CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 19	20 - 35	36 - 48	49 - 59	60 - 69	70 - 79	80 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 18	19 - 32	33 - 45	46 - 57	58 - 67	68 - 79	80 - 100

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

In this last ever session under the old assessment model the range of work submitted was wide but there was plenty of material that indicated that many schools are conducting excellent practical programmes and the students are benefiting as a result.

The range and suitability of the work submitted

There were a good number of schools who submitted challenging work which reinforced learning and provided suitable opportunities 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.

One issue of serious concern that was commented on by moderators was that the work from some schools was clearly guided by teachers,

fellow students or unreferenced sources to a level well beyond the instructions evidenced. For these schools, it was unfortunately not uncommon for all students 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 practice for failing to ensure that students carry out the task legitimately for themselves, at worst these cases may be considered malpractice. Teachers must therefore, ensure that assessment is carried out in good faith and that an individual's skills are being assessed.

It was pleasing to see that in a number of schools, investigations that gave the opportunity to more able students to stretch themselves and apply their knowledge were undertaken.

There was very little evidence of the use of data-logging techniques in the samples sent for assessment. Under the new assessment scheme all students must have used data-logging equipment at least once in the course and this will be indicated on the 4PSOW.

Candidate performance against each criterion

Planning (a)

When the set-task was appropriate this criterion was generally well fulfilled with students able to pose a research question, make a sensible hypothesis with some level of explanation and to identify the relevant control and independent variables. However, moderators also report that students were unable to fulfil criterion due to unsuitable investigations being set 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 previous years. Candidates generally selected suitable equipment and devised appropriate strategies for carrying out investigations. 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. In the latter some tasks were too simplistic for this level. 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.

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. Most candidates included the recording of the uncertainty of measurement although there was frequent inconsistency in the use of significant figures. Most candidates recorded qualitative data when it was clearly present and significant.

Tables should speak for themselves and it was a common failure to omit pertinent information (e.g. just recording changes in time for a kinetics lab and neglecting to include concentrations and temperatures of reagents). Pressure rarely appeared in many investigations where it should have been a controlled variable. Room temperature is not complete information and even then was often excluded from investigations where it should have been controlled or measured.

Data Processing and Presentation

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

The quantity and quality of graphs was similar to last year although correct use of Excel with the normal expectations of graphing, i.e. labeled axes with units, best-fit lines and curves, etc, is still not common. Note that a graphing program that does not permit user control over the processing or output is not suitable for assessment of this criterion. Few candidates undertook further processing of the data such as finding a gradient or intercept through extrapolation and teachers from next session should set tasks that will require them to do so. Some schools persist in only presenting bar graphs which are seldom appropriate for most investigations in our field.

Conclusion and Evaluation

The fulfilment of this criterion was to a reasonable standard. 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.

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

The following recommendations are made for the teaching and assessment of candidates for the new specifications that will apply from May 2009 onwards. Recommendations that reflect the changes in assessment scheme are as follows.

- All criteria are to be assessed on the new six point scale. Candidates should be made aware of the different aspects of the criteria by which they are assessed and evaluation of investigations using a grid of criteria/aspects, with n, p, c or 0, 1, 2, indicated clearly, is strongly encouraged.
- Please amend any copies of the 4PSOW forms to include the new criteria titles and all other information as indicated in the Handbook of Procedures for the Diploma Programme, May and November 2009, pages 295 to 300 of the p.d.f. file available on the Online Curriculum Centre.

- All students should have had exposure to the following applications of information technology at least once during the practical programme, and their use indicated on the 4PSOW:

  Data logging, Graph plotting software, Spreadsheet, Database and Computer model/simulation.

- The pieces of work relating to the use of information technology do not have to be formally assessed using the assessment criteria and evidence of their use will only be sent to the moderator if they form part of the sample of two best marks per criterion for a candidate in the sample.
- The Group 4 Project may not be used to assess Design, Data Collection & Processing and Conclusion & Evaluation.
- Teachers should complete and enclose one copy of the 4/IA cover sheet as contained in Handbook of Procedures for the Diploma Programme, May and November 2009, page 301 of the p.d.f. file with their sample for moderation.

Design

- An investigation that requires the teacher to specify the equipment or methodology is not appropriate for assessment of Design. Design tasks should evoke different responses from different candidates within the same class.
- There is no longer any requirement to formulate a hypothesis.
- Aspect 1 requires the (re)statement of the dependent variable as well as independent and control variables.
- The description of a method that controls variables and generates sufficient data does still require the description of apparatus and material used as well as step-wise description of procedure. Requesting that students still produce a clear apparatus/materials list is still good practice.
- A minimum of five data points is considered a guide to the minimum acceptable amount of data to fulfil Aspect 3.

Data Collection and Processing

- Data Collection and Processing should only be assessed through investigations that include the collection and processing of quantitative data.
- Students may now combine raw and processed data in a single table if it is appropriate to aid understanding.
- Simply plotting raw data as a scatter graph is no longer considered sufficient to be considered Data Processing if no further processing has taken place. If DCP is being assessed through work involving graphical processing, then that work should either have involved processing of raw data prior to plotting or it should involve further processing such as measuring a gradient or intercept to derive a quantity.
- Aspect 3 is only satisfied by Standard Level, as well as Higher Level candidates if the uncertainties have been taken into consideration according to the guidance given on pages 27 and 28 of the Subject Guide.

Conclusion and Evaluation

In justifying their conclusion, Standard and Higher Level students should discuss whether systematic error or further random errors were encountered. The direction of any systematic errors should be appreciated.

Manipulative Skills

This will now be assessed summatively i.e. over the whole course and range of skills. No evidence for the mark need be sent to the moderator.

Personal Skills and the Group 4 Project.

This is assessed through the Group 4 Project only.

The Group 4 Project ideal includes linking up with another school, possibly in another IBO region. The Online Curriculum Centre hosts the Group 4 Project Forum on the Chemistry homepage to facilitate linking up with other schools.

Other recommendations continuing from previous assessment scheme.

- It is essential to ensure that students 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 achieve criteria, and hence should not provide too much information/help for the fulfilling the criteria.
- 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 fulfil criteria for themselves.
- Candidates must record qualitative as well as quantitative raw data, where appropriate, including units and uncertainties where necessary.
- Candidates must compare their results to literature values where appropriate.
- When assessing the CE criterion, require candidates to 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.
- 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 Handbook of Procedures for the Diploma Programme before submitting work for moderation.

Instructions to Moderators

As in the last four examination 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 teacher's grading is a plausible interpretation of the criteria then it should be supported. These instructions provide an insight into the application of the criteria and the main points are reproduced below so as to aid assessment in schools.

A. 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 (eg. '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 a 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 judge purely on the student's 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.

B. 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)

- The dependent variable has been given by the teacher or the student has made no mention of a 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 (eg. Student predicts vitamin C contents of juices based on evidence supplied by packaging.) In this case support student but feedback to teacher as to the poor suitability of the task for meaningful hypothesis generation.
- The independent and controlled variables have been clearly identified in the 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 the procedure which is independent and which are controlled.

Planning (b)

- Similar (not word for word identical) procedures are given for a narrow task. Comment though on the poor suitability of the task on 4/IAF form.
- Do not only mark the equipment list. Give credit for equipment that is clearly identified in the stepwise procedure. Remember we mark the whole report.
- Do not insist on +/- precision of apparatus to be given in the 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 the teacher's stance.

Data Collection:

- 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 perfect' rule. This is an important principle since often good students who respond in full to an extended task unfairly get penalised more often than students addressing a simplistic exercise.
- The 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 the 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 is given 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, $(\Delta x/x)$ ▪ 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.

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 the third aspect, ie the modifications must correspond 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."

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 16	17 - 22	23 - 26	27 - 29	30 - 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 19 G2's that were returned. 61% found that it was of a similar standard, compared with last year's paper, 31% felt that it was a little more difficult and 8% thought that it was a much more difficult. 95% felt that the level of difficulty was appropriate, and 5% considered the paper too difficult. Syllabus coverage was considered satisfactory by 21% and good by 74%. Only 5% felt that the coverage was poor. In addition, 21% felt that the clarity of wording on the paper was satisfactory and 79% considered that the wording was good. The presentation of the paper was considered satisfactory by 11% and good by 89%. Overall, this paper appeared to be reasonably accessible.

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 89.36% to 26.68%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.70 to 0.21 (the higher the value, the better the discrimination). The following comments were made on selected individual questions:

Question 3

Two respondents stated that there were too many mathematical steps in this problem. However in the question the M_r and A_r of iron(III) oxide and carbon were given and were also cited as integer values (160 and 12 respectively), and hence this question really was testing the concepts of limiting reagent and theoretical yield which were easily found using the data given in the question. The question had an associated difficulty index of 64% and a discrimination index of 0.59.

Question 4

Some respondents suggested that the stem “Atomic Number for the first ionization energies of successive elements in the periodic table” was misleading. The main difficulty of this question however really related to the interpretation of the graph, and the correct answer D, was only identified by 53% of candidates. The fact that the individual data points were labeled as A-O and did not refer to specific elements should not have caused misinterpretation if candidates fully understood the variation of IE’s across periods of the periodic table of elements.

Question 6

This question referred to the mass spectrum of a sample of an element. The question could have been tackled either by inspection of the spectrum itself in particular by looking at the percentage abundances or else could be determined mathematically to give a final answer, C = 65.5. The former is probably the easiest method to determine the answer and better candidates would have approached the problem in this light. However, if candidates did choose to solve the problem mathematically, the answer of 65.5 could easily have been computed as [(40x64)+(66x30)+(67x30)]/100, even without the use of a calculator.

Question 10

In this question candidates were asked to determine which solution had the highest pH, given that equal amounts of four substances are added to separate samples of 100 cm^3 of water. This question was correctly answered by 58% of candidates with the correct answer being A = NaCl.

Question 16

One respondent claimed that this question where candidates were asked to determine the correct expression for molar mass was very difficult. However, 78% of candidates in fact got the correct answer and this question was the 13th easiest question on the entire paper.

Question 21

This question related to the determination of an enthalpy change. On respondent stated that the mathematical nature of this question made this question overly long. However, the enthalpy change for the question was easily determined as (3)(-602)-437+391 = -1852 kJ, and 78% of candidates got this question correct.

Question 33

This question referred to the electrolysis of molten sodium bromide. Three respondents commented on this question and one stated that the correct answer which is the fact that bromide ions move even if there is no current was confusing and raised the query as to how electrolysis can occur if there is no current. This was discussed at the Grade Award meeting and those present at the meeting largely agreed. However it was felt that since statements A, B and C are clearly incorrect, D could easily be deduced as the only correct answer and hence the question was found to be fair. However, only 38% of candidates got this question correct and this in fact was the second hardest question on the paper.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 33	34 - 45	46 - 54	55 - 64	65 - 73	74 - 90

General comments

The range of marks awarded was very wide; this session there were many candidates who were very well prepared and showed a thorough command of the material.

Teachers' impressions of the paper were conveyed by the 20 G2 forms that were returned. In comparison with last year's paper, 86% felt that it was of a similar standard and 22% that it was a little more difficult. All considered the level of difficulty of the question paper appropriate. Syllabus coverage was considered good by 60%, satisfactory by 35% and poor by 5%. Clarity of wording was considered good by 75% and satisfactory by 25% of respondents. The presentation of the paper was thought to be good by 85% and satisfactory by 15%.

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

This examination revealed the following weaknesses in candidates' knowledge and understanding:

- buffer solution calculations
- precise definitions such as average bond enthalpy
- lattice enthalpies and the Born-Haber cycle
- explanations for differences in lattice enthalpies
- hybridization and electron delocalization
- organic reaction mechanisms

- 3-D structures of optical isomers
- disproportionation reactions
- deducing units
- colour in complexes of d-block elements

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

Topics generally well answered included:

- determination of the order of a reaction
- application of Le Chatelier's Principle
- calculation of enthalpy changes
- atomic theory – isotopes, subatomic particles and electron configuration
- acid-base theory

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

Section A

Question 1

In part (a), most candidates successfully explained the mass loss due to carbon dioxide gas escaping from the flask. Most correctly calculated the amounts of $CaCO_3$ and HCl, although not all explained their choice of $CaCO_3$ as the reagent in excess. There were many errors seen in (a)(iv), with curves starting at points other than 0.00, with either or both curves being less steep than the original, and with the curve for Experiment 3 levelling off at 10, rather than 12.5, small squares below the starting point. In part (b), most were able to deduce the orders with respect to A and B, although the rate expression was sometimes written as $k = [B]^2$. The value of k was often correctly calculated, although there were many errors in the determination of the units, such as "mol dm^{-3}" instead of "mol^{-1} dm^3" and "s^{-1}" instead of "min^{-1}".

Question 2

This proved to be a very straightforward question that allowed many students to achieve high marks, although a range of errors were seen. In (a), some definitions managed to avoid the terms "element" and "atom", in (c), "$4d^{10}$" instead of "$3d^{10}$" and 10 instead of 20 electrons in the d orbitals of a xenon atom.

Question 3

In part (a) good candidates achieved high scores, but there were many errors in other scripts. Some *Brønsted-Lowry acid* definitions referred to electrons rather than to protons, the two species were not a conjugate pair, the chosen base was sometimes NH_4^+ rather than NH_3 and the type of bond formed was a hydrogen bond. In part (b), the formulas of the species were usually correct, although water and the reversible arrow were sometimes omitted.

The pOH calculation was generally well done by better candidates, although the assumption stated was frequently that $[CH_3NH_2] = [CH_3NH_3^+]$. In contrast, the buffer calculation in (b)(iii) was poorly done, with only the very best candidates achieving full marks. There were many blanks and several attempts that led nowhere and were poorly set out.

Question 4

Most candidates were able to calculate the amounts of the gases in the equilibrium mixture, although failure to include the coefficient for H_2 was a common error. Most K_c expressions were correct, but the final answer was usually wrong because the substituted values were amounts in moles and not concentrations in mol dm^{-3}.

Section B

Question 5

This was the most popular question chosen in Section B, and many good answers were seen. Part (a) was the most poorly answered part, with most candidates having the vaguest ideas of bond enthalpy; the mention of gaseous states was often omitted, and those who mentioned other compounds suggested that they were different rather than similar.

In part (b) (i), although many correct answers were seen, many candidates scored marks from errors carried forward; the commonest errors were to use the C–O rather than the C=O value from the Data Booklet, to double instead of quadruple the O–H value, and to subtract the total for bonds broken from the total for bonds formed instead of the other way round. Similar errors (ignoring coefficients and doing the subtraction the wrong way round) were seen in (a)(ii). In attempting to explain the prediction of the sign in (a)(iii), many candidates omitted any mention of order or disorder, and the number of gas moles. In the free energy change calculation in (a)(iv), again many candidates scored through error carried forward, but other errors seen included no unit conversion in the $T\Delta S°$ calculation and the use of 5 significant digits in the final answer. The calculation in part (c) contained the same errors as in the previous ones (failure to use coefficients, problems with signs). Few candidates scored full marks in part (d); the names of the enthalpy changes were often incorrect or omitted, and the electron was often missing from the two relevant equations. Part (e) proved to be the most difficult, with several explanations offered that were based on electronegativity difference, although the main problem was careless use of language, such as "sodium is a smaller atom" (instead of ion) and "CaF_2 has a bigger charge" (rather than comparing Ca^{2+} with K^+). Many of those who referred to electrostatic attractions described them as between nuclei and electrons instead of between oppositely charged ions.

Question 6

In part (a), although the definition of oxidation was usually correct, the species oxidized was frequently identified as bromine, rather than the bromide ion. In part (b), it was pleasing to see the absence of oxidation numbers given as +IV or $^{4+}$, although many values failed to include the + sign, and many answers lost marks through poor layout, where it was impossible to tell which numbers referred to reactants and which to products. Part (c) discriminated well, with better candidates obtaining full marks, while weaker ones gave a range of values for chromium and quoted either the oxidation or the reduction of chlorine, but not both. Although in part (d) most candidates were able to arrange the metals in the correct order, weaker ones lost marks for explanations through careless use of language, such as "X is below Y because X does not react with Y" instead of "X is lower than Y because X cannot reduce Y^{2+} / displace Y from YCl_2".

In part (e)(i), although silver was a popular choice, Ag^+ was often stated, and the deduced equation was often incorrectly balanced, sometimes by using Br instead of $\frac{1}{2}Br_2$. The main problems in (e)(i) and (ii) were adding values, using incorrect signs and the omission of units.

Only the best candidates did well in part (f), with blanks and irrelevant material appearing in scripts of weaker candidates. Several answers in (f)(ii) failed to mention d orbitals and the idea of a complementary colour being transmitted was given only by the very best candidates.

Question 7

Part (a) was generally well answered, as were parts (b)(i) and (ii). Organic reaction mechanisms still cause many problems for candidates, and the usual errors were seen in (b)(iii) – missing sign on ^-OH, arrow from H, arrow from C to Br, five full bonds and no sign in the transition state, and the formation of butan-1-ol rather than butan-2-ol. In (b)(iv) the structure of the carbonium ion intermediate was often $(CH_3)_3C^+$, while in (b)(v) G was often identified as butanal rather than butanone. Part (c) was generally well done, with correct choices made and explanations given. In part (d) it was disappointing to see so many poorly drawn 3-D structures and so many references to the rotation of isomers or the bending / reflecting of light.

Question 8

This was not a popular question and the overall performance was not as good as in the other three questions in the section. In part (a) the idea of hybridization was not well used to discuss the bond formation, and there was little mention of an electron moving from 2s to 2p or that one 2s and one 2p orbital hybridize (mix or combine) to form two sp hybrid orbitals. Many candidates stated that s orbitals rather than the sp hybrid orbitals form the sigma bond between the carbon atoms. In part (b) there was some confusion between cyclohexane and cyclohexene, while several answers to part (c) did not use the enthalpy data in any meaningful way. Part (d) was generally well done, with most stating that the carbon-carbon bonds in benzene are of the same length whereas alternate single and double bonds should result in two different bond lengths. In part (e) most candidates discussed bonding in COO^- in terms of electrons in p-orbitals overlapping to form a delocalized orbital extending over three atoms, and a correct comparison of the carbon-oxygen bond lengths in benzoic acid and the benzoate ion was usually made. A surprising number of candidates in part (f) failed to identify **I** as substitution and **II** as addition and then did not make the connection between delocalization and stability. Part (g) was generally well done except for the failure to identify a suitable indicator.

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:

- Consider the units and the appropriate number of significant figures for the final answer in calculations.
- Learn the common definitions on the syllabus.
- Practice the use of tapered bonds (wedge-dash notation) for 3-D structures in both organic compounds and inorganic complexes.
- Practice calculations based on acid-base reactions, especially those involving buffer solutions.
- Spend adequate time on the more demanding concepts, such as hybridization.
- Set out calculations neatly, giving consideration to significant figures, decimal places and units.
- Where appropriate, draw organic structures in full, including all atoms and bonds, and not use "sticks" in place of hydrogen atoms.
- Ensure that in organic structures the correct bonds are drawn, such as in alcohols C–OH and not C–HO.
- Practice questions from past papers and refer to their mark schemes.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 27	28 - 33	34 - 38	39 - 50

General comments

The paper discriminated well. Most candidates attempted answers to all parts of their chosen options and the best candidates showed a thorough command of the material and a high level of preparation. All of the options had questions where all but the very weak students were able to demonstrate their factual knowledge but also contained questions which tested understanding. It was evident that in several cases candidates did not study as much as they should, or had studied the option on their own. Questions that tested topics that have been tested before but asked in a different way proved difficult to those who relied mainly on rote learning. As has become the norm the most popular options were B, C and D, followed by G and H whereas very few opted for Options E and F. No candidates attempted more than two options.

Teachers' impressions of this paper were conveyed by the 18 G2 forms that were returned. In comparison with last year's paper, an overwhelming majority (72%) thought this year's paper to be of a similar standard, with most of the remainder considering it more difficult rather than easier. 78% of the respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by 28%, poor by 6% and good by 66%. Clarity of wording and presentation of the paper was considered satisfactory or good by 94% of the respondants.

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:

B. contributions by Florey and Chain. The influence of the ring in preventing cis/trans isomerism.

C. the principles behind the working of the sodium/potassium pump

D. explanation as to why carbon dioxide is a greenhouse gas and nitrogen is not

E. purification of silicon

F. electrode reactions in the fuel cell

G. the theory of gas liquid chromatography

H. acid/base behaviour of amines

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

During this session many excellent scripts were seen, invariably from those who had been taught two options, rather than from those who seemed to have been allocated little teaching time or who had made their choice of options on the day of the examination.

It was pleasing to see the use of precise scientific language in many cases although some of the weaker students are still relying on jargon particularly in options B and D. Good levels of knowledge, understanding and skill were demonstrated in the following areas:

- tolerance and lethal dosage
- calculation of enthalpy changes
- LD_{50}
- blast furnace
- half-life
- ^{1}H NMR spectroscopy
- optical isomerism.

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

Option B – Medicines and drugs

This was a popular option and discriminated well between candidates. A surprising number were unable to give the correct structure for an ester group in order to explain why both heroin and aspirin can be described as esters in B1(a). A common mistake involved writing COO-, without a C or R group attached to the O and a significant minority gave no ester functional group structure. Many knew how aspirin and heroin act in the body but some lost marks by giving loose and non specific answers. The side effects of aspirin were well known as was the definition of tolerance in part (d) although fewer candidates realised that increasing the dose of heroin to achieve the original effects risks approaching the lethal dose.

In B2 most candidates gave the correct equations for the reactions of magnesium hydroxide and sodium hydrogencarbonate with hydrochloric acid and realised that magnesium hydroxide will be more effective as it neutralises two moles of acid for every one mole of antacid. The functions of alginates (preventing heartburn or acid reflux) and anti-foaming agents (for the prevention of flatulence or bloating) were less well known. Students either knew or did not know the contributions made by Florey and Chain in the development of penicillin. This is the only reference to the history of chemistry on the entire programme and the question has not been asked before so many seemed unprepared and either guessed or confused their contribution with the discovery by Fleming.

It was pleasing to see that many correctly identified the amide group as group A in 5-flurouracil in B4(a) but rather too many candidates gave C=C as the name of group B rather than correctly naming it as an alkene or cycloalkene. Halogenoalkene and fluoroalkene were also acceptable answers. Only the most able students answered B4 (b) correctly. Very few realised that 5-fluorouracil cannot exist as geometrical isomers as the ring prevents the formation of *cis*- and *trans*- isomers. Too many confused geometrical isomerism with optical isomerism and talked about lack of a chiral carbon as a reason. The structure of transplatin was correctly given by most candidates but very few were able to suggest a sensible reason as to why the trans isomer is ineffective as an anti-cancer drug. B4(e) where students had to deduce which of six drugs can exist as enantiomers was also a good discriminator .

Option C – Human biochemistry

The calculation for the energy content of the breakfast cereal in C1 posed few problems. Those that got it wrong used the wrong mass in the calculation or were unable to convert the value obtained by burning 2.19 g into the value required for burning 45.0 g. A few also converted the temperature rise of 11.2 ^{o}C into a Kelvin value of 284.2 K. A surprising number were unable to suggest two reasons why the result was not completely accurate which suggests that they have never performed simple calorimetry experiments in the laboratory. Some candidates lost marks for describing an unsaturated fat as one that contains double bonds whereas saturated fats only contain single bonds. All fats contain double bonds but only unsaturated fats contain carbon to carbon double bonds. The iodine number calculation in (b)(iii) was usually answered correctly with the most common error not doubling the A_r of iodine even though the formula I_2 was given in the question.

C2 on vitamin D was relatively straightforward but the names of the functional groups in testosterone and oestradiol proved problematical with many just giving the structure of the group such as C=O or C=C without giving the name. Question C4 on the concentrations of sodium and potassium ions was only answered correctly by the stronger candidates. Most knew that the radius of a potassium ion is larger than a sodium ion but did not go on to equate that with charge density. A surprising number were unable to explain what is meant by K_m. Many knew that it equals ½ V_{max} but did not state that it refers to the substrate concentration.

Option D – Environmental chemistry

This was also a popular option but many candidates still do not realise the level of chemistry required to answer the questions and rely too much on 'journalistic' answers which do not have enough depth to score the marks. This was noticeable from the very first question. Even though it has appeared on previous papers many times before very few candidates scored full marks in their explanation as to why carbon dioxide is a greenhouse gas whereas nitrogen is not. Similarly 'lack of oxygen' or 'anaerobic' was often missing in their answer as to why cows convert grass to methane rather than carbon dioxide and water in D1(b). Parts (c) and (d) on global warming were answered well by most candidates.

Some candidates omitted to say that carbonic acid is a weak acid even though almost all knew that acid rain is rain with a pH less than 5.6 in D2(a). Journalistic answers such as 'car exhaust' or 'cars' are still being given as the source of oxides of nitrogen. Some candidates also had difficulties in writing the **ionic** equation for the reaction of hydrogen ions with carbonate ions. Most knew how acid rain affects plants. There were some very inventive answers to D3(a) which asked what PCB stands for. These included 'peroxocarbobromides', 'photochlorine bacteria' and 'personal cancer broadcasting'. One student even turned the letter round to BCP and wrote 'bad chemistry paper'. Much of the rest of the question on water pollutants was answered well although some confused LD_{50} with BOD. The Lewis structure of ozone caused some problems and there was some confusion as to why less energy is required to break the bonds in ozone compared to those in oxygen. Many gave a good answer when suggesting a mechanism for the reaction of nitrogen(IV) oxide with ozone. There is no single correct answer as the first step could involve either the dissociation of NO_2 or the dissociation of O_3 and any answer that was sensible and added up to the overall equation was accepted.

Option E – Chemical industries

This was the least popular option and yet proved relatively straightforward to those candidates who attempted it. It is noticeable however that some students rely more on simply memorising facts and then come unstuck when asked to explain the underlying chemistry. The chemistry of the blast furnace was generally well-answered in E1 although some students were unable to suggest using a magnet to separate steel cans from aluminium cans. Most knew that sulfur can poison catalysts and also when combusted can contribute to acid rain, however they were less certain about the conditions used for hydrocracking in E2(c).

The question that candidates found most difficult was on the necessity to obtain silicon in a pure state in E3. Very few could explain adequately why silicon is converted into silicon tetrachloride during the process and although zone refining was better known the underlying chemistry was often not explained clearly. Even though it has appeared on many papers before some had difficulty explaining how adding a group 3 element changes the electrical conductivity of silicon.

Option F – Fuels and energy

This was the last time this option was examined as it does not form part of the new programme although some of the content does appear elsewhere. Perhaps because of this it seemed to be less popular this year than in the past. Much of the question on nuclear energy was answered well by the able candidates with most being able to write nuclear equations and work out problems involving half-lives. The functions of the moderator and control rods were less well known and often confused with each other. The biggest problem was encountered with calculating the theoretical maximum amount of energy obtained from the nuclear reaction in F1(e). The most common error was confusion over the units of mass resulting in the wrong power of ten in the answer.

Some candidates also had problems calculating correctly whether 1.00 kg of methane or 1.00 kg of octane produces the most energy even though they were provided with the enthalpies of combustion. The half-equations for the reactions taking place at the electrodes in a hydrogen-oxygen fuel cell also caused some problems with a common error being to write them the wrong way round even though it should be obvious that at the positive electrode electrons are being gained and should appear on the reactants side of the half-equation.

Many candidates seemed unaware that the conversion of energy from one form into another always involves some loss of energy when answering F3(a). In F3(b) the advantages and disadvantages of pumping water or converting to hydrogen as a form of storage of energy were often stated vaguely without serious thought. Many candidates included reference to both methods not producing pollutants even though it specifically stated in the question that neither method produces chemical pollutants and thus they scored no marks for this.

Option G – Modern analytical chemistry

Many candidates who chose this option also chose to answer Option H. The questions on the spectra of ethyl methanoate were generally answered well, although candidates sometimes failed to score marks because they were not specific enough in their answers. For example the word *change* is necessary when talking about change in dipole moment to explain why some vibrations absorb in the infrared region whilst others do not. Similarly when explaining why the peak at 1.3 ppm is split into a triplet the answer ‘because there are two neighbouring hydrogen atoms’ will not score the mark. Candidates must state that it is because there are two hydrogen atoms on the neighbouring (or adjacent) carbon atom. Similarly when giving the species responsible for the peaks in the mass spectrum the positive charge must be given as all the peaks are due to positive ions. The way in which the infrared spectrum of propanoic acid differs to the two esters produced some interesting answers for G1(h). All three have an absorption due to the C-O bond so this cannot be used. Apart from the obvious difference due to the O-H bond the other main difference is the fingerprint region. One candidate has obviously been reading about carbon footprints and called this the footprint region.

Most scored some marks on describing how G.L.C works but relatively few scored full marks. There was uncertainty about the nature of the stationary phase and also how the different components are detected after they have been separated. The identification of the correct chromatographic techniques in G2(b) was generally answered well.

Option H – Further organic chemistry

The standard of organic chemistry has improved over the years and there were some very good answers from many candidates. Some still invoke Markovnikov’s rule as an explanation as to why 2-bromobutane rather than 1-bromobutane is formed when hydrogen bromide is added to but-1-ene. Markovnikov’s rule is useful for predicting the product but the explanation lies in the relative stabilities of the carbocations formed. Some also did not realise that 2-bromobutane will have a lower boiling point than 1-bromobutane as it is more spherical in shape so the forces of attraction between the molecules will be lower as there is less surface contact area. Enantioners **rotate** the **plane** of plane-polarised light. They do not bend or reflect it. The reason why aluminium chloride is added to the reaction between methylbenzene and chlorine was well-known. However some did not really appreciate that this is a Lewis acid-base reaction or that the chlorine changes oxidation number so that it is also a redox reaction. Perhaps the question that caused the most difficulty was H3(a). Although part (b) actually states that phenylamine is a base very few realised that when it reacts with an acid it forms a salt and that as the salt is ionic it will be much more soluble in water than the covalent compound phenylamine. Some were sloppy with their explanation as to why 4-nitrophenylamine is a weaker base than phenylamine. They talked about the nitro group being electron withdrawing but then did not specify clearly that it is the lone pair on the nitrogen atom in the amine group that is most affected by this.

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 (now called command terms in the new programme), candidates are advised to bear in mind the following points in this paper:

- Give answers that involve proper chemistry and not superficial or ‘journalistic’ answers. Also, avoid the use of jargon, and use correct scientific terms, such as "of lower density" instead of "lighter", and radiation "absorbed" instead of "blocked".
- Practice setting out calculations in a logical way, showing each step, and emphasising the final answer by underlining, as well as paying attention to units and significant figures.
- When writing organic structures, check that the total number of each atom is correct, and each carbon atom has four bonds.
- Practice 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, and following the convention of writing mass numbers above atomic numbers to the left of symbols.
- Do not give a long list when asked for a specified number of answers.

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.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 13	14 - 16	17 - 20	21 - 23	24 - 30

General comments

This paper consisted of 30 questions on the Subject Specific Core (SSC) and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and no credit deducted for incorrect answers. Teachers' impressions of this paper were conveyed by the 21 G2's that were returned. 50% found that it was of a similar standard, compared with last year's paper, 29% felt that it was a little more difficult and 14% thought that it was much more difficult. Only 7% considered the paper a little easier.

90% felt that the level of difficulty was appropriate, and 5% considered the paper too difficult. Equally, 5% found the paper too easy. Syllabus coverage was considered satisfactory by 33% and good by 57%. 10% felt that the coverage was poor. In addition, 66% felt that the clarity of wording on the paper was good, 24% satisfactory and 10% considered that the wording was poor. The presentation of the paper was considered satisfactory by 14% and good by 81%. Overall, this paper appeared to be reasonably accessible but somewhat harder than last years'.

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 80.04% to 15.94%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.61 to 0.03 (the higher the value, the better the discrimination). The following comments were made on selected individual questions:

Question 6

This question referred to the mass spectrum of a sample of an element. The question could have been tackled either by inspection of the spectrum itself in particular by looking at the percentage abundances or else could be determined mathematically to give a final answer, C = 65.5. The former is probably the easiest method to determine the answer and better candidates would have approached the problem in this light. However, if candidates did choose to solve the problem mathematically, the answer of 65.5 could easily have been computed as [(40x64)+(66x30)+(67x30)]/100, even without the use of a calculator. One respondent stated that the syllabus does not ask for recognition of this type of graph. However as mentioned in the teachers notes corresponding to AS 12.1.2 it is stated that students should be able to calculate the relative atomic mass from the abundance of isotopes. This comment was discussed fully at the Grade Award Meeting and it was the general consensus that the percentage abundances were easily identified from the spectrum given and in fact this is no different than presenting the data in tabulated format.

In the teachers note when it is stated that interpretation of fragmentation patters is not required, this refers to the interpretation of the patterns which are outlined in Option A: Higher Physical Organic Chemistry in AS A.1.3, which is entirely different to that being referred to in Question 6.

Question 12

A frequent comment seen in the G2's almost every examination session refers to questions been set on examples of molecular geometry which are not explicitly listed in the guide. In this question, candidates were asked to state the C-C-C bond angle in propanone which tests application of VSEPR for a 3-negative charge centred species i.e. A.S. 4.2.8. In the guide, it is stated that examples such as ethene, carbonate and nitrite can be used. However, this does **not** imply that these are the only examples that can be asked to test the determination of shape of 3-negative charge centred species using VSEPR Theory. The main point here is that students should be able to deduce the shape of any 2- or 3- negative charge centred species using the principles of VSEPR.

Question 20

One respondent stated that this question was off-syllabus. However, AS's 7.2.2, 7.2.3 and 7.2.4 do explore collision theory with respect to activation energy and 61% of students got the correct answer which is A i.e. the fact that the activation energy is changed by the presence of a catalyst but not by an increase in temperature.

Question 25

See comment on HL for Question 33.

Question 29

Two respondents stated that ethers are off-syllabus. However, in this question candidates were asked to determine the number of isomers with the molecular formula C_3H_8O, and it was felt that candidates should have been able to write all three isomers, as the question does not ask for functional groups. Candidates should realize that oxygen can be written with two single bonds around it, just as in water. However, the question was found to be the second hardest on the paper, with only 39% obtaining the correct answer. The discrimination index was found to be just 0.03 and most candidates wrote A = 2 as the answer.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 17	18 - 24	25 - 30	31 - 35	36 - 41	42 - 50

General comments

This was a very accessible paper in which students were able to demonstrate their knowledge of the syllabus. The G2 comments received (25 of them), suggested that over 90% of teachers who responded felt the paper was of a similar standard to last year and was a of an appropriate level of difficulty. The syllabus coverage, clarity of wording and presentation of the paper was found to be satisfactory or good by all of those who responded.

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

This examination revealed the following weaknesses in candidates' knowledge and understanding:

- drawing correct Lewis strucrures
- definition of average bond enthalpy
- standard free energy change symbol
- disproportionation reactions
- drawing a labelled enthalpy level diagram
- calculating standard enthalpy change
- deducing oxidation numbers
- predicting the formulas of ionic compounds and writing an equation
- deducing a repeating unit of a polymer

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

Many of the candidates had good recall of detailed chemistry information, and could apply this knowledge to explain various concepts. Only a few candidates had difficulty answering anything more challenging than simple recall questions.

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

Section A

Question 1

This question generally was very well answered in part (a)(i). Most candidates had no problem explaining why the mass of the reaction vessel decreased and nearly all equated this with the formation of carbon dioxide although some answered that the mass decreased because the calcium carbonate dissolved into the acid. Most candidates correctly calculated the number of moles of reactants in (a)(ii).

Some went on to factor in the mole ratio giving answers such as n(HCl) = 0.05 = 0.05 x 2 = 0.10 or n($CaCO_3$) = 0.05 = 0.05/2 = 0.025, most students were able to obtain 0.0500 mol for both calcium carbonate and hydrochloric acid, but many did not write their answers correct to 3 significant figures, although in this case it was decided not to penalise them. In (iv), candidates generally got 2 out of 4 for the two steeper lines and some mixed up line 2 and line 3. Although this is a very common experiment it appeared that few had done it as they found the graph very difficult to complete correctly. In part (b) collision theory was usually well understood although some talked about molecules instead of particles of calcium carbonate.

Also many candidates failed to talk about *increased frequency* of collisions saying just *more* collisions instead.

Question 2

This question was very well answered and a large number of candidates scored full marks here. Part (a) was answered well by the majority of the candidates. Many scored full marks. A small number of candidates referred to isomers. Some candidates incorrectly stated that isotopes have differing numbers of electrons. Some reversed the definition and stated that 'isotopes are atoms of an element which have different numbers of protons but the same number of neutrons'.

Most candidates successfully calculated relative atomic mass in 2(b) (i) although a handful of candidates resorted to quoting the Data Booklet value.

A large majority of candidates could deduce the number of protons, neutrons and electrons in an atom of Krypton in 2(b) (ii). There were a small number who didn't think to look at the Periodic Table and hence did not know the atomic number; this led to errors. Some candidates simply divided 84 by two and announced that there were 42 of each of the sub-atomic particles.

Question 3

Many candidates did not seem to know what was required in 3(a)(i) and identified molecules rather than bonds. However they were given the benefit of the doubt in most cases. Some candidates referred to intermolecular forces.

In (a) (ii) most candidates gave the answer that the carbon to carbon triple bond was the shortest while a small number used the Data Booklet and gave O-H as the answer, both were accepted.

Most candidates satisfactorily stated in (b)(i) how the equation indicates that ammonia is a base. (b) (ii) was answered well with nearly all candidates able to at least identify the reversible arrows as the evidence that ammonia is a weak base. Most continued and stated that this showed partial dissociation of ammonia. A few suggested that the ions partially dissociate rather than the molecule. Nearly everyone identified pH of 11 as the most likely pH value of an ammonia solution.

Lewis structures proved difficult for some candidates in 3(c). There were a few odd combinations and arrangements of electrons. Some candidates drew the structures of ammonia and water. A common error was to name the shape of H_3O^+ as trigonal planar.

Section B

Question 4

This was a popular question but was the most poorly done in Section B. Most candidates had difficulty defining average bond enthalpy in 4(a)(i). Most candidates omitted gaseous phase and so missed out on the first mark and many of the candidates had difficulty explaining the average value. 4(a)(ii) was poorly answered. Candidates gave answers which ranged from 'hydrogen molecules are only in covalent compounds' to 'the strong hydrogen bonding makes H_2 a liquid and bond enthalpy is only for gases'.

Many candidates made ΔH errors in 4(a)(iii) and scored ECF marks for the enthalpy change of the reaction. A few missed out on the follow through marks as they subtracted the reactant value from the product value. Even though the bonds were identified to make it easier for the candidates, a common mistake was to use C – C single bond enthalpy instead of the C=C value, or failing to multiply the bond enthalpy of O_2 by 0.5. 4(a)(iv) was poorly answered. Many candidates failed to label the vertical axis with enthalpy. Activation energy was often labelled but the ΔH value was not.

4(a)(v) was mostly answered correctly. A small number could give the correct reason (less disorder) but mistakenly stated that this made ΔS positive.

4(b)(i) had varied responses. Some candidates answered correctly for 4 marks. Some almost scored full marks but neglected to reverse the third equation and then had to score follow through marks. Some candidates seemed completely baffled by the question.

In (b)(ii) candidates seemed almost evenly split over whether I or II had the most negative enthalpy change. Only the best candidates scored the second mark.

Most candidates omitted the word 'standard' from the meaning of $\Delta G^{\ominus}$ in 4 (c) (i) and thus did not score any marks. 4(c)(ii) was generally answered well, although few were able to score all the marks by correctly explaining the relationship between ΔG and $T\Delta S$.

Question 5

Again this was a popular question. In (a), nearly all candidates knew that oxidation involves the loss of electrons, but only a few students stated that the bromide ion is the species oxidized in the reaction. A large majority said that bromine was oxidized. Part (b) was typically well done. However candidates made errors in the determination of the oxidation numbers or did not give oxidation numbers for both the reactants and the products. Many candidates identified the oxidation number of Cl in $TiCl_4$ as −4.

These difficulties were carried over into 5(c) where the oxidation numbers had to be determined to deduce whether oxidation or reduction had occurred. In (c)(i) many candidates found the oxidation numbers of Cr to be +6 and +12. In (c)(ii) several candidates managed to find the oxidation numbers of Cl to be +1 and −1 in the products but had apparently not met disproportionation before as they then determined that these two oxidation states cancelled out and overall no oxidation or reduction had occurred. A significant number of candidates only calculated the oxidation number of Cl in the products once and based their answer on that.

Many candidates correctly arranged the metals in a reactivity series and explained their decisions in 5(d)(i). A few had the correct reasoning but then wrote an incorrect order of reactivity.

5(d)(ii) was seldom answered correctly. Most wrote $V + XO \rightarrow VO + X$

5(e) on voltaic cells was generally well answered. In (e)(i) most candidates could describe why a salt bridge was necessary and could identify a suitable substance to use. A few thought that the salt bridge allowed electrons to flow and a small number of candidates incorrectly identified HNO_3 or $K_2Cr_2O_7$ as suitable compounds to use in a salt bridge.

Most candidates correctly answered (e)(ii), (iii) and (iv). Only a small number of candidates could not write correct half-equations.

Question 6

This question was selected by some very good candidates who scored particularly well. Nearly everyone correctly deduced the empirical formula in (a)(i). Most correctly deduced the structural formula and name of compound A in (a)(ii). A few did not give a structural (or condensed structural) formula and stated $C_4H_7O_2H$ as the formula.

In (a) (iii) most named the functional group in B, C and D as an ester. Some thought it was a ketone.

In 6(b) (i) some thought that O_2 was a necessary reagent. A few name $Cr_2O_7^{2-}$ as a catalyst. Most knew butanal as the intermediate product, but could not identify the reagents or conditions necessary for complete oxidation. Reflux was frequently mentioned but not heat.

In (b) (ii) some candidates managed to write the equation for the esterification reaction, but even those who could not do this, could identify the organic product.

Most candidates could draw the correct structural formulas of the isomers of ethyl ethanoate in (b) (iii).

In 6(c) most candidates knew about a chiral carbon atom, and many continued on to say that the carbon is surrounded by four different groups (although some identified these as functional groups). Most candidates drew correct structures for the optical isomers with only a few not drawing a 3-D structure.

Difficulties arose with stating how optical isomers could be distinguished with many candidates not stating that the *plane* of the polarised light is rotated. Several candidates suggested that the light caused the isomers to rotate. Several candidates suggested that the light bent or bounced off the isomer.

6(d) presented problems with many candidates unable to deduce the repeating unit. A few candidates connected two molecules only and left the acid group and the alcohol group on the ends of the dimer. Some candidates drew too much of the molecule and had more than one repeating unit. Some candidates had difficulty with C_6H_4.

Recommendations and guidance for the teaching of future candidates

Use past papers with markschemes for revision. Make sure that there is a thorough and varied practical programme which exposes students to a wide variety of techniques. In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and action verbs, candidates are advised to :

- Practice writing a variety of equations including ionic and half-equations paying careful attention to balancing and the inclusion of charges and electrons where appropriate.
- Practice 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.
- Practice drawing Lewis structures and 3-D diagrams of an appropriate size, and clearly showing the electron pairs.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 17	18 - 22	23 - 26	27 - 31	32 - 40

General comments

A very wide range of performance was seen - there were some excellent responses and also there were a number of candidates who were insufficiently prepared for the paper. The major problem continues to be that candidates do not answer questions with sufficient detail and their answers can tend to be journalistic rather than based on chemical principles. This is particularly the case with the Environmental Chemistry option, which continues to be the most popular of the options. Most candidates followed the rubric and answered two options.

Of the 24 G2s sent in 74% felt that the paper was a similar standard to last year, while the remainder were equally split between the paper being easier and more difficult. All of the teachers who responded felt the level of difficulty was appropriate. Syllabus coverage was considered to be good by 62% and satisfactory by 38%. For clarity of wording 71% felt it was good and 29% satisfactory. Finally, for presentation of the paper, 83% chose good and 17% satisfactory.

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

There was considerable variation in performance but some of the repeated weaknesses were:

- defining terms
- writing balanced chemical equations
- proton NMR and IR spectral interpretations
- pH calculations
- contributions made by Florey and Chain in the development of penicillin
- identification of functional groups
- calculation of the energy content of foods
- structural formula of a fat
- calculations using iodine number
- explanations pertaining to carbon dioxide acting as a greenhouse gas
- writing equations for processes occurring in hydrogen-oxygen fuel cells

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

Candidates seemed generally well prepared and there were some excellent candidates whose recall of the syllabus was very good. However, areas of the syllabus that had not been asked before, such as the contributions of Florey and Chain to the development of penicillin, showed that not everything is being taught/learnt to the same depth. Often candidates tripped up on key chemical concepts in the options, such as functional group identification, spectral interpretation, pH etc. In addition, although option D continues to be a very popular option, in practice, candidates often perform very poorly here with a tendency to give journalistic style answers to questions, with very little chemistry seen.

Certain areas of the course were particularly well understood. These included:

- tolerance
- antacids
- social problems caused with heroin
- vitamins
- half-life

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

Option A - Higher physical organic chemistry

For question 1, part (a), most candidates were able to define rate of reaction, although several did not mention change and just stated that rate was concentration over time and thus did not score the mark. In (b), some candidates appeared to be guessing the orders of reaction but most correctly deduced them. Several candidates found it more challenging to deduce the rate expression in part (c). The most common mistake was to write *k* = instead of rate = *k*... For part (d), most candidates were able to deduce the rate expression, but common errors included omitting *k* completely, or deriving an expression from the equation of the reaction.

Question two was either answered very well or very poorly. In (a) many candidates did not seem to be aware of the fingerprint region of the IR spectrum, even though this is mentioned in A.1.2 of the subject guide. Few candidates scored full marks on the proton NMR spectrum in part (b). In (c) the most common mistake involved candidates missing the + sign from the mass spectrum fragments.

Parts (a) and (b) of question 3 were generally answered well. Part (c) proved to be more challenging with many candidates unable to calculate pH. A common error was stating that K_a was equal to −4.87.

Option B - Medicines and Drugs

Drawing the ester linkage in question 1(a) proved difficult for candidates, with many writing COO^- without a C or R group attached to the O. Many tried unsuccessfully to describe the ester linkage in words. In (b), the majority of the candidates had a good idea of the mode of action of aspirin and heroin, although very few scored all 4 marks here. In part (c), nearly all candidates were able to state a serious side effect of aspirin. Additionally, in part (d) most candidates understood the idea of tolerance but only the better candidates referred explicitly to the danger of exceeding the lethal dose of heroin.

In 2(a) most candidates were able to write correct equations, although often the equations were not balanced. The majority of candidates could correctly explain the functions of alginates and anti-foaming agents in (b).

Perhaps the most difficult question in this option related to the contributions made by Florey and Chain in 3(a). Very few discussed purification methods and clearly the fact that this assessment statement had not been asked previously certainly posed real problems for candidates. In (b), most candidates were able to identify the amide and the carboxylic acid functional groups. Common mistakes included the amine group for B or the carboxyl group for A. In (c) most candidates knew that bacteria built up a resistance but only the best stated that penicillinase deactivates the original penicillin. Part (d) generally posed no problem, although a few candidates stated that the functional groups must be altered.

Option C - Human Biochemistry

Calculation of the heat released in 1(a)(i) was poorly answered. Some candidates found ΔT by adding 273. Many candidates forgot to divide by 2.19 or stated that the heat produced was = 600 x 4.18 x 2.19. Several candidates also lost marks for incorrect or missing units, or for stating too many significant figures in the final answer. Most candidates scored full marks in (a)(ii). In part (b), many candidates had difficulty drawing the structure of a fat in (i).

A common mistake in b(ii) was forgetting to mention carbon to carbon double bonds. In (b)(iii), many candidates correctly calculated the number of double bonds, although some used 127 instead of 254 for the molar mass of iodine. Several candidates simply stated that the information suggested there were many C=C double bonds in the fat. Part (b)(iv) was generally very well answered.

C2(a) was very well answered and it was good to see some candidates referring to the absence of a steroidal backbone with regards to vitamin D. In (b), some candidates never mentioned the long non-polar part when discussing the fact that vitamin D is fat soluble. Part (c) was well answered. In (d), although the majority were able to identify rickets, some candidates talked about weak bones, which was not enough to score the point. Only a few candidates stated that the uptake of calcium and phosphorus was hindered.

Several candidates forgot to mention chemical when defining a hormone in 3(a). In 3(b), some candidates had no idea where estradiol is produced and many answers were offered. A significant number stated female reproductive organs or pituitary gland. In part (c), many candidates offered formulas instead of names and failed to score marks. A common mistake was benzene, which of course is incorrect.

Option D - Environmental Chemistry

This was a very popular option, but candidate performance in general was very poor. Rarely did a candidate score full marks for 1(a). Even the best candidates did not answer the question or provide the detail required. In (b), only the better candidates identified that decomposition is anaerobic with regards to the conversion of grass to methane in cows. Most could list two greenhouse gases in (c), and in (d) the majority of candidates knew that particulates cool the Earth, but had more difficulty explaining how this happens.

In 2(a), surprisingly few candidates identified carbonic acid as a weak acid, or stated that the pH of acid rain is less than 5.6. In (b), many candidates could not identify both acids and a source for each of them. 2(c) also proved demanding with several candidates not able to write an ionic equation – a common mistake involved candidates writing a single negative charge on the carbonate ion. In (d), most candidates were able to gain a mark for saying that plant growth is reduced but few knew sufficient detail to access the second mark.

In 3(a), few candidates correctly wrote ice caps or glaciers without adding rivers or lakes, therfore losing the mark. In (b), most candidates stated that bacteria are killed by chlorine. Weaker candidates had difficulty coming up with a disadvantage. Reverse osmosis was well known in (c), but unfortunately a significant number of candidates failed to state that the membrane is semi-permeable or that high pressure is needed.

Option E - Chemical Industries

Most candidates could write one equation in E1(a) and (b), but it was rare for them to correctly write them all. In (c), the removal of silicon dioxide was problematic, and many candidates could not state that carbon is the main impurity of iron in (d). In part (e), most realised that a magnet would separate iron and aluminium.

Candidates commonly scored only 1 mark in E2(a), stating that sulfur is removed to prevent the formation of SO_x or acid rain, but few knew that it poisoned the catalyst. In (b), the majority knew that the sulfur is used to make sulfuric acid.

In (c), some candidates stated that high temperature is needed for hydrocracking instead of high pressure conditions. Vague answers such as add a catalyst, rather than naming the catalyst, were common. In (d), most candidates could write the equation for thermal cracking and give a use for the alkene.

Very few candidates could draw the repeating unit for poly(propene) in E3(a). In (b), candidates found it difficult to explain the difference between atactic and isotactic polymers. Many erroneously talked about branching of the chains. This then made it difficult for them to access marks in (c).

Option F - Fuels and Energy

This was a very popular option this session which was surprising. Student performance overall was very good.

The nuclear equation in 1(a) was well done, although some did not correctly identify the products. In (b), the better candidates correctly stated the number of alpha and beta emissions. Half-life was well known in (c), and the majority could correctly calculate the amount of U-235 remaining in (d). In (e), some candidates mixed up moderator and control rods.

In 2(a), most candidates could correctly write a balanced equation for the complete combustion of octane, but difficulties arose in the calculations of heat energy, with many candidates forgetting to multiply by 1000 or losing marks for too many significant figures. In (b), advantages and disadvantages were known, but not in depth, so most candidates scored only 2 out of 4 here. The equations for the fuel cell were done poorly in (c).

Recommendations and guidance for the teaching of future candidates

- Candidates continue to struggle with basic chemical concepts on many of the options. Teachers should emphasize the clear chemical concepts in each of the options.
- Candidates should exercise caution taking option D unless they are adequately prepared. This option can often look easy, but sometimes it can be difficult to score high marks as journalistic type answers are not sufficient.
- Candidates need to study each option in depth and ensure they know the equations relating to the processes they study.
- Candidates should practice writing balanced equations.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Candidates should take note of the command terms used and also the mark allocation for the question.
- Candidates should write clearly and neatly in the spaces provided for the answers.