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 - 43	44 - 54	55 - 66	67 - 77	78 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 30	31 - 43	44 - 54	55 - 65	66 - 76	77 - 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

The May 2011 session evidenced an improvement in terms of the suitability of the work submitted for assessment of the criteria compared to May 2010. Most teachers gave feedback using c, p, n or 2,1,0 notation with a good proportion giving at least a few written comments to explain where the candidate can make improvements. Pleasingly there were significantly fewer teachers providing handouts that gave too much support to the students although instances did still occur. There were still a number of schools that submitted investigations that were below IB Diploma Level in terms of complexity and expectation.

The work submitted in the practical programmes frequently was based on the examples listed in TSM particularly for the design investigations, resulting in less students being hindered by the setting of overly narrow tasks. Many schools restricted their assessment to two investigations with all students responding to the same two Design tasks that were then assessed for DCP and CE as well. This is permissible but more variety in the range of design tasks set to a class and the number of investigations over which the candidates are assessed would be welcome as this encourages independent learning and the development of a wider range of reporting skills, as well as for students to legitimately benefit from the regulation that only best two scores per criterion count.

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The organic practical activities reviewed by the moderators or as indicated on the 4PSOW moderators were infrequent and simplistic. It is understandable that organic chemistry does not feature strongly in assessed activities since the criteria lend themselves more readily to quantitative investigations but it would be pleasing to see more organic chemistry featured on the 4PSOW.

Happily there were less cases, especially when compared to November 2010, that were brought to the senior moderating team's attention of the work of candidates that was clearly guided by teachers, fellow candidates or unreferenced sources to a level well beyond the instructions evidenced.

Candidate performance against each criterion

Design
Aspect 1

This was frequently well addressed with many students able identify most variables. Being able to phrase a suitably focussed research question challenged some students but usually an award of at least Partial and in many cases Complete resulted.

Aspect 2

This is consistently the most challenging of the Design aspects and many students failed to identify any procedural methods to control or at least monitor the control variables that they had earlier identified as needing controlling.

Candidates need to be explicit as to how they are to control the variables they have selected and exactly what data they will collect. For example, what equipment will be used at each stage (e.g. for measuring is it a 50 cm3 measuring cylinder, or a cm3 pipette, or a 50 cm3 burette etc), the concentrations of vital solutions, they should address issues of limiting reagents or in excess, the control and recording of temperatures, the measurement and recording initial and final volumes. Other common problems to arise were the confusing of current with voltage in electrochemical cells and the mistaken view that in a rate of reaction experiment it is the room temperature that has to be held constant or monitored and not that of the reaction mixture itself.

Aspect 3

There was a good level of fulfilment of this aspect with most students able to design realistically for the collection of data that would include repeats or would be sufficient to analyse graphically with at least five data points.

Data Collection and Processing

Aspect1

There was generally a good level of fulfilment with most candidates including uncertainties and relevant qualitative data. However there were still too many simplistic tasks, which meant that students were able to score high points for processing very little data.

Aspect 2

The level of fulfilment was encouraging. Many students made some attempt to process data appropriately although following a calculation successfully through to its conclusion or to plot a graph from which a quantity could be determined remained demanding.

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In a significant number of cases, though, the processing was not extended when it could have been, especially by HL candidates. For example there were many rate investigations where a graph of change in some quantity, such as the volume of gas produced with time, was the end product of data processing whereas a continuation to calculate a rate should have been carried out.

Aspect 3

A good number of candidates tried to propagate uncertainties through a calculation although not always successfully. Students who failed to propagate the uncertainties were then hindered in addressing the Conclusion and Evaluation Aspect 1.

Conclusion and Evaluation

Aspect 1

This was once again a demanding aspect and generally only high achieving candidates successfully placed numerical results in the context of a literature value and then identified whether the difference indicated the presence of system error or could be explained by random error alone. Also only a small proportion of candidates presented any justification of their conclusions in terms of whether it was coherent with accepted theory.

Aspect 2

Partial was the most common award for this criterion with most students able to identify sensible sources of error but few being able to evaluate whether the source of error accounted for the direction of the deviation from a literature value encountered.

Aspect 3

This criterion was satisfied to a similar uneven extent to previous sessions with many good responses but a similar number of very superficial or simplistic contributions. Possibly less students than before simply stated that there should be more repetitions and that unspecified "more precise" apparatus be used.

Manipulative Skills and Personal Skills - All schools entered marks for these criteria.

Recommendations for the teaching of future candidates

It is recommended that:

- Teachers ensure that they act on specific feedback given by the moderator in the 4IAF feedback that is released through IBIS shortly after the results release.
- Candidates should be made aware of the different aspects of the criteria by which they are assessed and evaluation of investigations using a grid of criteria and aspects, with n, p and c indicated clearly, is strongly encouraged.
- It is essential to ensure that candidates are solely assessed on their individual contribution to any activity used for assessment of the written criteria.
- Teachers must ensure that candidates have the opportunity to fulfil criteria, and hence should not provide too much information for the students. The use of workbooks and worksheets with spaces to be filled in by the candidates is strongly discouraged for assessed work.
- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.

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- Candidates need to explicitly identify the dependent variable as well as independent and controlled variables in the Design criterion.
- All investigations for the assessment of DCP must include the recording and processing of quantitative data. Solely qualitative investigations do not give the students opportunity to fulfil this criterion completely.
- Teachers are encouraged to set some DCP tasks that will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.
- Candidates must record associated qualitative where appropriate as well as quantitative raw data.
- Candidates must compare their results to literature values when relevant and include the appropriate referencing of the literature source.
- When assessing the CE criterion, require candidates to evaluate the procedure, cite possible sources of random and systematic errors, and provide suggestions to improve the investigation following the identification of weaknesses.

Many schools have acted on these recommendations to the benefit of their students.

Further comments

Application of ICT

Most schools had checked the five ICT requirements at least once on the 4PSOW although the assessed work submitted rarely corresponded to these investigations so it is hard to evaluate the appropriateness of the tasks. Where data logging was involved in an assessed investigation often pages and pages of tables were supplied and one student had submitted 72 pages of tabulated data. Please consider sending just a sample of the raw data (with covering note) to assess the student's contribution to collecting the data and their appreciation of uncertainties, units and consistent decimal places.

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.

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- 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.

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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

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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.

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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

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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 - 31	32 - 35	36 - 40

General comments

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

Teachers' impressions of this paper were conveyed by the 92 G2's that were returned. 51% found that it was of a similar standard, compared with last year's paper, 3% thought that it was more difficult and 25% were of the view that it was a little easier. 1% stated that it was much easier. 87% described the level of difficulty as appropriate, 1% too difficult and 4% thought that it was too easy. 46% felt that the clarity of wording on the paper was satisfactory and 44% felt that the wording was good. Just 1% stated that the clarity of wording was poor. The presentation of the paper was considered satisfactory by 29% and good by 61%.

These statistics were also mirrored in the general comments, where it was generally felt that the paper was fair, straight-forward with a good balance of questions across the curriculum.

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 94.65% to 37.28%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.63 to 0.08 (the higher the value, the better the discrimination).

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The following comments were made on selected individual questions:

Question 1

One respondent stated that the numbers could have been more user-friendly in this question, as candidates do not have access to a calculator in P1. This is a fair comment which will be borne in mind for future paper-setting. The candidates however did reasonably okay on this question with 60.70% getting the correct answer as B. The inconsistent use of significant figures in the first two questions was also commented on which is also a valid comment.

Question 5

On one of the G2's it was stated that it would have been better if the 3d level was placed after the 4s level. It is true that in many textbooks that the electron configuration of V is written as $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$. However, most candidates (72.19%) gave B as the correct answer.

Question 10

In this question candidates were asked to state the number of sigma and pi bonds in propyne. One respondent stated that as alkynes are not on the syllabus why the name was necessary. However, this question involved candidates drawing out the full structural formula using valency rules and hence counting the number of sigma and pi bonds. Knowledge of the alkyne functional group was not necessary but candidates did have to realise that a carbon to carbon triple bond was present. Often in questions the style of IB papers is to also include both the name and the associated structural formula.

Question 13

One respondent stated that although the obvious answer is electrons cations also might be accepted. This was discussed during Grade Award and it was decided in fact that the correct answer is C. in the context of this question.

Question 14

There were two G2 comments on this question. One respondent stated that D. should be trigonal planar instead of triangular planar. Both terms are widely used in fact, though of course the correct answer is A. bent or V-shaped. Another respondent stated that it would have been better to represent the Lewis structure of SO_2 with valence expansion. It is true that SO_2 could be represented as an alternate Lewis structure. However, the question did not state what the best Lewis structure representation of SO_2 was and hence was not basing the representation at any distinction centred on formal charge differences versus expanded octets. Candidates simply had to look at the three negative charge centres present which equates to a triangular planar electron-domain geometry and hence a bent molecular geometry as the final shape giving A as the correct answer.

Question 17

One respondent stated that it would have been better to represent the four choices A-D as numerical values. However, candidates do not have access to a calculator in P1 and therefore simply had to use Hess's law without working out the final answer. 67.83% of candidates got the correct answer.

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Question 20

Two respondents stated that this question was somewhat misleading. The question was one of the more challenging questions on the paper but 51.70% of candidates did get B. as the correct answer.

Question 29

One G2 stated that the naming of carboxylic acids was not covered. However, according to AS 10.1.10, candidates should know how to apply IUPAC rules to name carboxylic acids up to six carbon atoms. Hence, it would be expected that candidates would know the structure of propanoic acid to subsequently answer this question on buffer solutions. The question was however the second most difficult question on the paper, with only 43.79% of candidates getting the correct answer.

Question 32

There were two G2 comments on this question. The correct answer is B (I. and III only), as II. would be ruled out as it is states *carbon* electrode. Typically a platinum electrode is used in the SHE, as it is an inert metal and also can act as a catalyst. 79.75% of candidates gave the correct answer.

Question 33

In this question, candidates had to identify which molecule had a chiral centre. One respondent stated that ethers are off-syllabus. It is true that as a functional group, ethers are not required based on Topic 10. However, it should be noted that candidates are expected to know that oxygen is divalent and hence can occur with two single bonds. This is also referred to in the Teacher's notes corresponding to AS 4.3.2, where a comparison between the intermolecular forces present in CH_3OCH_3 and CH_3CH_2OH is referred to. Hence, candidates are expected to be able to write a full structural formula from the condensed structural formula of $CH_3OCH_2CH_3$ to determine that it does not have a chiral centre.

Question 35

One respondent stated that this question was difficult. However, the question was in the mid-range of difficulty and in fact was the 14th easiest question on the paper with 77.42% of candidates getting the correct answer, A. The question had a linked discrimination index of 0.40.

Question 40

Two respondents stated that the wording of this question was vague. However, this in fact was the easiest question on the entire paper for candidates with 94.65% of candidates getting the correct answer, B.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 12	13 - 24	25 - 34	35 - 45	46 - 55	56 - 66	67 - 90

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General comments

This paper indicated a very broad range of capabilities as the marks varied significantly from very low to outstanding. The paper overall was found to be quite a good discriminator between those candidates that knew their subject material comprehensively and those that had a cursory understanding. Some candidates struggled with even the most basic concepts where answers lacked precision in terms of depth of wording used and explanations were often vague while others demonstrated an excellent depth of understanding of the subject. However, even the best candidates were challenged by some of the core chemical themes across the syllabus such as structure and bonding, organic reaction mechanisms, electrochemistry, delocalization etc. In general knowledge of physical chemistry was particularly solid.

Generally the paper was found to be accessible with a good balance between straight-forward questions and some more challenging parts in each Section B question with opportunity for candidates to convey their knowledge and understanding of chemistry.

However, it is imperative that candidates read each question carefully, pay attention to the action verbs and the number of marks allocated to an individual question and then write their answers accordingly. Calculations must be shown clearly and should be checked for accuracy, significant figures and units where appropriate. Teachers' impressions of the paper were conveyed by the 91 G2 forms submitted. In comparison with last year's paper, 54% felt that it was of a similar standard, 10% felt it was easier while the remainder felt it was more difficult. 79% considered the level of difficulty of the paper to be appropriate, while 1% thought it was easy and 20% thought it was too difficult. Clarity of wording was considered good by 36% and satisfactory by 60%. The presentation of the paper was thought to be good by 57%, satisfactory by 35% and just 8% stated that the presentation was poor.

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

- Candidates treatment of units and significant figures in general were noticeably weak on this paper
- Arrhenius equation
- Electron configuration of transition metal cations
- Uses of radioactive isotopes
- Vapour pressure
- Structure and bonding in allotropes of carbon
- Structure and bonding in silicon dioxide
- Delocalization
- Explanation of hybridization
- Organic reaction mechanisms
- Organic syntheses
- Environmental effects of weak acids
- Description of how an indicator works
- Acidic nature of $FeCl_3(aq)$
- Electrolytic cells – nature and corresponding half-equations

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

- Physical chemistry in general
- Entropy changes
- Subatomic particles
- Equilibrium
- Acids and bases
- Voltaic cells
- Oxidation numbers
- Oxidation and reduction half-equations

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

Section A

Question 1

Most candidates had little difficulty calculating the theoretical enthalpy of combustion of methanol in part (a), though some forgot to take into account the stoichiometry of the reaction. In (b) (i), the majority of candidates calculated *n*(methanol) = 0.0163 mol. Surprisingly a significant minority got the molar mass of methanol incorrect and a large proportion of candidates expressed it as 32 g mol^{-1}. Although the latter was not penalized, it should be emphasised to candidates that Data Booklet values should be used, correct to two places of decimals as best practice in answering questions. (ii) was poorly done and many mistakes were made determining ΔT, and units also were problematic. In (iii), the most common mistake was the omission of the negative sign. (c) (i) proved to be too challenging for candidates, though the better students did well on (ii). Some candidates simply stated heat lost which scored no marks. (d) caused difficulties for candidates with the multiplication factor for the oxygen – and the correct units were frequently omitted which caused problems then subsequently in part (e). In (e), problems of units were widespread. (f) usually was well done by the better candidates. One G2 comment also stated that it would have been better if the experimental value would have been closer to the expected value.

Question 2

This question on chemical kinetics was very poorly answered by candidates. In (a), many candidates simply gave the Arrhenius equation and failed to describe the explicit relationship between *k* and *T*. (b) was answered very poorly and although some candidates had an idea about the gradient expression, most were out by a factor of 100 in their final answer and many totally ignored units. In (c), the most common error related to the 10% reduction and units also proved challenging.

Question 3

Candidates did reasonably well on this question. Many candidates got (a) correct and most got the correct number of protons and electrons in the Co^{2+} ion in part (b). In (c), a small minority of candidates tried to answer this question with a 2,8,15 type electron arrangement which showed weakness at HL and many candidates did not realise that electrons come out

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of the 4s level first before the 3d in part (c). In (d), although many were able to identify Co-60 as a radioactive isotope, most could not state one of its uses. One respondent expressed surprise at this, though this is clearly noted on the syllabus in AS 2.1.7.

Question 4

This question was generally well answered by candidates. Most were able to state the correct equilibrium constant expression in part (a), though some gave incorrect brackets and some omitted the factor two.

In (b), most candidates were able to state the effect of changing the conditions but many were not able to explain the effect of changing the conditions themselves. In (ii), gaseous was often omitted. Both (c) and (d) however were well answered.

Question 5

Most candidates were able to compare the vapour pressures of ethoxyethane, benzene and water correctly and some were also able to identify the hydrogen bonding present between the water molecules as the cause of its low vapour pressure. Very few candidates were able to describe correctly the intermolecular forces present in ethoxyethane and benzene. Many referred to delocalized electrons in benzene. In contrast for 5(b) few candidates failed to gain a mark for this question.

Section B

Question 6

Candidates often struggled in (a). Few candidates scored well on this question because most candidates did not consistently describe the same three features of the allotropes. Many candidates referred to properties of the allotropes rather than structure or bonding features. (b) was very poorly answered because few candidates could describe the structure of silicon dioxide and few candidates could describe the fact that there are London dispersion forces between carbon dioxide molecules. Most candidates did not realise that silicon dioxide was macromolecular. In (c) many candidates identified that carbon monoxide contains a triple bond and some candidates knew that dative covalent bonding was present. However, a large majority simply described the carbon to oxygen double bond nature of carbon dioxide instead of carbon monoxide. In addition (d) was poorly answered since candidates were unable to logically structure their response – often a description of pi bonding alone was given. (e) usually was well done, although the precise meaning of hybridization was rarely given. Sometimes an incorrect hybridization of sp^4 was given for diamond.

In (f), most candidates were unable to state that molten sodium oxide is able to conduct electricity because the current is carried by mobile ions (not delocalized electrons). Most did not realise that molten sulfur trioxide consists of neutral molecules and therefore does not conduct an electric current. Most were also able to write the balanced chemical equations but then were not able to state that both solutions conduct. Many often gave the incorrect formula for sodium oxide.

Question 7

This was the least popular question in Section B. Most candidates either scored all five marks in (a) or just one. (b) was usually well done, though it was disappointing that more candidates did not use the equilibrium sign. In (c), a significant number of candidates omitted water from the equilibrium calculations. The organic reaction mechanism in (d) (i) was very poorly presented. Many even tried drawing curly arrows from NaOH as an attacking species. The

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majority could identify the product of the reaction but a mechanism was far beyond them. Transition states were poor or missing completely. In (ii) although many knew that OH^- has a negative charge, few linked this to the greater attraction to the carbon atom. In (iii) very few candidates did well here and the name of pentan-1-amine was rarely given. Other mistakes included incorrect catalysts. Further common mistakes included some candidates not including all the hydrogens in the structural formulas. In general for this part there was very poor knowledge of organic synthesis amongst candidates. Very few had a good "stab" at this question. The fact that pentylamine was mentioned in the question initially meant that very few candidates accessed the last mark for the name of the product.

Question 8

This was a popular question and often was well answered by candidates. In (a) (i) most candidates knew the formal definitions of an acid and a base and most could distinguish between a weak base and a strong base. Ammonia was generally given as a suitable example of a weak base. Some of the weaker students gave sodium hydroxide incorrectly as an example of a weak base which was quite surprising at HL. In (ii), common mistakes included nitric acid and this question proved to be problematic for candidates. There were a number of G2 comments expressing some concern at asking this style of question, though this is a clear Aim 8 type question that should be explored in the formal teaching programme. (iii) was well done but candidates rarely got (iv) correct. In (v) most candidates scored either two or three, but often an incorrect shape of the curve was given. In (b), few could describe how an indicator works and the equilibrium sign was sometimes omitted. In (ii), phenolphthalein was usually identified as an appropriate indicator. In (c) next to no candidate knew about the aqueous chemistry of transition metals or the existence of the hexaaqua ion. In (d), candidates who were able to think logically about all this did well; others scattered figures across the page and became hopelessly muddled. Often an incorrect answer of pH = 7.0 was seen.

Question 9

This was also a popular question but candidates often struggled to do well. In (a) (i), a number of candidates confused this question with one on voltaic cells and drew two half-cells connected rather than that of an electrolytic cell for the electrolysis of nickel bromide. The half-equations on the whole were poor and most were unlabelled. Use of equilibrium signs was widespread and many candidates did not realise that reduction takes place at the cathode leading to the formation of Ni etc. Few correctly answered correctly the equation for dilute solutions in (ii). In (b) (i) most candidates got the correct equation though Cu^+ was often given. In (ii) some candidates forgot to include V as the unit.

Few scored one mark in (iii). Most candidates did not have any clue about part (c). Few spotted that they needed to compare the oxidizing/reducing power to that of water. Most simply made a comparison between the two electrode potentials given. Most candidates scored zero on this question. (d) (i) was often well answered though many did not state that 2 mol of electrons are required for each mol of Ni. (ii) proved difficult and there were a number of G2 comments stating that this went somewhat beyond the syllabus. These points were valid and this was taken into account during Grade Award. In (e), although most candidates scored full marks, incorrect notations such as 3-, III were sometimes seen. In contrast both (ii) and (iii) were very well answered.

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Recommendations and guidance for the teaching of future candidates

In addition to the advice about reading the questions carefully, correctly addressing all points and paying attention to mark allocations and action verbs, candidates are advised to note the following points in this paper:

- Show the working for all calculations so that the chance of obtaining error carried forward (ECF) marks is maximised
- Learn the common definitions on the syllabus
- Consider the units and the appropriate number of significant figures for the final answer in calculations
- Consider the various steps of the common organic reaction mechanisms, with focus on the positions of curly arrows and reaction conditions.
- Try to look at some of the more general themes across the curriculum as a whole e.g. structure and bonding, intermolecular forces, delocalization etc.
- Examples given in the Teacher's notes are not the only examples that can be asked particularly in Objective 3 type questions – these serve only as examples of the type of problems that might be posed corresponding to a particular AS.

Additionally, teachers are strongly advised to use the latest Data Booklet in the teaching and during practice exams, and refer to past examination papers, their mark schemes and Examiner Reports to assist candidates with examination preparation.

Finally, there should be no need to use additional sheets in general in questions. If these additional sheets are used candidates should clearly indicate so on the answer booklet.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 15	16 - 19	20 - 25	26 - 30	31 - 36	37 - 50

General Comments

This paper identified a very broad range of candidate capabilities. Some candidates struggled with even the most basic concepts and factual knowledge while others demonstrated an excellent depth of understanding of the higher level material. In general, candidates did not appear well prepared. There were some schools where the candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank. Answers lacked precision in terms of the wording used and explanations were often vague. Responses to questions lacked chemical detail and particularly for Option D, E and F, some responses tended to be journalistic rather than based on chemical facts and principles.

The 90 G2 forms that were returned conveyed teachers' impressions of this paper. This number is a huge increase as compared to last year where 22 G2 forms were submitted. The comments received on the G2 forms are considered very important feedback by the IBO and are reviewed thoroughly during the grade award meeting.

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In comparison with last year's paper 58% of respondents felt that it was of a similar standard and 16% considered it a little more difficult while 4% felt and 1% felt the paper was a little easier and much more difficult respectively. 78% of respondents thought the level of difficulty was appropriate while 12% thought that it was too difficult. Clarity of wording was considered good by 43%, satisfactory by 48% of the respondents and poor by the remainder. The presentation of the paper was considered good by 56% and satisfactory by 35% of the respondents.

The most popular options were B and D while options C and F were least popular.

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 in each option were as follows:

Option A

- Naming the components and stating their functions in atomic absorption spectroscopy
- Identifying a stationary phase used in TLC
- Describing how HPLC is carried out and explaining how separation occurs
- Explaining the colour change of the indicator
- Explaining why copper sulphate solution is blue and how the ligand changes its colour

Option B

- Comparing the structural features of starch and cellulose
- Mentioning *cellulase* as the enzyme for digesting cellulose
- Relationship between Km and enzyme activity
- Stating the half equations for the oxidation of glucose and the reduction of oxygen

Option C

- The section on cracking and the Ziegler-Natta process
- Describing the function of the membrane in the membrane cell

Option D

- Stating the name of one functional group present in caffeine but absent in nicotine
- Describing two ways an antiviral drug works
- The conversion of fluoxetine and aspirin to salts

Option E

- Outlining the process responsible for the production acids causing acid rain
- Identifying the products formed in aerobic and anaerobic decomposition of organic matter
- Stating two methods of controlling CO emissions

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- Discussing the role of NO_x in ozone depletion and giving equations for the stepwise mechanism
- Explaining how the availability of nutrients is affected at low pH
- Deducing a half-equation for the reduction of the nitrate ion to ammonium ion

Option F

- Outlining the mechanism by which hydroperoxides are formed and stating the class of compounds responsible for the off flavours produced in food
- Explaining why anthocyanins and carotenes are coloured
- Stating one example of a compound and its enantiomers with different tastes or smells

Option G

- Most areas of this option proved difficult for candidates, especially when they were expected to write mechanisms
- The question on the Grignard reagent proved particularly difficult for the candidates

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

The areas which seemed well understood by candidates were:

- ^{1}HNMR, infrared and mass spectroscopy
- Outlining the mode of action of oral contraceptives
- The kinetics of an enzyme -catalysed reaction
- Identifying the products formed when glucose undergoes anaerobic respiration in the presence of yeast
- Nanotechnology
- Production of steel
- Uses of chlorine and sodium hydroxide
- Antacids
- Calculation in E2(b)
- Outlining a condition that leads to the production of CO in an internal combustion engine
- Identifying the environmental problem associated with CO_2
- Deducing saturated, mono-unsaturated and poly-unsaturated fats or oils
- Explaining the meaning of shelf life
- Naming an artificial antioxidant
- Stating a common food containing an anthocyanin and a carotene
- Identifying a coloured compound found in uncooked foods
- Genetically modified food

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

Option A – Modern Analytical Chemistry

This option was not very popular and was answered poorly by about half of the candidates.

Question 1

Most candidates scored the mark in (a), but none scored the six marks in part (b) where it was very rare to see three correct names for the components or explanations of the functions.

Question 2

Candidates understood this area well and scored most of the marks. Positive sign was often missing from the fragments produced in mass spectroscopy.

Question 3

This was not well answered, particularly the more open ended style of part (c) about HPLC.

Question 4

(a) Although about half of the candidates deduced the colours correctly but failed to offer explanation. Part (b) lacked proper understanding of the chemical principles and was poorly answered by most of the candidates.

Option B – Human biochemistry

This was one of the most popular options.

Question 1

In (a) the structural features were not well described, particularly addressing the command term *compare* that both are polymers of glucose. Alpha and beta glucose was not mentioned in about half of the answers when 1,4/1,6 was mentioned by candidates. In (b) about half mentioned *cellulase*, but the other half referred to enzymes without mentioning the name.

Question 2

This part was answered quite well but there were some cases in (b) where the candidates did not know the structures of the products.

Question 3

(a) Most candidates gained only 1 mark out of 3 by explaining that ovulation did not occur. Question seemed to cause ambiguous answers. The open ended nature meant that some candidates found it hard to stay on track with their answer and provided details of how to take contraceptive pills. In (b), as expected, there was a wide range of responses. The treatment of asthma was often quoted.

Question 4

This part was generally well answered with full marks awarded to more than half of the candidates. Those who did not score full marks usually failed to give a correct answer in (a) and (c).

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Question 5

Majority of candidates identified that glucose was oxidised and oxygen was reduced, but it was very rare to see correct half-equations. In (c) most gave ethanol and carbon dioxide, but lactic acid or alcohol instead of ethanol was a frequent response in the remaining answers.

Option C – Chemistry in industry and technology

This was one of the least popular options.

Question 1

This part was mostly correctly answered. Very few, though, described the arrangement of carbons at the end of the nanotube correctly, usually omitting hexagons.

Question 2

This part was very poorly answered. None of the candidates scored full marks in (a), in some rare cases the mark for catalytic cracking was scored. In (b) also it was rare to see correct answers regarding Ziegler-Natta process. Part (c) was answered well by many candidates.

Question 3

In part (a) a significant number of candidates outlined the process by which iron is produced in the blast furnace and a usual omission was "through/over molten iron". Part (b) was answered correctly by many candidates.

Question 4

Only a small number of candidates scored the mark in (a) regarding the function of the membrane, about half scored the two marks in (b) and many scored both marks in (c) regarding use of chlorine and sodium hydroxide.

Question 5

Although many scored the mark for "adding a Group 3 element", confused answers followed in about half of the responses.

Option D – Medicines and Drugs

This was one of the most popular options.

Question 1

(a) About half of the candidates did not recognise the amide group which is present in caffeine but absent in nicotine, stating ketone (and often keytone) as the answer. Many gave amine in (b) and the symptoms in (c). In (d) (i) the answer "affects/mimics the sympathetic nervous system" was given in about half of the responses. The vast majority gave a correct answer in (d) (ii), but there were cases where caffeine/nicotine were mentioned.

Question 2

In general, this part was well answered, but there were many cases where candidates did not know the formulas of aluminium hydroxide and magnesium hydroxide and could not give the explanation in part (b).

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Question 3

In (a) many candidates gave non-structural differences, e.g. response to antibiotics. In (b) quite a few confused answers to ways in which antiviral drugs work were seen. In (c) many gave "mutates rapidly" but naming the virus as AIDS not HIV and often "attacks helper cells" was given instead of "destroys".

Question 4

More than half of the candidates identified all functional groups correctly in (a) and (b). The vast majority gave THC as the active ingredient in (c), but only about half scored the second mark for relieving extreme pain or nausea.

Question 5

This part was poorly answered, very few candidates correctly identified the functional groups and the reagents or recognised the increased water solubility and facility of distribution in the body, a common response being "can be taken orally".

Option E – Environmental chemistry

This was also one of the most popular options.

Question 1

This part was answered rather poorly. A surprising number quoted CO_2/CO as a source of acid rain. Very few mentioned that high temperatures were required for the reaction between nitrogen and oxygen when nitric acid was identified. Some went on to give the mechanism of the formation of nitric acid and sulphuric acid.

Question 2

(a) This part was very poorly answered. Only a handful gave all eight correct products. Most scored one mark for giving carbon dioxide and methane. The connection between aerobic decomposition and the presence of oxygen in the products seemed to be made, but the actual products, excluding CO_2, were incorrect e.g. incorrect charges. Some included anaerobic products that had oxygen in their structure.

In (b) the calculation was done correctly by half of the candidates.

Question 3

(a) (b) and (c) were answered well by more than half of the candidates, but (d) was not well answered with lots of references to 'thermal converters'.

Question 4

In (a) most candidates stated the reaction and identified the double bond in oxygen, but very few mentioned the bond order of 1 1/2 for the ozone molecule. In (b), very few candidates answered correctly to score the three marks and did not recognise the role of NOx as a catalyst.

Question 5

This part was poorly answered. The *amount* of exchangeable cations in the soil was very seldom mentioned. Other parts had very vague answers and in most cases candidates struggled to respond correctly. Very rarely candidates recognised the reduced availability of the nitrogen or the inability of the plants to take in ammonium salts.

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Option F – Food chemistry

This was a fairly popular option.

Question 1

(a) and (b) were answered quite well. Majority of candidates struggled in part (c) with very few giving the correct mechanism and the class of compounds. In (d) while the vast majority gave the name of the antioxidant only some had a vague understanding of the action of the antioxidant. In (e) trans was not well explained, but quite a few gave why they are undesirable.

Question 2

In part (a), very few candidates linked colour to extended regions of delocalised electrons or conjugated double bonds. There was much general discussion of absorption of visible light. Some were confused with colour in transition metal compounds. Many correct answers appeared in (b), (c) and (d).

Question 3

This part was fairly well answered by many candidates.

Question 4

This was a low scoring question, particularly parts (b) (ii) and (b) (iii).

Option G – Further organic chemistry

This was one of the least popular options.

The mechanisms proved a problem for majority of candidates. About half of the candidates managed to score some marks in G1 (b) and G4 (a), but very few scored marks in G2 (a), leaving a lots of blanks spaces. Candidates must take care to accurately draw the position of the curly arrows illustrating the movement of electrons.

Question 1

In part (a), omission of water from the equation and heat from the conditions often resulted in loss of marks for candidates who were clearly familiar with the process. There was widespread use of 'reflux' as opposed to 'heat under reflux'. In (c) several quoted the formation of 1,2 and 2,3-dibromobutane from butan-2-ol without reference to the isomeric alkenes.

Question 2

Apart from part (a), there were very few good answers in (b) and (c). Grignard reagent proved quite difficult for majority of candidates

Question 3

Very few candidates mentioned amine salt in (a), but there were quite a few correct equations with $(CH_3)_2NH_2OH$ being a common error. Part (b) was answered quite well by many candidates.

Question 4

In (b) most candidates gave methylbenzene is more reactive, but only half of them scored the second mark for the explanation.

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Recommendations and guidance for the teaching of future candidates

- Candidates must be prepared equally well for the two options which they will answer in the examination. There was evidence that in some schools only one option was taught and not all parts of the options chosen had been covered with equal thoroughness.
- Teachers are strongly advised to refer to past examination papers and the corresponding mark schemes to assist candidates with examination preparation.
- Teachers should ensure that definitions covered in the assessment statements for each option are well known by candidates.
- Candidates should be given guidance as to the level of depth expected in responses to questions. Journalistic answers to questions will not suffice.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Teachers should encourage candidates to note the number of marks allocated to a question and correlate this to their response to ensure it is sufficiently detailed. This will enable candidates to avoid just writing rambling statements, hoping that they will pick up marks somewhere in their answer.
- Candidates should read questions carefully to avoid missing parts of the question. Chemical equations should be given wherever possible to support the processes discussed in options.
- Candidates need to be aware of the importance of command terms. Candidates must know the meaning of the different command terms that appear in the assessment statements and in the examination papers.
- Teachers should emphasise the importance of clearly set out calculations Significant figures should be considered in all calculation type questions. Candidates should read questions carefully to avoid errors in units. Candidates should write legibly so examines can read responses
- Candidates must be instructed to use the chemistry data booklet during the chemistry course so that they are familiar with what the chemistry data booklet includes and practise determining the molecular formulae for the compounds, the structures of which are given in the booklet.

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Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 12	13 - 17	18 - 20	21 - 23	24 - 25	26 - 30

General comments

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

Teachers' impressions of this paper were conveyed by the 130 G2's that were returned. 59% found that it was of a similar standard, compared with last year's paper, 8% thought that it was more difficult and the remainder were of the view that it was easier. 97% described the level of difficulty as appropriate. 51% felt that the clarity of wording on the paper was satisfactory and 48% felt that the wording was good. Just 1% stated that the clarity of wording was poor. The presentation of the paper was considered satisfactory by 35% and good by 65%.

These statistics were also reflected in the general comments, where it was generally felt that the paper was fair with good coverage of the curriculum.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 91.01% to 32.68%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.68 to 0.16 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Questions 2 and 3

Some respondents stated that the numbers could have been more user-friendly in these questions, as candidates do not have access to a calculator in P1. This is a fair comment which will be borne in mind for future paper-setting. Candidates found Q3 particularly challenging with only 35.79% of candidates getting the correct answer A. The inconsistent use of significant figures in Q2 was also commented on, equally a valid comment. One respondent stated that they found the use of dm^3 instead of L confusing for North American candidates. However on IB Chemistry papers the unit of dm^3 for volume is always used instead of L and candidates should be prepared for this.

Question 6

One respondent suggested that neutral should have been inserted into the question for clarification purposes. However, neutrality is implied by the term atom in the question itself.

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Question 10

One respondent stated that there are two correct answers to this question, namely A. and C. This is incorrect as C. is CH_3CHO which is an aldehyde, and this does not form hydrogen bonding between its molecules. Hence the only correct answer is A. C_2H_5OH.

Question 13

One G2 comment stated that the terms cation and anion are not stated on the syllabus. Although strictly correct, it would be assumed that these terms would be introduced to students in the classroom as they are universally used in chemistry (e.g. even the term carbocation is widely used in explaining certain nucleophilic substitution reaction mechanisms).

Question 14

There were three G2 comments on this question. Some suggested that it would be better if more consistent use of significant figures would be used, which is noted and one stated that the question was complicated. The question was certainly challenging for candidates and only 36.27% of candidates got the correct answer B.

Question 16

One respondent stated that there was too much mathematics required to answer this question. However, candidates simply had to use Hess's law and were not required to determine the numerical value of the final answer. In fact, the question was the eight easiest question on the paper and 76.61% of candidates got the correct answer C.

Question 24

One G2 comment suggested that it would have been better if other examples were used in this voltaic cell, instead of the salts chosen. Although a valid comment, candidates simply had to realise that zinc changes its oxidation number from 0 to +2 and hence is oxidized, so therefore must be the negative electrode and the reducing agent. The question itself was answered correctly by only 39.27% of candidates.

Question 27

There were several comments on this question. One respondent stated that the terms were not covered in their IB textbook. It should be emphasised that it is the guide which defines the syllabus ONLY and NOT any one particular textbook which may be written for the programme itself. Other respondents stated that terms such as transition state and intermediate were not covered in the programme. However, this question relates to AS 10.5.2 and as such it is expected that some universally used terms would be introduced to candidates in explaining both S_N mechanisms. The question certainly was very challenging for candidates and only 32.68% of candidates got the correct answer B.

Question 30

Two respondents stated that the wording of this question was vague. However, this in fact was the easiest question on the entire paper for candidates with 91.01% of candidates getting the correct answer, B.

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Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 18	19 - 24	25 - 30	31 - 36	37 - 50

General comments

This paper identified a very broad range of candidate capabilities. Some candidates struggled with even the most basic concepts and factual knowledge while others demonstrated an excellent depth of understanding. In general candidates did not appear well prepared. There were schools where the candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank. Answers lacked precision in terms of the wording used and explanations were often vague.

Candidates managed the more guided questions where they had to 'define', 'name' or 'state' but struggled when asked to 'explain' a chemical concept or idea. Candidates could not identify the key point to gain full marks.

The *126* G2 forms that were returned conveyed teachers' impressions of this paper. The comments received on the G2 forms are considered very important feedback by the IBO and are reviewed thoroughly. Teachers are strongly encouraged to complete the G2 forms in future.

In comparison with last year's paper *52%* of respondents felt that it was of a *similar standard* and *14%* considered it a little *more difficult*. This contradicts the overall performance by candidates which was better than last year's. *93%* of respondents thought the *level of difficulty* was *appropriate*. Clarity of wording was considered *good* by *48%* and *satisfactory* by *52%* of the respondents. The presentation of the paper was considered *good* by *54%* and *satisfactory* by *41%* of the respondents.

This session was the first where electronic marking was implemented. Candidates should ensure they write legibly, within the designated boxes and if they need to write on addition pages they should make it clear to the examiner that they have done so. Some candidates' handwriting was very difficult to be read and candidates' spelling of chemical terminology was far worse than it has been in previous years.

A significant number of candidates also answered more than one question in Section B, indicating that they did not read the instructions correctly and wasted time answering more than one question in Section B.

Finally some schools are still using the old data booklets. The data booklet used must not only state on the front cover: *'First examinations 2009'* but within the front cover should state: *'Revised edition published September 2008'*.

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

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

- Calculation of enthalpy of combustion using bond enthalpies and average bond enthalpies
- The use of the expression q = mc□T
- Explaining melting points and boiling points in terms of bonding and structure
- Bonding and structure of the allotropes of carbon
- Definition of a 'period' of the periodic table
- Definition of first ionization energy
- Hydrolysis equations of the oxides of period three
- Metallic bonding

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

There were some excellent scripts from some candidates whose answers indicated thorough knowledge and understanding across the syllabus.

Topics generally well answered included:

- Atomic structure
- Deducing electron arrangement
- Basic calculations of number of mole
- Features of homologous series
- Brnsted-Lowry definitions of acids and bases and the relationship between pH and concentration of H^+ ions.
- Radioactive isotopes of carbon and their uses
- Reactions of alkenes

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

Section A

Question 1

Many errors were seen in part (a). Candidates used the wrong values from the Data Booklet, wrong coefficients were used and not all the correct bonds were selected. Some candidates also reversed the final calculation to get an endothermic enthalpy rather than an exothermic enthalpy or made careless arithmetic errors. In part (b) candidates were proficient at correctly calculating the number of mole methanol burnt but did not use the expression q = mc□T well. Again numerous errors were seen here with candidates using the mass of methanol rather than water, adding 273 to the temperature change calculated and not converting J to kJ.

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Some candidates did not recognise that the combustion of methanol is exothermic and hence did not include the negative sign for the enthalpy change. Part (c) was generally well done, however candidates often just stated that 'heat was lost' in part (ii). A more detail response was expected, e.g. heat was lost to surroundings.

Question 2

This question was the best answered on the paper and generally well answered question. In part (a) candidates sometimes incorrectly used the term relative atomic mass instead of relative isotopic mass when referring to the mass of an isotope. Most candidates correctly deduced the number of protons and electrons in the K^+ ion, however some candidates did not read the question carefully and deduced the number of subatomic particles in the K atom. Many standard level students also wrote electron configuration, i.e. used subshell notation which it acceptable but in standard level only electron arrangement is required i.e. shell notation.

Question 3

Candidates were able to write an equilibrium expression accurately in part (a). In part (b) candidates had a good understanding of the effect of temperature and pressure on an equilibrium system but some did not make reference to the change in the amount of methanol produced and hence did not always achieved full marks. In (b) (ii) candidates also failed to achieve full marks if reference was not made to the gaseous nature of the reactants and products. Occasionally candidates incorrectly discussed the effect on the rate of reaction rather than answering the question. There was much confusion with part (c) and candidates often struggled to express themselves adequately, demonstrating that they did not fully understand the question. Part (d) on the other hand was extremely well answered with candidates having an excellent understanding of the function of a catalyst.

Question 4

Candidates were able to calculate the mass of ethanol and octane in the fuel mixture. The most common error here involved not expressing the answer in the requested units of grams. A number of candidates expressed answers in kg. Many candidates were able to calculate the number of mole of ethanol and octane in (a) (ii) but errors in the calculation of molar mass were seen regularly. Candidates should also use the relative atomic masses, expressed to two decimal places as in the Periodic Table provided in the Data Table. In part (a) (iii) some candidates multiplied incorrect numbers together or did not consider the number of moles of each part of the fuel mixture. Some candidates just added the enthalpies of combustion provided in the questions. Part (b) was found to be very challenging by candidates. Very few candidates had the depth of understanding to answer this question adequately.

Section B

Question 5

The definition of first ionisation energy given by most candidates in (a) (i) was incomplete. The word gaseous was missing from most definitions given. Candidates also struggled to explain the differences in first ionization energies of magnesium and sodium. Candidates did not need knowledge of subshells as was suggested in one comment in the G2 forms. Candidates needed to make reference to nuclear charge and size of atomic radius and their effect on the attraction to the electrons. Part (b) (i) clearly indicated that candidates were not familiar with metallic bonding and in part (ii) the candidates incorrectly discussed the bonding in the sulfur trioxide molecule rather than the intermolecular forces.

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Many candidates incorrectly wrote words to the effect that ionic bonding was stronger than covalent bonding to explain the differences in melting point of the two compounds. Parts (c) (i) and (iii) were well managed with candidates correctly defining acids and bases according to the Br□nsted-Lowry theory and had a good understanding of the relationship between pH and concentration of H^+ ions. Part (c) (ii) was reasonably well answered but candidates did not always provided one chemical and one physical method to distinguish between the two acids. Even though candidates were able to identify sodium oxide and sulfur trioxide as basic and acidic respectively they struggled to write correct equations for the oxides with water in part (d).

Question 6

Although this was the least popular Section B question it tended to be well done by those candidates who attempted it. Part (a) was generally well answered with most candidates able to achieve at least 2 out of the 3 marks. Candidates could state the trend in melting points of the first five members of the alkenes but did not always explain the trend thoroughly. In part (b) candidates tended to be careless with the use of terminology and used structural or molecular formula rather than general formula when describing a feature of a homologous series. Many candidates also stated that compounds in a homologous series differ by $-CH_2-$ group but it is successive members that differ by the $-CH_2-$ group. Greater care in the use of chemical terminology is needed. The structures in part (c) were well deduced but some candidates were very careless with naming compound C, not taking care with IUPAC nomenclature. In part (d) candidates were able to identify the bromine test for distinguishing between the alkane and alkene but often did not correctly identify the colour change associated with pent-1-ene and incorrectly suggested that the colour of the bromine changed to clear when it should be colourless. Part (e) was well done with the exception of identifying structure G as a primary halogenoalkane. Many candidates incorrectly identified it as a tertiary halogenalkane.

Candidates were able to explain with equations the free radical mechanism for the reaction between methane and chlorine. Candidates could only achieve the mark for the initiation step if reference was made to UV with the correct equation. Occasionally candidates incorrectly showed ions rather than radicals in the equations.

Question 7

This was a popular Section B question but clearly candidates found some sections challenging. The definition of period given by most candidates in (a) (i) was incomplete. Candidates stating that a period consisted of elements with the same number of shells rather than the same number of electron occupied shells. Part (b) was exceptionally well done. Many candidates struggled with Part (c) not being able to clearly identify the bonding and structure in the allotropes of carbon. Candidates often incorrectly discussed the properties of the allotropes. In Part (d), candidates were competent at drawing carbon dioxide but struggled to identify the bonding and structure in silicon dioxide. Most candidates incorrectly identifying silicon dioxide as molecular compound. Candidates also struggled to explain why CO_2 was a gas and SiO_2 was a solid a room temperature and again commented on the properties of the compounds rather than the structure and bonding. In part (e) many candidates failed to state that a dative bond was present in CO. Although the calculation in (f) was more challenging than similar questions in the past, it was managed by many candidates. Most candidates were able to identify a radioisotope of carbon and it use, but surprisingly a number of candidates misread the question and discussed radioisotopes of cobalt.

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Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding markschemes to assist candidates with examination preparation.
- Teachers should provide many opportunities to candidates to practice thermochemical calculations and explanations of physical properties of compounds and elements in terms of structure and bonding.
- Teachers should ensure that definitions covered in the assessment statements for each topic are well known by candidates.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Teacher should encourage candidates to note the number of marks allocated to a question and correlate this to their response to ensure it is sufficiently detailed.
- Candidates should practice writing balanced equations.
- Organic mechanisms should be clearly described.
- Strongly encourage candidates to answer ***only*** one question in Section B.
- Candidates need to be aware of the importance of ***command terms***. Candidates must know the meaning of the different command terms that appear in the assessment statements and in the examination papers.
- Teacher should emphasise the importance of clearly set out calculations
- Significant figures should be considered in all calculation type questions.
- Candidates should read questions carefully to avoid errors in units.
- Candidates should write legibly so examines can read responses.

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 - 24	25 - 28	29 - 40

General comments

The examiners were pleased to note that there was a very slight improvement in the overall performance of the candidates taking this paper as indicated by the decrease in the percentage of candidates obtaining the lower grades and an increase in those obtaining the highest grade. This may be connected with a decrease in the entry for this subject at HL and a significant increase at SL, indicating that schools may be giving their students more appropriate advice with regard to subject selection.

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There was the usual wide range of performance and some excellent scripts were written but, that being said, there were still far too many candidates taking the examination who had not been adequately prepared for this paper, as indicated by the fact that well over half of the entry were obtaining a grade of 3 or below, significantly greater than for the other components of the assessment.

Apart from inadequate knowledge, another major weakness was very generalised responses more appropriate to the popular press rather than a student who has an academic grasp of the topic. As in the past students from some schools attempted a wide variety of different options, implying perhaps that this part of the course had been set as a self-study exercise, rather than being taught. This is not appropriate to a component comprising 24% of the final mark.

In terms of the G2 forms submitted (still a disappointingly low percentage of the number of schools entering candidates) almost all rated the paper as satisfactory or good with regard to clarity of wording and presentation of the paper. In Option E however, Question 3 only occupied a small portion of the top of the page and this may have resulted in some candidates overlooking Question E4 overleaf. This has been noted and such potentially misleading layouts will be avoided in the future. Over 90% of those who responded (94 out of 111) felt that the difficulty of the paper was appropriate, though almost all the remainder felt it was too difficult and about a quarter of those who responded felt that the paper was more difficult than the one set last year. The least popular options were Option A, Option C and Option G, with Option D and Option E being the most popular.

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

There was considerable variation, but some areas of repeated weakness were:

- Atomic absorption spectroscopy
- Polysaccharides
- Structure of nanotubes
- Cracking methods
- Use of plasticizers
- Conversion of iron to steel
- Antiviral drugs
- Aerobic/anaerobic decomposition products
- Multi-stage distillation of sea water
- The nature of genetic modification
- Reaction mechanisms
- Quantitative chemistry
- Writing balanced equations

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

The areas candidates seemed to understand best were:

- Thin-layer chromatography
- Effect of triglyceride structure on melting point
- Use and abuse of anabolic steroids
- Effects of caffeine and nicotine
- The role of hormones and uses/abuses of steroids
- Antacids
- Sources of acid rain
- Reverse osmosis
- Formation of carbon monoxide
- Shelf life
- Difference between dyes and pigments
- Advantages of and concerns about genetically modified foods

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

Option A – Modern analytical chemistry

Question 1

Students could often indicate the uses of atomic absorption spectroscopy, but very few seemed familiar with how it is carried out.

Question 2

Quite a few candidates demonstrated some skill in interpreting the nmr spectrum in terms of the groups present and could identify features that were likely to be present and absent in the in the infra-red and mass spectra, though in the latter many omitted the charges on the ions. Candidates gave too little thought to predicting features of the nmr spectra of the other compounds, concentrating on the hydrocarbon group without taking into account the neighbouring functional group.

Question 3

This was generally well done though in the final part quite a number of students did not mark their spot with sufficient precision (±1 mm).

Option B – Human biochemistrty

Question 1

Very few candidates seemed familiar with the structures of the required polysaccharides and whilst most knew that cellulose could not be digested because humans lack the required enzyme, far fewer could name this enzyme.

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Question 2

Many candidates correctly identified the number of double bonds present from the molecular formula and could link this to the iodine number, but fewer knew that these were essential fatty acids (that is ones we cannot synthesise) and the way in which they are used in the body. It was surprising how few students could correctly identify the hydrolysis products of a triglyceride and, though many were aware of the links between structure and melting point, explaining this concisely sometimes proved to be a challenge.

Question 3

Most students had some idea of the modes of action of oral contraceptives, though many did not explain these in sufficient detail. The uses and abuses of anabolic steroids seemed to be generally well known, though some appeared to confuse these with the corticosteroids in the inhalers used for asthma.

Option C – Chemistry in industry and technology

Question 1

Though many candidates could quote the scale that nanotechnology deals with, few could state specific concerns about its implementation, and hardly any could distinguish between the bonding in the walls and the ends of nanotubes.

Question 2

Few candidates appear to have any knowledge of the different cracking techniques, though more appeared familiar with issues relating to catalysts. Quite a number of candidates were aware carbon-carbon double bonds were needed for addition polymerization, though the nature and effect of plasticizers was less well known

Question 3

Many students confused the conversion of iron to steel with the smelting of iron ore. A significant number seemed to have memorised a method of heat treatment of steel and many could indentify ways in which the iron and steel industry has an environmental impact.

Option D – Medicines and drugs

Question 1

Surprisingly few students could correctly answer the parts related to the structures of caffeine and nicotine, often not realising that the carbonyl group is not a ketone, but is present as part of an amide group. The effects of caffeine and nicotine were however better known, though they were sometimes confused and answers too general to gain credit were often encountered. Quite a few candidates were aware of the meaning of the terms *sympathomimetic* and *synergistic* and could quote suitable examples.

Question 2

Whilst quite a few candidates could write one of the required balanced equations a surprising large number could not succeed in this simple task. Answers to the second part of this question often lacked the stoichiometric rigour required and the reasons for not using strong alkalis provoked an amazing range of responses, mostly incorrect and many exposing a worrying lack of basic chemical knowledge. Only a minority of the students could correctly identify the function of alginates and dimethicone in antacid preparations.

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Question 3

Many students failed to note that the first part of the question referred to **structural** differences between viruses and bacteria, rather than more general differences. The mode of action of antiviral drugs appeared to be poorly understood and answers were often very vaguely expressed, as were answers to why effective AIDS treatment is such a problem.

Option E – Environmental chemistry

Question 1

Most candidates correctly identified carbon dioxide as the source of natural water acidity and wrote an acceptable equation. Many also identified sources of nitric and sulphuric acid, though these equations often proved trickier, with many candidates writing equations for the formation of the oxide from which the acid is derived. Balanced equations for the reaction with limestone also proved to be a challenge, with carbonic acid often appearing as a product.

Question 2

Relatively few candidates were aware of the final products of bacterial aerobic and anaerobic decomposition and the calculation of the mass of oxygen required was also beyond most.

Question 3

More students attempted to explain reverse osmosis, rather than multi-stage distillation, and generally speaking those that chose this option produced the better answers. Quite a few students incorrectly thought this question was about the second stage (aerobic bacterial decomposition) of waste water treatment.

Question 4

The conditions required to produce carbon monoxide were well known, as was the role of carbon dioxide as a greenhouse gas. Fewer students could write an equation for the reaction taking place in a catalytic converter and, whilst quite a number could correctly identify one way to reduce carbon monoxide emissions, relatively few could come up with the two ways that were required for the mark.

Option F – Food chemistry

Question 1

Quite a few candidates could correctly identify the relative degree of saturation of the oils, though some thought they had to include all four in their answer. The meaning of shelf life was quite well known, in addition many realised that increasing unsaturation decreased shelf life and could suggest ways of increasing it. The conditions requiredcfor hydrogenation were not well appreciated, especially the need for a catalyst, and few could write any specific details regarding trans-fats apart from the fact there were health concerns regarding these.

Question 2

Almost all students knew the difference between dyes and pigments and many could explain they way in which they affected reflected light. Many students also came up with appropriate examples of pigments, though responses to the final section, on differences in regulations, were often vague.

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Question 3

Many students appeared unaware of the exact meaning of the phrase *genetically modified*. They were however better briefed on the advantages and possible concerns regarding foodstuffs from such sources.

Option G – Further organic chemistry

Question 1

Quite a number of students could correctly identify the intermediate and though some could write a correct equation with conditions, only a few could write a correct mechanism for the reaction. Only a handful of students realised that butan-1-ol can only give one dehydration product and would hence be a better starting material.

Question 2

This was generally very poorly done. Not many candidates were aware that chlorobenzene is very difficult to hydrolyse and even fewer could explain this. The formulas of Grignard reagents and the conditions required for their production seemed to be poorly known. The final sections revealed that knowledge of cyanohydrins was as inadequate as that of Grignard reagents.

Question 3

Hardly any students recognised the compound as an amine salt and, although some knew that secondary amines were more basic than ammonia, few could explain this

Recommendations and guidance for the teaching of future candidates

- Given the quite high weighting of the paper, more time and resources need to be devoted to the teaching of the options. It is not necessary, or even advisable, to leave the options until the end of a teaching programme, when time can run out making the coverage of this material woefully inadequate.
- Candidates should ensure that they know any definitions in the options covered and can also write any balanced equations required.
- Candidates need to read questions carefully ensure they answer exactly what has been asked precisely, from the perspective of a chemist, rather than in vague, general, journalistic terms.
- Candidates need to take note of the action verb in the question and use this, along with the number of marks assigned, as a guide to the depth of answer required.
- Candidates should hone the skills required with regard to the previous three points, by practicing past paper questions and carefully studying the mark schemes.

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