Chemistry Time Zone 2

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 33	34 - 45	46 - 56	57 - 67	68 - 78	79 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 32	33 - 43	44 - 54	55 - 65	66 - 76	77 - 100

Time zone variants of examination papers

To protect the integrity of the examinations, increasing use is being made of time zone variants of examination papers. By using variants of the same examination paper candidates in part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the examination papers. For the May 2014 examination session the IB has produced time zone variants of Chemistry HL/SL papers.

Higher level and standard level practical work

HL and SL 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

As the current internal assessment model nears the end of its cycle, with May and November 2015 being its last assessment sessions, it is probably not surprising that moderators reported that the range and suitability of the work submitted was not greatly different to the previous few sessions. Most schools and teachers have gained significant experience in implementing an appropriate practical scheme of work and generally the work submitted was appropriate to be assessed by the criteria although the quality of the individual students' work was as varied as ever.

There were some trends which seem to be regionalised which maybe is a reflection of different customary practises in host countries. One such area is in the proportion of schools which were submitting Design assessments which were purely theoretical exercises and there had been no follow up experimental phase. A number of moderators commented that there was a significant rise in the number of schools adopting this strategy although one or two described the opposite. This approach to Design is not really best practise and although acceptable for one more year we will then move to an Internal Assessment model where the follow up data gathering phase will be a compulsory element.

Another issue regarding the assessment of Design was that once again a significant minority of schools provided very narrow Design assessment tasks and the students subsequently responded in a very similar manner to each other. This is poor practise that in some cases led to moderators feeling that malpractice had occurred, something which can have very serious consequences for the students involved and should be avoided at all costs.

Most schools submitted investigations that effectively facilitated the assessment of DCP and CE and only minority of schools provided the students with instructions that gave too much support in terms of how to record or process the data. However, a disappointingly small proportion of schools challenged students with tasks that required the determination of a quantity from a graph such as determining an activation energy.

Some schools submitted samples where the same essential skills assessed twice such two DCP/CE assessments on two similar titrations or two similar enthalpy determinations. This is not in the spirit of thorough and fair assessment.

Although most teachers gave feedback using c, p, n or 2,1,0 notation with a good proportion giving at least a few written comments to explain how the marks were awarded in some schools there were still a number of schools who sent in work with no marking evidenced on the report at all. This does not help the moderator support the teacher's grading.

Candidate performance against each criterion

Design

Generally achievement in the first aspect was good with many students were able to secure “complete” for phrasing a research question and identifying relevant variables. However there were several recurring weaknesses identified.

Often the research question did not identify a suitable independent variable that could be fully manipulated. A good general guideline is that when choosing a research question if the independent variable is a readily changeable and numerically quantifiable factor (e.g. mole fraction, concentration, temperature, pressure, ionic radius, molar mass, etc) then it is almost certainly going to be an acceptable research question that will hopefully generate some meaningful graphical analysis. If the only outcome is going to be a comparison of randomly selected brands of household cleaner, type of nut, etc, then it is quite probably going to be below expectation. Similarly surface area is best used as an independent variable if it is actually measured; many students just make the distinction between large, medium and small particle sizes, which makes concluding only a general qualitative trend possible

Another weakness in a significant number of research questions was that the chosen independent variable could not be reasonably expected to have any affect the chosen dependent variable. In particular investigations into voltaic cells generated a number of very weak researches that revealed the often recurring confusion between potential difference and current. Why should salt bridge length or electrode surface area affect the cell potential?

There was often an ambiguity in language in the research question or identified variables with students using the ambiguous term “amount” when they should be specific as to whether they are referring to moles, mass, volume of solution, etc. Another linguistic confusing was in the use of the terms “dissolving” and “reacting” with students discussing the dissolving of magnesium ribbon in acid or similar. Also a number of designs looking at factors affecting the dissolving of salts revealed a confusion between rate of dissolution rather than amount solute dissolved.

After comment in previous Subject Reports there was an apparent improvement in the number of students identifying the actual measurable dependant variable rather than the derived quantity such as reaction rate or enthalpy of reaction.

Aspect 2 continued to be the most challenging of the Design aspects and partial was a common award. The two main weaknesses identified in previous Subject Reports continue to be applicable. 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. Unfortunately air conditioners continue to be a popular suggestion for controlling reaction temperature when this is not appropriate.

The second frequent 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 the commonest weaknesses. 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.

Aspect 3 regarding sufficiency of data was often well fulfilled with 5 values of independent variable being planned for with often a suitable number of repeats. There were a small number of examples where students submitted unrealistic designs where method clearly would not work such as where a student required 10 cm solid gold electrodes! Where students had been given chance to follow up with an action phase these unrealistic plans were not apparent of course.

Data Collection and Processing

Achievement against this criterion was often high and 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 (often just presenting the raw data logger output) and increasingly often for presenting an inappropriate bar chart.

Aspect 1 saw the highest fulfilment with most students able to clearly present raw data with uncertainties and relevant qualitative data included.

Aspect 2 also saw a high proportion of good responses where candidates had satisfactorily worked through of numerical calculations or a simple graphical treatment. However there were few insightful contributions where candidates evidenced higher order skills by determining a numerical quantity from a graph or taking account of calorimeter heat capacity in an enthalpy calculation.

Achievement in Aspect 3 was in line with previous sessions with the propagation through a calculation of the uncertainties in the raw data attempted with varying degrees of success by most candidates. 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. Some teachers were also assessing the success of the uncertainty propagation in Aspect 2 and students were getting penalised twice. Quoting final calculated quantities to a reasonable number of significant figures proved difficult for many candidates. Most candidates who attempted graphical analysis could construct a best fit line should be drawn across the scattered points although we still saw some improper uses of Excel’s polynomial trend-line function and even the joining of points with straight segments.

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.

In Aspect 1 it was common for candidates to compare their results to literature values where appropriate but not many candidates were then able to identify whether the difference indicated the presence of system error or could be explained by random error alone. Although it does really affect the marking under the current criteria only a small proportion of candidates presented any justification of their conclusions in terms of whether it was coherent with accepted theory with most focussing on a simple comparison with reference. This is an area that will have to change when the new Subject Guide comes in to effect.

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. However, only a small proportion of candidates were able to insightfully comment on the direction and relative significance of the sources of error.

Most candidates achieved at least partial in Aspect 3 with some relevant suggestions as to how to improve the investigation although as is usually seen a significant minority were only able to propose superficial or simplistic modifications such as simply suggesting more repetitions to be carried out or for unspecified more precise apparatus to 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 and guidance 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.
- Encourage students to choose a research question where the independent variable is a readily changeable and numerically quantifiable factor e.g. mole fraction, concentration, temperature, pressure, ionic radius, etc.
- Teachers should endeavour to give their students the opportunity to carry out the practical phase associated with their Design investigations.
- All investigations for the assessment of DCP must include the recording and processing of quantitative data. Solely qualitative investigations do not give the students opportunity to fulfil this criterion completely.
- All candidates 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.

- Teachers are encouraged to set some DCP tasks, especially to HL students, which will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.
- Instruction of appropriate use of graphing software especially the construction of best-fit lines would benefit many candidates.
- Candidates 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.
- 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.
- 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.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 18	19 - 26	27 - 29	30 - 33	34 - 36	37 - 40

General comments

8591 candidates submitted this paper an 11% increase on May 2013.

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 187 respondents (from 831 schools).

Comparison with last year's paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
7	28	126	21	1

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	7	178	2

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	1	1	19	61	76	29
Presentation of paper	1	0	13	50	87	36

Respondents, in general, commented that this was a fair and straightforward paper although one suggested it might not discriminate too well between candidates. One commented on the need for examiners to recognize that most students sitting the exam are not native English speakers; much time is spent in paper editing meetings trying to ensure that we use the minimum words without losing clarity and meaning. Ideally, questions are clear and concise without unnecessary information.

Overall, this paper was easier than last year's with the distribution of marks shifting a little to the high end. The level of difficulty, however, needs to be considered together with paper 2.

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 95.37% to 36.12% (May 2013 for comparison, 96.47% to 23.46%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.59 to 0.11 (May 2013, 0.64 to 0.08), the higher the value, the better the discrimination.

The following comments were made on selected individual questions:

Question 8

There were a number of comments suggesting that the sentence "A catalyst creates a new reaction pathway of lower activation energy." should have been used. The examiners accept the rebuke. Nevertheless, nearly 85% of the candidates saw past the poor wording and gave B as the correct answer.

Question 13

This question was written in response to poor paper 2 answers in November 2011. The two-dimensional representation of the bonding was chosen to make the question easier for candidates. The question is about bonding and not structure and was designed to test one thing specifically; over 43% of candidates thought silicon dioxide to have the same structure as carbon dioxide, answer C.

Question 19

This question was designed to test an understanding of difference in temperature. Although over 78% gave the correct answer, nearly 14% added 273 (answer B).

Question 25

This question assumed an understanding of Periodicity (3.3.2) and Acid-Base (8.2.1). The majority of candidates (nearly 73%) had no difficulty in determining that calcium oxide is a basic oxide and choosing the only acidic oxide, sulfur dioxide, as the answer.

Question 28

The point was made by several people that weak base indicators are beyond the scope of the specification. In fairness to the candidates it was decided to accept both answers A and D.

Question 35

This question generated considerable discussion both in the G2s and on-line. The examiners accept that the question could have been worded better. Candidates are, however, instructed to choose the *best* answer and this over 60% of them did. Interestingly, 21% thought the answer to be A which is clearly wrong.

Question 37

The examiners regret the inclusion of R and S in the distractors. In the event, this question was the fifth easiest with over 84% giving the correct answer.

Question 38

One can only apologise for the error in distractor B; it will be corrected in the published version.

General comments for future teaching:

- Candidates need to be reminded that they should choose the best answer to each question.
- Candidates should be advised on how to approach a multiple-choice examination and, at the end, to have left no question unanswered.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 12	13 - 17	18 - 20	21 - 23	24 - 26	27 - 30

General comments

5773 candidates submitted this paper, a 16% increase on 2013.

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 142 respondents (from 831 schools).

Comparison with last year's paper:

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
1	26	96	21	0

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	2	144	1

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	3	18	39	66	21
Presentation of paper	0	0	14	32	70	31

In the general comments, the paper was thought to be fair overall although it was felt that two or three of the questions could have been worded more clearly.

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 90.66% to 30.24% (May 2013 for comparison, 89.99% to 20.57%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.58 to 0.21 (May 2013, 0.65 to 0.22), the higher the value, the better the discrimination.

The following comments were made on selected individual questions:

Question 3

One respondent commented that the question is unfair if candidates are not given the formula of the molecules. The examiners expect knowledge of simple molecules such as those in this question.

Question 4

There was a comment in the G2s that this question is too easy for IB level. Some easier questions are needed to give the paper balance. It was not the easiest question on the paper but 82% of the candidates got it right. Worryingly, 811 candidates thought NaCl to be the solvent.

Question 11

This was thought to be a fair question despite one respondent's worry that there would be ambiguity for candidates who believe NaCl has a small degree of covalency. 78% gave the expected answer.

Question 13

This question was written in response to poor paper 2 answers in November 2011. The two-dimensional representation of the bonding was chosen to make the question easier for candidates. The question is about bonding and not structure and was designed to test one thing specifically; over 43% of candidates thought silicon dioxide to have the same structure as carbon dioxide, answer C.

Question 16

This question was designed to test an understanding of difference in temperature. Although 68% gave the correct answer, nearly 20% added 273 (answer B).

Question 21

This question assumed an understanding of Periodicity (3.3.2) and Acid-Base (8.2.1). The majority of candidates (69%) had no difficulty in determining that calcium oxide is a basic oxide and choosing the only acidic oxide, sulfur dioxide, as the answer.

Question 26

This question generated considerable discussion both in the G2s and on-line. The examiners accept that the question could have been worded better. Candidates are, however, instructed to choose the *best* answer and this 40% of them did. Interestingly, 36% thought the answer to be A which is clearly wrong.

Question 27

One respondent opined that the word “gradation” is difficult to understand, particularly for students not working in their mother tongue. Whilst other words could have been used, this word was used because it appears in the syllabus.

Question 28

There was some concern that this is not on the syllabus. The examiners consider the question to be a fair extension of assessment statement 10.1.5.

Question 29

This question could have been better worded but 72% of the candidates chose the correct answer.

General comments for future teaching:

- Candidates need to be reminded that they should choose the best answer to each question.
- Candidates should be advised on how to approach a multiple-choice examination and, at the end, to have left no question unanswered.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 12	13 - 24	25 - 32	33 - 43	44 - 54	55 - 65	66 - 90

General comments

As is usually the case, the paper produced a wide range of marks, but the general impression was that candidates of average or below average ability found the paper a little more challenging than some that have been set in recent years. The main reason appears to be that such candidates were reasonably well prepared to answer simplistic recall questions, but were less able to apply chemical knowledge to novel situations. This was also reflected in the fact that candidates' answers were often to a related, standard question rather than the one that actually was asked.

Teachers' impressions of the paper were conveyed through the 205 G2 forms that were returned (about three times the number of recent years). In comparison with last year's paper, 37% felt that it was of a similar standard, 8% thought that it was a little easier, 41% a little more difficult and 12% were of the view that the paper was much more difficult. This increased difficulty was reflected by the drop in the mean mark on this paper from 45/90 in May 2013 to 43/90 this year. Of those who submitted G2 forms 77% considered the level of difficulty of the question paper appropriate and 22% felt it was too difficult. Clarity of wording was considered good or better by 77% and fair or below by 23% of respondents and the presentation of the paper was thought to be good or better by 84% and fair or below by 16%.

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

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

- Experimental uncertainties and their propagation
- Interpreting practical situations and experimental data
- Explaining aqueous solubility of substances
- Factors affecting the product of the reaction of a halogenoalkane with an alkali
- Writing redox half equations and combining these to produce balanced equations
- Deducing rate expressions from mechanisms
- Interpreting rate of reaction data
- Writing precise definitions

- Explaining changes in ionization energies in terms of the forces acting on the electron being lost
- Using the Born-Haber cycle to determine an enthalpy term

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

Topics generally well answered included:

- Straightforward mole calculations
- Writing equilibrium constant expressions and determining their value using data provided
- Calculations relating to relative atomic mass and natural abundance of isotopes
- Electron configurations
- Correlating shape of molecule, hybridization and σ/π-bonding to a Lewis structure
- "Le Chatelier" effects on the position of equilibrium
- The action of acid-base indicators
- Deducing oxidation numbers from formulas
- Conditions required for organic reactions
- Requirements for optical activity in an organic molecule
- Using enthalpy of formation data to calculate the enthalpy change of a reaction
- Combining thermodynamic data to predict the effect of temperature on reaction spontaneity

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

Section A

Question 1

Generally candidates found this question quite challenging and some left quite a number of parts unanswered. The tradition is that the first question on the paper is a data response question, which often addresses many aspects of the syllabus, and unfortunately candidates, especially those of average or below average ability, seem to have difficulty in tackling questions of this nature. One other issue with data response questions is that, of necessity, the data appears at the beginning of the question whilst, mainly because of the space left for candidates to answer, the later parts of the question referring to these data may not appear until a number of pages into the paper.

Part (a) concerning density, volume and amount of substance was generally reasonably well answered, but the following parts, concerning uncertainties, were rarely answered correctly and a number confused precision (uncertainty, either absolute or as a percentage) and accuracy (percentage error in the value obtained). Many candidates also seemed to lack experimental common sense, simply taking an average that included an initial titre that was much larger than the concordant second and third titres, rather than excluding it. This lack of experimental “know how” was also evident in responses to (c) (iii) where it was unusual for the approach to the question to indicate the candidate had realised that the alkali was neutralising two different acids (HCl and CH_3COOH) and again in part (d) where it was rare for the response to outline a practical solution to the problem, though quite a number of candidates suggested that the pH would become constant, presumably not realising that the pH would be dominated by the HCl catalyst. Most students could however carry out the more routine tasks of writing an equilibrium constant expression and determining its value from the data given. Many candidates were aware of Le Chatelier effects on the position of equilibrium, but a significant number failed to use this information to answer the question actually asked and the unusual approach to the effect of temperature disconcerted many. Whilst most students managed to identify the ester as the component of the mixture that was insoluble in water, the reasons given were usually couched in terms of the polarity of the molecule (many quite polar molecules, halogenoalkanes for example, are insoluble in water) rather than its inability to form strong hydrogen bonds to water, which is the critical factor. Quite a number of students came up with a valid reason why water would not be a suitable solvent, though some students appeared to have overlooked the fact the question stated “other reason”.

Question 2

This question in general was well answered, with an encouraging number of students being able to both calculate the proportions of the two isotopes of copper and state its atypical electron configuration. Responses to part (c) often centred around the splitting of d-orbitals rather than their completeness and a disturbing number of answers implied, or stated, that transition metals emit, rather than absorb light. In the final part, as might have been predicted, a significant number of students used the electrode potential for Cu^{2+}/Cu (+0.34 V), rather than those required, but a number of them managed to gain some credit by combining this with the other potential in a valid manner and correctly predicting the spontaneity that it would imply.

Question 3

The range of marks students gained for this question ranged very widely, with a significant number gaining full, or nearly full, marks whilst an approximately equal number of students gained one or less marks. This may reflect wide differences in the time devoted to organic chemistry in different schools.

Question 4

Many students scored well on this because, in order that candidates were not too heavily penalised, ECF was taken applied to the later parts of the question based on the number of electron domains and bonding represented by the Lewis diagram drawn in part (a). Hence, although quite a few students incorrectly tried to reflect the delocalization of ozone in their Lewis structures in part (a), their answers to the later parts of the question were correct. In the final part quite a number of students appeared unable to deduce that hydrogen peroxide contains a single O-O bond.

Section B

Question 5

Though it was the least popular question on the paper, it was still answered, though not very well, by a significant number of students. Correct responses to the colour change required in the first part were rare, though more students could write an appropriate equation and outline why the reaction occurred, even though this was often phrased in terms of electronegativity, rather than reactivity or electrode potential. In part (b) many students seemed to be aware of the difference between strong and weak acids, but few could use this to answer the question asked and frequently, even having displayed this knowledge, were unable to write an equation for the required reaction in water. Unfortunately changes in pagination meant that the phrase "*the equilibrium above*" in part (b) (iii) may have confused candidates with regard to which particular equilibrium the question referred to. Fortunately both of the equilibria that it could have referred to change in the same direction and students scored well on this, and both would eventually result in the release of chlorine, that a number recognized as a toxic gas. In contrast to Question 1, many students could correctly identify the hydrogen bonding, resulting from the –OH group, as being the reason for the solubility of HOCl in water. An encouraging number of students gained full marks for calculating the pH of the buffer, usually by memorizing the Henderson-Hasselbalch equation and substituting in this. An even greater number of students could accurately explain the mode of action of acid-base indicators. In part (c) very few students could write, much less combine, appropriate half equations, even though the reactants and products were given, but far more could correctly deduce the oxidation numbers of the species involved. In the final part most students had some general idea of what a standard electrode potential was, but in many cases the definitions lacked the detail required. Quite a few students correctly deduced that the oxidation of chromium(III) to dichromate(VI) was energetically feasible and give valid reasons to support this.

Question 6

This was quite a popular question, though generally not well answered. In the first part students again appeared to display a lack of expertise in a practical context with very few able to devise a mixture that would halve the concentration of thiosulfate, whilst keeping other concentrations constant, and answers predicting that this would halve the reaction time were far more commonly encountered than those doubling it. Many candidates did however suggest valid reasons why the reaction vessel should remain unchanged and a significant number of students were able to correctly deduce the rate equation that the mechanism given would predict. Again a lack of ability to interpret experimental data was evident in the fact that it was very rare to find students who realised that a graph of $(\text{time})^{-1}$ against concentration was required to be able to deduce the reaction order, with almost all simply plotting time-concentration graphs and, as a result, very few could evaluate the mechanism in the light of the experimental data. Part (c) was a fairly standard question on the effect of temperature on reaction rate, hence it was a surprise that students did not score better on it, with many of the oft repeated mistakes (number of collisions rather than collision frequency) again coming to the surface. Again it was probably inability to interpret experimental data that led to only very few students being able to correctly state the initial pH of the mixture (I am certain almost all would have gained the mark if the pH of 0.1 mol dm^{-3} HCl had been asked for) and the percentage that would have to be consumed to increase the pH by one unit (which is independent of the previous answer) proved too much for almost all candidates. In part (e) most students could quote and substitute into the ideal gas equation, but converting from m^3 to cm^3 posed a problem for most candidates. Quite a number of candidates were however able to calculate the pH of the sulfur dioxide solution and identify a stronger acid.

Question 7

Another quite popular question that was probably the best answered question in Section B. Almost all students correctly identified the reagent required for the conversion of an alkene to a bromoalkane and quite a few of these could gain most of the marks for explaining the mechanism of the reverse, elimination reaction. In part (c) many realised that UV light is required to initiate the halogenation of an alkane, though fewer realised that the much greater probability of forming a different isomer, or the problem of polysubstitution would result in a very low yield. The reagent required for the hydrolysis of the bromoalkane was also well known, though fewer could recognise it as a tertiary halogenoalkane and write down a rate expression for the S_N1 reaction that it would undergo. In contrast, many candidates adequately explained why the compound was not optically active and why it would not be easily oxidized. Deducing the structure of the required isomer was however more difficult with most candidates giving an isomer that was either optically active, or a primary alcohol, but rarely combining both aspects as was required. In part (d) again the reaction conditions were well known, as was the use of hydrogenation reactions in the production of margarine. Whilst most realised that the reaction would be accompanied by a negative entropy change, far fewer correctly attributed this to a decrease in the number of moles of <u>gaseous</u> molecules. Quite a number of students were obviously unaware that the enthalpy of formation of elements is zero and tried to use the bond enthalpy of hydrogen to calculate one. Apart from this, students appeared generally able to utilise enthalpy of formation data and some could then combine this with entropy data to predict the Gibbs free energy change and hence how temperature would affect reaction spontaneity. The calculation of the amount of fuel required to raise the temperature proved more difficult with many students overlooking the volume of water and using the data to calculate the mass of the hydrocarbon that the molar enthalpy of combustion would be heat by 80 ^oC (ironically, whilst using the specific heat capacity of water!). In the final part many students could predict that hexane would have a higher boiling point than its branch chain isomer and could correctly justify this in terms of the effect of molecular shape on the intermolecular forces.

Question 8

This was the most popular of the Section B questions, which was surprising because it was often not well answered. Most students were aware of the change involved in ionization, some realised this relates to the most easily lost electron, some that it refers to gas phase changes and a few both. Explanations of the changes in the values of successive ionization energies in terms of the attraction of the nucleus and the repulsion from other electrons were generally weak, however candidates quite often recognised that the third electron lost had to come from a more stable electron energy level. Very few were able to correctly sum the enthalpy terms involved in the Born-Haber cycle, in addition candidates rarely halved the bond enthalpy of chlorine and a significant number appeared not to realise the question referred to MgCl rather than $MgCl_2$. There were some G2 comments that space should have been left for students to draw a cycle, but this would have implied that such a drawing was required, hence it is better to train students to use additional paper for any background support they may require. Quite a lot of students correctly deduced the order of lattice enthalpy of the group (II) halides, and a number correctly explained this in terms of ionic radii, though many incorrectly invoked electronegativities. Many students could correctly explain the effect of pH on the solubility of $Mg(OH)_2$, though a significant number attempted to answer the opposite question; how pH would depend on the concentration of dissolved $Mg(OH)_2$! It was surprising how few students could correctly describe metallic bonding, how it is affected by the number of delocalized electrons per cation and the way it leads to malleability. Alloys are not specifically mentioned in the syllabus but the mark scheme gave credit for answers that indicated the student was aware that malleability is associated with layers of metal atoms/cations sliding over each other. Most students were able to draw appropriately labelled diagrams of electrolysis apparatus, though sometimes the labelling of the polarity of the electrodes did not correspond to the polarity of the battery symbol drawn. Quite a few candidates could quote equations for the reactions occurring the electrodes in both the liquid and aqueous state; both seemed to be equally well answered which was perhaps a little surprisingly. Many could also give good explanations as to why electrolysis of the aqueous solution did not produce magnesium metal, though confusions in terminology (such as hydrogen rather than hydrogen ions being reduced) were not uncommon.

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 in this paper:

- Give candidates more practice in applying chemical knowledge to problem solving in novel contexts
- Enable candidates to analyse descriptions of experimental situations and data related to these
- Train candidates to note what a question is asking and to answer this, rather than a related question
- Expect students to exercise care with terminology; for example atom, ion, molecule, element do not mean the same thing and care should be taken with regard to their use

- Ensure candidates know detailed definitions for terms required by the syllabus

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 - 30	31 - 36	37 - 50

General comments

The paper allowed the weaker candidates to demonstrate some chemical knowledge but was sufficiently challenging to test the strongest candidates who showed a thorough command of the material and high level of preparation. Teacher's impressions of the paper were conveyed by the 160 G2 forms that were completed. 80% of the respondents considered the level of difficulty of the question paper appropriate, 19% too difficult and 1% too easy. In comparison with last year's paper, 38% felt that it was of similar standard, 6% thought that it was easier and 56% were of the view that the paper was a little more difficult. There were some concerns about the relative difficulty of questions 1 and 4 in particular and this feedback was very helpful and informed the Grade Award process. These comments will be discussed in more detail later in the report. Clarity of wording was considered good or better by 76%. The presentation of the paper was thought to be good or better by 83%, fair by 14% and poor by 6%. Questions 5 and 6 were the most popular questions in section B and it was encouraging to see students do particularly well in the organic based question 6. The mean mark for the paper was 23.2 which compared to 24.21 for last year. The general impression was that candidates found the paper a little more challenging than some that have been set in recent years. Some teachers commented that candidates found question 1 particularly difficult as they had to relate content from different parts of the guide and refer to information on previous pages, whilst other teachers liked this style of question.

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

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

- Interpretation of experimental data
- Selection of the titres that should be used in order to determine the average volume of

alkali, needed to neutralize an acid

- Calculation of the percentage of ethanoic acid converted to ethyl ethanoate
- "Le Chatelier" effects on the position of equilibrium
- Deduction of the structure of polypropene
- An explanation of solubility of esters in terms of hydrogen bonding
- The reaction between excess aqueous chlorine and aqueous sodium iodide
- Explanation of the H–O–Cl bond angle in terms of the VSEPR theory
- Redox half equations and combining these to produce balanced equations
- Determination of the pH of reaction mixtures
- Description of the S_N1 mechanism

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

Topics generally well answered included:

- Determination of the amount of a substance from its volume and density and volumes from their concentrations
- The function of acid HCl(aq) as a catalyst in esterification
- Deduction of equilibrium constant expression for a reaction
- Determination of the composition of an atom from its atomic and mass number.
- The formula of the boron triflouride
- The equation for the complete combustion of nonane
- The reaction conditions for incomplete combustion
- "Le Chatelier" effects on the position of equilibrium
- The Lewis (electron dot) structure of chloric(I) acid
- Deduction of oxidation numbers
- Application of IUPAC rules
- Conditions required for organic reactions

- The oxidation of primary alcohols and the difficulties of oxidising tertiary alcohols
- Determination of the enthalpy change of reaction from bond enthalpies

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

Section A

Question 1

Generally candidates found some elements of this question quite challenging but there were accessible marks of even the weakest candidates. The majority of students were able to determine the molar mass of ethanoic acid but some struggled to calculate the mass from the volume. Most candidates were able to identify the role of hydrochloric acid as a catalyst but some struggled to identify the liquid whose volume had the greatest uncertainty. Most candidates were able to calculate the absolute uncertainty of the titre but some lost a mark by omitting the +/- sign. Candidates did not identify the first titre as incongruent and simply averaged the three values which perhaps suggests limited experimental experience. Most students could determine an equilibrium constant expression, but many did not answer the question in (g) and did not suggest how the equilibrium could be established experimentally with many referring to the equal rate of the forward and backward reaction. Many candidates were aware of Le Chatelier effects on the position of equilibrium, but a significant number failed to use this information to answer the question asked and could not explain the small effect of temperature changes. Whilst most students managed to identify the ester as the component of the mixture that was insoluble in water, many did not refer to its inability to form strong hydrogen bonds to water which was necessary for the mark. Quite a number of students came up with a valid reason why water would not be a suitable though some students appeared to have overlooked that the question asked for “one other reason” than that implied in (j).

Question 2

This question in general was well answered. Most candidates were able to identify the elementary particles of atomic boron with an encouraging number of students calculating the proportions of the two isotopes. A significant number did leave the question blank however although it should be a familiar example. Most candidates were able to state the formula of boron trifluoride and describe the action of Lewis acids although only a minority could explain its behaviour in terms of boron’s incomplete octet. .

Question 3

The range of marks students gained for this question ranged very widely, and responses were mixed. Many were able to give a balanced equation for the complete combustion of nonane although some gave hydrogen as a product and did not answer the question asked in (b) and instead referred to “incomplete combustion” as a condition. Addition polymerisation was unfamiliar to a surprising number of candidates and only the strongest candidates were able give the structure of polypropene.

Section B

Question 4

This was the least popular and the least successfully answered question on the paper. Many were unable to describe the colour change required in (a)(i) though more could give an appropriate equation and explain why the reaction occurred in terms of electronegativity. (b) was essentially a “dead” mark and perhaps was out of place on a SL paper. Many students seemed to be aware of the difference between strong and weak acids, but few could use this to answer (c)(i), and many were unable to write an equation for its reaction in water. The more able candidates realised that acids would affect the position of the equilibrium and a number recognized that the toxic gas chlorine would be a product. Many students identified hydrogen bonding from the –OH group as being the reason for the solubility of HOCl. Most were able to give the Lewis (electron dot) structure of chloric(I) acid, but few were able to give a detailed explanation of its bond angle, with only a minority referring to electron domains. In part (d) very few students could write, or combine, appropriate half equations, even though the reactants and products were given, though many could deduce the oxidation numbers of the species in the equations. Some marks were unfortunately lost as candidates omitted the sign.

Question 5

This was quite a popular question, but responses were mixed. As in question 1, students struggled to answer questions with a strong practical context, with very few able to devise a mixture that would halve the concentration of thiosulfate, whilst keeping other concentrations constant, and responses for the need for similar beakers to be used were often too vague. Explanations of changes of rates in terms of the collision theory were generally successful but a significant number referred to the “number” rather than “frequency” of collisions. Many candidates were able to sketch Maxwell–Boltzmann distribution curves for the two temperatures, T_1 and T_2, but marks were lost due to careless omissions; the graphs did not start at the origin, were not labelled or the activation energy was missing. Many struggled to calculate the pH and many teachers have commented that this question was beyond what is expected at Standard Level and it is acknowledged that the question would have been more accessible if candidates had been asked to calculate the concentration of H^+ ions and state the pH. In part (e) many students could quote and substitute into the ideal gas equation, correctly converting the temperature to Kelvin, but converting from m^3 to cm^3 posed a problem for most candidates. Although not necessary for the mark, as answers which referred to improved accuracy and precision were accepted, most candidates did not refer to the solubility of sulfur dioxide as a problem when using measuring cylinders to measure its volume.

Question 6

Probably the most popular and successfully answered. Most students were family with IUPAC nomenclature and realised that UV radiation is required to initiate the halogenation of an alkane, though fewer realised that the much greater probability of forming a different isomer, or the problem of polysubstitution would result in a very low yield. The conditions for the hydrolysis of the bromoalkane were well known, though fewer recognised it as a tertiary halogenoalkane and described the S_N1 reaction mechanism. Only a small number of candidates were able to show the electron pair originating from C – Br bond or the lone pair on the oxygen or negative charge of the hydroxide ion. Many candidates knew that tertiary alcohols could not be oxidised and correctly drew primary structures for alcohols that could be oxidised to carboxylic acids although some made careless errors and drew secondary structures or did not answer the question and proposed aldehydes. Many candidates were able to determine the enthalpy change, from bond enthalpies but some had not read the question carefully and did not address the final mark. A significant number of candidates made small errors but still gained ECF marks as they had set their working out clearly. The calculation of the amount of fuel required to raise the temperature proved more difficult with many students overlooking the volume of water and using the data to calculate the mass of the hydrocarbon that would be heated by 80^{o}C by the molar enthalpy of combustion and using the specific heat capacity of water.

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 teachers and candidates are advised to bear in mind the following points in this paper:

- The inclusion of questions on observations, data analysis, and error highlights the importance of experimental work in the teaching of the programme. Students need to be able to apply the skills they develop in experimental work to analyse data from a range of investigations which they may not necessarily have covered in class.

- Candidates should set out calculations logically and “keep going” even if in difficulty as errors are carried forward and a correct method in a later part of the question is rewarded. All steps in the calculation should be shown.

- Candidates should use the number of lines and the marks as a guide as to the detail needed for the answer and write answers in the boxes provided. In the exceptional case of more space been needed candidates should indicate that the answer is completed in a continuation booklet.

- Candidates should scan through the Section B questions to make sure that they choose the questions that they are best prepared for.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7

Mark range:	0 - 7	8 - 15	16 - 20	21 - 26	27 - 31	32 - 37	38 - 50

General comments

8591 candidates submitted this paper, an 11% increase on May 2013. There was also a nearly 5% increase in the number of schools entering candidates.

The paper consists of seven options of which two are to be chosen by candidates. It is important that candidates are taught the options – and that they attempt only the options they have been taught; it is generally apparent where candidates have been left to fend for themselves with only general guidance.

The following are some statistical data based on 205 respondents.

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	16	145	35	3

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	2	190	12

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	3	25	73	75	28
Presentation of paper	0	1	18	69	82	34

There was a wide range of ability and preparedness exhibited by candidates and, while some thought the paper too easy and others that is was too "picky", the "average" opinion of respondents was that the paper was fair to candidates.

Several commented on the new consecutive numbering scheme (first introduced in November 2013), a consequence of e-marking changes. This did not seem to cause problems for the candidates and each particular option was well signalled on every page. No examiners commented on candidates attempting more than two options. Some candidates used extra pages but they were, in general, able to tailor their answers to the size of the box provided and we, no doubt, are getting better at judging the size of box needed.

There was a general comment about the “value” of one mark; that is how much work has to be done to gain one mark. We are aware of this concern and try to standardize when authoring papers.

Another comment suggested there were too many questions dealing with structures of molecules. There has been an attempt to ensure that chemistry is examined in each option. Chemical equations are becoming more significant.

There is always disappointment expressed that the whole of an option is not examined. Except at a superficial level, that is just not possible. All we can do is to examine the syllabus evenly over several examination sessions. There are no plans, as one respondent suggested, to lengthen paper three.

Options C, F and G were the least popular.

Other 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

- Drawing the structural formula of a monosaccharide
- Drawing the five-membered ring structure of a monosaccharide
- Correct use of terms in the linkage of disaccharides
- Drawing the structural formula of a diglyceride.
- Structure of DNA
- Steps used in profiling
- Hemoglobin: structure and role
- Electrochemical equations
- Liquid crystals
- Net ionic equations
- Secondary pollutants in smog

- Mechanism of acid deposition caused by the oxides of nitrogen and oxides of sulfur
- K_{sp}
- Structural formulae
- CIF convention
- Organometallic chemistry
- Naming functional groups (rather than giving the formula)

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

- Purposes of different analytical techniques
- Absorption and emission spectra
- Relationship between energy values and wavelengths/frequencies
- Conjugated systems
- Antacids
- Analgesics
- Chiral centres
- Use of Markovnikov rule
- Drug action
- Elimination reactions
- Carbocations

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

Option A - Modern analytical chemistry

This was a relatively popular option.

In Q1, it was, perhaps, surprising that the method of detecting ethanol was most often wrong. The explanations for absorption were shakier than those for emission spectra.

In Q2, the R_f values were generally calculated correctly although quite a few managed to have the calculation upside-down and some left the answers as fractions. There was a tendency to suggest that B was attracted to the mobile phase. Many scored well in describing GLC as there were ten marking points for [4 max]. It was not always clear that the carrier gas carried the sample and the nature of the stationary phase was somewhat vague at times.

There were good answers to Q3 but the usual errors were encountered, such as the omission of a positive charge on mass spectrum fragments. Many were able to deduce the structure of the lactic acid although an ether was a common suggestion. It was disappointing to note that many candidates could not provide the correct *m/z* value for 3-methylbutanoic acid. Candidates found the ^{1}HNMR information difficult although most candidates managed to give one line correctly.

Candidates had little difficulty in choosing compound **I**, knew about conjugation but tended to omit the absorption of light in the visible region (or equivalent). Although it wasn’t penalized at this point, there are still candidates talking about reflected light. Students should have some knowledge of complementary colours without having specifically memorized the colour wheel.

Option B – Human biochemistry

This was one of the two most popular options. The other was D.

In Q5, candidates had little difficulty suggesting energy as a reason for eating pasta but the structures of fructose were done poorly even though they are specifically mentioned in the syllabus, B.3.2. The straight chains had pentavalent carbon atoms or even rings and for the ring, it seemed to be difficult to get all the groups in the correct orientation – and some were six-membered! Had memory failed, candidates could have taken sucrose “apart”; the structure of sucrose is in the data booklet. Most were able to identify the 1,4-glycosidic link but it is important to include three atoms in such a link. Glucose was generally identified as the common sugar in the two structures but descriptive skills were often not sufficient to outline how the structures of lactose and maltose differ.

The structure of glycerol in Q6 should have been an easy mark but the middle carbon often gained two hydrogen atoms. The functional group of the *tri*glyceride was poorly answered, many opting for carboxylic acid and the *di*glyceride was thought to be a derivative on ethane-1,2-diol.

Most recognized the absence of the steroid backbone in Q7 but the C=C was frequently missed in the comparison of functional groups.

In Q8 the best understanding was that of the complementary base pairs and the hydrogen bonding between them; the rest was not well explained and very few understood the importance of the hydrogen bonding. Candidates were either well prepared for DNA profiling – or showed very little understanding. The order of steps seemed to be incertain. It is accepted that “describe” followed by “explain the importance” would have been a more effective wording of the question.

The structure of hemoglobin in Q9 was not well understood and its role in the transport of oxygen was superficial with very little mention of the change in pH. The question was based on B.9.2.

Option C – Chemistry in industry and technology

Very few candidates presented this option and the answers tended to be of a lower standard.

Students found this difficult because of the equations that were needed; they are an integral part of the chemistry of this option.

In Q10, the omission of the aqueous nature of the electrolyte was the general error but most marks were lost with the equations. The equations were unbalanced, sometimes having both Cl^- and e^- on the same side of an otherwise correct equation and some proposed sodium at the cathode. Some suggested that a diaphragm cell is used in a modern factory – but error-carried-forward marks were still awarded for the reason.

Candidates who are seriously studying this option need to find some way of recalling (or working out) the equations required in Q11. The lead-acid equations were better recalled than those for the NiCad. Most understood the similarity between fuel cells and lead-acid batteries but the differences were not well *compared*.

HDPE and LDPE in Q12 needed two different physical properties and it was important to compare the structures. The conditions of their formation were less well answered than the mechanisms.

There was a generally poor understanding of liquid crystals in Q13 apart from the properties of suitable molecules.

Option D – Medicines and drugs

This, together with B, was one of the most popular options.

It was clear that candidates were not certain of what an ionic equation might be and the importance of using state symbols when asked. It was also important to notice that the examination asked for *named* functional groups on occasions.

Candidates had neither difficulty with stomach acid in Q14 nor with the type of reaction. Many, however, included spectator ions in the equation. Few were able to write a balanced equation for the active ingredient and there was much confusion with heartburn rather than bloating.

In Q15, the function of mild analgesics was well understood but few stated that the calcium salt is ionic and fewer still managed the ionic equation. The named functional groups were usually correctly identified although “benzene” was one of the incorrect answers as was “esther”. For the short-term advantages there was a tendency to repeat the stem of the question but the long-term disadvantages were better understood. Many scored one mark by including one correct short-term and one correct long-term answer. One respondent suggested that asking candidates about codeine was unfair – but this was regarded as a reasonable extension of D.3.4. Answers about the increased potency of diamorphine over morphine were better than in the past but if a mark were to be lost it would be for not commenting on the greater solubility of diamorphine in lipids specifically.

In Q16, most candidates seemed to have a reasonable idea about the effects of the mindaltering drugs and most made a solid attempt at the comparison between mescaline and psilocybin. The similarities were well noticed but some obvious differences, such as the phosphate group, tended to be missed. Answers here need to be better organized.

Option E – Environmental chemistry

This was one of the less popular options.

The only general comment suggested that this option was well balanced, covering a wider scope of the topic.

In Q17, the mark for the primary pollutant was generally gained except by those who gave an oxide of nitrogen; this is not produced by the *fuel*. There were one or two comments that the distinction between petrol (gasoline) and diesel was unfair but this was deemed to be a reasonable extension of E.1.1 and E.1.2; flexibility is needed in the interpretation of the syllabus. Answers given for the sources of sulfur dioxide lacked precision; "coal" is not acceptable for "burning of coal". Candidates understood how location affects the formation of smog but connected equations were rare.

Candidates confused acid rain with acid deposition in Q18 and the mechanism of acid deposition was patchy. The effect on the carbonate shell of shellfish was understood and most candidates illustrated the reaction with sulfuric acid.

The ionic equation for the precipitation of lead(II) chloride in Q19 was well done but there were few correct calculations and the assumption was poorly understood. This question is based on E.12.1.

In Q20, the causes of nutrient depletion were well understood and most managed one way of minimizing this. Explanations of increasing salinity lacked clarity.

Option F – Food chemistry

This was one of the less popular choices.

In Q21, candidates were usually aware of the intended purpose of food but the use of the nutrient was less well answered. For the functional groups, most here used names rather than formulae but many were not able to name all four. The final mark was usually scored in part (b). Candidates need to be aware of the need to specify carbon-to-carbon double bond (or C=C) rather than just double bonds when explaining the difference between saturated and unsaturated fats. Many did not spot the request for the *partial* hydrogenation and there was some carelessness in the presentation of the structures. Margarine was generally well known but a popular answer was peanut butter. The health implications of *trans* fats were well understood but the type of compound used to make olestra was not well answered.

In Q22, the word "solubility" in (a) was often missed and most did not spot the relevance of solubility in the discussion of vitamins B_2 and A. The interpretation of the colour wheel was well done for the most part but there were some who suggested that ß-carotene is violet and chlorophyll is red; candidates need to check their answers against everyday observations.

Many only gained one mark in Q23 for the names of the three stages in the free-radical chain mechanism and the types of antioxidants were either answered well – or not at all.

In Q24 candidates need to remember that + and – notations refer to the rotation of something – and need to say what it is; sometimes one was left with the impression that the crystal itself rotated. Nearly all identified the chiral centre correctly and, sensibly placed the asterisk on the diagram (whilst redrawing the diagram in the box to ensure it was marked). Candidates should, of course, have been directed to annotate the diagram in the first place. Many managed to assign S to the enantiomer; this is covered in F.9.1

Option G – Further organic chemistry

This was not a popular option in the paper but was generally offered by the better candidates.

The only real difficulty candidates seemed to face in Q25 was why concentrated phosphoric acid is used instead of concentrated sulfuric acid. That sulfuric acid is a strong oxidizing agent was felt to be common knowledge. In the event, candidates thought the answer had something to do with the number of hydrogens.

In Q26, the most common error was not to have the curly arrow originating from the negative charge or lone pair on the I^- ion in (a) (ii). Although the inductive effect itself was well understood, candidates need to take care to compare the inductive effects on both possible intermediates. The formation and reactions of Grignard reagents were well understood.

Q27 was well answered by most candidates although some need to take care with the placement of the delocalized positive charge in the intermediate.

Recommendations and guidance for the teaching of future candidates

Both chosen 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. 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.

Ensure that candidates are familiar with the contents of the examination data booklet well in advance of the examination.

Candidates should take care in the naming of functional groups, writing ionic equations and using subject specific vocabulary.

Candidates pick up language from their teachers so be specific with the language used in class. Insist on *carbon-carbon* double bonds, for instance, when discussing unsaturation.

Candidates should read the question carefully and take note of the “command term” used.

Stress the importance of correctly writing balanced chemical equations and formulas.

Candidates should prepare for the examination by practising past examination questions and carefully studying the markschemes provided.

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 a weak understanding of topic 10 are unlikely to perform well in this option.

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

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 15	16 - 19	20 - 23	24 - 27	28 - 40

General Comments

Many candidates demonstrated a good understanding of concepts, an awareness of the requirements of the different command terms and correct use of terminology. However, there was also a significant proportion of poor quality papers.

Option D was the most popular option among SL candidates this session, followed by options B, E and F. The least popular option was C. There were several straight-forward marks to be gained in each option and a handful of marks that discriminated at the top end.

In terms of skills, a high proportion of candidates could name functional groups correctly and were careful to connect bonds to the correct atoms when drawing structures. The answers were focused on answering the question asked, and candidates did attempt to provide explanations when requested. However, it was disappointing to see unbalanced chemical equations, incorrect state symbols and incorrect formulae for simple substances appearing in many of the scripts.

Feedback from teachers through the G2 forms showed that 92% of the 160 respondents judged the paper to be of appropriate difficulty, and 72% judged it to be of a similar standard to last year's paper while 18% judged it to be a little more difficult and 6% judged it to be a little easier. 87% of respondents found the clarity of the wording to be at least good and 89% found the presentation of the paper to be at least good. The questions were seen accessible to candidates with learning support and/or assessment access requirements by 93% of respondents, and accessible irrespective of candidates' religion, gender or ethnicity by over 95% of respondents.

In the G2 forms, some teachers commented that it was good to see questions that connected chemical concepts to daily life, and others thought the paper made good use of the Data Booklet.

There were some comments about the focus on ionic equations and the balancing of equations in the paper, especially in Option D. However, the intention is to assess more chemical concepts through the options as they provide a rich opportunity for applying the concepts covered in the Core programme in a variety of situations.

Some teachers also felt the focus on Diesel and Petrol engines in Option E was too demanding. This was assessed as part of assessment statement E.1.2 "evaluate current methods for the reduction of air pollution".

Some teachers thought there was excessive focus on cell reactions in Option C, although the reactions assessed were clearly covered in assessment statement C.5.2. There were also a few concerns that testing the identification of the colour of a pigment through the wavelength of light it absorbed was beyond the requirements of Option F. Interestingly, a high proportion of candidates manipulated the wavelengths provided in the question correctly and deduced the colours scoring full marks on the question.

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

- The straight-chain structure of fructose
- Half-equations in electrolysis
- Ionic equations
- Equations of cell reactions
- Explaining acidity of organic acids
- Grignard reagents

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

- Relating electronic transitions to absorption and emission spectra
- Calculating R_f values
- Identifying bonds responsible for peaks in an infrared spectrum
- Comparing TLC and paper chromatography
- The structure of glycerol
- Identification of functional groups
- Mode of function of mild analgesics
- Nutrient depletion
- The difference between saturated and unsaturated fats

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

Option A – Modern analytical chemistry

Question 1

(a) Most students scored one mark. Atomic absorption spectroscopy and Nuclear Magnetic Resonance were the analytical techniques that were most commonly stated for the correct purpose.

(b) Answers generally showed understanding of the relationship between the spectra and electronic transitions. Some candidates failed to highlight that emission spectra are obtained from an excited sample.

Question 2

(a) Well answered. A few candidates mixed up the mobile and stationary phases, and a few incorrectly suggested sulfuric acid as the mobile phase.

(b) The majority of candidates obtained the mark. The most common answer was that TLC was faster than paper chromatography.

(c)(i) Very well answered. Many candidates used an inappropriate number of significant figures for the calculated R_f values, but this was not penalized in this instance.

(c)(ii) Generally well answered. Some candidates successfully related the solubility of compound B to its polarity.

Question 3

(a) Most candidates scored this mark by identifying the bonds responsible for the absorptions.

(b) About half the candidates were able to analyze the integration trace correctly and deduced that is was a methyl group.

(c) Generally well answered. However, a few candidates are still forgetting to include the positive charge of the fragments of the mass spectrum.

(d) About a third of the candidates were able to deduce the correct structural formula of X based on the evidence presented.

(e)(i) Only few candidates deduced the correct structure for the isomer Y.

(e)(ii) About half the candidates predicted a reasonable difference between the ^{1}H NMR spectra of X and Y.

(f)(i) More than half the candidates were able to deduce the molecular formula from the name and hence calculated the *m/z* value of the molecular ion peak correctly.

(f)(ii) More than half of the candidates deduced the correct number of chemical environments in the ^{1}H NMR spectrum of 3-methylbutanoic acid.

Option B – Human Biochemistry

Question 4

(a) Almost all candidates related pasta to energy.

(b)(i) Only a few candidates were able to draw the straight-chain structure of fructose.

(b) (ii) About a quarter of the candidates were able to draw the five-membered ring structure of β-fructose. Many candidates had the orientation that suggested they drew the structure by referring to the structure of sucrose in the Data Booklet. A common mistake was missing the -OH at the position of the glycosidic link in sucrose.

(c)(i) Most candidates were able to circle the glycosidic link, although it was expected that the circle would include the two carbon atoms as well.

(c) (ii) Most candidate identified α-glucose as the sugar involved in sucrose and maltose.

(c) (iii) Less than a third of the candidates were able to give two valid differences between the structures of lactose and maltose. The most common answer was lactose containing galactose instead of glucose.

Question 5

(a)(i) About half of the candidates could define *iodine number* correctly. Others had the correct idea but gave imprecise answers.

(a) (ii) About half of the candidates obtained the number of moles of iodine that reacted and gained one mark. A smaller number of candidates were able to calculate the number of double bonds in the fatty acid.

(b)(i) Almost all candidates were able to draw the structure of glycerol.

(b) (ii) About half of the candidates recognized the functional group in a triglyceride as an ester, and more than half of the candidates recognized water as the other product formed.

(c) This was a discriminating question. Only a few candidates were able to deduce the structure of the diglyceride and even fewer recognized the other product as stearic acid.

(d) Many candidates obtained a mark for stating that fats contain less oxygen or are less oxidized than carbohydrates, but were unable to score the second mark.

Question 6

(a) Generally well-answered, but some candidates identified general side-effects of anabolic steroids rather than those specific to males.

(b) Quite well answered. Many candidates referred to the steroid backbone.

(c) Most candidates missed the alkene functional group that both testosterone and progesterone contain scoring only one of the two possible marks.

Option C – Chemistry in industry and technology

Question 7

(a)(i) Many candidates understood the principles behind the production of aluminium and the role of the cryolite, although not always managing to state the principles accurately to be able to score the first two marks, but many candidates showed weakness in writing the correct half-equations at the correct electrodes.

(a)(ii) About half of the candidates stated the there was no electricity available at that time.

(b)(i) More than half of the candidates were able to give an advantage of using an alloy over using the pure metal. A few candidates stated the misconception that alloys were less brittle than pure metals.

(b) (ii) Some candidates offered sensible suggestions mainly focusing on the importance of finding a low density metal.

(c) Quite well answered. Not many candidates discussed the impact of the purification of the bauxite or its mining. Candidates focused on the impact of the generation of large amounts of electricity and global warming.

Question 8

(a)(i) Poorly answered even by strong candidates. Very few candidates gave the correct equations for the reactions occurring at the electrodes of a lead-acid battery.

(a) (ii) This part-question was also poorly answered with very few candidates scoring one out of the two possible marks.

(b) Many candidates scored at least one mark, but many answers only reflected a shallow understanding of fuel cells and lead-acid batteries. Quite a few candidates are still neglecting to satisfy the demands of the “compare” command term that requires reference to both items in every point of comparison.

Question 9

(a) Only about a third of the candidates were able to score both marks by giving a balanced equation producing octane and ethene. Others scored one mark as they failed to balance the equation.

(b)(i) Less than half the candidates gave two physical properties that differed between LDPE and HDPE.

(b) (ii) A small number of candidates attributed the difference to the branching in the chains.

(c) The answers were mostly unsatisfactory as they failed to recognize the value of cracking products for the petrochemical industry.

Option D – Medicines and drugs

Question 10

(a) Very well answered by most candidates recognizing the acid in the stomach as hydrochloric acid and that it is a strong acid.

(b) Surprisingly only about half of the candidates recognized the reaction of antacids in the stomach as a neutralization reaction and only few candidates gave a correct ionic equation for the reaction.

(c) This was a discriminating question. Only the strong candidates were able to identify the correct products scoring one mark, and very few were able to add the correct state symbols and balance the equation. Common mistakes included writing solid state symbols for the salt products and writing an incorrect formula of aluminium chloride such as $AlCl_2$. A number of candidates had aluminium hydroxide as a product.

(d)(i) About a third of the candidates related anti-foaming agents to preventing gas. An equal number of candidates confused their use with the prevention of heartburn.

(ii) Only a few candidates gave a correct anti-foaming agent. Some candidates confused this with alginates used to prevent heartburn.

Question 11

(a) While many candidates scored the mark, some candidates offered vague and/or inaccurate descriptions of how mild analgesics functioned.

(b)(i) Few candidates scored here. Very often the answers would attribute the solubility to the presence of calcium.

(b)(ii) A highly discriminating question. A substantial number of candidates ignored the request for an ionic equation. Those who attempted one mostly failed to give the correct products.

(c)(i) Many correct answers. A few candidates stated “benzene” without “ring” which did not score the mark. Another mistake was using “esther” where it was not clear if “ester” or “ether” was meant.

(c) (ii) A well answered question.

(c) (iii) A good number of candidates scored at least one mark, often as a result of stating one short-term and one long-term advantage of using codeine.

Question 12

(a) Generally well answered. Some candidates were unable to give examples for the different methods of administering drugs. Another common mistake was to state inhalation as a method when it was already stated in the question.

(b) Generally well answered.

(c) Many correct answers with more polar being more popular than more hydrogen bonding.

Option E – Environmental chemistry

Question 13

(a) Well answered.

(b) The majority of candidates obtained at least one mark with catalytic converter and lean combustion engine being very popular. A common mistake was to suggest lean burn engines for diesel engines, which are already lean. Very few candidates showed awareness of soot traps or low sulfur diesel.

(c) Many candidates gave at least one anthropogenic source of sulfur dioxide gas and some candidates gave two sources gaining both marks.

Question 14

Some candidates related the effect to the water in the clouds and its action as a greenhouse gas. Many candidates gave answers that did not acknowledge that it was after sunset. Some of the descriptions of the greenhouse effect lacked the detail required by the markscheme.

Question 15

(a) Many correct answers. Some candidates oversimplified the term as acid rain.

(b) While this question received many correct answers it is worrying that a number of candidates used incorrect formulae for common substances (such as N instead of N_2) and a few did not balance their equations.

(c) Most candidates realized that the acid would react with the carbonate rendering the shell weaker and therefore obtained at least one mark. The second mark was scored by a smaller number of candidates. Some candidates lost the second mark by using an acid not found in acid deposition or using the wrong formula for the salt product.

Question 16

(a)(i) Mostly well answered.

(ii) Many students stated valid ways of minimizing nutrient depletion.

(b) Quite a few candidates scored at least one mark but the quality of the answers was sometimes below expectations. Some candidates were confused whether the irrigation water washed the salts away or introduced them into the top soil layer. To clarify the concept to students it helps to explain that the irrigation water and salts dissolved in it stay in the top layer of the soil because of poor drainage.

(c) Better answered than in previous sessions.

Option F – Food chemistry

Question 17

(a) Many good answers for distinguishing between a food and a nutrient.

(b) Well answered with most candidates gaining two marks. The most common mistake was failing to recognize OHC- as an aldehyde.

(c) The majority of candidates distinguished between saturated and unsaturated fats correctly.

(d)(i) The catalyst was usually well suggested but the structural formula was only provided by the strongest candidates. Some candidates gave the saturated product not taking note of the word “partial” in the question.

(d)(ii) Quite well answered.

(d) (iii) Another question better answered than in previous sessions. Many candidates related *trans* fats to LDL cholesterol.

(d) (iv) This was a discriminating question. Only a few candidates recognized the compound as a carbohydrate.

Question 18

(a) many correct answers. Students who didn't score often failed to relate the antioxidants to slower rates of oxidation.

(b)(i) The majority of candidate gave correct food sources for selenium and β- carotene, the most popular being fish and carrots.

(b) (ii) Most candidates were able to name a functional group that was present in both preservatives.

(b) (iii) Less than half of the candidates gave a correct description of a free radical. There were many vague answers as well.

(b) (iv) Most candidates were able to describe rancidity.

Question 19

(a) More than half of the candidates were able to distinguish between a dye and a pigment in terms of solubility. Some candidates did not mention the solvent losing the mark.

(b)(i) This was a discriminating question. The stronger candidates related the toxicity to the build up of vitamin A in the body due to its solubility in fats.

(b) (ii) The question was quite well answered. Many candidates were able to identify the absorbed colours and the complementary colours observed.

Option G - Further organic chemistry

Question 20

(a) Although a straight-forward question, most candidates were only able to score two out of the three possible marks in describing the structure of benzene.

(b) Well answered but some candidates gave physical instead of chemical evidence failing to gain the mark. The most popular answer was the tendency to undergo substitution reactions.

Question 21

(a)(i) Many candidates gave the correct product.

(a) (ii) Most candidates recognized the type of reaction.

(a) (iii) Only strong candidates recognized that sulfuric acid would also act as an oxidizing agent. The most common incorrect answer was based on the number of protons donated by each acid.

(b) Only about half of the candidates scored the marks. Some did not gain the mark for the explanation, and a number of candidates stated that butan-1-ol was the stronger acid.

Question 22

(a)(i) Very well answered by most candidates.

(a) (ii) An improvement in drawing mechanisms has been observed but they continue to be challenging for many candidates. Some candidates gained all three marks for the mechanism. One of the common mistakes was drawing the curly arrow from H to the double bond in step one, and another was neglecting to initiate the curly arrow from the lone pair or negative charge on the iodide ion in the second step. Most candidates gained the mark for the carbocation intermediate.

(a) (iii) Many candidates recognized that the secondary carbocation was more stable than the primary carbocation but failed to explain this in terms of the electron-releasing alkyl groups and hence did not score the mark.

(b)(i) A question poorly answered.

(b) (ii) Better answers than in previous sessions. Many candidates stated that the reaction must be carried out in dry conditions.

(b) (iii) Only the stronger candidates scored the first mark, while quite a few were able to state that it was an alcohol even when they failed to show the correct structure.

(b) (iv) Many good answers.

Recommendations and guidance for the teaching of future candidates

The options need to be given the recommended instruction time (15 teaching hours for each option besides the time spent on related lab activities). Students who study an option on their own fail to reach the required depth in their answers.

Refer to the Core material in the teaching of the options to clarify the chemical basis behind the knowledge.

Encourage candidates to give specific details and avoid general answers.

Insist on thorough explanations throughout the course. This serves to deepen students' understanding and give them a better chance of meeting all the required points in the markscheme.

Advise candidates to use the correct terminology as far as possible.

Provide plenty of opportunities for practicing writing balanced equations, adding state symbols and deducing ionic equations.

Candidates studying option B must be provided with opportunities to draw the structures and practice joining monomers to form the peptide, glycosidic and ester links and also breaking the links.

Pay attention to command terms. In particular, the command term compare requires mention of both items being compared for each point.

Some candidates list more than one answer hoping the examiners will choose the correct answer. This is not encouraged because a correct response followed by an incorrect response nullifies the mark.