CHEMISTRY TZ1

(IB Latin America & IB North America)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 32	33 - 44	45 - 55	56 - 66	67 - 77	78 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 29	30 - 42	43 - 53	54 - 64	65 - 74	75 - 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

It is encouraging that the standard overall has improved since the introduction of the new assessment criteria. The new 0 - 6 scale has provided candidates with greater opportunities to score better marks for the work they have conducted. This has been especially important when the teacher has provided too much information and the candidate has still been able to receive credit for their input. The new scale system is much more in line with the IB philosophy of awarding marks based on what candidates can do rather what they have failed to do.

The schools appear to have a better understanding of the criteria and which investigations to assess against the criteria. Very few schools are now assessing DCP with purely qualitative investigations or providing candidates with tables to fill in or providing step by step instructions for the calculation phase (DCP Aspect 2) or the conclusion and evaluation phases (CE).

There still seem to be some schools that are providing their candidates with very simplistic tasks. Although the moderation process is designed to support schools, this is not always possible if the task chosen by the teacher does not provide an opportunity for the candidates to fully demonstrate that they can meet the demands of each criterion.

More importantly simplistic tasks often fail to develop the candidates' practical skills and their understanding of the fundamentals of the course.

The vast majority of schools met the minimum requirements for the SL (40 hours) and HL (60 hours) courses recommended. There tended to be a balance of topics covered and logical progression of knowledgs and skills developed. The schools are making greater use of the Online Curriculum Centre (TSM) for ideas. This has led to a greater uniformity of practical work between schools and subsequently a decrease in diversity. It is, however, a real concern that candidates are still being given very narrow design tasks in which almost all cases, prevent candidates from being able to select meaningfully, an independent variable and then designing a focussed research question. The other problem it creates is that most candidates come up with nearly identical methods and subsequently the authenticity of candidate work is often questionable. It is almost certain in some instances that the teacher has had greater input than is declared on the written and verbal instructions provided by the school for moderation.

Although each criterion is only required to be assessed twice, it is encouraged that candidates are provided with a number of opportunities to be assessed against the criteria and then receive appropriate feedback through written comments and c,p,n notation. It was evident from 4/PSOW forms that there are a number of schools which appear to assess the criteria only twice. Although, it is possible that these schools are recording only the best two marks for each of the criteria and are exposing their candidates to more opportunities other than those declared on forms 4/PSOW.

Candidate performance against each criterion

Design

As stated above, most of the design tasks set by the schools were open-ended and provided candidates with the opportunity to select from a good range of independent variables and then formulate a focussed research question.

Aspect 1

Most candidates scored at least a partial for this aspect. The major problem was with the teacher providing the research question or providing a very narrow task.

Aspect 2

Candidates had some difficulty with this aspect. The main issue here was that the candidates did not indicate explicitly how they were going to control or manipulate the variables. If a candidate has identified a variable to be controlled in Aspect 1 then they must indicate how they are going to control that variable (or monitor it if this is not possible to control) for Aspect 2. Candidates often selected temperature as a variable to be controlled in an exothermic reaction for Aspect 1 and then indicated that they would carry out their investigation at room temperature for Aspect 2. This is clearly not controlling nor monitoring the variable selected.

At times it was difficult to determine whether candidates were using the appropriate equipment as they were not including the size of equipment nor the concentration of solutions used. Candidates need to be aware that their methods need to be reproducible.

Aspect 3

There was significant improvement in this aspect with the majority of candidates selecting a range of five for the independent variable or planning to carry out repeats when a trend or pattern was being investigated.

Data Collection and Processing

Candidates tended to score best in this criterion, especially in Aspects 1 and 2. The vast majority of schools provided candidates with tasks that allowed them to demonstrate a range of data collecting and processing skills.

Aspect 1

Most candidates scored well in this aspect. However, there were still a significant number of schools that do not require their candidates to record qualitative data when it is clearly present and quite clearly important to do so. The consistent use of significant figures and uncertainties is something that many schools need to address.

Aspect 2

Most candidates were able to receive some credit for this aspect. The main problem was with candidates who attempted to graph data and then not take it to the next obvious step of calculating some sort of rate or relationship.

Aspect 3

There is no doubt that there has been a real improvement in this aspect. Schools are clearly spending more time on formative tasks to ensure greater success with error propagation and the appropriate use of significant figures. The graphical work has in general improved also.

Conclusion and Evaluation

Many conclusions and evaluations are still superficial and candidates still do not seem to appreciate the importance of their calculated random error and systematic error when comparing their calculated value against a literature value.

Aspect 1

Although most candidates received some credit for this aspect, they still struggled to make a sensible concluding statement and compare their calculated value against a referenced literature value. Many candidates still do not seem to understand the difference between random and systematic error and their significance. However, it was very pleasing to note that the very best candidates were starting to explain and support their results using theory they had learned in class or had researched and referenced. Although this is not mandatory with respect to the requirements of Aspect 1 it is however good practice and provides the candidate with an excellent opportunity to crystallize their understanding.

Aspect 2

Most candidates were able to identify some appropriate errors and weaknesses and therefore gained some credit. However, very few candidates were able to indicate whether the error/weakness that they had identified supported their value calculated and its variance with the literature value. The practicals that determined a trend rather than a numerical value provided a real challenge for candidates with respect to determining errors/weaknesses as very few candidates looked critically at their processed data (normally in the form of a line or curve of best fit).

Aspect 3

A similar number of candidates compared to previous sessions were able to provide meaningful improvements. However, candidates should be encouraged to explain more fully how they are going to carry out their improvements and indicate what sort of impact they will have on the outcome.

Recommendations for the teaching of future candidates

- Candidates should be provided with plenty of formative work so that they fully understand the requirements of each of the aspects of the criteria. Getting candidates to mark work using the criteria often helps them to better understand the requirements.
- Candidates benefit enormously from the use of c,p,n notation and written comments. Written and verbal feedback on a candidates' practical reports provides them with clear guidance on what they need to improve on for next time. The use of self reflection is also a very powerful tool for improvement.
- Teachers are encouraged to select investigations that are in-keeping with the standard of the IB Chemistry syllabus and TSM material.
- It is recommended that use of workbooks or worksheets for internal assessment is discontinued as they generally provide the structure for the collection of data and the steps for data processing.
- It is mandatory that only the work of the individual candidate can be used for the summative assessment against the criteria.
- Teachers are encouraged not to use Design tasks that have methods that are easily obtainable in standard practical manuals and texts for summative processes. If candidates do use a method they have modified from another source it is mandatory they reference it appropriately.
- For Design tasks teachers are encouraged to provide very general questions which potentially have a number of independent variables to select from. This will reduce the chance of collaboration between candidates and therefore ensure authenticity.
- For Aspect 1 of Design the candidates are required to state the relevant variables they are going to control and then explicitly state how they are going to control them for Aspect 2.
- All investigations selected for the assessment of DCP must allow for the opportunity to collect quantitative data, and where relevant qualitative data must also be recorded.
- Teachers are encouraged to set DCP tasks that will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.
- For Aspect 1, candidates are encouraged to use the number of significant figures for their raw data that are consistent with their uncertainties and vice versa.
- For Aspect 1, candidates must record all relevant qualitative data. The observations noted are often a clue to the identification of errors and weaknesses which can be discussed in CE Aspect 2.

- Candidates are encouraged to record uncertainties in measurements and then to consider their implication on derived numerical quantities in DCP. Candidates are required to carry out error propagation or draw lines/curves of best fit to fulfil Aspect 3 of DCP.
- Candidates must compare their results against a referenced value where appropriate for CE. They are then required to determine the presence and significance of random and systematic error encountered.
- The candidate should identify all potential systematic and random errors through the full analysis of the procedure. The candidate can then list and discuss the errors that could have caused the variance and direction from the literature value and from this, suggest appropriate improvements or modifications.
- Teachers should not use an investigation for the summative assessment of a criterion if it does not allow candidates to meet all the requirements of the aspects of that criterion.
- Teachers should be encouraged to include all marks awarded on form 4/PSOW where the criteria have been assessed summatively.
- Evidence for participation of the Group 4 Project in the moderation sample is no longer a requirement. Entry on form 4/PSOW is now enough evidence.
- The Group 4 Project is the only opportunity for the candidates to be assessed against the Personal Skills criterion. The level awarded by the candidate is required to be recorded on form 4/PSOW against the Group 4 Project entry.
- Teachers are encouraged to implement the changes or modifications recommended by the moderator communicated in the 4IA form.
- Teachers are required to use the current 4/PSOW form or if using their own version, it must have all requirements included. Boxes where the the moderator and senior moderator can enter their marks is also a requirement.
- Teachers are encouraged to consult the Chemistry Subject Guide, the Teachers Support Material and the latest Handbook of Procedures for the Diploma Programme before submitting work for moderation.

Communication with moderators

Before moderation for the session started, guidance was 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 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).

Design Aspect 2

- This Aspect does demand that the candidates 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.
- Candidates 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 candidates the full procedure then award Not at All.
- If a teacher has given a partial procedure then see what can be awarded for the candidate's own contribution. Probable award here is Partial.
- If a candidate has used a partial method from another source then that source should be acknowledged. Once again see what can be awarded for the candidate's own contribution. If a candidate 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 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.

Design Aspect 3

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

- If the candidate has designed the procedure so poorly that you feel that no relevant data would be collected then award Not at All.
- If the candidate 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 candidates have failed to identify suitable materials to control the variable e.g., no ammeter in the common "factors affecting electrolysis" investigation where candidates 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 the 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 candidates then the maximum the moderator can give is n = 0.
- If the candidate 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 candidate does not find qualitative data to record. Sometimes there is no obviously relevant qualitative data to record.
- If a candidate 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 the 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 candidates 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 candidate 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 candidate has been inconsistent with significant digits for just one data point or missed units out of one column heading. If you feel the candidate has demonstrated that they were paying attention to these points and made one careless slip then you can still support the maximum mark under the ‘complete does not mean perfect’ rule. This is an important principle since often **good candidates responding in full to an extended task unfairly get penalised more often than candidates 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 candidates do all the hard work and then lose a mark from the moderator because they did not give the table a title. 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 candidates which quantities to plot then award Not at All.

- If a candidate 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 candidates have been told which variables to plot) or the candidates have followed structured questions in order to carry out data processing then the moderator should award Not at All.
- If a candidate has simply plotted raw data on axes with no trendline then award Not at All.

DCP Aspect 3

- If you cannot easily determine the candidate’s method of processing then award Partial at maximum.
- The candidate 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 the 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 there is 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 candidate 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 candidate has clearly attempted to propagate uncertainties then support a teacher's award even if you feel that the candidate could have made a more sophisticated effort. Please **do not** punish a teacher or candidate 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 candidates through the discussion, conclusion and criticism then, depending on how focussed the teacher's questions are and on the quality of candidates' response the maximum award is *partial* for each aspect the candidate has been guided through. You have to make a judgement based only on the candidate'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 and so on, such a clear statement earns Partial. To secure Complete the candidate 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 candidate has identified the major sources of error. There will always be other possible sources but I do not want to force candidates 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 candidates that could have been condensed into a quarter of the length.
- There is no written requirement to state the direction of each error source so we are not looking for an explicit statement. However, the candidate's comments on significance of sources of error must be CONSISTENT with direction of error. For example, heat loss to the environment being considered the main source of error when the experimentally determined enthalpy value is actually greater in magnitude than the literature value and, therefore, implying another more major source of error in the other direction. This inconsistency would reduce the aspect award to Partial.

When not to mark down CE Aspect 2

- Simply apply the principle of complete does not mean perfect. For example if the candidates 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 reported. Be sensible. If the candidate 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 candidate), 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 candidate. Yes, this does mean that candidates 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 candidates 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 candidates 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 candidates 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 - 26	27 - 29	30 - 33	34 - 39

General comments

This paper consisted of 40 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 14 G2 forms that were returned. In comparison with last year's paper, 45% of respondents considered the paper of a similar standard and the remainder considered the paper more difficult. 79% stated that the level of difficulty was appropriate and the remaining 21% considered the paper too difficult.

Syllabus coverage was considered good by 29%, satisfactory by 65% and poor by 6%. Clarity of wording was considered good by 16%, satisfactory by 62% and poor by the remainder. Presentation of the paper was considered good by 39% and satisfactory by 46%. Approximately 15% felt that the presentation of the paper 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 88% to 28% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.60 to 0.13. (The higher the value, the better the discrimination).

Comments were made on the following questions.

Question 3

As this is a common question, see SLP1 TZ1 Q.4 for comments. For HL, 62% of candidates got this question correct.

Question 8

One respondent stated that in this question there is an assumption that each of the statements across period 3 assumes a left to right trend. This is correct and normal conventions are assumed here on IB Chemistry MCQ's with respect to periodic trends. Another respondent stated that it would have been better to use the word continually instead of continuously, which is a valid comment in relation to the trend in first ionization energies across period 3. For this reason it was decided to accept two answers, both A and D.

Question 12

As this is a common question, see SLP1 TZ1 Q.11 for comments. For HL, 57% of candidates got this question correct.

Question 13

One respondent stated the wording of statement I. (σ bonds result from the axial overlap of orbitals) was confusing. However, the description of both σ and π bonds is explicitly mentioned in the teacher's notes corresponding to AS 14.2.1 in the guide.

Question 14

One G2 comment stated that the nomenclature of alkynes is off- syllabus. However, in this question, the condensed structural formula of propyne, CH_3CCH was given in B and HL candidates should realize that alkynes have a carbon-carbon triple bond (AS 14.2.2 and 14.2.3). Hence, in propyne one carbon is sp^3 hybridized and the other two carbon atoms are sp hybridized.

Question 19

One respondent stated that this was a difficult question if a candidate had not done a laboratory experiment previously on colorimetry. It is fair to say that the question itself was challenging (30% of candidates got the correct answer). However there was enough information in the question to determine that the correct answer was C, even by a process of elimination of the other three responses and basic knowledge of transition metal complexes (AS 13.2.6).

Question 20

As this is a common question, see SLP1 TZ1 Q.18 for comments. For HL, 37% of candidates got this question correct. The question also had the lowest discrimination index in the entire paper (0.13). For this reason it was agreed to remove this question entirely.

Questions 21 and 22

One respondent stated that this new style of question was tricky. However, 67% of candidates got the correct answer, B for Q.21. Q.22 proved to be tougher with 35% of candidates getting the correct answer D. The question proved to be a good discriminator however, with an associated discrimination index of 0.51, one of the highest on the paper.

Question 23

One respondent stated that this question is off-syllabus. This is not correct and falls well within the understanding of equilibria from Topic 7. 53% of candidates got the correct answer, D.

Question 26

One G2 comment suggested there are two answers to this question. However, the correct answer is C, namely that NaOH has a higher pH than NH_3. 71% of candidates got this question correct.

Question 31

There were two G2 comments on this question. Both referred to the fact that statement I. should have been more explicit i.e. a half-cell with an electrode in a 1.0 mol dm^{-3} solution of its ions, which is a valid comment. The majority of candidates however, 52%, chose D as the correct answer.

Question 32

One respondent felt that the wording of the question (onto a metal plate) could have been improved, which is a fair comment. It might have been clearer if "a copper spoon" for example was stated instead of a metal plate. Candidates however did not find the question difficult and 68% got the correct answer.

Question 38

The uses of esters are specified in AS 20.4.1 in the guide. However, only 28% of candidates gave D, as the correct answer (flavouring agents, perfumes and solvents), and this yielded a very low discrimination index (0.18). Most candidates did not realise that esters can also be used as solvents and this is referred to in a number of sources, including several textbooks and on the internet. Esters are used extensively as solvents (e.g. adhesives and are capable of dissolving various greases. Methyl acetate is used as a solvent for several oils and resins. In the pharmaceutical and food processing industries, ethyl acetate can be used as an extraction solvent. This was discussed at length during GA and it was hence decided to accept answer A, which most candidates gave, in addition to the actual correct answer D.

Question 39

One respondent stated that this question was difficult since it was the type of isomerism was not specified. However HL candidates, given the molecular formula $C_2H_2Cl_2$, should be able to determine that there are three isomers.

Question 40

There were two G2 comments on this question. However, the question did not pose a problem for candidates with 78% of candidates getting the correct answer as C, i.e. determining the enthalpy of neutralization in a beaker would be the experimental procedure most likely to lead to a large systematic error. The key point here is the phrase most likely.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 26	27 - 36	37 - 47	48 - 58	59 - 69	70 - 90

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. In general the performance of candidates this year was better than that last year. Teachers' impressions of this paper were conveyed by the 21 G2 forms that were returned. In comparison with last year's paper, 10 respondents thought this year's paper was of a similar standard or a little easier, with the remainder considering it a little more difficult. 13 out of 21 respondents thought the level of difficulty was appropriate and 8 thought it was too difficult. Syllabus coverage and clarity of wording were considered good or satisfactory by 19 of 21 respondents, and the presentation of the paper was considered good or satisfactory by all 21 of the respondents. Obviously with so few G2's 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:

- explanation of the colour of transition metal complexes
- stating correct redox equations
- quantitative kinetics
- drawing the Maxwell-Boltzmann distribution to show the effect of a catalyst
- the difference between a Maxwell-Boltzmann distribution curve and an enthalpy level diagram
- organic reaction pathways
- calculating the pH of a buffer
- structure and bonding of Al_2O_3 and $AlCl_3$ and structure and bonding in general
- explaining why compounds can or cannot conduct electricity
- products of electrolysis and calculations of electrolytic cells in series
- effect of volume changes on gaseous equilibrium
- Haber process, explaining the economic considerations
- showing organic reaction mechanisms using curly arrows, particularly elimination.

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:

- stoichiometry
- calculation of pH
- explanation of how catalysts work
- the names of the isomers of C_4H_9Br
- enthalpy change calculations.

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

Section A

Question 1

Most responses to (a) indicated a correct understanding of oxidation number, although many candidates failed to use the correct notation. 2+ and II were frequently seen instead of + 2 and these answers were not awarded marks. Although the calculation in (b) was carefully structured, few candidates ended up with the correct final answer. However, several scored intermediate marks, especially by the ECF principle. In (c), several errors were seen in the electron configuration, the commonest of which was to give that of elemental copper. Few attempts at the explanation of colour referred to the splitting of the d orbitals and electron transitions, and in several instances candidates referred to emission instead of absorption. This proved to be the most difficult part of question 1.

Question 2

The presented data in the question proved to be quite tricky for many candidates, and answers to this question were generally disappointing. Very few stated the need to maintain a constant volume in (a) and many thought that water was added in order to provide a solvent for the reagents. In (b)(i), although the question clearly told candidates to deduce the order for each substance, several did this for only two substances, often the species shown as reactants in the supplied equation. Then the orders shown in the rate expression did not always match the ones deduced. Only the better candidates got the rate expression correct and lots of guess work was seen here. A number gave K_c instead of k. The hypothesis question was also poorly answered and many candidates were not prepared for a question where both were incorrect. Part (c) proved difficult and only the very best candidates got the two concentrations correct most just substituted volumes into their rate expression. In (d), many candidates drew an enthalpy level diagram and not the Maxwell-Boltzmann distribution curve and others showed two curves. Those that did draw a correct curve often mislabelled the axes. However, the vast majority could explain how a catalyst worked.

Question 3

Most attempts in (a) at drawing the PVC structure were correct, although some showed terminal hydrogen's, or missed out the continuation bonds on carbon. Only the weakest candidates drew structures containing double bonds. Part (b), about the importance and disposal of plastics, was generally quite well done as there were a lot of possible answers allowed. Few candidates scored full marks in (c) - many attempts at equations were unbalanced, and several candidates used hydrogen in Step 1 to give ethene as an unlikely product. In (d)(i), the only issue was that some candidates forgot the reversible arrow in the equation, but a pleasing number were able to complete the pH calculation successfully. However, in (e), only the best candidates scored full marks for the buffer calculation; in some cases an incorrect expression was used, but more often there was no attempt to calculate the equilibrium amounts or concentrations. In (f), there were very few who could write appropriate equations for the buffer action, even though it clearly stated that the answer should include equations many explained buffer action without any equations and scored no marks as a result.

Section B

Question 4

This was a question which was often chosen by the weaker candidates. There was only 1 mark available for the A_r definition in (a), and hardly any candidates scored it. Although there were fortunately very few answers along the lines of "the numbers of protons and neutrons in the atom", most attempts omitted one or more of the key ideas (such as average, mass and relation to C-12). In (b), the majority of diagrams of the mass spectrometer were poorly drawn and some almost impossible to understand. The key stages were often shown, although rarely all of them in a single answer. Many candidates scored 3 or 4 marks but only the best candidates scored 5. However, the calculation of the abundances in (c) was generally well done although some candidates did get confused by using 100-x instead of 1-x as a way of working out the abundances. A great variety of isotopes appeared as examples of medical radioisotopes, many of which did not exist and others which were not radioactive; C-14 was a common wrong answer. Answers to (e) were disappointing - many candidates seem not to have considered the 3-mark allocation and often mentioned only the presence or absence of d electrons. There were disappointingly few correct equations in (f) - not all equations began with the symbol for sodium, many more showed sodium oxide as a product, while others were unbalanced. Also, state symbols if included were not always correct. The comparison of the reactivities of rubidium and sodium in (g) however was usually correct. Part (h) was a disaster for many candidates. Hardly any stated the correct structure and bonding of both aluminium compounds in (h)(i) - often both were covalent or both ionic, a large number tried to draw an aluminium oxide molecule. In (h)(ii), several answers referred to $Al(OH)_3$ instead of to $AlCl_3$ and few equations were correct, many thought that P_4O_{10} was basic. Those who lost marks in (h)(i) often lost marks in h(iii) as well, as they were very unclear about structure and bonding in general. A large number of answers referred to the movement of electrons instead of ions.

Question 5

This was a popular question and generally well answered by many. However, although many candidates were able to start the calculations in (a), errors were common, usually omitting or using wrong coefficients or, sometimes, doing the subtractions the wrong way round. Many marks were awarded by ECF. Also, many common mistakes with ΔG were seen- e.g. not converting ΔS to KJ, or temperature to Kelvin. In (b) few candidates gave two characteristics of equilibrium - the reference to constant concentrations was usually missing. Although the K_c expression was usually correct in (c), the substitution of concentrations in (d) was usually those of the initial values instead of the equilibrium values. Many incorrectly gave units for K_c which although not penalized are totally incorrect as equilibrium constants are based on activities and hence never have units. The effect of increasing pressure in (e) was usually correctly predicted, but many made the mistake of not stating gaseous. Answers to (f) showed evidence of considerable confusion, with few stating that lowering the temperature would lower the yield and explaining why. In (f) candidates struggled to outline why the conditions used were not the ideal ones and if they mentioned improving rate they often failed to mention the effect on yield. As in previous sessions, some candidates in (g) wrote that either or both of K_c and the equilibrium position would be changed by the catalyst, and many forgot to mention that the rates of forward and reverse reaction are affected equally.

Question 6

Although most diagrams in (a) looked like voltaic cells, there were some very poor diagrams. The salt bridge was quite often missing or unlabelled and, if there, was often not in contact with the solutions at all. Many candidates got the direction of electrons incorrect or failed to label this on their diagram. In (a)(ii) attempts at the equations were disappointing, with many written the wrong way round, or not identified as oxidation or reduction and some candidates gave equilibrium signs. In (a) (iii) there were many examples of the wrong sign used for the $E^{\ominus}$ calculation, or wrong data used; a few candidates forgot to include the unit V. In (b)(i) the most common mistake was stating Cd^{2+} instead of Cd. In (b) (ii) many candidates were tempted to write the more familiar equation involving Fe^{2+} and MnO_4^- ions even if they identified Cd. In (c), the hydrogen electrode did not seem to be well known, with few diagrams resembling the real thing, rarely were all 4 marks scored – often candidates mentioned 1 atm but not $H_2(g)$, or 1 mol dm^{-3} but not H^+. Most attempts in (d) were disappointing, with low marks in most cases. The belief that ionic compounds conduct by the movement of mobile electrons is widespread, and few candidates were able to state what happens during electrolysis in terms of electron loss and gain. The calculation was poorly done - in most cases it involved the wrong products, which usually included sodium, very few candidates realised that the products would be hydrogen and oxygen.

Question 7

This was the least popular question, but there were some very good answers seen. In parts (a) and (b), most candidates were able to correctly name the organic compounds, and identify which halogenoalkane would react via a Sn1 or Sn2 reaction, however in (b) (i) many candidates stated first order instead of unimolecular, which although we accepted it in this instance is not correct. Attempts at the mechanism were generally disappointing though, with errors of incorrectly drawn arrows and faults in the transition state frequently occurring. Also candidates often had an arrow coming from an H in OH^- instead of from a lone pair of electrons on O Answers to (c) explaining how $[OH^-]$ effects rate were generally good, however, some only predicted and didn't explain in terms of the rate limiting step.

Answers to (d) were generally good and only the weakest candidates didn't state that bromobutane reacted faster as the C-Br bond was weaker. Most candidates in (e) knew how enantiomers affected plane-polarized light, but few stated that their properties were identical and many instead suggested they were similar. The elimination mechanism in (f) proved the most difficult for candidates and many had no idea of how to write the mechanism.

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 the correct notation for writing oxidation numbers
- 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 distinguish between Maxwell–Boltzmann curves used to explain temperature effects from those used to explain the effect of a catalyst
- to include continuation bonds, but not terminal atoms, when drawing polymer sections
- to use reversible arrows in equations representing the dissociation of weak acids and bases
- to practise calculations involving buffer solutions and gaseous equilibria, especially the need to calculate equilibrium concentrations
- to use precise forms of words for key definitions, such as for relative atomic mass
- to practise drawing simple but clear diagrams for examples such as the mass spectrometer, the hydrogen electrode and voltaic cells
- to distinguish between conduction of electricity by mobile electrons and mobile ions
- to practise calculations involving enthalpy and entropy changes, especially those that require consideration of the numbers of bonds involved (as in Q5)
- to distinguish between those changes in conditions that affect equilibrium concentrations
- to practise writing all the organic reaction mechanisms that appear on the syllabus, with particular regard to the use of curly arrows.

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.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 18	19 - 23	24 - 29	30 - 34	35 - 50

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

Specially difficult was:

- A2 the principles of AA spectroscopy
- A3 explanation of the colours of transition metal complex ions
- B1 (d) the type of interactions in tertiary structures of proteins
- B3 (a) the bonding of a base in a nucleotide
- B3 (d) the role of restriction enzymes in DNA profiling
- C2 (e) the definitions of a liquid crystal and lyotropic
- D3 (c) the use of chiral auxiliaries
- E3 (d) writing the expression for Ksp and using it in calculations
- F1 (c) non-enzymatic browning
- F3 the identification of optical isomers and the CORN rule
- G mechanisms of reactions

Simple chemistry like balanced equations C1(b) and E3(c), polymerization C2(d), oxidation and reduction C1(a), identification of chiral atoms D3(a) also seemed difficult.

The levels of knowledge, understanding and skill demonstrated

Although there were some excellent results too, the majority of the candidates had difficulties with the paper and the results were in many cases poor. This can partly be explained by the fact that the options are left until the end of the course and probably are not covered thoroughly due to lack of time, but there was also evidence of poor knowledge in general chemistry.

The questions that scored the lowest marks were those where candidates have to explain something. Candidates have difficulties in expressing themselves with precision and answer superficially. Some candidates have difficulties interpreting the question and answer what is not asked for or are not aware that the question is worth several marks and answer too briefly.

It was surprising to see in a few cases that different candidates of the same school answered different options, giving the impression that the candidates may have chosen an option to self-study, which resulted in superficial knowledge.

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

Option A - Modern analytical Chemistry

Question A1

In (a) candidates generally identified the correct alcohols. Some candidates identified the first peak for a methyl group, but gave no evidence that it was clear that the peak was due to more than one methyl group. Hardly any structures were drawn, which would have helped to identify the protons better. The idea that the doublet in spectrum 2 was due to a neighboring carbon atom with only one hydrogen attached, was done better.

In (b) (i) most candidates identified several fragments, though charges were often forgotten, in (ii) many candidates identified the correct alcohol.

In (c) most candidates demonstrated their understanding of the similarities, though some did not see that the question was worth 2 marks, and only answered that both have the same types of bonds without specifying which ones.

Question A2

It seemed that very few candidates were familiar with the function of atomic absorption spectroscopy (a). Some could describe the function of fuel but few knew the function of the atomizer and the most confusing answers were given about the monochromatic light source.

Part (b) was done better, though some had difficulty in calculating the concentration of the original solution.

Question A3

Part (a) was done poorly, because although many candidates referred to the presence of double bonds in retinol, few included the idea of conjugation. Very few candidates referred to cholesterol.

In (b) quite a few candidates referred to electron transition between split d-orbitals, but they generally did not realize that the exchange of the ligand was the reason for the change in colour, and so lost 2 marks.

Option B - Human Biochemistry

This was a popular option.

Question B1

Questions (a), (b) and (c) were generally well answered, though in (b) many candidates gave the molecular form of the zwitterion.

Part (d) was answered poorly, hardly any candidate gained more than 2 or 3 marks, because of lack of precision in identifying the groups involved in the interaction.

Question B2

Few candidates knew the deficiencies in (a), but goiter was best known. Quite a few candidates mentioned vitamin B for the other two deficiencies, but they failed to specify B1 and B3 or gave them the wrong way around.

Candidates managed generally to obtain some marks in part (b), though vague answers like distribute “healthy food” or ban “unhealthy food” were often seen.

Question B3

Many candidates seemed to think in part (a) that they had to explain the spine of the DNA or the pairing of the bases. Very few used the word covalently to indicate the bonding and described that it is formed by a condensation reaction.

Part (b) was better, most candidates showed the correct base, and knew the hydrogen bonding, but very few could identify the hydrogen atoms taking part in it. Surprisingly many candidates think a C-H can make a hydrogen bond.

Part (c) was done poorly. In (d) many candidates described how the information is passed to the cells, named the bases in DNA and RNA, but clearly did not understand what was being asked.

Option C - Chemistry in Industry and Technology

Few candidates chose for this option and the results were generally poor.

Question C1

(a) Few candidates explained correctly that Al is more reactive than Fe as the cause of different methods of reduction.

The equations in (b) were generally better answered, although some candidates clearly struggle with the balancing of equations.

In (c) most candidates could at least obtain one mark in the explanation why iron is converted into steel, though they did not seem aware that an explanation was expected and that the question was worth two marks.

Surprisingly few candidates did not name the material used for the electrodes (d) and in general vague answers were given as to why it is important to recycle aluminum (e).

Question C2

The question was also not well done but, in (a) the branching of HDLE and LDPE was generally better. The mechanisms involved (b) were not so well known, but the change in properties (c) at the addition of pentane to polystyrene and its use were better known.

(d) Few candidates could give the correct equation to produce Kevlar, though some scored 1 mark for giving the correct products.

(e) The concept of liquid crystals was not understood by many. Very few mentioned that lyotropic is a solution.

Question C3

Like C1, this was a question that demanded knowledge of basic chemistry, but it was poorly done. Vague answers were given as to “toxic mercury”.

Option D - Medicines and drugs

Again a popular option.

Question D1

This question was done generally well. Parts (a), (b), (c) and (d) had generally good answers, though some confused the problems associated with excess of paracetamol with those of aspirin.

In (e) (i) several candidates could not identify the group, but the ester in (ii) was generally identified.

In part (f) most could name the type of the reaction, and many did not name the reagent, with "carboxylic acid" being a common answer.

Question D2

Many candidates identified that penicillin interferes with cell wall formation (a), but not all of them understood that it is through reaction with the enzyme responsible.

In part (b) were some vague answers about penicillin that it acts on "more bacteria" and very few named the resistance to stomach acid.

Surprisingly few candidates identified the amide in (c). The idea of the strained ring was well known, but very few stated that the opened molecule binds to the enzyme that synthesizes the cell wall, some stated that it binds to the cell wall itself.

Question D3

The better candidates could identify the chiral carbon atoms (a) and many could explain the importance of chirality in drug action (b) with an example.

(c) The use of chiral auxiliaries was less known, many candidates failed to recognize that they are chiral themselves and many confusing answers were given.

(d) The use of paroxetine as a salt was not well understood. Not many stated that it increases the polarity, but most recognized it becomes more water soluble. Some candidates identified the amine group as responsible, but most candidates thought it was the F atom.

Option E - Environmental chemistry

Question E1

In (a) many candidates stated that incomplete combustion as the source of carbon monoxide, but not many included the high temperature needed to produce the oxides of nitrogen.

In (b) many candidates did not identify the catalyst and very few described the passage of hot gases over the catalyst or the adsorption to its surface. Several equations that contained correct formulas were left unbalanced.

Sulfur dioxide was a common answer to part (c).

Only some of the candidates mentioned electrostatic precipitation but many described how it works.

Question E2

(a) The idea that incineration reduces volume was generally well known and toxic gases were identified as disadvantages, though it was sometimes vaguely described like "harmful emissions".

Part (b) was generally well done, though many candidates did not state both low activity and short half-life as characteristics for low-level waste. Many candidates could name a source of low-level waste.

(c) The disposal of high-level nuclear waste was answered well by most candidates, though many did not obtain the mark for not specifying "deep". The problems with the disposal were generally well answered.

Question E3

(a) The knowledge of secondary waste water treatment was superficial. Many named bacteria without oxygen or did not name activated sludge.

(b) The difficulty to remove nitrates was also poorly answered.

(c) Almost no correct equations were seen, many candidates wrote P for phosphate.

Part (d) was poorly answered. Only very few candidates scored full marks, generally giving the alternative calculation. Some managed to score partial and EFC marks.

In (e) few candidates obtained 2 marks, but those who did generally did so by stating that the position of the equilibrium shifts to the right instead of saying that $Ni(OH)_2$ precipitates due to the common ion effect.

Option F - Food Chemistry

Question F1

(a) The difference between a food and a nutrient was well understood.

(b) Surprisingly few candidates could give three characteristics of monosaccharide molecules.

(c) There were few good answers, most of them just stating that this is a Maillard reaction without further explanation.

Question F2

Part (a) was reasonable answered. Most candidates understood that certain wavelengths are absorbed and complementary are reflected, although many wrote light when visible light is meant.

(b) Few candidates saw that 375 nm is outside the visible region and for 530 nm often the wrong colour was named.

Part (c) was answered well by the candidates.

Question F3

(a) The chiral atom was generally identified by the candidates, chirality itself and the difference to +(d) and –(l) is not well understood.

(b) Many candidates drew the correct enantiomer.

(c) Many candidates guessed which was the D isomer. The CORN rule was generally stated, but not explained. Other candidates confused clockwise and anti-clockwise.

Question F4

Part (a) was done well, though some candidates just mentioned the alcohol or the benzene ring instead of the phenol and some candidates recognized BHT as a free radical inhibitor.

(b) Many candidates stated that vitamin C is a reducing agent, but few that it reduces the concentration of oxygen.

Option G - Further Organic Chemistry

Question G1

In (a) the majority of candidates gave the correct equation.

Many candidates named at least one alcohol correctly in (b).

In (c) most candidates named but-1-ene correctly but few obtained full marks for the mechanism. The use of curly arrows and their origin from a lone pair of electrons seems poorly understood.

Question G2

Very few candidates answered that an induced dipole is formed when bromine approaches the alkene in (a).

In (b) most candidates named the correct products.

Part (c) presented again problems in the mechanism. Markonikoff´s rule was mentioned very often, to indicate that 2-bromobutane is preferably formed, but the inductive effect was seldom stated.

Question G3

In (a) candidates generally knew the catalyst but again the mechanism was poorly done. It probably was for candidates the most challenging one.

(b) Candidates often named the products but had difficulty in the formation of the electrophile. The charge for NO_2^+ was often omitted.

Recommendations and guidance for the teaching of future candidates

- Candidates must be prepared more thoroughly for paper 3 as detailed knowledge is needed. It is also not recommended that candidates prepare the option on their own.
- Candidates should include relevant chemical concepts when giving explanations and not just describe what is happening during the process. More practice is needed in writing balanced chemical equations, identification of different functional groups and calculation. For option G more practice in outlining mechanisms is recommended.
- Candidates should read questions carefully and pay attention to the wording e.g. state or explain and to the marks allocated (to have an idea of how extended an answer should be). They should be discouraged from using the space provided by writing out – in order – half of the question before adding their own answer.
- Candidates need to practise past papers to see which type of questions are asked and how thorough their knowledge must be.
- Candidates should use the data booklet enough during the course to be familiar with it and to practise the identification of functional groups in the molecules given.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 16	17 - 19	20 - 22	23 - 24	25 - 29

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 18 G2 forms that were returned. In comparison with last year's paper, 44% of respondents considered the paper of a similar standard; 17% a little easier and the remainder considered the paper generally difficult. 89% thought the level of difficulty was appropriate and the remaining 11% considered the paper difficult.

Syllabus coverage was considered good by 61%, satisfactory by 33% and poor by 6%. Clarity of wording was considered good by 44%, satisfactory by 44% and poor by the remainder. Presentation of the paper was also considered mainly good (61%) with the remainder considering the paper satisfactory.

Overall, this paper appeared to be reasonably accessible and fair as borne out by the more general G2 comments received.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 89% to 23% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.59 to -0.01. (The higher the value, the better the discrimination).

Comments were made on the following questions.

Question 4

Some respondents felt that this question was confusing and suggested that the wording of the question could have been slightly modified to make it more accessible, especially as moles of gas was given in the stem of the question. This was discussed and deemed to be a fair comment. However, the question itself was generally well answered by candidates and in fact 58% of candidates gave answer A which is the correct answer.

Question 7

One G2 comment stated that in relation to statement II any collection of elements shows a trend. This is a valid comment and it was agreed that the wording of the question would have been better phrased if a specific group (such as group 7) was chosen and II. stated alternatively as elements in group 7 show a gradual change in physical properties.

In addition, the same respondent stated that although this is SL, any candidate who may have been exposed to HL material may have found statement III. confusing as this would really only be true for main group elements and would be further complicated if one considers the transition metal elements of the d-block. For this reason again it would have been better to have chosen a particular period (e.g. period 3) for this statement. However, this did not seem to have any effect on candidate performance and in fact 64% of candidates gave the correct answer C.

Question 8

One respondent stated that in this question there is an assumption that each of the statements across period 3 assumes a left to right trend. This is correct and normal conventions are assumed here in MCQ questions in IB papers with respect to periodic trends, a point perhaps worth noting to candidates in preparing for such questions. This question was also reasonably well answered, with 69% of candidates getting the correct answer, A.

Question 9

The correct answer to this question is A i.e. the best description of the bonding present in the ammonium cation is the sharing of electrons between atoms. Only 37% of candidates got the correct answer here and as pointed out in the G2 comment, many chose D, which proved to be a good distractor. Although many candidates recognized the term sharing of electrons, a significant number did not realize that the sharing is between atoms.

Question 10

One respondent stated that as cerium has more than one oxidation state, then technically Roman numerals should have been used for nomenclature purposes for both cerium sulfate and cerium phosphate. This is a valid point as cerium does occur in a number of oxidation states (+2, +3 and +4). The question could have simply asked for the correct formula of cerium(III) phosphate, which is D, $CePO_4$. 52% of candidates got the correct answer.

Question 11

Two G2 comments referred to the fact that the structure of CO is not expected of SL candidates. This is not correct in fact as in the guide in the teachers note in relation to AS 4.2.2, CO is explicitly mentioned as one of the key examples of dative covalent bonding. This was not a problem for the candidates either as 61% gave D as the correct answer.

Question 13

One respondent stated that this would have been a very difficult question unless fullerenes were known. However, the structure and bonding of all three allotropes of carbon (diamond, graphite and C_{60} fullerenes) are securely on syllabus as specified in AS 4.2.9 in the guide.

Question 14

One respondent stated that ideal gases are assumed to be made up of particles that are so distant from one another that the intermolecular forces are negligible, so the answer should be none of those listed. The question itself however did not mention ideal gases and the majority of candidates gave B as the correct answer i.e. that the intermolecular forces that exist between molecules of carbon monoxide are van der Waal's forces and dipole-dipole attractions.

Question 15

There were two G2 comments on this question. One commented that the question was complicated and the other stated that that the exothermic nature of a neutralization reaction is subtle. However, AS 5.1.2 clearly states that both combustion and neutralization are exothermic reactions, which means B is the correct answer. 45% of candidates got this question correct.

Question 18

There were several G2 comments on this question all of which related to statement I. Although it would have been better if not was put in bold in the question, the wording clearly proved difficult for candidates and as a result only 34% got the correct answer. In addition, this question was the only question on the paper which yielded a negative -0.01 discrimination index. For this reason it was agreed to remove this question entirely.

Question 20

One respondent stated that this question was tricky. However, the question proved no problem for candidates with 70% giving the correct response, A.

Question 24

One respondent suggested perhaps omitting this question which tested the IUPAC name for Fe_2O_3. However, this clearly tests AS 9.1.3 from Topic 9, which states that candidates should be able to state the names of compounds using oxidation numbers. In the Teacher's notes in the guide, it is also stated that oxidation numbers can be represented by Roman numerals, where variable oxidation states are involved. The question itself was well answered with 80% getting the correct answer.

Question 30

One G2 comment suggested that the distractors for this question were poor. In order of difficulty, the question itself was the 8^{th} easiest on the paper and the corresponding discrimination index was 0.27, which although relatively low, was not the lowest on the paper.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 17	18 - 23	24 - 29	30 - 35	36 - 50

General comments

The range of marks awarded varied considerably; the best candidates showed a thorough command of the material and a high level of preparation, although in this session there were many candidates who scored poorly in either Section A (especially in Q.1) or in their chosen Section B question. It was surprising the number of candidates who did very poorly on the volumetric chemistry question in Q.1 and the organic chemistry question, Q.6 in Section B. Clearly many candidates are not doing ample laboratory work throughout the programme or appear not to be getting a solid grounding in organic chemistry which is a concern.

Teachers' impressions of this paper were conveyed by the 28 G2 forms that were returned. In comparison with last year's paper, 25% of respondents considered the paper of a similar standard; 4% easier and the remainder considered the paper more difficult, with the majority claiming that the paper was a little more difficult (41%). 46% thought the level of difficulty was appropriate and 54% considered the paper too difficult.

Syllabus coverage was considered good by 32%, satisfactory by 50% and poor by 18%. Clarity of wording was considered good by 14%, satisfactory by 61% and poor by 25%. Presentation of the paper was considered mainly either satisfactory (57%) or good (39%) with the remainder considering the paper poor.

In general, the paper appears to have been slightly difficult for candidates.

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 chemistry
- Maxwell-Boltzmann distribution curves
- Definition of relative atomic mass
- Periodicity
- Electrolysis
- Organic chemistry in general and in particular organic reaction mechanisms

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

Topics generally well answered included:

- Description of how a catalyst works
- Lewis structures
- Aim 8 question on disposal of plastics
- Oxidation of alcohols

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

Section A

Question 1

There were several G2 comments on this question, all of which claimed that the question was difficult for SL candidates especially as a three-step reaction process was involved. Certainly some of the weaker candidates struggled with this question, but with the application of ECF marks, most candidates should have been able to score the majority of marks in the question. What was more worrying was the large number of candidates who scored zero or close to zero marks on Q.1, which meant they had little idea of a titration from their exposure to laboratory work in the programme as a whole.

In (a) (i), most candidates showed a reasonable understanding of oxidation numbers, but relatively few scored full marks as they did not read the question which asked explicitly for the change in oxidation numbers. A number also incorrectly wrote 5+ going to 4+ instead of +5 going to +4 i.e. they mixed up charges with oxidation numbers. In the oxidizing agent question in part (ii), the most common mistake was candidates writing nitrogen, instead of the nitric acid, which is the agent involved. In (b), candidates typically either did very well or scored almost no marks at all. In (i), a number of candidates did not convert to dm^3 and some did not use the average volume in their calculations, again failing to read the question carefully. (c) however was well answered, though some candidates made reference to the ions as charge carriers rather than giving a description of delocalized electrons. Other candidates stated just mobile electrons instead of stating sea of mobile electrons which was required for the mark.

Question 2

Most of the G2 comments on this question predicted the downfalls in the performance of the candidates. Q2 proved to be poorly answered overall with virtually no candidate scoring full marks. In (a), often the question was not addressed accurately. It appeared that some candidates interpreted the question to imply that one of the hypotheses was correct. Many candidates did however score at least one mark for stating that the concentration of iodine did not affect the rate. In (b), candidates typically understood the basics of the concept. However, the most common error was candidates stating that there are more collisions instead of stating that there are more frequent collisions i.e. some reference to time had to be given which has been commented extensively previously in subject reports. In (c), very few candidates knew how to draw a Maxwell-Boltzmann distribution curve which was very surprising, as this is securely on-syllabus. Many candidates drew an enthalpy-level diagram, others drew two curves and many dropped marks for incorrectly labelled axes or poorly sketched curves. For the latter, the most common mistakes involved symmetric curves, curves not starting at the origin or crossing the *x*-axis at high energy. In contrast however, (c) (ii) was very well answered with most candidates stating that a catalyst provides an alternative pathway of lower energy. Some candidates stated that a catalyst lowers the activation energy which was also accepted.

Question 3

The main G2 comments on this question related to the inclusion of organic chemistry in Section A. It should be noted that ANY Topic can be asked in Section A of P2, and there is no set-formula in relation to question setting. Organic chemistry is an integral part of the IB SL Chemistry programme, and is covered in Topic 10 of the guide (12 hours in total). Hence, candidates should be adequately prepared for questions on this topic, even in Section A. In 3(a), the Lewis structure of chlorethene was generally drawn correctly, though the weaker candidates often omitted the lone pairs on the chlorine. The bond angle was usually predicted, although right angles and 109.5^o were often given. Even some of the better candidates explained their choice of bond angle, based on the fact that the double bond occupies more space causing the HCCl bond angle to drop less than 120^o. In (ii), many candidates gave double bonds and some forgot to include continuation bonds. The Aim 8 question in part (iii) was very well answered this session. Almost all candidates scored the disposal problem of plastics mark and many achieved the economics importance mark also. In general (b) was very poorly answered, again showing a clear weakness in organic chemistry, which is an area of major concern. (i) was poorly done. Candidates who managed a correct reaction for the first step often used water instead of hydroxide ion for the second step.

In (ii), candidates who mentioned dichromate(VI) or permanganate(VIII) often omitted the acid. In addition, reflux was often missing. In (iii), very few candidates scored all three marks here, even though the question itself was easy. The equation was often correct, but the equilibrium arrow was rarely given. Some candidates did not know the formula for ethanoic acid which was surprising.

Section B

Question 4

This question was chosen by about 40% of candidates. In (a), virtually no candidates scored full marks for the definition of relative atomic mass. Most forgot to mention either average mass or relative to C-12.

It is very surprising that candidates are not well prepared for the various definitions listed on the syllabus, and hence are throwing away relatively easy marks on questions. Many candidates did reasonably well in (b), but very few picked up full marks. Diagrams of mass spectrometers were universally poor (e.g. charged plates were rarely shown). Often the steps were known, and cited in the correct order, but candidates typically lost one mark for not showing a fully labelled diagram. Candidates who knew how to calculate the abundances of Cu-63 and Cu-65 generally scored full marks, but many had no idea at all on how to approach the question in (c). Surprisingly very few candidates were able to state a radioisotope used in medicine. C-13 and C-14 were often given and sometimes elements were suggested but with no specified mass number. In (e), approximately 25% of candidates got the equation mark, but many gave incorrect state symbols. A significant number of candidates wrote equations with the formation of Na_2O or even atomic H. In (f), some of the weaker candidates explained the reactivity by referring to the change in reactivity down group 1 with no further explanation. Many referred to the increased number of shells in Rb or the increased distance the valence electron is from the nucleus, but some did not go on to explain that this affected its attraction/ease of loss. Very few candidates scored the marks for reference to valence electrons being in the third and fifth shells respectively. In (g), the colour change in (i) was usually known. There was rarely any explanation in (ii) as to why there is no observable reaction with the fluoride. In (h), the mark for reference to increased radius going down group 1 was often scored though surprisingly few actually referred to metallic bonding. In relation to going down group 7, the better candidates were able to state that since the M_r of the halogen molecules increases, there are more London/dispersion forces.

Question 5

This question was also chosen by approximately 40% of candidates. In (a), the diagram was reasonably attempted by most candidates, with just a few candidates giving both electrodes in one beaker. Some candidates omitted to include a voltmeter and other common mistakes included omission of states and incorrect direction of electron flow. In (ii), fewer candidates scored these marks and many equations were not labelled explicitly as oxidation and reduction. Other common errors included incorrect charges for the silver and magnesium ions. In (b), most candidates were able to place the metals in order, though a small minority misread the question, and gave zinc as the least reactive. In (ii), zinc was generally given as the best reducing agent, but often silver metal rather than silver(I) ion as given as the best oxidizing agent. There were many references to sodium chloride having a metallic structure in (c) (i), and describing its conduction in terms of electrons rather than ions.

In (ii), very few candidates mentioned that the ions move towards the oppositely charged electrode. The nature of the electrolytic process was not well explained. The characteristics of a chemical system in a dynamic equilibrium in (d) (i) typically were understood by most candidates, although many just scored one mark. (ii) was well answered.

Question 6

This was the least popular of the Section B questions. (a) (i) was poorly answered. Many candidates had no idea and some candidates used the mass of ethanol instead of water. A few calculated correctly but failed to convert the mass of water to kg, or kJ to J, thereby ending up with the wrong unit for the answer. Only a small minority of candidates got (ii) correct. (iii) was well answered. Nearly all candidates referred to heat loss but only the better candidates were able to give a second reason. Most candidates were able to describe two features of a homologous series in (b). (c) was usually well done, but some candidates struggled with the structural formula of the ether isomer of $C_4H_{10}O$ in (v).

One G2 comment stated that the ether functional group is not listed as one of the formal functional groups in Topic 10, which is correct. However, this aspect has been asked previously on SL papers in relation to deducing specific isomers (rather than naming the ether group) and although candidates are not required to know that C-O-C is the ether functional group, there is an expectation that they should be able to deduce an isomer based on C-O-C, as this is cited explicitly in AS 4.3.2, in the teacher's notes in relation to CH_3OCH_3 and CH_3CH_2OH, making this very much an objective 3 question, linking concepts across the syllabus. In (d), SN2 was commonly given but the mechanism in (ii) was exceptionally poorly answered in this session. In particular, the transition state was rarely drawn, and clearly candidates were not prepared for organic reaction mechanisms, even though there are only a few such examples on the syllabus as a whole.

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:

- Practise setting out calculations in a logical way, including a few words to indicate what process is being used, showing each step, and emphasising the final answer by underlining.
- Consider the units and the appropriate number of significant figures for the final answer in calculations.
- Know all definitions on the syllabus.
- Practise all the organic reaction mechanisms on the SL syllabus.
- Candidates need ample exposure to laboratory work in the programme and there should be considerable emphasis on this area – volumetric chemistry in particular in Section A was very weak.
- Candidates need to cover all topics in the SL guide. In particular there is an acute weakness in organic chemistry and candidates need to ensure that Topic 10 is simply not omitted as it can be included in any part of the paper, even in Section A.

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. Generally there should be no need to use extra sheets for Section A questions. In addition, this session in the Section B questions, it was noticed that many candidates showed cluttered work.

It is good practice to leave one blank line between each sub-section in Section B and teachers should encourage this in the class-room as well as stressing the importance of clear hand-writing.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 10	11 - 15	16 - 19	20 - 23	24 - 27	28 - 40

General comments

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

Of the 14 G2s sent in 79% felt that the paper was a similar standard to last year, while the remainder were equally split between the paper being a little easier and much more difficult. The majority (87%) of the teachers who responded felt the level of difficulty was appropriate, although 14% felt it was too difficult. Syllabus coverage was considered to be good by 33%, satisfactory by 54% and poor by 13%. For clarity of wording 53% felt it was good and 47% satisfactory. Finally, for presentation of the paper, 53% chose good and 47% 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:

- Function of components of an atomic absorption spectrophotometer
- Structure of amino acids in acidic and basic solutions, and structure of a zwitterion
- Interactions between amino acids and identification of atoms or groups joined together
- Definition of *iodine number* and associated calculations
- Obtaining iron and aluminium from their ores
- Electrodes used in electrolysis of aluminium
- Catalytic converter function
- Non-enzymatic browning mechanism

- Structure of oils and fats
- Structural difference of *cis* and *trans* fatty acids
- Reactions of Grignard reagents
- Action of electrophiles.

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

Some candidates gave very good answers and were obviously well prepared. Most candidates seemed able to complete the paper in the space provided.

The areas which seemed well understood were:

- Solving problems associated with malnutrition
- Uses of aspirin
- Tolerance problems with heroin
- Waste incineration
- CFC replacements
- Difference between a food and a nutrient
- Factors affecting colour of anthocyanins
- Explaining melting points of saturated and unsaturated fats

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

Option A - Modern analytical chemistry

Question 1

In (a) most candidates correctly identified the alcohols, but only the better candidates could explain which hydrogen atoms in the molecule were responsible for the peaks. One comment on the G2 forms was surprised by the reference to TMS. However, all ^{1}H NMR spectra have chemical shifts relative to TMS, and no questions were asked about its function. In part (b) many forgot the + charge of the fragments passing through a mass spectrometer and so lost marks. In part (c) the similar infrared spectra of the alcohols was often explained in general terms with no reference to the particular bonds present.

Question 2

Many candidates confused atomic absorption spectroscopy with UV/Visible spectroscopy in part (a). Only a minority could describe the functions of the AA spectrophotometer components in part (b). In part (c) many candidates could read the concentration from the graph but could not calculate the concentration of lead ions in the original sample. A few candidates had difficulty using the calibration curve.

Option B - Human biochemistry

Question 1

Most candidates simply drew the structure of the amino acid from the Data Booklet, and did not indicate the conjugate acid or base of the amino acid in solution in part (a). Few knew how to draw the structure of the zwitterion in part (b). One G2 respondent commented that deducing the structure of an amino acid at varying pH levels is not on the syllabus. It is, in fact, referred to in B.2.2. In part (c) the better candidates were able to draw structures of two dipeptides.

Many weaker candidates were unable to create peptide links, and joined the molecules creatively but incorrectly. Part (d) proved difficult with many candidates only able to identify two or three interactions between amino acids, and few able to identify the joined atoms or groups.

Question 2

In (a) many candidates were unable to state the causes of the deficiency diseases. Some simply guessed the same answer three times. The cause of goitre was best known of the three diseases. Part (b) on solving problems associated with malnutrition was answered well by most candidates.

Question 3

In part (a), many candidates failed to score a mark for defining iodine number as they stated it is the amount of iodine, rather than the mass of iodine. The Chemistry guide clearly states in 1.1.2 that amount means the number of moles of a substance. Few candidates could calculate the volume of iodine solution required in part (b). Few recognised that 2 moles of iodine reacts with each mole of linoleic acid. Many tried to use the volume of one mole of gas to find the volume of solution. This is a standard question that is clearly in the Chemistry Guide in B.4.5.

Option C - Chemistry in industry and technology

Question 1

Part (a), which required candidates to explain the relative reactivity of iron and aluminium, proved challenging for most candidates. In part (b), many candidates could correctly state the products of reduction of magnetite but several failed to balance the equations and thus lost marks. Most candidates could explain the advantages of steel over iron in part (c). In part (d) very few candidates could identify the electrodes used in the production of aluminium, but most could explain the importance of recycling aluminium in part (d).

Question 2

In part (a), most candidates had difficulty explaining the difference between HDPE and LDPE in terms of branching. Many mixed up the branching and properties, for example stating that increased branching led to a higher density. Part (b), which required candidates to explain why pentane is added to poly(styrene) to improve its thermal insulation properties, was also difficult for most candidates.

Question 3

Most candidates correctly stated the difference between homogeneous and heterogeneous catalysts in part (a), and could state one advantage and one disadvantage of homogeneous catalysts in part (b). Candidates were less successful in part (c) in discussing the choice of a suitable catalyst.

Option D - Medicines and drugs

Question 1

This question was generally answered very well compared with other sections of the paper. In part (a) most candidates knew that prostaglandins is involved in the transmission of pain impulses to the brain. In part (b) there was some confusion between signals and receptors when describing how morphine can prevent pain. In part (c) most candidates could outline problems associated with larger doses of paracetamol (acetaminophen), although some candidates confused aspirin and paracetamol and incorrectly referred to Reye's syndrome or stomach bleeding. Most candidates stated a use for aspirin other than relief of pain or fever in part (d). The identification of functional groups in part (e) was done well by some and poorly by others. In part (f) most candidates successfully stated the meaning of tolerance and suggested why it is a particular problem for heroin users.

Question 2

In part (a) there were some very good, very detailed explanations of how penicillins act as antibacterials, and some very vague statements. Many candidates scored only half marks for part (b) by correctly referring to resistance, although they correctly discussed the use of a cocktail of antibiotics to treat tuberculosis in part (c).

Question 3

Most candidates successfully wrote balanced equations for antacid reactions in part (a), although a few didn't know the products, some didn't balance the equations and many candidates incorrectly wrote the formula for magnesium chloride as MgCl. This led to difficulties in comparing the effectiveness of two antacids, with several candidates not even attempting to answer the question. Some candidates interpreted the coefficients in the equations as representing the mass ratio rather than a mole ratio. In part (b) several candidates confused the role of alginates and antacids or thought that alginates were anti-foaming agents. One G2 respondent commented that this was not on the syllabus, but it is clearly stated in the teachers' notes in D.2.1.

Option E - Environmental chemistry

Question 1

Part (a) required candidates to state man-made sources of carbon monoxide and nitrogen oxides. Many candidates simply gave the source of the pollutant (car exhaust) rather than a description of the reaction causing the pollution (incomplete combustion of fossil fuels). This reflects the difficulty many candidates experience in giving responses which demonstrate their knowledge of chemistry rather than a vague and journalistic style answer. In part (b) only a few candidates could write appropriate equations for catalysed reactions in a catalytic converter. Many candidates incorrectly thought that a catalytic converter allows complete combustion to occur. Few correctly described the action of the catalytic converter.

There were difficulties in part (c) in stating a third pollutant that can also be removed by a catalytic converter, with many candidates incorrectly guessing carbon dioxide and oxides of sulfur. The use of an electrostatic precipitator was reasonably well known in part (d) although many candidates either named the device or described it, but few did both.

Question 2

Stating an advantage and a disadvantage of incinerating waste in part (a) was reasonably well done. In part (b) few candidates stated both low activity and a short half-life as characteristics of low-level nuclear waste, but many correctly identified sources. In part (c) several candidates lost a mark for the storage of high-level nuclear waste by failing to specify deep burial of the waste. The discussion of problems associated with the storage was answered reasonably well.

Question 3

Part (a) produced mixed responses with some candidates writing appropriate equations, and some writing only one equation for the formation and depletion of ozone when two equations were needed for each process. A few candidates seemed to have no idea of the formula of ozone. Part (b) on the use of hydrocarbons as a replacement for CFCs was answered reasonably well.

Option F - Food chemistry

Question 1

The majority of candidates' could distinguish between a food and a nutrient in part (a). In part (b) many candidates stated physical properties of monosaccharides rather than structural features. Those who stated structural features often only gave one or two rather than the three required. Explaining the mechanism of non-enzymatic browning in part (c) was answered well by only a handful of candidates.

Question 2

In part (a) many candidates failed to mention that visible light is absorbed by coloured pigments and that the complimentary colour is seen. Part (b) was answered correctly by most candidates, although some neglected to refer to their Data Booklet to identify the regions of the spectrum. The majority of candidates could list factors which alter the precise colour of a particular anthocyanin in part (c).

Question 3

Few candidates knew the basic structure of a fat or oil in part (a), with the ester linkage frequently missing from the structures drawn. Describing the difference between a saturated and an unsaturated fatty acid was reasonably well answered, although often the strength of the van der Waals' forces was not mentioned. In part (b) most candidates could explain why the melting point of unsaturated fats is lower than that of saturated fats. Many candidates struggled to adequately describe the structural difference between *cis* and *trans* fatty acids in part (c). A simple diagram would have been sufficient. The disadvantage of consuming oils containing *trans* fatty acids was generally answered well, although some weaker candidates resorted to stating that they were bad for our health. Again, this reflects the difficulties some candidates experience in providing responses with sufficient detail.

Option G - Further organic chemistry

Question 1

A few candidates were well prepared and could write equations for reactions of Grignard reagents in parts (a) and (b). Unfortunately, the majority of candidates who answered this option had difficulty with the equations. Some candidates scored marks only for correctly naming products while others could perhaps draw correct structures of products but could not name them. Part (c) was slightly better answered with more candidates correctly naming the organic product for the elimination reaction of butan-1-ol. Explaining the mechanism was poorly done, with many candidates failing to appreciate the importance of precision in drawing the curly arrows.

Question 2

In part (a) candidates rarely explained the induced dipole in the bromine molecule which allows it to act as an electrophile. Part (b) was answered more effectively with many candidates correctly naming products formed from but-2-ene, although several candidates omitted 'di' from 2,3-dibromobutane and thus lost the mark. The poor use of curly arrows was again evident in part (c) although some candidates clearly explained why only one organic product is formed when but-1-ene reacts with hydrogen bromide.

Question 3

Many candidates scored marks by describing the physical evidence in part (a) and the chemical evidence in part (b), which shows that benzene does not contain three double bonds.

Recommendations and guidance for the teaching of future candidates

- Candidates in schools that offer instruction in only two or three options generally do better than candidates who study the options independently.
- Candidates should treat the options as seriously as the other material in the course.
- Candidates need to study each option in depth and ensure they know the equations relating to the processes they study.
- Candidates should practise writing balanced equations.
- Candidates should practise drawing curly arrows in mechanisms to ensure that they are precisely placed.
- Candidates should be discouraged from the use of line diagrams when writing structures.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Candidates should pay attention to the mark allocation to ensure that sufficient points have been stated.
- Candidates should take note of the command terms used.
- Candidates should prepare for the examination by practising past paper questions and carefully studying the mark schemes provided.