CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-18	19-33	34-47	48-58	59-68	69-79	80-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-32	33-45	46-56	57-66	67-77	78-100

Standard level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-11	12-15	16-18	19-21	22-24	25-30

General comments

This paper consisted of 30 questions on the Core and was to be completed without a calculator or Data Booklet. Each question had four possible responses, with credit awarded for correct answers and no credit deducted for incorrect answers.

The 29 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, nearly 61% felt that it was of a similar standard, with 9% considering it a little more difficult and 17% considering it a little too easy. The vast majority considered the level of difficulty appropriate.

Syllabus coverage was considered good by 45% and satisfactory by 55% of the respondents. Clarity of wording was felt to be good by 45% and satisfactory by 48%. The presentation of the paper was considered good by 72% and satisfactory by the remainder.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 87% to 31%. The discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates), ranged from 0.62 to 0.07 (the higher the value, the better the discrimination.)

Standard level Paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-21	22-27	28-32	33-38	39-50

General comments

The number of marks scored on this paper covered almost the full range. The best candidates demonstrated a solid mastery of the material and evidence that they were well prepared for this paper. On the other hand, the candidates at the other end of the distribution seemed to know very little chemistry and scored their marks at random places in the paper.

Teachers' impressions of this paper were conveyed in the G2 forms returned (28 as of 13/12/04). In comparison with last year's paper, 35% felt this year's to be of a similar standard, 45% thought it a little easier, 15% considered it a little more difficult and 5% believed it was much more difficult. 92% indicated that the level of difficulty was appropriate. Syllabus coverage was rated satisfactory by 54% and good by 39% of the respondents. The clarity of wording received satisfactory ratings by 36% and good ratings by 60%. The presentation of the paper was rated as satisfactory by 29% and good by 71%.

Difficulties for candidates

The question that posed the greatest difficulty for the largest number of candidates was defining the average bond enthalpy and carrying out bond enthalpy calculations. In addition, some individuals struggled with the stoichiometric calculation and the empirical formula. Further comments will be made about specific questions below.

Knowledge, understanding and skills demonstrated

This paper provided a suitable range of challenges and was answered satisfactorily by the majority of candidates, with some going beyond the minimum requirements of the questions. Further comments will be provided under the next section of this report.

Strengths and weaknesses in individual questions

Section A

Question 1

Part (a) was seldom answered correctly. The calculation in part (b) was done flawlessly by many. A small fraction of candidates seemed to have little idea of where to begin. Even with a correct empirical formula from part (b), few candidates could write a correct equation in part (c). A minority of candidates received both marks in part (d) with many of the responses failing to describe observations.

Question 2

This question was done well by the majority of candidates. Marks were lost in part (a) because of a lack of precision in definitions. For example, the common formula in a homologous series was frequently identified as "empirical" or "molecular" rather than "general". Hydrocarbon descriptions often omitted the word "only" that was required for the mark. Some individuals defined the term "saturated" by referring to solutions rather than hydrocarbons. Part (b) was generally done well, although boiling points were sometimes explained in terms of an increase in the number of bonds with no distinction between intermolecular and intramolecular forces. Most candidates received full credit for part (c) although some gave strange answers (e.g. H_2, carbon, alkanes, etc.).

Question 3

Part (a) was almost never answered correctly. The phrase "average bond enthalpy" appeared to be an unfamiliar one for many candidates. Equations were seldom given, were incorrect or inappropriate. Most candidates received some credit for part (b), but few achieved full marks. Marks lost were due to a wrong sign or a mathematical error. Part (c) was generally answered adequately. Most candidates showed the energy levels for the reactants and products in part (d), but some failed to indicate the activation energy. Diagrams often lacked appropriate labels.

Question 4

This short question was done well. Many candidates demonstrated a sound knowledge of pH and acids. The pH in part (a) was usually given correctly, although it was often based on a calculation rather than on the 10-fold increase in concentration. Many recognized that part (b) involved a weak acid (and some even calculated the pH using the equilibrium expression).

Section B

Question 5

This was the least popular of the three questions, but the majority of answers were well done. Some answers to part (a) (iv) suggested confusion about intermolecular and intramolecular forces. Part (b) was generally answered well. Some candidates ignored the need for two functional groups in (ii) while others had difficulty drawing the peptide linkage in (iii). Drawing optical isomers in (iv) posed the greatest difficulty for candidates.

Question 6

This was the most popular question and was well done by the majority. Part (a) posed few problems. In part (b), some candidates lost marks because they tried to account for differences in radii by referring to the position elements occupy in the periodic table rather than giving explanations based on atomic level properties. Candidates struggled with the definition of electronegativity, the representation of hydrogen bonding, and the determination of bond angles, molecular shapes and molecular polarity in parts (c) and (d).

Question 7

This was a fairly popular question. A few candidates had difficulty with part (a). Some misinterpreted the question and suggested ways to vary the conditions rather than ways to follow the reaction, while others suggested impractical methods, such as measuring the quantity of water formed or studying the mass of solid reacting. Collision theory discussions occasionally lacked precision in part (b). Part (c) was answered reasonably well. Marks were often scored in part (d) (i) and (ii), but few individuals were able to answer part (iii) adequately.

Assistance and guidance teachers should provide

Much of the advice below has been given many times before.

- Candidates should prepare for examinations with questions from past examinations and markschemes, both in class and through mock examinations.
- Candidates should focus on understanding the material not just memorizing information.
- Candidates should read questions carefully and answer the question that is being asked rather than making general comments.
- Candidates should answer questions accurately and concisely.

The following suggestions apply more specifically to chemistry examinations. Candidates should:

- be sure to balance equations and check for both atoms and charges.
- practice bond enthalpy calculations.
- be sure to label all diagrams, including enthalpy diagrams.
- be able to distinguish between intermolecular and intramolecular forces.
- ensure that carbon atoms in organic structures do not have more than four bonds.
- improve their three-dimensional drawing skills to show molecular shapes.

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-18	19-22	23-26	27-30	31-40

General comments

The range of marks awarded was very wide. The most successful candidates showed a thorough command of the material and a high level of preparation, but many candidates seemed unfamiliar with their options choices and scored very poorly. Few candidates attempted more than two options.

The 28 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, more than 75% thought that it was of a similar standard, with slightly more of the remainder of respondents considering it easier rather than more difficult. Almost all respondents thought the level of difficulty was appropriate.

Syllabus coverage was considered satisfactory by 66% and good by the remainder of respondents. Clarity of wording was considered good by over half and satisfactory by the remainder of respondents. The presentation of the paper was considered good by the majority and satisfactory by the remainder.

Difficulties for candidates

In general, answers lacked precision in terms of the wording used and explanation were often vague and repetitive. Calculations proved challenging for many candidates.

Knowledge, understanding and skills demonstrated

This was generally a straightforward paper with easily accessible marks. Schools where most or all the candidates answered the same two options achieved better results. The majority of the candidates knew the subject material well. However, there were some schools where candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank.

Strength and weaknesses in individual questions

Option A – Higher physical organic chemistry

Question A1

In parts (a) and (b), the most common error was omission of the positive charge on the mass spectrum fragments. Most of the candidates drew at least one structure in part (c). In part (d), the majority had little idea as to why the peak at 45 was more prominent. The last part was generally well done, but candidates made many mistakes in (e) (ii).

Question A2

In part (a), many candidates had problem in writing a correct equation for the decomposition of hydrogen iodide into its elements. Other parts were generally well done. The main area of weakness was molecularity and how to deduce its value for the reaction.

Question A3

The equation was usually correct, with relatively few missing ionic charges. Most candidates obtained the correct pK_a value from the Data Booklet, but some could not use their calculators to determine the correct answer. The weaker candidates had problems in arranging the given acids in the correct order of strength.

Option B – Medicines and drugs

Question B1

Only some candidates attained full credit in part (c). Many answers were vague and repetitive. The question asked for **specific** problems associated with consumption of large amounts of ethanol. Other parts were generally well done.

Question B2

Many candidates had problems in recognising two similarities in the structure of caffeine and nicotine. Very few scored full marks on problems associated with short and long-term effects of nicotine consumption.

Option C – Human biochemistry

Question C1

Drawing the structures of the two possible dipeptides proved difficult for many students. This also demonstrated a lack of understanding of the peptide bond. Part (c) was done quite well by the majority of candidates, although some used the structural formula of each amino acid instead of the symbols as required by the question. Part (d) was generally well done, although some candidates showed little understanding of the various bonds responsible for maintaining secondary and tertiary structure of proteins.

Question C2

There was some good attempts to draw the structure of the monosaccharides. Other parts of the question were well answered by many of the candidates.

Question C3

Some candidates correctly named the two functional groups present in both cholesterol and testosterone. Methyl, hydroxide and C=C are not accepted as functional groups. Deducing the number of hydrogen atoms joined directly to the carbon atoms in the five membered ring proved difficult for the majority of the candidates.

Option D – Environmental chemistry

Question D1

Some candidates demonstrated poor understanding of the electrostatic method and full marks were rarely obtained. Some also had problem in identifying the type of fuel which produces particulates on combustion. Only a few candidates could write an equation in which particulates are formed.

Question D2

This straightforward question was well answered by the majority of candidates. Some identified sulfur dioxide as causing rain to be naturally acidic. Some candidates had problems writing equations in part (b).

Question D3

The term *biological oxygen demand* was not well known. Anaerobic bacteria was the most common answer in water with a low BOD value. In part (ii), many candidates wrote oxides of these elements instead of methane, ammonia and hydrogen sulfide. Part (c) was generally well done, although the third mark was rarely achieved.

Option E – Chemical industries

This was the least popular option. The small number of candidates attempting this option had very little knowledge of it.

Question E1

The majority of candidates demonstrated a lack of knowledge of the froth flotation technique and scored very low marks. Other parts were generally well done, except as to why the percentage of gold as an element is much higher than that of iron in the Earth's crust.

Question E2

Most candidates identified the compound from which most aluminium is extracted, but had problems writing half-equations for the formation of each product. Many candidates could not write an equation for the reduction of iron(III) oxide.

Question E3

It was clear that most candidates were not familiar with this topic or had very superficial knowledge of low and high-density polythene. A few candidates made some attempt to explain the term thermoplastics.

Option F – Fuels and energy

Question F1

Many candidates knew how crude oil is formed. In part (b), some candidates did not seem to be familiar with such calculations, while others knew exactly what to do and made few errors. Parts (c) and (d) were well answered.

Question F2

Some candidates had no or very little knowledge of alpha and beta decay. The half-life calculation also proved to be challenging for some. Safety in nuclear power plants was poorly answered. There was confusion between the functions of the control rods and moderator. Lack of specific answers was a common problem and full marks were very rarely awarded for this question.

Assistance and guidance for future candidates

Teachers are advised to cover two options thoroughly and not attempt to cover more than two.

Candidates need to be provided with adequate practice with past examination papers. Particular attention must be paid to the number of marks allocated to each sub-question, familiarity with action verbs and reading the question carefully.

“General knowledge” or journalistic answers to question do not gain full credit.

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-15	16-20	21-25	26-28	29-33	34-40

General comments

This paper consisted of 40 questions on the Core 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 marks deducted for incorrect answers. 17 questions were also used on the standard level examination.

The 27 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, nearly 67% felt that it was of a similar standard, with 19% considering it a little more difficult and 14% considering it a little too easy. The vast majority considered the level of difficulty appropriate.

Syllabus coverage was considered good by 59% and satisfactory by 41% of the respondents. Clarity of wording was felt to be good by 62% and satisfactory by the remainder. The presentation of the paper was considered good by 65% 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 31%. The discrimination index (an indication of the extent to which questions discriminated between high- and low-scoring candidates), ranged from 0.72 to 0.14 (the higher the value, the better the discrimination.)

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-29	30-42	43-51	52-61	62-70	71-90

General comments

This paper was accessible to the majority of candidates with few questions causing concern. There were many candidates who attained high scores and relatively few very low ones. All but the very weakest candidates attempted most parts of most questions, and almost none answered more than two questions in Section B. 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. Candidates **must** pay attention to the action verbs used in the questions.

Teachers' impressions of this paper were conveyed by the 27 G2 forms that were returned. In comparison with last year's paper, two thirds thought it to be of a similar standard and none thought it to be either much easier or much more difficult. Less than one fifth thought it to be either a little easier or more difficult. The vast majority thought the level of difficulty was appropriate. Syllabus coverage was considered good by over half and poor by none. Nearly two thirds considered the clarity of wording to be good, with the remainder considering it satisfactory. The presentation of the paper was considered good by two thirds and satisfactory by the remainder.

Difficulties for candidates

- definitions (e.g. hydrocarbon, homologous series, ligand, half-life, isomerism)
- stoichiometry and mole calculations
- calculation of ΔG
- action of indicators
- hybridization and bonding
- VSEPR and shapes
- standard electrode potentials
- electrolysis

Levels of knowledge, understanding and skill demonstrated

- boiling points and intermolecular forces
- calculation of oxidation states
- drawing isomers
- determination of structure of organic chemicals
- order of reaction

Strengths and weaknesses in individual questions

Section A

Question 1

(a) As the reaction involved hydrated sodium carbonate crystals, even though the formula was given, many candidates were unable to give the correct equation. Many answers gave H_2CO_3 as a product instead of CO_2 and H_2O.

(b) With "error carried forward" allowed from the equation in (a), many candidates were able to calculate the molar concentration of the sodium carbonate solution. However, little attention was paid to significant figures, which was penalized.

(c) Most candidates correctly calculated the M_r of sodium carbonate. Incorrect or missing units were penalized. The calculation of the mass in $1.000 dm^3$ of solution was well done by the majority of candidates.

(d) Many candidates managed to calculate the number of moles of water present in the crystals, but did not proceed to identify the correct mole ratio. The most common answer given was $x = 1$.

Question 2

(a) Candidates lost marks because statements lacked sufficient detail. The majority only attained one mark in part (i), lost marks in part (ii) for not stating hydrogen and carbon <u>only</u> and lost marks in part (iii) for not being specific about carbon-carbon bonds.

(b) Most candidates knew the relationship between melting point and intermolecular forces, but a significant minority thought that larger molecules having more bonds would have higher melting points. Many candidates recognized combustion as an exothermic reaction.

(c) The majority of candidates gave both products of CO_2 and H_2O.

Question 3

(a) Many candidates realized that ΔH was not the same as ΔH^{o}_{f} and stated a correct definition for ΔH^{o}_{f}. The explanation of why the reaction in the question could not be so described was lacking in most answers.

(b) The most common error was not recognizing S as entropy, but omitting to describe Δ as "change in".

(c) The majority of candidates neglected to convert the units of either ΔH or ΔS in order to carry out the correct calculation. With allowance for "error carried forward", most candidates gained at least two marks.

Question 4

(a) Most candidates attempted an equation, although many gave reactions of the indicator with a specific acid rather than the required ionization. The most common error with the correct ionization equation was to have only a single arrow.

(b) The majority of candidates identified the correct colours, although appropriate explanations in terms of the equilibrium were rarely given.

Question 5

(a) The majority of candidates recognized atypical transition elements.

(b) Ligands were poorly defined and few candidates gained more than one mark.

(c) Most candidates correctly calculated at least two oxidation states.

(d) Fe in the Haber Process was well known, but other answers included non-industrial processes and were not accepted.

(e) Many answers were given here that differed from the expected variable oxidation states and coloured compounds. A number of candidates stated that the transition elements themselves were coloured.

Section B

In answering questions in section B, candidates should look at the number of marks available. This will give them a good idea of the length of the answer expected.

Question 9 was least popular, whereas the other three question were more or less equally chosen.

Question 6

(a) Most candidates realized the need to calculate the percentage of oxygen and then proceeded to calculate the empirical formula correctly.

(b) With a correct empirical formula, the molecular ion was recognized and the correct molecular formula given. The formulas of the fragment ions were correctly given by the majority of candidates, but many lost one mark for not writing in the + charge.

(c) Most candidates identified the missing or present bonds, but often did not refer to their frequencies.

(d) The most common error was to give the name and structure of methyl ethanoate, rather than ethyl methanoate. Candidates should remember to include all the hydrogen atoms in their diagrams. The uses given were mostly correct.

(e) Most candidates gained full marks here as a result of “error carried forward”.

(f) Many candidates identified the reaction as condensation, rather than esterification, and had difficulties with the equation.

(g) Only about half of the candidates could give an acceptable definition of isomerism.

(h) The majority of candidates scored two marks here, most as a result of “error carried forward”.

(i) The answer here needed to be consistent with the ester given in (d). Ethyl methanoate is small and sufficiently polar to give slight solubility. Insoluble, due to the absence of hydrogen bonding, was also accepted.

Question 7

(a) Candidates did not pay sufficient attention to the wording of their answers and only gained partial credit. Suitable diagrams were accepted. Some overly simplistic answers were given for double and triple bonds, but the majority of good answers described the correct number of sigma and pi bonds.

(b) Candidates attempted suitable diagrams and could usually identify the type of hybridization and give the correct shape. However, few could explain the shape in terms of VSEPR. Many candidates gave answers for C_2H_4 rather than C_2H_2 in part (iii).

(c) (i) Few candidates could give accurate descriptions of the bonding in diamond and graphite, with little mention of either covalent bonds or van der Waals' forces.

(ii) The majority of candidates gave long and confused answers, neglecting to compare the properties of the two allotropes.

(iii) The properties of C_{60} fullerene were not well known and comparisons were not specifically given.

Question 8

(a) Most candidates could identify and explain why the reaction was first order.

(b) The majority of candidates drew reasonable graphs.

(c) Many candidates gained this mark, often as a result of "error carried forward" from (a).

(d) The calculation was well attempted and explained, with most candidates gaining at least two marks.

(e) Error carried forward from (c) permitted most candidates to gain credit here. However, many could not give the correct units.

(f) Most candidates gained two marks for the graph, but lost the third mark for not correctly annotating the graph to show how the initial rate of reaction could be deduced. There were many well-reasoned determinations of orders of reaction, the one for O_2 proving to be the most difficult to explain.

(g) Few candidates could explain that order is linked to mechanism rather than stoichiometry.

(h) The majority of candidates referred to concentration, but few could explain why half-life is constant for first order reactions.

(i) The majority of candidates used the formula from the Data Booklet.

Question 9

(a) Most candidates, aided by diagrams, managed to gain at least three or four marks.

(b) Candidates defined oxidation in terms of electron loss but could not then identify the strongest oxidizing agent, suggesting that they did not understand the definition.

(c) The cell potential was correctly calculated, but state symbols were frequently omitted from the equation, which resulted in only one mark being awarded.

(d) This question was poorly answered. As many candidates chose tin as chose zinc. Few could identify the correct factors affecting the amount of metal discharged during electroplating. Many stated the concentration of the solution or just "the charge".

Very few candidates mentioned the discharge of hydrogen due to the presence of hydroxide ions in an aqueous solution.

(e) Most candidates correctly gave the identity and function of the salt bridge.

(f) Many candidates wrote the correct electrode reactions, but could not combine them for the cell reaction or failed to balance the resulting equation. The direction of electron flow was sometimes arbitrary and did not follow the given cell reaction. The majority of candidates calculated the cell potential correctly.

Assistance and guidance for future candidates

- Teachers are strongly urged to refer to past examination papers and their markschemes to assist candidates with examination preparation.
- Candidates must know the meanings of the different action verbs listed in the subject guide.
- Candidates should aim to match their answers to the number of marks allotted to the questions.
- Candidates should be encouraged to "keep going" with complex calcualations; errors are carried forward so that a correct method in a later part of the question is rewarded. All steps in the calculation must be shown.
- Candidates need to learn formal definitions and plan answers rather than ramble at length
- Candidates should, where appropriate, illustrate their answers with simple, neat and well-labelled diagrams.

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-8	9-16	17-24	25-29	30-35	36-40	41-50

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. Many candidates seemed unfamiliar with the options answered and scored very poorly. Few candidates attempted more than two options, which was pleasing.

Teachers' impressions of this paper were conveyed by the 25 G2 forms that were returned. In comparison with November 2003, two-thirds thought this year's paper to be of a similar standard, with the remainder evenly divided between those who thought it more difficult and those who thought it easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by nearly three-quarters and good by most of the rest. Clarity of wording was considered satisfactory by over half and good by most of the remainder. The presentation of the paper was considered good by over half and satisfactory by the remainder.

Difficulties for candidates

Each option question presented its own challenges. These will be apparent from the comments on individual questions in the next section, and especially from the assistance and guidance offered in the last section.

Knowledge, understanding and skills demonstrated

As there were few really poor scripts, it was pleasing to see even weaker candidates succeeding with some question parts.

Strengths and weaknesses in individual questions

Option B – Medicines and drugs

B1 Most candidates scored some marks in (a), although some points made were in the wrong part (low dose rather than high dose, or vice versa). Parts (b) and (d) were generally well answered, but in (c) many incorrect substances were listed.

B2 In (a), the cyclic nature of both compounds was usually recognized, although many candidates seemed to think that cyclic structures are always aromatic. There were many lengthy answers in (b), with several valid points made, although full marks were rare. There was some repetition, and long-term effects often appeared as short-term ones; several candidates did not make any distinction between the two.

B3 Answers were generally disappointing, with a significant number giving only one structure; some structures were tetrahedral. The term *geometrical isomerism* was not well explained, although there was little evidence of confusion with optical isomerism. Few candidates named more than one type of bond, and ionic was frequently mentioned.

B4 Part (a) was usually either completely correct or received no marks. Most candidates achieved at least one mark in (b).

Option C - Human biochemistry

C1 This question was generally well answered, with many candidates scoring most or all of the available marks. Some structures in (b) contained errors. Very few candidates used structural formulas in (c) in place of the symbols requested.

C2 In (a), a number of candidates gave a molecular formula instead of an empirical formula. Part (b) required candidates to deduce a structure from one given in the Data Booklet. Most candidates were successful, although some gave a non-cyclic structure. Names were often incorrect. Most candidates scored at least one mark in (c).

C3 Few candidates scored full marks in (a). While most included the idea of the active site, few clearly explained the action of an enzyme, in spite of being advised to use the E, S and P symbols. A considerable variety of lines on the graph in (b) was seen, although the explanation in (b) (i) was usually correct. Some answers to (b)(ii) looked like guesswork.

Option D - Environmental chemistry

D1 Some correct, detailed answers were seen in (a), but many candidates were obviously unfamiliar with electrostatic precipitation. Some answers resembled a description of electrolysis. Parts (b) and (c) were often correct, although some candidates did not seem to know the term *particulates* and gave equations in which CO, rather than C, was formed.

D2 Most answers to (a) were correct, although oxides of nitrogen and sulfur were seen in some scripts. In (b), the formula of nitrogen(II) oxide was often given as N_2O. The name of the acid was often correctly given in (b) (i). It was also possible to score full marks ("error carried forward" principle) in (b) (ii) for an equation using N_2O.

D3 Part (a), about biological oxygen demand, was better answered than in previous years. Candidates were able to distinguish aerobic from anaerobic bacteria in (b) and a number of correct answers were seen.

D4 Most answers to (a) were correct, although some candidates gave another Lewis structure for ozone. Most had some idea of how to answer (b), although a number of candidates made no reference to wavelength or thought that greater energy meant longer wavelength.

D5 Some candidates scored full marks, but many wrote lengthy answers that scored no marks. Vagueness was common, with the non-specific "industry" being held responsible for the release of both metals into the environment. Quite a number of responses did not refer to water supplies, as required by the question.

Option E - Chemical industries

E1 This was the least popular option. Many scripts contained gaps, including this question. Some candidates were clearly familiar with *froth flotation*, but most answers suggested pure guesswork and rarely scored marks.

E2 Generally well answered. Weaker candidates made errors in the equations in (a). Coke was commonly given as answer in (b) (i), although it was excluded by the wording of the question. The equation in (b) (ii) was often incorrectly balanced.

E3 In (a), the differences between the low- and high-density forms of polythene were not well known, although in (b) the meaning of the term *thermoplastics* was usually correct.

E4 In (a) (i) the terms *initiation, propagation* and *termination* were rarely seen. The movement of electrons in (b) (ii) was poorly described in spite of the help available in the equation provided in the question. Part (b) was rarely correct.

E5 Few candidates scored full marks. A temperature of 1250 K was often quoted, perhaps through reading the wrong line for carbon, rather than through an inaccurate estimate of where the correct lines crossed. The use of the diagrams to estimate the $\Delta G°$ value for a reaction was not well known, and many negative values were given.

Option F - Fuels and energy

F1 Part (a) was very straightforward and most candidates scored at least two marks here. Better candidates had no difficulty with the calculation in (b), but weaker candidates ignored the coefficients in the equation.

F2 Part (a) was often well done. In part (b), the symbols and mass numbers of the decay products were often incorrect. Full marks were rarely seen part (c) and quite a few candidates scored no marks. Common errors included "reaction gets out of control" (not specific enough) and "the oxygen burns" (instead of the graphite moderator). Few candidates mentioned the reaction of sodium with air or water.

F3 Some answers in part (a) were too vague to score both marks. The calculations in part (b) tended to be either complete and correct, or not attempted at all.

F4 This question was poorly answered. Many candidates simply repeated information from the question. Some wrote about chemical reactions involving sodium and sulfur, while others answered in terms of electronegativity instead of ionization energy.

Option G – Modern analytical chemistry

G1 Full marks were commonly scored. Clearly, many candidates had studied this part of the option in considerable depth.

G2 This question was poorly answered. Candidates were expected to recognise that the spectrum of **P** had lines in the ratio 3:1 that were two units apart on the m/z scale. These could only be due to the presence of either ^{35}Cl or ^{37}Cl in the structure, leading to $C_2H_5{}^{35}Cl^+$ and $C_2H_5{}^{37}Cl^+$ (positive charges were frequently missing). Similarly, **Q** had lines in the ratio 1:2:1, each separated by two units, indicating two of either ^{79}Br or ^{81}Br, or one of each. Part (b) was more straightforward but was still not answered well.

G3 Part (a) was better answered than similar questions in previous years. More candidates are referring to changes in bond angle, length and polarity. The bonds were usually correctly identified in part (b). Many candidates are adept at interpreting NMR spectra, and there were many correct answers to part (c). Some candidates did not clearly state the presence of adjacent CH_3 and CH_2 groups. Part (d) was well answered. The most common error in part (e) (i) was to mistake the narrow infrared absorption at 3000 cm^{-1} for a broad one and identified O–H, rather than C–H, as the bond responsible.

Option H – Further organic chemistry

H1 Answers to this question were generally poor. In part (a) there was much confusion between substitution in the ring and in the side-chain, in spite of the clues given in the question. The mechanisms in parts (c) and (g) were often hybrids of electrophilic and free-radical reactions, again in spite of helpful words in the questions ("use Cl^+" in (c) and "propagation" in (g)). Many of the free-radical mechanisms given in (g) applied to the formation of **J** or **L**, rather than to **K**.

H2 Although some very good candidates scored highly in both parts of this option, this question was generally not well answered. In part (a), some diagrams showed incorrect groups and others lacked clarity. A number of answers in part (b) contained either structural isomers or attempts at geometrical isomers showing only right angles between bonds, making the *cis*- and *trans*- isomers impossible to distinguish.

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.

- Practise writing and balancing a wide range of equations (molecular, ionic and nuclear), including balancing charges in the case of equations involving ions.
- Become familiar with the different types of organic reaction mechanism, including the use of “curly arrows”.

- Continue to carefully distinguish between the different types of bonding and intermolecular forces and their importance in explaining features such as boiling point and solubility.
- Spend time in gaining familiarity with the calculator to be used in the examination, especially for less frequently used functions such as log and antilog, square and square root.
- Practise setting out calculations logically, with occasional words to indicate what is being calculated.
- Become familiar with using (and carefully selecting from) tables in the Data Booklet.
- Avoid "journalistic" language, especially in Options D and E, when describing environmental problems. Also, if a problem is the result of industrial activity, the industry should be clearly stated.
- Remember that in equations, the formulas of non-metallic elements usually need a subscript (eg N_2 rather than N).
- Practice writing the structures of stereoisomers to clearly indicate the shapes.
- Use, where appropriate, formulas that distinguish between isotopes (eg $^{35}Cl–^{37}Cl$).

Internal assessment higher level 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 guidelines not being followed in submitting practical work for moderation. Schools continue to submit samples that are not complete, correct or properly annotated. Incorrect completion of form 4/PSOW, absence of instructions, and incorrect numbers of highlighted levels for moderation, suggest that some teachers are not reading instructions provided in the latest edition of the *Vade Mecum* and are not paying attention to past subject reports or to the teacher support material available on the online curriculum centre (OCC). Submitting full portfolios is no longer a requirement.

The task of moderation is made much easier when instructions 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. This helps students and the moderator, as the purpose of moderation is to validate teachers' assessment. Safety awareness and concern for the environment was evident in some schools but should be universal. Moderators were provided with copies of the feedback forms sent to teachers in November 2003. Unfortunately, in some cases, little improvement was noted. In most cases, teachers paid close attention to the advice given, leading to improved IA programmes and assessment.

The range and suitability of the work submitted

Most schools presented a practical scheme of work of a suitable academic standard. A broad range of investigations was submitted and many schools had an interesting practical programme. The majority of schools covered the areas of the syllabus with suitable experiments. Overall, the options at both SL and HL were covered reasonably well, with some very good experiments included for moderation. Concern still remains that some teachers do not seem to be familiar with the IA criteria. Attention is brought to the detailed examples related to various aspects of the IA criteria included in the teacher support material available on the OCC.

Some schools relied almost exclusively on textbook "recipes" with detailed instructions. This approach penalizes candidates, as they do not have the opportunity to meet the criteria. There were a number of schools whose practical schemes of work were short of the recommended number of hours (40 at SL and 60 at HL) or were trivial in nature. Candidates in such cases are less likely to score well when they are not given the opportunity to undertake more open-ended investigations. Schools that did not provide suitable assessment tasks were often those that were teaching IB chemistry alongside other non-IB courses.

Candidate performance against each criterion

Planning (a)

Many reports were structured so as to clearly show the aim, hypothesis and explicit identification of the independent and control variables. However, a significant number did not clearly highlight the variables. Overall, there was an improved understanding of the terms control, dependent and independent in relation to variables. This criterion requires that teachers provide a broad or general investigation problem, which allows candidates to come up with their own focused question. Many candidates are still being given a specific research question, which denies them the opportunity to achieve full marks for this criterion. Some candidates stated a hypothesis, but did not explain their reasons for it. Difficulties arose with poorly stated hypotheses which received little or no credit. Others gave a hypothesis together with a very superficial explanation.

There still seems to be confusion as to whether the explanation for a hypothesis has to be scientifically valid. Some teachers gave credit for trivial or unfounded explanations. This aspect needs to be built more firmly into the structure of the investigations. Not all investigations are susceptible to a hypothesis and so may not be appropriate for Planning (a). Please refer to the teacher support material on the OCC for examples of Planning (a) investigations.

Planning (b)

On the whole, candidates selected suitable equipment and devised appropriate methods for carrying out investigations. There are still teachers who give candidates the equipment and the method. In such cases, the marks awarded by the teacher were invariably reduced as a result of moderation. Candidates need to meet these aspects of the criterion on their own. Planning (b) should not be assessed if candidates have been provided with the method. Procedures that fail to control variables is a common weakness of Planning (b). This often follows on from the failure to recognize the need for controls in the discussion of the variables (in Planning (a)).

It is not uncommon for candidates to take large amounts of materials when the procedure could have been carried out on a smaller scale. Candidates must pay attention to the environment when planning an investigation. 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. Replication is often not considered. 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 (e.g., 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 (e.g., recording burette readings where a single table contained data such as: 5, 19.5, 20.37 cm^3).

The second aspect of the criterion, organizing and presenting raw data, cannot be assessed if data tables have been provided to the candidates. Some candidates do not seem to present raw data. Teachers must avoid assessing investigations for Data Collection when only a few values are being collected, or where only 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, processing of data was elementary or absent. In other cases, marks were awarded for graphs that did no more than present the raw data (such as rate of reaction graphs where volume of gas collected was plotted against time) without any data processing, such as subsequent calculation of a gradient to find the reaction rate at a given time. DPP was often being assessed for interpretation of qualitative data such as test-tube reactions, where balanced equations were inexplicably generated from a minimum of qualitative observation. Many candidates missed the opportunity to take uncertainties into account and carry out error analysis, even when this was clearly possible. Appreciation of significant figures is often lacking (please refer to examples in the teacher support material). In graphing, some candidates were unable to decide when to draw a straight line, when to draw a curve and when to join points. In some cases, the lack of feedback from the teacher resulted in repetition of the same error in other investigations.

Teachers must not provide too much information about how data is to be processed. Teachers should not provide a series of prescribed steps in calculations. It is sometimes evident that the teacher has told the candidates how to process the data. Computer generated graphs are encouraged, but control and formatting choices must be made by the candidate, not the program.

Conclusion and Evaluation

This is still an area where candidates do not score particularly well. It is uncommon 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, which was often missing in candidates' write-ups. Candidates often do not evaluate the procedure, nor do they list possible sources of error and make suggestions to improve the investigation following the identification of weaknesses. Comments such as "the readings must have been too low or too high" are not an appropriate evaluation of the procedure. Suggestions for improvement are frequently trivial. Candidates should attempt to identify reasonable systematic errors in the procedure and then suggest realistic improvements to the investigation. Note that not all investigations are 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. (This can take a variety of forms as stated in the IB *Chemistry Guide*.) Some schools failed to provide such evidence and a special request then had to be made by IBCA. Some reports submitted contained little or no chemistry content. The project should help stimulate group work across subjects boundaries but should not lack chemistry work. In some cases, the Group 4 Projects represent less than the 15 hours of work that is stated on the form 4/PSOW.

If the Group 4 Project is used to assess any of the criteria Pl (a) to CE, then the contribution of an individual candidate must be clearly identifiable. Group work cannot be submitted for assessment of criteria. To submit photocopies of group work and submit it for individual work within samples of multiple candidates is clearly unacceptable and risks being treated as malpractice. It is worth teachers noting that a significantly large proportion of schools use the Group 4 Project as an ideal opportunity to stimulate group collaboration within an interdisciplinary framework and assess the Personal Skills criteria.

Recommendations for the teaching of future candidates

Clearly many schools are doing fine work. Generally, 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 understood by the candidates. 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.
- Assessment of investigations using a grid of criteria/aspect with n, p and c indicated clearly, is strongly encouraged.
- Full portfolios are no longer required and should not be submitted unless 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 with respect to the Planning (a), Planning (b), Data Collection, Data Processing & Presentation and Conclusion and Evaluation criteria.
- Candidates need practice at proposing and explaining a hypothesis that is directly related to the research question.
- Candidates must record qualitative as well as quantitative raw data, where appropriate, including units and uncertainties where necessary.
- Teachers must provide instructions for investigations in the moderation sample.
- Candidates should compare their results to literature values where appropriate
- When assessing the Conclusion & Evaluation criterion, candidates are required 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 that criterion.
- Teachers should refer to the chemistry subject guide, the teachers support material on the online curriculum centre, and instructions provided in the *Vade Mecum*, before submitting work for moderation.

