Chemistry TZ1 (IBA)

Overall grade boundaries

Higher level

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

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 31	32 - 43	44 - 53	54 - 63	64 - 74	75 - 100

Internal assessment

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 27	28 - 33	34 - 38	39 - 48

Standard level

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 2012 session was similar to May 2011 in terms of the suitability of the work submitted for assessment of the criteria. Generally the samples were well presented and the procedures were followed. 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 their marking awards.

In comparison to the situation five or more years ago, the appropriateness of the assessed work has improved significantly and now most schools recognize that the Internal Assessment component requires special attention from both teachers and students alike. The quality may still be variable, such is the nature of the students themselves of course, but at least the work is assessable by the criteria in most cases. Increased support for teachers through face-to-face and online workshops, plus of course the Online Curriculum Centre, is hopefully having a permanent positive impact on global understanding of the requirements. The one frustration is that there are a number of schools who do not act on the same feedback comments from moderators in the 4IAF form on IBIS year after year. Possibly the DP Coordinator is not forwarding the feedback to the teacher which is such a pity for all concerned, especially the students.

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.

The most disappointing aspect of this session was the fact that more schools than ever before were submitting Design assessments which were purely theoretical exercises and there had been no follow up experimental phase. Although this is permissible by the regulations it is seen later in this report that this trend has led to a lowering of quality of Design achievement. Equally importantly the lack of practical implementation has also deprived students of the opportunity to fully participate in a valuable exercise in inquiry and practical problem solving while denying them the chance to feel the sense of ownership and excitement that comes from carrying out their own designed investigation.

In tasks being assessed for Data Collection and Processing fewer teachers now provide instructions that gave too much support to the students in terms of guidance on how to record or process the data which has helped improve attainment. Some schools limited the processing of data to excessively simple tasks which involved only very basic numerical manipulation such as finding an average or subtracting two numbers to find a temperature change. This approach is clearly below expectations.

There are still too few assessments that challenge students to determine a quantity from a graph rather than make a simple qualitative comparison, something that would benefit Higher Level candidates especially.

Candidate performance against each criterion

Design

Aspect 1

This was generally well addressed with many students being able to phrase a focussed research question and to identify most variables with an award of at least Partial, and in many cases Complete. One recurring failing was that students incorrectly identified the dependent variable as the derived quantity (e.g. “rate of reaction” or “enthalpy of reaction”) rather than the actual measured variable, such as time for a given volume of gas to be produced or the temperature increase of the reaction mixture.

Aspect 2

This was consistently the most challenging of the Design aspects and Partial was the most frequent award.

One common weakness as in previous years was that 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. For example if in a kinetics investigation temperature is identified as a control variable then the reaction mixture temperature (and not the surrounding room temperature as was frequently stated) should be controlled through use of a water bath or at least monitored with a thermometer or probe.

Two other weaknesses more frequently arose this year possibly owing to the fact that we saw an increase in the number of Design tasks set without an associated practical phase. Firstly very many student designs contained insufficient procedural detail for the reader to be able to reproduce the experiment. Not including details on how standard solutions were to be made up or what volumetric glassware is to be used, or not stating how to make up a salt bridge in an electrochemical cell or forgetting to think about drying an electrode in an electroplating investigation were among the common failings. The lack of an action phase certainly was the main factor in an increased number of absurdities appearing in students' designs, for example the use of extreme and unrealistic concentrations of acid up to 30M or the measurement of the mass gain in electroplating after only 15 seconds of current flow.

If teachers can ring fence sufficient time for the students to undergo the iterative process of initial planning, followed by trial experiments, followed by finalized written design, prior to the main action phase then achievement in this criterion will be enhanced.

Aspect 3

There was a good level of fulfilment of this aspect with most students able to design realistically for the collection of sufficient data. The only group of candidates who possibly missed out on any marks in this aspect were those who, as mentioned earlier, had not had the opportunity for any hands-on development of their designs and had submitted unrealistic procedures that would not have collected any relevant data at all.

Data Collection and Processing

Aspect 1

There was generally a good level of fulfilment with most candidates able to present data in suitably constructed tables with appropriate column headings, units, uncertainties and relevant qualitative data. There was however frequent inconsistency between the number of decimal places of the raw data compared to the cited uncertainty.

Aspect 2

Where schools had set meaningful processing tasks the outcomes were varied as would be expected of a criterion that challenges students' quantitative skills.

Where the assessment focussed on numerical calculations, often in stoichiometry, the students could usually process the data to reach the desired result with no or few significant errors. One area, enthalpy determinations, saw a variety of standard of response. Some students appropriately graphed temperature against time and extrapolated in order to compensate for heat loss as they calculated the temperature change after mixing reactants. Very few students however took into consideration the heat capacity of the calorimeter, something that should really be an expectation for at least Higher Level candidates.

The use of graphs was more encouraging than in previous sessions although still too few candidates were challenged to determine a quantity from the graph and in most cases a qualitative comment on the observed trend was the sole outcome.

Aspect 3

In general there was a good level of fulfilment and many candidates secured at least Partial although some inappropriate sketch graphs were presented and some schools still persisted in only presenting bar graphs which are seldom appropriate for most investigations in our field.

To secure Complete, the candidates must take uncertainties into consideration and either propagate them through the calculation or to treat them in graphical analysis through the construction of a best-fit line. In both cases this often proved problematic. Propagating errors through a calculation is clearly a demanding expectation and many students found it difficult. It is a pity that this requirement is causing so much anxiety amongst students and teachers since it is a small requirement. The effort being put into propagating uncertainties (often for no reward) seems to be deflecting from the conceptual insight that should be gained through practical work. Securing the mark through constructing a best-fit line should have proved easier, but poor selection of the trend line in Excel meant that many candidates did not meet the standard.

Conclusion and Evaluation

Aspect 1

It was more common during this session for candidates to compare their results to literature values where appropriate. A significant proportion of candidates were then able to identify 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

As last year, 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, simplistic or unrealistic contributions. Suggestions limited to increase the number of trials (even when the repetitions had been satisfactory for school level) or making use of unspecified more sophisticated equipment were fairly common and of little merit.

There still persists a trend in teachers to over-rate very simplistic evaluations or suggestions often not related to cited errors. Another rather common approach is to award Complete for suggestions that address cited limitations, but which are largely affected by the poor quality of the preceding evaluation. Several schools showed to have benefited from feedback and their approach was more accurate than during previous sessions and this is very encouraging.

Manipulative Skills and Personal Skills.

All schools entered marks for these criteria.

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. Happily, where data logging was involved in assessed investigations, we did not see the overwhelming number of pages of printed out data being included, a problem that had affected previous sessions.

Recommendations for the teaching of future candidates

- Candidates should be made aware of the different aspects of the criteria by which they are assessed.
- Teachers should endeavour to give their students the opportunity to carry out the practical phase associated with their Design investigations.
- 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.
- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.
- 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.
- Instruction of appropriate use of graphing software especially the construction of best-fit lines would benefit many candidates.
- 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.
- Teachers should 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.

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 (D)

Aspect 1

- 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 (for example, by correctly identifying a good number of control variables) then “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. It could be felt that it has also completely focussed the research question so the final aspect 1 award could be “not at all”.

- If the teacher has identified just the independent or just a control variable then “partial” can still be awarded.

- The teacher is allowed to specify the dependent variable when setting the task.

When not to mark down for aspect 1

- The independent and controlled variables have been clearly identified in the procedure but are not given as a separate list (the whole report must be marked and there is no obligation for candidates to write reports according to the aspect headings).

Aspect 2

- 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 DCP aspect 1, in the raw data uncertainties.

- If a teacher has given students the full procedure then award “not at all”.

- If a teacher has given a partial procedure then consider what can be awarded for the candidate's own contribution. The most probable award here is “partial”.

- If a candidate has used a partial method from another source then that source should be acknowledged. Again a moderator should consider what can be awarded for the candidate's own contribution. If a candidate has completely taken a design from another source then award “not at all”, even if the source is acknowledged.

When not to mark down in aspect 2

- Similar (not word for word identical) procedures are given by different candidates for a narrow task. Moderators should comment on poor suitability of task on 4/IAF form.

- No equipment list is present but the information is provided elsewhere, for example, in the stepwise procedure.

- The +/– precision of apparatus is not given in an apparatus list.

- Routine items such 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 and so don't need listing. Moderators should support the teacher's stance here.

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 a procedure so poorly that no relevant data would be collected then moderators should 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 (for example, titrations or calorimetry, etc.) moderators should award “partial”.

The material / apparatus

- There is no specified aspect to assess the equipment / materials list. If candidates have failed to identify suitable materials to control the variable for example, 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 (for example, only identifying two alkanes when looking at affect of alkane chain length on some property) then it would affect aspect 3 award.

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

Data collection and processing (DCP)

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 p, n, n = 1.

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).

Moderators should 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.

If a photocopied table is provided with heading and units that is filled in by students then the maximum the moderator can give is n = 0.

- If the candidate has only recorded quantitative data (for example, 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 should award “partial”.

- Moderators should 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. Moderators should 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 “partial” or “not at all” depending on how much other raw data is present.

When not to mark down aspect 1

- When the candidate has not included any qualitative observations and the moderator cannot identify any that would have been obviously relevant.

- If the candidate has been inconsistent with significant digits for just one data point or missed units out of one column heading in a comprehensive data collection exercise possibly with several tables of data. The principle “complete does not mean perfection” is significant in this case as otherwise good candidates responding in full to extended tasks get penalized more often than candidates addressing simplistic tasks.

- When there is no table title and it is obvious what the data in the table refers to. With the exception of extended investigations it is normally self evident what the table refers to and the section heading "Raw data" is sufficient. Again “complete does not mean perfection”.

Aspect 2

- If a teacher has given the method of calculation or told the students which quantities to plot then the moderator should award “not at all”.

- If a candidate has made an error in a calculation leading to an incorrect 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 trend line then moderators should award “not at all”.

Aspect 3

- If the candidate's method of processing cannot easily be followed then the maximum award is “partial”.
- 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”.
- Moderators should 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 “partial” at best. Moderators are reminded 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 protocol in the Teacher support material (TSM) or another accepted protocol. Moderators should 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 aspect 3

- If inconsistent significant figures are reported in the middle of a stepwise calculation and the final answer(s) is(are) reported appropriately.
- If the candidate has clearly attempted to propagate uncertainties even if it is felt that the candidate could have made a more sophisticated effort, the moderator should not punish the teacher or candidate if the protocol is not the one that the they teach, i.e. top pan balance uncertainties have been given as +/– 0.01g.

Conclusion and evaluation (CE)

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. Moderators should judge purely on the candidate's input.

Aspect 1

- The conclusion can take many forms depending on the nature of the investigation. It could be a clear restatement of the determined numerical quantity (for example, the molar mass or activation energy), a statement of the relationship found, etc. Such a clear statement should be awarded “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.

Aspect 2

- The moderator should check that the candidate has identified the major sources of error. Other possible sources may be present but overly long lists containing less important points are not required.

- There is no written requirement to state the direction of each source error 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 is 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 aspect 2

- Moderators should apply the principle that “complete does not mean perfection”. For example if the candidates have identified most sensible sources of systematic error then the moderator can support a teacher's award even if they think one more can be identified.

Aspect 3

- It is important that the suggested modifications are realistic and should relate in the main to the identified weaknesses. 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 a task was too simple to truly meet the spirit of the criteria, moderators should comment on the 4/IAF as to the unsuitability of the task giving full justifications but should not necessarily downgrade the particular candidate. This does mean that candidates achieve marks in DCP for brief work on limited data but if they have fulfilled the aspect's requirements within this small range moderators should support the grade.

Data logging

Data logging is encouraged 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, moderators should be guided by the teacher who knows exactly what the candidates had to do. Moderators should apply the normal standards regarding expectations of data presentation (units, uncertainties, etc.) and graphs (best fit lines, axes labels, suitable scales, etc). Where there are concerns as to whether the candidates have had sufficient input, moderators should comment in the feedback to the school on the 4/IAF.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 15	16 - 21	22 - 25	26 - 29	30 - 33	34 - 40

General comments

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) material and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and no credit deducted for incorrect answers. Teachers' impressions of this paper were conveyed by 66 G2 forms that were submitted. 95.5% reported the level of difficulty to be appropriate, with the remainder thinking it was too difficult. In comparison with last year's paper, 65.2% considered it to be of similar standard or a little easier, 24.2% considered it to be a little more difficult and 3% much more difficult. Clarity of wording and the presentation of the papers was considered good or satisfactory by 96.9%. These statistics were also reflected in the general comments and the syllabus coverage was found to be good.

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

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	365	1692	239	2719	5	54.16	0.56
2	2596	1626	393	386	19	51.71	0.56
3	2757	1103	811	340	9	21.97	0.35
4	1678	65	3257	17	3	64.88	0.43
5	552	439	3937	86	6	78.43	0.25
6	116	2891	1046	962	5	57.59	0.49
7	568	1076	245	3124	7	62.23	0.37
8	980	986	299	2751	4	54.8	0.49
9	594	3482	347	590	7	69.36	0.4
10	329	902	766	3013	10	60.02	0.33
11	3447	309	937	315	12	68.67	0.52
12	195	685	3559	580	1	70.9	0.39
13	579	2477	899	1049	16	49.34	0.37
14	145	344	553	3974	4	79.16	0.42
15	587	822	1189	2408	14	47.97	0.43
16	3366	478	869	294	13	67.05	0.36
17	703	763	2593	945	16	51.65	0.35
18	964	2627	653	753	23	52.33	0.46
19	3115	455	610	834	6	62.05	0.58

20	3341	643	483	549	4	66.55	0.31
21	581	2257	1224	945	13	44.96	0.24
22	2490	471	1755	293	11	49.6	0.52
23	86	99	4694	133	8	93.51	0.08
24	2749	252	555	1454	10	54.76	0.36
25	1510	1562	1116	812	20	31.12	0.22
26	3042	366	1172	427	13	60.6	0.44
27	1086	748	553	2618	15	52.15	0.48
28	1562	974	649	1802	33	35.9	0.44
29	3112	1412	233	260	3	61.99	0.57
30	667	632	3208	500	13	63.9	0.55
31	454	1642	883	2030	11	32.71	0.38
32	467	1393	2639	492	29	52.57	0.38
33	342	471	1377	2812	18	56.02	0.48
34	1390	2414	693	489	34	48.09	0.24
35	861	559	381	3202	17	63.78	0.53
36	606	554	684	3158	18	62.91	0.46
37	32	923	3254	798	13	64.82	0.2
38	2044	669	634	1631	42	40.72	0.37
39	1830	557	357	2242	34	44.66	0.41
40	496	133	4187	186	18	83.41	0.17

Number of candidates: 5020

The numbers in the columns A–D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank. The correct option is indicated by a grey cell. The *difficulty index* (perhaps better called facility index) is the percentage of candidates that gave the correct response. A high index thus indicates an easy question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

The difficulty index ranged from 93.51% to 21.97%, and the discrimination index ranged from 0.58 to 0.08.

The following comments were made on selected individual questions:

Question 7

Two respondents stated that silicon dioxide is actually amphoteric as cited in one textbook widely used for the current IB Chemistry Diploma programme. This statement in fact is incorrect in the textbook concerned as SiO_2 is actually classified as an acidic oxide. SiO_2 reacts with NaOH at T ~ 623 K, according to the equation $SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$. It is true that it does not react with water to form an acid. However, due to its clear reaction with sodium hydroxide it is classified as an acidic oxide. 62.23% of candidates got the correct answer, D for this question.

Question 9

One respondent stated that in class he/she uses the term steric number, instead of number of negative charge centres. It is true to state that there are a number of different terms that can be used for this concept. In some recent textbooks at University level, the more modern term electron domain is used instead of negative charge centres, in line with a recent review article on *Fifty Years of the VSEPR Model*, published in 2007 by R.J. Gillespie at McMaster University in Canada in *Coordination Chemistry Reviews*, where the idea of the electron-pair domain is mentioned. This can be a very useful concept in distinguishing between what is termed the Electron Domain Geometry and the Molecular Geometry (e.g. ammonia has a tetrahedral electron domain geometry but its molecular geometry is trigonal pyramidal). This more up to date terminology based on the literature is being currently considered as part of the new IB chemistry curriculum as well as more clearly distinguishing between the two types of geometries when dealing with VSEPR theory. However, it should be noted that at present the current term used in the guide is the number of negative charge centres as per AS 4.2.7, so candidates should be familiar with this term in questions although several different terms may be seen by students in textbooks.

Question 15

There were a couple of G2 comments on this question, ranging from one stating that the presentation of the question could have been better to one stating that it was difficult to choose the best answer from the choices given due to the wording. Although the question certainly could be considered in the top 20% of challenging questions on this paper, 47.97% of candidates did manage to get the correct answer, D. The related discrimination index was 0.43.

Question 16

There were three G2 comments on this question, stating that the way the Born-Haber cycle was represented for the lattice enthalpy of sodium chloride was somewhat unusual and confusing. However candidates did not have any great difficulty getting the correct answer A, and in fact this was found to be the eighth easiest question on the entire paper, with 67.05% of candidates getting the correct answer. It should also be stated that although an exothermic definition of lattice enthalpy is often cited in some sources, the endothermic definition of lattice enthalpy is used in the IB programme.

Question 19

A number of respondents stated that in this question it would have been better if the initial Maxwell-Boltzmann energy distribution curve would have been superimposed for comparison purposes on the four curves given in A–D respectively. This is a fair comment. Candidate performance was generally good, with 62.05% of candidates getting the correct answer, A.

Question 22

There were also a number of G2 comments stating that the wording in this question was somewhat confusing. Candidate performance on this question was in the mid-range, with 49.60% of candidates getting the correct answer A.

Question 24

One G2 comment on this question raised the question as whether or not a conjugate acid–base pair according to the Brønsted–Lowry theory could involve the removal of more than one proton, suggesting that H_2SO_4/SO_4^{2-} i.e. III. is also such a pair. This is incorrect. A conjugate acid–base pair involves a species differing by the gain or loss of a single proton, giving A as the only correct answer i.e. NH_4^+/NH_3 and $HCOOH/HCOO^-$ are conjugate acid–base pairs but the couple H_2SO_4/SO_4^{2-} is ruled out as a two proton difference is involved. 54.76% of candidates did get the correct answer A, but many candidates did think that the latter also was such a pair and D then became the second most common answer after A for this question.

Question 25

Two respondents expressed surprise at this question stating that candidates would need to know the relative reactivities of zinc and copper to answer the question. Although this is a fair comment per se, based on a combination of Topic 8 and Topic 9 and being exposed to some clear experimental work in this area, it would be assumed that candidates should be able to determine B as the correct answer. The question certainly was a very challenging question for candidates, and in fact was the second most challenging question on the paper with only 31.12% of candidates getting the correct answer. When the statistical data for this question was analysed, it was very surprising that the second most common answer given in fact was A (not C involving copper), namely that X = nitric acid and Y = calcium carbonate. However, this reaction with A as the answer, would not produce hydrogen gas, so candidates clearly were not able to make this distinction in arriving at the correct answer, B.

Question 26

One respondent stated that mol dm^{-3} should have been included for the unit concentrations, which is a valid point, though this did not affect candidates in answering the question itself. 60.60% of candidates got the correct answer, A.

Question 27

The correct answer to this question is D. i.e. $[Fe(H_2O)_6]Cl_3$. Although the better candidates did recognize the acidic nature of the highly charged iron(III) ion, with 52.15% getting the correct answer, it was surprising that 1086 candidates chose A, KNO_3 as the answer, showing poor understanding of salt hydrolysis involving highly charged transition metal ions such as Fe^{3+}.

Question 30

One G2 comment referred to the fact that the state of water should have been given as (l) in the equation and not (aq), which is correct. This will be amended in the final published paper.

Question 32

One respondent stated that the delta signs were confusing in the question (and would have been better omitted), which is a fair comment, but after discussion, it was felt that this would not have prevented candidates from answering the question.

Question 34

Two respondents stated that reduction of aldehydes is not on the syllabus. It is true to say that reduction of aldehydes is not strictly mentioned as an explicit assessment statement. However, oxidation of primary alcohols should be known relating to AS 10.4.2 and AS 10.4.3, and redox as a concept is covered as part of Topic 9, so candidates should be able to link the two ideas together in the context of this question, giving B as the only possible answer. Candidate performance resulted in 48.09% of candidates getting the correct answer, B. It is true to say that many did opt for A (I. and II.) as they failed to make this redox link.

Question 38

One respondent stated that this question should be omitted as students are not expected to be able to compare the rates of nucleophilic substitution in a methyl halide versus a secondary halide, since the methyl halide will proceed 100% by the S_N2 mechanism while the secondary halide will proceed by a combination of S_N1 and S_N2. This is a very valid point and was discussed at length during GA. However, although the point made is perfectly legitimate, the question was not omitted from the statistical analysis, as the only possible answer is A in fact. The reason for this is that the carbon to fluorine bond has a higher bond enthalpy than the carbon to chlorine bond, which means that CH_3F must always be less than CH_3Cl in terms of rate of reaction. This automatically rules out B, C and D, meaning the only possible answer is in fact A based on this fact alone. For this reason, the answer was kept as A.

Question 39

In this question, 44.66% of candidates gave the correct answer D. However, a large proportion of students gave A as the correct answer, and clearly did not understand that one of the monomers involved in the condensation polymerization reaction to form nylon is in fact $H_2N(CH_2)_6NH_2$.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 12	13 - 25	26 - 37	38 - 48	49 - 58	59 - 69	70 - 90

General comments

Generally the paper was found to be accessible. It allowed the weaker candidates to demonstrate some chemical knowledge but was sufficiently challenging to test the strongest candidates who showed a thorough command of the material and high level of preparation. There were 351 schools entered for this session and teacher's impressions of the paper were conveyed by the 66 G2 forms returned. 85% of the respondents considered the level of difficulty of the question paper appropriate and 15% too difficult. In comparison with last year's paper, 42% felt that it was of similar standard, 10% thought that it was easier and 41% were of the view that the paper was a little more difficult. Clarity of wording was considered good by 40% and satisfactory by 51% of respondents and poor by 9%. The presentation of the paper was thought to be good by 60%, and satisfactory by 37%.

Some commented positively on the reference to "real world" applications in some of the questions while others felt that the paper covered a larger breadth of topics than in previous sessions. Thanks are, as always, extended to all examiners who assessed the candidate scripts and whose individual reports form the basis of this subject report. In contrast to previous sessions, significant digits were only penalized in specific questions (Q1(a)(ii) and Q8 (a)(iii)) and not throughout the complete paper.

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

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

- Calculations of rate of reaction from the changes of concentration and time measurements
- Determination of percentage uncertainty and precision of experimental data
- Comparison of boiling points of organic functional groups
- Definition of standard electrode potentials
- Identification of the electrolysis products and corresponding half equations for aqueous solutions
- Explanation of the bond angles in terms of the number of negative charged centres around the central atoms
- Distinction between the concepts of bond and molecular polarity
- Description of structure and bonding in carbon dioxide and silicon dioxide
- Explanation of electrical conductivity of aqueous solutions in terms of mobility of ions
- The observable effects of changing the amounts of liquid bromine on a liquid-vapour equilibrium system
- Determination of pK_a from the pH curves
- Description of the mechanism of elimination reactions using curly arrows to represent the movement of electron pairs
- Description of how to distinguish between the optical isomers experimentally
- 3D representations of enantiomers
- Definition of relative atomic mass
- Explanation of why low pressures are used in mass spectrometers
- Explanation of the origin of the colour in transition metal compounds
- Description and explanation of the hydrogen emission spectrum.

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

Once again there were some excellent scripts seen from some candidates, whose answers indicated detailed knowledge and understanding across the syllabus.

Topics generally well answered included:

- Deduction of the rate expression from experimental data
- Determination of an empirical formula
- Calculation of standard cell potentials for a given reaction
- Drawing Lewis structures
- Identification of the hybridization shown by the silicon atoms
- Calculations of standard enthalpy changes using the average bond enthalpies
- Explanation of the effect of changing pressure on a homogenous equilibrium system
- Deduction of the equilibrium constant expression
- Definition of weak and strong acids
- Selection of an indicator for a titration from the pH curve
- Deduction of the oxidation numbers of bromine in a disproportionation reaction
- Calculation of volumes of gaseous reactions
- Determination of theoretical yield
- Description of the free-radical mechanism of the reaction between hexane and chlorine
- Calculation of the relative atomic mass
- Description of the full electron configuration of atoms.

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

Section A

Question 1

Most candidates were able to determine the order of reaction with respect to the reactants and the rate expression, however as many students didn’t use the data from experiment 5 to determine the rate, they consequently couldn't calculate the percentage error or comment correctly on the precision. One respondent commented that students who didn't know bromine was red were excessively punished in what is a kinetics question however the identity of the reagent could have been found from the rate of reaction / time data, although it is to be hoped that a student should be familiar with the colour of bromine as it is specifically referred in AS 10.3.3. Part (c) proved to be a good discriminator with the stronger candidates being able to comment on the non-validity of the proposed reaction mechanism.

Question 2

The question was generally well answered; most candidates were able to deduce the correct empirical and molecular formula, and determine the balanced equation for the combustion reaction. The majority of candidates were able to identify the exhaust gases in part (b) although some teachers commented on their G2 forms that there is no reference to global and local pollution in the specification, and that students studying the environmental chemistry options would be given an unfair advantage. The question related to the complete and incomplete combustion of hydrocarbons but specifically addressed Aim 8 which intends to raise students awareness of the environmental issues, and although the terms global and local are not specifically in the guide it was thought that such terms would not be problematic for IB students given the reference to the and the international dimension in all the subject guides. Nitrogen oxides were accepted as either local or global pollutants.

Question 3

The responses to part (a) varied. Some candidates showed very good understanding but others failed to identify the functional group and so had no access to the second mark. “Yellow to clear” was often incorrectly given as the observed colour change. Some candidates confused the products of oxidation reaction under the different conditions of distillation and reflux, but could still gain credit in (c) with ECF marks. Few candidates were able to give complete explanations for the relative order of boiling points and a significant number of candidates discussed the intramolecular bonds instead of the intermolecular forces.

Question 4

Although many candidates showed good understanding of the voltaic cells, giving the correct half equations and calculating the correct cell potential, very few candidates were able to define the term standard electrode cell potential correctly, either missing a reference to standard conditions or the standard hydrogen electrode. Electrolysis in part (d), by contrast, was poorly understood with many candidates failing to identify hydrogen as the cathode product with many giving Mg as the product. The majority of candidates were able to give correct answers to (c)(iii) with “increase in temperature” the most common response. Some did not read the questions carefully however and missed the reference to a saturated solution and suggested that the concentration could be increased.

Section B

The questions in section B was quite balanced in terms of relative selection and performance, with question 6 the most and question 7 the least popular by small margins.

Question 5

Although most candidates were able to give a Lewis structure for disilane and the correct bond angle, explanations in terms of VSEPR theory were very poor with few students referring to the four negative charge centres around the central silicon atoms. Most students were able to correctly identify the hybridization in silicon and identify the C–H bond as more polar but explanations as to the non-polarity of the molecules were more mixed. Explanations of the different boiling points of the hydrides proved to be more problematic and a significant number of candidates were unable to demonstrate an understanding of the relation between the molecular mass/number of electrons and the strength of van Der Waals’ forces. The thermochemical calculations were better done than in previous sessions although some confused the two different methods and others didn't realize that the enthalpy of formation of water is equivalent to the enthalpy of combustion of water and assumed it had the value of 0. Indeed there were some comments on the G2 forms that students would not know that the two enthalpy changes are equivalent but this was a good discriminator as students had to apply their understanding of the definition of the two terms. As reported in previous sessions many candidates struggle to give a good description of the bonding in silicon dioxide and assumed it is the same as carbon dioxide. Part (d) of the question was generally quite well answered with many candidates recognizing that the solution is acidic. The explanation of the relative electrical conductivity of the molten and aqueous silicon tetrachloride showed that many have misconceptions in this area with references to delocalized or free electrons.

Question 6

This was the most popular question and most candidates were able to give the equations for both equilibrium processes although very few students were able to give a description of what they would observe if liquid bromine was added to the liquid-vapour system. Most candidates could apply Le Chatelier's Principle to explain the effect of changes of concentration and pressure on the position of equilibrium and deduce the equilibrium constant, but many stated that an increase in $[H_2]$ would decrease the equilibrium constant as it was a denominator in the expression. Most were able to distinguish between a strong and weak acid although a significant number of candidates used acids such as CH_3COOH and HCl in the equations instead of those relevant to the question. The candidates struggled in part (d)(ii) to identify two data points from the titration curve, and determine pK_a using two different calculations. Although many candidates knew the pK_a equalled the pH at half-equivalence, very few related it to the initial pH. A range of values was accepted for the pK_a given the difficulty of judging the equivalence point precisely from the graph. Almost all candidates selected the correct indicator in (d)(iii) but some did not give sufficient details to support their choice. Most candidates demonstrated a good understanding of oxidation and reduction in (e) and (f), although some ignored the third oxidation number of bromine (+1 or –1) and incorrectly assumed that oxygen would be more oxidizing than fluorine. The calculation of the volume of oxygen produced in the reaction posed few difficulties.

Question 7

This question was the least popular, but those that did answer it were generally well prepared. Most candidates were successful in the calculations in (a) and many recognized that the presence of impurities/water would account for the apparent yield of over 100%. As in previous sessions the description of a mechanism using curly arrows to represent the movement of electron pairs proved difficult for some candidates but this was perhaps better done than in previous sessions. Many lost a mark however as they failed to show the formation of the inorganic products. Very few candidates seemed to know how to draw 3D representations for the optical isomers, with limited use of the wedges/dashes convention. Many showed mirror images of flat molecules with angles of 90 degrees. The description of the use of plane polarized light in distinguishing between enantiomers, was often incomplete as few mentioned that they had an equal but opposite effect. Most candidates were familiar with geometric isomerism but many were surprisingly unable to give the names of three isomers of hexane, although were able to identify hexane as having the highest boiling point. The explanation of the relative boiling points of the isomers was however often incomplete as references to both the straight chain and its effect on packing/surface area were needed. The free radical mechanism in (f) was generally well done.

Question 8

Generally candidates had a good understanding of mass spectrometry but few could define relative molar mass precisely either missing any reference to ^{12}C or a “weighted average”. Most students were able to calculate the relative atomic mass of the titanium but some included units or ignored instructions to give the answer to one decimal place. More students than in previous sessions were able to give an explanation for the low pressure in a mass spectrometer but this question still proved too challenging for most. Most candidates knew the electronic configuration of Ti and identified the 4s electron as the one removed first but the explanation of large differences between ionization energies between sub-levels was incomplete with limited reference to the appropriate sub-levels. Although students were not expected to recall the stable oxidation states of titanium, but instead predict possible states from the patterns in ionization energies, many were unable to do this: either predicting unusual states such as +12 or giving ionic charges instead of oxidation states. Many students obtained some credit when explaining the colour of transition metal complexes by referring to the split d sub-level but often referred to the emission of light as an excited electron falling to a lower level instead of absorption as the electron is excited. Few candidates used the colour wheel to identify red as the colour absorbed. The description and explanation of the hydrogen emission spectrum were often incomplete and only a minority of candidates were able to give complete answers. A significant number of students made no distinction between the different command terms and essentially repeated the same answer in both parts (c)(i) and (c)(ii).

Recommendations and guidance for the teaching of future candidates

In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and command terms, candidates are advised to bear in mind the following points:

- Candidates should check the precision of calculated answers is consistent with the question.
- Candidates must use the correct notation when identifying oxidation states.
- Candidates must learn the common definitions on the syllabus.
- Candidates should review the bonding and structure in carbon dioxide and silicon dioxide.
- Candidates must distinguish clearly between emission and absorption of radiation when discussing the hydrogen spectrum or colour in transition metal complexes
- Candidates should use the number of lines and the marks as a guide as to how much to write. Write answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is completed on a continuation sheet. However, the use of continuation sheets should not be encouraged as it can mean longer answers than necessary are provided.
- Candidates should scan through the section B questions to make sure that they choose the ones they are best prepared for.
- Question 1 (observations, data analysis and precision), question 3 (observation), question 6 (observation) and question 7 (organic preparation) highlight the

importance of experimental work in the teaching of the programme. Students need to be able to apply the skills they develop in experimental work to analyse data from a range of investigations which they may not necessarily have covered in class.

- The relative unpopularity of question 7 suggests that candidates still struggle with some areas of organic chemistry.
- The electrolysis of aqueous solutions needs to be better understood.
- Candidates should set out calculations logically and legibly and "keep going" with calculations because errors are carried forward so that a correct method in a later part of the question is rewarded. All steps in the calculation should be shown.
- Candidates must use the **latest** Data Booklet during the chemistry course so that they are familiar with what it includes. Some schools are still using old editions of the Data Booklet. The Data Booklet must not only state on the front cover "First examinations 2009" but also within the front cover should state "Revised edition published September 2008".

This report highlights a number of points which have been discussed in previous subject reports. This emphasizes the value in studying previous reports to ensure that future students have a better understanding of the issues that have traditionally caused problems.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 19	20 - 25	26 - 30	31 - 36	37 - 50

General comments

The performance of the candidates on this year's examination was very similar to that on the previous year's paper and this is reflected in the fact that the grade boundaries remained almost unchanged. This would seem to indicate that the degree of difficulty of the examination was similar to the previous year even though, on G2 submissions, a significant number of teachers felt it was slightly more difficult. The G2 forms submitted (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.

As is usual, there was a tremendous range of performance; some candidates scored very high marks, but a large number seemed to have little or no comprehension of the topics covered in the examination, indicating that many candidates were inadequately prepared for the paper. Often the performance on one option was significantly higher than the other, hence one speculates as to whether only one option had been taught and students had been left to "self-study" the second. Because papers were marked by candidate and not by school, it was not possible to corroborate this with checking whether the students from these schools also chose a wide range of second option. Another general failing was that the responses of many candidates were very generalized, more appropriate to the popular press rather than an examination, and gave little indication that, as a result of detailed study, students had advanced their knowledge beyond this level. This is disappointing for a component comprising 20% of the final mark.

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

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

- Practical details of chromatography
- Saccharides
- Fuel cells and rechargeable batteries
- Liquid crystals
- Modern pharmaceutical techniques
- Photochemical smog formation
- Colour in foodstuffs
- Disperse systems
- Reaction mechanisms.

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

The areas which seemed well understood were:

- Interpretation of IR spectra
- Nuclear magnetic resonance spectroscopy
- Characteristics of enzymes
- Nutrients
- Antibiotics
- The effect of stereoisomerism in drugs
- Stratospheric absorption of UV radiation
- Vehicle emission control
- Nutrient cycles and intensive agriculture
- Structures of amines.

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

Option A – Modern analytical chemistry

Option A was reasonably popular and seemed to attract quite a few of the stronger candidates, hence it was in general quite well answered.

Question 1

Most students correctly identified mass spectrometry as the best technique for determining the molar mass of a compound. They also successfully identified the functional groups in the IR spectrum, as well as interpreting the NMR splitting data. Only a small number could however correctly combine these data to deduce the structure of the compound. The reference standard for NMR and the reasons for its choice were well known.

Question 2

Quite a number of students correctly read the concentration from the AA calibration graph, but carrying out the calculation to find the percentage of magnesium was more challenging. Many knew that using the instrument to find calcium concentrations would require a lamp, employing calcium, that would emit a different frequency.

Question 3

Very few students seemed familiar with the practical method of carrying out TLC and the use of reference standards, especially the need for these to be run under identical conditions. Most students realized the significance of the starting time in HPLC though only a few could deduce the relative strength of bonding to the different phases from the order of elution.

Question 4

Most candidates were aware that multiple bonds are involved in UV absorption and could recognize conjugated systems. Many however thought that absorption of light resulted in dissociation rather than electron excitation.

Option B – Human biochemistry

Option B was, as usual, very popular though candidates did not seem to tackle it quite as successfully as they have in previous years.

Question 1

Only a few candidates were aware of the role of glycogen as an energy reserve. A few more could identify another class of lipid, along with its role, and could explain why these compounds have a higher calorific value than carbohydrates. Many students correctly gave hemoglobin and iron as the metal it contained, even though the question inaccurately classed this as an enzyme. Cytochrome, and its role in electron transport, appeared to be considerably less well known. Many students correctly identified lactic acid as the product of anaerobic respiration. The final section comparing enzymes and catalysts was generally well answered, though quite a few neglected to discuss the similarities of the two.

Question 2

The structures of α- and β-glucose and the relationship of the latter to cellulose were not well known, even the simple fact that cellulose is a polymer of glucose. The differences in the functional groups present in the straight chain form of glucose and fructose and the resultant difference in chemical properties was only slightly better known.

Question 3

Most students were aware of the difference between macro- and micronutrients and quite a few could state the consequences of thiamine deficiency. Ways of avoiding vitamin deficiencies were also well known.

Option C – Chemistry in industry and technology

Option C was probably the least popular option and seemed to attract quite a lot of weaker candidates, hence the level of achievement was disappointingly low.

Question 1

This question was surprisingly badly answered with very few knowing that steel is the most common alloy of iron and that it must contain carbon. The reason why alloying elements affects their hardness was also poorly understood.

Question 2

Very few candidates seemed to have any familiarity with either fuel cells or rechargeable batteries, hence it was unusual to be able to award any marks for this question.

Question 3

This was the best answered question in the option with many candidates being able to outline polymerization processes and examples of the products, though full marks were rare. The role of cross-linking and examples of polymers displaying this, was however very limited.

Question 4

A few students could identify some properties that liquid crystals must have, but very few were aware of the additional properties required for commercial application. The meaning of *lyotropic* was however reasonably well known.

Option D – Medicines and drugs

This was probably the most popular option and seemed to attract the more able students and so probably generated higher overall marks than the other options.

Question 1

This was well answered. Most students knew that the IR absorption is used for ethanol detection. Although some students incorrectly discussed drugs such as morphine and heroin, many students correctly identified the depressants with similar structures. However a number failed to identify the ionic nature of Prozac, just mentioning polarity, and hardly any explained why ionic compounds are soluble in water. The question on oral administration was well answered.

Question 2

Most candidates knew that AIDS was a viral disease, but knowledge of a bacterial disease (rather than the name of a bacterium) was more sketchy. The differences between bacteria and viruses and reasons for drug resistance in bacteria were generally well known. Many candidates also gave good answers about the mode of action of penicillin, but the action of antiviral drugs could only be explained by the best candidates.

Question 3

Whilst a drug in which stereochemistry was important was well known (usually Thalidomide), the other two parts of the question were poorly answered in very vague terms. Few seemed to realize the importance of the 3D modelling of the drug and its active site or to have grasped the concept that combinatorial chemistry involved the random ordering of specific chemical building blocks.

Option E – Environmental chemistry

This was quite a popular option, although considerably less so than Options D and B. Many parts of it proved challenging for the candidates and overall the marks obtained were not high.

Question 1

Most candidates were aware of the difference in bonding between diatomic oxygen and ozone, and the effect this has on the UV frequencies they absorb. The catalytic effect of nitrogen monoxide was less widely understood, but a rather generous markscheme ensured that many candidates gained some credit for this section. Knowledge of the formation of photochemical smog role, and the role of ozone in this, was however very limited.

Question 2

Dissolved carbon dioxide was correctly identified as the source of natural water acidity, although the second mark for indicating how this reaction produced $H^+(aq)$ was rarely awarded. Candidates often failed to obtain the mark for the source of nitrogen monoxide, writing “car engines” (the journalistic version) rather than “internal combustion engines” (the more scientific response that one hopes they may have learnt during their course). That being said, many could write the correct equation for both this reaction and that taking place in catalytic converters, whilst nitric acid was usually identified as the compound actually causing acidification resulting from NO_x pollution.

Question 3

The components of SOM and its role were often a challenge for the candidates, with very few scoring full marks. The way that intensive agriculture interferes with nutrient cycles was better known and most were aware of the types of chemicals used, though a significant number did not gain the final mark because they failed to note that they could not use an substance from a similar class to the example used in the previous part; for example “fertilizer” in part (b) and “phosphates” in part (c).

Option F – Food chemistry

Another quite popular option, but once again the candidates seemed to find it challenging and marks tended to be quite low.

Question 1

It was quite surprising how many candidates think that many common foodstuffs, such as potato crisps, do not contain nutrients, even though the definitions of these terms were often known. Only a small proportion of students could explain the features of pigments that give rise to them being coloured and even fewer could pinpoint why the molecule illustrated was colourless. Recognition of the wavelengths absorbed by carotenes and how this resulted in their colour was however much more successful and, whilst many gained some credit for explaining their different solubility characteristics, very few obtained a second or third mark. Stating one substance was more soluble than another, without specifying the solvent being discussed was a common failing.

Question 2

Some candidates gained credit for identifying the types of rancidity, but few could give enough detail of the processes to gain full marks and awareness of the free radical scavenger function of synthetic antioxidants was even less common. Quite a number of students gained credit for knowledge of natural antioxidants, especially those choosing vitamin C, although a number of candidates failed to gain credit because they named a food without specifying the active compound it contained.

Question 3

This question was not well answered, with many students confusing the terms “phase” and “state” and also failing to mention stability. The two phases in an emulsion was rather better known and some students gained some credit for explaining the action of lecithin in very general terms, but few could specify its action in enough detail to gain full marks.

Option G – Further organic chemistry

Not a popular option and one that seemed to attract extremes, so that the marks obtained tended to be either quite respectable or very weak.

Question 1

Though quite a few candidates deduced the common feature of the two reaction schemes, many of them seemed to have never encountered Grignard reagents and this made the question rather inaccessible for them. Those who had, often gained high marks for the Grignard structure and reagents required. There was a fairly equal distribution of which acid was the stronger and the explanations offered seemed to reinforce the idea that random selection, rather than specific knowledge, as being the major factor in making the choice.

Question 2

Most students knew the structures of the amines, the most common mistake being to give propan-2-amine as a secondary amine. Only a handful of the best candidates could however offer any explanation as to why secondary amines are stronger bases than primary ones.

The acylation reaction was slightly better known (it was felt that using the term ethylamine, rather than the IUPAC approved ethanamine had not confused students) and similarly only a few candidates knew the addition-elimination mechanism for the acylation reaction.

Question 3

A number of candidates deduced the intermediate products for the formation of methylnitrobenzenes from benzene however, which intermediate was for which isomer was not always accurately determined. Only a few candidates could write an equation for the formation of the NO_2^+ ion or the mechanism for its reaction with methylbenzene.

Recommendations and guidance for the teaching of future candidates

In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and command terms, candidates are advised to bear in mind the following points:

- Options should be taught in class as they are an important part of the programme. It is important that the recommended time is devoted to cover the two options thoroughly and in depth (there was evidence that some areas had not been covered by some schools). Students who are left to teach the material themselves generally do not perform well.

- Candidates must read the questions carefully, ensure they answer exactly what has been asked precisely (vague answers rarely gain the marks) and from the perspective of a chemist, using appropriate terminology and not give superficial or journalistic answers (avoid the use of everyday language but rather use correct scientific terms).

- Chemistry involves writing balanced equations and candidates should ensure that they are capable of writing balanced equations for the reactions involved in the options covered.

- Candidates should prepare for the examination by practicing past exam questions and carefully studying the markschemes provided.

- Candidates must use the **latest** Data Booklet during the chemistry course so that they are familiar with what it includes. Some schools are still using old editions of the Data Booklet. The Data Booklet must not only state on the front cover “First examinations 2009” but also within the front cover should state “Revised edition published September 2008”.

- Candidates should use the number of lines and the marks as a guide as to how much to write. Write answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is completed on a continuation sheet. However, the use of continuation sheets should not be encouraged as it can mean longer answers than necessary are provided.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 18	19 - 21	22 - 24	25 - 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 98 G2 forms that were submitted. 89.8% reported the level of difficulty to be appropriate, 1% thought it to be too easy and 9.2% too difficult. In comparison with last year's paper, 46.9% considered it to be of similar standard or a little easier, 34.7% considered it to be a little more difficult and 3.1% much more difficult. Clarity of wording was considered good or satisfactory by 92.8% and the presentation of the paper was considered good or satisfactory by 94.9%. The statistics were mirrored in the general comments, where it was generally felt that the paper was fair but did involve 5–6 quite challenging questions.

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

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
1	757	2681	404	3270	11	45.91	0.59
2	3624	2511	776	163	49	35.25	0.5
3	1085	331	4965	739	3	69.7	0.25
4	3690	1180	1418	804	31	16.57	0.25
5	4563	378	850	1306	26	64.06	0.46
6	2061	129	4899	29	5	68.78	0.44
7	3117	1570	1950	457	29	27.38	0.29
8	365	354	421	5972	11	83.84	0.28
9	1093	2014	429	3562	25	50.01	0.41
10	848	227	5524	516	8	77.55	0.37
11	1729	1448	3025	895	26	42.47	0.19
12	767	1305	1036	4002	13	56.18	0.36
13	4122	639	1818	511	33	57.87	0.57
14	389	824	1368	4534	8	63.65	0.58
15	1125	1304	2042	2605	47	36.57	0.37
16	492	724	360	5526	21	77.58	0.37
17	3687	832	2001	586	17	51.76	0.53
18	3565	898	1003	1644	13	50.05	0.57
19	2523	933	3104	537	26	35.42	0.49
20	1357	4319	640	791	16	60.63	0.45
21	3453	551	1092	2005	22	48.48	0.34
22	1137	1347	1389	3222	28	45.23	0.49

23	365	429	5630	692	7	79.04	0.44
24	1297	1353	3545	882	46	49.77	0.56
25	930	2190	1301	2668	34	30.75	0.29
26	1181	3474	1503	922	43	48.77	0.36
27	2352	672	3129	944	26	43.93	0.16
28	1772	978	925	3415	33	47.94	0.51
29	1075	1343	878	3778	49	53.04	0.43
30	889	288	5617	278	51	78.86	0.22

Number of candidates: 7123

The numbers in the columns A–D and Blank are the numbers of candidates choosing the labelled option or leaving the answer blank. The correct option is indicated by a grey cell. The *difficulty index* (perhaps better called facility index) is the percentage of candidates that gave the correct response. A high index thus indicates an easy question. The *discrimination index* is a measure of how well the question discriminated between the candidates of different abilities. In general, a higher discrimination index indicates that a greater proportion of the more able candidates correctly identified the key compared with the weaker candidates. This may not, however, be the case where the difficulty index is either high or low.

The difficulty index ranged from 83.84% to 16.57%, and the discrimination index ranged from 0.59 to 0.16.

The following comments were made on selected individual questions:

Question 2

This was the fourth most difficult question on the paper, with most candidates in fact choosing A. The correct answer was B. C_nH_{2n+2} + O_2 gives $4H_2O$ + CO_2, and from this 2n+2 = 8, meaning n = 3. Hence, $C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2$, meaning that 5 mol of O_2 molecules react. Only 35.25% of candidates got the correct answer B. The question had a reasonably good discrimination index of 0.50.

Question 3

One respondent stated that although the question was quite clear, it would be better to use the value of 22.7 $dm^3\ mol^{-1}$ as the molar volume corresponding to the more up to date standard pressure of 100 kPa (or 1 bar). It is correct that at 273 K the molar volume of an ideal gas is 22.7 $dm^3\ mol^{-1}$ or 24.8 $dm^3\ mol^{-1}$ at 298 K at a pressure of 100 kPa. Since 1982, IUPAC has in fact defined standard reference conditions as being at a temperature of 273 K and a pressure of 100 kPa (1 bar). However, in the current IB guide, under the teacher's notes corresponding to AS 1.4.5, the molar volume of an ideal gas under standard conditions is given as 22.4 $dm^3\ mol^{-1}$, corresponding to the older standard of 1 atm pressure (i.e. 101 kPa). Molar volume is currently being considered for the new chemistry curriculum.

Question 4

This question was found to be in fact the most difficult question on the paper for candidates, as predicted by one respondent. Only 16.57% of candidates got the correct answer B, with the majority opting for A, followed by C. Candidates clearly had some difficulty looking at the different conditions, and using the general relationship of $P_1V_1/T_1 = P_2V_2/T_2$. With the initial set of conditions, P_1V_1/T_1 = (1.01 x 10^5 Pa)(100 cm^3)/(300 K). For B, P_2V_2/T_2 = (1.01 x 10^5 Pa)(200 cm^3)/(600 K). These are the same numerically since the pressure is constant, so cancels, leaving a value of 1/3 on both sides. It was very surprising how few of the better candidates could arrive at the correct answer B. The question certainly would be considered a challenging question overall but candidates clearly lacked the ability to consider each of the four choices involved to arrive at the correct answer.

Question 7

One respondent stated that the wording of the question was not clear stating that ionization needs to take place before deflection in order to allow acceleration of the particles. This is a fair comment in relation to the ^{16}O atom, but the main difficulty with this question related to candidates choosing A as the correct answer instead of C. Surprisingly only 27.38% of candidates got the correct answer. Ions with greater mass are deflected less than those with smaller mass. In this case, the path Z will correspond to that of the $^{16}O^+$ ion for this reason.

Question 9

Five respondents stated that silicon dioxide is actually amphoteric as cited in one textbook widely used for the current IB Chemistry Diploma programme. This statement in fact is incorrect in the textbook concerned as SiO_2 is actually classified as an acidic oxide. SiO_2 reacts with NaOH at T ~ 623 K, according to the equation $SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$. It is true that it does not react with water to form an acid. However, due to its clear reaction with sodium hydroxide it is classified as an acidic oxide. 50.01% of candidates got the correct answer, D for this question.

Question 11

One respondent stated that this question does not relate specifically to the syllabus. However, this is clearly covered in Topic 4.5 corresponding to AS 4.5.1. Further guidance in relation to melting point and electrical conductivity is given in the teacher's notes associated with this AS. Graphite has a high melting point (like another allotrope of carbon, diamond). In order to melt graphite, covalent bonding throughout the entire structure has to be broken. Potassium chloride being an ionic substance also has a high melting point due to the very strong electrostatic forces of attraction between the potassium cations and chloride anions holding the solid lattice together, meaning that large energy is required. However, potassium chloride does not conduct electricity in the solid state since the ions are held tightly together in the lattice structure and therefore are not in a position to move. This then rules out B as a possible choice in this question. Silicon dioxide has a high melting point but does not contain delocalized electrons, with the electrons being held tightly between the atoms, and so cannot move. Potassium has a low melting point so this is ruled out. Graphite on the other hand can conduct electricity as it contains delocalized electrons which are free to move. The question itself proved to be the seventh hardest question on the paper, with 42.47% of candidates getting the correct answer C i.e. graphite.

Question 12

There were two G2 comments on this question. One respondent stated that recent research has suggested that there is some evidence for hydrogen bonding to exist between H_2S molecules, and suggested therefore that C also may be a possible answer. This is a valid point and in fact in a 2010 article in *Chemistry World* published by the Royal Society of Chemistry (http://www.rsc.org/chemistryworld/News/2010/November/03111001.asp) it is stated that Professor Richard Nelmes a crystallographer at the University of Edinburgh, Scotland discovered that solid hydrogen sulfide has a hydrogen bonding structure that resembles ice. The whole area of what constitutes a hydrogen bond in fact is currently being revisited by the chemical community and based on IUPAC recommendations an interesting publication on the definition of the hydrogen bond was published in 2011 in the chemical literature: *Pure Appl. Chem*., Vol. 83, No. 8, pp. 1637–1641, 2011, which may be of interest to teachers and students in considering the introduction of hydrogen bonding as part of the chemistry curriculum in the future. Hence for this reason, due to the existence of at least some evidence of hydrogen bonding in H_2S, it would have been better to avoid this example in C. As in all multiple-choice questions, candidates are required to choose the best answer (namely D). The majority of candidates did choose D in fact (56.18%), followed by B.

Question 16

There were two G2 comments on this question. One respondent stated that using algebraic variables surprised and confused students in this question on Hess's Law. Student performance on this question was actually very good, with 77.58% getting the correct answer, D. Similar examples of this type of question have appeared in the past with algebraic variables being used instead of numbers, and candidates should ensure that they look at previous examination papers as part of their preparation. As candidates are not allowed use a calculator in P1, in fact using algebraic variables has been found to help candidates rather than using actual numbers in answering this type of question. This approach was taken a number of years ago based on feedback from previous teachers' G2 comments.

Question 17

A number of respondents stated that the graphs could have been better presented in this question and some may have struggled comparing the two graphs given in A and B. This is a fair point and will certainly be taken into consideration in the production of future examination papers. Student performance on the question itself involved 51.76% of candidates getting the correct answer A. The second most popular choice was C followed by B and then D.

Question 18

Several respondents stated that in this question it would have been better if the initial Maxwell-Boltzmann energy distribution curve would have been superimposed for comparison purposes on the four curves given in A–D respectively. This is a valid comment. Candidate performance was generally average, with 50.05% of candidates getting the correct answer, A.

Question 19

There were some G2 comments stating that the wording in the stem of this question was somewhat confusing. One respondent stated that it would be better if the stem read as "The graph below represents a reaction reaching equilibrium from a starting point consisting only of the reactants". Candidate performance on this question was poor, with only 35.42% of candidates getting the correct answer A. This question was a common question with HLP1, but performance at HL was better than at SL, where candidates certainly found this a challenging question.

Question 20

There were two G2 comments on this question, with both suggesting that the question should have been better worded. The question itself was reasonably well answered by candidates with 60.63% getting the correct answer B.

Question 21

One G2 comment on this question raised the question as whether or not a conjugate acid-base pair according to the Brønsted–Lowry theory could involve the removal of more than one proton, suggesting that H_2SO_4/SO_4^{2-} i.e. III. is also such a pair. This is incorrect. A conjugate acid–base pair involves a species differing by the gain or loss of a single proton, giving A as the only correct answer i.e. NH_4^+/NH_3 and $HCOOH/HCOO^-$ are conjugate acid–base pairs but the couple H_2SO_4/SO_4^{2-} is ruled out as a two proton difference is involved. 48.48% of candidates did get the correct answer A, but many candidates did think that the latter also was such a pair and D then became the second most common answer after A for this question.

Question 27

Two respondents stated that it was not clear that the benzene ring is a functional group or not. In the guide however, corresponding to AS 10.1.11, benzene ring is identified as a functional group. Hence, in the molecule represented in this question, there are two functional groups present, namely an ester and a benzene ring, giving C as the correct answer. 43.93% of candidates got the correct answer.

Question 29

One respondent stated that this question was difficult as candidates may have struggled in the second stage seeing the addition of oxygen and hence hedged on oxidation as a choice. The correct answer is D with a free-radical substitution involved in stage I and nucleophilic substitution involved in stage II. Candidate performance involved 53.04% of candidates getting the correct answer D. Many did opt for B however, with oxidation cited as stage II. The discrimination index for this question was 0.43.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 18	19 - 24	25 - 29	30 - 35	36 - 50

General comments

The range of marks awarded was varied; the stronger candidates showed a thorough command of the material and a high level of preparation. Teachers' impressions of this paper were conveyed via the 97 G2 forms that were submitted. 73.2% reported the level of difficulty to be appropriate with the remainder thinking it was too difficult. In comparison with last year’s paper, 46.4% considered it to be of similar standard or a little easier, 30.5% thought it was a little more difficult and 7.4% much more difficult. Clarity of wording was considered good or satisfactory by 92.8% and the presentation of the paper was considered good or satisfactory by 96.9%.

The general comments on the paper were very favourable. Respondents found that there was good visual support given on the paper with the diagrams, and new layout (introduced in 2011) appeared well received. The main general comment related to a challenging Q1 section A, and several G2 comments related to this. This is commented on in detail below and how candidates should best prepare for this question in future papers. The amount of organic chemistry was also commented on and again this is mentioned below. Organic chemistry is an important topic in the SL programme (12 hours) and section A may have questions based on any topic of the programme itself, one of which is organic chemistry, so candidates should be prepared for all core topics in their preparation for section A.

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

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

- Precision and uncertainty related to experimental data
- Explanations of bond angles in relation to VSEPR theory
- Explanations of molecular polarity
- Intermolecular forces in general
- pH changes
- Structure and bonding in silicon dioxide
- Definition of average bond enthalpy
- Calculation of percentage yield.

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

There were some excellent scripts seen from some candidates, whose answers indicated knowledge and understanding across the syllabus. Electrochemistry was done particularly well on this paper, and candidates also did much better than in previous years on organic chemistry.

Topics generally well answered included:

- Determination of empirical and molecular formulas
- Electron arrangement
- Voltaic cells
- Topics related to chemical equilibrium

- Oxidation numbers
- Free-radical substitution mechanism.

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

Section A

Question 1

This question was a typical section A Q1 style question, which involved candidates tackling a data-response question and which also had a number of cross-syllabus linked topics, as well as a hypothesis question and an Aim 8 question which brought out some environmental chemistry. It was disappointing how candidates did not appear well prepared to answer such a multi-faceted data-response question of this nature, and in order for candidates to adequately prepare for this type of question, a comprehensive laboratory programme needs to be integrated as part of the overall chemistry programme and candidates need ample practice in looking at previous papers of the new programme which always have this type of question at the beginning of the paper.

In part (a), many students were able to state that the decolourization of bromine was the means by which the rate of the reaction was being monitored, but nearly all candidates made errors in their significant figures in the calculation of rate, even if they could calculate the rate correctly. This was perhaps due to the fact that the other rates given in the tabulated data were all given to three significant figures, thereby falsely leading the candidates to follow suit with their answers. Candidates were also unable to comment on the precision of their results with regards to the significant figures as they had mostly made mistakes in the first marking point. Many errors were also made in the calculation of uncertainty in part (iii). In general, precision and percentage uncertainty were clearly not understood by candidates and this was very surprising as such concepts are core experimental ideas which should be well known if a rigorous experimental programme is integrated within the IB Chemistry Diploma programme overall. Again, perusal of previous examination papers would also indicate to students that these types of Topic 11 concepts are frequently assessed in section A Q1, due to the experimental/project nature of the data-response question. In part (b), the majority of candidates understood that the rate of reaction would increase when the reactant concentration of CH_3COCH_3 increased, but many candidates missed quantifying that rate change by saying that it would double. Many candidates missed the molecular level explanation by failing to relate the increased number of collisions to time and correctly explaining that there would be an increase in frequency of collision, not just a greater number. In part (ii), the majority of candidates stated that a catalyst lowers the activation energy. Part (iii) however was poorly answered, and only the better candidates stated that the hypothesis is valid as the rate increases as $[H^+]$ increases comparing data in experiments 1 and 4 respectively. Many did not read the question which specifically stated that reference should be made to the experimental data. Very few candidates were able to articulate that the fact that H^+ is not chemically changed in the reaction as evidence for it being a catalyst as well as the rate data, which meant almost no candidate picked up full marks on this question. There were a number of G2 comments on this question who stated that the question was intimidating for students. Some felt that the question was more like an order question at HL. This was not the case and careful reading of the questions and use of the data would have led students to the correct answers, all within the SL core. It must be emphasized that candidates in the data-response question in section A should be prepared for a multi-faceted question, often linking a number of sub-topics across the curriculum and bringing in uncertainty etc., often in an unknown situation, but bringing out key experimental skills that may have been covered in other experiments as part of the programme.

Question 2

This question in general was very well done. Part (a)(i) was usually correctly answered, and typically part (ii) also. In part (iii), although a significant number of candidates were able to determine the equation for the complete combustion of PbC_8H_{20} and scored full marks, some struggled with correctly balancing the equation and some of the weaker candidates failed to realize that the equation should have PbO_2 in it as a product or failed to include O_2 as a reactant. Part (b) was sometimes misread and quite often answers were "factory outlet pollutants" solids such as carbon and lead whereas global pollutants were given as carbon monoxide and acid rain. Methane was also often cited as a local pollutant which scored no marks. There were also a few G2 comments who questioned whether the terms local and global pollutants would be known to candidates. This question in fact related to the Aim 8 aspects of AS 10.2.2. It should be noted that although there are a number of specific Aim 8 listed AS's in the guide, Aim 8 aspects may also be considered across other AS's within the curriculum and should be integrated as appropriate within the teaching programme.

Question 3

Many candidates struggled with this question. In part (a), many candidates gave the functional group incorrectly as the alcohol instead of alkene. Others when they did correctly identify alkene, stated that the colour change was from brown to clear instead of saying brown to colourless, which is a common mistake. In (b)(i), although some candidates were able to identify the functional group in Y, as a carboxylic acid, others stated incorrectly that an aldehyde was involved. Oxidation was often correctly stated as the type of reaction in (ii). In (c), usually if candidates got (b)(i) correct, they managed to state an aldehyde in (c)(i). Part (ii) however was really very poorly answered and even most of the best candidates failed to score all three marks here. Very few stated that the carboxylic acid, Y, has more electrons. A common feature of Q3 (b) and (c) however was a large number of blank answers, showing that these candidates simply were not prepared for organic chemistry, even though it forms 12 hours of the current programme as part of the SL core. Candidates need to be prepared for organic chemistry in section A also and should not be inclined to opt out of this topic as section A is compulsory and may contain assessment of Topic 10, just like any other topic in the core.

Question 4

This question was probably the best answered on the entire paper. In (a)(i), most candidates gave the electron arrangement of 2,8,2 for the magnesium atom. Many candidates gave a more detailed electron configuration such as $[Ne]3s^2$, although not a formal requirement at SL, clearly scored the mark. Some candidates did not appear to understand the terminology of electron arrangement and simply said two valence electrons, which scored no marks. Part (ii) was very well done, though a few candidates gave magnesium as the positive electrode (cathode) which was incorrect and a small number stated incorrectly that Fe^{2+} was the cathode, instead of iron. The equation for the overall reaction in the voltaic cell was very well answered. In general, understanding of the principles underpinning a voltaic cell was well conveyed as reflected by the type of responses given by most candidates.

Section B

Section 5

This was the second most popular question on section B of the paper, after Q6. However, candidates certainly struggled with this question in several parts. In (a)(i), most were able to write the correct Lewis structure for disilane. Part (ii) was done exceptionally poorly. All sort of mistakes were seen – the most common was citing a 90^{o} bond angle for H–Si–H. What was most disappointing on the entire paper however had to be the failure of nearly all candidates to realize that this bond angle was based on the fact that silicon has four negative charge centres (other terms such as electron domains could also have been used). Part (iii) was usually well done, but in part (iv), very few candidates stated that both ethane and disilane are non-polar and the fact that the molecules are symmetrical. Candidates really misunderstood the difference between bond polarity and molecular polarity. Part (v) was also very poorly answered. Very few stated that the reason why disilane has a higher boiling point than ethane is related to the fact that there are stronger van der Waals' forces (or London dispersion forces) and the fact that disilane has more electrons.

Part (b)(i) was usually well done. In contrast part (ii) was very poorly done. Many candidates stated that silicon dioxide had double bonds and very few recognized the macromolecular structure of it, a point made in recent subject reports. Virtually no candidates got (iii) correct – several students gave incorrect equations such as silicon dioxide reacting with water and hardly anyone was able to describe the pH changes. In (c)(i), very few gave a correct definition for average bond enthalpy, which has been asked on several papers in the past. Many candidates failed to mention gaseous for the first mark and very few stated that it is averaged over similar compounds for the second. Part (ii) was often well answered, though some ended up with an answer of –26 (kJ) instead of +26 (kJ), thereby only scoring 2/3.

Question 6

This was the most popular question in section B on the paper. One G2 comment stated that stating bromine and its hydride is confusing – this is a fair comment and a more accurate stem would have been better. Part (a) was generally well answered, though an odd few candidates forgot to include the equilibrium sign. Most candidates got (b)(i) correct. In (ii), only the better candidates scored both marks. In (c)(i), nearly all candidates were able to deduce the equilibrium constant expression, though some included a + sign in the denominator and others wrote [H] instead of [H_2]. In (ii), many did not realize that there is no effect of increasing [H_2] on the value of K_c, as this only depends on the temperature. This question became one of the questions which discriminated the stronger from the middle-tier candidates. In (d), most candidates could distinguish between a strong acid and a weak acid. However, a number failed to write the correct arrow for HBr and others forgot to give an equilibrium sign for the equation relating to that for HF. Some candidates used incorrect acids, such as HCl and CH_3CO_2H, and did not read the question carefully. On this paper, oxidation numbers were very well answered, as seen in (e)(i). Only a few candidates used incorrect notation such as Roman numerals or 1– and 1+ instead of –1 and +1. This difference between charge and oxidation numbers should be emphasized in the teaching programme. The better candidates recognized that a disproportionation was involved in (ii). In (iii), although many got $K_c < 1$, other choices were also incorrectly chosen here. In (iv), the first mark was usually scored i.e. a shift to the right, but very few scored the second. Parts (f)(i) and (ii) were generally well answered. In (iii), a lack of precision in the answers often lost candidates marks here (e.g. F is a smaller atom) although candidates did have some idea of the reasons for the greater reactivity of fluorine. For the final marking point, some did not mention the fact that it is the nucleus that attracts electrons more strongly for fluorine. Most picked up at least one mark for being able to recognize that fluorine is more electronegative.

Question 7

This was the least popular question of the three given in section B, but of those that did attempt it, performance often was very good. In (a), most students who attempted the question were able to do the associated calculations though they struggled more with the percentage yield question in (ii). A common incorrect answer was 52.4% instead of 63.6%. Most candidates noted that the yield in (iii) was anomalous, but few could adequately articulate an explanation to score points. In (b), many students missed the required catalyst but could draw the final product and name three isomers correctly. Some students failed to include the hydrogen atoms and just drew bonds which suggested methyl groups which are incorrect. Many could identify hexane as the isomer with the highest boiling point in (iii), but the majority could not adequately explain why. Many identified margarine as the commercial product in (iv). One respondent stated that although the expected answer is margarine, other products are possible and queried if these were accepted in the markscheme. This certainly was the case and several different answers were accepted, though the majority of candidates did give margarine, if they were able to answer the question. Many candidates did well in (c)(i) – several could write the equation and conditions necessary for initiation though some made errors in the propagation and termination steps. Another respondent stated that it was not clear what conditions were expected. UV light was the most common answer here although sunlight/hf/$h\nu$ were accepted. Heat was also accepted, though this was rarely seen. Most identified the correct number of straight chain structural isomers in (ii).

Recommendations and guidance for the teaching of future candidates

In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and command terms, candidates are advised to bear in mind the following points:

- It is imperative that candidates are exposed to a comprehensive laboratory programme across the entire curriculum. The experimental nature of chemistry should be brought to the forefront of the teaching programme and key laboratory skills and associated topics should be covered (e.g. accuracy and precision, uncertainty of measurement, titrations, filtrations (both gravity and vacuum), distillation and reflux, yields, rate of reaction etc.).

- There should be greater emphasis on core chemical concepts (e.g. structure and bonding, intermolecular forces, redox etc.) across the teaching programme – topics should not be covered just in isolation and cross-links should be highlighted across topics. This can serve as an excellent basis for understanding and also can serve as a useful revision tool for candidates. Many teaching tools are available for this purpose, including spider diagrams, mind-maps, concept maps, flow charts etc.

- There should also be a greater understanding of what the assessment statements mean as questions will expect students to understand what they are learning and be able to apply it to new situations.

- Candidates need plenty of practice on the data-response, multi-faceted questions integrated within section A, Q1. These questions involve several different facets, including experimental work, uncertainty of measurement, hypothesis, Aim 8, and linking of several different topics across the curriculum. Candidates cannot go into the exam without having adequately practised such questions from past papers. Interesting laboratory projects could also be devised which could integrate these types of ideas. Such projects would greatly help students in coping with this type of question in section A. In addition, and this is an important point to make, this type of question may not necessarily be based on a set, routine experiment that candidates would have necessarily have carried out in the laboratory, but may often involve an unknown experiment or project. However, having being exposed to a vibrant laboratory programme (with emphasis on skills development) would greatly make this type of question very accessible to candidates and certainly would lead to greater student performance. IB chemistry students should be challenged to think and not just depend on dealing *exclusively* with typical recipe type experiments that they may have covered in class.

- Candidates should set out calculations logically and legibly and “keep going” with calculations because errors are carried forward so that a correct method in a later part of the question is rewarded. All steps in the calculation should be shown.

- Practice typical calculations involving amounts, empirical and molecular formulas, yields and bond enthalpies. Such calculations should also emphasis significant figures, units and associated mark allocations.

- Candidates must learn the common definitions on the syllabus.

- Candidates should use the number of lines and the marks as a guide as to how much to write. Write answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is completed on a continuation sheet. However, the use of continuation sheets should not be encouraged as it can mean longer answers than necessary are provided.

- Candidates must use the **latest** Data Booklet during the chemistry course so that they are familiar with what it includes. Some schools are still using old editions of the Data Booklet. The Data Booklet must not only state on the front cover “First examinations 2009” but also within the front cover should state “Revised edition published September 2008”.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 18	19 - 21	22 - 24	25 - 27	28 - 40

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 standard 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 98 G2 forms that were returned conveyed teachers' impressions of this paper. This number is a slight increase as compared to last year where 90 G2 forms were submitted. The comments received on the G2 forms are considered very important feedback and are reviewed thoroughly during the grade award meeting. In comparison with last year's paper 63% of respondents felt that it was of a similar standard and 12% considered it a little more difficult while 5% and 4% felt the paper was a little easier and much more difficult respectively. 91% of respondents thought the level of difficulty was appropriate while 8% thought that it was too difficult. Clarity of wording was considered good by 37%, satisfactory by 62% of the respondents and poor by the remainder. The presentation of the paper was considered good by 48% and satisfactory by 52% of the respondents.

The most popular options were B, D and E while options A, F and G were less popular while option C was least popular and attempted by very few candidates.

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

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

- Elucidation of structure from different forms of spectroscopic data and molecular formula
- Calculation of % by mass of Mg from atomic absorption spectroscopy
- Thin-Layer Chromatography
- Higher energy content of lipids as compared to carbohydrates
- Structure of cellulose
- Construction of half-equations for reactions at the 2 electrodes in a hydrogen/oxygen fuel cell
- Liquid-crystal displays
- Water solubility explanation of Prozac
- Anti-viral drug action
- Greenhouse effect and interaction with different radiation
- Soil organic matter (SOM)
- Rancidity
- Emulsifiers and prevention of emulsion separation
- Grignard reagent
- Nucleophilic addition mechanism.

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

The areas which seemed well understood were:

- Determination of heat change (calorimetry)
- Lipids and their roles
- Function of cellulose
- Macronutrients and micronutrients
- Avoiding vitamin deficiencies
- Aluminium and iron
- Environmental problem from combustion of fuels
- Drug administration
- Consequences of ethanol abuse
- Diseases of bacteria and virus
- Misuses of antibiotics
- Formation of nitrogen monoxide
- Difference between food and nutrient
- Identification of nutrients
- Structure of benzene
- Primary, secondary and tertiary amines.

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

Candidates were for the most part, able to correctly deduce the structural features from the different spectroscopic evidence but were not able to deduce the structure of X as the molecular formula was not considered.

Question 2

Candidates understood how to plot a calibration graph and the concentration of solution was often achieved as graphs were drawn correctly but there were major difficulties in continuing the calculation in obtaining the final % of Magnesium in the sample.

Question 3

Candidates seemed to have difficulty describing clearly TLC, often confusing it with paper chromatography. Some candidates seemed to think that the plate was dipped into the sugar solution.

Option B – Human biochemistry

This was one of the most popular options.

Question 1

This part was generally well answered but there were some cases where 33.5°C was converted into Kelvin. Many candidates had serious problems with unit conversions and gave the answer as 2800 J or 2800 kJ. Some candidates had correct value for (ii) but lost the mark because of the omission of the negative sign. Part (b) was well answered but in part (c) very few candidates linked the fact that lipids have higher energy content due to being less oxidized.

Question 2

Part (a) was generally well answered with full marks awarded to more than half of the candidates. Those who did not score full marks usually reversed OH on carbon 4. Glucose has an aldehyde functional group which can undergo oxidation and this was covered in Topic 10. The fact that cellulose is a polymer of glucose and has beta-1,4 linkages seemed to have been overlooked by many candidates. In part (d) many candidates stated that cellulose cannot be digested by humans due to lack of an enzyme but failed to name it. The part on dietary component was well handled by majority of candidates.

Question 3

Most candidates gained full marks for this question and was answered quite well. Some candidates had difficulty in remembering the disease beriberi for deficiency of thiamine.

Option C – Chemistry in industry and technology

This was the least popular option.

Question 1

This question was generally answered correctly. Part (d) proved to be most challenging although it deals with the fundamental idea of the behaviour of alloys.

Question 2

Some candidates were able to write one similarity and one difference between fuel cells and rechargeable batteries but part (b) was very poorly answered. None of the candidates scored full marks particularly in part (c) where it was rare to see any correct half-equations; the candidates also overlooked the fact that the electrolyte was acidic. Part (d) seldom had any correct answers.

Question 3

In part (a) a significant number of candidates named two fuels obtained from petroleum and in part (b) described the environmental problem. The non-biodegradable property of plastics was stated correctly by many candidates. The properties of a material that made it suitable for use as a liquid crystal display demonstrated poor understanding by many candidates.

Option D – Medicines and drugs

This was one of the most popular options.

Question 1

In general, this question was well answered.

Question 2

The long-term consequences of ethanol were well handled by majority of candidates. In part (b), many candidates recognized the two depressants but with a fair number of candidates referring to strong analgesics. In part (c), candidates found it much more difficult when it came to describing, in terms of structure, the water solubility of a drug, with very few recognizing the ionic nature of the antidepressant. As a consequence, two marks were rarely awarded for this part.

Question 3

Many candidates stated the correct name of one bacterial and one viral disease but some had problems stating differences between bacteria and viruses. Candidates must realize that AIDS is a viral disease not HIV. Part (b) was reasonably handled by many candidates. In part (c), the terms “over dosage” and “over prescription” were often used interchangeably. In part (d), the method of action of anti-viral was poorly explained. It seemed candidates, at times, learned several key phrases without clearly understanding their meaning and so used them in inappropriate context.

Option E – Environmental chemistry

This was one of the most popular options.

Question 1

There seems to be a very poor understanding of the interaction of greenhouse gases with radiation although this question has frequently appeared in the examinations. A surprising number quoted ozone depletion and the use of terms often used in the media e.g. “trapped”, “bounces”. In part (b), the candidates failed to state the *increased* combustion of fossil fuels. Although the question stated “other than carbon dioxide and water identify one other green house gas”, many candidates identified CO_2 and H_2O.

Question 2

Many candidates identified that dissolved carbon dioxide causes the rain water to be acidic but did not show with the help of equation partial dissociation of carbonic acid. The source of nitrogen monoxide and the method used to control its emission appeared to be well known and many could include appropriate chemical equations. Very few candidates could identify that nitric or nitrous acid is responsible for acidity in lakes and rivers. Some candidates formed H_2SO_4, H_2SO_3, CH_3COOH and H_2CO_3 from nitrogen monoxide.

Question 3

Many candidates had difficulty identifying the SOM components. Few candidates stressed that intensive farming removes nutrients when crops are harvested. This question had very vague answers and in most cases candidates struggled to respond correctly.

Option F – Food chemistry

This was a fairly popular option.

Question 1

This question was generally well answered by many candidates. Though most had a general idea of the difference between a food and a nutrient, many did not appreciate the distinction between an “unhealthy” food and one that isn’t a nutrient.

Question 2

The majority of candidates struggled in part (a) where the difference between hydrolytic and oxidative rancidity was seldom written correctly. In part (b), many candidates stated correctly antioxidants but failed to state the name of one naturally occurring substance which has a similar effect. Many candidates managed to get one mark for the health benefit such as lowering of blood cholesterol/reducing blood pressure/preventing cancer/reducing heart diseases.

Question 3

This was a low scoring question. The term “dispersed system” as a stable mixture of two immiscible phases, and “two components of an emulsion” as both liquids, were often ignored by many candidates. In part (c), candidates often had difficulty providing coherent answers especially when trying to explain how emulsifiers can stabilize an emulsion.

Option G – Further organic chemistry

This was one of the least popular options.

Question 1

This part was generally well answered by many candidates.

Question 2

Many candidates had difficulty identifying that both reactions increase the length of the carbon chain. The majority of candidates encountered great difficulty identifying reactions involving a Grignard reagent or 2,4-dinitrophenylhydrazine. Identifying reagents required for reaction I and II was a major problem for most candidates. The mechanisms also proved a problem for majority of candidates. The use of curly arrows in reaction mechanisms continues not to be well understood, the arrow often pointing in the wrong direction. Candidates must take care to accurately draw the position of the curly arrows illustrating the movement of electrons.

Question 3

The difference between a primary, secondary and tertiary amine seemed to be the area best understood though the explanation of the relative strength of primary and secondary amines was often superficial.

Recommendations and guidance for the teaching of future candidates

In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and command terms, candidates are advised to bear in mind the following points:

- 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.

- Candidates should prepare for the examination by practicing past exam questions and carefully studying the markschemes provided.

- Candidates must learn the common definitions on the syllabus.

- Candidates must read the questions carefully, ensure they answer exactly what has been asked precisely (vague answers rarely gain the marks) and from the perspective of a chemist, using appropriate terminology and not give superficial or journalistic answers (avoid the use of everyday language but rather use correct scientific terms).

- Candidates should use the number of lines and the marks as a guide as to how much to write. Write answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is completed on a continuation sheet. However, the use of continuation sheets should not be encouraged as it can mean longer answers than necessary are provided.

- Teachers should emphasize 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 must use the **latest** Data Booklet during the chemistry course so that they are familiar with what it includes. Some schools are still using old editions of the Data Booklet. The Data Booklet must not only state on the front cover "First examinations 2009" but also within the front cover should state "Revised edition published September 2008".

- Some candidates are writing more than one answer hoping the examiners will pick up the correct answer. This is not encouraged because a correct response followed by an incorrect response nullifies the mark of that question.

- Candidates should use a good quality black ink pen to avoid illegible writing and ink seeping through the paper and appearing on the following page.