CHEMISTRY

Overall grade boundaries

Higher Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-32	33-46	47-56	57-66	67-76	77-100

Standard Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-30	31-42	43-53	54-65	66-75	76-100

Higher Level Paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-15	16-21	22-24	25-28	29-31	32-38

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. Nineteen of the questions were also used on the Standard Level examination.

Teachers' impressions of this paper were conveyed by the 118 G2 forms that were returned. In comparison with last year's paper, nearly three-quarters felt that it was of a similar standard, with more of the remainder considering it a little more difficult. The level of difficulty was considered to be appropriate by the vast majority. Syllabus coverage was considered good by about half and satisfactory by about half of the respondents. Clarity of wording was felt to be satisfactory by over half and good by most of the rest. The presentation of the paper was considered good by over half and satisfactory by the remainder.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 93 % to 27 %. The discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates), ranged from 0.53 to 0.02 (The higher the value, the better the discrimination.)

The following comments are made on individual questions.

4 The correct response (A) attracted more candidates than any other, but substantial numbers chose B and C as well, indicating that the stoichiometry of the reaction was not known.

10 Just over a half chose the correct response (C), although D was a popular distractor. It is accepted that it would have been better not to have used the term “spontaneous”.

12 Although the correct response (B) attracted more candidates than any other, substantial numbers chose A.

13 This was a difficult question, with many more candidates choosing response C than the correct response (B), no doubt thinking of the delocalization that would exist in the methanoate anion.

14 This was the most difficult question on the paper. After looking the comments received, it was decided that asking candidates to work out that the triiodide ion is linear rather than bent, was inappropriate; the question was deleted.

18 Over half chose the correct response (D), with substantial numbers choosing A.

23 Nearly two-thirds of candidates chose B rather than the correct response (D) suggesting that many consider that collisions involving four particles are likely.

30 Although this question discriminated well, more candidates chose D than the correct response (C), presumably dividing the K_a value by the concentration.

31 Many more candidates chose A rather than the correct response (C), presumably not realizing that a reaction would occur in II that would produce the extra substance needed for buffer action.

34 Although well over half chose what was intended to be the correct response (D), the comments made on the G2 forms, that C could also be correct at low solute concentration, was accepted. Both answers were allowed.

37 Nearly half the candidates chose the correct response (C), with D being the most popular distractor.

39 Nearly half the candidates chose the correct response (C), with most of the remainder choosing A. Although the discrimination index was satisfactory and candidates are expected to know that benzene undergoes substitution reactions, some teachers commented that the question went beyond the syllabus requirements. After careful consideration, the question was deleted.

Higher Level Paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-13	14-27	28-41	42-50	51-60	61-69	70-90

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 that proved difficult for candidates

- recall of formulas (e.g. nitric acid as well as the more complicated complex ions)
- ability to account for the physical properties of substances in terms of the bonding present
- definitions and units
- determination of a limiting reagent
- understanding of the operation of the mass spectrometer
- organic reaction sequences.

Knowledge, understanding and skills demonstrated

- rate calculations, catalysis and factors that affect rates of reaction
- calculation of A_r
- electron configuration
- acids and bases
- electrolysis calculations

Strengths and weaknesses in individual questions

Section A

Question 1 was a good opening question and the candidates frequently scored good marks. The examiners tried to ensure that errors were carried forward so that an early error did not disadvantage a candidate in later parts of the question.

(a) Candidates found it difficult to explain exactly what they meant. These definitions are worth learning.

(b) Candidates should be advised to show *how* they make their deductions rather than present the examiner with a bare answer.

(c) Some candidates omitted the rate constant from the rate expression and others seemed to think that [A] with no power represents zero order.

(d) Candidates tended to omit the units, or gave the time in s^{-1} rather than min^{-1}.

(e) Many candidates suggested that the rate would double rather than increase by a factor of 4.

(f) Many candidates seemed to be unaware of the sequence of events in heterogeneous catalysis – adsorption at active sites, weakening or breaking of bonds, followed by desorption. Others answered this very well.

(g) (i) Many candidates scored well here although there were a number who included inhibitors in their answer.

(ii) Some candidates misread the question and thought that they had to describe the effect on the equilibrium of decreasing the temperature.

Question 2 was straightforward and there were many candidates who achieved high marks.

(a) Whilst the mark for electron gun was usually scored, candidates did not always realize that they had to "knock" the electrons out of the atom.

(b) This was usually answered quite well, but the electric field was sometimes explained (rather than named) rather poorly. There was a tendency for the magnetic field to be used for both functions.

(c) There was usually little problem with this but some candidates did the calculation correctly and then quoted the answer as 24.3. The significance of the request for three *decimal* places is that the answer can only be achieved by the correct calculation (rather than using the Data Booklet!).

(d) Candidates had few problems here.

Question 3 was a little more demanding.

(a) Many candidates answered this correctly, although there were some that gave an incomplete definition such as "hydrogen donor".

(b) (i) Inevitably there were some candidates who repeated the question – *because HCl is a strong acid* – instead of explaining the difference in dissociation.

(ii) The pH of hydrochloric acid was generally given correctly, but many candidates attempted to calculate the pH of ethanoic acid rather than *suggest* a reasonable answer, i.e. greater than the value given for HCl and less than 7.

(c) The most common error was to omit the equilibrium sign from the equation. Others gave "H^+" as the acid rather than "H_3O^+".

(d) Some candidates left this as a power of ten ($10^{-4.76}$) and did not actually calculate a value.

(e) The common error was to include [H_2O] in the denominator.

(f) There were many good answers given to this part. Some candidates lost credit through carelessness (e.g. forgetting to take the square root).

Question 4 produced some surprisingly poor answers overall.

(a) All sorts of suggestions were made for the formula of nitric acid (some were similar to ammonia) and copper(II) oxide was often thought to signify Cu_2O. Nevertheless the examiners did their best to carry forward the mole ratios given in the equation into the remainder of the question

(b) Candidates could do this although there were simple errors such as being a factor of 10 out.

(c) Candidates found it hard to *justify* the limiting reagent clearly although many correctly identified it and determined the number of moles of copper(II) nitrate to be formed.

(d) The correct formula mass of the trihydrate was rare but the rest of the calculation usually received a mark under the *error carried forward* principle.

Section B

As a broad generalization, the more able candidates tended to choose questions 5 and 6 whilst the others opted for questions 7 and 8.

Question 5 was generally answered quite well and there were a good number of high-scoring scripts.

(a) Few candidates were unable to identify the correct bonds although some forgot to specify *both* bonds in compound **C**. Some candidates were unfortunate enough not to notice that there is no nitrogen in the formula and so failed to eliminate one of the possibilities for the 3400 cm^{-1} absorption.

(b) Many did not indicate that **A** was butan-**1**-ol and quite a few drew and named but-**2**-ene. Candidates must be careful to distinguish between the letters *a* and *o*. As so often, many of the structures of **B** gave no thought to what came before or after. Hence, butanone was a common answer. Any answers based on the identification of **A** as 2-methylpropan-1-ol would have received full credit.

(c) (i) Few candidates had a problem with this part although there was a good deal of sloppiness – dichromate being written rather than *potassium* or *sodium* dichromate.

(ii) Some had difficulty explaining why **B** might be further oxidized to **C**.

(d) This was often referred to as condensation rather than elimination or dehydration and the reagent was frequently wrong or omitted.

(e) This caused some difficulty to the candidates and the gaseous product was frequently some sort of sodium compound. Sodium butanoate was not very well known and the formulas of the products proved challenging.

(f) This was straightforward if the candidate understood about hydrogen bonding. Even though candidates were only asked to list compounds **A**, **B** and **C** in order of increasing boiling point, some also included compound **D**. Many indicated that boiling would involve breaking the covalent intramolecular bonds.

(g) Candidates seemed familiar with the concept of chirality.

Question 6 produced a variety of responses; some diagrams were particularly poor.

(a) (i) A number of candidates seemed keen to include a voltmeter in place of a power source as they confused an electrochemical cell with an electrolytic cell. Many candidates failed to label the *molten* NaCl. Most electrons seemed to travel in the correct direction but candidates could be quite sloppy about indicating the product at each electrode, although a fair attempt was made to balance the half-equations.

(ii) Most gave hydrogen, some with suitable explanation, but a surprising number gave oxygen in place of the chlorine.

(iii) Many candidates completed the calculation successfully.

(b) (i) Only a few candidates omitted the sign of the oxidation number (although some wrote 3+ instead of +3) and most indicated why this can be described as oxidation of carbon. A common error in the half-equation was to write C_2O_4 instead of $2CO_2$.

(ii) There was often some carelessness here with charges being omitted at random and manganate(VII) being used in place of dichromate(VI).

(c) (i) Candidates who answered without thinking were more concerned with the pressure than concentration of the solutions.

(ii) The contents of the salt bridge were rarely specified.

(iii) The weakest part of this answer was the value of the combined electrode potential, a common response being 0.57 V. Candidates must practise writing cell notations; too many write the species in the wrong order or omit the state symbols.

Question 7 should have given candidates the opportunity to think and express their thoughts clearly. The concepts involved are, however, difficult and lucid answers were not generally the norm. This was probably the question in which candidates scored less well.

(a) (i) Many candidates merely *stated* the trends and tried to explain the two trends together instead of giving a coherent answer for each trend.

(ii) A surprisingly large number of candidates were unable to write a correct balanced equation, many giving lithium oxide as a product. The comparison between Li and K was not always clear.

(iii) Candidates did not always pay sufficient attention to the mark allowance and the answers lacked depth.

(b) Discussion of electronic structure instead of bonding was a common failing in this part.

(i) There seemed to be a good deal of confusion about how metals bond. Many described ionic bonding instead of metallic and many focussed on ionisation energy issues.

(ii) Many candidates realized that they needed to describe a giant structure of covalently bonded atoms. Many, however, did not relate the high melting point to the energy required to break these covalent bonds.

(iii) There was a general lack of understanding of the small nature of these molecules.

(iv) In comparison with phosphorus, sulfur is a larger molecule with a higher M_r – but candidates seemed to want to find something more complicated than this. Again, reference to the mark allocation would have provided a clue.

(c) This was probably the question attempted with the least success. Candidates need to know the formulas of very few complex ions; those referred to in this question are all specifically mentioned in the syllabus. In general, there was very little knowledge of these complex ions.

Question 8 attracted a large number of candidates, but not always with success. Candidates need to write carefully and precisely about the different concepts examined.

(a) (i) Candidates found it difficult to explain the hardness of diamond, although graphite was generally better treated. They often did not make clear the distinction between the electrons localised in bonds in diamond and those delocalised between the layers in graphite.

(ii) Good candidates had no trouble with this part; others failed to draw the distinction between intramolecular and intermolecular bonds/forces of attraction.

(iii) Many candidates seemed to be under the impression that the ions only form when the solid becomes molten. Others thought that conduction was caused by the movement of electrons.

(b) This question was typified by some really poor diagrams. Candidates need to be taught carefully how to draw two-dimensional representations of 3-D shapes.

(i) Many did not appreciate the presence of the lone pairs and hence the square planar shape.

(ii) The tetrahedral shape was generally better known.

(iii) This was often answered well, but there were many indications of a planar molecule.

(c) (i) Hybridization produced a variety of answers. It was pleasing to see some very good answers and others that indicated in diagrammatic form the promotion of the 2s electron and mixing of the s and p orbitals. Sigma bonding produced some diagrams that were more likely to score the marks than many descriptions. Most candidates knew that ethane is sp^3 hybridized.

(ii) Some were able to draw good diagrams and the hybridization was generally well known, although many answers were poorly expressed.

Recommendations and guidance for the teaching of future candidates

- Candidates need to familiarize themselves with the equations for simple reactions included in the syllabus.
- Candidates need to make sure they understand the basic concepts involved in chemical bonding.
- Candidates should, where appropriate, illustrate their answers with simple, neat and well-labelled diagrams.
- Check the answer on a calculator mentally to ensure it is "sensible".
- Encourage candidates to keep going during calculations as errors are "carried forward".
- Candidates should take note of the mark allocation of each question.

Higher Level Paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-21	22-26	27-31	32-36	37-50

The areas of the programme that proved difficult for candidates

90 % of the teachers who returned G2 forms judged that the paper was appropriate and of a suitable standard. This was reflected in the answers provided by the candidates. Candidates, on average, did not achieve significantly higher marks on any one particular option and it was noticeable that they tended to score approximately equal marks on the two options they answered. This suggested that there was good parity between the different options.

Superficially, some of the options, for example Option D - Environmental Chemistry, appear to ask questions demanding more recall and therefore are sometimes considered easier than other options, such as Option G - Modern Analytical Chemistry, where more interpretation is required. However there is no evidence from the marks scored to support. Even though these reports repeatedly make the point, every year some candidates still lose marks by giving answers that are far too superficial or contain little chemistry. For example, very few candidates mentioned that it is the vibration of the bonds that causes greenhouse gases to absorb infrared radiation.

The levels of knowledge, understanding and skill demonstrated

The paper discriminated well between candidates and the better candidates gave some excellent answers, showing that they had been well prepared. As in previous years, candidates from centres where different combinations of options were attempted tended to show less detailed knowledge compared to those where most candidates answered the same two options. It is clearly in the candidates' interest for teachers to cover two options thoroughly rather than allow their candidates to study a variety of options on their own. Most candidates gave good answers to questions involving recall and most of those attempting Option G were able to make sensible conclusions from the spectra presented. It was pleasing to see that many of the candidates attempting Option H were able to use 'curly arrows' correctly although some did get confused over the different mechanisms.

Option C - Human biochemistry

Candidates generally performed well on this option. Most recognised that **W** and **X** would be water-soluble. They correctly stated that **W** contains several -OH groups but some did not then go on to state that these groups can form hydrogen bonds with water molecules. Many of those who chose **Z** also talked about several -OH groups, which scored the marks. However, this is probably less important than the fact that the molecule contains a charged group. Most realised that vitamin C dissolves in the water when vegetables are boiled but few stated that the vitamin is also oxidised. Vitamin C has several important functions in the body, but there is no reliable evidence that it prevents the onset of the common cold. Almost all candidates knew that a deficiency of vitamin C leads to scurvy.

Many candidates were able to correctly outline what is meant by a monosaccharide although a few simply stated that it is a single sugar molecule. The condensation of two monosaccharides to form sucrose was generally well known. Several candidates had problems interpreting the graph in C4. They tended to assume information that was not actually in the graph. For example, many stated that 40 °C showed the optimum temperature whereas the graph simply showed that as the temperature increased from 10 °C to 40 °C there was an increase in the rate of breakdown of starch. The graph also showed that the enzyme was inactive after it had been boiled. Most candidates explained why the amylase became inactive when boiled but did not adequately explain why the rate of catalysis increased with temperature. In C5 most candidates knew how two nucleotides join together but often omitted to include two phosphate groups in their final diagram. There was also some confusion over the correct pairing of bases by hydrogen bonding.

Option D - Environmental chemistry

This was a popular option and was answered well by many candidates. Most candidates were able to explain correctly that rain is naturally acidic as it contains dissolved carbon dioxide. Most also knew the two major pollutants which cause acid rain and could correctly identify the man-made source. A few candidates are still giving “car exhaust” as a source of nitrogen oxides rather than the combination of oxygen and nitrogen from the air at the high temperatures reached in the internal combustion engine. Some candidates failed to read the next question carefully and only gave one method by which each pollutant could be reduced. Virtually every candidate could name two greenhouse gases in D2 but very few scored the maximum marks for explaining how these gases contribute to the greenhouse effect, as most omitted the explanation on the molecular level. In D3 the ozone-oxygen equilibrium in the ozone layer was usually described well, although many candidates did not relate the wavelength of light necessary to break the O–O bond with the different bond strengths in oxygen and ozone. Generally those candidates that answered D3 (a) well also answered D3 (b) well, as the mechanisms have many similar features - for example they both occur by free-radical reactions.

Option E - Chemical industries

This option was probably answered by the smallest number of candidates. Good candidates answered it well but many poorer candidates seemed ill-prepared. The question on the production of aluminium revealed that whilst many candidates had a general knowledge of the process, very few understood it in detail. The weaker candidates were unable to explain why carbon is not used to reduce aluminium oxide and a surprising number were unable to give the correct equations for the reactions occurring at the electrodes. In E2 most were able to give the equation for the combustion of sulfur and explain the effects of increasing the temperature and pressure on the yield of sulfur trioxide. However, many candidates seemed unaware that a high pressure is not used as the yield is already very high at atmospheric pressure and also did not state that an optimum temperature is used to obtain a reasonable yield at a reasonable rate. Sulfuric acid is still one of the most important chemical feedstocks and yet many candidates were unable to give four major uses for it in E2 (d). Use as a reagent in school laboratories hardly qualifies as a major use.

Question E3 asked candidates to differentiate between the mercury cell and the diaphragm or ion-exchange membrane cell in the chlor-alkali industry. Many were confused about their relative advantages and disadvantages and there were also some wrong answers given for the reactions taking place at the electrodes, even though much of this question was based on recall.

Option F - Fuels and energy

Most candidates were able to name the three radiations and assign the correct charge and penetrating power to them. Most were also able to solve the problem involving half-life in F1 (b). However, many candidates could not give a satisfactory answer as to why it is meaningless to refer to the half-life of a single atom; the idea that decay cannot occur if there is only one atom left in the sample was common. Although the neutron : proton ratio in F1 (c) was usually calculated correctly, candidates seemed less able to relate this to the band of stability and predict how an atom of ^{90}Sr will decay.

In F2 the advantages of using air and water in active solar heating were not clearly understood. Many tended to talk rather vaguely instead of using the correct technical terms such as the high specific heat capacity (for water). Most candidates were familiar with the equation for the photosynthesis of glucose and the need for chlorophyll. Although appearing in the syllabus, the term *intrinsic* when used with semiconductors seemed unfamiliar to most candidates. Even so most guessed correctly what it meant and were able to explain how the doping of silicon can be used to form the different layers in a photovoltaic cell in F3.

Option G - Modern analytical chemistry

Most candidates who answered the questions on this option seemed well prepared. Almost all knew that TMS is used a reference in ^1H NMR spectroscopy and most were able to explain the information that can be obtained from the number of peaks and the area under each peak in G1. Some lost marks through carelessness. The number of peaks does not give simply the number of different chemical environments - it gives the number of different chemical environments in which hydrogen atoms are located. When using the Data Booklet for chemical shifts, candidates need to be aware that they can vary slightly. The peak at 1.3 ppm due to the methyl group is shifted downfield from its usual position of 0.9 ppm by the presence of the oxygen atom in the molecule. Even so most candidates were able to identify the compound correctly as ethyl ethanoate. Many correctly identified magnetic resonance imaging in G1 (f), but some candidates erroneously thought that as X-ray crystallography is on the syllabus, the technique must involve the use of X-rays.

Almost all candidates gained full marks for outlining the basic principles of chromatography in G2 (a). The best answer for the technique to separate a mixture of liquid hydrocarbons in G2 (b) is probably gas-liquid chromatography but high performance liquid chromatography was also accepted.

Option H - Further organic chemistry

Many candidates gave good answers to the questions on this option. Almost all gave the correct structures for the three compounds in H1 (a) and many also explained the mechanism of electrophilic addition correctly in (b). It was pleasing to see far fewer answers than in previous years just stating Markovnikov's rule as an explanation for the formation of 2-chloropropane. Most candidates do now realize that the relative stability of the intermediate carbocation is the key factor. The mechanism for the elimination reaction in part (c) was less well known, although both E1 and E2 mechanisms were accepted.

The reactions of ethanal in H2 were generally known well and many candidates gave the correct formula for the product formed between C_6H_5CHO and 2,4-DNPH. What was less well known was how 2,4-DNPH can be used to identify different carbonyl compounds. Although this is now a rather old method and modern laboratories would probably use spectroscopic techniques, it is still on the syllabus. Even candidates who knew that a coloured product is formed often did not state that it would need to be purified before the melting point is measured. A surprising number of candidates thought that the compound could be identified from its colour alone. Most candidates correctly knew or deduced the structure of 2-hydroxypropanoic acid in H2 (c) and could recognize that it possesses a chiral centre.

Recommendations and guidance for future candidates

- Some candidates had difficulty in answering the question asked. Sometimes parts of the question were missed and at times questions were misread. This can be overcome, at least in part, by frequent practice in examination type questions. Candidates should be given regular assignments and tests from past examination and specimen papers. This will give them the opportunity to develop the skills of answering questions clearly, directly and completely, so that they are not penalised for failing to answer the question asked. For example, if a question says give two properties of aluminium that make it suitable for use as cooking pans then one will not suffice. Candidates also need to be completely familiar with the action verbs and which objectives they relate to.
- Provide candidates with adequate resources to complement the teaching of the options. Apart from specific IB textbooks, many chemistry books do not contain enough information to cover the options and candidates often seem unfamiliar with some of the basic information.
- Responses to questions should demonstrate both depth and breadth. Candidates must ensure that they cover a sufficient number of points to score the marks allocated to each question.
- There must be a meaningful relationship between theory and practice – classroom presentations / discussions and practical investigations must reinforce each other.
- 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 at all.
- Teachers are advised to cover two options thoroughly and not to 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.

Standard Level Paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-14	15-17	18-21	22-24	25-30

General comments

This paper consisted of 30 questions on the Subject Specific Core (SSC) and was to be completed without a calculator or Data Booklet. Each question had four possible responses, with credit awarded for correct answers and no credit deducted for incorrect answers. Nineteen of the 30 questions were also used on the Higher Level examination.

Teachers' impressions of this paper were conveyed by the 136 G2 forms that were returned. In comparison with last year's paper, nearly two-thirds of respondents felt it was of a similar standard, with more of the remainder considering it a little more difficult than a little easier. Nearly all thought the level of difficulty was appropriate. Both syllabus coverage and clarity of wording were considered good by about half and satisfactory by about half. The presentation of the paper was considered good by about two-thirds of respondents and satisfactory by one-third.

The most common general comment made in the G2 forms was the difficulty experienced by many candidates in finishing in the time allowed, and this was mainly attributed to the number of numerical questions, most (although not all) involving calculations. This criticism will be borne in mind in setting future papers.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 84 % to 22 %, and the discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates), ranged from 0.58 to 0.22. (The higher the value, the better the discrimination).

The following comments are made on individual questions.

4 The correct response (A) attracted more candidates than any other, but substantial numbers chose B and C as well, indicating that the stoichiometry of the reaction was not known.

10 Just over a half chose the correct response (C), although D was a popular distractor. It is accepted that it would have been better not to have used the term “spontaneous”.

12 This discriminated well and almost half chose the correct response (A), although C was a popular distractor.

13 Although the correct response (B) attracted more candidates than any other, substantial numbers chose A and C.

16 This discriminated well, although a surprising number of candidates selected response A.

18 Over half chose the correct response (D), with substantial numbers choosing A.

20 This was the hardest question on the paper and did not discriminate well. About two-thirds chose B rather than the correct response (D) suggesting that that many consider that collisions involving four particles are likely.

22 Although over half chose the correct response (A), C attracted many candidates, suggesting that correctly applying Le Chatelier's Principle is easier with volume changes than with heat changes.

25 This discriminated well, although a large number of candidates chose response A.

27 The correct response (D) was given by the largest number of candidates, although C attracted nearly as many.

29 Although this was answered correctly by nearly half the candidates and it discriminated quite well, response C attracted many candidates.

Standard Level Paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-17	18-21	22-26	27-30	31-40

General comments

The general performance of the candidates was satisfactory and most of them had been adequately prepared for the examination. The actual performance varied from centre to centre and covered the entire mark range, so the examination was seen to discriminate successfully. There were possibly fewer very high scoring candidates than in previous years. Only a small percentage of the candidates opted for question 4 in Section B.

Teachers' impressions of this paper were conveyed by the 117 G2 forms that were returned. In comparison with last year's paper, over three-quarters of respondents felt it was of a similar standard, with rather more of the remainder considering it a little easier than a little more difficult. Nearly all thought the level of difficulty was appropriate. Both syllabus coverage and clarity of wording were considered good by about half and satisfactory by about half. The presentation of the paper was considered good by about two-thirds of respondents and satisfactory by one-third.

Strengths and weaknesses in individual questions

Section A

QUESTION 1

a) This was almost always answered correctly. Errors occasionally arose when electrons were added to make the cation and lost to make the anion.

b) Errors in this part were mainly of omission, in particular that the electrons are being added to the same principal energy level or that the shielding effect is essentially unaltered.

c) Most candidates were aware of the gain and loss of electrons to produce the ions but the majority failed to state that the anion had one more filled energy level.

d) (i) & (ii) Most candidates were able to state that (i) gave an acidic solution and that (ii) was alkaline or basic. The equations proved to be much more difficult. A lot of answers had the proton as a product for the reaction with sodium or gave equations that were unbalanced. The reaction with chlorine was known by a very small number of the candidates.

QUESTION 2

a) This was generally well known, although a few candidates did suggest that the two substances were bases because they generated hydroxide ions in solution, and a few referred to electrons rather than protons.

b) Most answers omitted any comparison between the two solutes. So "sodium hydroxide is a strong base" is not a full answer without any explanation as to why this is different from a weak base.

c) Many of the equations were incorrect because charges were omitted from the ionic products. Some candidates classified the reactants rather than the products as acid or base.

QUESTION 3

This question was generally well answered. The principal error in (a) was to omit the water in calculating the molar mass. The other two parts were marked consequentially, so part (b) usually scored the mark, as did (c), except in those cases where the atomic mass of copper was used instead of the molar mass of copper(II) oxide.

Section B

QUESTION 4

This was the least popular choice.

a) Compounds **A** and **C** were usually identified, most difficulty being with the identification of compound B.

b) Esterification was generally recognised, as was water as the other product. Sulfuric acid was the catalyst of choice for only a minority of candidates. Most were able to name a use for a compound of the same type as **D**.

c) This proved to be the most difficult part of the question. A few candidates gave hydrogen as the gas evolved but a formula for magnesium ethanoate proved too difficult for all but the very best candidates.

d) Most candidates had problems in arranging **A**, **B** and **C** in order of increasing boiling point, and some included **D** in their list; their explanations were often very confused. Dimerisation of ethanoic acid was very rarely mentioned. A significant number of answers related to the strengths of intramolecular bonding rather than intermolecular forces.

e) A few candidates identified one of the possible isomers, but most of these were not able to give it a correct name.

f) An encouraging number of candidates knew the meaning of a chiral centre.

QUESTION 5

This was the most popular of the optional questions.

a) Equality of rates of forward and reverse reactions was known - constancy of composition less commonly, in fact it was often stated that "the concentrations of reactants and products are equal".

b) A surprisingly large number of candidates stated that an homogeneous reaction was one that gave a single product.

c) This part was usually answered correctly, even by the weaker candidates.

d) There were many errors here. Some of these could be due to misreading the question, with answers relating to the position of equilibrium rather than the rate of reaction. Of those who discussed rates, it was common for the change in rate to be stated for one direction only.

e) Few candidates named "iron" as the catalyst. The list of suggestions was very extensive. In explaining the effect of a catalyst many considered the increase in rate or the decrease in activation energy, but very few mentioned that this effect operates by the same factor in both directions.

f) Many answers to this section were incomplete. "More collisions" was seen more often than "more frequent" or "more energetic" collisions.

g) Answers to (i) were usually correct. Responses to (ii) frequently referred to the rate of reaction. Many weaker candidates mentioned "the reaction" rather than "the position of equilibrium".

QUESTION 6

a) (i) The type of bonding in sodium was described variously as ionic, covalent, molecular and metallic. Very few candidates described an attraction between positive ions and delocalised electrons, though most were aware that it is these electrons that allow sodium to be an electrical conductor.

(ii) It was not uncommon for an answer to show a fluorine atom rather than a fluorine molecule. Knowledge of the forces between molecules was particularly poor. A surprisingly large number failed to describe a covalent bond as a shared pair of electrons.

(iii) Many candidates gave correct electron configurations for Na and F but explained the bond as covalent and drew a Lewis structure with a shared electron pair.

(iv) The most common error involved reference to the movement of electrons rather than ions.

b) Most candidates could name the shapes of silane and phosphine but many diagrams had no three-dimensional look to them. A few candidates thought that it was the names of the compounds rather than their shapes that were required.

c) The angle was usually identified correctly. The explanation for the smaller angle of phosphine was less convincing Some candidates think that repulsion is from lone pairs only, others referred to repulsion by the hydrogen atoms.

Assistance and guidance for future candidates

- As in previous years candidates would benefit from more attention to examination technique. It often appeared that marks were lost by candidates who gave good responses to a question other than the one asked.
- If time is available, candidates should practice using past papers.
- Candidates should also practice making use of diagrams in their answers, especially in VSEPR theory where the three-dimensional nature of molecules needs to be shown.
- From the range of marks awarded it was evident that all the material for the examination had been covered by the majority of candidates. However, the small number of answers to

question 4 suggests that organic chemistry may have received less attention. Areas that have surfaced again as in need of extra teacher support include:

- balancing equations
- conduction - whether by electrons or by ions
- intermolecular and intramolecular forces and metallic bonding
- the difference between position of equilibrium and equilibrium constant

Standard Level Paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-17	18-22	23-28	29-33	34-45

General comments

The range of marks awarded was very wide. The best candidates showed a thorough command of the material and a high level of preparation, but some candidates seemed unfamiliar with the options answered and scored very poorly, either through omitting many parts or guessing wildly. Candidates should be strongly encouraged not to attempt more than three options, but if they do, it is vital that the ones to be marked should be indicated on the front cover.

Teachers' impressions of this paper were conveyed by the 112 G2 forms that were returned. In comparison to last year's paper, three-quarters thought this year's paper was of a similar standard, and most of the remainder thought it easier rather than more difficult. Almost all thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by over a half and good by most of the rest. Clarity of wording was considered good by over half of the respondents and satisfactory by the remainder. The presentation of the paper was considered good by two-thirds and satisfactory by the rest.

Difficulties for candidates

Many of those who chose Option A did not score well, showing difficulties with writing formulas, recalling reactions in the syllabus and providing explanations. Chemical equations revealed many problems, including the formation of products containing elements not present in the reactants, as well as the more common faults of incorrect formulas and lack of balancing. Standard definitions, such as that for weak acid, and expressions, such as that for K_a, were often poorly done. Difficulties in distinguishing between the environmental issues of the greenhouse effect, acid rain and the ozone layer were evident. Calculations caused problems for many candidates. Options D and E, which seem to contain much descriptive material, appear attractive to weaker candidates, who often have not studied them, and the marks obtained are frequently lower than in the other Options.

Knowledge, understanding and skills demonstrated

There were some excellent sets of scripts seen from some centres, mostly those where all the candidates had answered the same three options. It is clearly in the candidates' interests that teachers cover three options thoroughly rather than allow their candidates to study a variety of the options on their own.

Strengths and weaknesses in individual questions

Option A – Higher organic chemistry

QUESTION A1

In (a) there were many correct structures seen for **A** and **B**, though not for **C**. Several candidates wrote condensed structural formulas, such as $CH_3CH_2CH_2OH$ for **A**, which are perfectly acceptable so long as they are unambiguous. Those who attempt formulas showing every bond and atom separately should check that all bonds and atoms are included, especially hydrogen atoms. The term dehydration was better known than the product of the reaction, many candidates attempting a product of oxidation or giving the structure of hexanol.

In (b) oxidation was often seen and there were many correct attempts at showing the formulas, although propanone frequently appeared instead of propanal. The conversion of **D** to **A** was done more often by H_2 than by $LiALH_4$. Although most candidates realized that **E** was an alkanoic acid and **A** was an alkanol, very few gave correct explanations of the difference in acidity.

QUESTION A2

In (a) very few candidates referred to internuclear distance when attempting to explain bond length, and although most were able to use the Data Booklet to state the trend, explanations were often not correct. Full marks in (b) could have been obtained quite easily by using the table indicated in the question, but several candidates referred to electronegativity values or the numbers of outer electrons instead.

Option B – Higher physical chemistry

QUESTION B1

In (a) the better candidates explained the term weak acid in terms of dissociation, while the others often referred to pH values. In (b) common errors were omitting water and not using a reversible arrow, while in (c) $[H_2O]$ was often included in the K_a expression, and the charges were frequently omitted from the CH_3COO^- and H_3O^+ ions. Some candidates in (d) left the answer as $10^{-4.76}$. The better candidates scored full marks in (e) with little difficulty, but for those who were less comfortable with calculations, there were many errors seen. Most managed to calculate the M_r of ethanoic acid, but the commonest errors were not realizing that the concentrations of the two ions formed were equal, and treating the acid as if it were strong.

QUESTION B2

The equation in (a) was usually correct, but in (b), several candidates wrote $K_a \times K_b$ for the K_w expression. Quite a number thought that water must have a pH value of 7, no matter what the temperature, while others worked out the $[H^+]$ value simply by taking the antilog of the K_w value. Many candidates who correctly argued that the $[H^+]$ value would increase failed to go on to state the effect on the pH value, and explanations were rare.

Option C - Human biochemistry

QUESTION C1

Most candidates identified the two water-soluble vitamins, although a few gave only one or chose the wrong pair. They correctly stated that **W** contains several -OH groups but some did not then go on to state that these are involved in hydrogen bonding with water molecules. Many of those who chose **Z** also referred to hydrogen bonding rather than to the presence of a charged group.

QUESTION C2

In (a) most realised that vitamin C dissolves in the water when vegetables are boiled but far fewer stated that the vitamin is also oxidised – denaturion was frequently mentioned. In (b) almost all knew that a deficiency of vitamin C leads to scurvy, but its role in the production of collagen or connective tissue was less well known.

QUESTION C3

In (a) few candidates were able to correctly outline the meaning of the term monosaccharide and many stated that it is a single sugar molecule. The intention in (b) was for candidates to base their answers on the structure of sucrose given in the Data Booklet; a minority wrote straight-chain structures and others lost marks for otherwise correct structures that were missing hydrogen or oxygen atoms. There was mixed success in identifying water as the product of a condensation reaction. In (c), most knew fructose, with a minority giving glucose.

Option D - Environmental chemistry

QUESTION D1

In (a), most candidates were able to give carbon dioxide as the origin of rain that is naturally acidic, although far fewer succeeded with a correct equation; a minority mentioned the pollutants expected in (b). Most also knew the two major pollutants that cause acid rain and could correctly give the man-made source. A few candidates are still giving simplistic answers such as "car exhaust" as a source of nitrogen oxides rather than the reaction of oxygen and nitrogen in the internal combustion engine. Some gave only one method by which each pollutant could be reduced.

QUESTION D2

Virtually every candidate could name two greenhouse gases in (a) but very few scored full marks for explaining how these gases contribute to the greenhouse effect as most omitted to mention how the molecules absorb the energy. There were many references to rays "bouncing" off the Earth or being reflected, accompanied by diagrams, and to "blankets". A significant minority wrote about acid rain or the ozone layer.

Option E - Chemical industries

It seemed that the majority of the relatively small number of candidates choosing this option did so without having prepared for it, or even having studied it. High scores were almost unknown and there were many scores of five and under.

QUESTION E1

It was rare to see evidence that a candidate had studied the production of aluminium. The impurity removed was often given as oxygen, and in (c) there were several references to a reaction between aluminium and carbon. There were many scripts with several blanks, the commonest of which was the ionic equations in (d). Even (e) produced low scores – some gave only one use for each, while others gave inappropriate properties, such as high melting point for overhead electric cables; "light" was not accepted as equivalent to "low density". In (f) few knew about the oxide layer, and several explanations in terms of displacement were attempted.

QUESTION E2

For several candidates the correct equation in (a) was their only mark in this option. Although quite a number were able to state the effects on the yield, the accompanying explanations were often missing. The idea of optimum conditions for the Contact process was often not known in (c), and almost no candidates could list four major uses of sulfuric acid – many stated uses were either vague ("in school laboratories" or "as a reagent") or ludicrous ("making foodstuffs" or "as a detergent").

Option F - Fuels and energy

QUESTION F1

In (a), most candidates were able to name and state the relative charges of the three types of radiation, and list them in order of penetrating power. However, a significant minority omitted the charge magnitudes. Most were also able to solve the problem involving half-life in (b). However, many candidates could not give a satisfactory explanation of why it is meaningless to refer to the half-life of a single atom; the idea that decay cannot occur if there is only one atom left in the sample was common.

QUESTION F2

In (a), the advantages of using air and water in active solar heating were not well known. Many gave vague answers instead of using the correct technical terms, such as the high specific heat capacity (for water), although many correct answers were seen to (b) and (c). In (d) most candidates were familiar with the equation for the photosynthesis of glucose and the need for chlorophyll, although quite a number of equations were written for the reverse reaction.

Assistance and guidance for future candidates

In addition to the usual comments about reading the questions carefully and paying attention to the mark allocations and action verbs, candidates are advised to bear in mind the following points.

- practice writing and balancing a wide range of equations (molecular, ionic and nuclear)
- onsider, when writing equations, whether a reversible arrow is more appropriate than a conventional one
- continue to emphasise the various types of intermolecular forces and their importance in explaining features such as boiling point and solubility
- spend time in gaining familiarity with the actual calculator to be used in the examination, especially for less frequently used functions such as log and antilog, square and square root

- in calculations, especially where the candidate has made more than one attempt, the final answer should be clearly underlined
- any candidates taught more than the number of options required for the examination (three in 2002 but two from 2003) should concentrate on the minimum number as the examination approaches.

Internal Assessment

Component grade boundaries

Higher Level and Standard Level

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 *Vade Mecum*.

The task of moderation is made much easier when details of what background and assistance have been provided to the candidates. Some schools omitted this information – particularly in the case of verbal instructions. In the majority of the samples, it was clear that teachers had monitored the candidates' work carefully and provided useful feedback. In some cases, however, there was no evidence of feedback at all. Candidates benefit much more from feedback on the IB criteria throughout the course. Also, 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 all 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 containing virtually no chemistry, and requiring very little planning. Although every effort is made by the moderators to reward candidates' efforts, it is nonetheless inevitable that candidates are less likely to score well when they are not given the opportunity to undertake more open-ended investigations.

Another weakness in somel 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.

Candidate performance against each criterion

Planning (a)

Some candidates 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 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…" or where a guess is made 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. Teachers must not provide a list of apparatus or materials as candidates need to meet this aspect of the criterion on their own. Sometimes the control of variables was not always explicitly identified. Candidates sometimes took too large 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 problem of teachers supplying candidates with the procedure or too much information was still present, although not to the same extent as last year. It is important to understand that Planning (b) **cannot** be assessed if candidates have been provided with the procedure.

Data Collection

This criterion was generally carried out well and many suitable investigations were carried out. 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, 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. Also, some candidates do not seem to present raw data, but rather data that has been recopied after the investigation has been carried out. The two aspects of data collection specifically refer to recording and presentation of (appropriate) raw data. Teachers must avoid investigations for submission of Data Collection criterion when only a few values of one variable are being collected, or where a small number of qualitative observations are required.

Data Analysis

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. Some candidates, however, 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 analysed – evidence should be present of the candidates' ability to process data on their own, rather than by a series of prescribed steps in calculations.

Evaluation

This is still an area where candidates do not score well as they do not satisfy the requirements of the 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 – 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 should identify reasonable systematic errors and then propose improvements based on these. Note that not all investigations are appropriate for assessment of this criterion.

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 and strongly encouraged to thoroughly cover these areas
- candidates may find sub-headings for each criterion useful
- full portfolios are no longer required and should not be submitted unless specifically asked for
- evidence for participation in the Group 4 Project by **each** candidate in the sample should be submitted with the sample for moderation
- teachers must not provide too much information/help for the Planning (a), Planning (b) and Data Collection, Data Analysis and Evaluation criteria
- candidates need practice at proposing a hypothesis that is directly related to the research question and that is explained
- candidates must record qualitative as well as quantitative **raw** data where appropriate, including units and uncertainties where necessary
- teachers must provide all written as well as any verbal instructions for investigations in the moderation sample
- candidates should compare their results to literature values where appropriate
- when assessing the Evaluation criterion, require 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 are **strongly** urged to use the c, p, n notation in the assessment of the investigations and in giving feedback to the candidates (note that not all investigations need be assessed)
- teachers should not assess for a particular criterion if an investigation clearly does not meet all aspects of the particular criterion
- teachers should refer to instructions provided in the *Vade Mecum* before submitting work for moderation.

