur at half of 25 cm^3 (using the information provided above the graph) or at half of 26 cm^3 (using the graph). In either case the pH value would be 4.8 or 4.9, which is what many gave. The concept of half-neutralization eluded some students and thus the calculation of pH was incorrectly done. Some suggested that it was half way between the highest pH (12) and the lowest pH (3), i.e., 7.5. Others gave a value of pH = 5, corresponding to a volume at half-neutralization of 15, and suggested that the volume at neutralization was 30 cm^3 rather than a value that is half-way on the vertical range (i.e., the point of inflection). Most students did not indicate that the starting pH for the 0.10 mol dm^{-3} HCl was 1 since HCl is a strong acid and fully dissociated. Others missed the point that the top end of the curve would be the same for the two titration curves. The part on describing what happens when an acid is added to a buffer solution was done well, but the calculation of the pH of a buffer solution was not done well.

Question 9

This was not a popular choice of question. The lack of reactivity of alkanes cannot be attributed to saturation (since halogenoalkanes are also unsaturated but do react with nucleophiles). Candidates often failed to recognize the high C–C and C–H bond enthalpies and the non-polar nature of the C–C and the slight polar nature of the C–H bonds for the lack of reactivity of alkanes. Candidates were able to identify the species formed in the homolysis of bromine molecule into bromine atoms as the formation of free radicals, and generally speaking candidates were able to deduce the peak height ratios for organic molecules given, although some confused NMR spectra with mass spectra.

Explanation of the terms in S_N2 was poorly done. Candidates typically only stated what the letters stood for (substitution and nucleophilic), rather than explaining the terms. It is important to encourage candidates to read the questions carefully so parts are not misinterpreted. There were many partially successful attempts at the mechanism in (b)(ii), but not all candidates positioned the curly arrows correctly, and omitting the charge on the intermediate was a common failing. Mechanisms in organic chemistry require candidates to show the movement of pairs of electrons using 'curly arrows' – this was missing in some answers. Explanations of the terms *primary* and *secondary,* and the structural formula of a tertiary halogenoalkane were well done, as was the recognition of the type of substitution reaction a tertiary halogenoalkane undergoes.

Identification of a suitable oxidizing agent for the oxidation of propan-1-ol should have been done better. The structural formulas of the aldehyde (alkanal) and the carboxylic acid (alkanoic acid) was well done, and some candidates were able to explain correctly why alkanoic acids are more acidic than alcohols (alkanols), although this explanation was the least satisfactory part of most candidates' answers.

The type of assistance and guidance the teachers should provide for future candidates:

- Teachers are strongly urged to refer to past examination questions and their markschemes to assist candidates with examination preparation.
- Students must know the meanings of the different action verbs that appear in the syllabus and in the examination papers.
- Candidates should aim to match their answers to the number of marks allotted.
- In calculations, candidates should be encouraged to "keep going"; errors are carried forward so that a correct method in a later part of the question is rewarded. All steps in the calculation must be shown.
- Candidates should check answers on a calculator mentally to ensure it is sensible.
- Learn formal definitions.
- Plan answers rather than ramble at length.
- Poor penmanship can be avoided by giving candidates plenty of practice in writing examination type questions and providing appropriate feedback – there were a few alarming examples of poor writing.
- Candidates should, where appropriate, illustrate their answers with simple, neat and well-labelled diagrams.

Higher Level

Paper 3

Component Grade Boundaries:

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-14	15-21	22-26	27-32	33-37	38-50

General comments

This paper discriminated well, with a good distribution of marks ranging from some excellent answers to a few that were poor. 67% of the schools that returned G2 forms thought that the paper was of a similar standard to last year, 11% thought it was as little more difficult and 17% thought it was a little easier. 88% of respondents thought that the level was appropriate. The syllabus coverage, clarity of wording and the general presentation of the paper was seen as either good or satisfactory by over 90% of the respondents.

All candidates answered or attempted to answer the correct number of options and almost all indicated which two options they had answered on the front cover. Although one or two teachers commented that there appeared to be some disparity between the level of difficulty among the various options this was not borne out by the marks awarded. Although Option C - Human Biochemistry and Option D - Environmental Chemistry were the most popular, no one option appeared to be easier to score marks on than any other.

Most candidates are now giving, or attempting to give, precise answers involving chemistry to each question. However there is still a tendency for some candidates to give more general “journalistic” answers which do not contain enough chemistry to score the marks for some questions.

Difficulties for candidates

The principal areas in which candidates scored poorly, or were only attempted briefly, included the formation of secondary pollutants, the distinction between different types of water treatment, the manufacture of silicon and nuclear calculations. Some candidates also had difficulties with organic reaction mechanisms.

Levels of knowledge, understanding and skill demonstrated

There was generally excellent recall of some of the detail relevant to specific options. For example in Option C the difference between competitive and non-competitive inhibitors was well set out by many candidates. Other areas that were generally well known and understood included hormones, ozone formation and depletion in the stratosphere, the formation of coal and the identification of particular bonds from their infra-red absorptions. Many who attempted calculations set them out in a logical way even if they did not eventually end up with the correct answer. Most candidates paid due attention to significant figures and included units where appropriate.

Strengths and weaknesses in individual questions

Option C – Human Biochemistry

Question C1 on hormones was generally answered well. Almost all knew the functions of insulin and thyroxine but some confused the locations of control and production. Water rather than propane-1,2,3-triol (glycerol) was often given as one of the products of the hydrolysis of fats and oils in C2. In (b)(i) there were many references to double bonds that did not mention carbon atoms. Since even saturated fats contain C=O double bonds, it is important to include C=C double bonds when describing unsaturation. Part (b)(ii) required candidates to think carefully, and many managed the correct answer. In (b)(iii) several candidates named more than one intermolecular force present in fatty acids. The correct answer was van der Waals' forces, although candidates who also mentioned hydrogen bonding were not penalized. A surprising number of candidates incorrectly included covalent bonds. In (b)(iv), the commonest error was to mention the breaking of covalent bonds. In (c), a common mistake was to use the A_r value for iodine instead of the M_r value; even so, many who calculated the number of moles of iodine could not then make a statement about the number of double bonds in the oil. Question C3 involved a comparison between competitive and non-competitive inhibitors. Many good answers were seen, and the distinction between the two types of inhibitor was usually clear, although the lines on the graph were sometimes labelled incorrectly. In C4 candidates had to describe either electron transport or oxygen transport. Neither of these topics was well known. Few candidates got beyond mentioning iron and hemoglobin for oxygen transport and very few candidates chose to describe electron transport.

Option D – Environmental Chemistry

Part (a) of question D1 was often well done, although some candidates confused ozone formation with depletion and others wrote equations involving pollutants, in spite of the word "natural" in the question. In (b) there were many all-correct answers stating what CFC stands for and listing two sources of CFCs in the atmosphere. Almost all candidates knew that a decrease in atmospheric ozone can lead to skin cancer but a considerable number were unable to give a second harmful effect on human health. Part (b) (iii), concerned with the disadvantages of using butane as an alternative to CFCs, was less well answered. The commonest error was to suggest that butane's contribution to the greenhouse effect was through its combustion to give carbon dioxide. There was a considerable variation in the answers given to D2 regarding the secondary treatment of waste water. The better candidates had no difficulty in scoring well, but the weaker ones often wrote extensively about primary and/or tertiary treatment and the purification of water with chlorine or ozone. In D3 (a) most candidates scored the majority of the marks for describing the conditions for the formation of photochemical smog. Many were unable to describe correctly a free radical in D3 (b) and there were a number of equations showing the formation of N_2 and N•. Although the better candidates knew about PANs, a surprising number gave CO or SO_2 as secondary pollutants in part (c).

Option E – Chemical Industries

Good candidates answered this option well but many poorer candidates seemed ill-prepared. In the description of how to liquefy air in E1 the commonest error was to omit the removal of water and carbon dioxide before liquefying the air. Most candidates identified nitrogen correctly as the gas given off first when liquid air is warmed. The Haber process was the most common correct answer for the use of nitrogen but several wrongly gave the production of iron as a use for oxygen. Air or a mixture of air and methane is used to make iron. Pure oxygen is, however, used for steel making. In E2 candidates either seemed to be well informed on cracking or to have little knowledge of the process. Several good answers were seen to part (a), the commonest error being not to attempt to explain why alkenes are not formed as products in hydrocracking. There were several reactions attempted in (b) concerned with aromatization that did not produce benzene. In E3 most candidates correctly identified the changes in the numbers of gas moles and the corresponding ΔS values, although the reference to the $T\Delta S$ term was often missing or confused. Very few good answers were seen for describing how silicon dioxide is converted into pure silicon in E4. Many candidates failed to state that the silicon (formed from the reduction of silicon dioxide) is converted into silicon tetrachloride during the process (so that it can be purified by distillation) and zone refining was often described in vague terms such as "pushing the silicon rod through a tube". Several candidates thought that it was the silicon dioxide that can be zone refined directly to give silicon.

Option F – Fuels and Energy

Most candidates were able to describe the formation of coal in F1 (a). The advantages and disadvantages of coal and oil were less well answered in part (b). Many contradictions and irrelevant points were made. Several wrote about the greenhouse effect, even though this is a disadvantage of both fuels. Pollution, with no further detail, featured in several answers. Many candidates stated that coal was cheaper or that oil was more expensive to obtain without stating why. In F2 the best candidates scored full marks, but weaker candidates made errors such as omitting oxygen as a product in the equation for photosynthesis or including it as a reagent in the conversion of glucose to ethanol by fermentation. The straightforward nuclear equation in F3 (a) was surprisingly often incorrect - the most common error was to include the symbol Co in the product, and many attempts at calculating the half-life were not based on the formula given in the Data Booklet. Part (b) was very badly done, with most candidates not scoring on the two definitions. Some obtained partial credit in the calculation, but very few correct final answers were seen. One common error for those who demonstrated some knowledge by giving $E = mc^2$ correctly, was to forget to square the value for the velocity of light in the subsequent calculation.

Option G – Modern Analytical Chemistry

Most candidates who answered the questions on this option seemed well prepared although some got confused in the final identification of compound **C** in D1 (e). Almost all candidates correctly determined the empirical formula of compound **C** as being $C_3H_6O_2$ in part (a). Most candidates also deduced the correct molecular formula in part (b) (i). Many knew that the small peak at m/z = 75 was due to the presence of isotopes. The majority of candidates gave the correct fragmentation ions that corresponded to the peaks in (b) (iii). Most candidates deduced from the graph in (c) that compound **C** could not be an alkanol or alkanoic acid or did not contain an OH group. Nearly all the candidates identified the bonds responsible for the infra-red absorptions given. Very few were able to state exactly what can be deduced from the splitting patterns in the NMR spectrum in part (d). The correct deduction is that compound **C** contains a -C_2H_5 group which is attached to a carbon atom to which there are no other hydrogen atoms attached. Those that did deduce the structure of compound **C** correctly often mistakenly called it methyl ethanoate rather than ethyl methanoate. Many candidates had problems describing the principles of X-ray crystallography in G2 although a good number did then go on to use the Bragg equation correctly in part (b) to calculate the distance between the layers in the crystal.

Option H – Further Organic Chemistry

Part (a) of question H1 was well attempted, with most candidates correctly naming the mechanism and drawing the structures of the carbocations. The use of “curly arrows” is improving, but many candidates failed to draw one of them or drew one the wrong way round. The explanation of the major product was usually well done although there are still candidates who think that simply stating Markovnikov's rule **explains** why the major product is formed. Part (b) was less well done, with several pairs of structural isomers being seen. Even where stereoisomers were attempted, the 3-D relationship was not always clear, and the physical and chemical differences were often interchanged. H2 tested understanding of geometrical isomerism and caused problem for many candidates. Even when the correct choice of isomers was made, the explanation, especially for **W**, was often inadequate. Question H3 on the reactions of methylbenzene proved to be an excellent discriminator. Many correct mechanisms were seen in part (a), with only a handful interchanging I and II. Part (b) was done much less well, with a relatively small number of candidates giving 2,4,6-trichlorophenol as the correct final product.

Assistance and guidance for future candidates

This was the last examination paper on the old syllabus. However, apart from also containing questions on the new Option B (Medicines and Drugs) future examinations testing the options material will have a very similar format. The following recommendations will help to prepare future candidates for examinations on the new programme.

- Students should be given regular assignments and tests from past examination and specimen papers. This will give candidates the opportunity to develop the skills of answering questions clearly, directly and completely, so that they are not penalized for failing to answer the question asked. For example, if a question says give **two** harmful effects on human health due to the decrease in atmospheric ozone, then one effect will not suffice nor will answers that do not relate to **human** health. Students also need to be completely familiar with the action verbs and which objective they relate to.
- Provide students with adequate resources to complement the teaching of the options. Students should also be given a copy of the syllabus for the relevant options so that they know what it is that they are being tested on.
- Responses to questions should demonstrate both depth and breadth. Candidates must ensure that they cover a sufficient number of different points to score the full range of marks assigned to each question.
- Candidates should be advised to attempt to answer all parts of an option. Better an attempt that may provide a small amount of credit than no attempt which will give no credit at all.
- Teachers are advised to cover two options thoroughly and not attempt to cover more than this unless time allows. There is strong evidence that candidates from schools covering several options do less well than those concentrating on just two options.
- Specific areas of weakness that were evident from this particular examination which future candidates could benefit from by improving include:
    - practice in calculations involving the addition of iodine to carbon-to-carbon double bonds to determine the degree of unsaturation
    - the role of metal ions in biological processes
    - making a clear distinction between primary, secondary and tertiary water treatments
    - the formation of secondary atmospheric pollutants
    - the manufacture of pure silicon
    - calculations involving isotopes

Internal Assessment

Higher and Standard Level

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

General comments

Whilst the general standard of internal assessment has improved, many moderators expressed concerns about instructions not being followed in submitting practical work for moderation. Schools still continue to submit samples that are not complete, correct or properly annotated. Full portfolios are still being submitted although this is no longer a requirement. Incorrect completion of form

4/PSOW, absence of instructions, incorrect numbers of highlighted marks for moderation can all be avoided by following the instructions provided in the latest edition of the *Vade Mecum*.

The task of moderation is made much easier when the instructions provided to the candidates are included with the samples submitted. Some schools omitted this information – particularly in the case of verbal instructions. In many cases, teachers had monitored the candidates' work carefully and provided useful feedback. Sometimes, however, there was no evidence of feedback at all. Often teachers used a grid where the "c, p, n" achievement levels were clearly indicated. This helps the students, as well as the moderator. This session moderators were provided with copies of the feedback forms sent to teachers in November 2001. Unfortunately in some cases, little or no improvement was noted. It was good to see that safety awareness and concern for the environment was evident in some schools. This should be expected universally.

The range and suitability of the work submitted

A broad range of practical investigations was submitted and many schools had interesting practical schemes of work. The majority of the schools covered the areas of the syllabus with suitable experiments. Most of the practical work undertaken was of a suitable level. Overall, the options at both SL and HL were better done compared to last year, with some very good practicals 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.

There are, however, some schools that do not seem to be delivering a laboratory programme in the spirit expected. Several schools seem to rely almost exclusively on textbook "recipes" with all procedures fully detailed. In such situations, it is very difficult to assess the candidates' work in some of the criteria (details follow). There were a small number of schools whose practical schemes of work were a long way short of the recommended number of hours or were rather trivial in nature. Although every effort is made by the moderators to reward candidates' efforts, it is nonetheless inevitable that candidates in such cases are less likely to score well when they are not given the opportunity to undertake more open-ended investigations.

Another weakness in some laboratory programmes is a high proportion of "investigations" that are actually demonstrations or passive descriptions such as observations of physical properties, or drawing conclusions from data tables. Whereas there is certainly scope for inclusion of such exercises in a full and varied programme, the emphasis must be on hands-on experience and development of practical skills in the laboratory. Some schools are below the specified minimum requirements. At least 40 hours must be spent on hands-on investigations at SL and 60 hours at HL.

Candidate performance against each criterion

Planning (a)

Candidates in some schools continue to have trouble with Planning (a). This criterion requires teachers to provide a broad or general investigation problem, which then allows candidates to come up with their own focused problem. Some candidates are still being given the research question, although others clearly stated a focused research question of their own. Some students stated a hypothesis, but did not explain their reasons for it. Difficulties arose with poorly stated hypotheses. Statements such as "I don't believe I can determine a value…" are meaningless. Others gave a hypothesis whose explanation was very superficial - an effort should be made to explain a hypothesis on the molecular level. This aspect 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 better done compared to last year and candidates selected suitable equipment and devised appropriate strategies for carrying out their investigations. There are still teachers who give out standard equipment, and the methods, and consequently these investigations were moderated down. Teachers must not provide a list of apparatus or materials or the procedure, as candidates need to meet these aspects of the criterion on their own. Often teachers set up an investigation so there is only one way to proceed. Both Pl (a) and Pl (b) should evoke different responses from different students within the same class. Sometimes the control of variables was not always explicitly identified. Candidates sometimes took excessive amounts of materials when the same investigation could have been carried out on the micro scale – candidates must pay attention to environmental consequences when planning an investigation. The inclusion of appropriate controls was often weakly discussed. This follows from the failure to recognize the need for controls in the discussion of the variables. Few candidates seem to have the notion of fair testing or they assume it is self-evident. It seems teachers are not reinforcing the need for this. The collection of sufficient data is also poorly considered. Replications are often limited to one repetition of the investigation, if at all.

Data Collection

This criterion was generally carried out well and many suitable investigations were undertaken. Overall, candidates 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 investigations (for example the colours of solutions and of the indicator, and colour change at the end point of a titration). Similarly, uncertainties are most often left out, and there was frequent inconsistency in the use of significant figures/decimal places, for example in recording burette readings where a single table contained data such as: 5, 19.5, 20.37 cm^3. Note that the second aspect of the criterion (organising and presenting raw data) can not be assessed if the teacher has provided data tables. Teachers should avoid submitting investigations for moderation where only a few values of one variable are being collected, or where a small number of qualitative observations are required.

Data Analysis

This criterion will be referred to as Data Processing and Presentation from May 2003 onwards. Candidates were generally able to perform satisfactorily on this criterion, although high levels of achievement were not common. In some cases, manipulation of the data was elementary or absent. Many candidates missed the opportunity to take uncertainties into account and carry out error analysis even when this was clearly possible. Appreciation of significant figures is also often missing. In graphing, some candidates were unable to decide when to draw a straight line, when to draw a curve and when to join points, and lack of feedback in some cases meant the same error was repeated again in other investigations. Teachers must not provide too much information about how data is to be processed – evidence should be clear of the candidates' ability to process data on their own, rather than by a series of prescribed steps in calculations. Sometimes it seems as if the teacher has told the students how to process the data, so once again the teacher's instructions are important for moderation. Computer generated graphs are acceptable. A computer may draw the line for the student but the student still has to set up the graph and make choices about its format. It can still be assessed using the IA criteria.

Evaluation

This criterion will be referred to as Conclusion and Evaluation from May 2003 onwards. This is still an area where candidates do not score well, as they do not satisfy the requirements of the three aspects. For example, it is still not common for candidates to compare their results to literature values where appropriate. This criterion also requires a valid conclusion with an explanation that is based on the correct interpretation of the results – this is often missing. Similarly, marks are still lost through candidates failing to evaluate the procedure, listing possible sources of error and making suggestions to improve the investigation following the identification of weaknesses. Comments such as "the readings must have been too low or too high, and "the manufacturer's batch must have been impure" are not appropriate evaluations of the procedure. Candidates often make trivial suggestions; they should identify reasonable systematic errors and then propose improvements based on these. Note that not all investigations are appropriate for assessment of this criterion.

Manipulative skills

The programmes in general are continuing to provide adequate scope for assessment of this criterion.

The Group 4 Project

This is an essential requirement of the IB programme. It is a very valuable exercise in practicing student-generated investigations and it is an ideal opportunity to assess Personal Skills. The moderation sample must provide evidence of participation in the Group 4 Project.

Recommendations for the teaching of future candidates

There is no doubt that some great work of an extremely high standard is being produced. Generally, many teachers gave their candidates 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 candidates. A small number of candidates made reference to ethics, safety and environmental issues and this is always pleasing to see. Overall, there were improvements compared to last year – this is 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.

- Candidates should be made aware of the different aspects of the criteria by which they are assessed
- Candidates may find sub-headings for each criterion useful
- Many schools are evaluating investigations using a grid of criteria / aspects with n, p and c indicated clearly. This helps the teacher and the student, as well as the moderator.
- Full portfolios are no longer required and should not be submitted unless specifically requested by IBCA
- 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/help.
- Avoid using workbooks and worksheets with spaces to be filled in for internal assessment.
- Candidates need practice at proposing a hypothesis that is directly related to the research question and is explained.
- Candidates must record qualitative as well as quantitative raw data where appropriate, including units and uncertainties where necessary.
- Teachers must provide 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 criterion Evaluation, require candidates to evaluate the procedure, list possible sources of errors, and provide suggestions to improve the investigation following the identification of weaknesses.

Remember the selection of materials for the moderation of internal assessment is changing from May 2003. Make sure that your IB Coordinator keeps you informed of changes in the *Vade Mecum*. Teachers should refer to the Chemistry curriculum guide and instructions provided in the *Vade Mecum* before submitting work for moderation.

