CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-30	31-41	42-53	54-63	64-75	76-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-31	32-44	45-55	56-64	65-74	75-100

Standard level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-13	14-19	20-21	22-23	24-25	26-30

General comments

This paper consisted of 30 questions on the Core 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 lower than November 2002, with fewer candidates scoring high marks.

The 24 G2 forms that were returned convey teachers' impressions of this paper. Nearly three-quarters of respondents felt it was of a similar standard to that of last year's paper. Most of the remainder considered that this year's paper a little more difficult than last year's. The great majority thought the level of difficulty to be appropriate, with a small number considering it too difficult. Syllabus coverage was considered good by nearly a half and satisfactory by over a half. Clarity of wording was considered good by nearly two-thirds and satisfactory by over a third. The presentation of the paper was considered good by over four-fifths and satisfactory by the remainder.

A general comment was made that there were too many questions of the multiple completion type (in which candidates are asked to choose a combination of correct responses from those labelled I, II and III). The number of this type of question to be included in the papers has never been specified, and has varied considerably in recent years. In the instructions given to paper authors it is now specified that between 10% and 20% of the questions should be of this type, and that the given combinations of responses should be the same in each question:

A I and II only
B I and III only
C II and III only
D I, II and III

It should be remembered that papers for some future sessions have already been written.

Strengths and weaknesses in individual questions

The Difficulty Index (the percentage of candidates achieving each correct answer) ranged from 86% to 34% and the Discrimination Index (an indication of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.62 to 0.14.

There were very few comments made on individual questions. In this paper there was only one question (Q26) where the largest number of candidates chose a response that was not correct; this was also the most difficult question. In Q26 slightly more chose response B than the correct response D; the question discriminated well enough.

Standard level paper 2

Component grade boundaries:

Grade:	1	2	3	4	5	6	7
Mark range:	0 to 6	7 to 12	13 to 17	18 to 23	24 to 28	29 to 34	35 to 50

General comments

When making comparisons with previous papers in November sessions it should be remembered that the maximum mark is now 50 instead of 40. Even taking this difference into account the mean mark on this paper was lower than last November, and there were an unprecedented number of candidates scoring very low marks. All but the very 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.

The 23 G2 forms that were returned convey teachers' impressions of this paper. In comparison with last year's paper, less than half thought it of a similar standard, with almost all the remainder considering it to be more difficult. About two-thirds thought the level of difficulty was appropriate, with the remainder considering it too difficult. Syllabus coverage was considered satisfactory by nearly two-thirds and good by the remainder. Clarity of wording was considered good by nearly two-thirds and satisfactory by most of the remainder. The presentation of the paper was considered good by over two-thirds and satisfactory by most of the remainder.

Difficulties for candidates

The main areas in which candidates scored poorly included the application of Hess's Law, explanations of periodic trends and changes in reaction rate during chemical reactions.

Levels of knowledge, understanding and skill demonstrated

Parts of the syllabus that were generally well attempted include homologous series, organic structures, optical isomers and esterification.

Strengths and weaknesses in individual questions

Section A

Question 1

This proved difficult for most candidates. Very few all-correct answers were seen. Although most attempted both parts, the results were very disappointing. Few candidates were able to cope with a relatively straightforward energy cycle in (a), although more showed an understanding of the relationship between ΔG, ΔH and ΔS.

Question 2

Marks scored in this question tended to be either close to the maximum or, more often, close to zero. The principle of e*rror carried forward* (ECF) was applied, although this benefited relatively few candidates. Many simply did not know how to apply what should have been familiar expressions involving amount of substance.

Question 3

This was well answered by many candidates, although a common error was to misunderstand the meaning of *physical property* in (a) and give as an answer as difference in the number of neutrons.

Question 4

Many candidates did not understand that Lewis structures require all non-bonding pairs of electrons to be shown; the bond angle predictions were disappointing, with 180° appearing in both parts of (b). The relationship between bond length and strength was much better known, although not its explanation.

Question 5

Most candidates scored at least one mark for knowing the meaning of the term *buffer solution*, although fewer were able to decide which were the buffers in (b). Many of the attempted explanations offered in (b) were wordy but not relevant; the idea that only in (b)(ii) the solution would contain both NH_3 and NH_4^+ was rarely seen.

Section B

Question 6

This question covered material that should have been familiar to candidates and was a popular question with almost all candidates attempting all parts. However, answers were generally poor. The classification of oxides according to acid-base character rarely scored full marks in (a).
Part (b) required the explanation of three separate trends in melting point. Most candidates clearly indicated in the way their answers were structured, which trend they were referring to and made appropriate reference to electrons in explaining the trends for metals and halogens. The content was often deficient and in many cases answers read as if they were about ionization energies.

Often the wrong comparisons were made in part (c). Those asked for in the question were for K with Na, K with Ar, Na with Mg; many candidates compared Na and Ar, and others mentioned valid points but not in the correct comparison. Points looked for included nuclear charge, energy level or distance from the nucleus, repulsion by other electrons.

Question 7

This was the least popular question, but it was well answered and some high scores were seen. Part (a) was well done. The most common error was representing the same isomer in two written differently structures. The isomer with optical activity was invariably correctly identified.
High scores in part (b) were common; the mark most often missed was for explaining how sulfuric acid acts as a catalyst in esterification.
In part (c), most candidates identified the compound that reacted with bromine, but the explanation was sometimes incomplete (to say that II reacts because it has double bonds is not sufficient – a reference to carbon-carbon double bonds is needed as both I and II contain C=O bonds). There were few good answers in (ii), with many candidates giving condensation polymerization; the repeating unit was rarely correct.

Question 8

Like Q6 there was much familiar material here and it was a popular question. In part (a), the equation and sketch graphs were generally well done. The explanations in terms of changes in concentration and collision theory were poorly done.
In part (b), many candidates drew two separate graphs (often on graph paper) instead of the two lines on one graph asked for. Some candidates scored only the mark for equilibrium being established when the two rates became equal.
Part (c) was usually correct.

Assistance and guidance for future candidates

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

- carefully distinguish between physical and chemical properties (eg when describing a homologous series)
- clearly refer to particular properties in explanations of periodic trends (i.e. melting point, electronegativity or ionization energy)

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-17	18-21	22-25	26-29	30-40

General comments

When making comparisons with previous papers in November sessions it should be remembered that the number of options tested has been reduced from three to two and the maximum mark is now 40 instead of 45. The mean mark on this paper was lower than paper 3 last November. Almost no candidates infringed the rubric by answering questions from more than two Options. More detailed comments are given in the sections below.

The 23 G2 forms that were returned convey teachers' impressions of this paper. In comparison with last year's paper, three-quarters thought it of a similar standard, with most of the remainder considering it a little more difficult. The vast majority thought the level of difficulty to be appropriate. Syllabus coverage was considered satisfactory by over half and good by over one-third. Clarity of wording was considered satisfactory by one-third and good by nearly two-thirds. The presentation of the paper was considered good by nearly three-quarters and satisfactory by one-quarter.

Strengths and weaknesses in individual questions

Option A – Higher physical organic chemistry

Question 1

Many candidates had problems defining the rate of reaction. Their answers often lacked precision and the calculation of the half-life was difficult for many. However, most knew the effect on rate of changing the concentration and the overall order of reaction. The mechanism for the S_N1 reaction was only done well by a few. There were no "curly arrows" or descriptions of the steps on many responses. The effect on rate of changing the halogen was generally well known but the ^1H NMR spectrum proved very difficult for the majority of candidates.

Question 2

Most candidates attempted these questions, but few scored full marks because of the general lack of precision in their answers, such as omitting charges from the fragment ions in the mass spectrum.

Option B – Medicines and drugs

Question 1

This was a straightforward question and was well answered by the majority of candidates.

Question 2

The question asked about a redox reaction and the majority of candidates who knew this were able to explain adequately. Few candidates were able to explain how an intoximeter works. Most knew the effects of taking alcohol with other drugs.

Question 3

Responses lacked precision. When asked to circle the amine group many just circled the nitrogen and so lost the mark. The majority of candidates did identify the group as a tertiary amine (and the amide in part (b)).
Few candidates scored all the marks in part (c). The structure was described incorrectly and the example of the effect of taking stimulants was often anecdotal.

Option C – Human biochemistry

Question C1

The topic of genetically modified food was generally well known and some high scores were seen.

Question C2

Many candidates did not know the straight chain structure of glucose but did know the difference between alpha and beta glucose. Few candidates knew the differences between amylopectin and amylose. The majority of candidates were able to calculate the heat evolved in the experiment. Relatively few candidates calculated the calorific value.

Question 3

The comparison of linoleic and stearic acids was generally well done. The structure of the fat was rarely correct in part (c).

Option D- Environmental chemistry

Question 1

Few candidates scored well in this question on primary pollutants. Candidates had difficulty with the equations.

Question 2

Despite the clear instruction in the question, candidates often stated that the alternatives should not harm the ozone layer.

Question 3

This straightforward question was well answered by the majority. A large number of candidates identified sulphur dioxide as causing rain to be naturally acidic and carbon dioxide as the gas released by burning coal that causes acid rain.

Option E – Chemical industries

Question 1

This question was reasonably well answered, although few candidates clearly stated the two factors that influenced the method of extraction.

Question 2

Factors influencing location of industry and the differences between consumer and intermediate products caused few problems and most could give a use of biotechnology, often insulin production.

Question 3

This question was the most difficult question in this option. Few candidates knew, or could work out, the relevant equations in (a) and (b). Detail was often missing in part (c) and there was some confusion between the extraction of iron and its conversion to steel.

Option F – Fuels and energy

Question 1

Nuclear fission and was generally well known. The part dealing with the nuclear reactor was poorly done. There was confusion between the functions of the control rods and moderators. The need for a secondary coolant was poorly understood.

Question 2

This question was not well answered. Octane rating was not understood, the equations were frequently incorrect and the calculations caused several problems

Question 3

The conversion of solar energy directly to electricity was not well known, although most candidates gained marks for listing the advantages.

Assistance and guidance for future candidates

- Candidates should make sure they answer the question set and that answers given are both detailed and precise.
- Candidates should do as much practical work as possible so that they can then understand the chemical concepts underlying the options.
- Candidates should practice with past papers and markschemes and get plenty of practice writing equations and structural formulas.

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-15	16-21	22-25	26-29	30-33	34-40

General comments

This paper consisted of 40 questions on the Core and 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 marginally higher than last November.

The 32 G2 forms that were returned convey teachers' impressions of this paper. In the comparison with last year's paper, just over a half of respondents felt it was of a similar standard, with most of the remainder considering that it was a little more difficult. The great majority thought the level of difficulty to be appropriate, with a small number considering it too difficult. Syllabus coverage was considered good by a half and satisfactory by a half. Clarity of wording was considered good by a half and satisfactory by most of the remainder. The presentation of the paper was considered good by over three-quarters and satisfactory by the remainder.

A general comment was made that there were too many questions of the multiple completion type (in which candidates are asked to choose a combination of correct responses from those labelled I, II and III). The number of this type of question to be included in the papers has never been specified, and has varied considerably in recent years. In the instructions given to paper authors it is now specified that between 10% and 20% of the questions should be of this type, and that the given combinations of responses should be the same in each question:

A I and II only
B I and III only
C II and III only
D I, II and III

It should be remembered that papers for some future sessions have already been written.

Strengths and weaknesses in individual questions

The Difficulty Index (the percentage of candidates achieving each correct answer) ranged from 92% 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 0.20.

There were very few comments made on individual questions. In this paper there was only one question (Q11) where the largest number of candidates chose a response that was not correct; this was not the most difficult question. In Q11 slightly more chose response C than the correct response B; the question discriminated well enough.

The following comments are made on individual questions.

7 A comment was made that the wording of the question suggested that the electronegativity of argon was greater than that of chlorine. The point is taken, and it would have been better to ask about the trends from sodium to chlorine. It did not prove a problem for candidates, as nearly three-quarters chose the correct response B.

11 A comment was made that there were two possible answers, including response C (based on considering all the compounds to have one bond between the carbon atoms). However, A.S. 4.2.3 and the accompanying teacher's note make it clear that a double bond contains two bonds (shared pairs of electrons). It is suggested that the reason for more candidates choosing C than B is that they interpreted the question as referring to the total number of bonds in the molecules.

33 A comment was made that the subject matter is not included in A.S. 19.3.2. It is unfortunate that the A.S. uses the term *list*, but it is considered that teachers would certainly cover the qualitative effects of these factors, as they are required in A.S. 19.3.3. The question was answered correctly by two-thirds of candidates and it discriminated well.

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-11	12-22	23-31	32-42	43-52	53-63	64-90

General comments

This paper provided strong candidates the opportunity to show what they could do, while candidates who were not strong could make some headway with the questions. All but the very weakest candidates attempted most parts of most questions, and almost none infringed the rubric by answering more than one question in Section B. In general, candidates need to 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. Candidates should read questions carefully; time was wasted by some candidates in writing equations and providing names of isomers not asked for. Candidates **must** pay attention to the action verbs used in the questions.

The mean mark on this paper was considerably lower than last November. More detailed comments are given in the sections below.

The 27 G2 forms that were returned convey teachers' impressions of this paper. In comparison with last year's paper, just over one-third thought it to be of a similar standard and very few thought it a little easier. Responses indicate that over a quarter of teachers thought it a little more difficult and over a quarter much more difficult than last year. Nearly one-third thought the level of difficulty too high. Syllabus coverage was considered good by over one-third, satisfactory by over a half, with a small number considering it poor. Over a half thought the clarity of wording to be good, with most of the remainder considering it satisfactory. The presentation of the paper was considered good by over four-fifths and satisfactory by most of the remainder.

Difficulties for candidates

- definitions (e.g., enthalpy of formation, bond enthalpy)
- application of Hess' law and Gibb's free energy equation
- electronic configuration and colour of d-block element ions
- preparation of a buffer of a particular pH
- electrolysis (particularly poorly done)
- equations to illustrate amphoteric nature of aluminum oxide
- resonance structures, consequence of delocalization, hybridization
- mechanisms
- characteristics of homologous series

Levels of knowledge, understanding and skill demonstrated

- good grasp of stoichiometry calculations
- calculation related to relative atomic mass based on isotopic abundance
- concept of weak acid and simple calculation, but not calculation of pH, pK_a or buffers
- good level of knowledge and understanding of ionization energy
- ligands and Lewis acid-base theory understood well

Strengths and weaknesses in individual questions

Section A

Question 1

(a) Calculation of the average bond energy required candidates to write out the equations corresponding to ΔH°_f and bond enthalpy and together with the enthalpy of sublimation provided apply Hess's law. A number of candidates were able to give the correct enthalpy cycle in order to calculate the value. Some did not calculate the bond enthalpy per mole of C–F asked for.

(b) This involved application of Gibb's free energy equation. It allowed candidates to predict and explain the effect of an increase in temperature on the spontaneity of the freezing of benzene, and explain the significance of the temperature at which ΔG = 0, namely the temperature at which the solid and the liquid are in equilibrium with each other. Although some candidates were able to apply it correctly, others did not understand the concept of spontaneity. Gibb's equation involves temperature in K and not °C, and calculation of the freezing point temperature required unit conversion which was missed by many candidates.

Question 2

(a) Candidates often missed the formula of the precipitate formed as $Ag_3XO_4(s)$. The principle of 'error carried forward' ensured that they were not further penalized if the incorrect stoichiometric ratio was used in part (b).

(b) Candidates must pay attention to the number of significant figures in calculations. The problem was generally well done, although some candidates did not convert the volume into dm^3 when calculating the amount of silver ions, given the volume (in cm^3) and the concentration in mol dm^{-3}.

Question 3

(a) Candidates would have benefited from reading the question more carefully as it asked for a physical property that is different for isotopes of an element. Answers such as "number of neutrons" or "they have the same number of protons and electrons" cannot receive credit. Acceptable answers were: isotopes differ in their mass, density, melting or boiling points (and for gases, their rate of diffusion).

(b) There was a tendency to round answers off, for example to 75% and 25% rather than 77.5% and 22.5%. Otherwise, generally candidates knew how to approach the problem.

(c) Whereas a majority of the candidates were correctly able to write the electronic configuration of Br, many made the error of leaving the $4s^2$ electrons in the configuration of Fe^{3+}.

Question 4

(a) A number of candidates were unable to calculate he K_a value given its pK_a. $K_a = 10^{-3.75}$ is not an acceptable substitute/answer for K_a = 1.78 x 10^{-4}. Generally, candidates recognized that a small K_a value implied a weak acid. Calculation of the hydrogen ion concentration, and calculation of the pH of the solution was not done well. Errors in writing K_a expression, and substitution of values were of concern. Candidates must include units when concentrations are being expressed. Many candidates did not correctly indicate the assumption made in such calculations (either dissociation of the weak acid is negligible or 25°C were acceptable answers).

(b) Preparation of (an optimum) buffer where pH = pK_a requires equal concentrations of the weak acid and its conjugate base so that the K_a expression reduces to K_a = pH. This can be achieved in several ways, but candidates generally did poorly on this part, and some had no idea how to proceed.

Question 5

(a) Some candidates wrote equations for the oxidation of sodium, and the reduction of chorine gas, suggesting they misunderstood the question. Formation of sodium was not uncommon, in spite of part (a)(ii), which clearly indicates sodium is not formed.

(b) Few candidates were able to score full marks on this question. Sodium and fluorine were frequently stated as products suggesting a lack of understanding of redox principles.

Section B

Candidates should always look at the number of marks available, as this is an indication of the detail/length and type of the answer expected. Question 6 was the most popular of the four in this section. The remaining three were equally chosen.

Question 6

(a) To only state that the oxides turn from basic to acidic does not answer the question. Many candidates did not recognize that argon has no oxide. Candidates were generally able to describe the acid-base character of the oxides of period 3, but most candidates could not write balanced equations to illustrate the amphoteric nature of aluminium oxide.

(b) The question on d-block chemistry was not done well. A common but inadequate explanation of why V^{3+} (aq) is coloured was "that vanadium is a transition metal". It was common to see either no or incorrect electronic configurations used in answering the question (for example $4s^2 3d^8$ for Zn^{2+}).

(c) Ionization energy and atomic radii were generally well done. Candidates were able to articulate their answers based on the nuclear charge, and determine from which energy levels the electron(s) came.

(d) Ligands and complex ion formation based on Lewis acid-base theory was generally well done.

Question 7

(a) The trend in the boiling points of the hydrides of group 6 and why water has the highest boiling point amongst the hydrides were generally well done.

(b) Candidates had difficulty recognizing that butane and chloroethane are insoluble in water due to their non-polar nature or little polarity of the molecules preventing them from forming hydrogen bonds with water. Propanone and porpan-1-ol are polar, can form hydrogen bonds with water and are water-soluble.

(c) Many candidates drew a double bond between the atoms in carbon monoxide instead of a triple bond and missed the concept of resonance to give equivalent bond lengths. A number of candidates did not know the formula of the carbonate ion. Few candidates could explain why the bonding in the carbonate ion is longer than the double bond in carbon dioxide, or the triple bond in carbon monoxide. The formula ClF_3 (chlorine trifluoride) appeared as CIF_3 (trifluoroiodomethane) due to a printing error. Those candidates who based their answers on the latter were able to score full marks.

(d) Candidates drew poor versions of the possible Lewis structures of N_3H in which the atoms can be arranged as NNNH. Five bonds around nitrogen or nitrogen atoms with incomplete octets were very common.

Question 8

(a) Most candidates who attempted this question were able to determine the rate expression for the reaction and the reasoning was often clearly given. Strong candidates were able to discuss the three mechanisms given and propose another consistent one. The first mechanism is not consistent since the slow rate-determining step involves only one NO and one O_2, not two NO and one O_2 as required by the rate expression. The second mechanism given is consistent but unlikely since it requires three particles to collide at the same time.

(b) Most candidates were able to explain the shape of each line until equilibrium is reached, when the rate of the forward reaction is equal to the rate of the reverse reaction.

(c) This part was well done and most candidates recognized that the reaction was endothermic. The equilibrium constant increases since the forward reaction is favoured using up some of the heat supplied. Generally, an explanation was provided rather than the inadequate phrase "because of Le Chatelier's principle".

Question 9

(a) Candidates had difficulties articulating three characteristics of an homologous series (any three of: same/one general formula, differ by CH_2, similar chemical properties, gradual change in physical properties). Some candidates missed the higher boiling point of ethanoic acid due to stronger intermolecular forces. A number of candidates could not draw the four structural isomers of alcohols of formula C_4H_9OH; some included ethers, and others wasted time writing down names which were not asked for. The optical isomer was identified by almost all who answered this part.

(b) The question on esterfication and the use of sulfuric acid in the reaction was well answered. Candidates were generally able to write the balanced chemical equation, and draw the structural formula of the ester, although some missed H_2O as the other product.

(c) Almost all candidates identified compound II with the C=C double bond that would react readily with bromine. Candidates were generally able to identify the infrared absorption at 1610 – 1680 cm^{-1} as a distinguishing feature. The use of ^1H NMR to distinguish between the two compounds was harder. Compound I would have three peaks in the ratio 1 : 2 : 3, whereas compound II would show three peaks but in the ratio 1 : 1 : 2. The last part on addition polymerization was not done well, and candidates generally did not appreciate that the addition was across the C=C double bond.

Assistance and guidance for future candidates

- Teachers are strongly urged to refer to past examination questions and their markschemes to assist candidates with examination preparation.
- Candidates must know the meanings of the different action verbs that appear in the curriculum as assessment statements and in the examination papers.
- Candidates should aim to match their answers to the number of marks allotted.
- Candidates should be encouraged to "keep going" with calculations as 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 calculations mentally to ensure the result is "sensible".
- Learn formal definitions.
- Plan answers rather than ramble at length.
- Penmanship, and hence readability, can be improved 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	8-15	16-20	21-25	26-31	32-36	37-50

General comments

Although this was the first November paper on the current programme, the number of options tested and the maximum mark are both unchanged (unlike in SLP3). The mean mark on this paper was slightly lower than last November, and there were slightly more candidates with very low scores. Almost no candidates infringed the rubric by answering questions from more than two Options. More detailed comments are given in the sections below.

The 26 G2 forms that were returned convey teachers' impressions of this paper. In comparison with last year's paper, less than half thought it of a similar standard, with most of the remainder considering it a little more difficult. Over three-quarters thought the level of difficulty to be appropriate. Syllabus coverage was considered satisfactory by nearly two-fifths and good by nearly two-fifths; a much larger number than last year (nearly a quarter) considered it poor. Clarity of wording was considered satisfactory by one-third and good by nearly two-thirds. The presentation of the paper was considered good by nearly three-quarters and satisfactory by the remainder.

Difficulties for candidates

Most candidates seemed very well prepared although a small but significant number gave the impression that they had not encountered much of the information or concepts before and performed very badly. The paper proved to be a good discriminator with the best candidates scoring high marks, particularly on those areas testing objective three. Precise details are given under the individual options in part C, but areas where considerable difficulty was encountered included:

- explaining how an intoximeter works
- stoichiometric calculations
- how Ziegler-Natta catalysts work
- interpreting Ellingham Diagrams
- the factors affecting the colour of transition metal complexes
- descriptions of the mechanisms of nucleophilic addition and addition- elimination reactions

Levels of knowledge, understanding and skill demonstrated

Clearly the majority of candidates were very familiar with the subject material. However, there are a few centres where candidates gave the impression that they had not been taught much of the material on the options they answered. This often correlates with the choice of options. As in previous years, centres where all the candidates answer the same two options tend to do considerably better than when a range of options is chosen. There is also a strong correlation between candidates' abilities to express clearly and concisely their ideas with their overall scores. Generally, most candidates demonstrated a good knowledge of the factual content of the options chosen. Areas that seemed particularly well known and understood included:

- identifying functional groups in medicines and drugs
- the structures of glucose and starch
- the reasons why unsaturated fatty acids have a lower melting point than saturated fatty acids
- the causes and effects of acid rain
- the conversion of iron into steel
- explaining how a photovoltaic cell works

Many candidates were able to write chemical equations correctly. A considerable number did not perform so well on the few calculations on the paper. Some candidates gave excellent answers to the questions on modern analytical chemistry but others found it hard to predict rather than interpret the ^{1}H NMR and IR spectra of propanal and propanone. On the further organic chemistry option, some candidates gave excellent answers, although there were many who were unable to recognise and describe the mechanistic pathways.

Strengths and weaknesses in individual questions

Option B – Medicines and drugs

This was the first time this option has been examined in the November paper and a good number of candidates selected this option. Question B1, on ways of injecting drugs into the body, was answered well. Almost all candidates understood what is meant by tolerance and why it is potentially dangerous. The way in which infra-red spectroscopy is used in the intoximeter was not well known. Most candidates could pick out and identify the correct class of amine group even in molecules that they were unlikely to have seen before, such as Ecstasy. Many candidates were not able to identify phenylethylamine as the common structural feature of the three sympathomimetic drugs in B3 (c)(i), even though it is specifically stated in the programme. Few candidates had difficulty with identifying the chiral carbon atom in ibuprofen in B4. Most were able to explain how chiral auxiliaries work, although many candidate left out the important point that the chiral auxiliaries are themselves optically active. Without this property one would be unable to create the stereochemical conditions necessary for a particular enantiomer of the drug to be synthesised.

Option C – Human biochemistry

This is a popular option and produced some good responses. Most candidates found little difficulty with question C1 parts (a), (b) and (c) on glucose and starch. A few candidates were unable to write the correct straight chain structure of glucose. The calculation for the combustion of sucrose produced many correct answers. Most errors resulted from the failure to express the heat evolved in kJ mol^{-1}. Most candidates realised that stearic acid is saturated and linoleic acid is unsaturated and how this affects their melting points and that no amount of iodine will add to stearic acid. About half of those who attempted it were able to calculate the mass of iodine adding to the linoleic acid in C2(b). The structure of DNA was generally well known in C3, although many candidates omitted to state that the phosphodiester bond occurs between the C_3 of the sugar and the neighbouring phosphate group. DNA profiling was generally described well, with a good number of candidates giving one way in which the bands separated by gel electrophoresis can be identified by, for example, using radioactive ^{32}P.

Option D – Environmental chemistry

Many candidates answered this option. Although there may be a perception that this is one of the easier options, answers given do not always bear this out. For example, very few candidates scored full marks for D1, which asked for a chemical method to reduce the amounts of specified primary pollutants entering the atmosphere. Some candidates had problems giving the correct equations and others chose a wrong method. Question D2 on acid rain was generally answered better, with most candidates knowing why unpolluted rain is naturally acidic and how acid rain can affect plants and buildings. Most were able to state correctly the definitions for LD_{50} and maximum daily tolerance in D3 but then often gave less than four disadvantages associated with these definitions in their discussion. The calculation for the maximum mass of sodium nitrate permissible in drinking water in D3 (b) was poorly answered.

Option E – Chemical industries

Responses suggest that some candidates concentrate only on factual content when studying this option. The first question on the factors influencing the location of modern chemical industries and the difference between intermediate and consumer products was generally answered well. Some candidates had difficulty giving suitable examples of intermediate and consumer products and sulfuric acid was often quoted to fit both. Those that knew that the mechanism for the formation of low density poly(ethene) is free-radical were able to describe the mechanism well in E2(a). Almost all candidates were able to state that a Ziegler-Natta catalyst is used in the manufacture of high-density poly(ethene). However, very few knew that it is the availability of the empty d orbitals on the titanium atom that enables it to form intermediate complexes with the π electrons of ethene molecules.

The explanation of Ellingham diagrams in E3 also caused problems. Candidates should be taught to understand them in terms of the order (or disorder) of the system and how the temperature will affect the overall value of ΔG. For example the line for the formation of carbon monoxide slopes *downwards* because one mole of gas is being converted into two moles of gas so the system is becoming more disordered and the factor $-T\Delta S$ becomes more negative with increasing temperature. The equation for the reduction of magnetite in E3(c) was given correctly in most cases. Most candidates were also able to give a reasonable answer for the conversion of ‘pig iron’ into steel in E3(d), although many did not mention that the temperature of the highly exothermic reaction is controlled by adding scrap steel.

Option F – Fuels and energy

Question F1 on the essential differences between chemical bond breaking and nuclear fission was not answered well and few candidates scored both marks. The common error was not to be specific enough either in terms of energy or of the particles involved. Almost all candidates correctly identified the product as a neutron in F1(b), but many were less successful in calculating the maximum amount of energy evolved when one mole of ^{235}U reacts completely. The most common error was to give the factor of ten to the wrong power. Most candidates were more successful in the calculation involving the half-life. A few were penalised for not giving the units of years in their answer. Most candidates were able to explain correctly why nuclear power stations contain a secondary coolant. In F2 (a), very few candidates correctly answered the octane rating question. The equations for the combustion of octane and the fermentation of glucose were well known. As with the other options, calculations concerning molar amounts proved problematic and relatively few got the correct answer for F2 (d) (ii). Although almost all of the candidates scored well on photovoltaic cells in F4, they were less sure about the advantages and disadvantages of converting water into hydrogen in F3. Most gave the possibility of an explosion as a disadvantage but did not often state that the conversion is inefficient or that the hydrogen must be stored and transported in large and heavy containers since it cannot be liquefied easily.

Option G – Modern analytical chemistry

This option produced some good answers. Most candidates made good attempts at question G1. Most realised that phenolphthalein is more conjugated in alkaline solution, but some failed to state that the consequence of this is that less energy is required to excite the electrons so the absorption occurs in the visible region of the spectrum. Candidates who understood the importance of the splitting of the d orbitals were able to answer In question G2 well. A number of candidates did not mention that the d orbitals are split scored few, if any, marks. G2 (b) seemed to discriminate between those candidates who had obviously studied the technique of determining an unknown concentration using a visible spectrometer and those who had not met it before. Few candidates realised the significance of the Beer-Lambert Law and that the law only applies to *dilute* solutions. Question G3 produced some interesting answers. Some candidates are probably more used to interpreting given spectra rather predicting the spectra that will be formed. Strong candidates realised, apart from the fingerprint region, that the IR spectra of propanal and propanone will be very similar. Propanone will only have one sharp peak (apart from TMS) in its ^{1}H NMR spectrum whereas propanal will show a triplet, a quartet and a singlet in the ratio of 3:2:1.

Many schools seem to favour the combination of Option G and Option H.

Option H – Further organic chemistry

Most candidates correctly indicated the fact that C=C and C=O bonds both contain a σ and a π bond in H1(a) but were less sure about a second similarity. Reference to reactivity rather bonding was a common error. C=O bond is polar was commonly given as one of the differences, but candidates were less forthcoming with bond length or bond strength as a second difference. The nucleophilic addition reaction with hydrogen cyanide was not well known. The paper's error with ethanal not propanal in the reaction made little difference. Answers having either $–CH_3$ or $–C_2H_5$ as the R group were accepted. The drawings of enantiomers were generally well done. Most candidates knew that the difference in their physical properties is their ability to rotate the plane of plane polarised light in opposite directions. Inadequate answers, such as rotate light or reflect light were common. The chemical differences were not generally known. The chemical properties of enantiomers are identical except in their reactions with other optically active compounds. In H2, very few candidates recognised that the conversion of a ketone to an alcohol is reduction. The mechanism for the elimination of water from an alcohol to form an alkene using sulfuric acid was not known by most candidates, even though it is one of the examples in the programme. Many candidates seemed unaware of the addition-elimination reaction of cyclohexanone with 2,4-dinitrophenylhydrazine reaction and few knew how the product could be used to confirm the identity of the cyclohexanone by taking its melting point and comparing it with known values.

Assistance and guidance for future candidates

- The options form an important part of the overall syllabus. Leaving the teaching of the options until last is strongly discouraged. If possible, refer to the options when covering the core part of the course and ensure that the recommended time is given to covering two options thoroughly.
- Use examples from the options to cover the stoichiometry part of the core programme to get candidates used to this type of question.

- Give candidates guidance about the level of answer expected. Journalistic answers to questions at this level will not suffice. Chemical equations should be given wherever possible. Organic mechanisms should be clearly described and definitions given precisely and accurately.
- Candidates often seem unfamiliar with some of the basic information.Provide candidates with adequate resources to complement the teaching of the options. Note that many text books do not contain/cover much of the option material. Give a copy of the syllabus to candidates so that they can run their own checklist.
- Strongly encourage candidates to answer questions **only** on the options they have studied.
- Ensure that candidates are aware of the importance of action verbs and that their answers address the questions that have been asked.
- Give candidates practice with past papers. Train them to pay attention to the number of marks allocated to each sub-question to ensure that they cover a sufficient number of different points to score the full range of marks allocated.

Internal assessment

Component grade boundaries (Standard and Higher Level)

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-15	16-21	22-27	28-31	32-37	38-48

General comments

The general standard of internal assessment was similar to last year. Some teachers in submitting work for moderation are not following instructions and some schools have submitted incomplete samples (most often where the Group 4 project is missing for each candidate in the sample). Note that submitting full portfolios is not a required. Common problems include incorrect completion of form 4/PSOW, absence of instructions given by teachers (particularly in the case of verbal instructions) and incorrect numbers of highlighted levels for moderation. Teachers are expected to follow the instructions provided in the latest edition of the *Vade Mecum*.

In many samples, teachers have monitored the candidates' work carefully and provided useful feedback. In other cases, there was little evidence of feedback. Often teachers used a grid where the aspects achieved for each criterion were indicated using the 'c, p, n' notation. Regular feedback using the c, p, n notation helps candidates achieve assessment criteria and helps the moderator validate teacher assessment based on application of IA criteria. Safety awareness and concern for the environment was evident only in some schools, but should be universal.

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. A majority of schools covered the areas of the curriculum well. Most practical work undertaken was of a suitable level. Overall, the options at both SL and HL were done reasonably well with some very good experiments included for moderation. However, concern still remains that some teachers were not familiar with the IA criteria. Teachers' are very strongly encouraged to refer to Teacher Support Material (TSM) now available on IBO's Online Curriculum Centre (OCC) where detailed examples of application of IA criteria are provided.

Several schools seem to rely exclusively on textbook "recipes" with detailed instructions. This denies candidates the opportunity to achieve all criteria. There were a number of schools whose practical schemes of work were short of the recommended number of hours (40 at SL and 60 at HL). A few required little planning. Candidates are less likely to score well when they are not given the opportunity to undertake more open-ended investigations.

Candidate performance against each criterion

Planning (a)
Teachers and candidates continue to have trouble with Planning (a). This requires teachers to provide a broad or general investigation problem, which then allows candidates to come up with their own focused problem to investigate depending on the independent and controlled variables chosen. Some candidates stated a hypothesis, but did not explain their reasons for it. Difficulties arose with poorly stated or inappropriate hypotheses. Statements such as "I will have a 10% loss from the theoretical yield" or "With a combination of NMR, IR and mass spectra, I will be able to determine structure of the compound", or "The result obtained should equal the established amount" are not be acceptable hypotheses. When appropriate, an effort should be made to explain a hypothesis at the molecular level rather as opposed to superficial hypotheses. This aspect needs to be built more firmly into the structure of the investigations. In many cases variables were not mentioned or only inferred in Planning (b). Note that all investigations are not susceptible to a hypothesis and/or a variety of variables. Such practicals are not appropriate for Planning (a). Please refer to the TSM on OCC for Planning (a) details and examples.

Planning (b)
In general, candidates selected suitable equipment and devised appropriate strategies to carry out investigations. Note that Planning (b) cannot be assessed if candidates have been provided with the method. Teachers should not provide a list of apparatus or materials, as candidates need to meet aspects of the criterion on their own. Control of variables should be explicitly indicated. For chemical reactions, candidates should show the workings based on stoichiometry (when appropriate) to indicate how they arrived at amounts of substances used. It is not uncommon for candidates to use large amounts of materials when a lab could be carried out on the micro scale – candidates must pay attention to environment when planning. Inclusion of appropriate controls is not generally well discussed. This follows from the failure to recognize the need for controls in the discussion of the variables, which should be reinforced by teachers. Few candidates seem to have the notion of fair testing or they assume it is self-evident. The collection of sufficient data was not considered at times. Replications are often limited to one repetition. Teachers often set up a practical so there is only one way to proceed in an investigation. Both Pl (a) and Pl (b) should enable different responses from different candidates within the same class.

Data Collection
This criterion was generally well carried out. 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 the indicator, and colour change at the end point of a titration). Uncertainties are often left out and there was frequent inconsistency in the use of significant figures. For example, in recording burette readings, a single table contained data such as: 5, 19.5, 20.37 cm^3. Note that the second aspect of the criterion (organizing and presenting raw data) cannot be assessed if the teacher has provided data tables. Some candidates do not seem to present raw data, but rather data that have been recopied afterwards. The two aspects of data collection specifically refer to recording and presentation of (appropriate) raw data. Teachers must avoid investigations for the Data Collection criterion when only a few values are being collected, or involve a small number of qualitative observations.

Data Processing and Presentation
Candidates were generally able to perform satisfactorily on this criterion, although high levels of achievement were not common. In some cases, processing of 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 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. Teachers must not provide too much information about how to process data and evidence should be present of candidates' ability to process data on their own, rather than by a series of prescribed steps in calculations. It often seems as if candidates have been told how to process the data; thus teacher's instructions are important for moderation. A computer/calculator may be used to draw graphs but the candidates must set up the graph from raw or processed data and make choices about graph format. A graph package that sets the format and analysis is not appropriate and denies the opportunity for the candidate to achieve this criterion. See information on computer graphing on the OCC.

Conclusion and Evaluation
This is an area where candidates habitually do not satisfy the requirements of all three aspects of the criterion. 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. Low scores result if candidates fail to evaluate the procedure, list possible sources of error and suggest improvement to the investigation following the identification of weaknesses. Comments such as "the readings must have been too low or too high" are not appropriate evaluations of the procedure. Trivial suggestions are not appropriate, instead reasonable systematic errors should be identified and then improvements should be proposed based on these. Note that all investigations are not appropriate for assessment of this criterion. Investigations such as the determination of enthalpy of neutralization, enthalpy of a redox reaction, determination of E_a or rates related investigations susceptible to systematic errors are conducive to meeting the requirements of this criterion.

Manipulative skills
The programmes in general provided good scope for assessment of this criterion.

The Group 4 Project
Most schools submitted evidence for participation in the Group 4 Project for each of the candidates in the sample. Some did not and a special request had to be made for the submission of such evidence. This is an essential requirement of the IB programme. It is also a very valuable exercise in practicing candidate-generated investigations and is an ideal opportunity to assess Personal Skills.

Recommendations for the teaching of future candidates

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, it is clear that the criteria are not clear to all candidates. Few candidates made reference to ethics, safety and environmental issues. Practical work 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 must be aware of the different aspects of the IA criteria and encouraged to fully cover each aspect of any criterion under investigation
- candidates may find sub-headings for each criterion useful
- many schools are evaluating investigations using a grid of criteria/aspect with c, p, n indicated clearly; use of a grid indicating the assessment details is **strongly** recommended

- full portfolios are not required and, unless specifically requested, should not be submitted
- individual evidence for participation in the Group 4 Project for **each** candidate in the sample should be submitted
- teachers must **not** provide too much information for Planning (a), Planning (b), Data Collection, Data Processing & Presentation and Conclusion & Evaluation criteria
- avoid using workbooks and worksheets with spaces to be filled in for internal assessment
- candidates need practice at proposing and explaining an hypothesis that is directly related to the research question
- 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 Conclusion & Evaluation criterion, teachers should require candidates to evaluate the procedure, list possible sources of random and systematic errors, and provide suggestions to improve the investigation following the identification of weaknesses
- teachers should not assess for a particular criterion if an investigation does not meet all aspects of the particular criterion
- please refer to the explanations and examples given in Phase 1 and 2 of the Teacher Support Material on the Online Curriculum Centre in planning and assessing of candidate's work
- teachers should refer to Chemistry curriculum guide and instructions provided in the *Vade Mecum* before submitting work for moderation.

