CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 18	19 - 34	35 - 48	49 - 59	60 - 68	69 - 79	80 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 33	34 - 46	47 - 57	58 - 66	67 - 77	78 - 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

As ever 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 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. It is disappointing that some of these schools were not implementing recommendations given on the previous years 4/IAF feedback form.

One issue of serious concern that was commented on by moderators was that the work of some candidates was clearly guided by teachers, fellow students or unreferenced sources to a level well beyond the instructions evidenced. 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. Teachers should 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. The fact that very few students refer to data-logging in planning activities indicates that they are not yet familiar with the technology concerned. There is no reason why data-logging cannot be incorporated into successful planning or CE tasks, and with careful forethought as to how much students input is possible, even into Data Collection and Data Processing.

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. Moderators also report however, that students were unable to fulfil the criterion due to being set unsuitable investigations based on confirmation of laws or determinations of specific values for example, 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. 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). for example 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 case, some tasks were too simplistic. Another failing of a large number of candidates was the absence of quantitative information regarding reactant concentrations, masses, and volumes and so on. 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 evoke 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 uncertainties often being left out and there was frequent inconsistency in the use of significant figures. More candidates than previously took the opportunity to record qualitative data when it was clearly present and significant (for example, the evidence of incomplete combustion in an enthalpy of combustion determination).

Teachers were prone to over-reward their students in purely qualitative DC tasks with full marks being given for poorly phrased observations that either lacked detail or were not primary observational statements or when just one or two data had been collected.

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).

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. The majority of schools encouraged meaningful treatment of errors or uncertainties in DPP.

The quantity and quality of graphs was improved from 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 should really 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 chemistry.

Conclusion and Evaluation

The fulfilment of this criterion has improved compared with previous sessions. 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 often not related to cited errors. But several schools showed to have benefited from feedback and their approach was more accurate than during previous sessions.

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. It is worth teachers noting that a significantly large proportion of schools use the Group 4 Project as an ideal opportunity to stimulate group collaboration within an interdisciplinary framework and assess the Personal Skills criteria, but do not award grades for the written criteria. This is in harmony with the aims of the Group 4 Project and the basis of the new guidelines for implementation from the May 2009 examination session onwards.

Recommendations for the teaching of future candidates

The following recommendations are made for the teaching and assessment of candidates for the November 2008 session. Thereafter the revised specifications in the new Subject Guide will apply.

- 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 and c indicated clearly is strongly encouraged.
- 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 Planning (a), Planning (b), Data Collection, Data Processing & Presentation and Conclusion & Evaluation criteria.
- Teachers should encourage consideration 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.
- Encourage candidates to form a hypothesis that is directly related to the research question and is explained in terms of chemistry concepts, often at the molecular level (the hypothesis will no longer be a compulsory element from 2009 onwards).
- Candidates should be encouraged to consider repeat trials, calibration or generation of sufficient data to undertake graphical analysis, when designing procedures for Pl (b).
- 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 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.
- In November 2008 evidence for participation in the Group 4 Project by each candidate in the sample must be submitted with evidence of individual contribution (evidence need not be supplied from 2009 onwards).

- 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.

Instructions to Moderators

As in the last three 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 (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 and so on 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 the 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 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 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 involved which are independent and which are 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:

- 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 the maximum mark under 'complete not meaning perfect' 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 +/- 0.01 g 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 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."

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 18	19 - 27	28 - 30	31 - 33	34 - 36	37 - 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 27 G2's that were returned. 72% found that it was of a similar standard, compared with last year's paper, 20% felt that it was a little easier, and 8% thought that it was a little more difficult. All felt that the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by 63% and good by 33%. Only 4% felt that the coverage was poor. In addition, 52% felt that the clarity of wording on the paper was satisfactory and 48% considered that the wording was good. The presentation of the paper was considered satisfactory by 41% and good by 59%.

Overall, this paper appeared to be reasonably accessible. Some of the more general comments which emerged from the G2's suggested that the number of questions on organic chemistry and molecular shape was slightly more than usual. There also was a comment with regards to translation on the Spanish paper in relation to Question 17, which was considered at the Grade Award Meeting.

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 96.60% to 50.00%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.65 to 0.08 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 5

One respondent suggested that since the question asked for the number of orbitals in the n = 3 energy level of an atom, then students could be confused between answer A (3) and the correct answer which is actually D (9). Students should have a clear understanding of the difference between the idea of an orbital and that of a subshell. In the n = 3 energy level, there are 9 definite orbitals, based on the 3 subshells, s, p and d. This question in fact was deemed a good question for this reason and had a related discrimination index of 0.58.

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 molecular geometry and the Cl-I-Cl bond angle in the ICl_4^- ion, which tests application of VSEPR for a 6-negative charge centred species i.e. A.S. 14.1.1. In the guide, it is stated that examples such as PCl_5, SF_6 and XeF_4 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 5- and 6-negative charge centred species using VSEPR Theory. The main point here is that students should be able to deduce the shape of any 2-, 3-, 4-, 5- or 6- negative charge centred species using the principles of VSEPR. Another respondent stated that students would have been thrown by the inclusion of square pyramidal with a bond angle of 90^o, as this is not mentioned in the syllabus. This is incorrect as this is clearly part of A.S. 14.1.1. 6-negative charge centres would cover molecular geometries such as octahedral, square pyramidal and square planar.

Question 13

This question asked for the geometry of the bonds around an atom with sp^2 hybridization. One respondent suggested that use of the word bonds is not appropriate here, unless it is specified that all electrons are involved in the bonding. The correct answer from those listed here is the one which states that there are 3 bonds at 120^o, which would be the case in a species such as carbonate. If one examines the other answers, none of these cite the 120^o angle and hence cannot be considered. Perhaps the question might have been phrased alternatively. However in the context of the answers given we felt that it was very clear that the answer had to be 3 bonds at 120^o. If one of the answers gave 2 bonds at approximately 120^o (ideal value) then the comment may be valid (e.g. in the nitrite oxoanion, the ONO angle is 115^o involving 2 bonds, as there is one non-bonding pair of electrons present, and the overall hybridization around the central N is sp^2). However this was not the case in the choices given.

Question 14

One respondent stated that this question involving gases was a repeat of a question asked on a previous paper. It should be noted that occasionally some questions might in fact be repeated. Usually, this could be the case if a particular question was answered poorly in a previous year. Performance on this question was good with 88.32% stating the correct answer.

Question 15

In this question, the specific heat capacity of water was given as 2.0 J g^{-1} K^{-1}. One respondent claimed that this is incorrect as students would know its true value of 4.18 J g^{-1} K^{-1}. It should be noted that the value of 2.0 J g^{-1} K^{-1} is in fact correct for water in the **solid** phase as ice, and the state is clearly stated in the question.

Question 19

One respondent posed the question as to whether grain size actually referred to particle size. The use of this term was discussed in detail, and it was felt that the question should have been written with the term particle size, which is used in the guide in 7.2.3. However, we did feel that this did not have an impact on the ability of students to answer the question and the difficulty index was in fact 77.71%, although certainly use of the term grain may have been somewhat obscure for those students where English is their second language. In the context of the question however, it was very clear that this did in fact refer to particle size, as related to the concept of rates of chemical reactions.

Question 23

This question asked for which combination of $\Delta H_{\text{vaporization}}$ and boiling point is the result of intermolecular forces. One respondent suggested that the wording of this question is challenging to understand. 82.59% of candidates in fact got the correct answer, which is A: large $\Delta H_{\text{vaporization}}$ and high boiling point.

Question 28

In this question, candidates were told that an acid-base indicator has an associated pK_a value of 4.0, and were asked to identify from a list of four possible answers (2.0, 4.0, 8.0 and 12.0) at which pH would the indicator change colour. The answer here, B = 4.0 is unambiguous from the list of possible choices. The question had a related difficulty index of 66.03.

Question 38

Six respondents stated that elimination reactions are not listed on the syllabus and only those students who would have taken Option H would know what is meant by an elimination reaction. This is a valid comment, and it would have been better if one of the options was dehydration for example. This question was looked at carefully, and 74.95% of candidates in fact did get the correct answer, namely that benzene undergoes both combustion and substitution reactions, which they would know. Although, elimination reactions are not explicitly listed on the syllabus, we did feel that by intuitive deduction students may understand the basic idea of elimination (for example the elimination of water in an esterification condensation reaction) and hence since students would know that benzene does undergo both combustion and substitution, then they would clearly opt for these two choices. This in fact was reflected in student performance based on the difficulty index.

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 - 59	60 - 69	70 - 90

General comments

This paper identified the broad range of capabilities of candidates. Some candidates struggled with basic concepts and answers lacked precision and depth in terms of wording used and explanations given, which were often vague. At other schools candidates seemed unfamiliar with some of the subject material and left areas of the question paper blank. On the other hand, some other students demonstrated an excellent depth and understanding of the Higher Level material and the paper allowed a broad range of candidates the opportunity to demonstrate their knowledge and understanding.

Candidates must pay attention to the action verbs stated in the questions as well as to the number of marks allocated to each question and write their answers accordingly. Typically each mark requires a statement; thus a three-mark question that asks to deduce and explain the shape and bond angle of a species can not be answered in a couple of words. For quantitative questions, calculations must be shown clearly and these should be checked for accuracy, significant figures and units where appropriate. Similarly, candidates must read questions carefully and answer them as required – on occasions, only part questions were answered and it was not uncommon for the reasoning to be missing when it was asked for.

The 30 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper 54% felt that it was of a similar standard, 7% thought it a little easier, 39% considered it a little more difficult. 100% of respondents thought the level of difficulty was appropriate. Syllabus coverage was considered to be good by 40% and satisfactory by 60% of the respondents. Clarity of wording was considered good by 40%, satisfactory by 53% but poor by 7% of the respondents. The presentation of the paper was considered good by 50% and satisfactory by 50% of the respondents.

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

- Periodicity: explaining trends in ionization energy values
- Concepts of bonding: distinguishing between metallic, ionic and van der Waals' forces
- Complexes of d-block elements
- The application of VSEPR theory
- Definition of enthalpy change of formation and average bond enthalpy
- Enthalpy cycles
- Ligands and complexes

- Core inorganic chemistry
- The use of curly arrows in organic mechanisms

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

- Organic chemistry
- Chemical kinetics
- Equilibrium
- Mole calculations
- Kinetic energy of gases
- Bond enthalpy calculations

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

Section A

Question 1

This question was answered well by many candidates.

a) Most candidates successfully calculated the amount of barium sulfate, although here, as throughout the paper, a disappointing number confused significant figures with decimal places.

b) This was mostly done well.

c) Again, this was done well, although several omitted the units asked for or stated grams as the unit for molar mass.

d) The stronger candidates determined that potassium was the alkali metal involved. When candidates obtained an incorrect value based on atomic mass a number, Selenium was often stated as the alkali metal which showed poor understanding of what constitutes a Group 1 metal.

e) Those that did manage to determine the correct alkali metal were generally able to write the correct subsequent precipitation reaction. One common mistake, however, was citing KSO_4 as the formula of potassium sulfate, instead of K_2SO_4. State symbols in general were correctly identified. However, many attempts at the equation were disappointing, and included only one product instead of two, incorrect formulas, lack of balancing and wrong state symbols.

Question 2

a) Very few correct definitions of A_r were seen, most lacking a key feature such as "average" and "atom". In (ii), the explanation of the more abundant isotope was much better done, although some missed the point and explained their choice in terms of greater stability due to fewer neutrons.

b) This part was done poorly and attempts revealed both misreading of the questions and misunderstanding of the chemical principles. "Successive" was sometimes interpreted as meaning across a period. A number of candidates did not state that the reason why successive ionization energies increase is due to the fact that it is harder to remove an electron from an ion with increasing positive charge. In part (ii), although most had some idea about changes in IE when the second and tenth electrons are removed, few scored full marks as the explanations were missing.

c) Students were generally able to answer this part correctly with V^{2+} or V^{3+} but some did not indicate the correct electrons that would be lost when that ion forms. V^{5+} often appeared as the answer, while some gave ions that included oxygen.

Question 3

Able candidates had few problems with this question, but less able ones seemed not to be able to visualise the situation described.

a) Many overlooked the "same temperature" in the question and stated that methane molecules were smaller/lighter and so would move faster, which would have been a correct answer to the next part.

b) Some candidates mixed up the idea of mass with the size of the molecules.

c) Full marks were rare because few candidates referred to concepts normally associated with the collision theory in their explanation.

Question 4

a) In part (i), oxidation numbers appeared to be well understood and many candidates scored well although several errors were seen including forgetting to state the fact that elemental iodine has an oxidation number of 0. Positive oxidation numbers are still being written without the essential + sign (5 instead of +5), and Roman instead of Arabic numerals. In part (ii), both oxidation and reduction were very well understood in terms of the increase or decrease in oxidation number. The equation in part (iiii) often contained correct formulae but was either balanced incorrectly or contained electrons.

b) The main errors were to use an incorrect value (0.34) from the Data Booklet, to add the values (giving 0.67) and to interpret a negative value as indicating spontaneity.

Question 5

This was the most successful question for most candidates, with few making serious errors about the structural formula of the ester propyl ethanoate. Some structural formulae were drawn with "sticks" instead of hydrogen atoms and the alcohol was simply named as propanol instead of propan-1-ol or 1-propanol.

Section B

Question 6

This was by far the most common question chosen in Section B but with overall unsatisfactory chemical knowledge of the periodic trends in physical properties, structure and bonding.

a) Key concepts such as screening was rarely mentioned by candidates. Although many successfully explained the sulfur-oxygen comparison, few students were able to explain why sulfur has a lower first ionization energy than phosphorus, in terms of the greater repulsion associated with the fact that there are two electrons paired in one of the 3*p* orbitals of sulfur. As a result, candidates rarely scored full marks in this part.

b) This part was also disappointing, with many candidates confusing metallic bonding with ionic bonding. Most candidates had some partial ideas of the various types of bonding, but again clear descriptive answers were rare, and only the best students gave precise answers for Mg, Si and the non-metallic elements of period 3. Thus it was often not clear that forces between molecules were involved in the non-metals of period 3 elements, and few stated that the molecules of these elements were simple (in comparison with silicon).

c) Many answers referred correctly to d-orbitals but failed to link colour with splitting of the d-orbitals and electron transitions between split d orbitals. The formula of the Fe^{3+}/CN^{-} complex was nearly always wrong, with $Fe(CN)_3$ being a popular choice instead $[Fe(CN)_6]^{3-}$.

d) Most attempts at Lewis structures included lone pairs of electrons, although many impossible formulas appeared, often involving oxygen atoms with only one bond; it then became difficult to score marks in the second part and linking the structures to volatility proved troublesome for many candidates.

e) Answers to part (e) were very disappointing; apart from giving incorrect shapes, references to VSEPR theory were often inadequate and failed to refer to all bonded and lone electron pairs. Some described repulsion between atoms rather than electron pairs.

Question 7

This was the next most popular question but few candidates scored near full marks.

a) This part was often well attempted, with most candidates scoring at least one mark for the definition in (i); some included (albeit incorrectly) STP conditions, instead of standard conditions of 1 atm and 298 K. The enthalpy cycle in (ii) proved a challenge to many candidates; others tried to answer this question directly using Hess's Law often with incorrect final answers. Many started with an incorrectly balanced equation or ignored coefficients altogether.

b) The definition in (i) was rarely completely correct, with most omitting the gaseous state or failing to make clear what *average* referred to; the calculation in (ii) was better attempted than that in part (a) above, but some who had an idea of the method used wrong values from the Data Booklet or did the subtraction the wrong way round. Surprising a number of candidates used the bond enthalpy value for C=C rather than for the carbon carbon triple bond present in C_2H_2.

c) Most candidates understood the term *molecularity* and S_N1 and S_N2, but some thought (incorrectly) that the 2 refers to a second order reaction. The mechanism in (ii) was generally attempted satisfactorily, but with several familiar errors appearing – imprecisely drawn arrows, incorrect or missing charges, and bonding shown as –HO rather than –OH. With respect to the C-X trend in bond enthalpies (X = a halogen), the better candidates were able to cite the correct trend, but few linked this to the increase in radius, which reinforces the earlier comment with respect to weak understanding of periodicity with regards to physical properties. However, the rate in parts (iii) and (iv) was well understood.

d) In (i), most candidates showed their understanding of ^{1}H NMR spectroscopy, but a common error in (ii) was to choose the wavenumber range for carboxylic acids instead of that for alcohols.

Question 8

This was not a popular question.

a) This was typically well answered overall, which showed solid understanding of chemical kinetics. However, it also revealed several misconceptions, including the careless use of "*K or k = ...*" instead of the rate expression. Although the question clearly states that 'the rate is independent of the bromine concentration', some included $[Br_2]$ in one or more of the expressions in (ii), while the predictions often ignored bromine. Rate expressions, half-life and catalysts were very well understood in parts (iii) and (iv) and better answered.

b) The writing of the equation in (ii) was disappointing – often it was unbalanced, or worse, involved substances (such as oxygen) that were not stated in the question, and some were not able to cite the correct units. Part (ii) was better attempted, with most candidates being able to apply Le Chatelier's principle to identify the high temperature and low pressure conditions. The most common mistake was the failure to mention the gaseous state when discussing the effect of low pressure. In part (iv), the better candidates were able to determine the value of K_c. In general, both chemical kinetics and equilibrium questions were well understood.

Question 9

This question was not a popular one overall, but the performance in the question in general was good.

a) Most candidates were able to write the equation for the reaction of ammonia with hydrochloric acid, although with some quantitative answers spoiled by arithmetic errors in the calculations. Most were also able to calculate the amount of HCl and NH_3 that react and the mass of NH_3 in the solution.

b) The sketch graph in part (b) was usually partly correct, although some candidates chose to use graph paper, which is not necessary when the term *sketch* is used in the question. A common mistake included candidates having the curve starting at pH = 13 instead of starting at pH lower than 13 as ammonia is a weak base. Inevitably some candidates started at a low pH, while many showed a central part that was a long way from vertical. Several candidates overlooked the instruction to explain the shape of the curve, and those that did often did so poorly. In (ii), the most common mistake involved students citing an incorrect indicator.

c) All but the most able candidates scored few marks in part (c); buffer composition was inadequately described as many students had great difficulty stating that an acidic buffer solution has a weak acid and its salt as its composition. The explanations and equations in (iii) were often nowhere near correct. The K_b expression in (iv) was sometimes inverted and often included $[H_2O]$. However, most had no major difficulty getting the pH = 9.25 in part (v).

Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding mark schemes to assist candidates with examination preparation. In the paper this year, there were questions similar to ones in the past (for example on periodicity, structure and bonding or buffers), and yet key parts of the answers were not always evident on papers.
- Candidates must pay attention to the action verb, note the number of marks allocated to a question and correlate this to their response to ensure it is sufficiently detailed.
- Candidates should practice questions from past papers and refer to their mark schemes.
- Teachers should emphasize the importance of clearly setting out calculations as well as significant figures in calculations, distinguish them from decimal places and stress units.
- Candidates should learn precise definitions, particularly the key words and phrases.
- When drawing organic structures, candidates should always include hydrogen atoms and not just "sticks".
- Candidates must read questions correctly and completely and answer them as required.

Higher level paper three

Component grade boundaries

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

General comments

The range of marks awarded was very wide; the best candidates showed a thorough command of the material and a high level of preparation, and this session it was pleasing to see more candidates who seemed very familiar with the material in the options than those who scored very poorly. Hardly any candidates attempted more than two options.

Teachers' impressions of this paper were conveyed by the 25 G2 forms that were returned. In comparison with last year's paper, two-thirds thought this year's paper to be of a similar standard, with most of the remainder considering it more difficult rather than easier. Most respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by over half and good by most of the rest. Clarity of wording and presentation of the paper was considered good by over half 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 B	The distinction between the modes of action of mild and strong analgesics
Option C	The working of the sodium-potassium pump
Option D	The inability to distinguish between the different methods used in primary, secondary and tertiary water treatment
Option E	The technique of froth flotation and the purification of silicon
Option F	The inability to write correct nuclear equations
Option G	The significance of ^{13}C in mass spectra
Option H	The drawing of stereoisomer structures without using appropriate bond angles and 3-D representations

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.

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

Option B – Medicines and Drugs

B1 Answers to (a) were invariably correct, but the equations in (b) were less well done; although most chose the correct products the equation for $Mg(OH)_2$ was often incorrectly balanced. In (c), the majority correctly chose $Al(OH)_3$ and were able to give a satisfactory reason.

B2 Part (a) was attempted by almost all candidates, although few scored full marks; most managed no more than the distinction between the brain and the source of the pain. The expected formula in (b)(i) was CH_3CO, but CH_3COO and CH_3COOH were just as common. The hydroxyl group was most commonly identified in (b)(ii), with the commonest errors being amine instead of amide and carbonyl or carboxyl instead of carboxylic acid. Most candidates scored both marks in (b)(iii) for identifying ibuprofen and its chiral nature.

B3 Only the best candidates completed the table correctly in part (a); common errors were NO or NO_2, propene and an incorrect attempt at the systematic name for halothane. Most candidates correctly worked out the mole ratio in (b)(i), although some gave the numbers as fractions or wrote 1:2:3 without indicating which gases the numbers referred to. The calculation of the oxygen percentage was often correct, sometimes because the error carried forward principle was applied.

B4 Most candidates scored well in this question.

Option C - Human Biochemistry

C1 In (a), although many all-correct solutions to the determination of calorific value were seen, many errors were also found, especially the use of 5 or 405 instead of 400 for the symbol *m* in the expression for heat produced; problems with incorrect units and failure to produce a final answer in kJ per 100 g were also noted. In part (b), many correct answers were seen, although predictably some candidates used the A_r instead of the M_r for iodine.

C2 Most candidates scored well in this question, especially in parts (a) and (c), although there were a surprising number of errors in (b), with many structures not including the correct number of carbon, oxygen or hydrogen atoms.

C3 Again, better candidates scored well in this question, especially in part (a). Common errors were to include vitamin D in part (b) and the omission of any reference to calcium uptake in part (c).

C4 Very few candidates succeeded in this question; in (a), many answers included fewer than the specified three of each letter, and others appeared to be random guesses. In (b), a surprising number did not choose thymine as the base, and very few identified the correct sites for hydrogen bonding in either base.

C5 Very few candidates scored full marks in this question. Some very detailed answers managed to score 3 or 4 points, but many candidates seemed completely unfamiliar with the sodium-potassium pump.

Option D - Environmental Chemistry

D1 Most candidates scored some marks in this question, but equations often showed incorrect products or were incorrectly balanced, and few included both carbon monoxide and hydrocarbons in part (a).

D2 In (a), most candidates chose UV light, although few could identify two correct effects; thankfully there were fewer references to melting of ice caps than in previous papers. In (b), quite a number of attempts were concerned with ozone depletion caused by pollutants, rather than by natural processes.

D3 Although this topic has been frequently tested, the completion of the table was usually poorly done, with very few high scores. The use of filtration or screening as the primary method and the removal of organic matter in secondary treatment were usually the best known.

D4 In part (a), most candidates attempted Lewis structures, although often with too few or too many lone pairs of electrons, and the ozone structure often appeared with a dashed line representing delocalization; most managed to suggest an appropriate bond enthalpy value and justify it. In (b), a surprising number of candidates could not identify ultraviolet as the radiation absorbed by a sunscreen, and few recognised the significance of conjugated double bonds in the structure of vitamin A.

D5 Answers to this question seemed to be polarized between full marks and hardly any marks.

Option E - Chemical Industries

E1 Most candidates had little idea of froth flotation, although some were able to show their knowledge and achieve full marks in part (a). Attempts at (b) and (c) sometimes achieved full marks, although weaker candidates struggled to produce equations that contained either the correct products or were correctly balanced.

E2 In (a), most candidates knew of cryolite and its purpose, although the equation in (a)(ii) was often incorrectly balanced. In (b), most candidates scored 1 or 2 marks, the commonest error being to state that aluminium was lighter than copper, with no reference to lower density.

E3 In-depth knowledge of the extraction of silicon was necessary to score high marks in this question, which only a few candidates could manage. Most weaker candidates were able to score 2 or 3 marks (for descriptions rather than for equations), and there were few who wrote about the use of silicon as a semiconductor.

E4 A pleasing number of candidates were able to list all three stages in part (a), but few knew the use of organic peroxides as a source of RO• radicals in (b). Most equations in (c) did not score the mark, and those that came close often had the radical symbol next to R or O.

Option F - Fuels and Energy

F1 The completion of the table in part (a) was usually well done, with a few candidates being penalised for the use of integer M_r values. There were many correct equations in (b), although the explanation in (b)(ii) was less often correct.

F2 The equation in part (a) was rarely correct, with many products including C and O_2. Part (b) was better answered, with most candidates scoring in both (i) and (ii).

F3 In part (a), a surprising number of candidates did not refer to the loss in mass that occurs in nuclear reactions, although the second mark, for the mass-to-energy conversion was usually scored. The element formed in (b)(i) was usually correctly identified, and the half-life calculation was usually correct. The nuclear equation in (c) caused problems for most candidates, and a disappointing number used the alpha symbol instead of He.

F4 There were several blanks in parts (a) and (b), but the most disappointing aspect of many candidates' answers was the appearance of A and Z values in the wrong order. In part (b), loss of alpha or beta particles was better known than positron loss or electron capture, but some better candidates did well here. The calculation in part (c) was well attempted, with many scoring full marks.

Option G – Modern Analytical Chemistry

G1 Most candidates scored 2 or 3 marks here, with the failure of oxygen to absorb infra-r ed radiation being the least well known.

G2 Most candidates satisfactorily explained the significance of the numbers and areas under the peaks in an ^{1}H NMR spectrum in part (a), but the reference to chemical shift values often went no further than quoting formulae from the Data Booklet. Parts (b) and (c) were well answered, with better candidates scoring full marks or losing just 1 mark in (b)(i) for not clearly stating that the CH_3 and CH_2 groups were adjacent.

G3 Parts (a) and (b) were generally well answered, the most common error being to omit the positive charges in (a)(ii). In part (c), although some candidates identified ^{13}C as the origin of the extra peak, very few knew its significance in identifying the number of carbon atoms in the molecule.

Option H – Further Organic Chemistry

H1 Answers to part (a) were disappointing, as although most candidates used the correct structural formula, many did not show the correct relationships within each pair of isomers; many structures with angles of 90° appeared for both geometrical and optical isomers. Parts (b) and (c) were well answered, the most common omission being the lack of rotation for a racemic mixture in (c). Part (c) was very well done, with few errors, mostly the choice of the 1,2- structure.

H2 The use of curly arrows in organic reaction mechanisms has improved in recent years, and many answers scored 3 or 4 marks in part (a); common errors were to omit the charge on the carbocation and to draw the arrow from I instead of from the bond when showing the I–Cl bond fission. In part (b), many candidates scored 3 marks, with some omitting the reference to the number of electron-releasing groups.

H3 In (a), most candidates identified the mechanism as S_N2, but only the better ones scored full marks in (b); quite a number stated the wrong effect on the rate and so could not score for an explanation. Answers to part (c) were disappointing, with few candidates scoring more than 1 point.

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 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, as well as paying attention to units and significant figures.
- When writing organic structures, always check that the total numbers of each atom are correct and that each carbon atom has four bonds.
- When representing 3-D structures, practise using wedge and taper bonds to indicate groups above and below the plane of the 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, 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 two or another specified number of answers.
- Avoid the use of everyday or journalistic language, and use correct scientific terms, such as "of lower density" instead of "lighter", and radiation "absorbed" instead of "blocked".
- In calculations involving A_r values obtained from the Data Booklet, quote the values to two decimal places where given.

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 - 14	15 - 21	22 - 23	24 - 24	25 - 26	27 - 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 26 G2's that were returned. 64% found that it was of a similar standard, compared with last year's paper, 18% felt that it was a little easier, 13% thought that it was a little more difficult and just 5% viewed the paper as much easier. 100% felt that the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by 46% and good by 54%. In addition, 42% felt that the clarity of wording on the paper was satisfactory and 54% felt that if was good. 4% were of the opinion that the wording was poor on the paper as a whole. The presentation of the paper was considered satisfactory by 38% and good by 62%.

There were very few general or specific comments on the paper overall and the impression was that it was well received. There was one translation comment on the Spanish paper, which referred to Question 12, which used the term triangular instead of the more common term trigonal used in the guide.

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 91.34% to 35.21%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.73 to 0.17 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 17

One respondent suggested that since + and – signs are used in the question for $\Delta H^{\ominus}$, then answers C. and D. also should be written as +66 and +123. The examiners at the meeting agreed but felt that this shouldn't have prevented students from arriving at the correct response.

Question 19

This question asked which statement is correct about the rate expression for a chemical reaction, from a list of four possible choices. Two respondents stated that the term rate expression is not on the SL syllabus. This is a valid comment and it would have been better if the term rate of a chemical reaction would have been used, as rate expression is involved only at HL and in actual fact is not the correct wording in the context of this particular question. It was not felt however that this mislead the students in terms of the overall correct answer, namely, D., i.e. that the rate can be determined by measuring the change in concentration of a reactant or product over time, and 81.39% of candidates did cite the correct answer.

Question 20

As at HL one respondent stated that the term grain size is obscure. The use of this term was discussed in detail, and it was felt that the question at SL should also have been written with the term particle size, which is used in the guide in 7.2.3. However, similarly at HL, it was thought that this did not have an impact on the ability of students to answer the question and the difficulty index was 78.64%, although use of the term grain may have been somewhat obscure for those students where English is their second language, as suggested by the respondent. In the context of the question however, it was very clear that this did in fact refer to particle size, as related to the concept of rates of chemical reactions.

Question 23

This question asked for candidates to state which of the following acids, HCl, HNO_3 and H_2SO_4 are strong acids. One respondent, suggested that this question was too simplistic. Interestingly, only 62.34% gave the correct answer, namely D, that all three are strong acids. One respondent also suggested that the states should have been included in this question. It was thought that in the context of this question, since it was clear that acids were involved, then it would not be necessary to specify the actual states.

Question 28

In this question, candidates were asked to identify the formula of an aldehyde. One respondent also stated that this question was too simplistic. The question itself had a difficulty index of 70.13%, and the question was only the 16^{th} easiest question on the entire paper.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 19	20 - 25	26 - 31	32 - 37	38 - 50

General comments

An accessible paper which was well answered in general although there were variations in performance.

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

- Definitions of *relative atomic mass* and *ionisation energy*
- Significant figures
- Explaining differences in electronegativity between elements
- Drawing structural formula including the lone pairs
- Predicting bond angles
- Intermolecular bonding
- Multi-step stoichiometric calculations
- Electrolysis

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

- Simple stoichiometric problems
- Oxidation numbers
- Aspects of organic chemistry
- Calculation of simple pH values from concentration values
- Explanation of trends in ionization energy
- Concept of addition polymerization
- Meaning of changes in entropy and Gibbs free energy
- Equilibrium constants
- Le Chatelier's Principle in relation to the Contact Process
- Catalysis

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

Section A

Question 1

(a) This question was generally very well done. Candidates managed the calculation well. Some candidates did not display their working. As a consequence, when the answer was wrong no marks could be awarded. Candidates also did not always use the correct number of significant figures.

(b) This question was generally very well done and most realised the answer was the same as in part a.

(c) Candidates were able to calculate the molar mass of the alkali metal sulfate but often had the incorrect units. Rather than g mol^{-1} , g or mol g^{-1} were often used or no unit at all.

(d) The most common error here involved the lack of recognition of an alkali metal (Group I metal). As a result candidates often did not divide their answer by 2 and suggested a group 2 metal or Rubidium.

(e) Most common errors involved the inclusion of water in the equation, K_2SO_4(s) rather than K_2SO_4(aq), and candidates not knowing the valency of the group I metals, e.g. $RbSO_4$ and KSO_4 rather than K_2SO_4.

Question 2

a) This question was very poorly answered. This definition of *relative atomic mass* was not well known. Common omissions included no comparison to ^{12}C or the word 'average' omitted. Some students also incorrectly discussed the A_r in terms of average mass of an element, instead of an atom.

b) Candidates managed this well overall and correctly stated the more abundant isotope. Some candidates used a calculation to support their answer although this was not necessary to gain the mark.

c) Although most candidates scored reasonably well in this question they did struggle to articulate their answers. Chemical expression was not always used accurately. When explaining the similarity with the chemical properties, candidates often failed to express the importance of the valence electrons and just said they had the same number of protons and electrons.

Question 3

(a) (i) This question was answered satisfactorily by most candidates. However, many candidates lost marks for significant figures as they often provided the value: 0.001 / 1×10^{-3} rather than 0.0010 or 1.0×10^{-3}. Most then correctly calculated the pH = 3.

(ii) Candidates could easily achieve the first two marking points regarding identifying and defining the strong or weak acid as they appeared to have a clear understanding of the fact that HCl is a strong acid and CH_3COOH is a weak acid. Candidates struggled to adequately express the similarity in the pH despite the difference in concentration of the strong and weak acid, few stated the fact that only one molecule in 100 dissociates in ethanoic acid so $[H^+]$ is 1/100.

(b) This part was well answered overall by candidates who were able to cite a method, other than pH, which could be used to distinguish between solutions of a strong acid and a weak acid of the same concentration, often using electrical conductivity. Very few were able to discuss correctly the method of titration curves, namely that a strong acid and a strong base will have an end-point at pH 7 and that a weak acid and a strong base will have an end-point at pH greater than 7. Other students did mention the fact that a reaction could be carried out with a metal, but usually failed to state the metal in question i.e. magnesium etc., which yielded no points. Other unacceptable answers included the use of universal indicator, methyl orange indicator or phenolphthalein indicator. These indicators would not distinguish between strong and weak acids.

Question 4

(a) (i) This was generally well understood but few candidates gained 2 marks because they missed the oxidation number of I_2 = 0, and also neglected to include the + sign for the oxidation number of iodine in IO_3^-.

(ii) Candidates managed to answer this part very well, either by using oxidation numbers or by electron transfer. A few did not give reasons and therefore lost both marks.

(b) In general this part was very problematic for candidates. Very few gave an appropriate electrolyte such as copper(II) sulfate, and sometimes the reduction half-reaction of Cu^{2+} at the cathode was stated incorrectly (usually this involved candidates either giving an incorrect Cu ion, or giving an oxidation half-reaction), not stating that the object was the cathode or that the anode was made of copper or an inert metal/carbon.

Section B

Question 5

This was the least popular question of the essays but was generally well answered.

(a) (i) Most candidates were able to write the correct equation for the reaction between ethene and hydrogen.

(ii) Candidates answered this question well and most were able to state that the products would be more stable but lower in energy.

(iii) Candidates often did not refer to the bonds in the molecules to explain why the reaction was exothermic. Candidates tried to use bond enthalpies to explain the exothermic nature of the reaction. Only the better candidates stated that bond breaking is endothermic and bond making is exothermic and the fact that stronger bonds in the product would mean the process is exothermic overall.

(b) (i) This was well answered and entropy was well understood. However as usual, many students omitted to mention the fact that it is the gaseous phase that is involved in relation to the decrease in entropy.

(ii) This was often well answered and candidates were able to predict and explain the spontaneity of the reaction with an increase in temperature.

(c) (i) Most candidates could give all 3 names of the organic molecules but when they wrote the equation they did not include water as a product and hence lost a mark as a result. Also, some students did not give the structural formula for ethyl ethanoate which was asked for. The most difficult part for the candidates was correctly identifying the reaction as oxidation with many suggesting hydrolysis instead.

(ii) That esters are used for flavouring was well known.

(iii) Many correctly identified chloroethene and drew it.

(iv) Most correctly identified the reaction as addition and not condensation, however some struggled to explain why.

Question 6

This was a popular question and it was perceived by candidates as the most accessible question; however, the candidates who did attempt it did not always answer it well.

(a) (i) This question was very poorly answered. The definition of *ionization energy* was not well known and the definition of ionization energy was often only partially described. The most common omission from the definition was the gaseous phase.

(ii) This equation was not well known. Common errors included:
$2Li + H_2O \rightarrow Li_2O + H_2$ and $Li + H_2O \rightarrow LiO + H_2$

(iii) Nearly all students stated the fact that ionization energy decreases down a group and most stated the fact that the valence electrons are further away from the nucleus. Candidates found it hard to express the third marking point regarding the shielding effect and decreasing effective nuclear charge.

(iv) Candidates often defined the term *electronegativity* rather than answering the question which asked for an explanation as to why the electronegativity of P is greater than Al. Only the better candidates stated the fact that the radius of P is smaller. Virtually no student mentioned the higher effective nuclear charge of P. Students often talked about attraction for electrons as opposed to electron pair or bonding electrons.

(v) Candidates were requested to explain by reference to both atomic structure and electron arrangements, why the two ionic radii of silicon differ. Candidates managed to answer this question satisfactorily but they often omitted explaining how the two ions Si^{4+} and Si^{4-} are formed, or the fact that they have the same nuclear charge. Some did correctly mention the electron configurations of the two species.

(b) (i) Some candidates tried to explain the difference in boiling points from PH_3 to SbH_3 in terms of electronegativity differences rather than intermolecular forces. Those that did identify increasing Van der Waal's forces as a factor didn't give comprehensible answers.

(ii) Hydrogen bonding **between** the molecules was identified correctly by some and both dispersion forces and hydrogen bonding were partially understood. However there were some very weak answers which showed that this concept is still not well understood by many students.

(c) Candidates often tackled this question by drawing Lewis diagrams. However, many did not seem to know VSEPR theory well and diagrams were often not drawn correctly because the lone pairs were omitted or the few who did reasonably well made the mistake of considering that the lone pairs of electrons were repelling the hydrogen atoms instead of the bonding pairs, leading to incorrect shapes. Furthermore, only the odd student discussed the angular deviations in terms of LP-LP, LP-BP and BP-BP interactions.

Question 7

This was a very popular question and also well answered overall.

(a) (i) This question was based on the Contact process, and nearly all the students were able to write an equilibrium constant expression for the reaction.

(ii) In addition, both the effect of pressure and temperature was well understood, although candidates did not always gain the explanation marks available. They described more moles on the left rather than more gaseous moles for example.

(iii) Some candidates clearly were not familiar with the conditions used commercially in the Contact process and hence found if difficult to justify their use.

(iv) The vanadium(V) oxide catalyst was correctly identified by some but others lost marks for saying vanadium or vanadium oxide.

(b) The graph showing the distribution of molecular energies was usually well answered, although some students cited incorrect labels for the axes. In contrast, the definition of activation energy was answered correctly by nearly all students.

The fact that the question asked about an endothermic reaction seemed to confuse some candidates and they tried to explain the effect on the extent of the reaction. Although almost all knew that the rate would increase.

(c) (i) and (ii) were generally well answered but some candidates gave a line instead of a curve for the variation of concentration of acid versus time, or had concentration increasing to a maximum. Most who correctly drew the graph were able to describe the decreasing slope of the line.

(iii) Candidates correctly identified a decrease in rate but often did not state fewer collisions per unit time.

Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding mark schemes to assist candidates with examination preparation.
- Teachers should emphasise the importance and use of significant figures and units.
- Teachers should emphasis the importance of clearly set out calculations
- Candidates should learn definitions accurately
- Candidates should practice drawing Lewis structures, including the lone pairs
- Candidates need to be aware to of the importance of action verbs.
- Candidates should check calculations to avoid the loss of marks due to careless calculation errors.
- Teachers should encourage candidates to note the number of marks allocated to a question and correlate this to their response to ensure it is sufficiently detailed.
- Candidates should read questions carefully to avoid errors in units.
- Candidates should read questions carefully to avoid missing parts of the question.
- Teachers should emphasize the importance of clearly set out calculations.
- Candidates should, where appropriate, illustrate their answers with simple, neat and well-labelled diagrams.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 16	17 - 20	21 - 25	26 - 29	30 - 40

General comments

This paper identified the 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 standard level options.

The 21 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper 61% felt that it was of a similar standard, 6% thought it a little easier, 28% considered it a little more difficult. 95% of respondents thought the level of difficulty was appropriate. Clarity of wording was considered good by 57% and satisfactory by 38% of the respondents. The presentation of the paper was considered good by 71% and satisfactory by 29% of the respondents.

This was generally a straightforward paper with easily accessible marks. Schools where most or all the candidates answered the same two options achieved better results. The majority of the candidates knew the subject material well. Most candidates seemed able to complete the paper in the space provided.

However, there were some schools where candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank. Answers lacked precision in terms of the wording used and explanations were often vague. From one school candidates only answered one rather than two options.

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:

- S_N1 and S_N2 mechanisms
- Understanding the finger print region of IR spectra
- Equilibrium nature of the pH of pure water
- Role of alginates in antacids
- Identifying and naming functional groups present in drugs and other organic molecules
- Food groups
- Importance of the ozone layer
- Waste water treatment
- Extraction of lead by the floatation method
- Relating the properties of metals to their uses

- Understanding the $E = mc^2$ equation
- Behaviour of alpha and beta particles.

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

The areas which seemed well understood were:

- Basic IR spectra
- Basic ^{1}H NMR spectra and concepts
- Calculation of pH
- Placebo effect
- Solubility and function of vitamins
- Combustion reactions

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

Option A-Higher physical organic chemistry

This was one of the least popular options and candidates struggled with many of the questions.

Question A1

(a) Many candidates were able to deduce the structure of the halogenoalkane and classify it as secondary. However, candidates struggled to explain why the halogenoalkane was secondary, often using inaccurate chemical language.

(b) Candidates were able to describe the mechanism as a nucleophilic substitution reaction but often incorrectly classified it as second order reaction not recognising that the 2 referred to the molecularity of the mechanism. Some of the weaker students tried to write equilibrium law expressions rather than a rate expression.

(c) Weaker candidates struggled to draw the intermediate formed in an S_N1 reaction and bonds were not correctly linked within the structure drawn.

Question A2

(a) Many candidates correctly identified the bonds but did not often link them to the corresponding IR absorptions.

(b) Very few students were able to state the finger print region.

(c) Students found it difficult to articulate the molecular ion.

(d) Candidates often were able to write a relevant formula but omitted the charge on the fragment formed.

(e) Candidates managed this reasonably well identifying the number and ratio of ^{1}H environments correctly. Stronger candidates drew the structure of methylpropan-2-ol correctly.

Question A3

(a) Most candidates were able to state the expression for the ionic product of water, K_w. Weaker candidates stated the equilibrium law expression or wrote K_w = $[OH^-]$ + $[H_3O^+]$.

(b) Candidates were able to calculate the pH of water well.

(c) The most common error involved candidates stating that at this temperature water is slightly acidic, missing the point that this temperature pure water is neutral because $[OH^-] = [H_3O^+]$.

Option B-Medicines and drugs

Once again this was a very popular option, with candidates having reasonable foundations.

Question B1

(a) Surprisingly some candidates struggled with the purpose of the necessity to make structural modifications to a drug at the research stage. Few candidates referred to the need to minimize the possible side-effects and some responses were vague and lacked chemical substance.

(b) The LD_{50} test was well answered, although some did not state that this is the dose needed to *kill* 50% of the animal population tested. If *lethal* was given in the response, credit was given.

(c) The placebo effect was generally well known and explained by candidates.

Question B2

(a) Candidates were able to identify HCl as the liquid responsible for the low pH of the stomach.

(b) Equations were written correctly with the main error involved failing to balance the equation with the $Mg(OH)_2$.

(c) A common error involved candidates stating that $Al(OH)_3$ neutralizes 3 mol of H^+, as opposed to 0.03 mol. Other candidates incorrectly referred to the molar mass of the antacids.

(d) Few candidates stated that alginates provide a neutralizing layer on top of the stomach content. Candidates confused alginates with antifoaming agents and often suggested that alginates prevented flatulence.

Question B3

(a) Some candidates were confused between mild and strong analgesics and found it difficult to describe the effect of strong analgesics.

(b) Some candidates made the mistake of stating that CH_3CO_2 as the formula of the group that replaces one hydrogen in a molecule of salicylic acid, instead of CH_3CO. Also, candidates stated the name rather than the formula of the group required. Candidates often included the amine rather than the amide in paracetamol and in this part of the question wrote the formula rather than the name of the functional group. Chirality appeared to be well understood by most candidates.

Option C - Human Biochemistry

Once again this was a very popular option, with candidates having reasonable foundations.

Question C1

(a) Only the better students were able to determine the calorific value of the food product fully. Very few got the value of 1565 kJ per 100 g, although a significant number of candidates calculated 78.2496 kJ, in the penultimate step. Most common errors involved conversion of units, significant figures and determination per 100 g.

(b) Surprisingly this was not well done. Candidates cited milk, fish, meat, fruit and vegetables as the main food groups.

(c) The addition reaction was commonly correctly answered. Some of the weaker candidates referred to the reaction as a saturation reaction. The most common error made by candidates when determining the number of double bonds was using the atomic mass of an iodine atom rather than the molecular mass of the diatomic iodine.

Question C2

(a) Most candidates were able to identify the ether bond as the oxygen-containing link between the two rings in the sucrose structure. Common errors included stating it was the ester link or oxide link.

(b) This was well answered by most candidates. Common errors by candidates included flipping the OH and H on the α and β faces. CHO bonds were also seen on papers. Teachers should stress the importance of correct valency in organic and biochemical structures, with respect to carbon, oxygen and hydrogen.

(d) The empirical formula of a monosaccharide was well known.

Question C3

(a) This was well answered by candidates.

(b) It was agreed that standard level candidates are not required to be familiar with the word *primary* alcohols. Candidates' results for this question were carefully analysed to ensure candidates were not disadvantage in any way by this question.

(c) This was well answered by candidates.

Option D-Environmental chemistry

This was the most popular option selected by candidates. Performance varied significantly by candidates. While some candidates had been well prepared for this option, others tended to use journalistic type answers which lacked chemistry.

Question D1

a) Many candidates identified carbon monoxide as a pollutant reduced by the recirculation of exhaust gases but struggled to identify unburnt hydrocarbons. Many incorrectly stated SO_2 or NO_x as the pollutants reduced. In addition, very few candidates were able to state that a Pt or Pd or Rh catalyst is used in the catalytic converter. Many candidates were able to write the equation for the reaction that can take place in the catalytic converter.

b) Many candidates were able to write the relevant equation with the most common error involving the lack of balancing the relevant equation.

Question D2

a) Ozone was generally identified well. However, the effects from the decrease in ozone concentration tended to be vague. General responses such as sunburn and problems with eyes were not specific enough. Other unacceptable responses included global warming and melting ice caps.

b) Only the better candidates wrote the equations correctly.

c) CFCs were often stated correctly but some candidates incorrectly included HCFC. Fewer candidates included NO_x and there source.

Question D3

Candidates struggled with completing this table. Flocculation was a common error as a method in the primary stage. Many candidates struggled to identify the substances used in the tertiary stage *i.e*. hydrogen sulfide, aluminium sulfate *etc*… Vague answers such as ions and alumimium/calcium were stated. In addition, in the secondary stage, some candidates stated that oxygenation and bacteria is the method used, which is basically an attempt to replicate the information in the question, which has oxygen and bacteria stated as the substances used. The correct answer of course is aeration.

Option E-Chemical industries

Very few candidates chose this option and those who did, often did not perform very well. Answers lacked depth and understanding.

Question E1

a) Candidates found it difficult to recall the process of flotation. Fundamentals and the important features of the process were not known.

b) Most candidates were able to write the relevant equation for the roasting of lead(II) sulfide but often omitted to balance the equation. Fertilisers were often identified incorrectly as a substance that can be manufactured from the sulfur dioxide rather than sulfuric acid.

c) Again equations were not well known and/or balance for the formation of lead in the blast furnace. Reduction was identified consistently correctly for the type of reaction that occurs to lead(II) oxide in the blast furnace.

Question E2

a) The process of the extraction of aluminium was better known by candidates. Most candidates were able to explain that it was the reactivity of aluminium that made it unsuitable for its extraction using a blast furnace.

b) The purpose and use of cryolite was well known. The reaction at the anode (positive) electrode was not well known, neither was the use of the carbon electrodes.

c) Candidates found it hard to relate the properties of the metals to their uses.

Question E3

Candidates did not know the details for hydrocracking. The use of hydrogen, the identification of high pressure and a catalyst were often missed. The structures of the molecules formed were often omitted or incorrectly identified.

Option F-Fuels and energy

This was another highly popular option.

Question F1

a) This was well answered, with most candidates getting the correct calorific values of 32.8 and 55.5. Candidates, however, should use the precise figures of Ar when calculating the Mr values. Some candidates used 12 rather than 12.01 or 1 rather than 1.01.

b) Candidates competently wrote the relevant chemical equation for the complete combustion of methane. However, candidates were not as able to explain why the combustion of methane was exothermic. They were unable to explain the exothermic nature of the reaction with respect to bond breaking and forming.

Question F2

a) The correct equation of carbon reacting with water to form carbon monoxide and hydrogen was not always written. Common mistakes here included candidates writing water, methane, oxygen gas or even carbon dioxide as a by-product.

b) Very few candidates stated that synthesis gas does not contain sulfur or that no soot is produced. Various vague answers were seen by examiners. In (ii), only the better candidates were able to state that the main disadvantage of converting coal to synthesis gas is the cost of the energy use.

Question F3

a) Very few candidates were able to explain the relevance of $E = mc^2$ to fission and fusion. The mass defect and that mass was converted to energy was not understood by candidates.

b) In most instances candidates were able to deduce the correct symbol Po, mass number and atomic number form the information provided. Common errors included writing Bi or even Pb as the answers. Half-life was well understood and used in part (ii).

c) Candidates struggled with all parts of this question. The equation for Li and a proton was poorly done. Candidates even struggled to write the atomic numbers and mass numbers in the correct position on the symbols. The comparative table of alpha and beta particles was not well completed. Candidates especially were unable to recall the penetrating power of the different particles.

Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding markschemes to assist candidates with examination preparation.

- Teachers should ensure that definitions covered in the assessment statements for each option should be well known by candidates.
- Teachers should emphasis the importance of clearly set out calculations.
- Significant figures should be considered in all calculation type questions.
- Candidates should read questions carefully to avoid errors in units.
- Candidates should be given guidance as to the level of depth expected in responses to questions. Journalistic answers to questions at this level will not suffice.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Teacher should encourage candidates to note the number of marks allocated to a question and correlate this to their response to ensure it is sufficiently detailed.
- Candidates should read questions carefully to avoid missing parts of the question.
- Chemical equations should be given wherever possible to support the processes discussed in options. Candidates should practice writing balanced equations.
- Organic mechanisms should be clearly described.
- Strongly encourage candidates to answer questions ***only*** on the options they have studied.
- Candidates need to be aware to of the importance of ***action verbs***. Candidates must know the meaning of the different actions verbs that appear in the assessment statements and in the examination papers.
- Advise candidates to exercise some caution when opting for the often perceived as “easier” options (Medicines and Drugs, Environmental Chemistry), unless fully prepared in terms of their chemistry.