CHEMISTRY

Overall grade boundaries

Higher Level

Grade:	1	2	3	4	5	6	7
Mark range:	0-18	19-34	35-47	48-58	59-68	69-79	80-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-30	31-44	45-56	57-67	68-79	80-100

Standard level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-12	13-17	18-20	21-23	24-26	27-30

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. Sixteen of the 30 questions were also used on the Higher Level examination.

The 151 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, nearly three-quarters of respondents felt the paper was of a similar standard. The remaining respondents were almost evenly divided between considering the paper a little more difficult and a little easier. Nearly all respondents 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 approximately two-thirds and satisfactory by one-third.

Only two respondents reported that candidates did not have enough time to complete the questions.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 91% to 34%. The discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates: the higher the value, the better the discrimination) ranged from 0.56 to 0.17.

The following comments are made on individual questions.

Question 2

Response D attracted more candidates than any other response, indicating confusion between empirical and molecular formula.

Question 5

Two respondents stated that the term *anion* did not appear in the programme. The question was well answered with 77% of candidates getting it right.

Question 6

This was the most difficult question on the paper. Nearly half of the candidates choose response C and most of the remaining candidates gave the correct response, B.

Question 7

Several respondents were concerned that candidates might be confused by the system used for numbering the groups in the Periodic Table. In fact, 72% of candidates chose the correct response, A. Note that the numbering system used appears in the Data Booklet and in the Periodic Table printed as part of Paper 1.

Question 14

It was pointed out that because the question had not mentioned the *ideal* nature of the gas then response D could be correct. In fact, 69% chose the correct response A, with most of the remainder equally split between B and C. Nevertheless the criticism is accepted.

Question 15

One respondent feared that candidates might not know whether the question referred to energy being absorbed / released by the system or the surroundings. It is considered that this is not likely. Since slightly more chose C than the correct response D, the question discriminated well (0.53).

Question 26

Several respondents were concerned that this question went beyond the Core syllabus requirements. It is considered that the question is covered by assessment statement 10.2.3. Almost half the candidates correctly chose B, with most of the remaining candidates opting for response A.

Question 27

Five respondents believed that both A and C were correct. 68% of candidates chose the intended response A and 19% selected C. It was agreed to accept both answers as being correct.

Standard level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-20	21-26	27-33	34-39	40-50

General comments

The candidates, in general, coped well with the examination. It was clear that the majority had been well prepared. As usual, actual performances varied from centre to centre and covered the entire mark range, so the examination was seen to discriminate successfully. Once again it seemed that there was a tendency for the candidates to avoid the organic chemistry question in Section B.

The 129 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's exam, three-quarters thought this year's paper of a similar standard, with the remainder evenly divided between those considering the paper easier and those considering it more difficult. Almost all respondents 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 and satisfactory by the remainder. The presentation of the paper was considered good by two-thirds and satisfactory by the remainder.

Strengths and weaknesses in individual questions

Section A

Question 1

a) This mark was usually awarded although some candidates wrote "high pressure and low temperature" thus not referring directly to the question asked, and a few gave the temperature as 95.4.

b) This was well done with most candidates having a reasonable understanding of Le Chatelier's principle, although some did give an explanation in terms of reaction rate rather than yield.

c) Many candidates scored only 1 of the 2 marks available here – the cost of the high pressure but not the need for higher temperature to obtain a reasonable rate of production of ammonia.

d) The expression for the equilibrium constant was almost always given correctly. A small number of candidates put a + sign in the denominator.

Question 2

a) The most common omission was the idea of a minimum energy.

e) Many of the curves drawn were disappointing. For example, one peak directly above the other, cutting the axis, no broadening of the peak, reduction of the size of the hatched area. A number of candidates drew a new activation energy at a lower value.

b) Answers rarely referred to the diagram; most candidates expected the rate to increase, usually as a result of greater collision frequency rather than more molecules with energy greater than the activation energy. Some candidates stated that a higher temperature gave rise to a lower activation energy or that an increased temperature causes molecules to "reach the activation energy" more quickly.

Question 3

a) The more able candidates produced complete and correct calculations; in some instances working was not shown so that it was not clear how the candidate had gone from empirical formula to molecular formula, or vice versa. Many attempted, often successfully, to determine the molecular formula first using the relative molecular mass and the percentages. This was given full credit.

b) The majority of candidates correctly calculated the concentration of the sodium hydroxide solution; common errors were to divide by 250 or multiply by 0.250 in the final step. Significant figures once again led to some candidates losing a mark.

Question 4

a) Many candidates failed to answer the question in that no explanation was given. Attempts were made in terms of a periodic trend - (because it increases across a period or decreases down a group). A number of candidates said that sodium was losing one electron while magnesium was losing two.

b) There was a lot of confusion between electronegativity and ionization energy. Electronegativity was sometimes effectively described as if it were the electron affinity. Many candidates referred to "chlorine having more electrons in its outer shell allowing it to have a complete outer shell by adding one more electron."

Question 5

a) Most candidates were aware of the basic distinction but were careless in their definition.

b) This was generally correct.

c) The correct isotope was often identified without any logical explanation.

d) A wide variety of species was seen here, particularly H-1, other isotopes of carbon, both vanadium isotopes and various others. Also relative atomic masses rather than mass numbers were sometimes suggested, e.g. the value 12.01 given in the Data Booklet.

Section B

Question 6 *This was the most popular choice in this section.*

a) (i) Again, there were many statements of the trends rather than explanations. Not many candidates mentioned the presence of van der Waals' forces.

(ii) Hydrogen bonding was mentioned, but often it was not made clear whether this was an intermolecular or intramolecular force.

b) Although most candidates knew the water molecule was angular, few could describe the electron distribution around oxygen as tetrahedral. The bond angle was usually known but many did not realise that the repulsion is of pairs of electrons rather than of atoms.

c) Not all the candidates were able to explain bond polarity using electronegativity. The cancelling effect of symmetry was often mentioned.

d) Most candidates correctly identified the three structures. The most common error was to omit the van der Waals' forces present between the molecules of iodine.

e) Many candidates believed conductance in sodium iodide to be by electrons and that iodine's high volatility was due to the ease of breaking the I-I covalent bonds.

Question 7

a) Most gave a correct description of a strong acid, but fewer candidates received credit for statements relating to a weak acid. The equilibrium sign was frequently missing in the equation for ethanoic acid.

b) Some candidates did not describe observations. The differences in rate caused some confusion. The calculations were usually well done, sometimes missing the factor 2 in (iii), using 44 instead of 22.4 in (iv) or quoting incorrect units.

c) (i) was often calculated correctly but the change in (ii), which could have been in absolute or relative terms, proved to be much more difficult. There were some convoluted calculations presented in (iii).

d) The definition was often only half correct, missing "when small amounts of acid or alkali are added."

Question 8 *The least popular choice though often attempted by the better-prepared candidates.*

a) Most candidates were able to identify **A** and the combustion equation was well done. A product of incomplete combustion was sometimes absent and more frequently why it is dangerous. Most tests involved bromine or bromine water but occasionally iodine appeared. Bromine was also sometimes suggested rather than hydrogen bromide for the conversion of **B** to **C**. Compound **C** was often drawn as 1-bromobutane.

b) This part was usually well answered; water as a product was sometimes absent.

c) Only the best candidates were able to deduce the structure of the monomer. The majority described the reaction as a condensation.

Assistance and guidance for future candidates

From the range of marks awarded it was again clear that all the material for this examination had been taught to the majority of the candidates. The relatively small number of answers to question 8 suggests that some centres may put less emphasis on organic chemistry.

If possible, more time practising past papers may be beneficial. Improved examination technique can be of great help in raising scores. Candidates must answer the questions that are asked. In particular, explanations must not be simply statements of phenomena or trends, and observations must be something that can be observed.

Areas that teachers might consider giving greater emphasis include:

- balancing equations
- consideration of significant figures
- the layout of calculations, including showing all working
- the importance of quoting units

- clearer explanation of the significance and meaning of energy distribution diagrams
- electron pair distributions and shapes of molecules and ions
- electrical conduction - when the charge is carried by electrons and when by ions
- the distinction between intermolecular and intramolecular bonding/forces.

Standard Level Paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-11	12-16	17-21	22-25	26-30	31-40

General comments

This was the first paper in which candidates were required to answer questions from two, rather than three, options. Almost all correctly followed the new rubric and indicated their option choices on the cover sheet. After allowing for the different total mark, the mean was almost identical to that of last May. The best candidates showed a thorough command of the material and a high level of preparation, although some candidates again seemed unfamiliar with the options answered and scored very poorly.

The 140 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's exam, two-thirds thought this year's paper to be of a similar standard, with the remainder dividing about 3:1 in considering it more difficult than considering it easier. Most respondents thought the level of difficulty was appropriate, although there was an increase from last year in those considering it too difficult. Syllabus coverage was considered satisfactory by a half and good by one-third. Clarity of wording was considered good by over half and satisfactory by the remainder. The presentation of the paper was considered good by two-thirds and satisfactory by the rest.

Difficulties for candidates

Statistical information about the popularity of Options, and about the average marks obtained in each, is not available, so comments made by individual examiners, from which this report is compiled, are based on their individual allocations. General comments on difficulties they observed often referred to lack of precision in the wording used in definitions and explanations, problems with calculations (use of calculators, significant figures and units), vague descriptions of experimental procedures. It is still the case that many candidates seem to choose Options that they have clearly not studied. Options D and E are often attractive to such candidates because they contain more descriptive material, although the evidence suggests that they score very poorly unless they have prepared fully for them.

Knowledge, understanding and skills demonstrated

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

Strengths and weaknesses in individual questions

Option A – Higher Physical Organic Chemistry

Question 1

It was disappointing to find many candidates unable to satisfactorily define the three terms italicised in this question. For *nucleophilic substitution*, what was wanted was some recognition that an existing atom or group in a molecule was being replaced by another and that the attacking species had a lone pair of electrons or was attacking a (slightly) positive site in the molecule. In contrast, parts (b) to (e) were generally well done, and the award of marks by error carried forward was rarely needed. Part (f) was rarely correct, with very few candidates giving the equations in the markscheme. Those who showed an S_N2 mechanism could score by error carried forward from their rate equation in (d), although this rarely happened.

Question 2

The equation in (a) was usually correct, with relatively few missing ionic charges. Most candidates correctly retrieved the correct pK_a value from the Data Booklet but a surprising number could not use their calculators to produce the correct answer. Quite a number gave their final answer as $10^{-4.87}$. There were many correct answer to the calculations in (c), although often badly set out.

Option B – Medicines and Drugs

This was the first examination of this Option, so it was encouraging to see a substantial number of candidates attempting it. It seemed that many of those who scored poorly had chosen the Option without having been taught it. In contrast there were rather more candidates who scored highly and had obviously been well prepared for it.

Question 1

Many full and nearly correct answers were seen, perhaps the most common error being the inability to write the neutralization equation in (c)(ii).

Question 2

Generally well done, the areas of weakness being the names of the functional groups in aspirin and the meaning of *tolerance* (some thought it referred to society tolerating the use of drugs).

Question 3

Many candidates scored no marks here (with several completely blank answers), even though potassium dichromate(VI) is mentioned in the teacher's note for B.4.3. The correct colours, but the wrong way round, and the colour purple, were often seen.

Option C - Human Biochemistry

Question 1

Many candidates lost the mark in (a) through giving the formula of a specific amino acid. The dipeptide formation in (b) was well known, with a minority omitting the water product, probably through oversight. The functions of proteins required in (c) were generally given correctly. Part (d) proved difficult for many candidates, and full marks were rare. In (d)(i), although the bond broken in protein hydrolysis was often correct, the conditions were not, and a very wide range of incorrect answers was seen. Some candidates opted to draw a diagram in (d)(ii), from which full marks could be scored if correctly labelled, but sadly many answers showed confusion with chromatography.

Question 2

In (a), the structure of glycerol was well known by the better candidates, although quite a number of alcohols with only one –OH group, or with more than one –OH group on the same carbon, were seen. A wide variety of answers to (a)(ii) was seen, predictably including 54. In (a)(iii) it is clear that only a small minority of candidates were not made aware of the printing error in the formula of stearic acid, and for those who could not therefore attempt (a)(iii), their marks for the Option were scaled out of 17 marks. However, in the answers of the majority who were in a position to attempt it there were many errors seen, the most serious being the suggestion that C–C (or C=C) bonds were more easily broken. In part (b), there were inevitably many candidates who used the relative atomic mass instead of the relative molecular mass of iodine in the calculation (for which ECF was allowed), and a surprising number failed to go on to state the number of C=C double bonds present.

Option D – Environmental Chemistry

Question 1

In (a)(i) most candidates wrote about the movement of a substance through a barrier, but often it was lacking in precision or appeared identical to filtration, so that marks were often lost. For example, *osmosis* could be described as the movement of water (or a solvent) from low to high solute concentration (or even high to low solvent concentration), but those who wrote from high to low concentration (without specifying whether this was a reference to solvent or solute) did not score. In (b), although most correctly stated that the oxygen concentration would decrease with increasing temperature, eutrophication was seemingly unfamiliar to many candidates and there were many suggestions of reactions between nitrate ions and oxygen. In contrast, the advantages and disadvantages of ozone in water treatment were well known, with many candidates scoring full marks.

Question 2

In (a) The term *biological oxygen demand* was not well known, with large numbers of candidates writing about the use of oxygen by living organisms rather than by decaying ones. A small minority of candidates scored full marks for the secondary treatment of water in (b), but those who scored little or nothing outnumbered them. Apart from the confusion with primary and tertiary treatments, few candidates focussed on the breakdown of organic matter; instead of using bacteria for the breakdown, many wrote about their removal. Quite a number drew a diagram, from which full marks could have been scored with correct labelling.

Option E - Chemical Industries

It seemed that the majority of the relatively small number of candidates choosing this Option did so with very little knowledge of it. High scores were rare and there were many low scores.

Question 1

In (a) very few candidates scored full marks for the fractional distillation of crude oil, and many seemed to have little idea of the process. Although heating was often mentioned, the idea of boiling or vaporization was often missing. Quite a number suggested that the fractions settled out into different layers according to their densities. Parts (b) and (c) were either nearly all-correct or contained nothing relevant; most candidates attempted the equation, with $2C_7H_{15}$ being the most common incorrect product.

Question 2

In (a), almost all correctly showed the structure of propene, but the structure of the polymer was rarely correct; often the structure shown was not that of any type of polypropene. A small minority of candidates knew how expanded polystyrene was produced, and although some of its properties were known, it was clear that most candidates were not familiar with this topic.

Option F - Fuels and Energy

Question 1

In (a), although candidates seemed to be familiar with coal formation, few included three conditions, as suggested by the mark allocation. The pollutants in (b) were usually correct. Part (c) was not well answered – many substances were listed in (i), not all of them combustible, and the advantages needed in (ii) were often vague. For example, "reduction in emissions of sulfur dioxide or particulates" would have been fine, but "cleaner burning" was not acceptable, because the question stated that amount of pollution was reduced.

Question 2

In (a), although the programme refers to the half-equations in the zinc-carbon cell, very few candidates seemed to be familiar with the topic, and the purpose of the manganese(IV) oxide was rarely correct ("catalyst" was a common answer). Even part (c) was poorly done, with many candidates suggesting that more reactive elements were needed.

Question 3

Very few candidates showed any familiarity with the working of a fuel cell.

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.

- learn definitions and explanations of familiar but important terms such as *nucleophilc substitution* and b*iological oxygen demand*
- 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 two Options required for the examination should concentrate on only two as the examination approaches

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-15	16-22	23-25	26-28	29-31	32-38

General comments

This paper consisted of 40 questions on the Core and AHL sections of the syllabus 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. Sixteen of the 40 questions were also used on the Standard Level examination.

The 120 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's exam, nearly three-quarters of respondents felt it was of a similar standard, with the remainder almost evenly divided between considering it a little more difficult and 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 and satisfactory by one-third.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 97% to 24%. The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.51 to 0.06. (The higher the value, the better the discrimination).

The following comments are made on individual questions.

Question 6

Several respondents were concerned that candidates might be confused by the system used for numbering the groups in the Periodic Table. In fact, 77% of candidates chose the correct response, A. It should be pointed out that the numbering system used by the IB appears in the Data Booklet and in the Periodic Table printed as part of Paper 1.

Question 13

This question was felt to be unsuitable for paper 1 and so was deleted.

Question 14

It was pointed out that there could be some ambiguity in what was meant by the number of sigma bonds (in the molecule or around the carbon atom). The wording used should have implied that reference was being made to the molecule, although as rather more candidates chose response D than the expected A, this might suggest that candidates were misled. However, it could also be that those who chose D considered that the C=O bond was only a pi bond and not a sigma bond.

Question 15

One respondent questioned whether the dependence of kinetic energy on particle mass was on the syllabus. The question was testing assessment statement 5.1.2, which states that average (kinetic) energy is proportional to absolute temperature, and 67% of candidates chose the correct response, C.

Question 17

One respondent was concerned that candidates might not know whether the question referred to energy being absorbed / released by the system or the surroundings. It is considered that this is not likely as 69% of candidates chose the correct response D and the question discriminated well.

Question 26

Two respondents stated that the question did not make it clear to which solution was being referred to. As 84% of candidates correctly chose D, and the fact that no response existed that corresponded to picking the wrong solution, this did not seem to be a problem. Nevertheless, the criticism is accepted.

Question 28

Four respondents stated that response D could also be correct; it is not accepted that OH^- acts as a Bronsted-Lowry acid in aqueous solution. 60% of candidates chose the correct response, C, and the question discriminated well.

Question 30

Four respondents pointed out that the question should have described the two acids as monoprotic; the criticism is accepted. Nevertheless, 57% of candidates correctly chose B and the question had the highest discrimination index of all.

Question 34

One respondent suggested that the question should not have appeared because Faraday's laws are no longer on the syllabus. However, it considered that the question is a fair test of the ability to work out the relative amounts of products, as required by assessment statement 19.3.3.

Question 35

This was the most difficult question on the paper, with nearly half choosing response B. The question also had the second lowest discrimination index, and so many candidates must have used first principles to arrive at response B. However, those familiar with assessment statement 11.3.4 should have been able to select response D.

Question 38

Several respondents stated that the phrase “halogen carrier” is not specifically mentioned in the syllabus. It is mentioned, but in Option H- H.4.2, so this question was deleted since it was testing Option material rather than AHL content.

Question 39

Although no comments were received about this question, it proved to be the second most difficult on the paper, with many more candidates choosing responses B and D than the correct response A. It was intended to be a reasonably straightforward test of assessment statement 20.3.4.

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-29	30-41	42-51	52-61	62-71	72-90

General comments

This was an accessible paper and candidates tackled it with confidence.

The standard of answers varied from centre to centre and clearly from the level of understanding of a particular candidate.

In general, candidates must pay particular attention to the number of marks allocated to any particular part of the question and tailor their answers accordingly. Calculations must be shown clearly and should be checked for accuracy, significant figures and units where appropriate.

Areas of the programme and examination which appeared difficult for the candidates

- some candidates seemed to have difficulty in translating the theory they have evidently learnt into cogent explanations in new situations
- candidates need to be able to handle the manipulation of units with confidence
- acid/base chemistry
- diagrams of the electrolysis cell
- organic structures
- empirical formula calculations

Areas of the programme and examination in which candidates appeared well prepared

- good grasp of kinetics
- simple calculations, e.g. rates, but *not* pH and buffers
- distribution of molecular energies, but *not* labeling the graph

Strengths and weaknesses in the treatment of individual questions

Question 1

a) In dealing with questions of this nature, candidates need to find the "crux" of the question. In (i), it was the loss of two electrons and the consequent loss of a shell. In (ii), it was the difference of a whole shell and some comment on the number of protons. In (iii), candidates needed to emphasise the isoelectronic nature of the two ions and the difference in nuclear charge.

b) The answer NaF was frequently given and many candidates realised that electronegativity would be involved. Some failed to indicate that it is the largest difference that is important. A common error was to look for the ions with the greatest charge.

c) Most candidates were able to identify aluminium oxide as the required compound, but there were a number of variations on amphoteric*,* the most common of which was amphiprotic.

Question 2

a) There was considerable carelessness in the drawing of these arrows and many drawings seemed to begin or end between the levels. It was common for only the mark for downward direction to be gained in (ii) as many candidates did not know where the visible series originates.

b) There was a good deal of success with the atomic particles in the tritium atom (although 3 neutrons was a common wrong answer) but the equations were found to be rather more difficult. It was intended to be a relatively straightforward recall of equations involving the preparation of ammonia and sodium hydroxide. Common errors were to write the nitrogen as 2N and to write H instead of T.

Question 3

a) Most candidates had little trouble choosing the answers A and E.

b) There were two routes – both giving the same answer! Candidates were poor at reading the graph carefully (0.37 was required) and many, having divided by 15, did not adjust the answer to two significant figures. The units were generally given correctly.

c) Most realised that equilibrium had been reached.

Question 4

a) This part was usually done better than (b). Candidates generally recognised that the molecules increase in mass but frequently were unable to name the type of interaction.

b) Hydrogen bonding was frequently given as the answer but examiners were often left with the impression that this is the O–H hydroxyl bond. Candidates needed to be clear that hydrogen bonding is stronger than the bonding mentioned in part (a) and is the bonding is between molecules.

Question 5

a) Marks tended to be low. The idea of *"*replacing*"* an atom or group was often missing, with "element" or "molecule" appearing instead, and *nucleophilic* behaviour was often described in terms of attraction between oppositely charged ions or between nuclei and electrons.

b) Many candidates were able to write these structures correctly; the commonest error was to give the branched primary structure (1-bromo-2-methylpropane) in (iii).

c) There were many correct attempts at showing the S_N1 mechanism, although some invariably gave the S_N2 mechanisms and some gave both. A number of equations lacked charges or inlcuded incorrect charges. The meaning of *rate-determining step* was well known but *molecularity* was frequently omitted or confused with molarity. Where S_N1 was identified in part (i), the rate-determining step was usually identified correctly.

Question 6 *This was a very popular question.*

a) Some candidates were unable to label the axes correctly but the explanation in (ii) was usually good. The two graphs should appear to have equal areas under them.

b) The effect of the catalyst was usually a "text book" answer and most candidates were able to distinguish between *homo-* and *heterogeneous*. Finding suitable examples proved to be more of a challenge, with homogeneous being more difficult.

c) *Order of reaction* was defined very poorly as many candidates failed to take note of the power of the concentration. The order of reaction was very well deduced and the calculations were often correct. Most candidates were able to carry out the calculation in (iii) correctly but units caused problems. A number of candidates did not adjust the answer in (iv) to the correct number of significant figures.

Question 7 *This was the third most popular question.*

a) The function of the salt bridge was generally well understood, although a sizeable minority thought that it allowed electrons to flow. In (ii) the half-cell was well written; only a small number gave the oxidation reaction of copper. Although pressure does not affect the electrode potential very much in this case, it is still a standard condition and needs to be given. The use of the data booklet caused difficulty for many otherwise good candidates; the wrong value for the copper was carelessly quoted. There were many good answers to (v) but candidates were over-optimistic in thinking they would see the zinc rod decreasing in size. Candidates need to be taught the importance of a full description of an observation. They often did not indicate that the blue colour would decrease in intensity.

b) In (i), many candidates gave Ti^{3+} as the answer, clearly without thinking about the question. A reason in terms of losing electrons was insufficient without some indication that it was the best at doing so in the three systems. The equation was generally correctly written in (ii), and even if it was incorrect, few candidates failed to get the marks for the stated symbols. Part (iii) was usually answered correctly.

b) Water was not accepted as a solution. Candidates needed to specify the solution rather than write "acidified" water. (HCl was not accepted as an answer.) The diagrams were generally very poorly presented. The "double volume" of hydrogen was well known and the gases were usually assigned to the correct electrode. Some candidates, inevitably, drew a cell with an ammeter in place of a power source.

d) The answers to (i) were sound, but the idea of increasing time and current in (ii) was often lost on the candidates.

Question 8 *This was the least popular.*

a) The answers to this were centre dependent; in general, there were too many attempts at defining pH by an expression, and most worded attempts were too vague to receive credit.

b) While many candidates were able to assign acidic, neutral and basic correctly, the quality of the explanations varied considerably. In (i) and (iii) candidates needed to be aware of the equilibria involved.

c) Candidates seemed unaware of how to find the pH at the equivalence point and there were fewer explanations of why the pH changes so rapidly in this region. A simple statement that "NaOH is a strong base" would have been a good starting point. Few realised that part (ii) involved a simple titration calculation and only strong candidates were able to answer (iii).

d) This definition was usually well known, except that candidates must be careful to say that the amount of added acid or alkali is small. The calculation in (ii) was frequently wrong because candidates could not work out the molar mass of sodium ethanoate. Examiners made much use of error carried forward (ECF). In (iii), many candidates seemed to think that the concentration of hydrogen ions would be equal to that of the ethanoate ions.

Question 9 *This was the second most popular question.*

a) In (i), M_r was usually correctly identified but in (ii) the positive charge was frequently omitted, although the mass numbers of fragments lost to achieve the m/z values were given. Many candidates were able to give the correct structural formula in (iii).

b) The empirical formula and the molecular formula were generally given correctly, but few candidates showed how they had derived the molecular formula. Although some candidates did not appreciate that an ether was possible, most candidates scored full marks in (ii). The broad absorption was well known in (iii) but many candidates did not understand the different number of peaks in (iv).

c) Candidates should have realised that "refluxing" is the clue that means the compound has been oxidised as far as possible. Thus D must be a ketone. For those who identified an aldehyde, examiners had to identify error carried forward (ECF) marks.

d) Even though some candidates correctly deduced the structure of **C**, they failed to transfer the information to the formation of the ester, many reverting to the primary alcohol.

e) Many candidates were able to do this well and marks could still be gained if the alcohol was incorrectly identified. In (ii), many candidates failed to include water in the right-hand side of the equation. Condensation was not acceptable as a reaction type.

Recommendations and guidance for the teaching of future candidates

- read the questions carefully and pay attention to the action verbs used
- candidates should take note of the mark allocation for each question
- do not neglect organic chemistry
- use past examination questions to practice examination technique
- check a calculator answer mentally to ensure it is "sensible"
- encourage candidates to complete calculations, errors are "carried forward" and penalties are imposed only once
- learn terms and definitions
- appreciate why salt solutions are not always neutral
- understand the distinction between electrolysis cells and electrochemical cells

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-8	9-17	18-21	22-27	28-33	34-39	40-50

The areas of the programme that proved difficult for candidates

In their responses on the G2 forms, 81% of the teachers felt that the paper was of a similar standard to last year with 11% rating it a little more difficult and 5% a little easier. A slightly higher percentage, 89%, felt that the level of difficulty was appropriate, with 7% suggesting that the paper was too difficult and 5% too easy. As usual the performance of candidates showed huge variation. This was noticeable between schools but often also within the same school. Candidates seemed generally well prepared, but many found particular problems with the following:

- giving precise and accurate definitions of specific terms such as *osmosis*, *partially permeable membrane*, *biological oxygen demand*, *stationary phase, mobile phase* and *partition*
- identifying the chiral centre in a molecule (thalidomide), even when the full structural formula has been given
- describing particular practical techniques; for example protein hydrolysis, electrophoresis, paper chromatography and how a polarimeter works
- radioactive decay of lighter elements

The levels of knowledge, understanding and skill demonstrated

It is evident that the majority of students knew the subject material well. However there are a few centres where students seemed unfamiliar with much of the material. Often this correlates with the choice of options. As in past 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 a candidate's ability to express clearly and concisely their ideas with their overall scores. Generally, most students demonstrated a good knowledge of the factual content of the options chosen. Topics that seemed particularly well-known and understood included medicines and drugs, the function of proteins, the pollutants formed from the burning of coal, the equations for ozone depletion by CCl_2F_2 and the use of IR and ^1H NMR spectroscopy. Although there were exceptions, many candidates were able to write chemical equations correctly and performed well on the few calculations on the paper. Candidates gave excellent answers on the further organic chemistry option, but there were many candidates who were unable to recognise and describe a mechanistic pathway such as electrophilic substitution.

Strengths and weaknesses of candidates of individual questions

Option B – Medicines and Drugs

Question B1 was generally answered well. Most candidates were able to state three ways, apart from orally, in which drugs may be taken. A few listed the three different methods of injection (subcutaneous, intravenous and intramuscular) and were awarded one of the two marks. The equation for the neutralization of sodium hydrogencarbonate by hydrochloric acid was well known and most candidates understood the cause of heartburn and the reason for adding dimethicone to some antacids. In question B2, most candidates were able to explain the difference in the mode of action of mild and strong analgesics. The functional groups attached to the benzene ring in aspirin and the side effects of aspirin generally presented few problems. Ketone instead of ester was the most common error. Some candidates calculated the full relative formula masses of both morphine and codeine in order to determine the difference between them. Most realised that the only difference is in the functional groups and arrived directly at the answer. Question B3(a), relating to thalidomide, posed the most difficulty. Very few candidates were able to correctly identify the chiral carbon atom in thalidomide and many confused the type of isomerism shown by this molecule. The arguments for and against the legalisation of cannabis were stated well, although some candidates tended to be too general in their answers. At this level it is not enough to state that cannabis is used to treat some diseases. Candidates should state a specific condition such as glaucoma, multiple sclerosis, Huntington's chorea, Parkinson's disease or epilepsy where there is documented evidence that treatment with cannabis can be beneficial.

Option C – Human Biochemistry

This is a popular Option and produced some good responses. Most found little difficulty with C1 parts (a), (b) and (c) on amino acids, and the functions of proteins, but candidates were less sure on the hydrolysis of proteins. Only a few candidates gained all three marks for correctly stating the reagents and conditions, i.e. an acid which must be concentrated and heated. Similarly, many talked about isoelectric points when explaining how amino acids can be identified by electrolysis, but omitted to give some of the essential experimental details such as how the acids are located by dyeing with a compound, such as ninhydrin. Question C2 concerned fats and oils. Some candidates had difficulty in calculating the number of carbon atoms in a triglyceride containing three molecules of stearic acid. Most were able to correctly deduce the number of double bonds in a molecule of the oil in part (b), provided that they used the correct relative molar mass for the diatomic iodine molecule. Some candidates failed to answer the questions asked in C3, concerning the action of enzymes. Instead of relating their answer to the graph and system shown, they tended to simply repeat what they had been taught about enzyme action without the specific context. Many omitted the correct powers of ten and the units in part (b) (ii), where they were asked to determine the values for the maximum rate and the Michaelis constant.

Option D – Environmental Chemistry

This is another popular Option answered by many candidates. Although there may be a perception that this is one of the easier options, answers given did not always bear this out. Many gave incorrect definitions of *osmosis* and *partially permeable membrane*. A partially permeable membrane does not filter particles according to their size. Sodium and chloride ions are actually smaller than water molecules and yet the membrane allows the passage of water (or other solvent) molecules and restricts the movement of solute. Many stated that a high pressure is needed for reverse osmosis to occur, but did not make it clear that this is necessary to overcome the normal osmotic pressure. Almost all candidates suggested a suitable way for a householder to reduce the amount of water, although this question and the answers given did tend to assume a developed country lifestyle. The effect of temperature on the solubility of oxygen was well known, but some were unable to explain how the release of nitrates into a river can lead to eutrophication. Many candidates omitted to state a specified time period (usually five days) when defining the term *biological oxygen demand* in D2(a). Question D2(b), on the activated sludge process, presented few problems. The main impurity removed is organic matter and not nitrates and phosphates, which are only removed during tertiary treatment. Question D3 required students to relate the type of bonding between oxygen atoms in oxygen gas and ozone to the energy required to break the bond. Most were able to do this well, including stating the bond order of 1.5 in ozone. Similarly, the equations for the destruction of ozone by CFCs in the upper atmosphere had generally been well-learned and correctly reproduced for part (b).

Option E – Chemical Industries

This is one of the least popular Options and received some very mixed answers. Several candidates did not even mention that the crude oil must be heated and vaporised when explaining how crude oil can be separated using a fractionating column. Some gave the radical C_7H_{15} as the product for the cracking of $C_{14}H_{30}$ rather than the correct two products C_7H_{14} and C_7H_{16} for question E1(b) and many were uncertain about the characteristic structural features of the hydrocarbons produced during hydrocracking. Most could give the correct equation for the aromatisation of hexane and identify a use for the hydrogen formed during the process. Question E2 on polymers presented some students with a problem. They had learned the properties of the atactic and isotactic forms of poly(propene) but were unable to draw adequately a diagram to show the regular isotactic arrangement. The disadvantages of disposing of polyvinylchloride, also known as poly(chloroethene) were not well known. Although most candidates mentioned global warming due to the carbon dioxide produced very few mentioned that the chlorine containing residues are toxic. The description of the manufacture of chlorine using a diaphragm cell was generally answered well. Most candidates knew of the problems associated with the mercury cell although one did suggest that the escape of mercury caused lead poisoning.

Option F – Fuels and Energy

Question F1 on coal was straightforward and was answered reasonably well, although some candidates talked rather vaguely about it taking "a long time" for coal to be formed rather than talking in terms of millions of years. Question F2 on dry cells was more challenging. Many students did not identify the other main reaction occurring in the zinc-carbon cell correctly so wrote a wrong equation for the reaction in part (a)(i). Very few stated the purpose of the manganese(IV) oxide correctly in part (ii). The advantages of the alkaline cell were also not known well. In part (c) some candidates suggested that increasing the surface area of the electrodes would produce more power whereas the correct answer is increasing the amount of materials. Most realised correctly that connecting four cells in series would produce a battery with a voltage of about 6 V in part (c)(ii). The two half-equations for the reactions taking place in a fuel cell were given wrongly by many candidates in F3 but most provided a creditable answer to explain why fuel cells are considered more economical than gasoline engines. Question F4 on nuclear energy also caused some problems. Although most candidates calculated the neutron:proton ratio correctly in part (a), relatively few went on to predict and explain fully the type of decay expected for the magnesium isotope. Part (b) on the disposal of nuclear waste was answered better although there are still some students who advocate sending it all off into outer space.

Option G – Modern Analytical Chemistry

This option appears to be increasing in popularity and many candidates provided good answers. It was pleasing to see that many mentioned that a change in dipole occurs for infra-red active vibrations as well as breaking these down into stretching and bending in G1 (a). Almost all candidates correctly deduced the functional groups present from the infra-red data given in (b). The mass spectrum of the compound in part (c) caused more problems. Some missed the information that the two peaks were of equal height and assumed it was due to 13-carbon isotopes rather than the two isotopes of bromine. The remainder of G1 caused few problems and many gained full marks for parts (d), (e) and (f). The answers given for G2 on paper chromatography were either very full and well explained or rather vague and imprecise. Although nearly all candidates could state and explain that P4 was a mixture some were unable to calculate the R_f value of P1 correctly. The most common error was to measure the heights from the bottom of the paper rather than from where the samples were spotted originally.

Option H – Further Organic Chemistry

Many candidates chose this Option. Although question H1 required relatively straightforward recall of a typical electrophilic substitution reaction using a halogen carrier as a catalyst, some candidates still find it difficult to write the mechanism correctly. Others, however, provided very good answers and used 'curly arrows' correctly and described the intermediates properly. Most candidates were able to draw the two optical isomers in part (b) using a recognised method to show that they are mirror images. It was pleasing to see that many understood the concept of plane polarised light and stated correctly that optical isomers rotate the plane of plane polarised light rather than talking vaguely about them bending or deflecting polarised light which has been the case in previous years. The part that caused most problems was (c) which asked student to identify and explain whether chlorobenzene or compound **Y** would react more slowly with aqueous sodium hydroxide. There are two acceptable explanations as to why chlorobenzene reacts more slowly but many students seemed unaware that what they were really being asked to explain was why chlorobenzene does not readily undergo nucleophilic substititution. Question H2 concerned the strengths of organic acids and bases. Part (a) on K_a and pK_a values was actually Core chemistry and was answered correctly by almost all candidates. The reason why phenol is more acidic than ethanol was less well explained in part (b) but most gave a reasonable answer for the strengths of the different pairs of acids in part (c).

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

- The Options form an important part of the overall syllabus. Many teachers leave the teaching of the Options until last. 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. Students who are left to teach themselves the material in the Options generally do not perform well in the exam.
- Give students guidance as to the level of answer expected. Journalistic answers to questions at this level will not suffice. Chemical equations should be given wherever possible. Organic mechanism should be clearly described and definitions given precisely and accurately.
- Provide students with adequate resources to complement the teaching of the Options. Students often seem unfamiliar with some of the basic information.
- Make sure every part of the syllabus has been covered. Give a copy of the syllabus to students so that they can run their own checklist
- Strongly encourage students to answer questions **only** on the Options they have studied. Ensure that students are aware of the importance of "action verbs" and that their answer addresses the question that has actually been asked.
- Give students 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 marks assigned.

Internal Assessment

Higher and standard level

Component grade boundaries

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 (IA) was similar to last year. The 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. Some schools are still submitting full portfolios but this is no longer a requirement. Incorrect completion of form

4/PSOW, absence of instructions, and incorrect numbers of highlighted levels for moderation demonstrate that the instructions provided in the latest edition of the *Vade Mecum* are not being read and followed.

The task of moderation is made much easier when details of what been provided to the candidates are included with the samples. Some schools omitted this information, particularly in the case of summaries of verbal instructions. Many samples show that teachers had monitored the candidates' work carefully and provided useful feedback. In other cases, there was no evidence of feedback at all. 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 the students and also the moderator. Safety awareness and concern for the environment was evident in some schools but should have been universal. Moderators were provided with copies of the feedback forms sent to teachers in May 2002. Unfortunately, in some cases, little improvement was noted.

The range and suitability of the work submitted

A broad range of investigations was submitted and many schools had interesting practical schemes of work. The majority of the schools covered the areas of the syllabus with suitable experiments. Most of the practical work undertaken was of a suitable level. Overall, the Options at both SL and HL were done reasonably well with some very good experiments included for moderation. However, concern still remains that some teachers do not seem to be familiar with the IA criteria. Teachers' attention is brought to the Teacher Support Material (TSM) now available on IBO's online curriculum centre (OCC) where detailed examples related to various aspects of IA criteria are posted.

Some schools do not seem to deliver a laboratory programme in the spirit expected. Several schools relied almost exclusively on textbook "recipes" with detailed instructions. In such situations, it is very difficult to assess the candidates' work against some of the criteria. There were a number of schools whose practical schemes of work were far short of the recommended number of hours (40 at SL and 60 at HL) or were trivial in nature. Although every effort is made by the moderators to reward candidates' efforts, it is nonetheless inevitable that candidates in such cases are less likely to score well when they are not given the opportunity to undertake more open-ended investigations.

Another weakness in some laboratory programmes is a high proportion of "investigations" that are actually demonstrations, passive descriptions - such as observations of physical properties, or drawing conclusions from data tables. The emphasis must be on hands-on experience and development of practical skills in the laboratory.

Candidate performance against each criterion

Planning (a)

Some teachers and students continue to have trouble with Planning (a). This criterion requires that teachers 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 a specific/focused research question. Some candidates 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. This aspect needs to be built more firmly into the structure of the investigations. In many cases variables were not mentioned or inferred in Planning (b) rather than being specifically identified. Note that not all investigations are susceptible to a hypothesis and so may not be appropriate for Planning (a). Please refer to the TSM on the OCC for Planning (a) details and examples.

Planning (b)

On the whole, candidates selected suitable equipment and devised appropriate strategies for carrying out investigations. There are still teachers who give out equipment and the method, and consequently these samples were moderated down. It is important to understand that Planning (b) **cannot** be assessed if candidates have been provided with the method. Teachers must not provide a list of apparatus, materials or the procedure, as candidates need to meet these aspects of the criterion on their own. Sometimes the control of variables was not always explicitly identified. It is not uncommon for candidates to take large amounts of materials when it could be carried out on the micro scale – candidates must pay attention to environmental consequences when planning an investigation. The inclusion of appropriate controls is often inadequately discussed. This follows from the failure to recognize the need for controls in the discussion of the variables. Few candidates seem to appreciate the notion of fair testing or they assume it is self-evident. Teachers must reinforce the need for this. The collection of sufficient data is also poorly considered. Replications are often not included. Teachers sometimes set up an investigation so there is only one way to proceed. Both Pl (a) and Pl (b) should evoke different responses from different students within the same class.

Data Collection

Performance was generally good and many suitable investigations were carried out. 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). Similarly, uncertainties are most often left out and there was frequent inconsistency in the use of significant figures. For example, 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, cannot be assessed if the teacher has provided data tables. Some candidates do not seem to present raw data. Instead, data is presented that has been recopied after the investigation has been carried out. Teachers must avoid investigations for 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 Processing and Presentation

Candidates were generally able to perform satisfactorily on this criterion, although high levels of achievement were not common. In some cases, manipulation of the data was elementary or absent. Many candidates missed the opportunity to take uncertainties into account and carry out error analysis even when this was clearly possible. Appreciation of significant figures is also often missing – please refer to examples in the TSM. In graphing, some candidates were unable to decide when to draw a straight line, when to draw a curve and when to join points, and lack of feedback in some cases meant the same error was repeated in other investigations. Teachers must not provide too much information about how data is to be processed – evidence should be present of the candidates' ability to process data on their own, rather than by a series of prescribed steps in calculations. Sometimes it seems as if the teacher has told the students how to process the data, so once again the teacher's instructions are important for moderation. Computer generated graphs are acceptable. A computer may draw the line for the student but the student still has to set up the graph from raw or processed data and make choices about its format. However, if the graph is drawn as part of a package where the student has little/no control over the analysis or output, then such graphs are not suitable for assessment against this criterion.

Conclusion and Evaluation

This is still an area where candidates do not score particularly well, 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. Candidates often do not 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. Suggestions for improvement are frequently trivial. Note that all investigations are not appropriate for assessment of this criterion.

Manipulative skills

The practical programmes in general provided adequate scope for assessment of this criterion.

The Group 4 Project

Most schools provided 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. This is an essential requirement of the IB programme.

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. 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 should be made aware of the different aspects of the criteria by which they are assessed candidates may find sub-headings for each criterion useful
- many schools are evaluating investigations using a grid of criteria/aspect with n, p and c indicated clearly – the use of such a grid is encouraged
- full portfolios are no longer required and should not be submitted unless specifically asked for by IBCA
- evidence for participation in the Group 4 Project by each candidate in the sample should be submitted
- teachers must not provide too much information/help for the Planning (a), Planning (b), Data Collection, Data Processing & Presentation and Conclusion & Evaluation criteria
- avoid using workbooks and worksheets with spaces to be filled in by the candidates for internal assessment
- candidates need practice at proposing a hypothesis that is directly related to the research question and is explained
- candidates must record qualitative as well as quantitative raw data, where appropriate, including units and uncertainties where necessary
- teachers must provide instructions for investigations in the moderation sample
- candidates should compare their results to literature values where appropriate
- when assessing the Conclusion & 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 should not assess for a particular criterion if an investigation does not meet all aspects of the particular criterion
- teachers should refer to chemistry subject guide, the Teachers Support Material on the online curriculum centre, and instructions provided in the *Vade Mecum* before submitting work for moderation.

