November 2013 subject reports

Chemistry

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-31	32-44	45-55	56-66	67-77	78-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-16	17-29	30-40	41-52	53-65	66-76	77-100

Higher level & Standard level internal assessment

Component grade boundaries Higher level

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

Component grade boundaries Standard level

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

The range and suitability of the work submitted

The moderators reported that the range and suitability of the work submitted for November 2013 was similar to the previous couple of sessions reflecting that this current assessment model has now been in place for five November sessions and it is clear that a significant proportion of teachers have reached a level of competence and confidence in designing an appropriate practical scheme of work and satisfactorily applying the criteria that is pleasing.

Generally the samples were well presented and most teachers gave feedback using the c, p, n or 2, 1, 0 notation, with a good proportion also giving at least a few written comments to explain their marking awards. 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.

A significant minority of schools are submitting Design assessments which were purely theoretical exercises and there had been no follow up experimental phase. Although this is permissible by the regulations it is felt that this practise lowers achievement since students rarely design the procedure in sufficient detail unless they have had access to the apparatus and materials for themselves.

Pleasingly compared to previous sessions there were less cases where all the candidates in a school had chosen essentially the same variables and designed near identical procedures. There was, though, a concern voided that some school's carried out two Design assessments in the same narrow area of the syllabus most typically kinetics. Students essentially produced the same design twice with just the change of identity of the independent variable. This then fed through to CE where students in some cases reproduced word for word the same evaluation of sources of error and suggestions for modification. Although it is not strictly plagiarism since it is the student's own work originally it is most certainly very poor assessment practise and teachers should eliminate it at source. The advice here is to ensure that students two assessed Designs relate different syllabus areas.

The tasks being assessed for Data Collection and Processing have significantly improved during the cycle of the current internal assessment model. No longer do we see a large number of inappropriate non-quantitative tasks nor teachers supplying students with pre-prepared data tables and step wise guides to calculations. The remaining issue though is that many of the data processing tasks are quite simplistic and many involve just simple averaging.

The length of the students' reports from some schools is excessive and rarely to good effect in terms of clarity of communication. Students use the cut and paste function to reproduce pages of procedure when they change the value of just one variable. Similarly pages of near identical data processing is presented for each possible trial when one fully shown calculation and then a summary table would suffice.

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. The one common failing was that students incorrectly identified the dependent variable as the derived quantity (e.g. 'rate of reaction' or 'enthalpy of reaction') rather than the actual measured variable such as time for a given volume of gas to be produced or the temperature increase of the reaction mixture. 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.

Aspect 2 is consistently the most challenging of the Design aspects and partial was the most frequent award. There were two common weaknesses.

One is that students failed to identify any procedural methods to control or at least monitor the control variables that they had earlier identified as needing controlling. For example if in a kinetics investigation temperature is identified as a control variable then the reaction mixture temperature (and not the surrounding room temperature as was frequently stated) should be controlled through use of a water bath or at least monitored with a thermometer or probe. Unfortunately air conditioners continue to be a popular suggestion for controlling reaction temperature and show that students do not appreciate the difference between atmospheric conditions and the reaction conditions.

The second common failing for this aspect is that students simply did not include enough detail in their designed method. Not including details on how standard solutions were to be made up, what volumetric glassware is to be used, not stating how to make up a salt bridge in an electrochemical cell or forgetting to think about drying an electrode in an electroplating investigation were among the common failings. The guiding principle to relate to students is that their design should be communicated in sufficient detail to allow the reader to reproduce their experiment if desired.

Data Collection and Processing

Achievement against this criterion was in line with last year and 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 by most candidates and although flawed, most attempts were worthy of credit. Please note that the reward for the successful propagation of uncertainties is confined to DCP Aspect 3 as a discriminator between the partial and complete descriptors.

When evaluating the presentation of processed data in graphical analyses the fit of the best-fit line is a factor to consider. Many students used Excel’s trendline function inappropriately to construct lines that were anything but best-fit.

DCP assessed investigations using data loggers should follow the guidance in the Subject Guide (The use of ICT, pp. 30-32). At times it was unclear the actual individual input while in others graphs qualified more as raw rather than processed data.

Conclusion and Evaluation

Conclusion and Evaluation continues to be the most challenging of the criteria and few candidates achieved the top level across all three aspects.

With respect to Aspect 1, most candidates compared their results to literature values where available. However only a 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. Hence Partial was by far the most common award.

An issue for teachers is how to assess this aspect when the investigation does not involve the determination of a quantity that can be compared to literature and a percentage error calculated but instead involves the determination of a trend such as is commonly seen for example in many kinetics investigations. In such cases the student should try and describe the nature of trend. For example even a SL student can conclude whether the rate of a reaction increases in direct proportion with concentration of one of the reactants or not. This can then be compared to the literature expectation and the likely impact of systematic or random errors discussed.

For Aspect 2 many candidates identified a good number of relevant procedural limitations or weaknesses although few were able to make comment on the direction and relative significance of the source of error which limited the achievement to Partial in many cases. In the final Aspect 3 assessment many candidates offered some clear and relevant suggestions as to how to improve the although a sizeable minority were only able to propose superficial or simplistic modifications such as simply suggesting 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.

Recommendations for the teaching of future candidates

Teachers should set open-ended questions to facilitate the assessment of Design and should strive to ensure that as an outcome there is a diversity of Designs produced.

Teachers should endeavour to give their students the opportunity to carry out the practical phase associated with their Design investigations.

The two highest marks per criterion for each student should come from two different types of task. Students should not receive double reward for two very similar designs or data processing tasks or evaluations.

All investigations for the assessment of DCP must include the recording and processing of quantitative data. Solely qualitative investigations do not give the students opportunity to fulfil this criterion completely.

All candidates need to record, consider during processing (by propagating through calculations or most simply constructing a best fit line in graphical analysis) and evaluate the significance of errors and uncertainties.

Instruction of appropriate use of graphing software especially the construction of best-fit lines would benefit many candidates.

Candidates should compare their results to literature values when relevant and include the appropriate referencing of the literature source.

Students should evaluate sources of error as random or systematic and should be able to show an awareness of the direction and significance of the error.

Suggested modifications should realistically address the identified sources of error.

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.

Teachers should provide feedback to candidates in terms of the separate aspect awards and any further brief comments on the reports explaining the mark awarded is equally useful to the moderator and student.

Internal standardisation of marks should be carried out when more than one teacher is involved in the subject.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-16	17-23	24-27	28-31	32-35	36-40

General comments

1679 candidates submitted this paper.

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) 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. Some candidates did *not* answer every question.

The following are some statistical data based on 33 respondents (from 267 schools).

Comparison with last year’s paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	2	26	3	1

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	32	1

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	1	3	13	13	3
Presentation of paper	0	0	3	11	13	6

Respondents, in general, commented favourably. A compilation of comments said that this was “an excellent and fair paper where students were able to demonstrate what they understood. There was a good balance of questions and the framing of the questions was such that any average learner could interpret them. The test was well presented and the wording was a good balance between chemistry terminology and actual usage.”

One respondent said that “many questions were slightly harder than usual adding up to a paper that was a lot harder than usual”. This was not reflected in the performance of the candidates whose mean mark rose by over 1.0. Indeed the % candidates scoring 39 marks showed an almost three-fold increase from November 2012 whilst those scoring 40 rose by well over five times.

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 97.62% to 37.76% (November 2012 for comparison, 90.52% and 36.56%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.72 to 0.04 (November 2012, 0.74 to 0.10), the higher the value, the better the discrimination.

The following comments were made on selected individual questions:

Question 11

One respondent commented that carbon monoxide, CO, is non-polar. In fact it has a dipole moment of 0.11D and there is an electronegativity difference of 0.8. Over 82% of candidates gave the correct answer.

Question 13

This was thought to be a hard example “to test student understanding of hybridization and bond types”. This type of question is not new and was answered correctly by 79% of the candidates. All a candidate needs to do is to count the number of π-bonds.

Question 14

This was thought to be tricky for those who had not studied Option G for paper 3 as they might have less idea about hybridization in a benzene ring. This should be covered in topics 14.2.2 and 14.3.1. It was one of the harder questions but, even so, 68.20% gave the correct answer. “B” was the next most common answer, presumably because candidates had forgotten the hydrogen atom on carbon X.

Question 16

This was a common question with standard level where there was concern about the use of algebraic notation rather than actual numerical data. Algebraic notation has been used since November 2010 so candidates should be familiar with this type of question.

While one comment in HL agreed with this sentiment, the other said it was “good to use pronumerals”. In the event, it was the fifth easiest question; nearly 91% of candidates gave the correct answer and less than 6% gave B.

Question 17

This question was thought to be “ambiguous as lattice energy can be defined as an exothermic or endothermic process”. Students should be familiar with the idea of lattice energy as an endothermic process as that is how it is described in the IB Chemistry Data Booklet. A similar question was set in May 2011, TZ2.

This was the fourth hardest question, being scored correctly by 55.81%. The other answers were fairly evenly spread between A, C and B (in that order).

Question 22

This was reported to be “demanding (makes them think) but good”. It was the sixth hardest question with 63% scoring correctly. The most common error was not to recognize that the overall reaction equation is correct.

Question 28

It was thought “good to mix the data types, pK_a and K_a”. This was the fifth hardest question (60.81% correct) with the wrong answers almost equally chosen.

Question 34

There were four comments on this question, more than the others and, indeed, it was the second most difficult question (just under 46% correct).

This was a tough but fair question. Students have studied the electrolysis of aqueous sodium chloride (19.2.1) so would be expected to transfer that understanding to aqueous potassium chloride. Chlorine gas is produced at the anode but much of this will bubble away as a gas rather than cause acidity to neutralize the hydroxide ions forming around the cathode.

Question 35

One respondent commented that "very few IB specific text books highlight the role of priority of naming functional groups". It was the seventh hardest question; nearly 65% gave the correct answer with close to 28% opting for A (as expected).

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-10	11-14	15-18	19-22	23-26	27-30

General comments

1173 candidates submitted this paper.

It 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. Despite this, some candidates did not answer every question.

The following are some statistical data based on 30 respondents (from 196 schools).

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	3	23	4	0

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	29	1

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	0	5	9	14	2
Presentation of paper	0	0	4	9	13	4

General comments

- The paper was thought to be “a good paper for basic SL students”.
- The paper was “clearly written with questions that evaluate the knowledge that an SL student would have acquired – and no questions that were intricate or convoluted.”
- “The questions were clear and presented in a way that was easy to understand. The test content was of a similar standard to last year but there were a few more questions tending towards HL.”

Although there may have been a perception that there were more “HL-type” questions, this was not shown in the statistics. There were no questions that less than 40% of the candidates answered correctly. (In November 2012, there were four below this level.) In addition, the mean mark increased from November 2012 (and November 2011) and there was a considerable increase in the number of candidates scoring 28, 29 and 30.

- Another commented that questions 4 and 17 required “very careful reading of minor details”. The Examiners recommend that candidates read *all* questions very carefully.
- There was also a comment that, given the number of questions requiring mathematical analysis, the candidates required more time. Chemistry is a quantitative science so candidates must expect to be able to carry out simple calculations.

It is interesting to note that the % candidates scoring 28 marks showed an almost 50% increase from November 2012 whilst those scoring 29 more than doubled and those 30 nearly tripled.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 95.54% to 40.32% (November 2012 for comparison, 92.28% to 23.59%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.64 to 0.10 (November 2012, 0.64 to 0.14), the higher the value, the better the discrimination.

The following comments were made on selected individual questions:

Question 5

There was some concern that, for the mathematically challenged, the figures given were too difficult. Although it could perhaps have been simplified to 7.1 g and 142 g mol^{-1} nearly 57% of candidates gave the correct answer, the next most common being A (nearly 25%) which showed an incorrect concentration calculation.

Question 13

One respondent in HL commented that carbon monoxide, CO, is non-polar. In fact it has a dipole moment of 0.11D and there is an electronegativity difference of 0.8. Nearly 68% of candidates gave the correct answer. The next most popular answer was B (13%) so perhaps there is a misconception here.

Question 16

There was concern about the use of algebraic notation rather than actual numerical data. This has been used since November 2010 so candidates should be familiar with this type of question. (In fact, some G2s in the past have suggested it would be better to use algebraic notation!) In the event it was the sixth easiest question; over 81% of candidates gave the correct answer and 9% gave B.

Question 17

There was a concern about the use of the word “can” in the question stem. The word was used to make the question about reactions in general. It does not seem to have troubled the candidates; it was the seventh easiest question, answered correctly by nearly 80% of the candidates.

Question 18

One respondent commented that it “is more difficult than it might be because of the use of algebra symbols”. This was the fourth easiest question with nearly 84% giving the correct answer.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-12	13-25	26-35	36-45	46-56	57-66	67-90

General comments

The paper was perceived as being significantly more challenging than the previous year’s paper with less marks being dependent on straight factual recall and more on applying chemical principles in unfamiliar situations. This did not seem to hinder able students, but students less well prepared for challenging questions under examination conditions were perhaps intimidated by the paper and did not perform well even on the more straightforward sections. Another factor was that students often lost marks through not reading carefully what the question was requiring. In Section B the number of students answering the different questions seemed to be fairly even indicating that they were perceived as being of comparable difficulty. Overall the paper gave a very even distribution between about 20% and 80% facilitating discrimination between the various levels of achievement.

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

Candidates frequently failed to give enough specific detail and employ correct vocabulary in explanations. Other areas of particular weakness were:

- Propagation of uncertainties
- Delocalized bonds
- Applying VSEPR to determine the shape of unfamiliar molecules
- Use of $E^{\ominus}$ values
- Combining half-equations
- Functioning of a polarimeter

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

In general students seemed to perform best in tasks involved simple recall of factual data. Other specific examples of areas for which students were well prepared were:

- Reagents and conditions for the oxidation of alcohols
- Recognizing whether bonding is ionic or covalent
- Ligands and their bonding to cations
- Inserting coefficients to balance an unbalanced equation
- Correspondence of ΔS and degree of disorder
- Correlation between bond order and bond length
- Predicting polarity from molecular geometry
- Using oxidation numbers and electron gain/loss to identify oxidation and reduction
- Similarities of elements in the periodic table
- Use of half equivalence point to determine pK_a
- Identification of organic intermediates

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

Question 1

This question explored basic chemical concepts in the context of a practical situation. Whilst this is one frequently carried out during practical courses, none of the questions depended on prior knowledge. Students varied significantly in their ability to interpret the information given to answer parts (a) to (c), but very few could correctly carry out the propagation of uncertainties required in part (d). An encouraging number were able to carry out the rate calculation required in part (e). It was surprising how many students, though unable to identify the axes of the Arrhenius graph given in part (f), were still able to interpret it to correctly calculate the activation energy. Part (g) was deliberately open ended and elicited a number of interesting responses, though frequently the tests proposed would not in fact confirm the suggested hypothesis.

Question 2

This was frequently well answered with many students gaining good marks. A common mistake was for students to identify the bond present in the polymer rather than the type of polymerization.

Question 3

It was distressing how many students taking HL Chemistry (over 50%?) do not know the formula of the nitrate ion! Many students also gave the type of bonding present between the ions, rather than the nature of the force asked for, though almost all could correctly identify the covalently bonded atoms. Hardly any could explain delocalization in terms of the overlap of p-orbitals, or the extension of a π-bond, over more than two atoms, though its effect on structure and stability were better known. In part (c), which tested Aim 8 of the syllabus, most managed to gain some of the marks available for atmospheric pollution from oxides of nitrogen. Inevitably, owing to some overlap in assessment statements these concepts would be more familiar to those studying the Environmental Chemistry option, but undoubtedly studying other options assists in other areas, such as organic chemistry.

Question 4

Very few candidates could interpret the electron structure of manganese from its oxidation state, though the term “ligand” and the nature of its bond to metal ions were almost universally known. The general properties of transition metals seemed to have been well memorized, even though they were not always correctly applied. The splitting of the d sub-shell was generally known, though a worrying number of students believe that transition metal ions emit coloured light.

Question 5

Most students could insert the coefficients to balance the equation provided and many recognized the benign nature of the products formed. Though the structure of trinitramide was not given this did not seem to hinder students in calculating the required enthalpy change. A worryingly high number of students however used bond enthalpies to calculate the enthalpy change in the part (a) equation rather than the much simpler decomposition asked for, so to allow them to gain some credit, the mark scheme was adjusted. The sections relating to entropy and free energy changes were generally well tackled, as was the comparative lengths of the N-N bonds. Predicting the shape and polarity of the trinitramide molecule often proved more difficult, especially explaining the polarity of the molecule.

Explanations of the effect of external pressure on boiling point, in terms of vapour pressure, and of the effect of temperature, in terms of kinetic theory, often lacked clarity.

Question 6

The required definition and the effect of acid on the oxidizing power of TiO^{2+} was often well done, though it proved a challenge for some candidates, and most could interpret the change in terms of oxidation numbers. Very few candidates could use $E^{\ominus}$ values to predict whether a reaction with another half-cell would occur and even less could correctly combine the half-equations to produce a balanced equation for the overall reaction. Relatively few candidates managed to gain full marks for the questions relating to the voltaic cell illustrated, with the different parts appearing to be of approximately equal difficulty. The nature of the period 3 oxides was generally well appreciated, though often the effect on pH was expressed as, for example, “basic” rather than “increases”. In spite of the efficiency of modern plants many considered the contact process to be a major source of sulfur dioxide pollution, rather than combustion of coal and other “high sulfur” fossil fuels. The comparison of the structure of silicon dioxide to those of carbon and xenon dioxides was poorly done, the root cause often being a lack of awareness of the structure of silicon dioxide. Many candidates could however write correct equations for the reaction of silicon tetrachloride with water.

Question 7

Most students could identify an element which would be expected to have similar properties to antimony and the reaction between its fluoride and hydrogen fluoride was generally well interpreted in terms of acid-base theories, though hardly any students realized that HF is acting as both a base (to give H_2F^+) and an acid (to give F^- which complexes with AsF_5). The significance of the strength of the hydrogen-halogen bond on the strength of the hydrogen halides was often appreciated though very few seemed to realize that HF hydrogen bonds to water whereas HCl does not. Many students think that weak acids require a smaller volume of alkali for neutralization than strong acids of equal concentration, though most could correctly identify an appropriate indicator for the titration and justify their choice. Most realized that sulfuric acid was dibasic, were aware of the significance of the pH at the half equivalence point and correctly identified HQ as a weak acid, though justifying this proved more of a challenge. Quite a few students gained full credit the calculation of the pK_a from the initial pH and many gained some marks for the calculation of the pH of the buffer system.

Question 8

Many students could recall the reagents for the hydration of an alkene and recognize the alcohol as a tertiary alcohol that would not undergo oxidation. Statements regarding optical activity often lacked precision and betrayed confusion with chirality. Very few could correctly describe how a polarimeter worked, especially the second rotating sheet of polaroid, and students frequently drew the structure of 2-methylbutan-2-ol rather than its chiral isomer. Most students stated that the alcohol was more polar than the alkene, but fewer mentioned that it could form hydrogen bonds to water and even less linked this to the presence of the hydroxyl group. Almost all students recognized that the hydrolysis was S_N1, with an encouraging number being able to write reasonable mechanisms, though many still lost marks through a lack of precision in where their curly arrows started and ended. Many candidates also stated an appropriate rate equation along with the units of the rate constant. Very few students linked the difference of two molar mass units to the presence in the molecule of chlorine, with its naturally occurring isotopes, and the discussion of any effect on the hydrolysis rate often revealed a lack of clear thinking. In contrast many students correctly identified the nitrile as the intermediate in the chain extension reaction and reagents for its formation and hydrogenation were generally well known.

Recommendations and guidance for the teaching of future candidates

- Greater practice at working through previous examination papers and carefully studying the mark schemes, especially with regard to reading questions carefully so as to recognize what precisely is being asked, taking into account the number of marks allocated.
- Increased interpretation of practical work, especially the underlying reasons for having particular reagents and concentrations, as well as handling uncertainties and their propagation.
- More familiarity with the use of electrode potential data in predicting the feasibility of reactions and writing equations for these through the combination of half equations.
- Coaching students to write clear explanations based on underlying chemical concepts, through developing precise language skills (“less exothermic” rather than “lower”) and vocabulary (the difference between “end point” and “equivalence point”).

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-17	18-23	24-30	31-36	37-50

General comments

This paper identified a very broad range of candidate capabilities. Some candidates struggled with even the most basic concepts and factual knowledge while others demonstrated an excellent depth of understanding of the standard level material. In general, candidates appeared well prepared. There were some schools where the candidates seemed unfamiliar with some of the subject material and left many areas of the question paper blank. Answers lacked precision in terms of the wording used and explanations were often vague and lacked chemical concepts and key points.

The 32 G2 forms that were returned conveyed teachers’ impressions of this paper. The comments received on the G2 forms are considered very important feedback by the IBO and are reviewed thoroughly during the grade award meeting.

In comparison with last year’s paper 22% of respondents felt that it was of a similar standard and 28% considered it a little more difficult while 50% felt that it was much more difficult. 37% of respondents thought the level of difficulty was appropriate while 63% thought that it was too difficult. Clarity of wording was considered very good by 12%, good by 41%, satisfactory by 28%, poor by 16% of the respondents and very poor by the remainder. The presentation of the paper was considered very good by 37%, good by 31%, satisfactory by 28% of the respondents and poor by the remainder.

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

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

- Quantitative chemistry
- Free radical substitution
- Atmospheric pollutants
- Bond enthalpy calculations
- Reactivity series and Redox equations
- Titration
- Explanation of molecular shapes and polarity
- Drawing mechanisms with curly arrows

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

The areas which seemed well understood by candidates were:

- Effect of temperature on the rate of reaction
- Mass spectrometer (except the detection stage)
- Calorimetry
- Oxidation numbers
- Acid-Base definitions
- Collision theory

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

Section A

Question 1

This was a data based question based on quantitative chemistry and proved difficult for many candidates. Majority of candidates were able to gain almost full marks in parts (a) and (b). In part (c), many candidates failing to recognise that KI is rapidly reformed in the second stage of the reaction. In part (d), majority of candidates could not interpret the information correctly and hence lost two marks. Similarly, only 1 mark was obtained in part (e) where candidates recognized that iodine forms the starch-iodine complex. Many candidates managed the systematic and random errors in part (f). Calculation of uncertainty in part (g) was relatively well done by many candidates. In part (h), calculation of rate of reaction occasionally saw the erroneous use of volume in cm^3. In part (i), the candidates just repeated the stem of the question but obtained credit for the second mark for stating less frequent collisions. Part (j) was quite open ended and elicited a number of interesting responses (instead of acting as catalyst) whereas the suggested tests would not in fact confirm the hypothesis suggested. In part (k), the effect of increasing temperature on the rate of reaction proved easy for majority of candidates.

Question 2

The reaction of ethane reacting with chlorine in presence of sunlight was well answered although many candidates in part (a) wrote hydrogen as the product. In part (b) the candidates missed the word substitution or free radical instead of the complete answer *free radical substitution.* In part (c), several candidates mixed up the idea of ethyl free radicals with ethane molecules.

Question 3

This question was surprisingly very poorly answered. In part (a), it was distressing to see a large number of candidates who could not write the correct charge or formula of nitrate ion. In addition, the terminology appears to have confused a number of candidates and for the nature of force, ionic bonding was often stated which was incorrect, as electrostatic attraction was required. In (a) (ii), again candidates failed to answer the question and nitrate was commonly given which was not accepted. The question specifically asked for the atoms involved.

In part (b), the Aim 8 component of AS 3.3.2 was assessed and this was very poorly answered overall. Inevitably, owing to some overlap in assessment statements these concepts would be more familiar to those studying the Environmental Chemistry option, but undoubtedly studying other options assists in other areas, such as organic chemistry. In (b) (i), many candidates gave generic answers such as cars or factories which did not score. In (ii), many incorrect answers were given such as nitrogen oxides, hydrogen or ozone. In (iii), acid rain was frequently seen and many referred to depletion of the ozone layer. However it was extremely disappointing that many candidates gave the greenhouse effect or global warming or air pollution as the answer, which of course scored no marks.

Section B

Question 4

This was the least popular question answered in Section B.

Most candidates got the correct stoichiometric coefficients for the equation in part (a). In part (b), a high number of candidates discussed their answer in terms of the fact that no chlorine is produced for trinitramide. In Part (c), the typical errors were using the incorrect bond enthalpies from the Data Booklet and using the sum of the bond enthalpies of bond forming (products) minus bond breaking (reactants) instead of the reverse. Some candidates surprisingly used the combustion equation from part (a) for their extensive calculations which was partially given credit.

Part (d) was well answered although a number of candidates thought that nitrogen has a single or double bond instead of a triple bond which was worrying. VSEPR theory however was exceptionally poor and most candidates demonstrated little or no understanding. Many incorrect geometries were cited, especially trigonal planar and even linear and v-shaped! Very few candidates related the geometry to four negative charge centres or electron domains around the central nitrogen atom. In part (f), polarity typically involved just guess work and only few candidates could explain the reason for the polarity or gave a diagram showing the net dipole moment which suggested poor understanding of the topic. Part (g) was generally well answered and of those that attempted the question they often scored full marks demonstrating good understanding of calorimetry.

Question 5

This was the most popular question answered in Section B and generally well answered.

In part (a) (i), most candidates scored full marks although some candidates continue to write incorrect notation (4, 4+) for oxidation states. In part (ii), some candidates missed the word equilibrium in the question and hence could not state that equilibrium will shift towards right and strength of oxidizing agent will increase. In part (b) (i), (iii), the correct answer was Cd^{2+} but many candidates wrote Cd, Eu or Ti. In part (ii), the better candidates wrote the correct balanced chemical equation. Some included electrons in the equation which was surprising and some did not read the question where the reaction with Ti metal was asked. In part (iv), many candidates identified the salt bridge but some missed the reference to the movement of ions. In part (c), most candidates were able to define a *Bronsted-Lowry* acid. The difference between strong and weak was usually correctly stated although only better candidates stated that strong acid is *assumed* to be 100% dissociated. Part (iii) proved to be difficult where very few candidates stated correctly that it is not a good choice because it requires the same volume of the base. Many candidates, however, knew the fact that sulfuric acid is diprotic in part (iv). In part (v), majority of candidates correctly identified the strong and weak acid whereas weaker candidates stated NaOH as a weak acid. Part (vi) was poorly done with many candidates stating pH 3.7 as strong acid. In part (vii), many candidates scored full marks but universal indicator paper was often suggested, which of course, scored no marks.

Question 6

This was the second most popular question answered in Section B. This question was focussed on organic chemistry and attempted by many candidates.

Most candidates were able to draw the correct structure of 2-methylbut-2-ene in part (a). In part (b), water and sulfuric acid were stated correctly as the reagents. In part (c), most candidates knew that tertiary alcohols do not react. In part (d), the most common mistake was some candidates thinking that the hydroxyl group in an alcohol was a hydrogen bond. Some other candidates could not write that the alcohol forms hydrogen bonds with water. In part (e), many candidates got S_N1, though an odd few candidates identified the mechanism as S_N2. In part (e) (ii), the mechanisms proved a problem for several candidates. The use of curly arrows in reaction mechanisms continues to be poorly understood, the arrow often pointing in the wrong direction. Candidates must take care to accurately draw the position of the curly arrows illustrating the movement of electrons. Some candidates forgot to include the lone pair for the curly arrow going from the lone pair on O to C^+. Some candidates had the lone pair incorrectly located on the H and others had the curly arrow going to an atom instead of between the O and the C^+. Part (iii) was well answered.

Part (f) proved challenging for candidates and very few referred to chlorines isotopes. In addition, the majority of candidates did not state that the same rate could be applied as the isotopes have the same chemical properties. In part (g), many candidates scored three out of five marks. Some candidates forgot to state that the sample is converted to the gaseous state for the vaporization stage. Many candidates although knew about detection but only few stated that the ions hit the counter and an electrical signal is generated.

Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding mark schemes to assist candidates with examination preparation.
- Teachers should ensure that candidates read the questions carefully to ensure they answer appropriately and to avoid missing parts of the question. Candidates must know the meaning of the different command terms that appear in the assessment statements and in the examination papers.
- Candidates should use the number of lines and the marks as a guide as to how much to write. It should be possible to write the answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is continued on a separate sheet. However, the use of continuation sheet is not encouraged and candidates should use the space provided
- Candidates need to practice on the data-response question, which involves different facets including experimental work, uncertainty measurements, hypothesis, Aim 8 and linking of different topics across the curriculum.
- The experimental nature of chemistry should be brought to the forefront of the teaching programme including key experimental skills. There should be greater emphasis on core chemical concepts and definitions covered in the assessment statements for each topic
- Candidates should set out calculations logically and legibly and “keep going” with calculations because error carried forward in the later part is usually awarded full marks if the method is correct. All steps in the calculation should be shown and attention must be paid to significant digits and units.
- Candidates must be instructed to use the latest chemistry Data Booklet during the chemistry course so that they are familiar with what the Data Booklet includes.
- Some candidates are writing more than one answer hoping the examiners will pick up the correct answer. This is not encouraged because a correct response followed by an incorrect response nullifies the mark of that question. Candidates should avoid writing rambling statements, hoping that they will pick up marks somewhere in their answer.
- Candidates should write legibly so examiners can read responses

Higher level paper three

Component grade boundaries

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

General comments

On the whole the cohort was solid and candidates performed well in the exam. Most seemed very well prepared and attempted every part of their chosen Options. Each Option is supposed to be twenty two hours study, and each is subdivided into about ten or twelve sections of approximately two hours study each. It is not possible to examine all the syllabus content in one exam but effort is made to ensure there is no over emphasis on certain topics. However, to set meaningful questions it is deemed appropriate to set 3/4 mark questions on topics with 2 or more hours of study.

Difficulty of the paper

Too easy	Appropriate	Too difficult
0%	90.91%	9.09%

Difficulty in comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult	NA
0%	0%	69.7%	18.18%	9.09%	3.03%

Suitability of question paper in terms of:

- **Clarity of wording**

Very poor	Poor	Fair	Good	Very good	Excellent
0% (0)	12.12% (4)	12.12% (4)	30.30% (10)	39.39% (13)	6.06% (2)

- **Presentation of paper:**

Very poor	Poor	Fair	Good	Very good	Excellent
0%	6.06%	12.12%	33.33%	33.33%	15.15%

(0)	(2)	(4)	(11)	(11)	(5)

The most popular options were A, B, followed by D, and G 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 in which candidates appeared well prepared

- NMR
- IR
- Delocalization
- Structural groups in biological compounds
- Vitamins
- Competitive and non-competitive inhibition
- Drug absorption
- Structural features of drugs
- Synthesis of optically active drugs
- Soil organic matter
- Ozone layer chemistry
- Synthetic anti-oxidants
- Fatty acid melting points
- *Trans* geometry
- Emulsion and foam
- Chiral chemistry in food chemistry
- Organic mechanisms
- Inductive effects

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

Option A - Modern analytical chemistry

Option A proved to be very popular. Most candidates were able to state spin as the property of protons that allows them to be detected by MRI but stated molecular spin. The advantage of MRI over X-ray of being able to detect soft tissue was well answered although some did not read the question carefully and stated the reduced health risk which was already mentioned in the question. Part 2 was generally well done by many candidates but with the following concerns: most arrived at the correct molecular mass, but then omitted positive sign on the molecular ion; a significant number drew the correct formula but with some fanciful formulae. Explaining the splitting pattern for the quartet caused the biggest challenge with very few scoring full marks; the H was incorrectly assigned to the OH (with results in no splitting due to rapid proton exchange) rather than the one attached to the C atom and the relative heights of the peaks (1:3:3:1) was not identified by almost all candidates.

Identification of infrared ranges was generally done correctly, but occasionally the wrong value was given in the similarities. The suggestion as to why HPLC is used for the detection of drug in urine sample was not done well with few scoring full marks; the understanding that the substance is non-volatile or decomposes at high temperatures was rarely identified. Also, identification of features that allow molecules to absorb UV radiation was not answered well. The question on atomic Absorption spectroscopy was answered with mixed results – some failed to specify that it must be an aluminium lamp and the idea of absorption of radiation (at Z) was missed by many. Most graphs were correctly drawn; however, some did not connect the line to the origin which was the first point in the data table; others blundered at reading off the graph. A significant number of candidates were able to use arguments related to delocalization and absorption in the visible range. However, hybridization was not often identified or used usually correctly.

Option B – Human biochemistry

Option B was a very popular, and question 6 was well answered with the exception of not listing alkenyl when identifying two functional groups common to three vitamins (A, C and D). Some students did not read the question on formula of zwitterion carefully and instead have the formula of the amino acid itself without any charges. In the separation of alanine and cysteine, the first mark was well scored by many while the second mark proved to be more demanding and often candidates lost this mark as no reference was made to charges or charges inversely stated. Although the disulfide bridge was correctly identified by even weaker candidates a much few were able to identify this as a covalent bond. Structure of the triglyceride was better answered than in past sessions but drawing the ester linkage correctly was still challenging for many candidates. Although the identification of the other reactant (water) was identified by many, the one essential condition (enzyme/lipase) was done poorly. Identification of the polyunsaturated fatty acid was done well by most but the second mark on its ability to lower LDL cholesterol was missed by most. The question on enzymes and inorganic catalysts was done poorly since comparison was often missing. While some candidates were able to suggest a pair of ions in cytochrome oxidase, only stronger candidates provided both pairs. Competitive and non-competitive inhibition was generally well done; however, the reason why it is more likely that NO, rather than the cyanide ion, acts competitively was not done as well. The redox reaction of the reducing agent XH_2 with O_2 produced a range of possible equations but rarely did candidates scored full marks.

Option C – Chemistry in industry and technology

Option C was not a popular option.

While many candidates scored the mark in 10 (a), those who did not often failed to provide the correct name for an ore. Although many identified slag, some were able to give the correct equation and others gave equations which were either incorrect or not from raw materials as asked. This question unfortunately shows that chemical equations seem not to be as well covered as expected. The answer to the question on alloys was rather disappointing and weaker than in previous sessions. The lack of subject specific vocabulary was often observed with many candidates providing answers that were clearly not addressing the question. Very few candidates were able to score even one mark on the mechanism by which the carbon chain increases in length during the manufacture of LDPE suggesting that this topic requires further attention. Many candidates were familiar with the catalyst used in the formation of HDPE although some lost the mark due to writing names that differed widely from correct one. Many were able to score at least one mark for the structure of the isotactic form of the polymer but very few drew 3D structures. Many candidates were able to score partial points when explaining why the isotactic form is more suitable for the manufacture of strong fibres but many missed the idea of chains not being able to move past each other easily (hence fibre is strong/rigid).

The part on liquid crystal displays was done with mixed results with many correct answers but still below expectations. Many candidates scored a mark for the explanation of how the addition of a LC to a cell changes what the observer sees usually from establishing the rotation of the plane of polarized light, but far too often replies were shallow with limited use of correct terminology. In the explanation of how the application of an electric filed between electrodes changes what the observer sees, many students were able to score one mark by stating that light is not transmitted but only stronger candidates included in their answers that molecules are aligned or not twisted. The question on the Ni-Cd battery was answered poorly with many candidates not even attempting it or getting the equation completely wrong and not being able to identify insolubility of the products that allows the reaction to be reversed and the cell charged. Description of the addition of small amounts of arsenic to increase the conductivity of silicon was surprising not done well and is a topic that needs closer attention.

Option D – Medicines and drugs

Option D was a popular option. The identification of the wavenumber range used in the determination of ethanol lead to many correct answers. However, why the absorption range 3200- 3600 cm^{-1} is not used still eludes a substantial number of candidates. How the transmission of IR radiation changes with increased levels of ethanol was not answered well, showing a poor understanding of transmittance. The question on the mild analgesic was not very well except for being able to identify the amide group in the molecules in question. The physiological effect of the drug as well as the reason for some drugs being less effective when taken orally was both very well answered. The ‘mix and split’ approach to combinatorial chemistry was generally not done well with answers that were weak showing shallow understanding.

The two structural features found in the sympathomimetic drugs were mostly correctly identified. Although many students were able to identify two chiral centers in the two structures given, not as many could identify the three needed for the mark. In the preferred method for the synthesis of optically active drugs, where many scored full marks but the difficulty of separating enantiomers due to their similar physical properties was the least popular explanation given. Surprisingly, the suggestion for increasing the aqueous solubility of an alkaline drug by adding an acid or converting it to its salt was done poorly showing a lack of understanding of acid-base chemistry and bonding.

In one argument for and one against the legalization of cannabis, while many candidates scored at least one mark out of two, some journalistic answers were seen. Description of the bonding changes that occur when the anti-cancer drug cisplatin attaches to the DNA chain was typically not well answered questions with many candidates being able to provide only one of the two ideas, usually the missing one was that Cl^- leave Pt/Pt^{2+}. Why the *trans*-cisplatin is ineffective in the treatment of cancer elicited fewer correct answers than expected. Question 18 was not on AIDS *per se* but rather on why viral infections are more difficult to treat than bacterial infections. A significant number of students scored part marks thus illustrating shallow understanding and deserves further attention in class. Very often marks were lost due to incomplete arguments.

Option E – Environmental chemistry

Option E was one of the less popular options. In outlining the meaning of the term BOD, most candidates scored at least one mark out of two - typically the time and temperature condition - was not specified. Often in the reason why the concentration of dissolved oxygen falls, candidates did not identify aerobic respiration or decomposition of the organic matter by oxygen or that the increase in dissolved oxygen is from air. Graph for the effect of temperature on the concentration of dissolved oxygen was generally done well showing a line or a curve with a negative slope. Description of the physical and biological functions of SOM improve the quality of the soil was typically done well but answers revealed that the understanding of SOM is shallow with more sophisticated alternatives being rare.

In the question on K_{sp} many candidates at least scored one mark from correctly stating the K_{sp} expression with stronger candidates scoring fully. Deduction of the pH of aluminium hydroxide at the same pH and reduction of the toxicity of soil by increasing the pH shows a lack of understanding of key equilibrium and K_{sp} concepts.

Although chemical equations that show the natural depletion of ozone were correct, some did not read the question carefully and stated the effect of CFCs on ozone depletion. Example of two ozone-depleting substances was well done; however, it is important to underline that often NO was presented rather than NO_x or oxides of nitrogen. In the formation of ozone in smog, many candidates were able to state the reaction between the oxygen radical and oxygen molecule, but only a few candidates scored fully as a result of not starting from nitrogen(II) oxide as stated in the question.

Option F – Food chemistry

Option F was one of the less popular options. Identification of the two functional groups in the three antioxidants and why they contain *tert-* in the prefix to their name was generally done well. Strong candidates were able to provide the correct formula of BHT but many weaker candidates were not and this is a source of concern as it involves skills that should be basic in chemistry. Explanation of how natural and synthetic antioxidants act chemically in the process of auto-oxidation was generally done well. However, the mode of action of SO_2 as an antioxidant was not as successful as expected. The question on beta-carotene was done well.

Identification of the fatty acid with the highest melting point and the reason why was correctly answered by many but then many also failed to make use of intermolecular forces and therefore did not fully score. Another disappointing result was the equation for the complete hydrogenation of linolenic acid and once again related to difficulties in writing and balancing chemical equations. Many candidates were able to score the second mark by providing two correct conditions. The meaning of the term *trans* and the associated structure was answered very well.

Many correct answers were given for the meaning of a *dispersed* system but also many did not make use of subject specific vocabulary or repeated the word *dispersed* in the answer. The idea of an emulsion and foam was well understood as was the part on the structural features of an emulsifier.

Many candidates identified the chiral carbon atom correctly in the structure given and two different ways in which enantiomers might affect the properties of foods. However, the reason for the difference in optical activity when carvone is synthesized using limonene from natural or chemical source was poorly answered with many not scoring at all.

Option G – Further organic chemistry

Option G was both popular and extremely well answered, most candidates giving correct equations and mechanisms. Question 27 on delocalization in benzene and bond length was correctly done by many. Only stronger candidates were able to obtain both marks for the explanation of why phenol is a stronger acid that ethanol. Those who scored just one did so by stating the interaction between the lone pair on O and delocalized electrons on phenyl, but answers often showed a poor use of vocabulary. The effect of the presence of the nitro group on phenol eluded all but the stronger candidates where most obtained typically scored one mark out of two. In general this mark resulted from stating the withdrawing effect of NO_2. Many were able to identify the nitronium ion. Reagents and conditions required to produce two different compounds starting from methylbenzene was generally done well but sufficient number of students got it wrong to suggest the need for more attention to this topic. The electron releasing effect of the methyl group that directs electrophiles to the 2- and 4-positions and why was generally not well understood and students will benefit from explanation in this regard.

Typically the mechanism of the reaction of propene and hydrogen chloride provided at least two marks, usually coming from the correct carbocation and product, whilst some others scoring dull marks. The reaction of ethanal with HCN was not as well answered as expected with some candidates losing their marks due to wrong use of convention for aldehydes. However, the name of the mechanism for the above reaction was named correctly by most students.

The structural formula of the Grignard reagent was answered correctly by most candidates but many lost marks in the conversion of the Grignard reagent to a carboxylic acid or an alcohol by not deducing the correct reagents required. The mechanism for the preparation of aspirin from the reactants given was done well by many; however, a good number of candidates still scored less than full marks with answers where intermediate was rarely correctly presented and the use of curly arrows continues to be challenging for them.

Recommendations and guidance for the teaching of future candidates

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

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

- 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 should prepare for the examination by practicing past exam questions and carefully studying the markschemes provided. This practice should be done relating requests in markschemes to specific questions and assessment statements in the guide. This strategy should not be used to speculate on possible questions in terms of those included in previous past sessions though.

- Teachers should emphasize the importance of clearly setting out calculations, showing each step, and addressing units and significant figures in the final answer.

- Candidates should practice drawing accurate structures of organic molecules, checking that the valency of each atom is correct, and remember to always include hydrogen atoms in full structural formulas. Particular attention has to be paid to correct representations.

- Candidates must be fully familiar with organic reaction mechanisms in Option G and pay special attention to the correct use of curly arrows to represent the movement of electron pairs in mechanisms. The practice should underline the point where curly arrows start and finish. This option is rarely a good choice when candidates have poor understanding of Organic Chemistry both at core and AHL level.

- Candidates must learn the common definitions on the syllabus.

- Candidates should use the number of lines and the marks as a guide as to how much to write. Write answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is completed on a continuation sheet. However, the use of continuation sheets should not be encouraged as it can mean longer answers than necessary are provided. Coordinators should ensure that candidates cross out blank pages and parts of questions they don't want to be corrected.

- Candidates that attempt more than the requested number of options rarely benefit from this strategy. It is worth mentioning that this session showed a dramatic decrease in this approach.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-11	12-15	16-19	20-24	25-28	29-40

General comments

The following are some statistical data based on 32 respondents.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult

0	0	23	7	2

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	27	5

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	1	5	16	8	2
Presentation of paper	0	0	3	15	11	3

There was a wide range of ability and preparedness exhibited by candidates and the paper was found to be more testing that last year. No examiners, however, commented on candidates attempting more than two options and there was a marked decline in the use of extra pages. Candidates were, in general, able to tailor their answers to the size of the box provided.

Options C, F and G were the least popular.

The general comments made in the G2s are addressed in section 3 with the questions to which they refer.

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

- Interpretation of graphs such as those in Q4 and Q15
- Distinction between paper chromatography and TLC
- AA spectroscopy
- Identifying and *naming* common functional groups
- Formation of zwitterions and the charges on amino acids at specific pH values
- Ester formation
- Understanding the IR determination of ethanol
- Virus and bacteria comparisons
- Radioactive waste
- Understanding acidity in organic compounds
- Writing balanced chemical equations

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

- Identifying MS fragments
- Graph plotting

- Vitamin solubility and deficiency
- Liquid crystal properties
- Synergistic drug effects
- Electrophilic addition mechanism

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

Option A - Modern analytical chemistry

This was one of the most popular options and generally answered well.

Question 1

Most understood the concept of proton spin (although some of the answers assumed more detail was required for one mark) and how MRI differs from X-rays. There were, however, many answers of the “non-invasive” variety which were excluded under the terms of the question.

Question 2

The Relative Molecular Mass was determined correctly but, curiously, the positive charge was omitted from the molecular ion even though it was given in parts (ii) and (iii). Part (b) was answered well although some candidates introduced a phenyl group in the structure. In part (c), the explanations were reasonable although candidates need to realize that the molecule is already vibrating; it now vibrates *more.* Many realized that there is a change in the dipole moment of the molecule.

As far as possible examiners use actual, rather than modified, spectra. The large peak at m/z = 19 is caused by the presence of H_3O^+ and that at m/z = 15 is very unstable. Candidates, in general, had little difficulty interpreting the mass spectrum.

Question 3

The comparison of paper thin-layer chromatography was not well understood although it was encouraging to see many correctly giving water in the paper as the stationary phase. We recognize that the answer required in the column labeled “Partition/adsorption” may not have been clear to candidates. In (b), most gave “less time” as the answer. Candidates should realize that “repeatable” is not the same as “reproducible”. Most gave the R_f value correctly but there were inevitably some who did not begin their measurements at the start line.

Question 4

Candidates had some difficulty outlining the characteristics of the lamp clearly and there was much confusion about the changes at Y and Z. The stages of AA spectroscopy seemed unfamiliar to candidates although, in retrospect, we recognize that it may have been difficult for candidates to interpret the diagram. The graph was generally plotted correctly although candidates must ensure that the points show clearly enough for the scan. A surprising number of candidates was unable to read the concentration from the graph correctly.

Option B – Human biochemistry

This was another of the most popular options.

Question 5

In (a) the alkenyl group was usually replaced by something else but it was pleasing to see the general absence of the answer “hydroxide”. Parts (b) and (c) were answered well and candidates seemed well aware of the dangers of modern technology keeping them indoors.

Question 6

The zwitterion mark was often lost (missing H or charge on the amine end) but pH values in (b) were correctly identified. The second mark in (b)(ii) was often lost because there was no reference to charges and the direction of migration. About half of the candidates correctly identified the ***di***sulfide bridge but fewer were able to outline the difference from other tertiary structure interactions. Part (d) caused problems for all but well-prepared candidates; they need a good grasp of subject-specific vocabulary.

Question 7

It was clearly a challenge for candidates to reconstruct the triglyceride and in (b) conditions for the formation (rather than hydrolysis) of the triglyceride were given. Careful reading of questions is important. If water *was* given in (b), the enzyme was omitted or replaced by “heat”. In (c), the *un*saturated product was often given in place of the *poly*unsaturated and only cholesterol was discussed rather than LDL cholesterol. The common error in (d) was to state that lipids “provide better insulation”.

Option C – Chemistry in industry and technology

This was one of the least popular options.

Question 8

The common errors in (a) were to give a formula rather than the name of an ore and to add it at R. Whilst part (ii) was generally answered correctly it was slightly alarming to see oxygen given from time to time. Few seemed to know the equation of the reaction primarily responsible for the temperature of 1900 °C. Slag was usually correctly identified in (c) but the equations given seldom started from the raw material, $CaCO_3$. Part (d) was often answered successfully whilst candidates were generally unable to earn both marks in (e) (i). Most understood the effect of tempering on steel.

Question 9

Some very strange polymers were suggested in (a) (i) with the –CN group becoming integrated into the carbon backbone. Candidates were, however, able to explain why the isotactic form is more suitable for fibres. The role of the zeolite in (b) was usually correctly identified but it was not known that the dimensions, size or shape of the cage were an explanation for its efficiency. Most were able to give a good account of carbon nanotubes although some introduced pentagons at the end. This was specifically ruled out in the question – *open* carbon nano-tubes.

Question 10

Examiners reported an average understanding of liquid crystal properties.

Option D – Medicines and drugs

This was one of the more popular options.

Question 11

The range 1050 to 1410 cm^{-1} was often given in (a) (i) and few realized the relevance of water in the 3200 to 3600 cm^{-1} range; the reason for not using this range was generally attributed to interference by phenols. This was an examination of assessment statement D.4.3. Part (b) required careful wording and many did not seem to realize the decrease in transmittance. Part (c) caused little difficulty with aspirin being a popular choice.

Question 12

This was answered well although few recognized the amide group in (a) (ii) and the therapeutic window was a little shaky. Many defined the therapeutic *index* which is not quite the same thing.

Question 13

There were various interpretations of the formula of aluminium hydroxide in (a) and many were able to gain one mark, the stoichiometric mark, in (b). Many did not realize that molar mass is also of consequence. Part (c) was a source of concern with many candidates showing an absolute lack of knowledge of potassium hydroxide and its chemical nature. Indeed, many seemed to think that we were asking about potassium itself! One common answer was that KOH only neutralizes one mole of HCl. The answers to (d) were either very good or somewhat vague and lacked specific reference to how placebos are used in drug development.

Question 14

Candidates tended to write a lot in this answer – and it was not very well structured. They needed to keep the focus of their answer on the differences between viral and bacterial infections. It may be that the examiners' intention to help the candidates by setting the question in context turned out to be more of a hindrance. Candidates spent far too long discussing the specifics of HIV rather than answering the question required.

Option E – Environmental chemistry

This was one of the less popular options.

Question 15

Biochemical oxygen demand was often not well explained in (a) and candidates found interpretation of the graph difficult. Many candidates suggested species for **X** where the element was already in its highest oxidation state, such as nitrate. Few realized in (iii) that oxygen would be replenished by dissolving from the air. Most gave a suitable graph with negative gradient in (c).

Question 16

There was a fair understanding of the cause of salinization and its effect on soil although few understood why the build up of salts prevents plants from growing. The introduction of SOM was generally well understood but the answers to (c) were often not related to the answer given in (b).

Question 17

This question was not done well. Few candidates were able to form the two different nitrogen containing acids and the acid used in (b) was generally sulfuric!

Question 18

There was some confusion about what constitutes “low level waste” and candidates needed to be more specific than just “hospitals”. The methods of storage/disposal showed a shallow understanding. Some seemed to think that incineration (only) would be suitable.

Option F – Food chemistry

This was one of the less popular choices.

Question 19

Candidates had a fairly good understanding of the term antioxidant but they were usually unable to name the common functional groups. There were many correct answers for *tert-* in the prefix. There was some concern expressed in the G2s that it is not valid to ask a question such as (b) (iii) at this level. Whilst the examiners have some sympathy with this view, candidates ought to be able to determine a molecular (and not a condensed structural) formula correctly. In the event, there were very few correct answers from all but the best candidates. This is a source of concern. Part (c) (i) was answered well and many were able to identify two other natural antioxidants. Answers to part (d) tended to be rather vague. Candidates need to remember that they are writing for a scientific audience and not for the popular press.

Question 20

Even though the correct acid was often not identified, explanations for the highest melting point often gained full credit in (a). Disappointingly few candidates were able to write a correct equation in (b) (with the addition of three moles of H_2 (g)) although the conditions were usually correct. In (c), many were able to show a *trans* orientation – but didn’t use a fatty acid – and many did not score both marks in (ii).

Question 21

Answers to this question suffered from a lack both of understanding and subject specific vocabulary. The best answers were seen in parts (b) (ii) and (c) (ii).

Option G – Further organic chemistry

This was not a popular option in the paper.

Question 22

The answers to (a) (i) were generally satisfactory but some lacked clarity. It was disappointing that more candidates did not score the mark in (a) (ii) as this is a calculation they are most likely to have seen during the course. Part (b) (i) was answered well but the idea of the intermediate bond sometimes eluded candidates. The stability of the conjugate base was not explained well in (c) and many explanations for the nitrophenol did not satisfactorily explain the *increase* in acidity.

Question 23

If a mark were to be lost in (a) it was for the omission of "electrophile". Many completed the mechanism in (b) very well but candidates still need to pay attention to the start and finish of curly arrows. In (c) candidates needed to state the reason for the favoured reaction route (relative stabilities of the carbocation intermediates) rather than quote Markovnikov's rule.

Question 24

Knowledge of Grignard reagents was mixed with few knowing why water is not used as a solvent in their formation reaction. Part (b) was variable; many gave carbon dioxide and propanone but omitted the water required in both reactions.

Recommendations and guidance for the teaching of future candidates

In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and command terms, the following points should be borne in mind:

- 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 study the material by themselves generally do not perform well. Integration of options within core teaching would support deeper understanding and better answers.
- 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. They should use appropriate terminology and not give superficial or journalistic answers. In other words, avoid the use of everyday language but rather use correct scientific terms.
- Candidates should prepare for the examination by practising past examination questions and carefully studying the markschemes provided.
- Teachers should emphasize the importance of setting out calculations clearly, 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 be fully familiar with organic reaction mechanisms in Option G and pay special attention to the correct use of curly arrows to represent the movement of electron pairs in mechanisms. The practice should underline the point where curly arrows start and finish. Students with weak understanding of topic 10 are unlikely to perform well in this option.
- Candidates must learn the common definitions on the syllabus.
- Use the number of lines and the marks as a guide as to how much to write. Write answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is completed on a continuation sheet. However, the use of continuation sheets should not be encouraged as it can

mean longer answers than necessary are provided. Coordinators should ensure that candidates cross out blank pages and parts of questions they don't want to be corrected.