CHEMISTRY TZ2

(IB Africa, Europe & Middle East & IB Asia-Pacific)

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 18	19 - 33	34 - 46	47 - 57	58 - 68	69 - 80	81 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 30	31 - 41	42 - 53	54 - 65	66 - 75	76 - 100

Higher and standard level internal assessment

Component grade boundaries

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

The range and suitability of the work submitted

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

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

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

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

Candidate performance against each criterion

Design

Aspect 1

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

Aspect 2

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

Candidates need to be explicit as to how they are to control the variables they have selected and exactly what data they will collect. For example:

- What equipment will be used at each stage e.g. when measuring out a volume, are you using a measuring cylinder, a pipette or a burette?
- The concentrations of vital solutions **must** be stated
- The situation of limiting reagents should be addressed
- The control and recording of temperature is important
- In titrations, the recording of initial and final volumes is good practice and should be encouraged

Other common problems to arise were the confusion of current with voltage in electrochemical cells and the mistaken view that in a rate of reaction experiment, it is the room temperature that has to be held constant or monitored and not that of the reaction mixture itself.

Aspect 3

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

Data Collection and Processing

Aspect1

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

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Aspect 2

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

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

Aspect 3

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

Conclusion and Evaluation

Aspect 1

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

Aspect 2

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

Aspect 3

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

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

Recommendations for the teaching of future candidates

It is recommended that:

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

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

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

Further comments

Application of ICT

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

Communication with moderators

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

Design Aspect 1

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

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- If the teacher has identified just the independent or just a control variable then Partial can still be awarded.
- The teacher is allowed to specify the dependent variable when setting the task.

When not to mark down in Design Aspect 1

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

Design Aspect 2

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

When not to mark down in Design Aspect 2

- Similar (not word for word identical) procedures are given for a narrow task. Comment though on poor suitability of task on 4/IAF form.
- Do not only mark the equipment list. Give credit for equipment clearly identified in a stepwise procedure. Remember we mark the whole report.
- Do not insist on the (+/-) precision of apparatus to be given in an apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DCP.
- Do not downgrade a teacher's mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Support teacher's stance.

Design Aspect 3

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

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

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The material/apparatus

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

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

Data collection and processing

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

DCP Aspect 1

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

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

- If a photocopied table is provided with heading and units that is filled in by candidates then the maximum the moderator can give is n = 0.
- If the candidate has only recorded qualitative data (e.g. colour changes in titration, observation of soot due to incomplete combustion in calorimetry, residual solid left in a beaker when reaction has excess solid reactant, bubbles being released when a gaseous product is formed are missing) then the moderator gives partial.
- However, do not be overzealous and penalize Aspect 1 every time a candidate does not find qualitative data to record. Sometimes there is no obviously relevant qualitative data to record.
- If a candidate has not recorded uncertainties in any quantitative data then the maximum award is Partial.
- If the data is *repeatedly* to an inconsistent number of decimal places or in disagreement with the stated precision then Complete cannot be awarded. Be sensible and support the teacher if there is just one single slip in a large body of data where all the rest is consistent with each other and the stated uncertainty.
- In tasks such as establishing a reactivity series, too often the candidates put in a reaction equation as opposed to the observation. This cannot be supported and will reduce first aspect to 'p' or 'n' depending on how much other raw data is present.

When not to mark down in DCP Aspect 1

- When the candidate has not included any qualitative observations and you cannot think of any that would have been obviously relevant.
- If in a comprehensive data collection exercise possibly with several tables of data the candidate has been inconsistent with significant digits for just one data point or missed units out of one column heading.

  If you feel the candidate has demonstrated that they were paying attention to these points and made one careless slip then you can still support the maximum mark

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under the 'complete does not mean perfect' rule. This is an important principle since often **good candidates responding in full to an extended task unfairly get penalised more often than candidates addressing a simplistic exercise**.

- When there is no table title when it is obvious what the data in the table refers to. I have seen candidates do all the hard work and then lose a mark from the moderator because they did not give the table a title. Except for extended investigations, it is normally self evident what the table refers to and the section heading Raw Data is sufficient. Once again 'c' does not mean perfect.

DCP Aspect 2

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

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

DCP Aspect 3

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

When not to mark down DCP Aspect 3

- Do not punish inconsistent significant figures reported in the middle of a stepwise calculation if the final answer(s) is (are) reported appropriately.
- If the candidate has clearly attempted to propagate uncertainties then support a teacher's award even if you feel that the candidate could have made a more sophisticated effort. Please **do not** punish a teacher or candidate if the protocol is not the one that you teach, i.e. top pan balance uncertainties have been given as +/- 0.01g when you may feel that if we consider the tare weighing then it should be doubled.

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Conclusion & Evaluation

If structured questions are given to prompt candidates through the discussion, conclusion and criticism then, depending on how focussed the teacher's questions are and on the quality of candidates' response the maximum award is *partial* for each aspect the candidate has been guided through. You have to make a judgement based only on the candidate's input.

CE Aspect 1

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

CE Aspect 2

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

When not to mark down CE Aspect 2

- Simply apply the principle of complete does not mean perfect. For example if the candidates have identified most sensible sources of systematic error then you can support a teacher's award even if you think that you can identify one more. Do however be a bit more critical in third aspect that the modifications are actually relating to the cited sources of error.

CE Aspect 3

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

Other Issues

Simplicity

If you feel a task was too simple to truly meet the spirit of the criteria then comment on the 4/IAF as to the unsuitability of the task, giving full justifications but do not necessarily downgrade the candidate.

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Yes, this does mean that candidates could get high DCP marks for some quite brief work on limited data but if they have fulfilled the aspect's requirements within this small range then support the grade.

Data logging

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

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

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 16	17 - 23	24 - 27	28 - 31	32 - 35	36 - 39

General comments

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

Teachers' impressions of this paper were conveyed by the 253 G2's that were returned. 67% found that it was of a similar standard, compared with last year's paper, 14% thought that it was more difficult and the remainder were of the view that it was easier. 96% described the level of difficulty as appropriate, 3% too difficult and 1% thought that it was too easy. 34% felt that the clarity of wording on the paper was satisfactory and 64% felt that the wording was good. Just 2% stated that the clarity of wording was poor.

The presentation of the paper was considered satisfactory by 27% and good by 71%. Just 1% stated that the presentation of the paper was poor.

These statistics were also mirrored in the general comments, where it was generally felt that the paper was fair with topics well distributed.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 95.22% to 37.66%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.61 to 0.08 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

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Question 5

One respondent suggested that some guesswork would be required to answer this question. However, this question was based on the emission spectrum of hydrogen, which relates to AS 2.3.3 in the guide and in the Teacher's notes it is clearly stated that the ultraviolet, visible and infrared regions of the spectrum should be considered. The question itself was answered correctly by 73.90% of candidates.

Question 11

One G2 comment stated that the question was badly worded. However, in the sulfur dioxide molecule there is a non-bonding pair of electrons present giving B as the correct answer, which is clearly what the question was asking candidates to ascertain. The question itself was answered correctly by 75.31% of candidates.

Question 12

There were several comments on this question and many teachers stated that although they assumed that the required answer was C. i.e. electrons, many felt that as molten aluminium was involved, the cations are mobile and thus could conduct electricity, so A. could be another answer. Although the correct answer C. (electrons) was given by the majority of candidates (69.98%), it was decided at Grade Award to also accept A. as clearly some candidates may have approached the question in the vein articulated by several teachers.

Question 14

One respondent mentioned the fact that there is some debate in the literature in relation to possible sigma delocalization in cyclopropane which is a valid comment and although 63.98% of candidates chose D. C_3H_6 as the correct answer, it is fair to state that a different example might have been selected where there is no evidence of delocalization.

Question 15

One respondent claimed that this question was too difficult. However, Topic 14.2 on hybridization is firmly on the syllabus and candidates should be expected to be able to answer this type of question. The question itself was correctly answered by 79.08% of candidates, and was the thirteenth easiest question on the paper.

Question 19

There were eight G2 comments on this question. Most stated that a table would have been better for the presentation of the four possible combinations which is a reasonable suggestion.

Question 22

There were three G2 comments on this question. Two of these comments stated the question was very difficult and one comment stated that the first step should have had an equilibrium sign which is correct. The question itself was answered correctly by only 46.28% and was the third most difficult question on the entire paper.

Question 28

One G2 comment stated that the buffer example B. involving 100 cm^3 of 0.10 mol dm^{-3} ethanoic acid with 50 cm^3 of 0.10 mol dm^{-3} sodium hydroxide is not listed explicitly in the Teacher's notes corresponding to AS 18.2.2.

However, candidates should have an understanding of the composition of a buffer solution based on AS 18.2.1 and it should also be stated that examples given in the Teachers' notes in the guide are not the only possible examples that can be asked in a given question. This is

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an important point which is often referred to in subject reports especially in relation to the shapes of molecules, buffer solutions etc.

Question 29

There were three G2 comments on this question. Some commented on the length of the question itself. The question certainly was challenging though 53.88% of candidates did manage to get the correct answer C.

Question 34

There were seven G2 comments on this question. Many teachers stated that the wording of the question was ambiguous (e.g. use of the word relatively etc.). This was discussed at Grade Award and for this reason it was decided to remove this question.

Question 37

One respondent stated that propanenitrile should have been written instead of propanitrile, which is correct.

Question 39

Several respondents suggested that it would have been better if atomic labels were given in the 3D diagrams in this question which is a fair comment.

Question 40

One respondent stated that this question was not fair as calculators are not permitted in P1. However, candidates did not have to do an actual calculation here as all they had to look at was the number of significant figures in the numerator (5 SF) and the number of significant figures in the denominator (3 SF) and look at the list of four choices to see which one contains only 3 SF, which results in C. being the only correct answer. 70.13% of candidates got the correct answer.

Higher level paper two

Component grade boundaries

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

General comments

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. Teachers' impressions of the paper were conveyed by the 247 G2 forms that were completed. 88% of the respondents considered the level of difficulty of the question paper appropriate, 10% too difficult and 2% too easy.

In comparison with last year's paper, 59% felt that it was of similar standard, 11% thought that it was easier and 26% were of the view that the paper was a little more difficult. Clarity of wording was considered good by 57% and satisfactory by 39% of respondents. The presentation of the paper was thought to be good by 58%, satisfactory by 30% and poor by

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12%. The paper had a new look to it in Section B which met with a mixed response from teachers. Some thought it offered a more organised layout which allowed student to refine their answers while others thought that it made it more difficult for students to see, at a glance, what a question required and so made question selection more difficult. Concerns were also expressed about the size of the answer boxes. Some teachers reported that they were unaware of the change in format although a specimen paper had been available on the OCC since Feb 2011. The new format did not appear, however, to affect candidate performance; the mean mark a little higher than last year.

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

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

- Use of a temperature-time graph to deduce the temperature change that would have occurred if a reaction had taken place instantaneously.
- Treatment of significant figures and use of units.
- An explanation of why $[Cu(H_2O)_6]^{2+}$ and $[CuCl_4]^{2-}$ ions have different colours.
- An explanation of the operation of a mass spectrometer's detector.
- Deduction of the common oxidation states of antimony from its position in the periodic table.
- An explanation of salt hydrolysis including the acidity of aqueous iron(III) complexes.
- Calculation of the pH of buffer solutions of known composition.
- An explanation of the action of buffer solutions.
- An explanation of why it is difficult to obtain sodium from sodium chloride using methods other than the electrolysis of molten salt.
- An explanation of why primary halogenoalkanes under substitution by a S_N2 mechanism and tertiary halogenoalkanes by a S_N1 mechanism.
- Prediction of the structures of the organic products from elimination reactions and condensation polymerisation reactions.

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:

- Calculation of the amount of solid of known mass.
- Calculation of the isotope abundances from the relative atomic mass of the element.
- Knowledge of pollutant gases and their effects.
- An explanation of the action of the magnetic field in the mass spectrometer.
- Deduction of atomic structures and electron configurations.
- An understanding of the meaning of square brackets in electron configuration and rate equations.

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- An explanation of the physical properties of methoxymethane and ethanol in terms of molecular structure and intermolecular forces.
- An explanation of the basic properties of nitrogen trifluoride.
- Calculating pH from pK_b values.
- A description of the characteristics of a homogenous equilibrium, and the determination of an equilibrium constant.
- An explanation of the effect of catalysts and changes of temperature and pressure on the position of equilibrium.
- Calculation of Δ*H*, Δ*S* and Δ*G values*.
- The use of bromine water to distinguish between alkanes and alkenes.
- The use of structural formulae and curly arrows to explain S_N2 and S_N1 mechanisms.

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

Section A

Question 1

This was generally accessible to most candidates although very few scored full marks and there was some confusion about units and the precision of calculated answers. Many candidates benefited from Error Carried Forward (ecf) marks. Most calculated the amount of $CuSO_4$ in (a) (i) but many could not read and extrapolate the graph accurately in (a) (ii): the most common mistake resulted in a final temperature change of 6.6 ^oC. In (a) (iii) many incorrectly used the mass of the solid (3.99 g) instead of the mass of the water (50 g) or solution (53.99 g), which were both accepted.

Many candidates struggled to identify which reaction was exothermic and which was endothermic but most were able to apply Hess's Law to deduce ΔH_x and calculate the percentage error. Many candidates identified the presence of water as the reason for the pale blue colour but few stated that it had originated from the air. Few students could explain why the value of ΔH_x would be less exothermic as a result of this systematic error.

Question 2

In (a) (i) most candidates calculated the molecular mass but many lost a mark as they forget to multiply by 2 when calculating the mass of antimony. A small number of candidates also lost the second mark as they failed to report the answer to four significant figures as directed by the question. Most candidates were able to deduce the oxidation state of antimony but many lost a mark as they used an incorrect format such as 3, or 3+. It was expected that candidates would be able to deduce the other oxidation states from the position of the element in the periodic table but most candidates incorrectly gave +2 as an answer. Generally at least one mark was scored in (b) (i) with ecf being applied when the formula of the oxide was incorrect.

Most candidates were aware of some environmental concerns due to the production of pollutant gases but some incorrectly identified both carbon dioxide and sulfur dioxide as greenhouse gases. Most candidates were able to calculate the relative abundance of the two isotopes and the use of a magnetic field to deflect ions in a mass spectrometer was generally understood, although a significant number of responses were penalised as they referred to *atoms* rather than *ions*. Few students were able, however, to describe the deflection stage in sufficient detail. Most candidates were able to deduce the number of neutrons in ^{121}Sb.

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Question 3

Most candidates were familiar with the use of square brackets to represent noble gas electron configurations and concentrations in rate expressions and it was encouraging to see candidates give a correct orbital diagram with the d electrons unpaired. A significant number of students were unaware of the exceptional nature of the electron configuration for chromium, but were able to gain the mark in (a) (iii) with ecf. The understanding of the use of square bracket to represent complex ions was limited, however, and many omitted the s^{-1} in the units for the rate constant. (c) (ii) proved to be more challenging with many candidates mixing up sub-shells with orbitals and absorption with emission spectra. Many candidates were familiar with the use of the term *spontaneous* when used in a chemical context.

Question 4

Most candidates were familiar with the presence of hydrogen bonds in ethanol and van der Waal's or dipole-dipole forces in methoxymethane. Some responses lost marks, however, as they did not refer to the intermolecular nature of the interactions. Marks were also lost when no reference was made to their relative strength.

Section B

Question 6 was the most popular choice for candidates and was generally well answered. Question 8 was the least popular and again highlighted the reluctance of some candidates to tackle organic chemistry.

Question 5

This was the second most popular question. The Lewis structures were generally drawn correctly in (a) though the square brackets and charge were often missing from the Lewis structure of NH_4^+ and the shapes and bond angles were not always correct. In (a) (iii) some candidate did not mention the need for a *lone pair* even though they had an understanding of the need for a pair of electrons when explaining the basic properties of nitrogen trifluoride. Answers to (a) (iv) were encouraging with many candidates able to calculate the pH from the pK_b value for ammonia. The more difficult (a) (v) was only answered correctly by the strongest candidates and a significant number left it blank. Some candidates lost marks in (a) (vi) as they did not explicitly state that buffers are resistant to changes of pH when *small* amounts of acid or base are added. Many also did not respond directly to the requirements of the question and explain the action of the specific buffer mixture of ammonia and ammonium chloride. Salt hydrolysis was poorly understood. In (b) (i) answers included "NaCl dissociates to form a strong acid and a strong base" and only the better candidates referred to the carbonate ion removing hydrogen ions from the water molecules to form hydroxide ions Explaining the acidity of iron(III) proved to be a challenge with few mentioning the polarisation of the O-H bond in a water ligand by the high charge density of the Fe^{3+} ion. Most could give an equation for the reaction of sodium oxide with water but the formation of phosphoric (V) acid from phosphorus (V) oxide proved more problematic.

Question 6

This was the most popularly answered question. Most candidates were able to give a good description of the characteristics of homogenous equilibrium, and apply Le Chatelier's Principle to explain the effect of catalysts and changes of temperature and pressure on the position of equilibrium and the equilibrium constant. A good majority were able to calculate the value of K_c although a significant number of candidates incorrectly used the initial rather than the equilibrium concentrations. Although most candidates clearly understood the concept of standard *enthalpy change of formation* many were unable to explain why the value for hydrogen is zero. Many responses neglected to mention that H_2 is an element in its standard

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state. Most candidate were able to calculate Δ*H* and Δ*S* although some inverted the equation and gave a positive value instead of negative answer or confused the values for propane and propene. There were some inconsistencies in the use of units and significant figures when calculating ΔG from ΔH and ΔS values although there was a significant improvement in this area compared to previous. This error resulted in some very strange temperatures for the thermal decomposition of propane to propene. The majority of candidates were familiar with the bromine water test to distinguish between alkanes and alkenes in (c) (i) and most correctly identified the process in (c) (ii) as addition polymerisation but few were able to correctly identify the polymer's repeating unit. Many formulae included C = C or all C – H bonds with no side chains. Almost all students were familiar with the economic importance of the manufacture of margarine or the hydration of alkenes although a common incorrect answer was the hydrogenation of alkenes.

Question 7

This was the third most popular question. Most candidates were able to give only an incomplete definition of the *standard electrode potential*; the need for standard conditions was often omitted. Only the strongest candidates were able to clearly explain the significance of the negative sign for the standard electrode potential of the half cell. 7(b) proved to be confusing for some candidates with many giving the half-equation instead of a specific species.

Labelling the voltaic cell was generally well done in (c) (i) but some responses mixed up the cathode and anode or gave a battery instead off a voltmeter. The most common omission, however, involved the concentrations (1 mol dm^{-3}) of the solution and the temperature of 298 K. A minority of candidates gave an equilibrium sign for the cell reaction and some candidates forgot the V units. In (d) a surprising number of candidates were unable to give the colour change observed when dichromate(VI) ions are reduced to chromium(III) ions by ethanol and the majority of candidates were not able to write the balanced redox reaction for the production of ethanal. Most candidates were able, however, to identify ethanoic acid as the product of further oxidation under reflux. Many were unable to explain the need to carry out the reaction under acidic conditions; the presence of H^+ as a reactant in the equation was the expected response. (e) proved to be very challenging with not many able to explain why it is difficult to obtain sodium from the electrolysis of aqueous sodium chloride; all sorts of misunderstandings were in evidence, many involving a discussion of the compound's high lattice enthalpy.

Question 8

Although the least popular question, candidates were generally well prepared particularly in drawing enantiomers and describing the mechanisms for the two nucleophilic substitution reactions. The representation of the S_N1 and S_N2 mechanisms using curly arrows has significantly improved from previous sessions but mistakes are still being made.

Common errors in the S_N2 mechanism include the curly arrow originating from the H in the hydroxide ion instead of the lone pair on the oxygen and the omission of the negative charge or square brackets from the transition state. It was also disappointing to see H – C bonds in the transition state and HO – C – Br angles of less than 180^o. If a candidate fully understood that the attack must be on the opposite side from the leaving group than this type of mistake would not appear. Explanations of why primary halogenoalkanes undergo S_N2 reactions and why primary structures favour S_N1 reactions in terms of steric hindrance and carbocation stability were often incomplete with few candidates gaining full marks. Students should note that when asked to compare two molecules, their answers should refer explicitly to both; i.e. they had to mention that a tertiary compound halogenoalkane **did** have steric hindrance and a primary compound **did not** have steric hindrance. Some candidates also struggled to gave a

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full explanation of the higher boiling point of 1-bromopentane in terms of the greater surface contact between neighbouring molecules. Most candidates were familiar with the esterification reaction and able to give the structural formula of pentyl ethanoate. The prediction of the organic products of the elimination reaction proved to be beyond many, as candidates struggled to apply their knowledge in an unfamiliar context. Similarly, many were unable to give the equation for the condensation polymerisation reaction between benzene-1,4-dicarboxylc acid and pentane-1,5-diol. A significant number of students misread the question and attempted to describe a reaction between the acid and 1,5-dibromopentane instead.

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 in this paper:

- Check whether a reaction is exothermic or endothermic and ensure that enthalpy changes are given the correct sign.
- Use the correct scientific vocabulary such as “atom”, “ion” and “molecule” in written responses.
- Use the correct notation when identifying oxidation states.
- Learn the bond angles in the different molecular geometries.
- Avoid leaving blanks particularly in calculations as several marks can still be gained as errors are carried forward.
- Check the precision of calculated answers is consistent with the question and physical quantities have the appropriate units.
- Do not write outside the box when responding to questions and indicate where you have used additional sheets.
- Scan through the Section B questions to make sure that you choose the ones that you are best prepared for. Look particularly closely at the 5 mark questions as they are worth 20% of the marks for the question.
- When asked to compare two things make sure that your answer refers to both.

Question 1 (extrapolation of graphs and systematic errors) and Question 7 (observation) highlight the importance of experimental work in the teaching of the programme. Candidates should also be prepared to analyse data from a range of investigations which may not necessarily be covered in class.

The relative unpopularity of question 8 suggests that candidates still struggle with some areas of organic chemistry such as elimination reactions and the relative stability of carbocation. The electrolysis of aqueous and molten sodium chloride also needs to be better understood.

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Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 21	22 - 27	28 - 32	33 - 38	39 - 50

General comments

Although paper three was not marked electronically this session, it had the format with the boxes to prepare students to this type of marking. This was a surprise for many students and teachers as they apparently had not been informed by their coordinator. The lack of space in the boxes was the complaint most mentioned in the G2 forms.

The range of capabilities of the students varied very much between candidates. Strong candidates demonstrated excellent understanding and were able to explain difficult concepts, whereas weak candidates struggled with basic concepts and often only could manage more guided questions.

Many students seem poorly prepared for paper three, giving the impression that possibly out of lack of time, in some schools the options are not taught in class, letting the students prepare themselves. In some schools different students answered different options, with very poor results. Some candidates answered more than three options, also with poor results in all.

This year IBO obtained much more feedback from teachers with 245 G2 forms. 92% of the teachers described the level of difficulty was appropriate, and only 6% found it too difficult. Compared to last year, 56% described it of similar standard, while 7% found the paper easier and 1% much easier. 23% of the teachers found the paper a little more difficult and 3% much more difficult.

The clarity of wording was found as good by 58% of the teachers, 40% found it satisfactory and 2% poor.

The presentation of the paper was described as good by 67%, satisfactory by 32% and poor by 1%.

The most popular options were B and D, while C and F were the least popular. From the G2 comments teachers found that some options, especially B, D and E had too many marks on subtopics. Most comments were referring to a mistake in a question in option G, which will be discussed below.

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

Most candidates have difficulties describing processes, failing to answer the details needed for the marks. Special difficult was:

- A3 the explanation of NMR imaging
- B3 the half equations of the oxidation of glucose
- C2 c (ii) the composition of a Ziegler-Natta catalyst
- D3 (e) the use of combinatorial chemistry
- E1 (c) the explanation of the annual fluctuation of the carbon dioxide concentration

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- E3 (b) (iii) the effect of pH on the availability of nutrients
- F1 (b) the mechanism of oxidative rancity
- F2 (b) the effect of pH on anthocyanins and the effect of blueberries on aluminium
- G1 (c) many did not describe the need for an electron deficient carbon for a nucleophilic attack
- G: drawing curly arrows on precise location in mechanisms

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

All candidates were able to answer those questions that referred to general knowledge, at least for a chemistry student: use of DNA profiling, consequences of global warming, effect of THC, use of placebos.

Students seemed well prepared for:

- A2: Identification of compounds by spectroscopy
- B4: DNA and RNA structures and DNA profiling
- C1 (a) (i) the function of cryolite in the electrolysis of alumina
- D3 (b) use of placebos
- D4 the structural similarities and difference between LSD and psilocybin and the short-term mind altering affect of THC
- E1 (d) the effect of global warming
- E2 (b) multistage distillation and reverse osmosis
- F2 (c) the structures of chlorophyll and heme
- G2 the products of chemical reactions and the types of reactions

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

Option A – Modern analytical chemistry

Question 1

Almost students named radiowaves, but they could often not identify the processes associated with microwave or UV absorption. In (c) many candidates repeated that IR occurs at higher frequency but they did not relate it to energy.

Question 2

Most candidates showed good knowledge of IR and MS, sometimes forgetting the charge of the ions in MS. NMR proved a little more difficult, especially in (iv) where information of the integration traces was asked. Students had sometimes difficulty to predict the splitting patterns.

Question 3

Candidates often described the equipment and outcome instead of chemical explanations. The interaction of NMR with protons in water molecules was often not clearly stated.

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Question 4

The markscheme provided good opportunity to obtain some marks, and most students were familiar with the principles of the technique. The detection was seldom described.

Option B – Human Biochemistry

Question 1

Most students identified glycerol and fatty acids, though weak student could not give the structure. Students often recognized in (c) that the fatty acids were saturated, and are closer together, but did not explain that the intermolecular forces are greater. The type of reaction in (d) was generally correctly identified.

Question 2

Many candidates did not read question (a) (i) well and gave irrelevant answers. Glutamic acid was generally correctly identified, but the explanation was often very weak. Most students obtained the mark in a(iii) but they had difficulties with the buffer equation of Gly.

Question 3

Very poor answers were given. Few students made the correct reaction for oxidation and the reduction was generally done to copper metal.

Question 4

Knowledge of RNA and DNA was generally good. DNA profiling was something most students were familiar with, though some had troubles indicating the stages of the process and few candidates recognized that DNA fragments are negatively charged. The use of DNA profiling presented no problem.

Option C – Chemistry in industry and technology

Question 1

Candidates knew the function of cryolite in the electrolysis of alumina, but very poor half-equations for the positive electrode were given. Students could name at least one way CO_2 is produced in (c).

Question 2

Most candidates could tell what a heterogeneous catalyst is, but could not explain their mechanism or disadvantage. They had some knowledge of the factors to be considered when selecting a catalyst. Knowledge of Ziegler-Natta catalyst was poor.

Question 3

The concept of liquid-crystals was generally understood, but students often failed to obtain full marks because their answers were not detailed enough. In (b) they generally named some properties.

In (c), many candidates did not realize that Kevlar is lyotropic. They generally obtained at least one mark explaining the strength of Kevlar, but could not explain why it should be stored far away from acids.

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Option D – Medicines and drugs

Question 1

Most candidates answered the question satisfactory, though some did not name the difference in polarity in (b)

Question 2

In general answered well, but some candidates did not pay attention to the “large amount” in the question and offered answers like “increased alertness”. In (b) amines were generally well responded and better students recognized amides.

Question 3

Many candidates found it difficult to define or explain the meaning of therapeutic window and basically went around the definition of LD_{50} and ED_{50}, never referring to dependence on age/sex etc.

Students were familiar with the use of placebos though they sometimes had strange definitions and even weak students could explain the “fooling effect”. Most candidates answered (c) correct. Many candidates confused the type of isomerism displayed in thalidomide. Combinatorial synthesis was generally badly described. The markscheme awarded marks for general combinatorial synthesis techniques, but many candidates interpreted the question as if they were being asked to refer to specifically sorafenib. Few candidates could state an advantage of solid-phase chemistry.

Question 4

This was generally answered well.

Option E – Environmental chemistry

Question 1

Candidates generally identified H_2O as a greenhouse gas, many named NO or NO_2 instead of N_2O. Most candidates were not precise in the formation of methane by cows. Very few students could explain the seasonal variations of CO_2, some referring to the burning of fossile fuels in winter. The effect of global warming was well known.

Question 2

Better candidates stated correct sources of PCB and mercury. Many candidates obtained several marks for the methods of purification of water, but few evaluated the economic differences.

Question 3

Few candidates could calculate the concentrations correctly having problems with the calculations but most named AgCl as the first to precipitate.

In (b) many students had difficulties stating what is meant with cation-exchange capacity, often repeating “the capacity to exchange cations”

Many candidates could describe the chemical functions of SOM, but some described the physical functions instead.

The effect of pH on the availability of nutrients seemed clearly unknown to most of the candidates. Some candidates stated that phosphorous is more available at low pH, but did

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not refer to phosphates and some described that nitrogen is most available at nearly neutral pH, but did not make any explanations.

Option F – Food chemistry

Question 1

Candidates had no problem with (a) (i) and (ii) but found it more difficult to explain the need for opaque and nitrogen-filled packaging for potato chips. Students had more difficulty with the mechanism of oxidative rancidity.

Question 2

Candidates had difficulty in (a) (i) but generally could name at least one health benefit of green tea and oregano.

The equation to describe the effect of pH was answered very poorly. Candidates could not relate blueberry acid to the release of Al^{3+} cations in (b) (ii) and subsequent reactions to form coordination complexes. Most candidates could however compare successfully the structures of chlorophyll and heme B.

Question 3

Most candidates could identify the chiral C of carvone. Though some candidates answered (b) and (c) well, there was generally confusion explaining the R and S rotation and the explaining why the structure was (S)-(+)-carvone.

Option G – Further organic chemistry

Question 1

Candidates generally identified correctly the compound with the shortest C-C length, but most failed to relate the occurrence of substitution rather than addition reactions in benzene in terms of stabilization energy.

In (c) most students did not refer to the electron deficient carbon on $–CH_2Cl$, just said that chloromethylbenzene reacts as any “normal” halogenoalkane. Many recognized that the C-Cl bond is stronger in chlorobenzene.

Question 2

Most candidates could write the major products of eaction and few candidates had difficulties in identifying the type of reactions in (c).

Question 3

Part (a) was generally answered well, though some students gave the structure for the meta – isomer. Others gave incorrect structural formula for the nitro group. Students with good knowledge of mechanisms had no difficulty with (b) but the location of the curly arrows was not precise in many scripts.

Question 4

The question had an error: it said the formation of a “nucleophile” where it should have been “electrophile”. Candidates seem however not been affected by it, and those candidates that showed good knowledge of mechanisms in question 3, also did well in question 4. Some candidates even changed the word nucleophile to electrophile on the script. Problems

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presented again lack of knowledge of mechanisms and the precise location of the curly arrows.

Question 5

Dehydration of butanol to buten-2-ene presented no problem.

Recommendations and guidance for the teaching of future candidates

- Options should be taught in class, they are an important part of the syllabus.
- Students should study enough for paper 3 to acquire specific detail and vocabulary related to procedures and instead of relying on general type of answers.
- Students should be made acquainted with the new format with boxes and be told not to write outside the box but on a separate sheet of paper when the box does not have enough space.
- Teachers should use past examination papers and their corresponding markschemes to prepare the candidates for the examination.
- Candidates should be given guidance to the depth of the question observing the action verbs and the amount of marks a question allocated to the question.
- Students should be very familiar with the data booklet.
- Candidates should be aware of the precise location for curly arrows for option G.
- Questions should be read carefully to be able to answer with precision.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 15	16 - 19	20 - 22	23 - 25	26 - 29

General comments

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

Teachers' impressions of this paper were conveyed by the 224 G2's that were returned. 61% found that it was of a similar standard, compared with last year's paper, 22% thought that it was more difficult and the remainder were of the view that it was easier. 99% described the level of difficulty as appropriate. 42% felt that the clarity of wording on the paper was satisfactory and 55% felt that the wording was good. Just 2% stated that the clarity of wording was poor. The presentation of the paper was considered satisfactory by 30% and good by 67%.

These statistics were also reflected in the general comments, where it was generally felt that the paper was fair equally representing all topics.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 91.87% to 24.91%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.62 to 0.15 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 5

One respondent suggested that this question was mathematically difficult. However, 54.42% of candidates did get the correct answer C.

Question 7

One respondent suggested that guesswork may be required to answer this question. However, this question was based on the emission spectrum of hydrogen, which relates to AS 2.3.3 in the guide and in the Teacher's notes it is clearly stated that the ultraviolet, visible and infrared regions of the spectrum should be considered. The question itself was answered correctly by 58.93% of candidates.

Question 13

One respondent stated that as the hydronium cation involves dative covalent bonding it would have been better if the dot-cross representation would have reflected this, which is a valid point. However, this did not stop candidates answering the question and 72.31% of candidates got the correct answer, namely that the ion has a trigonal pyramidal shape i.e. D.

Question 14

There were a number of comments on this question and many teachers stated that although they assumed that the required answer was C. i.e. electrons, many felt that as molten aluminium was involved, the cations are mobile and thus could conduct electricity, so A. could be another answer. Although the correct answer C. (electrons) was given by the majority of candidates (71.18%), it was decided at Grade Award to also accept A. as clearly some candidates may have approached the question in the sense articulated by several teachers.

Question 16

Two respondents stated that there was too much mathematics required to answer this question. However, candidates simply had to use Hess's law and were not required to determine the numerical value of the final answer. In fact, the question was the second easiest question on the paper and 82.41% of candidates got the correct answer C.

Question 18

There were two G2 comments on this question, both stating that the question was demanding. The question was answered correctly by 54.51% of candidates.

Question 27

There were three G2 comments on this question stating that the wording of the question was ambiguous (e.g. use of the word relatively etc.). This was discussed at Grade Award and for this reason it was decided to remove this question.

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Question 30

One respondent stated that the question would have been clearer if “most appropriate” was used instead of “best value”. 58.77% of candidates got the correct answer.

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 - 30	31 - 36	37 - 50

General comments

The range of marks awarded was very wide; the best candidates showed a thorough command of the material and a high level of preparation. Teachers' impressions of this paper were conveyed by the 220 G2 forms that were returned. In comparison with last year's paper, 59% thought this year's paper was of a similar standard or a little easier, and 33% considered it to be a little more, or much more difficult. However 85% thought the level of difficulty was appropriate and 14% thought it was more difficult, and 1% thought it easier. Clarity of wording was considered good or satisfactory by 96% and the presentation of the paper was considered good or satisfactory by 91% of respondents. This represents a decrease in previous years which was without doubt due to the introduction of text boxes in Section B. Many G2’s commented that the change in format had not been sufficiently publicized and also that the change from Section A to Section B needs to be far more obvious. G2 forms suggested that many students carried on and answered all questions as they didn’t realise they needed to choose. Certainly there were a number of students who answered more than one response in Section B. However, if students do inadvertently answer more than one question then all responses are marked and the students are awarded the best mark for their Section B response.

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

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

- Using a temperature-time graph to deduce the temperature change that would have occurred if the reaction had taken place instantaneously
- Using raw date to calculate enthalpy changes in calorimetry experiments
- Explaining deflection and detection in the mass spectrometer
- Explaining the different boiling points of isomers in terms of their intermolecular forces
- Drawing Maxwell- Boltzmann energy distributions
- Drawing a voltaic cell
- Definition of average bond enthalpy

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

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

Topics generally well answered included:

- Atomic structure
- Drawing Lewis structures
- Acid-base
- Equilibrium
- Oxidation of alcohols

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

Section A

Question 1

Question 1 was a generally difficult question for candidates, but most students did pick up marks thanks to the application of error carried forward (ecf). In part (a) students could usually calculate the moles of anhydrous copper sulphate. However, very few could correctly extrapolate the graph to calculate a temperature rise of 7.0 ºC. Calculating using $q= mc\Delta T$ also caused problems as many students used the mass of the copper sulphate instead of the mass of water, and some also added 273 to the temperature change. Many candidates also forgot to convert to kJ. The last part of this question required the calculation of ΔH, here many students forgot the – symbol to indicate it was exothermic and so did not gain the mark. In part (b) the problems were similar as students used incorrect values in their calculation but were able to obtain some marks by error carried forward. In part (c) many could calculate the % error and apply Hess's law to calculate ΔH. Throughout this question there were numerous instances of students using an incorrect number of significant figures and this led to another mark being lost.

Question 2

This question proved difficult to candidates as the antimony was unfamiliar to them. However they were expected to just apply what they already knew about other members of the group such as nitrogen and phosphorous. Those that could calculate the oxidation state of antinomy in stibnite often forgot to add the + charge. Writing the chemical equations proved difficult for candidates but again many picked up 1 out of 2 marks as ecf was applied. The identification of SO_2 leading to acid rain and CO_2 contributing to global warming caused some problems but underlines the importance of relating chemistry to the real world when teaching it.

Question 3

This question was answered very well by those that knew the correct mathematical technique; however some candidates did not have any idea how to tackle this problem. In part (b) it was clear that although many students knew about a mass spectrometer they didn't necessarily understand why things happened, so many did not explain the deflection by magnetic field and what it is based on.

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Very few candidates scored the third marking point by explaining that the ions generated an electric current in the detector which enabled their abundance to be calculated. However, the vast majority of candidates could correctly state the number of electrons and neutrons present in Rubidium- 87.

Question 4

This question was not answered well and many candidates showed they were confused about the different intermolecular forces present between the molecules. Also, many seemed to be trying to explain the difference in boiling point based on the differing strengths of covalent bonds that were present. Those that did correctly identify the stronger hydrogen bonding in ethanol leading to its higher boiling point often forgot to mention that it was intermolecular and between the molecules of ethanol.

Section B

Question 5

Candidates could draw the Lewis structures in part (a) and generally they could name the shape and suggest the bond angle. Most knew what a Lewis acid was but some were careless in their definition and said it was an electron acceptor instead of an electron pair acceptor. Some candidates mistakenly described ammonia as a Lewis acid but most recognised it was a Lewis base as it could accept an electron pair. Generally candidates could suggest ways of distinguishing between strong and weak acids using pH or conductivity. The final part of this question caused some difficulty though as students found it hard to show water acting as an acid and a base even though many could correctly state that an acid is a proton donor and a base is a proton acceptor.

Part (b) focused on electrochemistry and although some candidates were able to score 4 marks most lost marks for their diagrams which were often incomplete and/or incorrectly annotated.

Students that could draw the diagram had little problem writing the equations, however many could not do them correctly. This carried through to the final part of the question and those that could write the half equations could generally write the overall equation. Identifying the oxidizing agent and the species that has been reduced proved tricky as students were reluctant to suggest the same species- Cu^{2+}, also some students just said copper which was not specific enough to gain the mark.

Question 6

Part (a) of this question focused on equilibrium and many candidates were able to show a good understanding of what would happen when the conditions were changed and were able to deduce the equilibrium expression. Most could describe the properties of a homogeneous equilibrium but some said that concentrations of reactants and products were equal at equilibrium as opposed to constant. The candidates also could state and explain the effect of a catalyst. Part (b) proved more problematic and relatively few could describe the necessary conditions for hydrogenation, and even fewer could correctly state a definition of average bond enthalpy. The calculation of the bond enthalpy of propene proved difficult for many and although some gained marks by ecf few obtained the correct answer -125. Candidates also had difficulty explaining why the process was exothermic in terms of the relative strengths of the bonds being made and broken. Part (c) was also based in organic chemistry and although most candidates could suggest bromine as a test for unsaturation, they did not all state a correct test result.

Candidates must make sure that they state that the bromine becomes colourless and not clear. Many realised that propene polymerises by addition polymerisation but few could

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successfully draw the structure of the repeating unit. Also few could suggest a reaction of alkenes of economic importance- such as hydration to make alcohols.

Question 7

This question began with kinetics and although many did well, there were also a lot of marks lost. Some did not have a correct definition of rate of reaction and many misread the question that asked for the properties of reactant particles that affect rate. Many candidates talked about surface area, concentration etc as opposed to collision frequency, collision geometry and reactant particle kinetic energy. The Maxwell-Bolzmann energy curves were drawn very badly and even candidates who could do it lost marks for the sloppy drawing of the curves e.g curves did not start at the origin or they crossed the x axis.

Also candidates could not label the axes correctly. However most could suggest that coal dust burns faster as it has a larger surface area. Part (b) was based on organic chemistry and most candidates knew that the products of combusting propan-2-ol were carbon dioxide and water- although few could balance the equation correctly. In the next part of the question the colour change from orange to green was well known, but the necessary conditions of reflux and acidifying the dichromate were not. The final part of this question was often done very well and many candidates could draw the structures of the 3 oxidation products and name them.

Recommendations and guidance for the teaching of future candidates

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

- “keep going” with calculations as errors are carried forward so that a correct method in a later part of the question is rewarded. All steps in the calculation should be shown
- practice calculations involving calorimetry and bond enthalpies
- learn definitions correctly
- practice drawing voltaic cells
- practice drawing the Maxwell-Boltzmann energy distribution curves
- teachers should give candidates an opportunity to experience a wide range of experimental activities to assist with the understanding of questions with a practical basis.
- candidates must check that both significant figures and units are correct in all calculations.
- candidates should write their answers in the spaces provided in the examination booklet, using the number of lines and the marks as a guide to how much to write. The number of lines for a question part is meant to suggest the amount of space for a typical response, if more space is needed they should continue on a continuation sheet, but they must indicate that they have done this in the box that they are writing in.
- candidates should practice answering past exam questions as part of their preparation. As similar questions regularly appear on exams, familiarity with past papers and mark schemes should confer an advantage to candidates.

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Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 11	12 - 14	15 - 18	19 - 23	24 - 27	28 - 40

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

There was considerable variation in performance but some of the repeated weaknesses were:

- coordinating spectroscopic information to deduce a structure
- understanding MRI
- structure of triglycerides
- writing equations
- aluminium electrolysis
- greenhouse gases and their sources
- PCBs
- emulsifiers
- relative reactivity of chlorobenzene and chloromethylbenzene
- writing extended responses with sufficient information

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

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

The areas which seemed well understood were:

- interpreting spectra
- vitamin deficiencies
- analgesics
- sources of CFCs
- GM food advantages
- Identifying reaction types
- Mechanisms

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

Option A – Modern analytical chemistry

Question 1

Most candidates were familiar with regions of the electromagnetic spectrum and their uses, but had difficulty describing the relationship between energy and frequency or wavelength.

Question 2

Many candidates identified the molecules as polar or non-polar but did not appreciate the effect of radiation on the dipoles in (a). In (b) most candidates confused the IR absorptions of O-H and C-H bonds. The positive charge was frequently omitted from the mass spectroscopy fragments and the number of hydrogen atoms in the same chemical environment was often not stated. Most candidates were unable to coordinate all the spectroscopic data to deduce the tertiary structure.

Question 3

Very few candidates could explain the role of NMR in magnetic resonance imaging.

Option B – Human Biochemistry

Question 1

This question which was expected to be fairly straightforward proved to be rather tricky for candidates. In part (a) very few correctly identified glycerol in the formation of a triglyceride, and drawing the structure of a triglyceride in (b) was challenging for many. Some candidates explained very well why the triglyceride was a solid at room temperature, but others could only state that it was solid and were unclear of the reasons. Only the best candidates could explain why fats have a higher energy value per mole than carbohydrates.

Question 2

Many candidates described electrophoresis instead of stating that ninhydrin was used to develop the amino acid spots. The process of electrophoresis was detailed in the stem of the question, so candidates should have been able to determine what was required if the question had been read carefully. Predicting which amino acid was closer to the positive electrode was challenging, although many candidates scored some marks for their reasoning. The majority of candidates correctly described one characteristic of an amino acid at its isoelectric point, but in (b) very few could write equations to explain how glycine can act as a buffer. Most candidates answered in words only, even though equations were specifically requested. A G2 comment suggested that SL candidates did not need to know about buffers. This is clearly stated as a requirement in B.2.2.

Question 3

This question was done well, although some candidates forgot to specify that very small amounts of micronutrients are required and some gave vitamins as examples. In (c), most candidates knew that vitamin E is fat soluble but could not explain further to achieve the marks.

Option C – Chemistry in industry and technology

Question 1

This was either answered very well or very poorly. Only the best candidates could state half-equations for the electrolysis of aluminium. Many candidates scored one mark out of two for

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outlining how carbon dioxide may be produced during aluminium production in (b). C.1.10 states that candidates should know the environmental impacts of aluminium production.

Question 2

Most candidates were aware of the differences between homogeneous and heterogeneous catalysts, but several described a heterogeneous catalyst as providing an alternate energy pathway. In (d), few candidates could name the catalyst but knew one other condition needed for catalytic cracking. Most correctly stated an equation for the catalytic cracking of pentadecane, but some added oxygen or water, and some had too many hydrogen atoms in the products.

Question 3

Liquid-crystals were known well by many candidates. Some were ill-prepared to answer these questions.

Option D - Medicines and drugs

Question 1

Most candidates were very familiar with analgesics and the synergistic effect of ethanol and aspirin. In part (b), many of the weaker candidates thought that parenteral administration of morphine required supervision by parents or authorities. Assessment statement D.1.3 outlines the meaning of this technique. Many candidates gave good descriptions of how morphine prevents pain.

Question 2

This question was generally answered well, although candidates should beware of providing too many responses when a specific number are required as penalties may be incurred if incorrect answers are also given. Most candidates correctly identified the functional groups.

Question 3

Many candidates clearly had an understanding of therapeutic window and placebos but failed to score full marks as insufficient details were given.

Option E - Environmental chemistry

Question 1

Part (a) required candidates to identify two greenhouse gases not mentioned already in the stem of the question. It was also stated that one of these gases should contain a nitrogen atom. Only the best candidates could identify two greenhouse gases and their sources. There were many incorrect responses, and many responses that did not meet the requirements of the question. Parts (b) and (c) indicated that candidates did not have sufficient experiences of real situations to set their knowledge in context, and few candidates linked the annual fluctuations to seasonal changes in photosynthesis. Some G2 comments reflected that teachers felt these questions were not directly related to the syllabus, but E.3.2 indicates that candidates should have familiarity with these sources. Nearly all candidates could state one effect of global warming in (d).

Question 2

Most candidates correctly stated equations for the formation of stratospheric ozone, although some only gave one equation even though there were two marks allocated. Sources of CFCs and advantages and disadvantages of using hydrocarbons instead of CFCs were answered well.

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Question 3

Part (a) was poorly answered with very few candidates knowing the sources of mercury and PCBs. Most candidates stated thermometers as sources of mercury and seemed unfamiliar with PCBs. Descriptions of multi-stage distillation and reverse osmosis were very well answered by some candidates. Some wrote essays on continuation pages, providing far more detail than required. Many candidates could describe the two processes but had difficulty evaluating them, stating simply that the processes are too costly. Answers need to be more than journalistic statements to score marks.

Option F - Food chemistry

Question 1

Some candidates scored well on this question, but there were many weak responses. Candidates needed to relate the packaging of potato crisps to the exclusion of oxygen and light in (a). In part (b), many candidates scored a mark for stating that emulsifiers have hydrophobic and hydrophilic groups but few were able to give a coherent explanation of how emulsifiers work.

Question 2

Most candidates correctly compared structural features of EGCG and rosmarinic acid in (a), but poorly demonstrated the application of knowledge of the factors that affect the colour of anthocyanins. One G2 respondent wondered whether candidates need to know the colours of pigments. This is clearly stated in F.4.3

Question 3

Many candidates gave detailed definitions of genetically modified food, but some failed to score by referring to the modification of food rather than the modification of the organism from which food is obtained. Candidates could state many benefits and concerns regarding the use of genetically modified crops in food, although some responses were insufficiently detailed. The concept of a discussion was not well applied, with a list commonly being provided.

Option G - Further organic chemistry

Question 1

Many candidates had difficulty answering this question. In (b), many candidates referred to delocalized electrons in benzene but did not relate this to addition reactions. Only the very best candidates could describe the relative reactivity of chlorobenzene and chloromethylbenzene in part (c). Many scored 1 mark for identifying the strong C-Cl bond in chlorobenzene.

Question 2

This question was answered quite well by many well-prepared candidates. Most scored full marks for identifying the types of reaction in part (c).

Question 3

This was answered well by many candidates although there were some odd mechanisms drawn.

Question 4

This question was also answered well by many candidates.

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Recommendations and guidance for the teaching of future candidates

- Candidates in schools that offer instruction in only two or three options generally do better than candidates who study the options independently.
- Candidates should treat the options as seriously as the other material in the course.
- Candidates should have access to appropriate resource materials in terms of the syllabus, books and practical exercises.
- Candidates need to study each option in depth and ensure they know the equations relating to the processes they study.
- Candidates should practise writing balanced equations.
- Candidates should practise analytical structural determination.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Candidates should pay attention to the mark allocation to ensure that sufficient points have been stated.
- Candidates should take note of the command terms used.
- Candidates should prepare for the examination by practising past paper questions and carefully studying the mark schemes provided.

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