CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 18	19 - 35	36 - 48	49 - 58	59 - 69	70 - 79	80 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 33	34 - 47	48 - 58	59 - 69	70 - 79	80 - 100

Higher and standard level internal assessment

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 - 48

The range and suitability of the work submitted

Once again the November session evidenced a good number of schools who submitted challenging work which reinforced learning and provided a suitable opportunity for assessment. This was particularly heartening since it was the first November session in which the current Internal Assessment framework applied and a significant majority of schools had made the transition smoothly. Only a small number proportion of schools did not undertake a suitable practical scheme of work and were failed to appropriately address the assessment criteria.

Overall the standard of students work appeared similar to previous November sessions, which was on the whole satisfactory with number of examples of very good or excellent work presented. One issue that remained a serious concern with a small number of schools was that the work of some candidates was clearly guided by teachers, fellow candidates or unreferenced sources to a level well beyond the instructions evidenced. It was unfortunately not uncommon in these schools for all candidates to choose exactly the same variables, carry out an identical procedure or follow through with identical methods in complex calculations, while the instructions provided had indicated an independent, open-ended task. At best this could be considered poor practice for failing to ensure that candidates carry out the task legitimately for themselves. Teachers should ensure that assessment is carried out in good faith and that an individual's skills are being assessed.

Candidate performance against each criterion

Design

Aspect 1

This was well addressed with most students being able to phrase a research question and identify most variables, thereby securing an award of at least Partial and in many cases Complete. A large number of students presented hypotheses which is acceptable practice but is not a compulsory part of the aspect descriptor. The absence of a hypothesis should not result in a lower mark.

Aspect 2

As in May 2009 this was the most challenging of the Design aspects and many students failed to identify any procedural methods to control or at least monitor the control variables that they had earlier identified as needing controlling. Some common failings amongst students in the aspect were: not doing proper dilutions in a volumetric flask (for quantitative work this is significant); adding small quantities with large measuring cylinders when volumetric pipettes should be used; in the task to investigate factors affecting rate of electrolysis students changed current by increasing voltage but did not check current with an ammeter; students varied Mg ribbon surface area by cutting ribbon in half (minimal change of surface area results), students did not control or at least monitor reaction temperature in rate investigations where surface area or concentration of reactants were the independent variable.

Aspect 3

The clarification in the Subject Guide as to the minimum sufficiency of the data led to a good level of fulfilment of this aspect with most students able to design for the collection of data that would include repeats or would be sufficient to analyse graphically (enough to generate at least five data points in such a case).

Data Collection and Processing

Aspect 1

There was generally a good level of fulfilment with more candidates than before including uncertainties and relevant qualitative data.

Aspect 2

The level of fulfilment was mixed. Most students made some attempt to process data appropriately, although following a calculation successfully through to its conclusion or to plotting a graph from which a quantity could be determined remained demanding and Partial was a frequent award.

Aspect 3

Far more candidates than before tried to propagate uncertainties through a calculation although not always successfully. Still a significant number of candidates could not construct a line of best fit on a graph and there were a significant number of inappropriate bar charts presented. Presentation of unreasonable number significant figures in a final processed numerical quantity was a common failing that prevented candidates from achieving Complete.

Conclusion and Evaluation

Aspect 1

Although most candidates could achieve some credit, this proved a demanding criterion and few candidates successfully placed numerical results in the context of a literature value and then identified whether the difference indicated the presence of system error or could be explained by random error alone.

Aspect 2

This criterion was satisfied to a reasonable extent with most students able to identify sensible sources of error. Few students though could evaluate whether the source of error accounted for the direction of the deviation from a literature value encountered, although a few schools had clearly done a good job in stressing that this comparison is a component of the requirements. Assessing this criterion in investigations which did not yield a numerical value to be compared to literature but instead identified a trend was less well defined and variable.

Aspect 3

This criterion was satisfied to a similar uneven extent to previous sessions with many good responses but a similar number of very superficial or simplistic contributions.

Manipulative Skills and Personal Skills

All schools entered marks for these criteria although no evidence needed to be submitted so it is not possible to pass comment on these awards.

Application of ICT

Most schools had checked the five ICT requirements at least once on the 4PSOW although the assessed work submitted rarely corresponded to these investigations so it is hard to evaluate the appropriateness of the tasks.

Guide Amendment

Subject guide page 26: 'Example considerations when assessing sufficiency of data could be the following: If a trend line is to be plotted though a scattergraph then at least five data points are needed, *so* the plan should allow for repeated measurements to calculate a mean

(for example, repeat calorimetric determinations when investigating an enthalpy of reaction). The plan should show an appreciation of the need for a trial run and repeats until consistent results are obtained in titrimetric determinations. *So* should be *or* therefore five data points, no repeats, sufficient for c'.Recommendations for the teaching of future candidates

- 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 candidates are solely assessed on their individual contribution to any activity used for assessment of the written criteria.
- Teachers must ensure that candidates have the opportunity to fulfil criteria, and hence should not provide too much information or help for the Design (D), Data Collection & Processing (DCP) and Conclusion & Evaluation (CE) criteria.

- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.
- It is recommended not to use workbooks and worksheets with spaces to be filled in by the candidates for internal assessment as they usually provide too much information and deny the candidates the opportunity to achieve criteria.
- Candidates need to explicitly identify the dependent variable as well as independent and controlled variables in the Design criterion.
- Candidates should be encouraged to consider repeat trials, calibration, or generation of sufficient data to undertake graphical analysis, when designing procedures for Design.
- All investigations for the assessment of DCP must include the recording and processing of quantitative data.
- Teachers are encouraged to set some DCP tasks that will generate a graph that will require further processing of the data, such as finding a gradient or intercept through extrapolation.
- Candidates must record associated qualitative data where appropriate as well as quantitative raw data.
- Candidates must compare their results to literature values when relevant.
- When assessing the CE criterion, require candidates to evaluate the procedure, cite possible sources of random and systematic error, 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 facilitate all aspects of that 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.
- The Group 4 Project is only to be used for assessment of the Personal Skills criterion.
- The Manipulative Skills criterion is to be assessed summatively over the whole practical scheme of work. No evidence for the MS mark need be submitted to the moderator.
- Teachers must refer to, and follow, instructions found in the chemistry subject guide, the Teachers Support Material, and instructions provided in the up to date *Handbook of procedures for the Diploma programme* before submitting work for moderation.

Communication with moderators

Before moderation for the session started, guidance was then given as to when and how moderators should and should not change marks. Teachers are asked to take note of these instructions with respect to the preparation of samples for future sessions.

Design Aspect 1

- Aspect 1 is really a two part aspect (R.Q. and then Variables). Complete for both parts then gets 2 marks, cp, pp, and p,n would all get 1 mark (a broad band admittedly) and (n,n will get zero).
- If a teacher has supplied the Research Question then this nullifies the first half of the criterion. However if they have satisfied the second half partially (e.g. by correctly identifying a good number of control variables) then maybe Partial can be awarded overall for Aspect 1.
- If the teacher has specified the independent and control variables then the second half of the aspect is nullified automatically. It could be felt that it has also completely focussed the research question so the final Aspect 1 award could well be Not at All.
- If the teacher has identified just the independent or just a control variable then Partial can still be awarded.
- The teacher is allowed to specify the Dependent Variable when setting the task.

When not to mark down in Design Aspect 1

- The independent and controlled variables have been clearly identified in procedure but are not given as a separate list (we mark the whole report and there is no obligation to write up according to the aspect headings).

Design Aspect 2

- This Aspect does demand that the students clearly describe the procedure to be followed including the materials to be used. The materials could be in list form or embedded in a step-wise description of procedure. If the procedure lacks sufficient detail, so that it could not be followed by the reader in order to reproduce the experiment, the maximum award is Partial.
- Students do not need to make a description of the precision of apparatus in the apparatus list or procedural steps because that is assessed in effect in DCP Aspect 1 in the raw data uncertainties.
- If a teacher has given students the full procedure then award Not at All.
- If a teacher has given a partial procedure then see what can be awarded for the student's own contribution. Probable award here is Partial.
- If a student has used a partial method from another source then that source should be acknowledged. Once again see what can be awarded for the student's own contribution. If a student has completely taken a Design from another source then the Award is Not at All, even if the source is acknowledged. (In other disciplines you would not be credited for solely quoting someone else's work, acknowledged or not).

When not to mark down in Design Aspect 2

- 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 the equipment list. Give credit for equipment clearly identified in a stepwise procedure. Remember we mark the whole report.

- Do not insist on the +/- precision of apparatus to be given in an apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DCP.
- Do not downgrade a teacher's mark if something as routine as safety glasses or lab coats is 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.

Design Aspect 3

This Aspect assesses how much appropriate data is **designed** for, even if the student is then unable to follow it up exactly in the laboratory.

- If the student has designed procedure so poorly that you feel that no relevant data would be collected then award Not at All.
- If the student has planned for less than five data points (if a graph is to be produced) or has not planned for any repeats in quantitative determinations (e.g. titrations or calorimetry, etc) then award Partial.

The material/apparatus

There is no longer a specified aspect to assess the equipment/materials list. If the students have failed to identify suitable materials to control the variable e.g., no ammeter in the common "factors affecting electrolysis" investigation where students identified current as a control variable then it is going to affect aspect 2. If, however, the missing material is going to affect the sufficiency of data (e.g. only identifying two alkanes when looking at affect of alkane chain length on some property) then it would affect Aspect 3 award.

There will be cases where missing materials/apparatus will affect both aspects.

Data collection and processing

This criterion should be assessed through investigations that are essentially quantitative, either calculation and/or graph based. If a purely qualitative investigation has been assessed for DCP then the maximum award would be probably p, n, n = 1.

DCP Aspect 1

This aspect refers to the written record of raw data, not the manipulation of the equipment needed to generate it (that is assessed in Manipulative Skills).

Do not mark down if the teacher has given detailed step by step procedural instructions (this may have been marked down in Design Aspect 3 if it is a Design assessment task. Not in DCP though).

- If a photocopied table is provided with heading and units that is filled in by students then the maximum the moderator can give is n = 0.
- If the student has only recorded quantitative data (e.g. colour changes in titration, observation of soot due to incomplete combustion in calorimetry, residual solid left in a beaker when reaction has excess solid reactant, bubbles being released when a gaseous product is formed are missing) then the moderator gives partial.

- However, do not be overzealous and penalize Aspect 1 every time a student does not find qualitative data to record. Sometimes there is no obviously relevant qualitative data to record.
- If a student has not recorded uncertainties in any quantitative data then the maximum award is Partial.
- If the data is *repeatedly* to an inconsistent number of decimal places or in disagreement with the stated precision then Complete cannot be awarded. Be sensible and support teacher if there is just one single slip in a large body of data where all the rest is consistent with each other and the stated uncertainty.
- In 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.

When not to mark down in DCP Aspect 1

- When the student has not included any qualitative observations and you cannot think of any that would have been obviously relevant.
- If in a comprehensive data collection exercise possibly with several tables of data the student has been inconsistent with significant digits for just one data point or missed units out of one column heading. If you feel the student has demonstrated that they were paying attention to these points and made one careless slip then you can still support maximum mark under ‘complete not meaning perfection’ rule. This is an important principle since often **good students responding in full to an extended task unfairly get penalised more often than students addressing a simplistic exercise**.
- When there is no table title when it is obvious what the data in the table refers to. I have seen students do all the hard work 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.

DCP Aspect 2

If a teacher has given the method of calculation or told the students which quantities to plot then award Not at All.

- If a student has made an error in a calculation leading to the wrong determined quantity then the award may be Partial or Not at All depending on the severity of the error.
- If a graph with axes already labelled is provided (or students have been told which variables to plot) or the students have followed structured questions in order to carry out data processing then the moderator should award Not at All.
- If a student has simply plotted raw data on axes with no trendline then award Not at All.

DCP Aspect 3

- If you cannot easily determine the student's method of processing then award Partial at maximum.
- The student must report any final quantitatively determined quantity to a number of significant figures that is consistent with the precision of the input data. Failure to do so will reduce maximum award to partial.
- Do not punish inconsistent significant figures reported in the middle of a stepwise calculation if the final answer(s) is(are) reported appropriately.
- If no evidence of errors being propagated through a calculation then award Partial at best. Remember that a best fit line graph is sufficient to meet the requirement for error and uncertainty propagation.
- The error propagation should be correctly followed through to a reasonable extent according to either the TSM's protocol or another accepted protocol. Try to support the teacher if the student has made a sincere attempt even if there is a small flaw.

When not to mark down DCP Aspect 3

- Do not punish inconsistent significant figures reported in the middle of a stepwise calculation if the final answer(s) is (are) reported appropriately.
- If the student has clearly attempted to propagate uncertainties 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 been given as +/- 0.01g when you may feel that if we consider the tare weighing then it should be doubled.

Conclusion & Evaluation

If structured questions are given to prompt students through the discussion, conclusion and criticism then, 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 student's input.

CE Aspect 1

- This is another multiple Aspect. The conclusion can take many forms depending on the nature of the investigation. It could be a clear restatement of the determined numerical quantity (e.g. the molar mass or activation energy), a statement of the relationship found, etc. Such a clear statement earns Partial. To secure Complete the student must comment on systematic/random error and where appropriate relate this to literature values. The comment on systematic/random error may well come after the sources of error have been discussed. This is fine.

CE Aspect 2

- Look to see that a student has identified the major sources of error. There will always be other possible sources but I do not want to force students into overly long lists of trivial points just so that they feel they have covered the options. I am concerned at the number of twenty page reports that we are increasingly seeing from diligent students that could have been condensed into a quarter of the length.
- There is no written requirement to state the direction of each source error so we are not looking for an explicit statement. However, the student's comments on significance of sources of error must be CONSISTENT with direction of error. For example, heat loss to the environment is considered the main source of error when experimentally determined enthalpy value is actually greater in magnitude than the literature and therefore implying another more major source of error in the other direction. This inconsistency would reduce aspect award to Partial.

When not to mark down CE Aspect 2

- 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 however be a bit more critical in third aspect that the modifications are actually relating to the cited sources of error.

CE Aspect 3

- It is important that the suggested modifications be realistic and should relate in the main to the weaknesses. Be sensible. If the student has cited five weaknesses and come up with good suggestions for modification to address four of them (and the fifth one has no modification readily accessible to an IB student), then Complete can be awarded.

Other Issues

Simplicity

If you feel a task was too simple to truly meet the spirit of the criteria then comment on the 4/IAF as to the unsuitability of the task giving full justifications but do not necessarily downgrade the student. Yes, this does mean that students could get high DCP marks for some quite brief work on limited data but if they have fulfilled the aspect's requirements within this small range then support the grade.

Data logging

We are trying to encourage the use of data logging even in assessed work. The key axiom to be followed is that the students are to be assessed on their individual contribution to the assessed task. To judge this we have to be guided by the teacher who knows exactly what the students had to do. Apply the normal standards regarding expectations of data presentation (units, uncertainties, etc.) and graphs (best fit lines, axes labels, suitable scales, etc).

If you are concerned as to whether the students have had sufficient input, feedback to the teacher.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 16	17 - 22	23 - 25	26 - 29	30 - 32	33 - 39

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 15 G2 forms that were returned. 73% found that it was of a similar standard, compared with last year's paper, 7% felt that it was a little easier, 7% considered the paper much easier, 13% thought that it was a little more difficult though none were of the view that it was much more difficult.

93% felt that the level of difficulty was appropriate, 7% thought that it was too difficult, but none considered that the question paper was too easy overall. Syllabus coverage was considered satisfactory by 36% and good by 64%, with none considering it poor. In addition, 36% felt that the clarity of wording on the paper was satisfactory, 57% felt that the wording was good and 7% felt it was poor. The presentation of the paper was considered satisfactory by 29% and good by 71%.

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 97% to 28%, and the Discrimination Index, an indication of the extent to which questions discriminated between high and low-scoring candidates, ranged from 0.76 to 0.07 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 1

In spite of a concern on the part of one teacher that this question was too difficult, this was one of the questions that students found easiest, with a Difficulty Index of 94%; hence it provided a nice easy start to settle students into the paper.

Question 3

Students found this question on concentrations of ions surprisingly challenging with a Difficulty Index of 56%, with many thinking the concentration of the ion would be the same as that of the compound. It did however prove to be an excellent discriminator with the highest Discrimination Index (0.76).

Question 4

This question on the ideal gas law proved to be the most challenging on the paper (Difficulty Index 28%). It did involve students carrying out a multistage calculation without the benefit of a calculator, but the fact that most felt that doubling the temperature in ^{o}C would cause a doubling of the pressure hints at a more basic misunderstanding.

Question 5

This question on the processes occurring in the mass spectrometer proved to be the easiest on the paper (Difficulty Index 97%), indicating that students have a good grasp of this section of the syllabus.

Question 8

Though students did not find this question on particle radius particularly difficult (Difficulty Index 68%), it proved to be a poor discriminator (Discrimination Index 0.15) indicating that even good students find it difficult to apply a variety of trends simultaneously.

Question 14

This question on hybridization was particularly badly answered (Difficulty Index 29%), though it was not clear as to whether this arose from a lack of comprehension of the concept itself or the structure of silicon dioxide.

Question 15

There was a mistake in the units for heat capacity in this question (kJ kg^{-1} mol^{-1} rather than kJ K^{-1} mol^{-1}), but this did not appear to put students off as the Difficulty Index and Discrimination Index were both of the order of magnitude that was anticipated.

Question 17

This question on the effect of ionic radius on lattice enthalpy proved to be quite challenging, with a Difficulty Index of 43%, with many students considering that the larger potassium ion would give rise to a more endothermic lattice enthalpy than the smaller sodium ion.

Question 22

Although it was correctly pointed out that the assessment statement only refers to the direction in which a change in conditions will cause an equilibrium to shift, rather than the fundamental chemistry underlying this, students did not find the question unduly difficult (Difficulty Index 67%) and it was a reasonable discriminator, (Discrimination Index 0.39), hence it was decided to retain this question in the assessment.

Question 25

This question on the neutralization of an alkali by various acids proved to be a particularly good discriminator (Discrimination Index 0.68), with many of the weaker students considering that the strength of the acid would affect the amount required.

Question 32

This question, on the electrolysis of molten and aqueous salts anticipated that students would know from practical experience that water was more easily reduced than the magnesium ion and that the bromide ion is more easily oxidised than water, hence the electrode potentials, which would have confirmed this, were not given. This did not prove to be the case with the question proving quite difficult (Difficulty Index = 32%) and a poor discriminator (Discrimination Index 0.14). As a consequence it was decided to exclude this question from the assessment. This question was amended in the published version of the paper.

Question 33

This question on the number of structural isomers that a particular molecular formula would give rise to proved to be one of the more challenging questions (Difficulty Index = 41%), with all of the distractors proving to be about equal in popularity.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 28	29 - 41	42 - 51	52 - 60	61 - 70	71 - 90

General comments

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

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

The 12 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, 59% felt that it was of a similar standard, while the remainder of respondents opted for a little easier (8%) and a little more difficult. The vast majority (92%) of the respondents thought the level of difficulty was appropriate. Syllabus coverage was considered good by 69% and satisfactory by the remainder of respondents. Clarity of wording was considered good by 54%, satisfactory by 38% and poor by 8%. The presentation of the paper was considered good by 62% and satisfactory by the remainder of the respondents.

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

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

- Volumetric analysis and balancing redox equations.
- Structure of SF_4.
- Movement of ion flow through a salt bridge.
- Explanation of the amount of heat evolved per gram for pentane and pentan-1-ol.
- Calculation of activation energy.
- Equilibrium calculation.
- Definition of enthalpy of formation and ionization energy.
- Calculation involving buffer solution.
- Equation to support the acidic behavior of $AlCl_3$.
- Equation to support the hydrolysis reaction at equivalence point.
- Geometrical isomers of but-2-ene-1,4-dioic acid.
- Proper use of curly arrows in organic reaction mechanisms.

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

Once again there were some excellent scripts seen from some candidates, whose answers indicated knowledge and understanding across the syllabus, especially when answers to their chosen Section B question matched the quality of their answers in Section A.

Topics that were generally well answered included:

- Oxidation numbers.
- Electrolytic and voltaic cells.
- CNG and improvement in air quality.
- Rate equations and equilibrium constant expressions.
- Born Haber cycle.
- Calculations involving Hess's Law.
- Bond enthalpy calculations.

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

Section A

Question 1

There seems to be considerable difficulty in transferring the lab skills in terms of volumetric analysis to various aspects of question 1. It was surprising to see that many candidates were not able to balance the redox equation. Some candidates realised that the first value was a trial and took the average of the last two values. In addition, there seems to be some confusion that there was one sample and three titres which was unfortunate; however, it did not impact the candidates performance. Many candidates failed to calculate the amount in moles of Fe present in the sample of iron and subsequently the percentage by mass of iron. Many candidates benefitted from the error carried forward marks. Question 1 in all papers is meant to be data response and candidates are expected to be familiar with basic experimental techniques.

Question 2

This question was generally well answered and many high scores were seen. Common errors included the omission of non-bonding pairs of electrons on fluorine atoms and sometimes on sulfur. The shape of SF_4 was not well known but candidates were able to write correctly the name of the shape for SF_2 and SF_6.

Question 3

In the emission spectrum of hydrogen some candidates missed stating about convergence at high energy/frequency while some other candidates forgot to write that it is a line spectrum. The majority of candidates deduced the oxidation number of iron in the complex ions correctly although some candidates still wrote 2+ and 3+ which deprived them of one mark.

Question 4

This question was generally well answered. The majority of candidates were able to state two differences between a voltaic and an electrolytic cell. In part (b), a balanced equation and cell potential were correctly deduced by most candidates. The ability to label the direction of the movement of cations and anions through the salt bridge proved to be the most difficult question on the paper.

Question 5

Many candidates got the correct order for the boiling points of A, B and C but were unable to relate the extent of branching to the Van der Waals forces and subsequently to boiling points. The correct IUPAC name for the isomers of pentane proved to be challenging for some candidates. Part (b) also proved to be difficult for many candidates. The candidates failed to recognize that pentane would release a greater amount of heat per gram than pentan1-ol, which is partially oxidised. The aim 8 question on CNG was very well answered which proves that just because a question is new and unfamiliar does not mean that candidates cannot use their chemical knowledge to answer it. A few candidates forgot to state that no sulfur dioxide was produced in the case of CNG.

Section B

Question 6

This was the most popular question in Section B and was generally well answered.

In part (a) the rate expression was correctly stated although some confused this with an equilibrium constant expression. Only the better candidates realized that the rate of reaction will decrease by a factor of four and there will be no effect on the rate constant. Although most candidates were able to correctly sketch the concentration versus time graph many forgot to label the axes or include units. Part (b) was well answered and candidates demonstrated a good understanding of rate expressions based on reaction mechanism. The better candidates were able to figure out that the rate of a chemical reaction is equal to the rate constant when all concentrations are 1.0 mol dm^{-3} or for a zero order reaction. Most candidates had difficulty in calculating activation energy from the graph in part (d) and some gave the answer in J mol^{-1} instead of kJ mol^{-1} which showed that they missed this instruction in the question. In part (e), the equilibrium constant expression was correctly stated by the majority but calculating the value of Kc proved to be difficult.

A large number of candidates obtained the incorrect answer of 10.34 as a result of using the initial concentrations of the reactants instead of equilibrium concentrations. The application of Le Chatelier's principle was handled well by the majority with minor omissions such as not using the term gaseous particles in part (iv).

Some candidates stated that the addition of a catalyst does not affect the value of Kc or the position of equilibrium, which did not answer the question and scored no marks because they had not commented on the concentration of $SOCl_2$. Some candidates correctly stated that a catalyst increases the rate of forward and reverse reactions equally.

Question 7

This was the second most popular question and in general candidates demonstrated a good understanding of the Born Haber cycle. Some candidates identified the process A as vaporization instead of atomization. Most candidates correctly stated the definition of enthalpy change of formation although some omitted to specify the standard conditions. The majority of candidates correctly calculated the lattice enthalpy value. The definition of the first ionization energy was stated correctly by most candidates but in a few cases the term gaseous state was missing. The compound with higher lattice enthalpy was correctly identified including the reason. The majority of candidates manipulated the thermo-chemical equations and calculated the correct answer of +137 kJ although some reversed the sign. The explanation for why the reaction was non-spontaneous at low temperature but became spontaneous at high temperature was not always precise and deprived many candidates of at least one mark. The bond enthalpy calculation had the usual mistakes of using the wrong value from the data booklet, bond making minus bond breaking and –125 kJ instead of +125 kJ.

Question 8

Most candidates were able to determine the pH at the equivalence point. Salt hydrolysis was very poorly understood by many candidates and therefore they were not able to write an equation. In part (b) most candidates described the use of indicators during titrations, but lost credit for not using the reversible equilibrium equation to explain how they function qualitatively.

Part c (ii) baffled the majority of candidates. It is surprising to see that calculations based on buffers are almost an exclusive domain of the better candidates.

Most candidates were able to identify the acidic nature of aluminium chloride, but few could give a correct equation to justify their answer. In part (e), only the able candidates scored the maximum five marks for calculating the pH and the base dissociation constant for ammonia. Overall knowledge of acid-base chemistry was considerably weak, especially calculations.

Question 9

The standard of organic chemistry this session was slightly better when compared to previous sessions. In part (a), some candidates missed that no rotation is possible due to the pi bond. The question required candidates to draw the two geometrical isomers of 1-chloro-but-2-ene but some candidates had drawn the isomers of 1-chloro-but-1-ene or 2-chloro-but-2-ene. Only the able candidates could draw the optical isomer of C_4H_7Cl and identify the chiral carbon atom. For the two geometrical isomers of but-2-ene-1,4-dioic acid, not many candidates understood intermolecular and intramolecular hydrogen or the formation of cyclic anhydride.

In part (c), the S_N2 mechanism between bromoethane and potassium cyanide proved to be a challenge as candidates continued to make the same errors as found in previous sessions, such as an incorrect placement of curly arrows, the omission of non-bonding pairs of electrons on the nucleophile and the failure to include partial bonds and an overall charge in the formula of the S_N2 transition state. Candidates are encouraged to show the entering and leaving groups at 180° instead of 90° on the transition state.

The mechanism of elimination reaction proved to be the most difficult part in this question. Many candidates had used curly arrows incorrectly while others were not aware of the reaction conditions. Addition polymerization was correctly identified by the majority of the candidates.

Recommendations and guidance for the teaching of future candidates

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

- Teachers are strongly advised to refer to past examination papers and their markschemes to assist candidates with examination preparation.
- Candidates must know the meaning of the different Command Terms that appear in the assessment statements and in examination papers.
- Candidates must read the question carefully and correctly address all points. Working must be shown for all calculations so that the chances of obtaining ECF marks is maximised.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 9	10 - 19	20 - 23	24 - 28	29 - 34	35 - 39	40 - 50

General comments

The range of marks awarded was very wide for this paper. The best candidates showed a thorough command of the material and a high level of preparation, but others seemed unfamiliar with a number of the options, in particular some of the newer material on the syllabus. A number of the better candidates this session chose to do Options A and G and in fact performance here was very good. In Options D and F, many students struggled with some of the key chemical principles, which are an integral part of these options. In Option E, a number of the weaker students chose to take this Option but generally struggled and tended to give more journalistic type answers. In Option C, a significant number of students struggled with the new material. In general, Option B was very well answered.

Of the 14 G2 forms received, 69% felt that the paper was a similar standard to last year, 8% felt it was a little easier, 15% a little more difficult and 8% thought the paper much more difficult. The vast majority (93%) of the teachers who responded felt the level of difficulty was appropriate and just 7% considered it was too difficult.

Syllabus coverage was considered to be good by 29%, satisfactory by 50% and poor by 21%. 50% felt the clarity of wording was good and 50% satisfactory. For the presentation of the paper, 57% stated that it was good and 43% 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:

- The presence of undetected uncharged fragments in a mass spectrometer.
- Explanation of colour of transition metal complexes.
- The structure of dipeptides.
- The half equation at the negative electrode during the electrolysis of aluminum oxide.
- An explanation of the difference in flexibility between PVC and polyethene.
- The structure of the *isotactic* form of PVC.
- An understanding of the significance of the insolubility of $Cd(OH)_2$ in the nickel-cadmium battery.
- The presence of the *phenylethylamine* group in amphetamines and adrenaline.
- The role of molecular modelling and data bases in drug design.
- Ring strain in the beta-lactam ring.

- The role of polarity in heroin and morphine.
- PANs.
- The use of solubility Product type calculations.
- A comparison of the structural features of the common antioxidants.
- The understanding of chelate ligands in examples in food chemistry.
- The determination of R and S notation.
- Oxidative rancidity – equations governing the chemical process.
- The explanation of the relative basicity of amines.

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

The areas which seemed well understood were:

- The bonds responsible for IR absorptions.
- The definition and calculation of R_f values.
- Enzymes in general.
- The meaning of the terms: *side-effect* and *placebo effect*.
- Landfill and incineration.
- The function of nutrients.
- Grignard reactions.
- Electrophilic substitution reactions.

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

Option A - Modern analytical chemistry

Question 1

See SL comment. One G2 comment stated that the region of the electromagnetic spectrum used in ^1H NMR spectroscopy is not on the course. This is incorrect - as part of the Aim 8 on the use of NMR in body scanners in AS A.5.2, it would be expected that students would know that radiowaves are involved, as part of the wider discussion of proton NMR spectroscopy.

Question 2

In (a), although most identified the formula of the molecular ion in (i) and the fragment in (ii), the positive charge was often missing. Very few candidates were able to explain the absence of a peak at *m/z* = 29 in (iii) in the mass spectrum. This is because the fragment produced after loss of $C_2H_5^+$ has no charge. In (b), most candidates were able to identify the bonds as C=O for A and C-O for B, but a common mistake in (ii) involved candidates stating that the functional group was a carboxylic acid and not an ester. One G2 comment stated that the presence of the peak absorption at 3000 cm^{-1} confused students. However, there was no evidence of this and students should be prepared to analyze real spectra in examinations.

In part (c), most of the better candidates deduced the structure as $CH_3COOCH_2CH_3$ and subsequently the correct chemical shift, relative peak area and splitting patter for the third peak. In addition, the splitting pattern of the peak at 4.1 ppm was usually well answered. Many students displayed very good knowledge of ^1H NMR spectra in this question.

Question 3

See SL comment.

Question 4

Surprisingly this was very poorly answered and few students scored all four marks here. There was often no clear understanding of the mechanism of colour absorption (and hence the observed colour being complementary – many candidates thought that the colour was caused by the subsequent emission of energy by electrons falling back). Some of the better candidates did refer to the fact that the ammonia ligand has a greater crystal field/ligand field splitting, which clearly showed comprehensive understanding of this subject.

Option B - Human biochemistry

This was one of the most popular options.

Question 1

See SL comment.

Question 2

The major function of enzymes in the human body was very well answered and most candidates were able to describe the mechanism of enzyme action in terms of structure. In addition, the idea of a competitive inhibitor, V_m and K_m were all clearly understood and many candidates scored full marks in (c) (i) and (ii). In (d) the answers tended to vary and many candidates did not distinguish between the temperature effect below and above 40°C.

Option C - Chemistry in industry and technology

A number of G2 comments stated that this was a difficult Option. It is true to say that this was not generally a popular option and many candidates struggled with the new syllabus content which may have caused the difficulty for students.

Question 1

This was reasonably well answered. However a surprising number of candidates were unable to write the half equation for the reaction at the negative electrode in (a) (i), and few candidates were able to give an explanation of the reduced malleability of the alloys in terms of their structure in b (ii). Another common mistake was evident in (c) (a) (ii), where candidates failed to read the question which asked for the name of the gas and not the formula. Some candidates also incorrectly stated that the gas was hydrogen.

Question 2

See SL comment.

Question 3

Responses to this question were generally poor perhaps reflecting the unfamiliarity of candidates with the new syllabus content. In (a), very few convincing answers were seen. In (b), reference to high selectivity was rarely cited, although a number of candidates were aware of unknown health effects.

Question 4

See SL comment.

Question 5

In (a), very few candidates scored full marks. In (b), candidates struggled greatly in trying to explain in molecular terms the workings of a twisted nematic liquid crystal.

Option D - Medicines and drugs

This was one of the most popular options but a number of candidates struggled with the chemical concepts embedded within the questions themselves. One G2 comment stated that students were asked very few questions here. However, students should be prepared to respond to either a series of sub-topics within an Option or fewer in more detail. This is not different to previous sessions, however in the past HL material that extended SL questions would have been given a separate question number (i.e., they would have always been labeled number 4 or 5) whereas we have now made a decision to integrate the extension HL material into the SL questions. This may give the impression of a reduction of coverage.

The challenge of reflecting both the depth and the breadth of Option material in 25 marks however is one of which the examining team are aware.

Question 1

The mode of action of penicillins in treating infectious diseases was well understood. In (b), one mark was usually scored for the resistances. However, only the better candidates scored M2. In (ii), the vast majority of candidates were completely thrown by this question on the use of computers in drug design. The idea of using computers for molecular modelling and as data bases looks like it was not touched on to any great extent. In (c), many students could not relate the hybridization of the carbon atoms in the beta-lactam ring to ring strain and a significant number appear to have difficulty linking some key chemical concepts in this option.

Question 2

See SL comment.

Question 3

Parts (a) (b) and (c) were generally answered quite well but only the better candidates managed to describe the structural similarity of amphetamine and adrenaline. Very few referred to phenylethylamine. Candidates found it more difficult to explain the use of chiral auxiliaries and discussion of polarity with regard to morphine and heroin was often omitted in (e), again suggesting poor chemical understanding by many candidates.

Option E - Environmental chemistry

This was one of the most popular options on the paper but student performance was often quite weak with an over-emphasis on journalistic type answers particularly from the weaker candidates. Although some of the questions appeared easy and familiar in terms of the topics asked, in reality, a number of candidates often performed better on other options during this session.

Question 1

See SL comment.

Question 2

See SL comment.

Question 3

In (a), most candidates scored M1, but reference to high temperature was often omitted. Part (b) was also poorly answered. In (c), a number of candidates tried to explain the inversion instead of stating that polluted air is trapped closer to the ground. The equation in (d) was well answered.

Question 4

See SL comment.

Question 5

Although the better candidates were able to solve the K_{sp} problem in (a), most did not know the subsequent answer to (b).

Option F - Food chemistry

Only a relatively small number of candidates choose to do this option and in general the performance was very weak. This was a pity as the questions contained a number of key chemistry type ideas applied to the chemistry of food which one would have expected to be well covered by any candidate taking this option. Similar to Option D, many candidates struggled with the clear chemical concepts integrated within the questions themselves.

Question 1

See SL comment.

Question 2

Many candidates had difficulty comparing the structural features of the three antioxidants. Most candidates could identify an antioxidant in (c), but the decrease of the risk of cancer or heart disease was less well known. In (d), very few candidates knew why $(EDTA)^-$ can be described as a chelate ligand which again showed a clear weakness of a key chemical concept within this option.

Question 3

In (a), surprisingly a number of students were not able to identify the chiral centre. Although some knew what *d* and *l* referred to, a number did not refer to plane-polarized light. Equally, R and S notation was not understood and only the best candidates were able to determine the structure as S. Some simple class exercises on chiral centres, *d* and *l* notation and R and S notation using a number of simple molecules would greatly improve student understanding of this topic.

Question 4

Again another prime example of a basic chemical concept applied to food chemistry which defeated most students. Many students failed to gain even one mark here.

Option G - Further organic chemistry

This option was often taken by the stronger candidates. Interestingly, student performance was often excellent and some high scores were seen.

Question 1

The Grignard reaction in (a) (i) was well answered. One G2 comment stated that the reaction of the Grignard should have been written in two parts, which is a valid comment. However, this did not affect student performance. In (ii), some candidates made mistakes in the phenylhydrazone structure, but knew that the reaction type involved addition-elimination.

Question 2

Part (a) was often poorly answered. Many of the better candidates gave some excellent reaction pathways in (b), but the weaker students did not appreciate the need for a specialist add a carbon type reaction.

Question 3

Many HL candidates did well in this question and a number of excellent mechanisms were seen. Care still needs to be applied however in relation to the correct use of curly arrows in mechanisms. As this option has several different mechanisms, there should be a large emphasis in the teaching of this option on mechanisms and student practice is key to competency in this area. In (b), electrophilic substitution was usually well answered and so were (c) and (d). However, (e) was often poorly answered and an adequate explanation of the relative basicities of the two amines was rarely seen.

Recommendations and guidance for the teaching of future candidates

See general comments made at SL. In addition:

- The choice of options for students should be carefully exercised. Some of the more popular options which can appear easy (such as Options D and E) often resulted in poor performance this session, as students tended to think that journalistic type answers would be sufficient in answering questions or there was a tendency to answer questions from a biological perspective ignoring the key chemical concepts.

- In options D and F, teachers should try to emphasise the major chemical ideas underpinning these options which are well documented in the guide in both the assessment statements and linked teacher's notes.
- Students should have precise knowledge of any definitions cited in the Options.
- Students should be encouraged to practise past examination papers.
- Every part of the syllabus must be covered in detail. There was evidence that some areas had not been covered by some schools. In addition the newer areas of the syllabus should be explored fully, particularly in Options C and F.
- Candidates should practise using curly arrows in organic mechanisms. They should check that arrows start and finish in the correct places and point in the right direction. In Option G there are several different mechanisms and candidates need to make sure that they are prepared to explain each of these mechanisms if choosing this option.
- Candidates should always balance chemical equations.
- There should be no need to use extra sheets in answering questions. The amount of space in the answer booklet should give a student a clear indication of the length of the answer required. Teachers should emphasize this point in class.
- Units and significant figures should also be stressed in problems in the Options.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 12	13 - 18	19 - 21	22 - 23	24 - 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 21 G2 forms that were returned. 50% found the paper a little more difficult and 25% considered the paper much more difficult compared with last year's paper. 25% felt that the paper was a little easier. 95% considered that the level of difficulty was appropriate, 5% thought that it was too difficult, but none considered that the question paper was too easy overall. Syllabus coverage was considered satisfactory by 62% and good by 38%. In addition, 48% felt that the clarity of wording on the paper was satisfactory, 47% considered that the wording was good and just 5% claimed it was poor. The presentation of the paper was considered satisfactory by 33%, good by 62% whereas 5% stated that that the presentation was poor.

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 95% to 16%, and the Discrimination Index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.62 to 0.14 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 4

One respondent stated that general chemical nomenclature of ionic species is not explicitly on the syllabus and that a compound such as $KAl(SO_4)_2$ is not encountered frequently. For this reason, the respondent felt that students would have found this individual question difficult. The question overall proved to be the second most difficult question on the entire paper (after Question 5), with an associated Difficulty Index of 29%. However, it also proved to be a good discriminator with a value of 0.50. The question itself is based on AS 1.5.2 and has nothing to do with chemical nomenclature. As the formula of the species is given in the question, the most common mistake for students related to the fact that there are two sulfates present, leading to an answer of 4.0 and not 2.0. As an aside in response to the G2 comment itself, the syllabus does state in AS 4.1.7 that the formula of common polyatomic ions formed by non-metals in periods 2 and 3 should be known and a number of such species are listed in the TN corresponding to this AS, which includes sulfate.

Question 7

One respondent stated that this question is on the processes in a mass spectrometer which are not required for SL. This is incorrect as AS 2.2.1 states that candidates should know the description and explanation of the operation of a mass spectrometer. In addition, the TN in the guide states that the stages of operation should be considered, i.e. vaporization, ionization, acceleration, deflection and detection.

Question 16

The comment on incorrect units of specific heat capacity is discussed already in HLP1, Question 15.

Question 17

One G2 comment stated that the question should have asked for the enthalpy change in the reaction in units of $kJ\ mol^{-1}$ instead of kJ. This aspect of units has been discussed in detail in several previous subject reports and teachers are referred to these reports for further reference.

Question 19

Five respondents alluded to the fact that the three options were listed as I, II and II, instead of I, II and III. The question overall was well answered by candidates (Difficulty Index was 76%). Another respondent stated that statement II, the fact the catalyst lowers the activation energy for the reaction is in fact misleading, as a catalyst provides in fact an alternative reaction pathway with a lower activation energy requirement. This is a valid interpretation, but it was felt that the wording did not have an impact on student performance.

Question 21

One G2 comment stated that the SL syllabus only requires students to consider K_c from the equation for a homogeneous reaction as outlined in AS 7.2.1. The respondent stated that the equilibrium as written involves two phases, (s) and (aq), and hence this would have confused candidates. 52% of candidates however did get the question correct and the question proved to be a reasonably good discriminator also, with a discrimination index of 0.45.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 21	22 - 27	28 - 32	33 - 38	39 - 50

General comments

The range of marks awarded was very broad; the best candidates showed a thorough command of the material and a high level of preparation. Teachers' impressions of this paper were conveyed by the 19 G2 forms that were returned. In comparison with last year's paper, 60% thought this year's paper was of a similar standard or a little easier, with the remainder considering it a little more difficult.

84% thought the level of difficulty was appropriate and 16% thought it was more difficult. Syllabus coverage and clarity of wording were considered good or satisfactory by 79% of respondents, and the presentation of the paper was considered good or satisfactory by all respondents. Obviously with so few G2 forms returned it is hard to draw conclusions from this.

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

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

- Balancing redox equations.
- Volumetric analysis.
- Explanation of the relative energy densities of pentane and pentan-1-ol.
- Explaining trends in boiling point.
- Predicting which compound releases more heat per gram.
- The effect of volume changes on gaseous equilibrium.
- Explanations of how the rate of reaction can be determined from the tangent of a concentration / time graph.
- Understanding of the relative strengths of different bases.

- Lewis acids and drawing structural formulas of Lewis acids and bases.
- Showing the S_N1 and S_N2 reaction mechanisms using curly arrows.
- Determining ratio of $[H^+]$ of two acids.
- Describing experimental procedures for comparing bases.

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

Once again there were some excellent scripts seen from some candidates, whose answers indicated knowledge and understanding across the syllabus, especially when answers to their chosen Section B question matched the quality of their answers in Section A.

Topics generally well answered included:

- Identifying the reducing agent using oxidation numbers.
- Deduction of equilibrium constants from stoichiometric equations.
- The relationship between pH and $[H^+]$ values.
- The meaning of the term S_N1.
- The structural formulas of the isomers of $C_4H_{10}O$.
- Oxidation products of the primary and secondary alcohol.
- Lewis structures and molecular shapes.
- Enthalpy change calculations.

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

Section A

Question 1

Most G2 comments on Section A were about this question. Many commented that titration is not part of the SL syllabus; however it is the expectation that students would cover this and other basic chemical techniques as part of their practical programme. Question 1 in all papers is meant to be data response and students will be expected to be familiar with experimental techniques. Also, there was some confusion caused because there was one sample and three titres. However this unfortunate cause of confusion did not seem to impact on candidate performance as poor performance was found throughout the question even with some very routine questions. Generally this question was poorly answered. In a) not many candidates managed to write the correct balanced equation, however many gave the correct species that were missing, H^+ and H_2O. Most candidates were able to identify the reducing agent although a few candidates just mentioned “iron” or Fe, but metallic iron was not in the equation. In (c) candidates were not familiar with the process of selecting the 2 best titres and averaging them. Some chose the first written, some averaged all three and some weaker candidates merely added the 3 titres and used this. Some candidates also forgot to convert cm^3 to dm^3. In 1(e), a few candidates scored ECF marks for the % based on n(Fe) calculated in (d). A couple of candidates realised that their answer to (d) did not help and followed on from (c) to find the number of moles of Fe^{2+} and hence the % of Fe, scoring ECF marks.

Question 2

This question was generally well answered and many high scores were seen. Common errors included the omission of non-bonding pairs of electrons from fluorine atoms and using S instead of Si as the symbol for the central atom in SiF_4.The shapes were well known although a significant number of candidates fell into the trap of saying SF_2 was linear and some thought that PF_3 was planar. A number of students stated that SF_2 was bent linear, which is not correct. A few candidates, especially those answering in Spanish did not read the question properly and tried to write the name of the compound instead of its shape.

Question 3

A significant number of candidates scored full marks here. Although the setting out of the calculations was often difficult to follow, a pleasing number of correct final answers was seen. The commonest errors were to give a correct numerical value with a negative sign and to fail to divide the value for the first equation by 2.

Question 4

This question also featured on the G2 forms, as some teachers thought that the inclusion of Aim 8 type questions such as this would disadvantage candidates. However performance by the majority was very good. It should be noted that questions of this type will always be asked in future papers**.** In (a), most candidates correctly identified the boiling points although some reversed the order and a few had B with the highest boiling point. Explanations for this trend were not so well answered. Some candidates referred to breaking bonds in the carbon chain and several answers referred to the length of the carbon chain rather than the degree of branching.

The IUPAC names were generally well known, with the most common errors being the use of "pent" instead of "prop" and the omission of one of the locants, or “di” in "2,2-dimethylpropane".

Many candidates scored 0 in part b) as they incorrectly suggested that pentan-1-ol would have a larger energy density than pentane. It is clear from the variety of wrong answers and reasons that candidates are not familiar with the ideas tested in this question. Many candidates referred to hydrogen bonds between molecules, as a reason for pentan-1-ol releasing more energy, only a few consulted their Data Booklet and made reference to this. In c) there were 2 marks for improvements to air quality and 1 mark for a reason. Most candidates included the idea that there would be less carbon monoxide formed and that this was a poisonous gas. There were fewer references to oxides of sulfur, although many said that CNG has fewer S impurities rather than to say that less SO_2/SOx is released, in this case as they had already scored their explanation mark they could not score for this and ended up with 2 marks out of 3. Some candidates did not centre their answer on what was being asked. Also, some candidates said that natural gas is a natural fuel while diesel is not, and that natural gas, when it burns does not produce carbon dioxide.

Section B

Question 5

This was the most popular question in Section B and there was a generally pleasing level of performance. In (a)(i) most candidates were able to correctly deduce the equilibrium constant and in (ii) most candidates realized the exothermic reaction would be favoured, and gained full marks for their explanation.

However, some candidates seemed not to appreciate that the specified temperature of 300 ºC was lower than the original, and so based their answers on a temperature increase. In (iii) most forgot to mention the word gaseous when talking about the particles and many forgot that K_c is only affected by temperature. In (iv) candidates correctly stated that concentration would not change and stated that reaction rates of both forward and reverse reactions would be affected equally. However, some answered 'the addition of a catalyst does not affect K_c or the position of equilibrium' which did not answer the question and scored no marks as they had not commented on the concentration of SOCl2.

For (b), although most students were able to correctly sketch the reactant concentration / time graph by labeling the axes and drawing an appropriate curve, some candidates incorrectly read the question and sketched product / concentration time curve. Drawing a tangent to determine the rate was not well known and only some were able to describe how the rate at a particular instant could be determined from the tangent to the curve.

In (c), most scored the marks in (i) and were able to correctly describe the effect of concentration on rate in terms of collision theory, although some forgot to mention the frequency of the collisions just stating there would be more. In part (ii), most candidates assumed that the rate would increase with surface area of the solute, and few realized that once the sodium iodide was in solution then the particle size of the solid used to make it was not relevant as it is the solution which reacts. Part (d) was well answered but some candidates lost marks due to imprecise responses. For example it is the kinetic energy that increases with temperature, not energy. Also there were some errors such as the omission of the idea of frequency when referring to collisions and the belief that an increase in temperature caused a decrease in activation energy.

Question 6

This was the second most popular question. In (a) many candidates scored marks for their understanding of acid-base behaviour in terms of proton transfer and correctly identified H_2O as acting as an acid. Identifying and explaining NH_2^- as the strongest base and NH_4^+ as the strongest acid proved more problematic. In (b), in spite of the wording in the question ("experimental methods") many answers mentioned only a property, such as "a strong base has a higher pH than a weak base", and several who chose an indicator to distinguish them picked one with only two colours, such as phenolphthalein. Most candidates omitted to mention that the solutions should be of the same concentration. Although most could describe one good method (either pH or conductivity), the second method often involved reaction rates or titrations and descriptions of how these were poor.

In (c), although most were able to convert pH values into $[H^+]$ values, fewer were able to compare them as a ratio in the correct form -10,000:1. Some candidates had difficulty identifying the stronger acid. In (d), the involvement of electrons in Lewis acid-base behaviour was often known, although sometimes the word pair was omitted.

However, (d)(ii) was poorly done and a surprising number did not choose the familiar examples of boron trifluoride and ammonia as examples of Lewis acids and bases but chose completely unsuitable ones instead. Very few candidates referred to the bond as a dative covalent bond, some said it was dative only, and some covalent only.

Question 7

This was the least popular optional question but many who chose it did very well. In (a), most candidates could write the equation in (i) and knew nucleophilic substitution in (ii), the term "unimolecular" was less well known. Almost no all-correct answers were seen in (iv), and candidates continue to make the same errors as in previous sessions; commonly, the incorrect placing of curly arrows, the omission of non-bonding pairs of electrons on nucleophiles, and the failure to include partial bonds and an overall charge in the formula of the S_N2 transition state. Also students should be encouraged to show the entering and leaving groups at 180° instead of 90°. Part (b) was better answered, although common errors were drawing of identical isomers in different ways in (i) and the inclusion of an extra hydrogen atom on the carbonyl group of the ketone in (iii).

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:

- To practise calculations based on titration data.
- To practise balancing redox equation using oxidation numbers.
- To practise common organic reaction mechanisms using curly arrows to represent the movement of electrons.
- “Keep going” with calculations as errors are carried forward so that a correct method in a later part of the question is rewarded. All steps in the calculation should be shown.
- To set out calculations logically, using a few words to indicate what is being done, underlining final answers and giving due consideration to significant digits.
- To include all non-bonding pairs of electrons in Lewis structures.
- To practise calculations involving enthalpy changes, especially those that require changes of sign and coefficients (as in Question 3).
- To distinguish between those changes in conditions that affect equilibrium concentrations and those that affect equilibrium constants.
- To compare the Bronsted-Lowry and Lewis acid-base theories.
- Candidates should answer a variety of questions, including writing equations, performing calculations and writing detailed descriptions.
- Candidates should practise answering past exam questions as part of their preparation. As similar questions seem to regularly appear on exams, familiarity with past papers and markschemes should confer an advantage to candidates. This is especially the case when we require candidates to refer to gaseous particles or the frequency of collisions, for instance.
- Candidates should write their answers in the spaces provided in the examination booklet, using the number of lines and the marks as a guide to how much to write. 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 three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 18	19 - 22	23 - 27	28 - 31	32 - 40

General comments

The range of marks awarded was very wide (1-40). The most successful candidates showed a thorough command of the material and a high level of preparation, but others seemed unfamiliar with their options. Responses to some questions lacked detail, particularly for Options D, E and F and tended to be journalistic rather than based on chemical facts and principles. All students however followed the rubric and answered two options.

Of the 13 G2 forms sent in, 58% felt that the paper was a smilar standard to last year, 17% felt it was a little easier and 8% thought the paper more difficult. The vast majority (84%) of the teachers who responded felt the level of difficulty was appropriate, 8% considered it was too difficult and 8% too easy. Syllabus coverage was considered to be good by 39%, satisfactory by 46% and poor by 15%. 69% felt the clarity of wording was good, 23% satisfactory and 8% poor. Finally, for presentation of the paper, 69% chose good, 23% satisfactory and 8% poor.

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:

- The presence of undetected uncharged fragments in a mass spectrometer.
- The structure of dipeptides.
- The half equation at the negative electrode during the electrolysis of aluminum oxide.
- An explanation of the difference in flexibility between PVC and polyethene.
- The structure of the *isotactic* form of PVC.
- An understanding of the significance of the insolubility of $Cd(OH)_2$ in the nickel-cadmium battery.
- The presence of the *phenylethylamine* group in amphetamines and adrenaline.
- The structural composition of fats, oils and monosaccharides.

- A comparison of the structural features of the common antioxidants.
- The reaction pathway for the synthesis of ethanoic acid starting from chloromethane.
- The mechanism of electrophilic addition reactions and the relative stability of carbocations.
- The mechanism of elimination reactions.

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

This was an accessible paper and many candidates were familiar with the material. Some gave very good answers and were obviously well prepared. Most students seemed able to complete the paper in the space given.

The areas which seemed well understood were:

- The bonds responsible for IR absorptions.
- The definition and calculation of R_f values.
- The distinction between *macronutrients* and *micronutrients*.
- The effect of a deficiency in vitamin C.
- The change in oxidation number of cadmium in the rechargeable nickel-cadmium battery.
- The contribution of Fleming to the development of penicillin.
- The mode of action of penicillin in treating infectious diseases.
- The meaning of the terms: *side-effect* and *placebo effect*.
- The influence of increasing amounts of greenhouse gases on the environment.
- The functions of nutrients.
- The definition the term *GM food*.

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

Option A - Modern analytical chemistry

Question 1

Candidates had few problems in (a), but although the correct selection of HCl was usually made in (b), many lost a mark as they did not refer to the *change* of dipole during the absorption of IR radiation.

Question 2

In (a), although most identified the formulas of the molecular ion in (i) and the fragment in (ii), the positive charge was often missing. Very few candidates were able to explain the absence of a peak at *m/z* = 29 in (iii) in the mass spectrum. This is because the fragment produced after loss of $C_2H_5^+$ has no charge. A significant number referred to the C–F bond in (b), even though the empirical formula of X given in the question contained no fluorine.

Part (c) was generally well answered, although with some errors in the table in (ii) and the structure of a carboxylic acid in (iii).

Question 3

In (a), most candidates seemed familiar with paper chromatography, but in (iii) many failed to indicate that the pattern of spots would be different. Perhaps the commonest error was to state that the R_f values would be the same but that the solvent would move a different distance. In (b), many candidates knew that the stationary phase in paper chromatography was water, rather than the actual paper.

Option B - Human biochemistry

This was one of the most popular options.

Question 1

Most attempts at (a) were successful, but a surprising number of candidates failed in (b) to give properties, as they misinterpreted the question and quoted structural features, such as the presence of an amino group. Some students had difficulty deducing the structure of the two dipeptides in (c), however most candidates were able to identify the other product as water. Most answers in (d) showed an understanding of protein primary and secondary structures. Responses to (e) were better than in some previous sessions; even so, full marks were rare, with many either omitting the hydrolysis of the protein or referring to a current being passed through the sample rather than a voltage being applied.

Question 2

This was generally well done, although some candidates did not refer to hydrogen bonds when explaining the solubility of vitamin C in water.

Option C - Chemistry in industry and technology

Question 1

This was reasonably well answered. However a surprising number of candidates were unable to write the half equation for reaction at the negative electrode in (a) (ii), and few candidates were able to give an explanation of the reduced malleability of the alloys in terms of their structure in b (ii).

Question 2

Most answers in (a) did not mention the polarity of the C–Cl bond, and the explanation of PVC's flexibility in (b) did not usually refer to the polymer chains being pushed apart. A significant number of candidates drew the isotactic form of polypropene instead of PVC in response to (c).

Question 3

Responses to this question were generally poor perhaps reflecting the unfamiliarity of candidates with the new syllabus content.

Question 4

Most candidates were able to identify the change of oxidation number of cadmium but very few identified the insolubility of cadmium hydroxide as the physical property which allows the process to be reversed.

Option D - Medicines and drugs

This was one of the most popular options.

Question 1

Most candidates were familiar in (a) with the work of Alexander Fleming, but the contribution of Florey and Chain was less well known. The mode of action of penicillin in treating infectious diseases was generally well understood although some candidates referred to viruses instead of bacteria in their answers. The two functional groups were usually correctly identified in (b) although some candidates lost marks due to imprecise answers: *benzene* instead of *benzene ring*, *amid*e instead of *amine.* Similarly explanations in (b) (ii) were often vague and failed to score the marks.

Question 2

This was generally very well answered, with no serious errors.

Question 3

This was answered quite well but very few candidates managed to describe the structural similarity of amphetamine and adrenaline.

Option E - Environmental chemistry

This was one of the most popular options.

Question 1

As in previous sessions, most answers revealed that candidates are much better at describing the effects of greenhouse gases than explaining their interaction with different forms of radiation. Many candidates lost marks in (a) due to imprecise responses. The earth "reflects" and CO_2 "traps" were, as in previous sessions, all too common responses.

Question 2

In (a), most candidates knew the meaning of BOD, but in (b) some did not identify the correct stage of sewage treatment and failed to refer to the oxidation of organic matter. In (c) there was the usual confusion between oxygen used for plant growth and in plant decay and some thought the nitrate and phosphate ions reacted with the water itself.

Question 3

Most candidates could identify two pollutants but explanations as to how they were produced were often too vague.

Question 4

This was generally well done although few realised that oxygen was needed for the decomposition of the plastics in landfill sites.

Option F - Food chemistry

Only a relatively small number of candidates responded with this option.

Question 1

Part (a) was well attempted, but the descriptions of structure in (b) often lacked the essential points - perhaps some candidates did not know how to interpret "structural composition". The effect of double bonds on the intermolecular forces in unsaturated fats was well known in (c), and thankfully few candidates referred to the breaking of covalent bonds.

Question 2

The definition of the GM food and their benefits was generally well understood.

Question 3

Many candidates had difficulty comparing the structural features of the three antioxidants. Most candidates could identify an antioxidant in (c), but the decrease of the risk of cancer or heart disease risk was less well known.

Option G - Further organic chemistry

Overall the questions in this option were not well answered. Many candidates demonstrated only a superficial understanding of organic reactions and mechanisms.

Question 1

In part (a) most candidates identified the correct amine, but the explanation in (b) was often superficial and did not mention the electron-releasing effect.

Question 2

Part (a) proved straightforward for most candidates, but choosing the suitable intermediate for the conversion of chloromethane to ethanoic acid was more difficult, with many not appreciating that an increase in the number of carbon atoms was needed. Very few suggested a reaction pathway involving Grignard reagents.

Question 3

Answers were generally disappointing, with few candidates giving the correct formulas in (a), although the reaction type in (b) was better known.

Question 4

Although some candidates did well in this question, the correct use of curly arrows in organic reaction mechanisms continues to be a problem for many.

Recommendations and guidance for the teaching of future candidates

If possible, reference should be made to the options when covering the core part of the course. It is important that the recommended time is devoted to cover the two options thoroughly. Students who are left to teach themselves the material generally do not perform well. Candidates and teachers are advised to bear in mind the following points:

- Students should give answers that involve proper chemistry and not superficial or 'journalistic' answers. The greenhouse effect, for example, involves radiation being absorbed and re-radiated and not trapped or reflected.
- Students must learn definitions and answer the question very precisely - vague answers rarely gain the marks.
- Teachers should stress the importance of correctly writing balanced equations, and formulas.
- Practise with past papers. Encourage students to highlight the salient points in the questions and markschemes.
- Every part of the syllabus must be covered in detail. There was evidence that some areas had not been covered by some schools.
- Candidates should practise using curly arrows in organic mechanisms. They should check that arrows start and finish in the correct places and point in the right direction (arrows should always start from an electron pair, either from a bond line or from a lone pair on a particular atom).