CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 32	33 - 45	46 - 56	57 - 66	67 - 77	78 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 29	30 - 41	42 - 52	53 - 63	64 - 74	75 - 100

Higher and standard level internal assessment

Component grade boundaries

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

The range and suitability of the work submitted

The moderating team in the main reflected that the work submitted for the November 2011 session was similar in standard to the previous two November sessions with no discernible advance evidenced in terms of the variety and applicability of the assessed tasks undertaken and the quality of the work thereby generated. A common concern was that a number of schools presented samples where the candidates all were set the same simple design task such as under demanding rate experiments involving magnesium or calcium carbonate in acid. The resultant outcome work was on occasion below expectation for IB Chemistry, especially Higher Level, and lacked diversity.

However, a good number of students produced work that was well presented, with data recorded and processed appropriately and the procedure evaluated to a satisfactory extent. The internal assessment marks secured by the majority of candidates will have benefitted the overall final grade even if the teachers' marks were not always fully supported by the moderating team.

One common weakness was that when designing an investigation many students failed to include sufficient detail for the procedure to be reproduced. Although the recording of uncertainties and their propagation through calculations has become more commonplace it has been on occasion to the detriment of a simple consideration of significant figures. Also it is now not uncommon to see many pages of error analysis which actually obscure the purpose and findings of the investigation being reported upon. Similarly a small number of students included very many pages (up to fifty!) of raw data from data loggers. This once again obscured the report and is environmentally damaging as so much unnecessary material was sent across the globe for moderation. In such datalogging experiments a graphic print out of the large quantity of raw data is often more appropriate.

There were two very common misunderstandings of chemical principles that frequently arose in the candidates' work. One related to the confusion between the processes of reacting and dissolving especially in the context that many students stated that a reactive metal or a carbonate "dissolved" in an acidic solution. The second common misunderstanding related to the many design experiments seen that looked at factors affecting the rate of electrolysis. Very many candidates approached this under the assumption that an electrolytic reaction is directly analogous to the other systems they have studied in relation to kinetics and proceeded to plan and conclude wrongly in terms of collision theory. It is a concern that the teacher on many occasions did not make comment to highlight or correct these misunderstandings.

Some of the moderating team reported that some teachers are not including any marking comments on the work and in effect the moderator is having then to primarily mark the work in front of them with no guidance from the teacher. Moderators are instructed to support teachers wherever the first given mark seems sensible and justified so short comments on the work justifying grade awards helps support the candidates' best interests.

As reported in other sessions a small number of schools sent work that was clearly guided by teachers, fellow candidates or unreferenced sources to a level well beyond the instructions evidenced. It was unfortunately not uncommon in these schools for all candidates to choose exactly the same variables, carry out an identical procedure or follow through with identical methods in complex calculations, while the instructions provided had indicated an independent, open-ended task. Increasingly moderators are being requested to fill in Problem Report Forms (PRF) citing suspect malpractice so teachers should ensure that assessment is carried out in good faith and that an individual's skills are being assessed.

Candidate performance against each criterion

Design

Where the candidates had been set appropriate tasks the achievement level in the criterion was good. Many students were able to secure "complete" in the first aspect for phrasing a research question and identifying relevant variables. Instances of confusing the different kinds of variable were generally few. Also "complete" was correctly awarded in many cases for the third aspect regarding designing an experiment that will generate sufficient data, with most students planning to include repeats or to generate at least five data points in order to analyse graphically.

The second aspect was the most challenging of Design with many candidates failing 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 specifically how they are to control the variables they have selected and exactly what data they will collect. Candidates often lost marks on this aspect because they failed to include sufficient procedural detail regarding quantities, equipment and the measurement of controlled variables. Two common errors at this point were that students did not use appropriate volumetric techniques when making up solutions and that many students felt a single measure of room temperature sufficed as a control of reaction temperature in rate experiments.

Data Collection and Processing

Achievement against this criterion was generally high. Where achievement was low it was often linked to the set or designed task not lending itself to full assessment of DCP. Often students had been over-rewarded for simply determining a simple mean, plotting the raw data on axes with no further quantitative processing or even presenting an inappropriate bar chart.

When recording raw data most candidates included uncertainties and relevant qualitative data so Aspect 1 was well fulfilled in many cases. The correct processing of data for Aspect 2 assessment was achieved to at least a partial extent by most students usually through the satisfactory working through of numerical calculations. Relatively few candidates had presented work where they had determined a quantitative result by graphically processing the data to find a gradient or intercept through extrapolation.

The propagation through a calculation of the uncertainties in the raw data was carried out more frequently and to a better extent than previously and Aspect 3 often resulted in a “complete” award. However the pendulum has swung possibly too far and a number of reports are now being received where the consideration of uncertainties is swamping the purpose of the investigation. Also, it is noticeable that a sensible consideration of what is an appropriate number of significant figures possibly because the students’ focus is now on the propagation of uncertainties. In those reports where graphs were presented the students’ trendline, as generated though Excel was often not the best fit with often an inappropriate straight line was inserted. This reduced Aspect 3 achievement.

Conclusion and Evaluation

Conclusion and Evaluation continues to be the most discriminating of the criteria and few candidates achieved the top level. Unsurprisingly in view of the wording of this criterion many students limited conclusions to a clear statement of methodology whereas it is encouraged that they also justify their conclusions in terms of whether it was coherent with accepted theory. However the level of effort and detail in their conclusions showed improvement and in general the conclusions were adequate with nearly all candidates making an attempt to conclude their data.

It was more common during this session for candidates to compare their results to literature values where appropriate although it was rare to find correct citations of such resources. A slightly increased minority of candidates were then able to state whether the deviation of their experimental result from the literature value was explainable solely by the calculated random error or whether it indicated the presence of systematic errors as well.

As with previous years the majority of the candidates identified a number of relevant procedural limitations or weaknesses but then did not deal with the direction of error which limited aspect 2 achievement. Most candidates offered some clear and relevant suggestions as to how to improve the investigation and did relate to the weakness identified and probably a declining minority offered only superficial or simplistic suggestions such as simply more repetitions to be carried out or more precise apparatus be used.

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.

Recommendations for the teaching of future candidates

- 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.
- Candidates should be made aware of the different aspects of the criteria by which they are assessed and evaluation of investigations using a grid of criteria/aspects, with c, p and n indicated clearly, is strongly encouraged.
- It is encouraged to annotate work with further qualitative written feedback comments that help explain the aspect levels awarded will both help the students' reflection and development whilst also justify the schools' awards to the moderator.
- It is essential to ensure that candidates are solely assessed on their individual contribution to any activity used for assessment of the written criteria.
- Teachers must ensure that candidates have the opportunity to fulfil criteria, and hence should not provide too much information for the students. The use of workbooks and worksheets with spaces to be filled in by the candidates is strongly discouraged for assessed work.
- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.
- Students should cite final numerical quantities to an appropriate and consistent number of significant figures.
- Candidates need to explicitly identify the dependent variable as well as independent and controlled variables in the Design criterion.
- All investigations for the assessment of DCP must include the recording and processing of quantitative data. Solely qualitative investigations do not give the students opportunity to fulfil this criterion completely.
- Teachers are encouraged to set some DCP tasks that will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.
- Candidates must record associated qualitative where appropriate as well as quantitative raw data.
- Candidates must compare their results to literature values when relevant.
- 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 follow instructions found in the chemistry subject guide, the Teachers Support Material, and instructions provided in the up to date Handbook of Procedures for the Diploma Programme before submitting work for moderation.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 16	17 - 22	23 - 26	27 - 29	30 - 33	34 - 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. The following are some statistical data based on 45 respondents.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	3	31	10	0

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	45	0

	Poor	Satisfactory	Good
Clarity of wording	1	15	33
Presentation of paper	0	10	39

The statistics above were also reflected in the general comments where it was generally felt that the paper was fair and straight-forward with well constructed questions that spanned the entire syllabus. It was found that the paper allowed good room to every level of candidate to portray his or her capabilities.

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 91.58% to 38.05%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.69 to 0.14 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 11

One G2 comment stated that none of the answers were correct for this question and stated that the question was not clear as there was no mention of intermolecular force considerations. The question itself simply involved looking at two features for both substances, carbon and carbon dioxide – firstly whether the bonding is ionic or covalent and secondly whether the melting point is high or low. It was not necessary to include intermolecular force considerations to answer this question, as clearly from the choices given, A is the most appropriate answer. Clearly both carbon and carbon dioxide involve covalent bonding and carbon will involve a high melting point (particularly in the case of the allotropes, graphite and diamond, though of course the melting points of graphite and diamond are higher than that of fullerene) whereas the melting point for carbon dioxide will be low. 86% of candidates gave A as the correct answer.

Question 15

There were two G2 comments on this question, both suggesting that the graph given was confusing to candidates. In this question candidates had to use a combination of ideas to ascertain that the correct answer is A, namely I. and II. From the graph shown, candidates need to realise that the reaction is exothermic, and therefore from this information, the products are more stable than the reactants. 64% of candidates got the correct answer, A at HL.

Question 16

There was one G2 comment on this question on Hess's law, which stated that giving *x*, *y* and *z* variables instead of numeric data was confusing. However, candidates do not have the use of a calculator in P1 and hence it is common practice to use algebraic notation for this purpose. This notation has been used previously in P1 (though not always). In addition, this is a very common question and in fact, candidates had no problem answering this question, with 81% getting the correct answer, C.

Question 18

There were three G2 comments on this question which asked candidates to ascertain which factors would increase the entropy of a given system. All three comments suggested that the wording of the question could have been clearer. 45% of candidates got the correct answer.

Question 19

One respondent also suggested that the wording for this question could have been clearer in relation to the reactant in excess. However, 64% of candidates got the correct answer, B.

Question 20

One respondent stated that this question on Kinetic Theory was off-syllabus. However, Kinetic Theory is clearly covered under AS 6.2.1 in the guide. Another respondent stated that the term fixed points might confuse candidates. Again, this should not be the case if candidates understood the nature of Kinetic Theory. Most candidates did reasonably good in answering this question with 68% of the cohort getting the correct answer, C.

Question 24

In this question, candidates were asked to identify the container with the highest vapour pressure from a list of two substances and related temperatures. One of the substances was CH_3OCH_3, methoxymethane. One respondent stated that ethers are off-syllabus. This is an important point that has been addressed before in a number of subject reports. It is true to say that in the current programme candidates are not required to either identify ethers as a formal functional group or to name them, applying IUPAC rules. However, it should be noted that ethers are referred to in the TN corresponding to AS 4.3.2 in relation to the difference in boiling point between ethanol and methoxymethane, with regard to hydrogen bonding considerations. Hence, it is perfectly valid for methoxymethane to be cited in this particular question on vapour pressure.

Question 26

One respondent stated that this question could have been phrased better. 67% of candidates got the correct answer, D, with pH of the solution equal to 3.0.

Question 30

The two G2 comments on this question both stated that it would have been better if no reaction was given for the second equation, instead of repeating YCl + Z as the products. This is a valid comment. The question however was generally well answered and 85% got the correct answer, D.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 27	28 - 38	39 - 48	49 - 58	59 - 68	69 - 90

General comments

This paper indicated a wide range of capabilities as the marks varied from poor to excellent. In general, the paper was found to be very accessible, and although there were some challenging questions these in fact proved to be quite good discriminators between those candidates that knew their subject material comprehensively and those that had a cursory understanding. The fairness of the paper also appeared to be the general consensus of the generic comments from the G2's and the nature of the questions seemed to have been well received, with good syllabus coverage and good integration of core chemical topics. A number of the G2's did comment on the reading time required for the paper as a whole and there were a number of comments on the length of the paper, now that boxes have been included. This is a new development in P2 since May 2011, and it is important that future candidates are prepared for this format of examination paper in future sessions, which results from the move over exclusively to e-marking for P2 and P3 commencing May 2012 for Chemistry as a whole. Although the length of the questions themselves have not changed, candidates may think otherwise with the inclusion of the boxes which invariably makes for a much longer paper in terms of the number of pages. Teachers should try to ensure that candidates are very familiar with the new format.

The following are some statistical data based on 43 respondents.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	6	20	14	2

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	40	1

	Poor	Satisfactory	Good
Clarity of wording	1	12	30
Presentation of paper	2	8	33

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

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

- Misunderstanding of ionic bonding (many thought that this only occurs between metals and non-metals);
- Treatment of units in general;
- Macromolecular structure of silicon dioxide;
- Electron configuration of transition metal ions;
- Definition of average bond enthalpy;
- State symbols;
- Explanation of molecular polarity;
- Hybridization;
- Nomenclature of transition metal compounds;
- Voltaic cells;
- Maxwell-Boltzmann energy distribution curve;
- Determination of activation energy graphically;
- Aim 8 and hypothesis type questions.

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

- Metallic bonding;
- Calculations of rate;
- Collision Theory;
- Sub-atomic particles;
- Calculations involving entropy, enthalpy and Gibbs Free energy;
- Lewis structures;
- Shapes of molecules;
- Haber process;
- Homologous Series.

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

Section A

Question 1

a) Surprisingly for HL, a large proportion of candidates seemed to think that ionic bonding *only* occurs between metals and non-metals and this is an area that teachers should emphasise in class with an appropriate example such as ammonium chloride. In addition, many did not mention the idea of attraction in describing ionic bonding thereby losing the mark. In general, most had a very clear idea of metallic bonding however.

b) (i) Surprisingly maybe 30% of candidates got the number of significant figures incorrect, and 2 SF was a common incorrect answer for *T*.

(ii) The typical mistake here was not looking at the units carefully enough and hence approximately 50% got this incorrect which was surprising for a data-response type question.

(iii) Performance here was mixed. The better students got either 3 or 4 marks, some forgot to multiply by 10^3. The weaker students did not convert degrees centigrade to Kelvin. Some students used 24 dm^3 as the molar volume.

c) (i) The very best students were able to answer this hypothesis type question and stated that sodium reacts violently with water. This proved a good discriminator at the top end. This was a clear case of a hypothesis type question whereby candidates had to link their chemical knowledge (AS 3.3.1) to a situation. Typically in Section A Question 1, questions like this occur and usually have a marks allocation of one or two marks. These type of questions are often identified by the command term suggest and candidates should ensure that they have looked at past papers to see the different types of questions that can be asked here. The emphasis is on candidates using their broad chemical knowledge acquired throughout the programme to rationalise a particular situation which might be unknown to them.

(ii) It was very disappointing at HL that most candidates had no clue about the network covalent structure of silicon dioxide. Clearly candidates were not prepared for a question on SiO_2 nested outside its typical question style and simply could not put this into context which is surely an essential facet of chemistry. All sorts of incorrect structures were given, with double bonds, Na bonded to oxygen *etc*. This proved again to be a very good discriminator and the very top students did draw the structure of SiO_2 correctly, with clear tetrahedral arrangements and extension bonds on the oxygens. One G2 comment was that this was unfair to ask as according to the syllabus candidates are only required to describe the structure of silicon dioxide. An important point to be made however is that the command term describe is objective 2 (which means give a detailed account). In the IB Chemistry programme it would be expected that candidates should certainly be able to draw the structure of SiO_2 which is a lower objective in fact (Objective 1 – draw by means of pencil lines). Knowing that SiO_2 is macromolecular alone would involve the command term state, and with the command term describe, a lot more detail is required, including the tetrahedral nature about the silicon. In addition, a tetrahedral arrangement is covered in Topic 4.2 in the guide and candidates should be able to link the two ideas together. Most got covalent however, though the weaker students did not understand the term structure and bonding and linear was a common incorrect answer for the bonding response. Some simply wrote 180 degrees!

d) (i) This was usually well answered. Some of the weaker candidates did just multiply by 0.04 however and some gave dm^{-3}/s instead of dm^3/s as the unit.

(ii) This was very well answered though a minority forgot as usual to refer to time (*i.e.* more frequent) in relation to collisions.

Question 2

a) Sub-atomic particles were well answered though some gave 53 instead of 125 and Co was often given instead of I.

b) The top students mentioned gamma rays and again this proved to be a good discriminator. One G2 comment stated that this question was not strictly part of AS 2.1.7. However, this is both an Aim 8 AS and Objective 3 and it is expected that candidates would be exposed to this degree of discussion.

c) The better students managed to write the correct electron configuration for Co^{3+}, but surprisingly a significant number of students forgot that electrons come out of the 4s before the 3d for first-row transition meal ions.

Question 3

a) Very few scored both marks. Gaseous was often omitted and few stated that the average values are obtained from a number of similar bonds (again similar was often omitted).

b) Many of the better candidates were able to write the correct balanced combustion reaction. Some had an incorrect coefficient for oxygen and others wrote incorrect products (often hydrocarbons).

c) This was poorly done even by candidates who had the correct equation. O-O values were often given instead of O=O. Others mixed up the signs.

d) Nearly all knew that hydrogen bonding occurs in butan-1-ol, but only the top students mentioned the dipole-dipole interactions in butanal.

Question 4

a) This was generally well answered.

b) Many of the better students scored full marks here, and even the weaker students gained some marks.

Question 5

a) The negative nature of the change gained a mark, but the explanations sometimes lacked clarity and states often were not referred to.

b) In (i), often there was no mention of element. (ii) to (iv) was often very well done, though as usual some candidates struggled with units.

Section B

The most popular questions were Questions 7 and 8. Question 6 was less so and Question 9 the least, though these very much depended on the actual centres and all four questions were seen on papers.

Question 6

a) The first part on acid-base behaviour was well answered though a few stated that silicon is amphoteric which is incorrect. As regards the equations, hydrogen was often given as a product. The equation for the reaction of P_4O_{10} with H_2O was not well known.

b) (i) This was usually well answered.

(ii) This was very poorly answered. Candidates often knew the pH's but very few knew that the high charge density of Mg^{2+} releases H^+ from water.

c) The Lewis structures were usually well drawn but some omitted the lone pairs. The shapes were also usually correct, though some stated that the shape of PBr_3 is tetrahedral which is incorrect. The electron domain geometry of PBr_3 is tetrahedral as there are four negative charge centres or four electron domains, but the molecular geometry and hence the shape is trigonal/triangular pyramidal. It is worth emphasising this difference between electron domain geometry and molecular geometry in discussions of shape in VSEPR Theory. As regards the bond angles, a few forgot the fact that the lone pair on the P occupies more space and hence the angle drops below 109.5 degrees. Many simply wrote 107 degrees, which is the bond angle in ammonia. An important point to make here is that every trigonal pyramidal geometry does not have a bond angle equivalent to that of ammonia, 107 degrees, which is a point often misunderstood by candidates. In fact, many factors can come into play here including lone pairs and electronegativity considerations. In fact, the experimental bond angle for PBr_3 is 101 degrees and candidates would have scored the mark if they gave any value in the range 100 to less than 109.5 degrees. Candidates are not required to know experimental values but should not make sweeping conclusions that all trigonal pyramidal geometries have 107 degree bond angles, which certainly is not the case. For SF_6, 90 and 120 bond angles were often incorrectly given. The most disappointing part of this sub-section however was the poor explanations of polarity. Some of the top candidates did however give complete explanations and referred to the polar PBr bonds and the fact that as the molecule is not symmetrical there is an asymmetric distribution of the electron cloud. It was nice to see vectorial addition of bond dipoles supporting this type of explanation resulting in a clearly defined and drawn net dipole moment in the case of PBr_3 leading to its polar nature and similar arguments and drawings in the case of the non-polar of SF_6.

d) (i) Very few candidates scored both marks on sigma and pi bonds. In (ii), candidates often had the correct number of pi bonds but the incorrect number of sigma bonds. In (iii) and (iv), candidates seemed to have little spatial awareness which would have helped in answering these questions.

e) Hybridization was very poorly answered and many candidates did not even mention which specific oxygen had which hybridization. Others simply guessed the answer. Clearly candidates were not prepared for this type of question.

Question 7

a) Candidates generally knew that oxidation involves an increase in oxidation number and reduction a decrease.

b) Some forgot to include the Roman Numerals here and a large majority simply got the Roman Numeral incorrect. One G2 comment suggested that it would have been better if systematic was included in the question which is a fair point, though typically candidates simply put chromium oxide for both compounds which showed misunderstanding of what was really required.

c) The definition of an oxidizing agent was well answered in (i). In (ii), most candidates knew that the dichromate ion acted as the oxidizing agent but many made lots of errors in deducing the balanced chemical equation.

d) In (i), only the best candidates scored all five marks, though most candidates scored at least two marks. Some candidates mixed up the cathode and anode. Equilibrium signs were often written and very few gave the correct direction of the movement of ions. Some G2 comments stated that is was not clear what ion movement was required – flow of ions through the salt bridge or just movement of ions towards the electrodes in the electrolyte. In fact most candidates could not write either and the markscheme in fact allowed credit for either of these to be fair to candidates. In (ii), standard conditions often was omitted. (iii) was well answered.

e) Most candidates scored full marks here in (i) and (ii). In (iii), many candidates scored two out of three marks. In (iv) many candidates put two electrons in the 4s level and four electrons in the 3d level which was incorrect in the orbital diagram.

f) Candidates often scored two out of three marks here with the most common error relating to the electrolyte.

Question 8

a) Most candidates were able to define the term activation energy, though some forgot to refer to minimum energy.

b) Many candidates were able to state that NO acts as a catalyst though some struggled in explaining that NO is regenerated at the end of the reaction.

c) The definition of endothermic reaction was usually well answered, though some candidates failed to mention from the surroundings in (i). In (ii), incorrect labels for the axes were often given, as well as a very high proportion of symmetric curves! The catalyzed and uncatalyzed activation energies were often mixed up. It was nice to see also a significant number of the stronger candidates stating probability of particles with that kinetic energy as the y-axis label instead of simply number of particles, which although allowed is not as accurate a label as probability of particles.

d) Some forgot to mention concentration (or otherwise) in (i). In (ii), the most common score was three out of four.

e) (i) was usually well done. In (ii), some did not answer the question which asked for the overall order of the reaction. Some candidates also got their units incorrect. A few G2 comments mentioned the fact that the data was quite complicated as there was no experiment with [NH_3] constant. It is true that the maths here may appear more challenging than normal, but candidates should be able to handle this type of data and in fact a significant number of the better candidates did score full marks on this question.

f) This was well answered.

g) Although most candidates stated that the rds was step 1, many struggled with the explanation.

h) Although this question has been asked on a number of recent papers, candidates really struggled with this graphical based format. All sorts of mistakes were made, including gradients, units etc. Some did not even know how to approach the question.

Question 9

a) The idea of a homologous series was well understood though some stated incorrectly that there were the same physical properties.

b) In (i), many candidates only scored one mark. In (ii), most candidates were able to write the formula of the amide (assuming of course strong heating in the reaction – up to 200 degrees centigrade, which is a point worth flagging in discussions of this type of reaction). Some candidates gave incorrect bonds and throughout Question 9, some candidates forgot to include hydrogens, which were penalised once only as bonds without hydrogens in full structural formulas were not accepted as these represent methyl groups. In (iii), distillation often was not mentioned. (iv) was very well answered.

c) Although a five mark question which involved combustion and gravimetric analyses, many candidates in fact scored three out of five marks here and some got the problem completely correct – usually the top candidates.

d) (i) While the monomers were often correctly identified, there were some errors in providing the polymer. In (ii), this question was really an Aim 8 type question and careful reading of the stem would have helped candidates (e.g. the water resistant nature of the sleeping bag for example) or the high (specific) strength or good durability of nylon (used in climbing ropes). Again, there were a few G2 comments on this question and candidates should be prepared for Aim 8 type questions as part of the programme.

e) The better, prepared candidates often scored nearly full marks on the mechanism type question. However, weaker candidates struggled and common errors included omission of lone pairs, curly arrows coming from hydrogen etc.

Recommendations and guidance for the teaching of future candidates

- Be well prepared for data-response type questions in Section A, and carefully handle units and significant figures.
- Practice hypothesis type questions in Section A from past papers. These often include the command term suggest and what is usually looked for here is application of chemical knowledge from the programme. Often these questions are not difficult if you apply your chemical knowledge to an unusual situation.

- Be very well prepared for Aim 8 type questions – these are clearly listed in the guide and candidates should approach these topics looking at a range of environmental, social, economic, moral and ethical considerations of using science and technology.
- Know the definitions exactly cited in the specific AS's in the programme.
- Practise writing all the organic reaction mechanisms, and pay special attention to curly arrows etc.
- Look carefully at the marks allocation for each question e.g. three marks usually means three distinct points etc. If there is only one mark, don't be tempted to write a one page essay to answer the question!
- Do not be tempted to use continuation sheets – use only the space provided in the boxes. These should give you a clear indication of what length of answer is required.
- Try to approach the end of the programme from a number of clear themes bringing out some fundamental chemical concepts e.g. structure and bonding, intermolecular forces etc. These can prepare you significantly for some of the problems in Section A which tend to integrate a number of chemical principles straddling several topics. The best candidates usually apply their chemistry to new problems from this perspective and it is a great way of capping the programme as a whole rather than looking at individual assessment statements in isolation.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 20	21 - 25	26 - 30	31 - 35	36 - 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 which will be implemented from the May 2012 examination session. The lack of space in the boxes was a complaint mentioned in the G2 forms.

This paper identified a very broad range of candidate capabilities. Some candidates struggled with even the most basic concepts and factual knowledge while others demonstrated an excellent depth of understanding of the higher level material. In general, candidates did appear 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. Some answers lacked precision in terms of the wording used and explanations were often vague. In some other questions, responses to questions lacked chemical detail and particularly for Option C, D, E and F, some responses tended to be journalistic rather than based on chemical facts and principles. Students need to be reminded of the nature of the subject – general answers to specific questions do not score marks. Students need to pay particular attention to the action verbs (command terms) and use chemical knowledge and concepts to answer 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 two options, also with poor results in all.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	1	31	9	6

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	41	2

	Poor	Satisfactory	Good
Clarity of wording	2	11	36
Presentation of paper	1	7	41

The most popular options were B and D, while F was the least popular. Many of the weaker candidates appeared to opt for Option E on Environmental Chemistry. However, in many cases these candidates tried to answer questions with limited specific chemical knowledge of the option itself and hence performed poorly. It is imperative that candidates are well prepared for their chosen options. In addition, many candidates with a strong biology background often over-depend on their biological knowledge and it is important that candidates choosing Option B on Human Biochemistry or Option D on Medicines and Drugs are well prepared for some of the specific chemical concepts embedded in these options. This pattern was evident with some candidates this session. Many of the stronger candidates tended to opt for Options A, D and G and performance here was generally of a very high standard. It was encouraging however to see more candidates choosing Option C and good scripts were often seen.

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

Students experienced difficulties in areas that required knowledge of specific processes or reactions, and did not succeed in answering questions in sufficient detail in order to score marks such as explaining the difference in colours due to difference in conjugation, different chromatography principles and operations, solving the relatively straightforward problem (in B1), outlining steps involved in DNA profiling of a blood sample, choosing catalysts, fuel cells and liquid crystals concepts, chiral auxiliaries, mechanism for formation of HNO_3 and SO_3, calculations based on K_{sp} and browning of food processes.

Option choice in order of number of choices was the following: Option B, D and E, A, C, G and lastly F. The options in order of increasing difficulty were: B, D and E, A, G, F, C.

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

During this session many excellent scripts were seen. Good levels of knowledge, understanding and skill were demonstrated in the following areas:

- In modern analytical chemistry, candidates were generally able to answer questions related to spectrometry, IR, NMR and MS where they could analyse structures and find differences and similarities.
- In human biochemistry, they were generally able to explain how electrophoresis is used to analyse a protein and explain how enzymes catalyse reactions and the effect of increasing temperature on enzyme-catalysed reactions.
- In medicines and drugs, they were able to discuss problems associated with the over prescription of penicillin and also discuss the importance of chirality in drug action.
- In organic Chemistry they were able to write mechanisms correctly, respecting conventions and drawing curly arrows correctly.

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 proved more difficult, with few candidates scoring full marks.

Question 1

A1. Many candidates were unable to define they type of process which absorbs UV or microwave energy. Most were able to score marks for specific applications of atomic absorption spectroscopy.

Question 2

Identification of two types of molecular vibrations that occur in CO_2 molecules exposed to IR radiation and explanation of IR active and IR inactive vibrations was generally very well done, with little evidence of misunderstanding the chemistry involved.

Question 3

Similarities and difference in the 1NMR spectra of the two isomers was generally well done, with the commonest errors being to include the 0.9-1.0 chemical shift for the methyl group and omitting the charges on the ions in the mass spectrum fragments. Candidates did not understand the way MRI works though they did know that it was possible to obtain a 3-D image of body organs.

Question 4

The effect of conjugation on colour proved far more difficult, with few candidates scoring full marks, although some had some idea of what conjugation was. Candidates found it difficult to associate the length of conjugated systems to the wavelength of UV/Visible absorbance or frequency and energy and many could not estimate the wavelength of absorbance of oxybenzone.

Question 5

Scoring full marks on GLC and HPLC were rare, but most candidates were able to score for sugars decomposing in GLC and the two phases in HPLC. There was some confusion between HPLC and column chromatography, with several references to solvents and elution. HPLC seemed to be especially difficult to understand or describe. In the case of GC, though candidates seem to have a better understanding of how it works.

Option B – Human biochemistry

This was one of the most popular options.

Question 1

Most candidates ignored the heat capacity of the glass beaker in calculating the energy value of food but were able to solve the problem aside from that, thus scoring 2 marks out of 3. Errors more rarely seen were the addition of 273 to the temperature difference.

Question 2

The name of the linkage broken during the hydrolysis of a protein was usually correct although in some cases glycosidic or ester appeared, and only about half could draw the structure of the peptide bond. Explanation of how electrophoresis is used to analyse a protein was generally done well although some candidates forget that proteins have to be hydrolysed before analysing the amino acids by electrophoresis.

Question 3

The part on hormones was usually well done and the majority scored the marks, but there were cases where –OH was given as the answer instead of the name that was asked for.

Question 4

Many had some idea of α and β origins of starch and cellulose respectively but it was disappointing to see weak answers where candidates compared other features such as digestibility or solubility instead of comparing the structures as asked for.

Question 5

In the explanation of how enzymes are able to catalyse reactions, many referred to active sites but fewer made reference to the lowering of activation energy. Though candidates seemed to understand enzyme activity at different temperatures, they often omitted details on the exact temperature ranges. Some were nicely able to illustrate their answer with a properly labelled graph.

Question 6

Many scored the mark for the structure of a nucleotide of DNA - usually the ones who did not score the mark failed to mention the base being organic or nitrogenous or the sugar being pentose or deoxyribose. About half the candidates incorrectly stated hydrogen bonding in relation to how nucleotides are linked together. The steps involved in the DNA profiling of a blood sample produced answers that varied from very good to very poor with "chromatography" mentioned and restriction enzymes often omitted. Also, DNA profiling was sometimes confused with amino-acid profiling and very few scored the mark for the detection of the pattern by labeling with radioactive phosphorus, ^{32}P.

Option C – Chemistry in industry and technology

This was not a popular option.

Question 1

Generally the equation for the reaction of coke with air was well done, although the correct equation for the reaction of CO_2 with coke was sometimes missing and especially the conversion of impure iron into steel was usually incompletely answered where use of silicon dioxide was not easy to describe.

Question 2

Not all candidates understood how to discuss two factors in choosing catalysts although they should have studied several factors. Most did not correctly answer why the polymer given was not an example of condensation polymer, namely condensation should involve loss of a small molecule whereas all atoms in the two monomers end up in the polymer (and thus it is an addition polymer). However, hydrogen bonding between chains in Kevlar was well known, but almost none scored the mark for recognizing chains have cis orientation, making close approach possible.

Question 3

The question on fuel cells was poorly answered, with very few including both graphite and a Pd or Pt or Ag metal in the composition of the electrodes. Better candidates had no difficulty with the half-equations at each electrode in the hydrogen-oxygen alkaline fuel cell although some were reversed or incorrect.

Question 4

Very few scored full marks on the description of the nematic liquid-crystal phase probably because of the difficulty of selecting the right words, and surprisingly only a few scored the mark in terms of the effect of the extra energy, namely causing greater movement or overcoming intermolecular forces.

Question 5

The chlor-alkali cell was well known, and this straightforward question saw some high scores and most candidates were able to state either the composition or the type of membrane used in the cell. However, only about half were able to state the half-equations for the reactions taking place at each electrode. Candidates had some idea about the different types of cells and their advantages/ disadvantages.

Option D – Medicines and Drugs

This was one of the most popular options.

Question 1

The general effects of medicines and drugs on the functioning of the human body were generally very well done. Some students struggled with the definition of a placebo.

Question 2

Comparison of the structures of amphetamines and adrenaline was generally well done, with the most common marks not scored were the formation of hydrogen bonds in adrenaline and the reason for caffeine's basic behaviour – this was missed by a surprisingly large number of candidates. Well over half answered acidic or neutral and for those who answered basic only half of them could score the mark for the explanation - they simply did not seem to know that amines are basic.

Question 3

Many correctly identified the side chain in benzyl penicillin but many did not recognise the loss of beneficial bacteria in the problems associated with over prescription of penicillin. A surprising number were not able to explain the modification of the side chain R group to change penicillin effectiveness**.**

Question 4

Identification of the chiral carbon atom was generally well done but some were not able to describe the composition of a racemic mixture correctly by not mentioning an equimolar (50:50) mixture. The importance of chirality in drug action was very well discussed.

Question 5

The equations for the formation of the ionic salt of aspirin and the ionic salt of fluoxetine were poorly done with H_2O, NaCl, HCl and Na used in the first case instead of NaOH and H_2O and NaOH used in the second case instead of HCl. When the correct reagent was chosen the products were often incorrect and in quite a few cases this part was left blank. Description of how a chiral auxiliary works was not well understood and chiral axillaries function in synthesis was also sometimes confused. The argument for and against the legalization of cannabis often produced general answers that were rather journalistic in nature with little specific detail provided to score the marks. Usually the last marking point for argument against was scored.

Option E – Environmental chemistry

This was not a popular option, one probably not taken seriously enough by candidates, who rely on general concepts and misconceptions they´ve acquired over time.

Question 1

The man-made source of nitrogen oxide was generally very well done, although the equations for its formation proved demanding. A method for the removal of nitrogen dioxide from emission gases was correctly answered by a majority, but only half mentioned alkaline or wet scrubbing or limestone-based fluidized bed" for sulfur dioxide removal. Only very few scored full marks on their ability to outline the mechanism for the formation of HNO_3 and SO_3.

Question 2

It was surprising to see that many candidates could not score full marks in a question on the greenhouse effect which appears often in examination papers. The use of unacceptable language (reflecting, bouncing, trapping, etc.) cost many candidates marks although most knew that carbon dioxide was more abundant, far fewer could clearly express the point about methane being better at absorbing IR radiation.

Question 3

K_{sp} problem proved very difficult and was solved fully by only a few candidates. The first challenge they had was stating the K_{sp} equation correctly. Half scored 1 or 2 marks through ECF, but there were enough cases where the calculation was not attempted at all. It seems processes for obtaining fresh water from sea water was not covered or covered superficially by many schools. Almost no one scored full marks and although the statement asked for evaluation of the two processes, students often just stated facts without much evaluation. Answers were disappointing, with many too vague to score (e.g. efficient with no reference to a multi-stage process, expensive with no reference to high energy consumption).

Question 4

Most did not score full marks in listing common organic soil pollutants and stating their sources. There were quite a few cases where the candidates failed to read “organic” and answers such as nitrates, phosphates and aluminium appeared.

Question 5

Many correct answers were seen for the outline of mechanism by which nitrogen oxides are able to deplete ozone, though rarely achieving full marks.

Option F – Food chemistry

This was attempted by few candidates and was generally not done well.

Question 1

The vast majority were able to state the empirical formula of monosaccharides but a good number were not able to state its structural features. Only about half could draw the structural formula of 2-aminoethanoic acid correctly, the other half indicated lack of knowledge for organic nomenclature. It was surprising to see that only about half could deduce the structure of the triester correctly and identify the ester linkage. About half were able to deduce the number of C=C bonds correctly from the list of fatty acids and most deduced the least stable fatty acids correctly, but a majority of them could not explain.

Question 2

Half the candidates scored full marks for the free-radical mechanism and the others scored partial marks, usually for the initiation step although surprisingly there were a good number who left this question blank.

Question 3

Very few full marks were achieved in the comparison of the two browning processes of foods. Some had little idea and others left the question blank. Almost no one, for example, scored the mark for the Maillard reaction even though the formulas were provided.

Question 4

The benefit and concern of consuming genetically modified foods was answered very well by the vast majority of candidates.

Question 5

The vast majority chose the correct "L" isomer for the structure given, but only about half of them could give a convincing explanation or justify their answer. About half were correctly able to state the (*d*) or the (*l*) convention.

Question 6

Candidates could not relate the length of conjugation with absorption in the UV/Visible spectrum. On the other hand, many were able to deduce the water or fat-solubity of the two natural pigments given.

Option G – Further organic chemistry

This was one of the least popular options.

Many scripts scored very highly in this Option, perhaps because better candidates chose it. The mechanisms proved a problem for a minority of candidates with some leaving blanks spaces. Candidates must take care to accurately draw the position of the curly arrows illustrating the movement of electrons.

Question 1

The mechanism for the reaction of the alkene with HBr was well done, and most arrows in the mechanism were accurately drawn. The explanation of the major product elicited the phrase "Markovnikov's rule" instead of explaining it. Only a few candidates could write the equation corresponding to the reaction with ethanoyl chloride but answers for reaction with 2,4-dinitrophenylhydrazine and Grignard´s reaction were generally correctly done although enough let these blank.

Question 2

Most stated the correct order of basicity and knew about the inductive effect. Those that did not had a major problem because they interpreted the pK_a/pK_b values given in the Data Booklet incorrectly. Those that got the order right generally had no trouble justifying the answer through the presence of methyl groups, though they generally omitted referring to the effect of the increasing number of them.

Question 3

A well-answered question on the mechanism for the reaction of benzene with bromomethane, with the commonest omission being the equation for the formation of the electrophile. Vast majority were able to deduce the structural formula of one product when methylbenzene reacts with bromine by electrophilic substitution. Also, the justification for greater rate of reaction between methylbenzene and bromine was generally correctly answered.

Recommendations and guidance for the teaching of future candidates

Candidates should be advised to pay attention to mark allocations and command terms (action verbs) in each question and to bear in mind the following points in this paper:

- Provide answers that involve proper chemistry and not superficial or journalistic type of answers, avoid the use of everyday language but rather use correct scientific terms.
- Practise setting out calculations in a logical way, showing each step, and emphasising the final answer by paying due attention to units and significant digits.
- When writing organic structures, check that the valency of each atom is correct and always include hydrogen atoms in full structural formulas.
- Be consistent with the use of dots in radical representations.
- Be fully familiar with organic reaction mechanisms in Option G and pay special attention to the correct use of curly arrows in mechanisms.
- Chemical equations should be given wherever possible to support the processes discussed in options.
- Options should be taught in class as they are an important part of the programme.
- Teachers should ensure that definitions covered in the assessment statements for each option is well known by candidates.
- Students should be 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.
- Candidates must use the chemistry data booklet during the chemistry course so that they are familiar with what the chemistry data booklet includes.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Teachers should use past examination papers and their corresponding markschemes to prepare the candidates for the examination.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 9	10 - 14	15 - 17	18 - 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. The following are some statistical data based on 49 respondents.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	6	27	12	0

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	46	3

	Poor	Satisfactory	Good
Clarity of wording	2	14	33
Presentation of paper	1	9	39

The statistics above were also mirrored in the general comments, where it was generally felt that the paper was fair. One respondent also welcomed inclusion of some of the new type of questions on the paper.

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 82.11% to 20.84%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.68 to 0.28 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:

Question 2

One respondent stated that the equation was a difficult choice to test the balancing of chemical equations. However, this type of question has been asked several times on previous papers and 59% of candidates got the correct answer, D. Candidates should be exposed to the balancing of some challenging equations as part of the teaching programme.

Question 5

Another respondent stated that this question was very difficult without the use of a calculator. This was found not to be the case in fact for candidates as 73% got the correct answer, B.

Question 6

In one G2 comment it was stated that this question was more physics in nature. However, AS 2.3.1 states that candidates should be able to describe the electromagnetic spectrum (EMS) and in the corresponding TN for this AS, it is clearly indicated that variations in wavelength, frequency and energy in the UV, Vis and IR regions of the EMS should be known. 62% of candidates got the correct answer to the question, namely, B.

Question 8

One respondent stated that the wording of the question could have been better if it was stated which of the redox reactions are likely to occur, which is a fair point. The question was one of the more difficult questions on the paper, though 54% did manage to get the correct answer, namely A.

Question 10

One G2 comment stated that none of the answers were correct for this question and stated that the question was not clear as there was no mention of intermolecular force considerations. The question itself simply involved looking at two features for both substances, carbon and carbon dioxide – firstly whether the bonding is ionic or covalent and secondly whether the melting point is high or low. It was not necessary to include intermolecular force considerations to answer this question, as clearly from the choices given A is the most appropriate answer. Clearly both carbon and carbon dioxide involve covalent bonding and carbon will involve a high melting point (particularly in the case of the allotropes, graphite and diamond, though of course the melting points of graphite and diamond are higher than that of fullerene) whereas the melting point for carbon dioxide will be low. 69% of candidates gave A as the correct answer.

Question 12

There were four G2 comments on this question all of which stated that some of the Lewis structures for ethane were not represented clear enough, particularly in relation to choice C, which is a valid comment and this will be taken on board in future paper settings. In the case of choice A one respondent stated that it would have been better to represent the carbon to carbon double bond in the Lewis structure as C:::C instead of having the electrons shown in a vertical line. However, candidates should realise that electrons in Lewis structural representations can be represented in a variety of ways and hence teachers should ensure that students in class get ample practice of writing Lewis structures in different ways.

Question 14

There were two G2 comments on this question, both suggesting that the graph given was confusing to candidates. In this question candidates had to use a combination of ideas to ascertain that the correct answer is A, namely I. and II. From the graph shown, candidates need to realise that the reaction is exothermic, and therefore from this information, the products are more stable than the reactants. 55% of candidates got the correct answer.

Question 16

There were three G2 comments on this question on Hess's law, all of which stated that giving *x*, *y* and *z* variables instead of numeric data was confusing. However, candidates do not have the use of a calculator in P1 and hence it is common practice to use algebraic notation for this purpose. This notation has been used previously in P1 (though not always). In addition, this is a very common question and in fact, candidates had no problem whatsoever answering this question, with 80% getting the correct answer, C. The question was the third easiest question on the paper.

Question 18

There were two G2 comments on this question both of which stated that this was a difficult question at SL. The question certainly was challenging and was found to be the third hardest question on the paper. However, 49% of candidates did manage to get the correct answer, C.

Question 23

The two G2 comments on this question both stated that it would have been better if no reaction was given for the second equation, instead of repeating YCl + Z as the products. This is a valid comment. The question however was generally well answered and 69% got the correct answer, D.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 19	20 - 25	26 - 31	32 - 37	38 - 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 via the 50 G2 forms that were returned. In comparison with last year's paper, 36 people thought this year's paper was of a similar standard or a little easier and 11 considered it to be a little more, or much more difficult. However 44 thought the level of difficulty was appropriate and 6 thought it was difficult. Clarity of wording was considered good or satisfactory by 48 and the presentation of the paper was also considered good or satisfactory by 48 of the 50 respondents. This represents a slight 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. However, if students do inadvertently answer more than one question in Section B because of this change then all responses are marked and the students are awarded the best mark for their Section B response.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	8	28	8	3

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	44	6

	Poor	Satisfactory	Good
Clarity of wording	2	18	30
Presentation of paper	1	14	35

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 the ideal gas equation to calculate a gas volume
- Determining the number of significant figures
- Drawing the structure of silicon dioxide
- Determining the cell equation for an electrolysis reaction including state symbols
- Explaining the use of Co-60 in radiotherapy
- Drawing Maxwell- Boltzmann energy distributions
- Definition of average bond enthalpy

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
- Explanations of bonding
- Calculating enthalpy changes
- Drawing Lewis structures
- Equilibrium

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

Section A

Question 1

Question 1 tested a number of concepts and very few students were able to gain all the marks available. Part (a) was fairly well done and students could explain ionic and metallic bonding although weak students did not explain the bonding but simply stated that ionic was between metal and non metal etc. Surprisingly in part (b) (i) a number of students could not state the number of significant figures and many stated that 25.00 was 2 SF instead of 4. Part (b) (ii) required the calculation of the amount of substance in moles, and was generally well done although some did not realise the value was in kg and so had a value 1000 times too small. In part (b) (iii) a number of students lost marks for forgetting to convert temperature or pressure and also to multiply the amount by 1.5. Also many forgot to convert the pressure into kPa if they wanted their answer in dm^3. However, most students could obtain at least one of the marks available. In part (c) (i) many did not relate the removal of sodium to the potential for it to react with water and instead gave a far too vague of answer that it was reactive. However, the very best students were able to answer this hypothesis type question and stated that sodium reacts with water. This proved a good discriminator at the top end of the candidature. Part (c)(ii) was very poorly answered and the majority of students believed that SiO_2 had a similar structure to CO_2. The very few students that drew a giant structure often did not then show a tetrahedral arrangement of the atoms, however most did realise that the bonding was covalent. Part (d) was generally well answered and most students calculated a rate from their results although some lost the mark for incorrect or absent units. Most students could then successfully explain why the rate increased with temperature. However a minority forgot to refer to time (i.e. more frequent) in relation to collisions.

Question 2

This was generally well answered and sub-atomic particles were well known although some gave 53 instead of 125 and Co was often given instead of I. Part (b) was poorly answered and only the top students mentioned gamma rays or something similar to explain its use as a radioisotope, again this proved to be a good discriminator between students.

Question 3

In part (a)(i) Some students mixed up electrolytic cells with voltaic cells and salt bridges were often seen. Others mixed up the products at the cathode and anode. For the anode, Cl was sometimes given instead of Cl_2 meaning that the mark was not awarded. Also occasionally the electrolyte was incorrectly given as an aqueous solution. In part (ii) The most common mistake here involved the incorrect set of state symbols. Very few candidates realised that sodium would be a liquid. Also there were equilibrium arrows incorrectly used in the redox equations.

In part (b) many candidates did not refer to ions in their answer and instead referred to the lack of delocalised electrons. In part (c) only some of the better students stated that Al was less dense. It was disappointing that candidates wrote loose journalistic answers such as Al is lighter. Also some wrote that Aluminium does not oxidize, which is incorrect, however we did accept that it doesn’t rust.

Question 4

Again this definition proved very challenging even though it has appeared on recent examination papers and very few scored both marks. Gaseous was often omitted and few stated that the average values are obtained from a number of similar bonds (again similar was often omitted). In part (b) many of the better candidates were able to write the correct balanced combustion reaction. Some had an incorrect coefficient for oxygen and others wrote incorrect products which were often hydrocarbons. In part (c) there were some fully correct responses, but many did lose marks. Common mistakes included using the O-O bond energy value instead of O=O. Others mixed up the signs. In part (d) it was pleasing that nearly all candidates knew that hydrogen bonding occurs in butan-1-ol, but only the best students mentioned the dipole-dipole interactions in butanal. Generally butanal was described as having van der Waal's or dispersion forces.

Section B

Section 5

This was one of the least popular questions but those candidates that did attempt it, often performed well. In part (a) the equation was well answered, as were the electron arrangements of sodium and sulfur, but candidates struggled with the electron arrangements of the ions. Also, some forgot to give a reason as to why sulfur is reduced.

(b) The first part on acid-base behaviour was well answered though a few stated that silicon is amphoteric which is incorrect, unfortunately this is an error that has appeared in some IB textbooks. As regards the equations, hydrogen was often given as a product, and although many could successfully write the equation of sodium oxide with water, very few could successfully write the equation with phosphorous (V) oxide.

In part (c) candidates could draw the Lewis structures and generally they could name the shape and suggest the bond angle. However lone pairs were often omitted, especially on oxygen and bromine. Explaining molecular polarity often was more challenging, and clearly it is poorly understood. In part (d)(i) few candidates correctly used the Roman numeral III, however many did realise in part (ii) that there was no change in oxidation number of chromium and so no redox reaction. In part (iii) candidates could define what an oxidizing agent was and most correctly identified dichromate, as the oxidizing agent, however some just incorrectly stated chromium.

Question 6

This was by far the most popular question and was generally well-answered.

In part (a) of this question the K_c expression was usually written correctly though the very weak students did mix up the numerator and denominator in (i), or include a + sign between substances. In part (ii), candidates generally had few problems, but the reaction condition that proved to be the most the most difficult factor was the volume. In part (b) Activation energy was often clearly defined though some forgot to mention minimum. In part (c) the best students realised that NO acted as a catalyst as it was regenerated at the end of the reaction. However many weaker students stated it was not a catalyst as it was not involved in the reaction. In part (d) the definition of an endothermic reaction was generally well answered in (i), however some just said it absorbs heat and forgot to mention the surroundings in their answer. In (ii), incorrect labels for the axes were often seen, as well as a very high proportion of symmetrical curves, some which did not start at the origin. Also many drew two curves. Also in some cases the catalyzed and uncatalyzed activation energies were often mixed up. The weaker students drew an enthalpy level diagram instead of a Maxwell- Boltzmann distribution.

In part (e), in the definition for rate of reaction some students forgot to mention concentration in part (i). However in part (ii), most candidates gained some marks and they were able to explain how and why the conditions used in the Haber process were different. In part (iii) the better candidates did well as it only involved rearranging a familiar equation, although some forgot to state the final temperature in Kelvin as requested by the question. Unfortunately weaker candidates made lots of silly errors.

Question 7

This was the second most popular question in Section B and focussed on organic chemistry.

Part (a) which asked for a description of a homologous series was generally very well answered. In part (b) (i), 1 out of 2 marks were commonly awarded, as students had the incorrect prefix or made errors such as 4-methylpentan-1-al instead of 4-methylpentanal. In part (ii) most candidates knew the reagents for the conversions of the alcohol but only the best candidates also knew the conditions. Explanations of a weak acid in part (iii) and explanations of volatility in (iv) were well done.

In part (c) the mechanisms proved to be difficult for some SL students. S_N1 and S_N2 were sometimes interchanged, and students often forgot to show the arrow leaving from a lone pair or negative charge on oxygen.

Part (d) was a moles calculation based on experimental data, and was done very well by some of those that attempted it. However many candidates could not get through it and some left it blank.

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:

Greater emphasis on chemical concepts in the teaching programme, and an 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.

- "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 moles and bond enthalpies.
- Learn definitions correctly.
- 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. However, in practice the use of continuation sheets should not be encouraged and candidates should use the space provided.
- Candidates should practice answering past examination 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.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 5	6 - 10	11 - 14	15 - 18	19 - 21	22 - 25	26 - 40

General comments

This paper identified a very broad range of candidate capabilities. A very wide range of performance was seen, there were some excellent responses and also there were a number of students that were insufficiently prepared for the paper.

Some responses lacked precision, chemical detail and explanations were often vague, and, particularly for Options C, D, E and F, tended to be journalistic rather than based on chemical facts and principles. Students need to be reminded of the nature of the subject; general answers to specific questions do not score marks.

Many candidates appeared to be uncomfortable with some of the more chemistry type questions in Options B on Human Biochemistry and Option D on Medicines and Drugs, which suggests that some students who are strong in biology struggled somewhat - it should be borne in mind that this is a chemistry paper and the emphasis should be in chemistry.

Many of the weaker candidates appeared to opt for Option E on Environmental Chemistry. However, in many cases these candidates tried to answer questions with limited specific chemical knowledge of the option itself and hence performed poorly. It is imperative that candidates are well prepared for their chosen options.

Where all the candidates in a centre studied the same two options they tended to perform better than candidates who appeared to have a wide variety of choice of the options studied.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	1	32	5	8

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	43	6

	Poor	Satisfactory	Good
Clarity of wording	2	13	34
Presentation of paper	0	10	37

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:

- Describing the principles of AA spectroscopy.
- Listing possible ions detected by AA spectroscopy and corresponding source.
- Describing the chemical principle behind the conversion of impure iron into steel.
- Discussing the factors in choosing a catalyst for a process.
- Describing the composition of the electrodes and stating the half-equations at the electrodes in the alkaline hydrogen-oxygen fuel cell.
- Writing and balancing half-equations for oxidation and reduction occurring in breathalysers.
- Evaluating the processes of reverse osmosis and multi-stage distillation to obtain fresh water from sea water.
- Compare the processes of hydrolytic and oxidative rancidity.
- Compare the processes of non enzymatic browning and caramelization.
- Writing the mechanism for nucleophilic addition.

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

The areas which seemed well understood were:

- IR, mass and ^{1}H NMR spectra.
- Electrophoresis.
- Identification of functional groups in organic molecules.
- Explaining the difference in melting point between LDPE and HDPE.
- Effects of depressants.
- Ozone depletion.
- Stating the meaning of rancidity of fats.
- Genetically modified food.
- Writing the mechanism for the electrophilic addition.
- Structure of benzene.

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

Option A - Modern Analytical Chemistry

This was not a very popular option and proved more difficult, with few candidates scoring full marks.

Question 1

In (a) many candidates were unable to identify both processes, usually the one associated with UV was given correctly. Very few candidates scored many marks in (b). Most answers to (i) and (iii) were vague and low-scoring. In (i) most students tried to explain how AAS works rather than to answer the actual question "three principles of AAS". In (ii) few scored the mark.

Question 2

This part was answered generally very well, with little evidence of misunderstanding the chemistry involved.

Question 3

(a) and (b) were generally answered well, the commonest errors being to include the 0.9-1.0 ppm chemical shift for the methyl group in (a) and omitting the charges on the ions in (b). In (c) candidates showed little understanding of how MRI works, though they did know that it produces a 3-D image of body organs.

Option B - Human Biochemistry

This was one of the most popular options.

Question 1

Most candidates did not use all the data given. The vast majority of candidates ignored the heat capacity of the beaker, but through ECF many scores of 2 marks were seen. An error, more rarely seen, was the addition of 273 to the temperature difference.

Question 2

In (a) it was surprising to see that quite a few candidates did not know the name of the linkage broken during the hydrolysis of a protein and only about half of the candidates, who stated the name could draw the structure of the peptide bond correctly. In some cases glycosidic or ester linkage appeared. In (b) the explanation of how electrophoresis is used to analyse a protein was generally answered very well.

Question 3

Most parts of this question were answered well by candidates. In (a) many candidates mentioned "chemical messenger". In (b) ketone or carbonyl was invariably mentioned, but alkene was missed by quite a few of the candidates. In (c) the vast majority of candidates scored the mark, but there were cases where "–OH" was given as the answer instead for the name that was asked for. Many scored the 3 marks in (d).

Question 4

In (a) many candidates had some idea of the α-glucose and β-glucose origins of starch and cellulose respectively, but it was disappointing to see weak answers where candidates compared other features/properties, such as digestibility or solubility, instead of comparing the structures as it was asked for.

In (b) about half of the candidates scored the mark by stating the name of the enzyme needed to digest cellulose being absent in humans.

Option C - Chemistry in industry and technology

This was one of the least popular options.

Question 1

Generally the equation for the reaction of coke with air was given correctly in (a)(i), although the correct equation for the reaction of CO_2 with coke was sometimes missing in (a)(ii). In (b) the conversion of impure iron into steel was usually incompletely answered where the use of silicon dioxide was not easy to describe and correct equations were sometimes missing.

Question 2

(a) was surprisingly poorly answered, with very few candidates understanding how to discuss two factors in choosing catalysts, although they should have studied several factors, but (b) and (c) were answered well.

Question 3

The question on fuel cells was poorly answered, with very few including both graphite and a Pd or Pt or Ag metal in the composition of electrodes in (a). Only the better candidates had no difficulty with the half-equations at each electrode in the hydrogen-oxygen alkaline fuel cell in (b). In the majority of cases the equations were incorrect and when sometimes correct half-equations were given the electrodes at which they occur were incorrect.

Question 4

Very few of the candidates scored full marks on the description of the nematic liquid-crystal phase in (a), probably because of the difficulty of selecting the correct words, and surprisingly only a few scored the mark in terms of the effect of the extra energy, namely causing greater movement or overcoming intermolecular forces in (b).

Option D - Medicines and Drugs

This was another very popular option.

Question 1

The general effects of medicines and drugs on the functioning of the human body were generally very well answered in (a), but some candidates struggled with the description of the placebo effect in (b).

Question 2

(a) was generally answered very well. Very few candidates could deduce the correct half-equations in (b), at least the one in (b) (ii) should have been given correctly as it is included in Table 14 in the Data Booklet, but obviously most candidates did not know this! In (c) only about half of the candidates gave two methods correctly to score the mark.

Question 3

The comparison of the structures of amphetamine and adrenaline was generally answered well in (a). Many candidates predicted correctly which of the two is more soluble in water in (b), but half of them failed to score the second mark because they did not mention the formation of hydrogen bonding. In (c) about half of the candidates identified the type of amine correctly in (i). It was surprising to see that candidates did not seem to know that amines are basic and the reason for caffeine's basic behaviour, as well over half of the candidates answered acidic or neutral in (ii) and for those who answered basic only half of them could score the mark for the explanation. (c) (iii) was answered very well by the vast majority.

Question 4

Many candidates scored the mark in (a) by correctly identifying the side-chain, but a surprising number of candidates only circled the aromatic ring without including the CH_2. The general structure of penicillin is given in Table 20 of the Data Booklet, so if all candidates referred to the table they should have scored the mark. In (b) many candidates did not recognise the loss of beneficial bacteria in the problems associated with over prescription of penicillin. A surprising number were not able to explain the modification of the side chain/R group to change the effectiveness of penicillin.

Option E - Environmental Chemistry

This was not a popular option, one probably not taken seriously enough by candidates, who rely on general concepts and misconceptions they have acquired over time.

Question 1

The man-made source of nitrogen oxide was generally very well answered in (a), although the equations for its formation proved demanding. A method for the removal of nitrogen dioxide from emission gases was correctly answered by the majority of candidates, but only half mentioned “alkaline or wet scrubbing or limestone-based fluidized bed” for sulfur dioxide removal in (b). In (c) the chemical equation for the formation of sulfuric acid was given correctly by many candidates, but it was surprising to see that a significant number of candidates did not know the chemical formula for nitric acid.

Question 2

It was surprising to see that many candidates could not score full marks in a question on the greenhouse effect which appears often in examination papers. The use of unacceptable language (reflecting, bouncing, trapping, etc.) cost many candidates marks in (a), although most knew that carbon dioxide was more abundant, far fewer could clearly express the point about methane being better at absorbing IR radiation in (b).

Question 3

It seems processes for obtaining fresh water from sea water was not covered or covered superficially by many schools. Almost no one scored full marks and although the statement asked for evaluation of the two processes, students often just stated facts without much evaluation. Answers were disappointing, with many too vague to score (e.g. efficient with no reference to a multi-stage process, expensive with no reference to high energy consumption).

Question 4

(a) was answered well by candidates. In (b) many candidates scored the mark for CFCs and their source, but very few for nitrogen oxides and their source.

Option F - Food Chemistry

This was one of the least popular options.

Question 1

The vast majority of candidates were able to state the empirical formula of monosaccharides, but a good number were not able to state its structural features in (a). Only about half of the candidates could draw the structural formula of 2-aminoethanoic acid correctly, the other half indicated lack of knowledge for organic nomenclature in (b)(i). It was surprising to see that only about half could deduce the structure of the triester correctly and identify the ester linkage in (b)(ii). About half of the candidates were able to deduce the number of C=C bonds correctly from the list of fatty acids in (c)(i) and most deduced the least stable fatty acid correctly in (c)(ii), but the majority of them could not explain.

Question 2

The vast majority of candidates answered (a) correctly. (b) (i) was poorly answered by the vast majority with only very few candidates scoring some marks here. (b) (ii) was answered better with many scoring at least one mark usually for the example of hydrolytic rancidity.

Question 3

Very few full marks were achieved in the comparison of the two browning processes of foods. Some had little idea and others left the question blank. Almost no one, for example, scored the mark for the Maillard reaction equation, even though the formulas were provided.

Question 4

The benefit and concern of consuming genetically modified foods was answered very well by the vast majority of candidates, but there were cases with rather vague and journalistic responses.

Option G - Further Organic Chemistry

This was one of the least popular options.

Question 1

The structural formulas were drawn correctly by the vast majority of candidates in (a) (i). In (a)(ii) the mechanism for the reaction of the alkene with HBr was answered well by candidates and most arrows in the mechanism were accurately drawn. In (a) (iii) the explanation of the major product elicited the phrase “Markovnikov’s rule” instead of explaining it. (b) was answered correctly by the vast majority of candidates. In (c)(i) about half of the candidates deduced the structural formula of butanone and went on to correctly deduce the structural formula of E in (c) (ii). The mechanism in (c) (iii) proved rather challenging for the candidates.

Question 2

Most of the candidates stated the correct order of basicity and knew about the inductive effect. Those that did not had a major problem because they interpreted the pK_b values given in the Data Booklet incorrectly. Those that got the order right generally had no trouble justifying the answer through the presence of methyl groups, though they generally omitted referring to the effect of the increasing number of them.

Question 3

A well answered question, with candidates helped by the availability of five scoring points for 3 marks.

Recommendations and guidance for the teaching of future candidates

- 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.
- Teachers should stress the importance of correctly writing balanced chemical equations and formulas.
- 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 must pay particular attention to the action verb and use this as a guide to the depth of the answer required.
- Candidates must pay particular attention to the number of marks allocated in each part and use this as a guide to the detail required in the answer.
- Candidates should prepare for the examination by practising past paper questions and carefully studying the markschemes provided and be encouraged to highlight the salient points in the questions and markschemes.
- Teachers should emphasise the importance of clearly setting out calculations, showing each step, and addressing units and significant figures in the final answer.

- Candidates should practise drawing accurate structures of organic molecules, checking that the valency of each atom is correct, and always include hydrogen atoms in full structural formulas.
- Candidates must use the chemistry Data Booklet during the chemistry course so that they are familiar with what it includes.
- Candidates must be fully familiar with organic reaction mechanisms in Option G and pay special attention to the correct use of curly arrows in mechanisms.
- Teachers should ensure that definitions covered in the assessment statements for each option are well known by candidates.
- Candidates should be 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.