CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-33	34-46	47-57	58-67	68-78	79-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-31	32-44	45-55	56-66	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	12-16	17-19	20-22	23-25	26-30

General comments

This paper consisted of 30 questions on 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 125 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, two-thirds of respondents felt it was of a similar standard. The remaining respondents were almost evenly divided in considering it more difficult or easier. Nearly all respondents thought the level of difficulty was appropriate. Both syllabus coverage and clarity of wording were considered good by over half and satisfactory by the remainder. The presentation of the paper was considered good by nearly three-quarters of the respondents and satisfactory by one-quarter of the respondents.

A variety of general comments, the majority complimentary, were made on the G2 forms.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 95% to 24% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.51 to 0.01. (The higher the value, the better the discrimination).

The following comments are made on individual questions.

Question 5

The diagram attracted some adverse comments, as line 4 was not well drawn. It was not a detracting factor for candidates and 85% choose the correct response A.

Question 10

Several respondents suggested that a table of electronegativity values was needed to answer this question. This is not the case. The purpose of the question was to test candidates' application of A.S.4.2.4 and 4.2.5. Two-thirds of candidates chose the correct response (the C–O bond, with an electronegativity difference of 1.0). The other bonds all had differences of 0.5; the most popular of these was the O–F bond, probably chosen because these two elements are the two most electronegative.

Question 11

Several respondents thought this too difficult for SL candidates. The question discriminated well and 46% chose the correct response D, although B was a popular distractor. The criticism is not accepted, especially as the example chosen (SO_2) is mentioned in the teachers' note in A.S.4.2.8.

Question 12

A comment was made that ethers (response B) are not mentioned in the syllabus. The question could be answered by considering the compounds' ability to form hydrogen bonds with water molecules (testing A.S.4.5.2). The question discriminated very well and the correct response C was chosen by 58% of candidates. The most popular distractor was A (ethane), perhaps because it was the smallest molecule.

Question 24

It was suggested that this question was too difficult for SL candidates. Although it discriminated well, it was the most difficult question on the paper. It is considered that it was a fair test of A.S.9.4.2 (describe ways of preparing buffer solutions).

Standard level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-20	21-26	27-32	33-38	39-50

General comments

In general the candidates appeared to have been well prepared for this examination. As in past sessions, it seemed that there was a tendency for candidates to avoid the organic chemistry questions in Section B.

Strengths and weaknesses in individual questions

Section A

Question 1

(a)
(i) A common error was to answer in terms of the amount of nitrogen rather than the rate of its production. Few candidates stated that the frequency of collisions decreases as the concentration of reactants decreases.

(ii) A significant number of candidates stated that the reaction goes to equilibrium even though there is no equilibrium sign in the equation given in the question.

b)
(i) This was a very easy mark gained by virtually all the candidates.

(ii) Most candidates were aware of an increase in energy for the molecules; "more collisions" rather than "more frequent collisions" was often suggested. Only a small percentage of candidates made any reference to activation energy.

(iii) This concept was well known and most candidates scored both the marks available.

Question 2

(a) Most candidates were aware of the difference between two isotopes but lacked precision when giving a definition. Thus many candidates lost a mark by describing an isotope as an "element" rather than an "atom" with specific properties.

(b) The method asked was generally well known, but answers were often given to an inappropriate number of significant figures.

(c) This was well understood.

Question 3

(a)
(i) The Lewis structures were almost always drawn correctly.

(ii) The two shapes were usually both correctly stated, but the explanations lacked clarity. The numbers of bonds and lone pairs (even if zero) around each central atom need to be stated.

(iii) The polarities were usually known, but explanations were often poor. Lacking was mentions of the bond polarities and the fact that they cancel in carbon dioxide, but not in hydrogen sulphide.

(b) This part was done quite well done. A minority of candidates gave intramolecular forces such as covalent bonds.

Question 4

(a) Most candidates correctly predicted the direction of change and stated that the forward reaction is exothermic. A small number referred to an increase in reaction rate rather than the position of equilibrium.

(b) This was usually answered correctly.

Section B

Question 5

(a)
(i) Most candidates calculated the value correctly and related "exothermic" to the appropriate sign in their answer.

(ii) Some candidates had no legend on either axis. A few gave the conditions simply as "stp".

(iii) Most candidates suggested small (or zero) change in entropy and were able to relate this to similarities in the structures of reactants and products, in addition to the fact that they are all solids.

(b) Most candidates were able to quote (or find in the data booklet) the correct equation for free energy change, and to state that this needs to be negative for a reaction to be spontaneous. In many cases, the explanation was very difficult to follow. Some candidates referred to T (in Kelvin) as being negative.

(c)
(i) Many answers used N-N instead of N ≡ N for the bond energy of the nitrogen molecule. The coefficients for H-H and, particularly, N-H were often incorrectly selected.

(ii) Most candidates suggested that the entropy change would be negative and could relate this to the decrease in the number of molecules of gas.

(iii) The sign of the entropy change, the temperature left in degrees Celcius, the units of the entropy change we all sources of error.

Question 6

(a)
(i) This was generally correctly answered.

(ii) Many candidates simply wrote "iron".

(iii) Most candidates were able to calculate both oxidation states correctly.

b)
(i) Correct responses from most candidates.
(ii) Correct responses from most candidates.

(iii) Few candidates mentioned a colour change, but most suggested a precipitate or a deposit of silver.

c)
(i) There remain a large number of candidates who think that molten ionic compounds conduct via electrons. Some of the descriptions were inadequately vague.

(ii) The equations at the electrodes were generally known.

(iii) Many candidates interpreted the question as a use of electrolysis or electrochemistry in general, giving answers such as the production of electricity, electroplating etcetera.

Question 7

(a) The name and structure were usually known.

(b) Most answers omitted the presence of acid for the dichromate oxidation.

(c) The structures were presented correctly. A significant number thought that substitution could be carried out directly.

(d) The isomer was generally identified correctly, but the reason for it not being formed directly was rarely clearly explained.

(e) Most candidates gained both marks.

(f) Condensation polymerisation was generally known and most candidates gave at least one example, although "carbohydrates" alone is not a sufficient answer.

(g)

(i) In general, was not sufficiently described.

(ii) Identification of the chiral centre was an easily gained mark for most candidates.

(iii) Diagrams were adequate. Note that it is the three-dimensional nature that should be shown.

Assistance and guidance for future candidates

From the answers produced it was clear that the majority of the candidates had covered the material for this examination. Question 7 had only a small number of answers leading to the supposition that some centres rush through organic chemistry at the end of the course.

As in previous years, candidates would likely benefit from more attention to examination technique and time should be allocated to practice tests using past papers.

Candidates must answer the question that is asked in the manner indicated. Simple statements of facts do not qualify as explanations in most cases. An observation is what can actually be seen. Thus, "a metallic-looking precipitate" is appropriate where as "a named substance is formed" is not. Definitions must be clear and precise. Candidates should practise making use of diagrams in their answers, especially in VSEPR theory and chirality where the three-dimensional nature of molecules needs to be shown.

Areas that teachers might consider giving greater emphasis include:

- layout of calculations, showing all working, a consideration of significant figures, the importance of quoting units and the significance of the sign in thermochemistry
- conduction - whether by electrons or by ions
- electron distributions and the shapes of molecules and ions, including the importance of any lone pairs with a recognition that it is the electron pairs that repel but the shape is conventionally described by the positions of the atoms
- definitions

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-11	12-17	18-21	22-25	26-29	30-40

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 111 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, two-thirds of respondents thought this year's paper to be of a similar standard, with slightly more of the remainder of respondents considering it more difficult rather than easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by nearly a half 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 two-thirds of respondents and satisfactory by the remainder.

Difficulties for candidates

Many of those who chose Option A did not score well. Response demonstrated difficulties with recalling the meanings of terms and providing adequate explanations; the use of curly arrows in reaction mechanisms causes candidates difficulties, as noted in past sessions. Option B provided the most successful candidates with opportunities to demonstrate their knowledge and understanding, and this was particularly evident in the question about bacteria and viruses. In Option D there answers written in a journalistic style were noted, a failing noted in previous sessions. Answers evidenced considerable confusion between the greenhouse effect and issues to do with the ozone layer. Relatively few candidates attempted Option E. Parts of Option F were problematic for different candidates. Some candidates scored full marks for the calculation in F2(e) while others left it blank or made many errors. Question F3(b) was likely the most inadequately answered question of this paper. In spite of the mention in the question of masses of particles, many candidates' answers contained no references to these.

Knowledge, understanding and skills demonstrated

There were some excellent sets scripts seen from some centres, invariably from centres 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 candidates to study a variety of options on their own.

Strengths and weaknesses in individual questions

Option A – Higher physical organic chemistry

Question A1

(a) Most candidates knew the meanings of S and $_N$ but 2 was often stated to refer to order instead of molecularity.

(b) The amine was usually correctly named , although a minority quoted the name of an amide.

(c) Organic mechanisms continue to be badly done by many candidates. In the nucleophilic attack the curly arrow should start from the nitrogen atom of ammonia. In this example the transition state has no overall charge, although many candidates seem to think that a negative charge needs to be shown.

(d) Most candidates correctly identified both bonds, with a minority giving only one. The connection between organic structures and NMR spectra was generally well known, with few candidates opting for two or five peaks (presumably ignoring the NH_2 group).

Question A2

(a) Few candidates scored both marks. Some reference was required to the facts that all the carbon-carbon bonds in B were the same length, while those in A would have two different values. Many answers referred only to "bonds", with no mention of carbon.

(b) Poorly answered by most candidates. Some candidates confused cyclohexene with cyclohexane. The points required were a recognition that the value for cyclohexene was for the hydrogenation of one C=C bond, so A should have three times the value and that the lower value for benzene indicated its greater stability.

Question A3

(a) Invariably correct, with just a few ions missing charges or $[H_2O]$ appearing as a denominator.

(b) Many completely correct answers seen.

(c) Most often correct, with the most common omission being to the fact that $[H^+]$ and $[OH^-]$ would be equal; it was not sufficient to state that the concentrations of both ions would increase.

Option B – Medicines and drugs

Question B1

(a) The distinction between mild and strong analgesics was usually correct.

(b) The names of the functional groups was usually correct, although some candidates gave formulas instead of the names demanded in the question.

(c) The esterification reaction needed was well known.

Question B2

(a) Most candidates correctly identified bacteria as the micro-organism killed by penicillins, but fewer knew about their effect on cell wall formation.

(b) Most candidates knew about the problem of increased resistance or immunity, but fewer knew about the effect on useful bacteria.

Question B3

(a) Most candidates knew enough about the differences between bacteria and viruses to score 3 or 4 marks.

(b) Well answered, although several candidates referred to the killing of viruses rather than blocking replication.

Option C - Human Biochemistry

Question C1

(a) Most candidates correctly associated the appropriate solubility for each vitamin named. Slightly fewer candidates gave correct/appropriate explanations. It was not sufficient to state that there was a hydroxyl group in vitamin C, as vitamins A and D also contain one. A reference to there being several such groups needed to be stated.

(b) Most often correct.

(c) Most often correct.

(d) Many candidates wrote C=C instead of the required name.

(e) Not well done. Oxidation or destruction by high temperature, and dissolving in water, were the expected answers.

Question C2

(a) Carbonyl and ketone, but not aldehyde, were accepted as names for the C=O group; methyl or alkyl is not accepted as a functional group (see A.S. 11.3.1).

(b) Most often correct.

(c) Most candidates scored 2 or 3 marks.

Option D - Environmental Chemistry

Question D1

Most candidates consider that they know enough about the greenhouse effect to answer questions on the topic. Unfortunately, many of them either do not read the questions carefully enough or confuse the topic with ozone depletion.

(a) Discriminated well, with the most successful candidates scoring full marks. Candidates who failed to mention wavelength, or used journalistic terms such as "bounce off" or "reflect" did less well.

(b) Most candidates knew about evaporation from bodies of water as the natural source but far fewer candidates identified combustion of fuels as the man-made source.

(c) Only the top candidates recognized the distinction between abundance and effectiveness at absorbing radiation.

(d) Generally well done, with scores of 3 and 4 marks being common.

Question D2

(a) A few candidates ignored the question in and wrote about distillation. A number of answers showed lack of familiarity with ion exchange.

(b) Some candidates thought ozone was used to remove more impurities by chemical action rather than to deal with microorganisms, although its lack of taste was well known. In trying to state that the use of ozone avoids the formation of poisonous chlorinated compounds, a common error was to state that ozone is less toxic than chlorine.

Option E - Chemical Industries

Question E1

(a)
(i) The removal of sulfur to prevent the formation of sulfur dioxide on combustion was better known than its poisoning of catalysts during refining.

(ii) The equations required discriminated well.

(iii) The equations required discriminated well

(b) Full marks were rare and C_6H_6 was often identified as cyclohexene.

Question E2

(a) Some candidates left several blanks in this question. Serious attempts scored well.

(b) Some candidates left several blanks in this question. Serious attempts scored well

(c) Equation given this session were more often correct that for previous sessions.

Option F - Fuels and Energy

Question F1

Most candidates were familiar with the advantages of liquids fuels.

Question F2

(a) Generally well attempted.

(b) Generally well attempted.

(c) Generally well attempted.

(d) Generally well attempted, although a common error in was to give "lead" rather than "tetraethyllead".

(e) The calculation most commonly resulted in either scores of zero or full marks. Some candidates did not seem to be familiar with such calculations, while others knew exactly what to do and made few errors. The value for the specific heat capacity of water appears in the Data Booklet, but several candidates used other values. A minority added 273 to the temperature change. Many candidates failed to give a negative sign for the final answer.

Question F3

(a) Full range of marks was seen.

(b) Disappointing, with many answers lacking any reference to mass and energy; some candidates referred to molecules rather than to nuclei (or atoms).

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 for charges in the case of equations involving ions
- become familiar with the different purposes of curly arrows in organic reaction mechanisms

- 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 actual 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, and underlining the final answer
- any candidates taught more than the two Options required for the examination should concentrate on two as the examination approaches

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-8	9-14	15-21	22-25	26-28	29-32	33-40

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 credit deducted for incorrect answers.

The 103 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, over three-quarters of respondents felt that it was of a similar standard, with more of the remaining respondents considering it a little easier than a little more difficult. Almost all respondents considered the level of difficulty appropriate. Syllabus coverage was considered good by over half and satisfactory by most of the remainder of respondents. Clarity of wording was considered good by nearly two-thirds and satisfactory by over one-third. The presentation of the paper was considered good by over three-quarters respondents and satisfactory by the remainder.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 96% to 25% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.57 to 0.03 (The higher the value, the better the discrimination).

The following comments are made on individual questions.

Question 7

Some respondents suggested that phosphorus(III) oxide would be unfamiliar to candidates. The teachers' note for A.S.13.1.1 specifically mentions this compound as one whose physical state should be known. The correct response, B, was chosen by 45% of candidates, although D was chosen by almost as many (those who believed that P_4O_6 was also a gas).

Question 9

Several respondents suggested that a table of electronegativity values was needed to answer this question. This is not the case. The purpose of the question was to test candidates' application

of A.S.4.2.4 and 4.2.5. Two-thirds of candidates chose the correct response (the C–O bond, with an electronegativity difference of 1.0). The other bonds all had differences of 0.5; the most popular of these was the O–F bond, probably chosen because these two elements are the two most electronegative.

Question 21

Some respondents suggested the expression that relates *k* to *T* appears in the Data Booklet and knowledge of it should not be tested in paper 1, which did not include the Data Booklet with the examination materials. Inclusion of a fact or item in the Data Booklet does not automatically eliminate the necessity of knowing by the candidate. The teachers' note for A.S.16.3.2 clearly states that this method should be explained. The question discriminated very well and was answered correctly by 56% of candidates.

Question 28

Some respondents criticised the appearance of the curves in the four pH graphs. It is accepted that they should have been drawn more accurately, although it is not considered that it caused difficulties for candidates. The question discriminated well and was answered correctly by 65% of candidates.

Question 34

Some respondents suggested that the wording was not clear, particularly the use of the word *neighbouring*. It is accepted that better wording could have been used, although the term *neighbouring* is used in the teachers' note for A.S.11.1.1, where its use is clearly indicated.

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 15	16 – 29	30 – 41	42 – 51	52 – 61	62 – 71	72 – 90

General comments

This paper provided good candidates with the opportunity to show what they could do but still provide opportunity for less strong candidates to make some headway with the questions. In general, candidates must pay particular attention to the number of marks allocated to a particular question and tailor their answers accordingly. Calculations must be shown clearly and should be checked for accuracy, significant figures and units where appropriate. Candidates must read questions carefully since some candidates provided no explanations when the question asked to state and explain. Candidates must pay attention to the actions verbs stated in the questions.

The areas of the programme and examination, which appeared difficult for the candidates:

- significant figures
- reaction mechanism in relation to rate
- line spectra

- molecular processes at equilibrium
- intermolecular forces and boiling points
- energetics definitions
- changes occurring in electrochemical cells or during electrolysis
- conditions for the oxidation of alcohols, S_N2 mechanism, product of esterification

The areas of the programme and examination in which candidates appeared well prepared:

- determining orders of reaction
- stoichiometry
- calculating relative atomic mass from isotopic composition equilibrium
- shapes of molecules
- application of free energy equation
- electrochemical cells
- reaction spontaneity

Strengths and weaknesses in individual questions

Section A

Question 1

(a) – (c) Determination of reaction orders was done well and many candidates were able to correctly determine the value of the rate constant.

The more able candidates were able to state and explain that the mechanism agrees with the experimental rate expression; others had difficulty recognizing that the slow rate determining step depends on [X] and [NO], and [X] depends on [H_2] and [NO]. An important thing to note was that the overall equation from the mechanism agrees with the stoichiometric equation.
Candidates generally had difficulty explaining why a single step mechanism would be unlikely for the reaction that involves the collision of four particles.

Comparisons of the rate of formation of different products were generally done well.

Question 2

Writing the equation for the complete combustion of ethane was done very well.
Some candidates had difficulty calculating the volumes of carbon dioxide produced or of oxygen remaining. Some calculated the moles of gases first, thus unnecessarily adding to the calculations required.

Question 3

A number of candidates did not know the formula of zinc iodide; others wrote incorrect reactants such as zinc ions or iodide ion in spite of the fact that the reactants were specified. Most candidates were able to identify the excess reagent.

Question 4

The term *isotope* is notoriously difficult to define, but candidates made a good job of it. Some candidates did not refer to atoms of the same element; others referred to different elements. The part on determining average atomic mass was done well, but some did not pay attention to the number of significant figures and gave answers to 2 or as many as 7 significant figures.

Question 5

A number of candidates had difficulty stating how a line spectrum differs from a continuous spectrum. To state that a line spectrum consists of lines and a continuous spectrum does not consist of lines cannot be an acceptable answer at the HL. The answer has to be in terms of discrete or all colours/wavelengths/frequencies. Some candidates did not recognize that the visible line spectrum of hydrogen converges towards high energy, but most were able to identify that a line represents electron transition between energy levels.

Question 6

Many candidates did not read the question with enough care. To "describe in molecular terms" requires one to mention molecules in the answer.

(a) Candidates did not recognize the importance of molecular processes occurring at the same rate when a system is at equilibrium.

(b) A number of candidates mistakenly tried to explain what happens in terms of a chemical reaction.

Question 7

The equilibrium question was generally well done and candidates were able to explain the effect on the position of equilibrium when temperature or pressure is changed. It is the change in the number of moles of gases that is important when pressure effect is being considered. Some candidates did not read the question carefully and missed the detail about the effect of an increase of temperature on the value of K_c.

Section B

In answering questions in Section B, candidates should particularly note the number of marks available, as this will give them a good idea of the length of the answer expected.

Question 8

(a) Most candidates were able to state the correct electron configuration for argon, and give formulas of two oppositely charged ions that are isoelectronic with argon. However, a few candidates did not seem to read the question carefully and incorrectly stated Na^+ as one of the ions.

(b) Lewis structures were generally drawn correctly and shapes correctly stated, but many candidates had difficulty explaining the shapes. It was not uncommon for candidates to make reference to electron pairs on the terminal atom or to suggest that the atoms needed to be far apart rather than refer to the total number of charge centres (bonded and lone electron pairs) around the central atom that cause the repulsion.

(c) Candidates were often able to identify molecular polarity and correctly state the order of increasing boiling point for the four organic compounds, but were sometimes not able to explain it based on the type and strength of inter-particle forces involved.

(d) This part on conductivity solicited a range of answers from graphite being a better conductor than diamond (true but does not imply that diamond is a nonconductor), to potassium chloride being a good conductor because of mobile electrons rather than recognizing that it is in the molten or aqueous state that the ionic compound conducts since ions can move.

Question 9

(a) This part could have been done much better if more candidates had noted the action verb in the question, "Explain". It was common for candidates to state that at high temperature, ΔG° is negative without explaining why, and as a result did not score full marks.

(b) The most common error in calculating enthalpy change of reaction based on bond enthalpies was the reversal of the sign (namely, used sum of energies of bonds formed – sum of energies of bonds broken, rather than the other way around). Method was sometimes not clearly given, and there was a tendency to simply scribble numbers rather than show the method followed. In calculating ΔS° candidates at times forgot to include coefficients in their calculations. The sign of ΔS° was often correctly determined, but lacked explanation based on there being fewer gas molecules in the product.

(c) Candidates had great difficulty defining *standard enthalpy of formation;* candidates often referred to energy required rather than enthalpy change and did not refer to the formation of one mole (in the gaseous state).

(d) The concept of *average bond enthalpy* as the average of the enthalpies for a specific bond in a variety of compounds was not well done. Candidates seemed to have not noted the action verb expression, "Explain what this term means", instead explaining why an average must be taken.

(e) The question on enthalpies of reaction of cyclohexane and benzene based on bond enthalpies was generally not done well. The important point missed: cyclohexane contains single bonds of same strength and thus can use average bond enthalpies for it, whereas benzene has resonance structure with intermediate bond strength (1.5 bond order), and thus bond enthalpies cannot be used for benzene.

Question 10

(a)
(i) Conditions for the standard hydrogen electrode were generally correctly stated.
(ii) Many candidates were able to calculate the cell potential. However, candidates had difficulty outlining the changes occurring at the electrodes and in the solutions during the process.

(b) Generally done correctly, but some candidates mixed the signs up.

(c) Not done well. "Because bromide is above oxygen and chloride is below" is not sufficient to score marks. Candidates should either address this question by working out the E° values (positive for reaction of oxygen or dichromate(VI) ions with bromide ions, and negative with chloride ions), or in terms of the strength relative strengths of the oxidizing agents bromine, oxygen or dichromate(VI) ions and chlorine.

(d) It was not uncommon for candidates to mix up the electrodes at which reactions took place. The cations, Na^+ go to the negative electrode where sodium is formed, and the anions, Cl^-, go to the positive electrode where chlorine gas is formed.

(e) Candidates had to recognize that when a concentrated solution of sodium chloride is electrolyzed, the product is hydrogen and chlorine in a 1:1 ratio, whereas when a dilute solution of it electrolyzed, the products are hydrogen and oxygen in a 2:1 ratio.

Question 11

(a) Candidates were able to identify the aldehyde as compound A and the acid as compound B. That there are three different chemical environments was not always appreciated. When candidates refer to infrared absorptions, they must also identify the bond that is responsible for it.

(b) Candidates were typically able to identify the structure of alcohol B, but often not correctly predict the ratio of areas under the peaks in its proton NMR spectrum.

(c) Although the oxidizing agent was often correctly identified, the conditions of the agent being acidified, or distilling off the aldehyde product to avoid further oxidation product, was often missed.

(d) Candidates could generally explain the meaning of the term S_N2, but the mechanism was generally not well understood. In particular, many candidates had problems with the "curly arrows', despite the direct instruction in the question wording to include them.

(e) Candidates were generally able to deduce that the halogenobromide would react faster than the corresponding chloride due to the C–Br bond being weaker.

(f) The part on ester formation was well done with many candidates being able to name the reaction and deduce the structure of the product.

(g) The structure of the ester isomer and why it is less soluble seemed harder for candidates. The decreased solubility is due to the absence of the OH group in the isomer and which thus does not allow for hydrogen bonding.

Assistance and guidance for future candidates

Candidates and teachers are advised to bear in mind the following points.

- teachers are strongly urged to refer to past examination questions and their markschemes to assist candidates with examination preparation
- candidates must know the meanings of the different action verbs that appear in the curriculum as assessment statements and in the examination papers
- candidates should aim to match their answers to the number of marks allotted.
- in calculations, candidates should be encouraged to "keep going"; errors are carried forward so that a correct method in a later part of the question is rewarded
- all steps in the calculation must be shown
- candidates should check calculator answers mentally to ensure they are appropriate
- candidates must learn formal definitions
- candidates should plan answers rather than ramble at length
- poor penmanship can be avoided by giving candidates plenty of practice in writing examination type questions and providing appropriate feedback – there were a few alarming examples of poor writing

- candidates should, where appropriate, illustrate their answers with simple, neat and well-labelled diagrams.

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-21	22-27	28-33	34-39	40-50

General comments

No one option scored on average significantly higher than any of the others. It was noticeable that candidates tended to score approximately equal marks on the two options they answered which suggest that there was good parity between the different options.

Difficulties for candidates

Superficially some of the options, for example Medicines and drugs, appear to ask questions demanding more recall and therefore are sometimes considered easier than other options where more interpretation is required, for example Modern analytical chemistry. However, as in previous sessions, there is no evidence from the marks scored to support this fact.

Even though it is stated every year, some candidates still lose marks by giving answers that are far too superficial or contain little chemistry. For example very few candidates mentioned that it is the vibration of the bonds between the atoms within the molecules that causes greenhouse gases to trap or absorb infrared radiation.

Knowledge, understanding and skills demonstrated

The paper discriminated well between candidates and the better candidates gave some excellent answers showing that they had been well prepared. As in previous years candidates from centres where candidates opted for different combinations of options tended to show less detailed knowledge compared to those where most candidates chose the same two options to answer. It is clearly in the candidates' interest for teachers to cover two options thoroughly rather than allow their candidates to study a variety of the options on their own.

Many candidates were able to give good answers to questions involving recall as well as giving good answers where they had to apply their knowledge, for example on questions testing objective 3. This was most noticeable in Option G where many were able to make sensible conclusions from the spectra presented. Most of the candidates attempting Option H were able to use “curly arrows” correctly, although there was still some confusion shown over the different mechanisms.

Strengths and weaknesses in individual questions

Option B - Medicine and drugs

This is the second year that this option has been examined at Higher level and it becoming an increasingly popular choice. Most candidates demonstrated a good knowledge of the topics.

Question B1

(a) Some Candidates still find difficulty in identifying functional groups within molecules. Most candidates knew the essential difference between mild and strong analgesics but relatively few correctly gave amide as the N-containing functional group in acetaminophen (also know as paracetamol or Tylenol®).

(b) The correct answer for the N-containing functional group in heroin is a tertiary amine. "Amine" was accepted but candidates did not score the mark if they wrote primary or secondary amine.

Question B2

(a) Many were able appropriately explain how penicillin(s) work.

(b) Many candidates gained some of the marks for the effects of over-prescription, but many candidates omitted to state that they also destroy useful bacteria.

Question B3

Candidates generally knew the differences between bacteria and viruses but some did not read the question carefully and did not refer specifically to their structures and the way in which they multiply.

Question B4

(a) Mostly answered well although phrases like "put to sleep" (which might be mistaken for the terminology relating to veterinary surgeons terminating the lives of sick animals) were sometimes used instead of lose consciousness or unconsciousness.

(b) Candidates seemed to have been guessing at the properties of the two anesthetics, trichloromethane and cyclopropane. Several candidates incorrectly stated that it was cyclopropane that does not burn and that a disadvantage of trichloromethane is that it is inflammable.

Question B5

(a) and (b) Those candidates who understood chirality had little difficult with this question, although some are still not drawing the two enantiomers as clear mirror images of each other.

Option C - Human biochemistry

Candidates generally performed well on the first two parts of this option but found the last two questions harder.

Question C1

(a) Most candidates were able to correctly state whether or not the three vitamins referred to were water or fat-soluble. Some were not specific in their reasoning as they failed to mention that although vitamin A also has a polar -OH group it is the long non polar hydrocarbon chain which determines its solubility. Even when they had correctly stated that vitamin C contains several -OH groups some did not then go on to state that these groups can form hydrogen bonds with water molecules.

(b)
(i) The function of vitamin C in the body were well known.

(ii) Many candidates omitted to state that vitamin C it can be lost through boiling as it dissolves in water. Even those that realised that it is also chemically decomposed by heat sometimes incorrectly called this "being denatured".

Question C2

(a) Many candidates correctly identified alkene and carbonyl (or ketone) as the functional groups present in progesterone and testosterone. However several candidates wrote "alkyl group" but no marks were awarded for this.

(b) and (c) No comments.

Question C3

(a) Answers were generally good. If candidates did not specifically use the word "catalyst" they could still gain the marks if they gave a suitable description of how an enzyme functions as a catalyst.

(b) Many candidates had problems explaining the graph and many omitted to both state and explain why the rate initially increases as the temperature increases. Some omitted to talk about why the rate reaches a maximum at about 37^{o}C and although almost every candidate talked about the enzyme denaturing at higher temperatures, many did not mention that it is the active site that is affected.

Question C4

Generally was not answered well. This question definitely testing objective 3 and was not something that candidates can simply learn by heart.

(a) The most effective ion to produce rapid changes such as those involved in nerve action will be the most mobile ion i.e. Z - the one with the lowest charge density.

(b) The answer was X as the formation of strong bonds within a structural unit will be most likely with an ion of high charge density.

Option D - Environmental chemistry

As expected, this was a popular option and was answered quite well by many candidates, although there were still plenty examples of candidates not answering in terms of chemistry, thus not achieving all the marks.

Question D1

(a) Some candidates did not know that it is mainly fertilizer run off that is causing nitrates in drinking water

(b) An unfortunate number did not know that it is in the tertiary stage of sewage treatment that nitrates are removed. Too many candidates talked about 'flocculation' or precipitating nitrates rather than using ion exchange, microorganisms or algal ponds.

Question D2

The advantages of using ozone rather than chlorine to purify drinking water was well known and many candidates scored full marks.

Question D3

(a) and (b) In contrast very few candidates scored the maximum marks for D3 as almost all candidates omitted to explain how greenhouse gas molecules absorb infrared radiation. Many candidates also tend to talk about the Earth reflecting rather than radiating longer wave radiation.

(c) Some candidates had problems relating the abundance and their ability to absorb radiation to explain the importance of carbon dioxide and methane as greenhouse gases

(d) The effects of global warming were generally well known.

Question D4

Candidates that seemed to have read the question carefully and then addressed the question points by point did well. Many candidates were not specific enough in the origin of photochemical smog. "Car exhaust" is not a sufficient chemical cause to gain marks. Some talked about "bowl shaped cities" which was not asked for but omitted to talk about thermal inversion which was asked for.

Option E - Chemical industries

This option was answered by the least number of candidates. Good candidates answered it well but many poorer candidates seemed ill-prepared.

Question E1

(a)
(i) Most knew why it is necessary to remove sulfur from oil, although several stated that it causes acid rain without explaining that it has to first be combusted to form sulfur dioxide before this can happen.

(ii) The reaction of hydrogen sulfide with sulfur dioxide was difficult for candidates.

(b)
(i) The types of reforming processes was poorly answered.

(ii) Many could not name 3-methylpentane correctly and often confused aromatization with cyclization.

Question E2

Generally answered well.

Question E3

The effects of adding gallium or arsenic to silicon was also known well, but a number of candidates omitted to answer the question asked and failed to state and explain how the conductivity of silicon increases through doping.

Question E4

Unexpected answers were given on species produced during cracking processes. The fact that one was an ion and one was a radical should have alerted the candidates to the type of bond being broken, but often they failed to complete this part correctly.

Option F - Fuels and energy

Question F1

Most candidates were able to state two advantages of converting coal to a liquid fuel.

Question F2

(a) Not answered well. Most knew the problem of pre-ignition or "knocking".

(b) Few candidates were able to state the name of 2,2,4-trimethylpentane correctly as the fuel with an octane rating of 100 even though it is clearly stated on the syllabus.

(c) Error carried forward was allowed in this part where the structural difference between heptane and the answer given in (b) was required.

(d) Although many candidates correctly suggested tetraethyl lead or aromatic compounds as a substance added to increase the octane number, several candidates just wrote "lead" and did not score the mark.

(e) Few candidates scored all five of the marks for the calculation of the molar enthalpy of combustion . The most common errors were to miss out or incorrectly state the units and to miss out the negative sign for the value or at least indicate in some way that heat is evolved in the process.

Question F3

Most candidates clearly had an idea of the difference between nuclear fusion and nuclear fission but were unable to express their answer clearly in terms of atoms and or nuclei and the products formed, thus often failing to gain all three marks.

Question F4

The advantages and disadvantages of energy storage in produced some varied answers. Some candidates addressed the points well, but a significant number of candidates seemed to have failed to read the question clearly and talked about hydrogen and nuclear power as primary sources of energy rather than how energy can be stored.

Question F5

Ra-225 as a beta emitter tended to be done either very well or very badly with candidates either scoring maximum marks or none at all.

Option G - Modern analytical chemistry

Most candidates who answered the questions on this option seemed well prepared and there were some good answers, apart from the last question on column chromatography. There are in fact five isomeric alcohols and the question should have stated that there are four *structural* isomers of $C_4H_{10}O$. However, this did not seem to produce any problems or confusion for candidates when it came to answering the question.

(a) and (b) Generally done well.

(c)

(i) and (ii) Candidates often failed to indicate that the number of peaks corresponds to the different number of environments *for the hydrogen atoms* rather than just chemical environments.

(ii) Perhaps because candidates often did not really understand correspondence of peaks issue, the ratio of the areas under the peaks were often given incorrectly

(d) No comment.

(e) Candidates need to be taught that when assigning peaks in the mass spectra, the species giving the peak is always a positive ion. Too often candidates leave out the positive charge.

(f)
(i) Interpreting the splitting of an NMR spectra was done well.

(ii) Most candidates were able to assign the splitting to a $-CH_2$ group next to a $-CH_3$ group and correctly identify the ether.

Question G2

(a) and (b) Generally answered well. The difference between adsorption and partition and stationary and mobile phases was known by most candidates.

(c) However, the technique of column chromatography was not well explained. This suggests that very few candidates had either carried out this method themselves or seen it demonstrated.

Option H - Further organic chemistry

There was considerable variation in some of the answers given for this option.

Question H1

(a), (b) (i) and (ii) Most answers were based on the different types of isomerism tested.

(b)(iii) Many candidates gained full marks for showing the mechanism of electrophilic addition. Almost all candidates can now draw the "curly arrows" in the correct places, showing where the pair of electrons originate from and where they are moving to.

(iv) Markovinkov's rule produced some interesting answers. Some candidates explained it correctly in terms of the stability of the intermediate carbocations. Others candidates read the question well and simply stated the rule and then explained that as X and Y both had one hydrogen atom on each of the alkene carbon atoms the rule could not apply, which was all that was necessary to gain the marks.

(c) (ii) and (ii) Some candidates experienced difficulty in explaining how the rate of nucleophilic substitution of X compared to that of $(CH_3)_3CBr$ and bromobenzene. Relatively few candidates commented on the fact that the C-Br bond in bromobenzene is shorter as one of the non bonding pairs of electrons on the bromine atom delocalises with the π electrons in the benzene ring and thus it is harder to break and so much less reactive towards nucleophiles.

Question H2

The basicity of amines compared to ammonia was often not well known. Some candidates did correctly state in their answers that ethylamine is more basic than ammonia. They arrived at this sensibly from a comparison of their pK_b values, but were often not able to explain this in terms

of the electron releasing effect of the alkyl groups increasing the ability of the non bonding pair of electrons on the N atom to attract a proton.

Assistance and guidance for future candidates

Some candidates had difficulty in answering the question asked. Sometimes parts of the question were missed and at times questions were obviously misread. This can at least in part be overcome by more frequent practice in examination type questions. Candidates should be given regular assignments and tests from past examination and specimen papers. This will give candidates the opportunity to develop the skills of answering questions clearly, directly and completely, so that they are not penalised for failing to answer the question asked. For example if a question says give two advantages of converting coal to liquid fuel then one will not suffice. Similarly if the question is concerned with the storage of energy then an answer relating to the production of energy will score no marks.

Candidates and teachers are advised to bear in mind the following points.

- Candidates need to be completely familiar with the action verbs, which objectives they relate to and to the style and form of appropriate answers related to particular action verbs and objectives. Responses to questions should demonstrate both depth and breadth. Candidates must ensure that they cover a sufficient number of different points to score the full range of marks assigned to each question.
- Candidates need to be provided with adequate resources to complement the teaching of the options. Few chemistry textbooks adequately cover the material and information of all the options. Candidates often demonstrate a lack of basic familiarity with the options they are choosing to answer.
- The poor performance on the column chromatography question suggests that perhaps more reinforcement is needed in terms of the meaningful relationship between theory and practice – classroom presentations/discussions and practical investigations .
- Candidates should be advised to attempt to answer all parts of an option. Better an attempt that may provide a small amount of credit than no attempt which will give no credit at all.
- Teachers are advised to cover two options thoroughly and not attempt to cover more than this unless time allows. There is strong evidence that candidates from schools covering several options do less well than those concentrating on just two options.

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. 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, and some teachers are not paying attention to past examiner reports or to the Teacher Support Material (TSM) available on the Online Curriculum Centre (OCC). Note that submitting full portfolios is no longer a requirement.

The task of moderation is made much easier when details provided to the candidates are included with the samples. Some schools omitted this information, particularly in the case 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. Teachers often used a grid and c, p, n notation to indicate aspects achieved for each criterion. This practice helps candidates and the moderator, as the purpose of moderation is to validate teachers' assessment. Safety awareness and concern for the environment were evident in some schools but lacked in other – these concerns should be universal. Moderators were provided with copies of the feedback forms sent to teachers in May 2003. In some cases, little improvement was noted; in others, teachers paid close attention to the advice given, leading to improved IA programme 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 the schools covered the syllabus and initiated suitable experiments. Options at both SL and HL were done 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, both in their suitability, and in the accuracy of the assessment. Attention is brought to the detailed examples related to various aspects of IA criteria found in the TSM as posted on the OCC.

Some schools relied almost exclusively on textbook "recipes" with detailed instructions; this practice denies candidates the opportunity to achieve most aspects of 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. The strong correlation between schools teaching IB Chemistry simultaneously with other educational programmes and schools failing to provide suitable assessment tasks was noted.

Candidate performance against each criterion

Planning (a)

Many reports were structured to clearly show the aim, hypothesis and explicit identification of the independent and control variables. A significant number of reports still remain that lack this structure and did not highlight the variables clearly. There was an improved understanding of the terms *control*, *dependent* and *independent* in relation to variables; however, some candidates continue to have trouble with Pl (a). This criterion requires the provision of a broad or general investigation problem that is subsequently narrowed or focused by the candidate. A specific research question is still being given, denying the opportunity to fully achieve this criterion. Some candidates stated a hypothesis, but did not explain their reasons for it or the hypotheses were poorly worded or superficial. Statements such as "The value will lower" are meaningless.

There still seems to be confusion as to whether the explanation for a hypothesis has to be scientifically valid or not with reward given for trivial or unfounded explanations. Not all investigations are predisposed to generating a hypothesis and for this reason are not appropriate for Pl (a). Please refer to the TSM on the OCC for Pl (a) details and examples.

Planning (b)

Candidates generally selected suitable equipment and devised appropriate strategies for carrying out investigations. If candidates are provided with equipment or methodology, then candidates cannot achieve aspects of the criterion. An investigation that requires the provision of equipment or methodology for practical reasons is not appropriate for assessment of Pl (b). A common weakness in Pl (b) is the lack of (or vague) control of variables, mostly because the procedure was not favourable for identification and control of variables. This may be in part a result of failure to recognize the need for controls in the discussion of the variables in Pl (a).

It was not uncommon for candidates to take large amounts of materials when the procedure could have been carried out at a smaller scale. This is an indication that environmental impact is being ignored in the planning of an investigation. Teachers need to reinforce the notion of *fair testing* as few candidates seem to appreciate *fair testing* or its self-evidence. Investigations lack a consideration of the necessity of the collection of sufficient data. Replications are often not included. Teachers sometimes over-plan and set up an investigation leading to only one possible procedure, and this denies candidates opportunity to achieve criteria. Pl (a) and Pl (b) should evoke different responses from different candidates within the same class. A uniform set of responses is an indication that an investigation might not be appropriate for assessment of Pl (a) and / or Pl (b).

Data Collection

Performance was generally good and many suitable investigations were carried out. However, candidates still overlook 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 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, organising and presenting raw data, cannot be assessed / achieved if data tables have been provided. Some candidates do not seem to present raw data. Instead, data is presented that has been recopied after the investigation has been carried out. Investigations requiring the collection of only a few values, or a small number of qualitative observations, are not appropriate for assessment of the DC criterion.

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, levels were awarded for raw graphs lacking any analysis, for example rate of reaction graphs where volume of gas collected was plotted against time. Data processing such as subsequent calculation of a gradient to find the reaction rate at a given time should be included. DPP was often being assessed for interpretation of qualitative data such as test-tube reactions where balanced equations were generated from a minimum of qualitative observation and lacked substantiation. These responses are more appropriate for the assessment of the first aspect of CE. The opportunity to take uncertainties into account and carry out error analysis was often overlooked even when this was clearly possible for the investigation. Appreciation of significant figures is also often lacking (please refer to examples in the TSM). In terms of graphing, some candidates were unable to decide when to draw a straight line, when to draw a curve and when to join points. Investigations lacking feedback often resulted in follow-up investigations with the same error.

Teachers must not provide too much information about how data is to be processed and evidence should indicate the candidates' ability to process data on their own, rather than an

indication of a series of prescribed steps in calculations. An indication of the teacher's instructions are important for moderation, especially if there is an appearance that the teacher has told the candidates how to process the data. Computer generated graphs are acceptable (even encouraged) as long as the program requires the candidate to set up the graph from raw or processed data and make choices about the graph format. A graphing program that does not permit user control over the processing or output is not suitable for assessment of 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 and this is often missing. Candidates do not commonly evaluate the procedure, list possible sources of error or make appropriate 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 appropriate evaluations of the procedure. Too often the suggestions for improvement are grossly trivial. Note that all not investigations are appropriate for assessment of this criterion. Candidates should attempt to identify reasonable systematic errors in the procedure and then suggest realistic improvements to the investigation.

Manipulative skills

In general, the practical programmes 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 is an essential requirement of the IB programme. A special request had to be made for the submission of such evidence for schools failing to provide evidence. Group 4 Projects should represent real content and experimental time allocation in each and every one of the subject areas. In some cases the Group 4 Projects do not represent the 15 hours of work that is stated on the 4/PSOW.

When submitting samples for moderation, teachers should provide evidence of participation in the group 4 project for each candidate in the sample. This can take a variety of forms as stated in the IB *Chemistry Guide* (page 32). Group evidence is not appropriate when the group 4 project is to be used to assess any of the written criteria. Identical pieces of work for different candidates in the moderation sample, i.e. where a teacher has awarded the same marks to all candidates in a group for one piece of group work cannot be use to assessment written criteria for individual candidates. Photocopies of a single report completed by a group of candidates are not acceptable for assessment of written criteria of one candidate. Additional samples that clearly represent individual candidates work will be requested. Note that this is clearly unacceptable and if evidence of individual work cannot be supplied, the situation could be construed as malpractice for which the consequences can be serious.

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, but do not award grades for the written criteria. This is in perfect harmony with the aims of the group 4 project.

Recommendations for the teaching of future candidates

Clearly many schools are doing fine work and the current assessment model provides opportunity for both high attainment and a suitable spread of achievement levels. 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. As a result of investigations being unsuitable for particular criteria, and/or inaccuracy of marking, samples are unfortunately moderated down. 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
- evaluation of investigations using a grid of criteria/aspect with n, p and c indicated clearly is strongly encouraged
- full portfolios should not be submitted unless requested by IBCA
- evidence for participation in the group 4 project by each candidate in the sample must be submitted
- clear evidence for individual work in the group 4 project must be included if the work is to be assessed for written criteria: this must represent individual work and not group work
- teachers must ensure that candidates have the opportunity to achieve criteria, and hence, should not provide too much information/help for the Planning (a), Planning (b), Data Collection, Data Processing & Presentation and Conclusion & Evaluation criteria
- do not use workbooks and worksheets with spaces to be filled in by the candidates for internal assessment as they usually provide too much information and deny the candidates the opportunity to achieve criteria
- 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 the instructions given for investigations in the moderation sample
- candidates must 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 must refer to, and follow, instructions found in the chemistry subject guide, the Teachers Support Material on the online curriculum centre, and instructions provided in the up to date *Vade Mecum* before submitting work for moderation.

