CHEMISTRY (IBNA / IBLA)

Overall grade boundaries

Higher level

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

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 18	19 - 34	35 - 47	48 - 58	59 - 69	70 - 80	81 - 100

Time zone variants of examination papers

To protect the integrity of the examinations, increasing use is being made of time zone variants of examination papers. By using variants of the same examination paper candidates in one part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the examination papers. For the May 2008 examination session the IB has produced time zone variants of the Chemistry papers.

Higher and standard level internal assessment

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

This was the last May examination session that worked within the old internal assessment model and there was evidence that most schools and teachers with prior experience of the current Chemistry I.A. model had successfully applied the criteria to a much greater extent than was evident a few years ago. However many new schools and teachers come into the IB world each year and it is clear that the internal assessment requirements often present a challenge for newcomers.

As in previous sessions the moderating team were working to instructions from the Principal Moderator that emphasised that teachers are the primary markers and that moderators should support the teacher wherever possible. Moderators are not primary marking and if the teachers grading is a plausible interpretation of the criteria then it should be supported.

Guidance was then given as to when and how moderators should and should not change marks as follows:

When to mark down

Planning (a):

- The research question, hypothesis and/or independent and controlled variables are given by teacher. Mark the relevant aspect down to ‘n’. A general aim is fine if the students have significantly modified it (e.g. made it more precise).
- The hypothesis has not been explained or the explanation is clearly counter to theory as can be reasonably expected to be known by an average IB chemistry student (e.g. ‘reaction rate will decrease with increasing temperature because ………’). Award ‘p’ for second aspect.

Planning (b):

- A method sheet is given which the student follows without any modification or **all** students are using identical methods. Moderator gives n, n = 0.
- Teacher gives c, c, c but it is clear that the students have been told what apparatus and materials they require. Maximum moderator can award is n, c, c = 2.

Data Collection:

- A photocopied table is provided with heading and units that is filled in by students. Maximum moderator can give is p, n = 0.
- The teacher gives 3 (c, c), but the student has only recorded quantitative data (e.g., in titration) and qualitative data such as colours of solutions, indicator, colour change etc. are missing. Moderator gives p, c = 2. However, do not be overzealous and penalize DC every time a student does not find qualitative data to record.
- Student has not recorded uncertainties in any quantitative data. Maximum ‘p’ for first aspect.
- Student has been repeatedly inconsistent in use of significant digits when recording data. Award ‘p’ for second aspect.
- In purely qualitative DC tasks such as establishing a reactivity series. Too often the students put in a reaction equation as opposed to the observation. This cannot be supported and will reduce first aspect to ‘p’ or ‘n’ depending on how much other raw data is present.

Data Processing & Presentation:

- A graph with axes already labelled is provided (or students have been told which variables to plot) or students follow structured questions in order to carry out data processing. Moderator gives c, n = 1.
- No evidence of errors being propagated (HL) or total random error being estimated in any way (SL). Maximum award c, p = 2. Remember that best fit line graph is sufficient to meet requirement for error and uncertainty propagation.

Conclusion & Evaluation:

- Structured questions are given to prompt students through the discussion, conclusion and criticism. Depending on how focussed the teacher's questions are and on the quality of students' response the maximum award is partial for each aspect the student has been guided through. You have to be judging purely on the students input.
- Teacher gives c, c, c = 3 but the student has only indicated as a criticism that they ran out of time. Maximum moderator can give is c, n, p = 1.

When not to mark down

In the following cases support the teacher's stance as they are aware of their own expectations of the students.

Planning (a)

- Dependent variable has been given by teacher or student has made no mention of dependent variable (surprisingly it is not featured in aspect 3 descriptor!)
- You disagree with the explained hypothesis but you feel that it is a reasonable application of IB level knowledge.
- The hypothesis explanation is simplistic but the only one possible within the framework of the task (e.g. Student predicts vitamin C contents of juices based on evidence supplied by packaging.) In this case support student but feedback to teacher as to poor suitability of task for meaningful hypothesis generation.
- The independent and controlled variables have been clearly identified in procedure but are not given as a separate list (we mark the whole report and there is no obligation to write up according to the aspect headings)
- There is a list of variables and it is clearly apparent from procedure which is independent and which is controlled.

Planning (b)

- Similar (not word for word identical) procedures are given for a narrow task. Comment though on poor suitability of task on 4/IAF form.
- Do not only mark equipment list. Give credit for equipment clearly identified in stepwise procedure. Remember we mark the whole report.
- Do not insist on +/- precision of apparatus to be given in apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DC.
- Do not downgrade a teacher's mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Support teacher's stance.

Data Collection:

- When teacher has supplied stepwise instructions including when to record data. This criterion has evolved into assessing the written record only.
- In a comprehensive data collection exercise possibly with several tables of data the student has been inconsistent with significant digits for just one data point or missed

units out of one column heading. If you feel the student has demonstrated that they were paying attention to these points and made one careless slip then you can still support maximum mark under ‘complete not meaning perfection’ rule. This is an important principle since often **good students responding in full to an extended task unfairly get penalised more often than students addressing a simplistic exercise**.

- Student has not included any qualitative observations and you cannot think of any that would have been obviously relevant.
- Purely qualitative DC such as in establishing a reactivity series. These are currently allowable but not recommended since they do not facilitate recording of uncertainties. Please feedback to that effect. However when marking do make sure that it is genuine raw data (see section A above).
- No table title when it is obvious what the data in the table refers to. I have seen students do all the hard work for DC and then lose a mark from the moderator because they did not title the table. Except for extended investigations it is normally self evident what the table refers to and the section heading Raw Data is sufficient. Once again ‘c’ does not mean perfect.

Data Processing

- **Errors and Uncertainties**

  The expectation in chemistry, as described in the TSM 1, is:

  Standard level candidates are **not** expected to process uncertainties in calculations. However, they can make statements about the minimum uncertainty, based on the least significant figure in a measurement, and can also make statements about the manufacturer's claim of accuracy. They can estimate uncertainties in compound measurements, and can make educated guesses about uncertainties in the method of measurement. If uncertainties are small enough to be ignored, the candidate should note this fact.

  Higher level candidates should be able to express uncertainties as fractions, $\Delta x/x$, and as percentages, $(\Delta x/x) \cdot 100$. They should also be able to propagate uncertainties through a calculation.

  Note: Standard level and higher level candidates are **not** expected to construct uncertainty bars on their graphs.”

  Note that a best-fit line graph is sufficient to support ‘c’ for the second aspect at both SL and HL.

  For both DC and DPP, if the student has clearly attempted to consider or propagate uncertainties (according to whether HL or SL) then support a teacher’s award even if you may feel that the student could have made a more sophisticated effort. Please **do not** punish a teacher or student if the protocol is not the one that you teach i.e. top pan balance uncertainties have given as +/- 0.01g when you may feel that if we consider the tare weighing then it should be doubled. Moderation is not the time or place to establish the favoured IB protocol.

- **Is a graph on its own necessarily data processing?**

  The current subject guide clearly states on page 25 under DPP that processing raw data includes 'converting tabulated data into graphical form' and does not require further treatment such as finding a gradient or intercept. Maximum DPP can be awarded if the graph is properly and accurately constructed and with a suitable best-fit line as long as it has been used as an aid to interpret the data. For HL we most certainly would prefer to see quantitative results generated but I do not feel we can disallow the hundreds of rate of reaction graphs that directly plot volume of gas produced against time that we are about to mark! If the graph has been used to draw qualitative conclusions regarding relative rates then allow it to be assessed according to its merits. A diplomatic 4IAF comment advising the teacher to make greater demands on DPP in future sessions would be appropriate. The new curriculum for first exam in 2009 will tighten up the requirements in this area.

Conclusion and Evaluation

- Simply apply the principle of complete not meaning perfect. For example if the students have identified most sensible sources of systematic error then you can support a teacher's award even if you think that you can identify one more. Do be a bit more critical in third aspect that the modifications are actually relating to the cited sources of error."

Finally the moderators were guided:

> "So the broad message is be positive in your marking. Look for what is present in a piece of work and not for minor omissions. Try to avoid pettiness and remember that sometimes you can mark upwards."

The range and suitability of the work submitted

There were a good number of schools who submitted challenging work which reinforced learning and provided a suitable opportunity for assessment. A small number of schools were still not undertaking a suitable practical scheme of work and were failing to appropriately address the assessment criteria. To a better extent than previously, schools appeared to be implementing recommendations given on the previous years 4/IAF feedback form.

Once again the issue of most serious concern was that the work of some candidates was clearly guided by teachers, fellow candidates or unreferenced sources to a level well beyond the instructions evidenced. It was unfortunately not uncommon for all candidates to choose exactly the same variables, carry out an identical procedure or follow through with identical methods in complex calculations, while the instructions provided had indicated an independent, open-ended task. At best this could be considered poor practise for failing to ensure that candidates carry out the task legitimately for themselves.

Teachers should ensure that assessment is carried out in good faith and that an individual's skills are being assessed.

Candidate performance against each criterion

Planning (a)

When the set-task was appropriate this criterion was generally well fulfilled with candidates able to pose a research question, make a sensible hypothesis with some level of explanation and to identify the relevant control and independent variables. Moderators did report that a significant number of candidates were unable to fulfil criterion due to being set unsuitable investigations such as those based on confirmation of laws or determinations of specific values. E.g. confirming gas laws.

Planning (b)

This criterion was fulfilled to a similar extent as in previous years. Candidates generally selected suitable equipment and devised appropriate strategies for carrying out investigations. Some schools were setting very simplistic tasks such as finding the density of a penny. A common weakness in Pl (b) was the lack of control of variables even though candidates have identified variables to be manipulated or controlled when addressing Pl (a), e.g. the failure to control reaction temperature when undertaking a kinetic study of a significantly exothermic reaction. Variables were frequently not properly controlled in electrochemical investigations, calorimetric labs and chromatography analysis. Another failing of a large number of candidates was the absence of quantitative information regarding reactant concentrations, masses, volumes, etc. Volume measuring instruments were often omitted or the choice was inappropriate. One common reason for incomplete fulfilment of Pl (b) was that the candidates often did not plan to collect sufficient data. It is recommended that five data points at least should be planned for.

An investigation that requires the teacher to specify the equipment or methodology is not appropriate for assessment of Pl (b). Teachers sometimes over-plan and set up an investigation leading to only one possible procedure, and this denies candidates opportunity to achieve in this criterion. Both Pl (a) and Pl (b) should have evoked different responses from different candidates within the same class.

Data Collection

Most candidates had been presented with suitable data collection tasks and their performance was generally good with candidates independently able to present data in suitably constructed tables with appropriate column headings and units. The most common failings still related to the first aspect with associated qualitative data not being recorded although more candidates than previously recorded uncertainties and were consistent in the use of significant figures.

Data Processing and Presentation

Most schools had appropriately assessed DPP in quantitative tasks and the overall standard was satisfactory with few schools still unwisely using purely qualitative investigations for DPP assessment. A majority of schools encouraged meaningful treatment of errors or uncertainties in DPP for Higher Level candidates.

The quantity and quality of graphs, including those generated by Excel, was improved from last year. Note that a graphing program that does not permit user control over the processing or output is not suitable for assessment of this criterion. Only a few schools persist in only presenting bar graphs which are seldom appropriate for most investigations in our field.

Conclusion and Evaluation

Moderators reported that this was often the most difficult criterion for candidates to fulfil. Most candidates could compare their results to literature values where appropriate and included some level of explanation. Most candidates did attempt to evaluate the procedure and list possible sources of error although very few were able to assess if the final result was explainable by random error or required the consideration of systematic errors. Some candidates were able to make appropriate suggestions to improve the investigation following the identification of weaknesses, although many were only able to suggest simplistic or completely unrealistic improvements. There still persists a trend in teachers to over-reward very simplistic evaluations or suggestions not related to cited errors.

Manipulative skills

In general, the practical programmes provided adequate scope for assessment of this criterion.

The Group 4 Project

All schools provided evidence for participation in the Group 4 Project for each of the candidates in the sample. Many schools seemed to have undertaken stimulating and imaginative projects.

Recommendations for the teaching of future candidates

From May 2009 session onwards the revised specifications in the new Subject Guide will apply.

- The new criteria will be marked on a scale of 0 to 6, not 0 to 3 as present.
- Candidates should be made aware of the different aspects of the new criteria by which they are assessed and evaluation of investigations using a grid of criteria/aspects with n, p and c indicated clearly is strongly encouraged.
- It is essential to ensure that candidates are solely assessed on their individual contribution to any activity used for assessment of the written criteria.
- Teachers must ensure that candidates have the opportunity to fulfil criteria, and hence should not provide too much information/help for the Design (D), Data Collection & Processing (DCP) and Conclusion & Evaluation (CE) criteria.
- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.
- It is recommended not to 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 no longer will need to formulate a hypothesis to fulfil completely the assessment criteria, although teachers are still free to promote their inclusion.
- Candidates will need to explicitly identify the dependent variable as well as independent and controlled variables in the Design criterion.
- Candidates should be encouraged to consider repeat trials, calibration or generation of sufficient data to undertake graphical analysis, when designing procedures for Design.
- All investigations for the assessment of DCP must include the recording and processing of quantitative data.
- Teachers are encouraged to set DCP tasks that will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.
- Candidates must record associated qualitative as well as quantitative raw data, where appropriate where relevant.
- Candidates must compare their results to literature values where appropriate.

- When assessing the CE 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.
- If candidates need to be introduced to the skills required for investigative practical work through simple introductory experiments that do not fully meet all aspects of a criterion then it is important that the marks generated are not included on the form 4/PSOW.
- From May 2009 there is no formal requirement to submit evidence of Group 4 Project participation. The Group 4 Project is only to be used for assessment of the Personal Skills criterion.
- The Manipulative Skills criterion is to be assessed summatively over the whole practical scheme of work. No evidence for the MS mark need be submitted to the moderator.
- Teachers must refer to, and follow, instructions found in the chemistry subject guide, the Teachers Support Material, and instructions provided in the up to date *Vade Mecum* before submitting work for moderation.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 17	18 - 24	25 - 27	28 - 30	31 - 33	34 - 40

General comments

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) material and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and no credit deducted for incorrect answers.

Teachers' impressions of this paper were conveyed by the 45 G2's that were returned. 74% found that it was of a similar standard, compared with last year's paper, 11% felt that it was a little easier and 15% were of the view that it was a little more difficult. 98% felt that the level of difficulty was appropriate and only 2% considered that the question paper overall was too difficult. Syllabus coverage was considered satisfactory by 16% and good by 84%. In addition, 13% thought that the clarity of wording on the paper was satisfactory and 85% stated that the wording was good. Only 2% considered the clarity of wording poor. The presentation of the paper was considered satisfactory by 11% and good by 89%.

The strengths and weaknesses of the candidates in the treatment of individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 91.90% to 22.84%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.64 to 0.09 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 3

A number of respondents stated that students may not be familiar with the unit tonnes. However, even if candidates were not familiar with tonnes as an explicit unit, this should not have had an impact on their understanding of the chemical principles underling this question, and the correct answer B = 56 tonnes, was obtained by approximately 69% of candidates. One respondent also commented on the use of the symbol M_r, which represents the relative molecular mass. The use of this symbol is clearly mentioned on the syllabus, in relation to A.S. 1.2.3.

Question 6

One G2 comment stated that questions on mass spectrometry were given in both paper one and paper two. However, this question in paper 1 was based on the actual processes that occur in a mass spectrometer, based on A.S. 12.1.1 whereas the corresponding Question 2, (a), in section A of paper two, tested other areas of this same topic in more depth, which is the inherent difference between paper one and paper two.

Question 15

Some respondents felt that the main difficulty with this question related to the mathematical calculation, which they commented was very difficult without the availability of a calculator. The most common error in this question however involved candidates not converting degrees Celsius to Kelvin, and hence D = 2.0 dm^3 was given as the answer by most candidates. The difficulty index for this question was 22.98%, which made the question the second most difficult question on the entire paper. Using the relationship $P_1V_1/T_1 = P_2V_2/T_2$, V_2 can easily be determined, which then becomes a calculation of 337/305 = 1.1 dm^3.m, alternatively a simple observation that the increase in temperature was approximately 10% in the Kelvin scale would increase the volume of the gas by 10%. Even without doing the formal calculation, looking at the four choices of answer, 1.1, 1.3, 1.6 and 2.0, it should be obvious that A = 1.1 dm^3 is the correct answer.

Question 34

This question asked candidates to identify which alcohol cannot be easily oxidized using acidified potassium dichromate (VI) solution. One respondent stated that the use of the word “easily” may have confused candidates, as candidates who know that tertiary alcohols cannot undergo oxidation in this question might infer that the question is asking for a compound which can be oxidized and therefore is not a tertiary alcohol and hence conclude that a secondary alcohol such as B = $CH_3CH(OH)CH_3$ is in fact the correct answer. This is a valid comment and it would perhaps have been better if the question was phrased differently. The correct answer, D = $(CH_3)_3COH$, however was in fact obtained by approximately 54% of candidates. The question did serve as a good discriminator, with a discriminator index of 0.61.

General comment

The only general comment on this paper referred to the use of dm^3 instead of L as a unit of volume. In the guide, dm^3 is explicitly mentioned (*e.g.* A.S. 1.5.1 for concentration), and has been used traditionally on IB Chemistry papers as the preferred unit of volume, instead of litres.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 29	30 - 39	40 - 49	50 - 60	61 - 70	71 - 90

General comments

This paper indicated a very broad range of capabilities of candidates. Some candidates struggled with even the most basic concepts while others demonstrated an excellent depth of understanding of the Higher level course. It produced a range of responses from almost full marks to zero. In general, answers lacked precision in terms of wording used and explanations were often vague and repetitive. There were some schools where candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank.

Candidates must pay particular attention to the number of marks allocated to the question and write their answers accordingly. Calculations must be shown clearly and should be checked for accuracy, significant figures and units where appropriate.

The 42 G2 forms that were returned from this region, conveyed teachers' impressions of this paper. In comparison with last year's paper, two-thirds felt that it was of a similar standard, while the remainder of respondents opted for a little more difficult. The majority of the respondents thought the level of difficulty was appropriate. Syllabus coverage, clarity of wording and the presentation of the paper were considered good by three quarters and satisfactory by the remainder of respondents.

The areas of the programme and examination that appeared difficult for the candidates

- Chemical tests to distinguish between different functional groups
- Deduction of mechanism from rate equations
- Maxwell-Boltzmann distribution curve
- Electrolysis of $CuSO_4$ and diagram of a voltaic cell
- K_a and buffer calculations
- Mechanism for a nucleoplilic substitution reaction using curly arrows

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

- Determination of a $\Delta G^{\ominus}$ value
- Calculation of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ value
- Writing K_c expressions

- Writing structural formulas of isomers
- Stoichiometry calculations
- Drawing Lewis structures
- Application of Le Chatelier's principle
- Gas law calculations
- Order of reaction and rate constant expression

The strengths and weaknesses of the candidates in the treatment of individual questions

Section A

Question 1

Most candidates were able to calculate the amount, in moles of $BaSO_4$ in part (a) but some could not elicit correct answers to (b) and (c).

Candidates were able to score sequential marks for calculating masses in (c) and then many did score further sequential marks for (e) and (f). This question did prove quite challenging for a fair number of candidates as it was clear that they had not been exposed to this type of problem-solving. Candidates who showed working and continued with the calculations were able to gain the marks, even when some parts were incorrect as *error carried forward* was applied.

Question 2

Most candidates were successful in stating the symbols of the two singly charged ions but with a minority showing negatively charged ions. It was surprising to see incorrect answers for (ii). In (iii) many did suggest that doubly charged ions would be deflected more but some had incorrect reasoning. The majority of candidates correctly determined the percentage abundance of the isotopes in part (b).

Question 3

The lactic acid equilibrium equation frequently contained a single arrow rather than the reversible arrows and was often balanced incorrectly with H_2O on the reactant side but no H_3O^+ on the product side, just H^+. There were a few cases of the charges on the products being omitted. In (b), the ionization constant expression was stated correctly but sometimes OH^- appeared and formulas of the equilibrium species were incorrect. The calculation of $[H^+]$ in (c) was not done well. The calculation of the pH of the buffer proved challenging for many candidates. It was surprising that many answers for (e) did not examine the effect of the common ion, lactate on the weak acid dissociation but rather discussed how buffers work and that there would be little or no change in pH.

Question 4

It was surprising to see many candidates having no knowledge of the term isomers. The isomers were generally drawn but an appropriate chemical test was missing. Some obtained zero marks, even when dichromate was mentioned in one form or another, usually "acidified" was missing and even if this were present virtually none said orange to green for the aldehyde and no effect for the ketone. Somewhat similar problem occurred with part (ii) with many indicating pH would distinguish between the carboxylic acid and ester. Many suggested the use of NMR and/or IR spectroscopy as suitable techniques and some suggested physical properties such as solubility in water, boiling point and melting point.

Adding to this problem of not reading the question carefully there were many cases of the same functional group appearing in the drawn isomers and many imaginative isomers were drawn.

Question 5

This question on gas laws was accessible to the majority of candidates. Some candidates had problems stating the correct units of pressure.

Section B

Question 6

A number of candidates managed this calculation but some failed to convert units from J to kJ for entropy. Some candidates lost marks for not paying attention to standard temperature (298K). In part (iii), some candidates surprisingly calculated negative temperatures on the Kelvin scale while others failed to explain the answer.

Many candidates were able to show the correct Lewis structures, although often poorly drawn, and sometimes missing the non-bonding electron pairs or stating wrong shapes.

The presence of a lone pair of electrons and formation of dative covalent bond was missed by many candidates. Oxidation states must be written as +2 and +3. In part (iii), properties of metals (malleable, ductile, conductor of heat and electricity etc.) were stated instead of coloured compounds and catalytic activity.

Question 7

There were several cases where candidates had problems in determining the order for the NO and O_2 from the data supplied; results ranged from zero to third order. The rate expression was usually done correctly but there were many occasions when the units for the rate constant were determined incorrectly. For some, there was no connection between the calculated rate of reaction in part (iv) and their explanation; they used the supplied concentration of each reactant and divided by two to get the new initial rate (increased) but argued that the rate would decrease because, as a result of the volume doubling, the space between the molecules increased and collisions would occur less often. The reaction mechanism eluded the majority of the candidates. Very few candidates could give the correct mechanism and determine the rate determining step.

Many candidates knew the effect of increasing temperature on rate but were not able to express themselves with precision in this question. A large number of students did not draw Maxwell-Boltzmann distribution curves for the two temperatures listed. The distribution curves drawn by a few candidates were not accurate, with incorrectly labelled axes and unclear differences in the curves at the lower and higher temperatures.

Candidates generally had a good understanding of the Le Chatelier's principle and explained the shift in equilibrium position but gained only one mark because they did not state what the effect was on the nitrogen monoxide concentration.

The equilibrium constant expression was correctly stated by majority of the candidates except many missed stating the units as required by the question.

It was surprising to see how many candidates thought that pressure would change the overall value of K_c instead of the temperature.

Question 8

A surprising number of candidates could not identify the half equations or observations either at anode or cathode. There were many poor responses to other parts of this question. Almost none of the candidates could determine the relative amount in moles in part (iv) or identify the compound in (v).

Many candidates stated two factors (current and time) correctly but temperature, concentration and voltage were also common responses.

Many candidates listed 1 atm. and 25^{o}C as a requirement for standard conditions instead of the concentration. The redox reaction was usually balanced correctly; Ni(s) was listed as the reducing agent but there were several cases of incorrect values for the change in oxidation number. Most correctly calculated the cell potential but a few had sign problems. The diagram for the voltaic cell in part (v) was usually poorly drawn and sometimes contained the salt bridge and the two electrodes; Ni(s) as the anode but no metal identified for the cathode. The electron flow in the external circuit was usually correct but few indicated ion flow in the electrolyte. There were several instances of features drawn but not identified.

The concept of spontaneous / non-spontaneous redox reaction or chemical energy converted into electrical energy and vice versa was not well known.

Question 9

The empirical and molecular formula calculation was usually well done but there were cases where for (ii) the branched isomer was not drawn and cyclobutane was given for (iii). In (iv) the alcohol and alkene were identified correctly but several suggested that condensation had occurred.

There were a few cases where the candidates had S_N1 and S_N2 confused and as a consequence drew a five-coordinate transition state but usually the product was identified and the carbocation drawn. Curly arrows were shown starting at and/or finishing at the wrong point. Unfortunately in (ii) incomplete answers resulted in no mark as step 1 was identified as the rate determining step but nothing further was stated.

There was much discussion of electronegativity in (i) to account for the difference in rate and usually, incorrectly, rate would increase for the C–Cl compared to the C–Br. Quite a few candidates thought that an increased concentration of OH^- in (ii) would result in an increased rate.

It was surprising that there were many suggestions of bond angles in benzene, other than 120^{o}. Hybridization of sp^2 and delocalization of electrons were listed but the shape was often simply described as a ring with no mention of hexagonal planar. Virtually everyone correctly stated the number of main peaks in the NMR spectrum and gave an adequate reason.

The majority of candidates calculated the enthalpy change correctly and explained the difference in values.

Recommendations and guidance for the teaching of future candidates

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

- Teachers are strongly advised to refer to past examination papers and their mark schemes to assist candidates with examination preparation.
- Candidates must know the meaning of the different action verbs that appear in the assessment statements and in the examination papers.
- Candidates must read the question carefully and correctly address all points. Working must be shown for all calculations so that the chance of obtaining ECF marks is maximised.
- Candidates must ensure that they cover a sufficient number of different points to score the full range of marks assigned to each question.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 28	29 - 33	34 - 39	40 - 50

General comments

Generally this paper was of comparable standard to last year if perhaps slightly easier. The teachers who completed a G2 confirmed this with 78% stating that it was of a similar standard to last year and 11% stating that it was a little easier. 90% of the G2 responses thought that the suitability of the paper was appropriate and more than 90% thought that the syllabus coverage, clarity of wording and presentation of the paper was good or satisfactory.

The areas of the programme and examination that appeared difficult for the candidates

Students seem generally well prepared but many found particular problems with the following:

- Describing particular practical techniques. For example, electrophoresis, fractional distillation, paper chromatography and how a polarimeter works.
- The sources and effects of mercury and cadmium poisoning.
- The workings of a lead-acid battery.

The levels of knowledge, understanding and skills demonstrated

It is evident that the majority of students knew the subject material well. However there are a few centres where students seemed unfamiliar with much of the material. Often this correlates with the choice of options. As in past years centres where all the candidates answer the same two options tended to do considerably better than when a range of options was chosen. There was also a strong correlation between a candidate’s ability to express clearly and concisely their ideas with their overall scores. Generally most students demonstrated a good knowledge of the factual content of the options chosen (although there was a distinct lack of knowledge about mercury and cadmium poisoning and the lead acid accumulator). Areas which seemed particularly well-known and understood included Dalton’s Law of Partial Pressures, amino acids and polypeptides, primary air pollutants, the pollutants formed from the burning of coal, the reactions taking place in a blast furnace, radioactive isotopes, the use of IR spectroscopy and electrophilic substitution reactions. Although there were exceptions many students were able to write chemical equations correctly and many performed well on the few calculations on the paper.

The strengths and weaknesses of the candidates in the treatment of individual questions

Option B – Medicines and drugs

It is not unreasonable to expect all Higher Level candidates to be able to write correctly the equations for the reactions of sodium hydrogencarbonate and calcium carbonate with hydrochloric acid and yet sadly this was beyond some in question B1 (a). Even though most students gave carbon dioxide as a product many could not relate this to the use of dimethicone in part (d)(i). Magnesium oxide, magnesium hydroxide and aluminium hydroxide were all accepted for d(ii). Some gave sodium hydroxide without realising that this is far too caustic to be taken as an antacid. Most candidates knew that long term use of excess alcohol affects the liver but some included social aspects of alcoholism even though the question clearly said 'on the human body'. Question B3 on penicillins was generally answered well. Candidates had more problems identifying the functional groups in lidocaine and procaine consequently very few candidates scored full marks on part (a) of question B4 whereas many correctly identified the properties associated with particular anesthetics in part (b). Most candidates were able to determine correctly the partial pressure of the halothane in part (c).

Option C – Human biochemistry

Like Option B this was also a popular option and produced some very good responses. Most correctly gave the structures of the dipeptides in C1 part (a) and almost all candidates knew that the formation of a dipetide is a condensation reaction with water as the other product. Some omitted to include a buffer solution and a potential difference in their description of electrophoresis in part (c) (ii). Question C2 on saturated and unsaturated fatty acids presented few problems to the more able candidates. A few candidates still answered part (b) in terms of breaking C-C or C=C bonds within the fatty acids rather than considering the strengths of the intermolecular forces between the fatty acids to account for their melting points. Question C3 on the structure of DNA was also answered well by the stronger candidates. Common mistakes here were not to include the word pentose or ribose to describe the sugar and to state the number of hydrogen bonds between the base pairs the wrong way round. A surprisingly large number of candidates had difficulty reading the graph correctly in C4 to obtain the values for V_{max} and K_m although most could explain how a non-competitive inhibitor works.

Option D – Environmental chemistry

This is another popular option answered by many candidates. Although there may be a perception that this is one of the easier options the answers given do not always bear this out. A few candidates were unable to give the equation for the formation of nitrogen (II) oxide from oxygen and nitrogen and a larger number gave hydrogen rather than water as one of the products of the oxidation of hydrogen sulphide in D1 part (b). The stronger candidates found little difficulty with parts (c), (d) and (e). Most correctly answered D2 (a) on the relative importance of CO_2 and N_2O as greenhouse gases. More surprising was that some candidates confused the greenhouse effect with ozone depletion. Even some of the stronger candidates talked about the Earth reflecting longer wavelength light rather than absorbing incoming shorter wavelength radiation from the sun then **radiating** longer wavelength light back into the atmosphere. Although most candidates knew that using ozone is more expensive than using chlorine to purify water in D3 very few knew why. The main reason is that ozone must be prepared on site whereas chlorine can be transported and stored on site. Many candidates were able to deduce correctly the five equations to represent the radical reactions required in D4. Question D5 on the toxicity of cadmium and mercury was not answered well. This was a straightforward recall question and many candidates were clearly guessing and hoping to score marks by listing vague or all-embracing answers like ‘cancer’ for a specific effect of cadmium on human health.

Option E – Chemical industries

This tends to be one of the least popular options and received some very mixed answers. Good candidates generally answered the questions on the blast furnace in E1 well but many of the weaker candidates were unable to correctly deduce the redox equations in part (a). A surprising number could not explain why the graphite electrodes used to produce aluminium need to be replaced frequently. This is an important Aim 8 area as the carbon dioxide formed in this process makes a significant contribution to total greenhouse gas emissions. Many of the answers given to explain how a fractionating column works in E3 were very vague. This suggests that most students have not actually used a simple fractionating column in the laboratory. The equations required for the cracking and cyclization of alkanes presented few problems. Similarly those who had obviously learned the content of the option generally scored highly on the different forms of poly(ethene) in E4 and the diaphragm cell in E5.

Option F – Fuels and energy

Question F1 (a) required a straightforward calculation of enthalpy of combustion values expressed in kJ g^{-1} rather than the more usual kJ mol^{-1}. Most candidates had few problems with this and answers based either on whole number relative atomic masses or the values to two decimal places as given in the data booklet were accepted. A surprising number could not deduce the equation for coal gasification in part (b) with products such as oxygen and carbon dioxide appearing even though the question stated that two flammable gases are formed. F2 which concerned radioactive isotopes was generally answered well although some candidates were unable to state two differences in the movement of alpha and beta particles in an electric field in (b) (iv). Only a few candidates answered F3 well. The half-equations for the reactions taking place in the lead-acid battery were not well-known and remarkably few candidates knew that the voltage depends on the redox potentials of the two half-cells so that it can only be substantially changed by altering the materials involved. The calculation on the conversion of mass to energy in F4 was successfully completed by the stronger candidates but many of the weaker candidates confused the units of mass and used grams rather than kilograms. Although the doping of silicon with Group 5 or Group 3 elements is clearly covered on the programme and the question has been asked several times before some candidates still scored poorly on F5.

Option G – Modern analytical chemistry

This option appears to be increasing in popularity and many students provided good answers. Most correctly deduced the types of radiation in G1 (a) and also answered part (b) well. Some were unable to explain why a molecule such as oxygen is IR inactive and did not realise the significance of a change in dipole. The use of IR in G2 was well understood and most candidates were able to give one of many possible different isomers in (a) (iii). Similarly the NMR question in part (b) produced some good responses. Many students did actually use the (n+1) rule correctly and deduce correctly that the splitting pattern in C will be 1 singlet + 1 doublet + 1 septet even though splitting by more than 3 adjacent hydrogen atoms is not on the programme. For this reason a splitting pattern of 1 singlet + 1 double + 1 quartet was also accepted. G3 which was concerned with chromatography was the question that gave the most problems in this option. It seems likely that many of the candidates have never actually performed a simple paper chromatography experiment in the laboratory as they were unable to draw correctly a simple diagram of the appearance of the paper at the end of the experiment and confused solvent front with the distance travelled by the solvent. Many did not know that the stationary phase in paper chromatography is the water attached to the cellulose molecules in the paper.

Option H – Further organic chemistry

Many candidates also chose this option. Some students have clearly not been taught how to give a 3-D representation of optical isomers on paper and ended up either drawing the same isomer twice in H1 (b), or not clearly showing that one is different from the other. Similarly students need to be taught that optical isomers rotate the plane of plane-polarized light. Many students were writing ‘bend’ or ‘refract’ or ‘rotate’ and omitting to mention that it is the plane that is rotated in (b) (ii). The significance of intramolecular hydrogen bonding and the effect it has on melting points was not understood or deduced by many candidates and part (c) tended not to be answered well. Those who had learned their mechanisms had few problems with the electrophilic substitution mechanism in part (d) and many also scored well in part (e). H2 was a good discriminator between the stronger and weaker candidates. Many of the weaker candidates did get the order of the strengths of the carboxylic acids correct in part (a) but based their reasoning on the pK_a values given in the data book rather than explaining it in terms of positive inductive effects or electron withdrawing effects of the relevant substituents.

Recommendations and guidance for the teaching of future candidates

- The options form an important part of the overall syllabus. Many teachers leave the teaching of the options until last. If possible, refer to the options when covering the core part of the course and ensure that the recommended time is given to covering two options thoroughly. Students who are left to teach themselves the options material generally do not perform well in the exam.

- From May 2009 the examination will be testing the new programme. Teachers should ensure their students are completely familiar with the programme and understand the objectives covered by each assessment statement.

- Try to include hands-on practical experience of the techniques covered in the option studied. Examples could include fractional distillation, paper chromatography, colorimetry (or visible spectroscopy) and a simulated breathalyser.

- Give students guidance as to the level of answer expected. Journalistic answers to questions at this level will not suffice. Chemical equations should be given wherever possible. Organic mechanism should be clearly described and definitions given precisely and accurately.

- Provide students with adequate resources to complement the teaching of the options. Apart from specific IB text books many chemistry books do not contain much of the option material and students often seem unfamiliar with some of the basic information
- Strongly encourage students to answer questions **only** on the options they have studied. Ensure that students are aware of the importance of "action verbs" and that their answer addresses the question that has actually been asked.
- Give students practice with past papers. Train them to pay attention to the number of marks allocated to each sub-question to ensure that they cover a sufficient number of different points to score the full range of marks assigned. Train them also to use information given in the question wisely such as 'the products are flammable gases'.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 12	13 - 17	18 - 20	21 - 24	25 - 27	28 - 30

General comments

This paper consisted of 30 questions on the Subject Specific Core (SSC) and was to be completed without a calculator or Data Booklet. A periodic table was provided. Each question had four possible responses with credit awarded for correct answers and no credit deducted for incorrect answers.

The G2 forms provided teachers with an opportunity to compare this year's paper with last year's. Of the 58 G2s returned, 75% commented that this year's paper was of a similar standard to last year's paper, 21% felt that it was a little easier and 4% thought that it was a little more difficult. 95% felt that the level of difficulty was appropriate, 2% considered it was too easy and 3% thought that the question paper was too difficult. Syllabus coverage was considered satisfactory by 14% and good by 86%. The clarity of wording was thought to be satisfactory by 16%, good by 79% and poor by 5%. The presentation of the paper was considered satisfactory by 10% and good by 90%.

Various comments were made about several questions, some of which are addressed in the next section. There was a concern expressed that the number of calculation-type questions on this paper had increased. The number of these questions is in the accepted range for this paper. Two questions which appear at first glance to require a calculation did not. These are referred to below.

The strengths and weaknesses of the candidates in the treatment of individual questions

The difficulty index, which is the percentage of candidates achieving a correct answer, ranged from 83.50% to 15.27%, and the discrimination index, which compares the high-scoring candidates with the low-scoring candidates, ranged from 0.59 to 0.24. A higher value indicates better discrimination with the high-scoring candidates more likely to answer correctly and the low-scoring candidates more likely to answer incorrectly.

The following comments were made on selected individual questions.

Question 4

This question required candidates to perform a simple mass to mass calculation where the mass of a reactant was given in tonnes. A large proportion of candidates left this question blank, suggesting that the unfamiliar mass unit caused them to leave the question to last, and then through lack of time did not return to answer the question. Of the candidates who answered this question, most selected the correct answer. This question discriminated quite well.

Question 6

This question to determine the percentage abundance of one isotope of bromine appears at first glance to involve a calculation but it is easily answered with logic. As the two isotopes of bromine have atomic masses of 79 and 81, and the relative atomic mass is less than 80, it follows that there must be more than 50% of bromine-79. There is then only one possible answer. This was one of the more difficult questions with a difficulty index of 50.04%, but it discriminated well with a discrimination index of 0.42.

Question 8

Candidates were required to identify three consecutive elements from given ionization energy values. Concern was raised that candidates may have been confused by whether this question involved first or second ionization energy trends. The question refers to the ionization energy of elements, defined clearly in 3.2.1. 67.41% of candidates answered correctly.

Question 9

This question asked candidates to identify which substance will not conduct an electrical current. Many candidates appeared confused by the inclusion of graphite and incorrectly selected this as the answer. Some comments on the G2 forms stated that candidates do not have to study allotropes of carbon. However in electrolysis, candidates should be familiar with the use of carbon (graphite) electrodes and this should make them aware that graphite is an electrical conductor. Even without this knowledge, the instructions are to select the best answer to each question, and the solid ionic compound is an obvious choice of a non-conductor.

Question 13

Candidates were asked to determine the new volume of a gas after temperature was increased at constant pressure. A surprisingly large number of candidates fell for the trap of doubling the temperature and hence doubling the volume. If the candidates remembered to convert the temperatures to Kelvin then a simple ratio of 300 to 330 should have been realised when temperature values were approximated. This then gave the correct answer of 1.1 dm^3 for the new volume. This question was the most difficult on the paper, with a difficulty index of 15.27%.

Question 14

A correct statement about evaporation had to be selected. One G2 comment suggested that evaporation was a HL concept but it is clearly stated in States of Matter, 5.1.1. A significant number of candidates incorrectly selected B, that a liquid must be at its boiling point for evaporation to occur. 70.33% of candidates correctly answered this question.

Question 15

This question required candidates to select the correct equation to determine the enthalpy of combustion. Although it looks to be a calculation, no calculations are necessary. It was suggested that the enthalpy change should have been asked for in kJ mol^{-1} rather than kJ, and that the answers should have been stated as negative values. These are valid comments, but all answer choices included the value for the number of moles, so candidates were not confused. The difficulty index for this question was 70.93% with a discrimination index of 0.48.

Question 17

This question asked candidates to select the correct combination of ΔH and temperature change for an endothermic reaction. A significant number of candidates selected the correct sign for ΔH but thought that the temperature of the solution increases. This question discriminated very well.

Question 19

As some G2 comments indicated, this question presented difficulties for candidates. The question asked candidates to identify the factors which determine whether a collision results in a chemical reaction. If a collision has occurred only two of the selections would affect the outcome. The majority of candidates answered incorrectly. Candidates must read questions carefully and answer what is asked, not what they think they are being asked. Although only 35.98% of candidates answered correctly, this question discriminated well.

Question 22

Candidates were asked to determine which concentration change increases the pH of a solution from 3 to 6. Some candidates may have used calculations to determine the change in concentration of acid when pH increases by 3 but it should be just a matter of recall. This was one of the easier questions on the paper, with 76.26% of candidates answering correctly, and it discriminated well between high-scoring and low-scoring candidates.

Question 23

This question asked candidates to select which two compounds in aqueous solution could be mixed to produce a buffer solution. One respondent queried why buffer solutions are frequently examined with partial neutralization of a weak acid or base. Statement 9.4.2 clearly states that candidates must know how to make a buffer solution, so this question is quite valid. Answer C tricked quite a few candidates as it involved a familiar acidic salt. 37.90% of candidates were able to select the correct answer.

Question 25

Candidates were asked to determine in which reaction hydrogen had acted as an oxidizing agent. There was concern expressed on a G2 that candidates may have not encountered hydrides before, but the oxidation state of hydrogen was not necessary to answer this question. This question discriminated very well with a discrimination index of 0.54.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 15	16 - 22	23 - 28	29 - 34	35 - 40	41 - 50

General comments

Teachers' impressions of this paper were conveyed by the 55 G2 forms that were returned. In comparison with last year's paper, 78% thought this year's paper to be of a similar standard, 11% more difficult and 11% a little easier. 93% of the respondents thought the level of difficulty was appropriate and 7% too difficult. Syllabus coverage was considered good by 76% and satisfactory by 24%. Clarity of wording was considered good by 75% and satisfactory by 25%. The presentation of the paper was considered 84% and satisfactory by 16%.

The areas of the programme and examination that appeared difficult for the candidates

The candidates had difficulty with explanations and descriptions. Many tried to explain the formation of continuous and line spectra rather than give a description. Often the colour change observed on brominating an alkene was not described. Explanations for a decrease in entropy were often not sound, and assessment of solution mixtures as buffers or not was weak with many candidates unable to distinguish strong and weak acids and bases. The polymerization question also proved to be difficult. Many candidates could classify the process as an addition polymerization but correct answers for the structure were very rare. Many showed a 3-carbon chain as the monomer or showed some species containing bromine. This was an example of the candidates failing to read the question correctly. This was also found in the reactions of metal oxides with water where many equations had the reaction of the metal with water instead.

The Levels of Knowledge, Understanding and Skill Demonstrated

Overall this was variable though few came anywhere near full marks. The calculations, both of enthalpy change and relative atomic mass, were carried out well. Marks were often lost by candidates not always answering the question that was being asked. So, in Section B the equilibrium question proved to be the most popular choice but marks were lost where the information given by the candidates was not that which was asked for. Many candidates had great difficulty in deciding whether the solutions described were buffer solutions or not and even more difficulty in explaining why they had reached their decisions. Lewis structures were competently drawn by those who opted for question 6. Chiral carbon atoms were usually located correctly by those who had drawn the addition product correctly.

The strengths and weaknesses of the candidates in the treatment of individual questions

Section A

Question 1

There was a high proportion of full mark answers for the better candidates. For (a) a number of candidates included potassium nitrate in their equation. In (b) a number of candidates made use of the molar volume of a gas or Avogadro's number in attempting this calculation. In part (c) many assumed that the mass of calcium chloride was 0.265g whilst in (d) a number of answers gave a percentage calculated to be in excess of 100%.

Question 2

For part (a) the calculation was generally well carried out; a mark was lost for giving the answer to too many significant figures or giving it units of grams. Some of the weakest candidates simply quoted the value of the relative atomic mass from their data book. In part (b) this was often answered for the atoms rather than the ions, (c) proved to be very demanding. There were many answers which attempted to relate the spectra to specific electronic processes. A continuous spectrum was often described as one that "continues on forever".

Question 3

Part (a) was generally carried out correctly. Candidates had clearly been well prepared for questions of this type. The most common error was to omit the factor of two for the combustions of carbon and hydrogen. For (b) many candidates correctly identified a decrease in entropy but explanations were often very confused, "Because the reaction is exothermic" or "because the reaction is spontaneous" appeared frequently. The importance of a decrease in the number of moles of gas was rarely mentioned.

Question 4

This question seemed to highlight an area where many candidates had gained only a superficial understanding of buffer solutions and therefore did not score many marks. A definition of a buffer was often correct but for (b) explanations were often very wild. Many stated that sulphuric acid was a weak acid, some even describing it as a weak base.

Question 5

Most candidates could write a correct equation n part (a) but very few gave a correct observation, often just describing the reaction as an addition to a double bond. For (b) those who were able to draw the structure correctly, location of the chiral centre was not a problem. For (c) most candidates realised that this was an example of an addition polymerization but very few could provide the correct segment of polymer. Many gave a bromine-containing compound for this.

Section B

Question 6

This was a fairly popular choice. Part (a) was generally well done with sulfur dioxide being the most likely to be drawn incorrectly. Part (b) scored reasonably well for the very best candidates but many could not explain why potassium was more reactive than sodium, this often being related to electronegativity rather than ionization energy, or even a comparison of all three was given i.e. sodium, potassium and chlorine. In (ii) iodine and iodide were frequently used interchangeably. Part (c) was poorly answered with hardly any candidates able to write correct equations, many of these were for the metal with water rather than the oxide.

Question 7

This was the most popular option for Section B. Marks were lost in (a) when candidates failed to answer the question in terms of the concentration of NO. In (iii) the fact that a catalyst affects both reactions equally was often omitted. Most could write a correct expression for the equilibrium constant (part (b)) though the persistent few still had + signs in it, but very few even attempted to give it any units. In part (c) pressure was frequently suggested as having an affect on the value of the equilibrium constant. Marks were lost in (d) as references to collisions were made without any reference to frequency or time. Molecules of hydrochloric acid and calcium carbonate were also mentioned. Part (e) was generally answered correctly.

Question 8

This was not a popular question. In (a) (iii) many lost marks by suggesting Cu instead of its ion as the best reducing agent. The candidates often talked about molecules and mobile electrons rather than ions for (b). In (ii) and (iii) oxidation and reduction were sometimes confused and the half equations proved to be difficult. In part (d) the colour change was often given as just one colour and for (d) (ii) the position of the –OH group was rarely specified, the compound being referred to simply as propanol. The other compounds were usually named correctly though the ester in (III) was sometimes referred to as ethyl propanoate. Finally in (b) (iv) most candidates recognised the H-bonding in compound A but failed to mention what occurs with compound B.

Recommendations and guidance for the teaching of future candidates

The understanding of organic chemistry seems to be very sketchy. In some instances it appeared that the syllabus had not been fully covered. It is important that all the material likely to appear on the examination paper has been encountered by the candidates.

The mole concept is clearly quite difficult for many candidates to grasp, but it is a core concept for this subject. Calculations appear to be taught in a very convoluted way. A simple manipulation of moles = mass/Mr would be easier.

Candidates should be advised to read the questions more carefully and to answer the ones that are set. They should check their answers for completeness. The number of marks for a section will often give a good clue as to how much is required for a particular answer.

Explanations of why chemical phenomena occur should be emphasised, along with rigorous definitions for terms and concepts. The difference between an explanation and an observation or a trend should be stressed. Significant figures and units need careful review.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 18	19 - 22	23 - 26	27 - 30	31 - 40

General comments

The range of marks awarded was very wide; the best candidates showed a thorough command of the material and a high level of preparation, but this session there were many candidates who seemed unfamiliar with the material in the options and scored very poorly. A handful of candidates attempted questions in all or most Options and still scored very low marks.

Teachers' impressions of this paper were conveyed by the 53 G2 forms that were returned. In comparison with last year's paper, three-quarters thought this year's paper to be of a similar standard, with slightly more of the remainder considering it more difficult rather than easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage and clarity of wording was considered good by three-quarters and satisfactory by most of the rest. The presentation of the paper was considered good by over three-quarters and satisfactory by the remainder.

The areas of the programme and examination that appeared difficult for the candidates

This examination revealed weaknesses in candidates' knowledge and understanding in all Options. These included:

Option A – the lack of familiarity with the correct presentation of organic reaction mechanisms and with ^{1}H NMR spectra

Option B – the inability to write straightforward equations for familiar chemical reactions

Option C – confusion between chromatography and electrophoresis in the analysis of proteins

Option D – confusion between effects on the greenhouse effect and the ozone layer

Option E – the inability to explain fractional distillation

Option F – the behaviour of alpha and beta particles in an electric field, and the lead-acid battery

Knowledge, understanding and skills demonstrated

Once again there were some excellent scripts seen from some candidates, probably from those who had been taught two (or perhaps three) options, rather than from those who may have been allocated little teaching time or who had made their choice of options on the day of the examination. It is clearly in the candidates' interests that teachers cover two options thoroughly, rather than allow their students to study a variety of options on their own.

The strengths and weaknesses of the candidates in the treatment of individual questions

Option A – Higher Physical Organic Chemistry

Question 1

In (a), a disappointing number of candidates were unable to recognise that the given compound was a secondary halogenoalkane, while weaker candidates did not know the meanings of the symbols in S_N1. Answers to part (b) were very disappointing, with very few candidates scoring full marks. Even though there was a mechanism on the opposite page that showed the correct way of drawing curly arrows, few candidates were able to follow the examples. Many showed arrows originating from the C atom rather than from the C–Br bond, and from the H of the ^{-}OH ion rather than from the O; the transition state (where shown) often contained one or more errors (especially a missing charge, or C---HO instead of C---OH). Very few candidates were able to predict either the number or the area ratio of the peaks in the ^{1}H NMR spectrum, and there were many cases where the total of the numbers used for the ratio did not equal the number of peaks stated by the candidate.

Question 2

The calculations were often well done, with the better candidates scoring full, or nearly full, marks. The commonest errors were to identify iodoethanoic acid as the strongest acid in (a) and carelessness in writing the formulas of the species in the K_a expression in (c).

Option B – Medicines and Drugs

Question 1

It was disappointing to see so many errors in the equations in (a); some started with incorrect formulas for the carbonates, and CO_2 was frequently missing from the products. In (b) and (d)(i), although the question required a reference to the equations in (a), these were frequently missing. The functions of alginates and dimethicone were sometimes confused, while others wrote that they neutralised the acid. Suggestions for another base in (d)(ii) frequently included NaOH, Mg and other carbonates.

Question 2

Parts (a) to (c)(i) were often correct, although a common error in (c)(i) was to refer to social problems rather than to the effects on the human body, in spite of the clear instruction in the question. Part (c)(ii) was rarely all correct; especially disappointing was the inclusion of species such as CO_2 and Cr^{3+} as organic products.

Question 3

High scores were rare in this question, even though this material has been frequently tested in recent sessions. Part (c) was the one most often correct, with most candidates being able to refer to the effect on the cell walls of bacteria.

Option C - Human Biochemistry

Question 1

In part (a), few correct structures were seen; some candidates started with the wrong amino acids, while others showed how the two amino acids reacted together, but without showing the structure of the product. Other errors included abbreviations such as –C–O–N–H–, missing hydrogen atoms. Part (c) was poorly done, with many candidates being careless in their use of language in explaining the role of hydrochloric acid in (c)(i), although the main problem was in describing electrophoresis in (c)(ii). Several answers read like descriptions of chromatography (including references to R_f values), while others used inappropriate terms such as "pass a current through the solution" instead of "apply a potential difference across the gel".

Question 2

Better candidates scored well in this question, although in (a)(i) quite a number simply replaced the double bond with a single bond but failed to adjust the number of carbon atoms. Although the examples of acids used were unfamiliar, the understanding being tested in (b) has been frequently tested in recent sessions, so it was disappointing to find so few candidates achieving full marks for this part. The calculation in (c) was set in a way different from most previous examples testing iodine number, and relatively few correctly deduced the number of double bonds. As usual, partial credit was given to those who used the A_r instead of the M_r value of iodine.

Question 3

Again, better candidates scored well in this question. The commonest error was to identify only one other element present in thyroxine, while weaker candidates often quoted the adrenal gland in (b) as well as in (a).

Option D - Environmental Chemistry

Question 1

There were very few all-correct answers to this question. In (a) the straightforward equation was sometimes unbalanced or showed 2N instead of N_2, while some showed NO_2 as a product. In (b), most candidates gave H_2 instead of H_2O as an oxidation product, although the equation in (d) was better known. In (e), NO and CO often appeared on the wrong lines. The expected answer in (f) was "electrostatic precipitation", although a brief description of the method that did not use either word was able to score the mark; there were a surprising number of answers that referred to magnets.

Question 2

Answers to (a) were often correct, with a minority giving the explanations the wrong way round. Once again, in (b), many accounts of the greenhouse effect scored low marks. Common errors included failure to mention wavelengths, references to the ozone layer, radiation described as "reflecting" or "bouncing" off the earth's surface or the gases in the atmosphere.

Question 3

Part (a) was not well done, with few candidates being able to give four marking points. Ozone was frequently stated to have a longer retention time than chlorine, and the effects of the gases on bacteria and viruses were not generally known. Part (b) was disappointing, with some candidates writing about distillation instead of reverse osmosis. Few of those who had some idea of the process scored full marks – the partially permeable membrane was often stated to act as a filter, with the solids in sea water being unable to pass through it, and in the absence of a high pressure, the water was sometimes stated to diffuse through the membrane.

Option E - Chemical Industries

This was the least popular Option, and relatively few scripts were seen.

Question 1

Better candidates managed to score 2 or 3 marks for the equations in (a), but in (b) the increase in malleability and the role of lime in neutralising acidic impurities were less well known.

Question 2

The greater reactivity of aluminium compared to iron was usually known, as was the function of cryolite. The preferred answer to the latter would be in terms of lowering the operating temperature, or the temperature of the electrolyte; although it is not strictly correct to state that the melting point of aluminium oxide is lowered, this statement was accepted. However, to state that it lowers the melting point of aluminium is not an acceptable answer to this question. The equations in (c) were usually correctly written by better candidates, but by weaker ones were shown on the wrong lines or unbalanced.

Question 3

Accounts of fractional distillation in (a) were universally poorly done, with few candidates able to make the connections between molecular size, boiling point and condensation height in the column. The completion of the table in (b) was usually attempted, although the formation of alkenes by steam cracking was not often included. Most attempts at the equations in (c) and (d) were correct.

Option F - Fuels and Energy

Question 1

In (a), most candidates were able to retrieve the correct values from the Data Booklet and use them correctly in the required calculation, although there were some arithmetic errors and problems with significant figures. In (b), many candidates gave a pollutant that would be formed from natural gas as well as from coal (such as carbon monoxide); it was disappointing to see that the deduced equation showed water or carbon dioxide as products, even though the question asked for two flammable gases.

Question 2

Part (a) was generally well answered. In (b), some candidates omitted the atomic number from one or more of the species, and even more failed to include the two neutrons on the right.

In (c), some candidates did not score with their definition of *half-life* through using inappropriate terms (decompose, disappear), but most scored full marks for the accompanying calculation. The commonest error in (c)(iii) was to write Ti instead of Tl. Few candidates scored both points in (c)(iv), with many stating the different directions of movement and the amounts of deflection for the wrong particles.

Question 3

Scores were generally very low in this question, and the commonest incorrect equation was for the reaction of lead and sulfuric acid to give lead sulfate and hydrogen. Part (b) was expected to be answered better than part (a), but this was not usually the case.

Recommendations and guidance for the teaching of future candidates

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

- Practise writing a variety of equations (including ion-electron half-equations and nuclear equations), paying careful attention to balancing and the inclusion of charges and electrons where appropriate.
- Practise setting out calculations in a logical way, including a few words to indicate what process is being used, showing each step, and emphasising the final answer by underlining.
- Consider the units and the appropriate number of significant figures for the final answer in calculations.
- Do not give a long list when asked for two or another specified number of answers, since contradictions may well cancel out correct answers.
- Avoid the use of everyday or journalistic language, and use correct scientific terms, such as radiation "absorbed and re-radiated by" instead of "bouncing off" or "being reflected by".

Finally, some advice that is not specific to chemistry

- The number of lines for a question part is meant to suggest the amount of space for a typical response, although some candidates write answers that are longer than the spaces available. Such candidates should complete their answers in the white space below the lines where possible, in preference to writing a few words on a continuation sheet. If they must use continuation sheets in this way, then they should indicate in the booklet that the particular answer is continued elsewhere.