November 2014 subject reports

Chemistry TZ0

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 18	19 - 33	34 - 45	46 - 57	58 - 68	69 - 80	81 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 31	32 - 45	46 - 56	57 - 68	69 - 79	80 - 100

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

The feedback from the moderator team indicated that the suitability of the range and suitability work presented for internal assessment moderation was extremely variable. A quarter of the moderating team indicated that their samples were on the whole of lower standard than in previous years whereas the rest of the team indicated that the work evidenced was of similar standard to other November sessions which in turn has generally seen a favourable standard in comparison to May sessions over the years.

The tasks set to the students in most schools were appropriate for the assessment of the criteria. As this cycle of the current assessment model nears its end (with November 2015 being its last session) it appeared that most teachers played safe with their assessment strategies. The most common approach was that teachers set a range of prescribed tasks for DCP & CE assessment and then did two separate Design assessments. Disappointingly many of the Design tasks were completely theoretical in nature with no follow up action phase. While permissible under current regulations this was to the detriment of the present experimental designs presented since the students did not get the chance to really immerse themselves in the procedure and to really identify all the necessary steps in suitable detail.

The new IA assessment model to be assessed from 2016 onwards will require a radical change in strategy from the teachers.

There were three overwhelmingly popular Design task areas which involved investigations that determined factors that influenced the (i) rate of a reaction, (ii) enthalpy of combustion of alcohols and (iii) voltage of an electrochemical cell. In addition other popular “DCP/CE only” assessment tasks included titrations (often of vinegar or vitamin C), enthalpy determinations based on Hess’s Law and for HL students determining the order of a reaction or an activation energy. Generally these tasks were appropriate although some titrations generated relatively little data and led to unchallenging data processing and evaluation.

Some moderators did voice the concern that a number of schools submitted design assessments from the students that were overly similar to each other. One explanation is that some teachers are providing more direction for the design tasks than they subsequently evidence to the moderators. In some cases the students write ups did reveal this to be the case. Another common frustration expressed has been that some schools have repeatedly submitted inappropriate assessment tasks that have been commented on each session in the 4IAF feedback available through IBIS yet not acted upon. It appears unfortunately probable that some teachers do not receive the 4IAF feedback from their DP coordinators.

Candidate performance against each criterion

Design

Design Aspect 1: This aspect was usually well addressed with most candidates being able to phrase a focused research question and then to identify the appropriate variables. The exception to this related to electrochemistry investigations where frequently confusion arose between current and voltage which many students seem to consider to be the same variable. There were also still a few schools where the research question was provided by the teacher which was then not altered or refined by the candidate. Another weakness was students choosing to study unsuitable independent variables, most typically changing brands of a foodstuff or cleaning material. It is much better for students to identify a continuously measurable variable that can then be plotted on the x-axis of a scatter graph.

Design Aspect 2: Once again many candidates failed to plan to explicitly control the constant variables they had already identified. Often the candidates indicated that they would control the reaction temperature through the use of the class thermostat or air conditioner.

Design Aspect 3: This was generally well met with most students designing to collect at least five different values of independent variable.

Data Collection and Processing (DCP)

DCP Aspect 1: This aspect was generally well fulfilled. Most candidates recorded quantitative data in tables and usually recorded some associated qualitative observations. Many students recorded uncertainties with the data associated with the dependent variable but many students did not record the uncertainty in the values of the independent variable.

A number of candidates/schools used data loggers to measure the temperature change in enthalpy determinations but some just recorded the maximum temperature which seems to miss the point of the data logger.

DCP2: Most candidates gained credited for DCP 2 having selected an appropriate method for processing the data, either graphical or calculation, and then carrying it out to a decent extent.

However there were some recurring weaknesses. Very few students however took into consideration the heat capacity of the calorimeter, something that should really be an expectation for at least Higher Level candidates.

Another trend that is on the increase is associated with activities, such as calorimetry experiments, where students have to average the values of two variables obtained from repeat trials. What they should do is calculate an enthalpy value from each trial based on and then average the outcomes whereas what was frequently seen was the students averaging the input data (*e*.g. the masses of alcohol combusted and temperature change of water) and then doing one calculated. This is mathematically invalid and introduces an error into the calculation.

Another unexpected trend was the re-appearance of inappropriate bar charts and even pie charts. These are rarely the most appropriate data processing tools in Chemistry.

DCP3: Where graphical work was presented some candidates produced well drawn, full page graphs that made good use of the scales on both axes both by hand and through software. However, a large number of candidates produced computer generated graphs that consisted of very large and imprecise data points, an unsuitable trend line or no even trend line at all, poor y-scale use and graphs that were simply too small. Candidates need to be encouraged to apply the same rules for hand drawn graphs to electronic graphs as this would result in less corrupted data analysis.

Many students attempted lengthy uncertainty propagation calculations (sometimes to the detriment of obscuring the key calculations and findings) although often not fully successfully. If these uncertainty calculations are significantly wrong then the correct award is Partial for DCP aspect 3. However there is no need to double penalise in aspect 2 as well. The issue of significant figures is also a cause for concern and instruction needs to be carried out in this area.

Conclusion and Evaluation (CE)

CE Aspect 1: Candidates generally presented a reasonable conclusion and made a good attempt to justify it. However candidates frequently did not discuss the reliability of their data even if there were clear anomalous data points. Although most candidates did make efforts to compare percent error with percent uncertainty many candidates subsequently discounted random errors upon finding % error to be larger than % uncertainty even if % uncertainty itself was large and therefore a considerable contributor to the large % error. Candidates should comment on the magnitude of both and not discount either entirely.

CE Aspect 2: This was not a particularly well achieved aspect especially if aspect 1 had not been well fulfilled. Candidates often did not understand the magnitude or direction of impact of their identified weaknesses on their final results. Few students questioned or identified assumptions made such as the density of solution equals density of water for enthalpy change investigations, the accuracy of the standard solution concentration they were given for titration investigations, etc.

CE Aspect 3: This was fulfilled moderately well and most students achieved at least partial being able to identify one or two realistic improvements. Common weaknesses included suggestions being limited to increase the number of trials (even when the repetitions had been satisfactory for school level) or making use of unspecified more sophisticated equipment. There still persists a trend in teachers to over-rate very simplistic evaluations or suggestions often not related to cited errors. Candidates should evidence a clear understanding that manipulative mistakes are not considered limitations of the methodology.

Recommendations for the teaching of future candidates

- In Design tasks encourage students to identify a continuously measurable independent variable.

- All investigations for the assessment of DCP must include the recording and processing of quantitative data. Solely qualitative investigations do not give the students opportunity to fulfil this criterion completely. Teachers should check numerical calculations carefully.

- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.

- Teachers are encouraged to set some DCP tasks that will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.

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

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

- When assessing the CE criterion, require candidates to evaluate the procedure, cite possible sources of random and systematic errors, and provide suggestions to improve the investigation following the identification of weaknesses.

- Teachers should ensure that they act on specific feedback given by the moderator in the 4IAF feedback that is released through IBIS shortly after the results release.

- Teachers should ensure to implement internal moderation when the sample involves material from more than one teacher.

Further comments

With a view to gradually adjusting to the requirements of the new Internal Assessment framework and the demands of the Individual Investigation teachers are encouraged to take on board some new approaches even for the November 2015 cohort who will still be assessed under the old model. In particular looking at how to facilitate individualised action phases for the Design activities would be a good practise for the staff involved. Also it is time to rein in excessive length from high achievers. One report for simply DCP & CE assessment ran to fifty pages just for three simple enthlapy of neutralisation determinations – there is no need to wait for the new Communication criterion to sift out such excesses for the benefit of the student, teacher and moderator alike.

Higher level paper one

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 15	16 - 20	21 - 25	26 - 29	30 - 34	35 - 40

Component grade boundaries

General comments

1879 candidates submitted this paper, a 10% increase on November 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. It is therefore surprising that nearly all of the questions were left unanswered by at least one candidate.

The following are some statistical data based on 27 respondents (from 287 schools).

Comparison with last year’s paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
1	4	18	3	1

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	1	23	3

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	2	2	8	11	4
Presentation of paper	0	0	4	7	9	7

Two respondents commented that the clarity of wording was poor. It would help examiners setting future papers if *specific* examples could be included in the G2 if a less than “fair” grade is given.

Respondents commented that there was good coverage of the course and that the questions were fair. One or two suggested that candidates might find some of the questions “tricky”, although this might be because they hadn’t read the questions carefully enough. There is no intention on the part of the examiners to be “tricky”; all questions are designed to test one specific aspect of the course. Papers one and two complement each other in covering the entire syllabus.

Overall, this paper proved more difficult than last year’s, producing a lower mean mark (27.66 compared with 30.01).

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 90.51% to 37.59% (November 2013 for comparison, 97.62% to 37.76%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.78 to 0.21 (November 2013, 0.72 to 0.04), the higher the value, the higher the discrimination.

The following comments are made on selected individual questions:

Question 1

Two comments were offered. First that this question was relatively easy and secondly that it would be tedious to work out the M_r without the use of a calculator. In fact, the M_r was not required; all candidates had to do was multiply 0.040 by 10. The most popular incorrect answer was C, the candidates presumably not realizing that there are two moles of ammonium ions in each mole of compound.

Question 2

A significant number of candidates chose C having not taken the mole ratio into account.

Question 4

The most common incorrect answer was A, the candidates not having noticed that the question asks about the emission spectrum.

Question 7

The most common wrong answer was C.

Question 8

According to IUPAC, oxidation numbers are quoted in Roman numerals, oxidation states in Arabic. The nomenclature is clarified in the new syllabus, taught from September 2014.

Question 14

This was answered successfully by the most candidates (90.51%).

Question 15

The most common incorrect answer was D, with the sign reversed.

Question 20

There were two comments. One suggested a “quantum change in difficulty” and the other commented that “students are not normally taught how to eliminate the intermediate from the rate expression for the slow step”. In the event, 82.71% of the candidates scored correctly, the sixth “easiest” question on the paper.

Question 28

This proved to be answered correctly by fewest candidates (37.59%) with many choosing option D, reversing [HA] and $[A^-]$.

Question 27

Quite a few candidates included water in the expression, giving answer C.

Question 30

Over a quarter of the candidates were distracted by B.

Question 31

Candidates needed to notice that it is the “species produced” that is required. Many gave B, the *ions* attracted to the electrodes or A, the wrong ions attracted to the electrodes.

Question 32

60.56% gave the correct answer with the others fairly evenly spread over the three distractors.

Question 34

Although 65.41% gave the correct answer, nearly a quarter chose D.

Question 37

This was the second “most difficult” question with 38.52% scoring correctly. The common misconception was that there was homolytic fission of the C–Cl bond.

Question 39

Nearly a quarter of the candidates were persuaded, presumably by the C=C, to chose option C.

Recommendations and guidance for the teaching of future candidates

- In general, each question tests one specific aspect (assessment statement) of the syllabus.

- Paper one complements paper two so there is full coverage of the syllabus.

- Candidates should choose the best answer to each question.

- Candidates should be advised on how to approach a multiple-choice examination. No marks are deducted for incorrect answers so all questions should be answered.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 18	19 - 22	23 - 25	26 - 30

General comments

1218 candidates submitted this paper, a 1% increase on November 2013.

This paper consisted of 30 questions on the Subject Specific Core (SSC) and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and *no* credit deducted for incorrect answers. Most questions were not attempted by at least one candidate.

The following are some statistical data based on 26 respondents (from 204 schools).

Comparison with last year's paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
1	3	19	1	2

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	1	22	3

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	2	2	7	12	3
Presentation of paper	0	0	2	7	11	6

There were few comments but it was thought to be a good paper with an appropriate range of difficulty and clear diagrams. Whilst the paper setters do not set out to “trick” students, it is wise, as one respondent pointed out, for students to read the questions carefully.

Overall, this paper produced a lower mean mark (19.26) than last year’s (20.07).

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 87.72% to 25.23% (November 2013 for comparison, 97.62% to 37.76%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.66 to 0.26 (November 2013, 0.72 to 0.04), the higher the value, the higher the discrimination.

The following are comments on selected individual questions:

Question 1

This was the most difficult question on the paper (correctly answered by 25.23% of the candidates) but it was fair as it merely required candidates to multiply 0.040 by 10. Most candidates gave answer C, forgetting that one mole of the compound contains two moles of ammonium ions. Candidates sometimes find the questions on Topic 1 somewhat testing and they could be advised to leave them until later in the given time.

Question 5

We recognize that students might have found the molecular ions confusing. The question was answered correctly by 49.8% of the candidates and the question discriminated well (0.48). This is an example of a question set to discriminate the higher-grade candidates.

Question 9

Many thought that HCN would contain a dative bond.

Question 10

This caused some difficulties for candidates with opinion evenly divided between B (N_2, correct) and D (F_2). Candidates were presumably thinking about electronegativity rather than the number of bonds between the atoms.

Question 11

The most common misconception was that CO is non-polar.

Question 12

Many considered B, the breaking of C–H bonds, to be correct.

Question 14

Answer D was the most common error.

Question 15

This question was answered correctly by nearly 85% of the candidates which was encouraging.

Question 16

The most common error was to reverse the sign of the correct answer.

Question 22

Opinion was fairly evenly divided between answers B and C (correct).

Question 26

This question was answered correctly by the most candidates (87.72%).

Question 28

Answer C was the most popular distractor, given by nearly a quarter of the candidates. It is a common misconception that a bromine radical can displace a hydrogen radical.

Question 29

Answers A and B were often chosen as candidates presumably thought the mechanism to be either S_N1 or free radical.

Question 30

This was answered correctly by about 73% of candidates.

Recommendations and guidance for the teaching of future candidates

- In general, each question tests one specific aspect (assessment statement) of the syllabus.

- Paper one complements paper two so there is full coverage of the syllabus.

- Candidates should choose the best answer to each question.

- Candidates should be advised on how to approach a multiple-choice examination. No marks are deducted for incorrect answers so all questions should be answered.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 29	30 - 40	41 - 50	51 - 61	62 - 71	72 - 90

General comments

Many candidates were well prepared for the examination and answered questions with the required level of detail. There was evidence of understanding and analytical thinking in the stronger scripts.

The feedback on G2 Forms was mostly positive. 17 out of 21 respondents indicated that the paper was of “appropriate difficulty” while 3 respondents indicated that it was “too easy” and 1 respondent indicated that it was “too difficult”. 9 teachers found the paper easier than last November’s paper, 9 teachers found it of similar standard and 3 teachers found it more difficult.

A number of teachers commented that it was a fair and straightforward paper, and that there was a good spread of topics and a balance between quantitative and qualitative questions.

Some teachers welcomed the absence of a challenging Question 1 as they felt it helped students approach the paper with more confidence and demonstrate their knowledge and skills more successfully. A few teachers were concerned that the paper did not discriminate well between the more able students and recommended the inclusion of a larger proportion of more challenging questions. Some teachers thought the number of lines given for some answers should have been greater, although the vast majority of candidates did not need to use lined paper to complete their answers.

Questions 9 and 10 were the most popular in Section B.

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

- Writing precise definitions
- Correct use of significant figures and decimal places
- Explaining phenomena at a molecular level
- Applying chemical reasoning to answer unfamiliar questions

- Using the difference of pH units to determine the ratio of [H^+] between two solutions
- Explaining the conditions used in industrial processes involving equilibria using Le Chatelier's Principle, kinetics, value of K_c and economic considerations
- Explaining the nature of chemical bonds
- Correctly explaining the increase in successive ionisation energies within a shell in terms of decreasing electron-electron repulsion
- Identifying hybridization in a molecule
- Drawing electron energy diagrams to explain hybridization
- Drawing curly arrows with accurate starting and ending points
- Explaining solubility in terms of intermolecular forces
- Use of standard electrode potentials and the impact of concentration of solutions on the products of electrolysis
- Writing half-equations at electrodes
- Distinguishing between amount and concentration in kinetic effects
- Relating order and rate expression to mechanism
- Labelling the axes of the Maxwell-Boltzmann distribution curve
- Electronic configuration of transition metals

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

- Relating pH values to acidity
- Converting absolute to percentage uncertainty
- Calculating the enthalpy change of reaction from the enthalpies of formation
- Predicting the sign of the entropy change from the chemical equation
- Reading data from graphs
- Calculating relative atomic mass of a sample of an element from the mass numbers of its isotopes and their abundances
- Naming a compound from its structural formula

- Structural isomerism
- The difficulty of oxidizing ketones
- Esterification reactions
- The equation for the equilibrium in aqueous ammonia
- Identifying whether a half-reaction represents oxidation or reduction and justifying it
- Identifying the reducing agent in a redox reaction
- The relationship between electronic structure and the periodic table
- Recalling examples of transition metal catalysis
- The equation for the dissociation of water and the resulting equilibrium constant expression
- Electroplating
- Explaining the effect of a catalyst in terms of its effect on activation energy

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

SECTION A

Question 1

(a) A very well answered question.

(b) The majority of candidates calculated the percentage uncertainty correctly, however, more than half of them did not pay attention to stating the answer to the appropriate number of significant figures. Some candidates used river water data instead of rain water.

(c) More than half of the candidates calculated the correct ratio of hydrogen ion concentration. The majority of these candidates calculated the concentration of hydrogen ions in both samples, instead of simply using the difference of 2 pH units.

(d) Generally well answered. Some students only scored one mark, stopping at the calculation of the pOH or the concentration of hydrogen.

(e) About half the candidates wrote correct products, however, most of the candidates did not use reversible arrows. Several variations of incorrect products were given including H_2O_2 and CO.

Question 2

(a) More than half of the candidates identified the correct types and numbers of bonds, and many calculated the enthalpy change of reaction correctly gaining full marks. Common mistakes included reversing the signs of bonds broken and bonds formed, and using incorrect types or numbers of bonds, and arithmetic errors.

(b) (i) Less than half of the candidates answered the question correctly. Some were not specific in the definition of the standard enthalpy change of formation, while others had totally incorrect answers such as the formation of the compound from gaseous atoms.

(ii) The majority of candidates calculated the enthalpy change correctly. Some candidates made arithmetic errors.

(c) More than half of the candidates referred to bond enthalpies being average values that lead to a less accurate calculated value of the enthalpy change.

(d) A well-answered question by many candidates. Some candidates could not articulate a reason for predicting a negative entropy change and a few tried to explain the sign of the entropy change using the sign of the enthalpy change.

Question 3

(a) A very well answered question.

(b) Most candidates presented a curve that was steeper than the water vapour curve gaining the mark. However, most of the candidates started from the same vapour pressure as water at 0°C which was not penalized. Very few candidates drew an accurate curve.

(c) (i) This question was not well answered. Only a few candidates were able to give an appropriate observation. Many candidates could state the characteristics of a system in equilibrium but did not apply their knowledge to state an observation.

(ii) Only a few candidates gave adequate explanations gaining two marks. Many obtained one mark for saying that more molecules will be in the gaseous state. The reference to “molecular level” often went unnoticed.

Question 4

(a) The majority of candidates calculated the amounts of reactants correctly, and many of them applied the stoichiometric ratio correctly to determine the limiting reactant.

(b) More than half of the candidates calculated the mass of product correctly. Even if the final result was incorrect quite frequently students gained some credit through the application of ECF.

(c) Many candidates appreciated that a higher pK_a means a weaker acid. Some candidates did not refer to the pK_a or K_a value in their reasoning, failing to score a mark.

(d) More than half of the candidates were able to give the correct equation and many of them gave the correct state symbols.

Question 5

(a) Less than half the candidates recognized van der Waals' forces between the layers in graphite. Some candidates identified the type of attraction as "electrostatic" and others as "intermolecular forces" which were too general and did not score the mark.

(b) Well answered generally. Most candidates gave two uses (usually pencil lead and electrical conductor) and they were often able to explain the uses in terms of the structure.

Some teachers commented on the G2 Form that this question went beyond the scope of the syllabus. We consider that Assessment Statement 4.2.9 (which is an objective 3) includes this understanding and similar questions were asked in the past. It seems in fact that the majority of teachers discussed the uses of graphite during the teaching of its structure, and most candidates answered the question confidently.

Question 6

(a) Many candidates were able to name the two functional groups. Please note that to prepare new candidates for the 2016 syllabus, the markscheme was later altered to include the correct naming of functional groups following IUPAC guidelines.

(b) Many candidates were able to deduce the correct empirical formula.

(c) Many candidates were able to calculate the percentage composition by mass. Some candidates were inconsistent with significant figures. Some candidates left this question blank indicating that they are unfamiliar with the meaning of percentage composition.

Question 7

(a) More than half of the candidates answered correctly. Some candidates recognized that the concentration of products is larger than the concentration of reactants, but they failed to highlight the significance of a very large K_c. Some candidates said that the reaction went to completion, and were not awarded the mark, as they did not acknowledge the presence of equilibrium.

(b) Very few candidates commented that the hypothesis is not valid as the reaction nearly goes to completion when air is used (and hence there is no need to use pure oxygen).

The most commonly scored point was the expense of using pure oxygen, the second most common point was the shift in equilibrium position, and the third was rate of reaction. Some candidates showed a poor grasp of Le Chatelier's Principle, and some said there was no shift in equilibrium position. Other candidates wrote general answers that mixed up kinetics and equilibrium concepts. Many incorrect responses focussed on other gases in air that may also have reacted with SO_2 requiring the removal of impurities.

SECTION B

Question 8

(a) (i) Most candidates were able to calculate the relative atomic mass to the correct number of decimal places.

(ii) Only strong candidates were able to predict the same radius for the isotopes and gave correct reasoning. However, the majority of candidates predicted that a larger number of neutrons resulted is a smaller radius, reflecting a poor understanding of atomic structure.

(b) (i) Very few candidates were able to explain the increase in successive ionization energies for electrons removed from the same sub-shell. Many candidates gave incorrect reasoning.

(ii) The increase between the 10^{th} and 11^{th} ionization energies of magnesium was explained correctly by about half of the candidates. Few candidates scored the first mark by identifying the correct shells or sub-shells the electrons are removed from.

(c) (i) Well answered by many candidates. A few candidates were confusing ionic with covalent bonding, and some referred to a linear MgO molecule in an ionic lattice.

(ii) Few candidates were able to describe the covalent bond precisely. Those who didn’t score usually didn’t make any reference to pairs of electrons.

(iii) Many candidates obtained this mark with satisfactory arguments. It was disappointing to see the abundance of answers based on “is a metal with a non-metal” or “both are non-metals”.

(d) (i) A few candidates identified sp hybridization based on a linear structure. Only the strongest candidates were able to give the correct hybridization for oxygen as well.

(ii) This was most challenging question on the paper. It was rare to see a correct answer. It seems candidates did not have a good understanding of hybridization.

(iii) Less than half the candidates were able to define electronegativity precisely. Many candidates did not relate it to the pair of electrons in a covalent bond, and simply talked about attracting electrons, which was not sufficient for the mark.

(iv) Many candidates gained the first mark by stating that oxygen has more protons than carbon. But very few candidates identified the second factor, which is the smaller radius of oxygen.

(e) (i) More than half of the candidates drew a smooth curve that was central to the data points. Errors included straight lines, curves joining all data points, or a curve that was not central to the points.

(ii) A very well answered question. Some candidates converted the units of p and V incorrectly and others did not read the scales of the graph correctly.

(f) (i) Many candidates could explain the behaviour of indicators, but there were also some poor answers that did not acknowledge the importance of equilibrium in the action of an indicator.

(ii) Most candidates suggested a suitable indicator.

Question 9

(a) The naming of the organic compounds was generally well answered, though quite frequently candidates benefited from the decision not to penalise the unnecessary “2” in “butan-2-one”. Propanol was a frequent incorrect answer.

(b) (i) Generally well answered but there were some answers that reflected a poor understanding of structural isomerism.

(ii) Well answered.

(c) (i) Generally well answered. But some candidates gave propanal as the product for propan-1-ol, and other candidates were confused about the products of the oxidation of alcohols.

(ii) Most candidates knew the colour change of the dichromate solution during the reaction.

(d) About half of the candidates gave the correct two-stage conversion gaining four marks. Many candidates were not able to score any marks and some only scored marks for the reagents. Several candidates named the products instead of drawing the structural formulas.

(e) It was pleasing to see a large number of candidates able to draw the curly arrows accurately and gaining full marks on the elimination mechanism, though some candidates continue to lose marks through a lack of precision about the start and finish points of curly arrows. Common mistakes also included attacking the wrong H, reversing the direction of some of the curly arrows, and giving an S_N2 mechanism instead of elimination.

(f) (i) Most candidates identified and drew the ester correctly.

(ii) Very well answered.

(g) About half of the candidates gained full marks. Many candidates omitted the reversible arrow. Some candidates only answered part of the question.

Question 10

(a) (i) Very well answered.

(ii) Most candidates answered correctly. The most common mistakes were doubling the oxidation number of H in H_2O, and entering a wrong oxidation number for elemental oxygen.

(iii) A well-answered question.

(b) The aqueous solubility of oxygen gas was often poorly explained, with the discussion focussing on the intermolecular forces found in each substance separately and then stating that “like dissolves like”.

(c) Well answered by most candidates.

(d) The majority of candidates were able to give two valid examples of transition metals or their compounds acting as catalysts.

(e) (i) Very well answered.

(ii) Well answered.

(iii) About half of the candidates were able to gain full marks. Some candidates found difficulty in connecting the increase in K_w to the position of equilibrium.

(iv) About half of the candidates were able to calculate the pH from the K_w value.

(f) (i) Many candidates identified chlorine as the product, but the other two marks were more discriminating. Some candidates clarified that Cl^- was oxidized in preference to OH^- because of its high concentration, but very few related the situation to the electrochemical series.

(ii) This was poorly answered by many candidates. Common mistakes included releasing sodium at the cathode, reversing electrodes and unbalanced redox half-reactions where the electrons were sometimes on the wrong side of the equation.

(g) Very well answered. Most candidates determined both electrodes correctly. The main difficulty for some candidates was choosing a suitable electrolyte.

Question 11

(a) (i) Most candidates related the rate of reaction to the gradient of the curve, but only a few suggested drawing a tangent at $t = 0$.

(ii) Answers were often disappointing and only a few candidates gained full marks. Candidates often talked about the number of reactant molecules decreasing but neglected to relate this to a lower concentration. Also some candidates still fail to highlight frequency rather than the number of collisions.

(b) Well answered by more than half of the candidates. The labelling of the axes was a challenge for some candidates. The annotation of the diagram with the energy of activation with and without a catalyst was mostly correct, though some weaker students confused it with the effect of temperature and constructed a second curve. Some candidates could not offer an explanation for the third mark.

(c) (i) Only a few candidates scored this mark. Many candidates stated that a reactant concentration having no effect indicated that the reaction that was zero order in that species, rather than describing the underlying mechanistic reason for the zero order dependence.

(ii) More than half of the candidates could construct a correct rate expression from information about the order of the reactants.

(d) A number of candidates gave a linear relationship, rather than an exponential one, between reaction rate and temperature.

(e) (i) Defining the standard enthalpy change of reaction was not well answered.

(ii) More than half of the candidates calculated the amount of energy released correctly.

(iii) Half of the candidates were able to gain the three marks. Many candidates lost the third mark for not quoting the negative sign for the enthalpy change. Quite a few candidates used a wrong value for the mass of water.

(iv) Many good answers. A Hess's Law cycle wasn't often seen. Quite a few candidates scored through ECF from (iii).

(f) (i) Most candidates knew that zinc has a full 3d sub-shell but almost all missed out on the second mark about only having one possible oxidation state in its compounds.

(ii) This was a challenging question for many candidates. A large number of candidates did not give the correct electron configurations for the ions, and only few mentioned the stability of the half-full d-sub-shell. Very few scored the third mark.

Recommendations and guidance for the teaching of future candidates

- Give candidates more practice in applying chemical knowledge to problem solving in novel contexts.

- Enable candidates to analyze descriptions of experimental situations and data related to these.

- Provide opportunities for writing explanations of bonding, successive ionization energy trends, periodic trends, solubility, etc. This helps to deepen understanding and avoid recall.

- Provide opportunities for practicing explaining chemical phenomena in terms of the behaviour of particles.

- Ensure the students use precise terminology.

- Integrate the practical programme with the rest of the course.

- Practice writing equations for electrode reactions and predicting the products of electrolysis using the electrochemical series.

- Practice dealing with significant figures and decimal places appropriately throughout the course.

- Practice organic mechanisms, ensuring that curly arrows start and end in the correct positions.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 21	22 - 27	28 - 33	34 - 39	40 - 50

General comments

The paper was generally more straightforward than that set the previous year with many questions being similar to those that candidates may have met in papers that they used for exam preparation. Some teachers felt that the paper was too long for the time available, but there was little evidence of this on student scripts.

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

- Relating the ratio of pH to the ratio of $[H^+]$

- Writing chemical equations for simple reactions

- Handling of units of *p* and *V*

- Fully explaining of equilibrium situations and the choice of reaction conditions

- Answering hypothesis questions by supporting a statement with good chemical reasoning

- Explaining fundamental processes, especially detection, in a mass spectrometer

- Applying chemical reasoning to answer unfamiliar questions

- Describing metallic bonding

- Drawing curly arrows with accurate starting and ending points

- Basic definitions
- Explaining aqueous solubility in terms of intermolecular forces

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

- Relating pH values to acidity
- Converting absolute to percentage uncertainty
- Drawing a best-fit curve through the data points on a graph
- Reading data from a graph
- Identifying functional groups in a structural formula
- Writing combustion equations
- Calculating the relative atomic mass of an element from those of its isotopes and their natural abundances
- Using stoichiometric calculations to identify the limiting reagent and calculate the mass of a product
- Drawing simple Lewis structures
- Predicting bond angles and bond polarity
- Naming a compound from its structural formula
- Structural isomerism
- The oxidation of alcohols and carbonyl compounds by potassium dichromate(VI)
- Applying Hess' law
- Identifying and justifying whether a half-reaction represents oxidation or reduction
- Identifying the reducing agent in a redox reaction
- Writing electrode reactions for electrolysis
- The property used to order elements in the periodic table
- The relationship between electronic structure and the periodic table

- Determining the effect of catalyst improvement on a product -versus- time graph

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

Section A

Q1 – Parts (a) and (b) were correctly answered by the majority of candidates, the most common mistake being to assume that (b) referred to the sample identified in (a). Part (c) was rather more challenging and students frequently used the ratio of the pH rather than the ratio of the $[H^+]$. Part (d) should have been very straightforward, but was often poorly answered with some innovative products. The absence of an equilibrium arrow was not penalised, but if it had been many students would have lost a mark.

Q2 - Almost all candidates gained the mark for drawing a best-fit curve through the data points on the graph, though some insisted in trying to put a straight line through obviously non-linear data. Many students identified the inverse proportionality of pressure and volume in Part (b), though the terminology often lacked precision. Most students could identify the correct equation to use in Part (c) in order to calculate the amount of gas from the specified data point, though quite often they had problems with units, either as a result of incorrectly reading the axis on the graph or as a result of conversion.

Q3 – The better candidates had little difficulty in correctly identifying the forces both within and between the layers of graphite and pointing out that stronger forces produce shorter bonds. In Part (b) most candidates knew of the use of graphite in pencils, though the property identified was often the ability of the layers to slide over each other rather than their ability to break free, and many students struggled for a second use, though a significant number mentioned and correctly explain its electrical conductivity.

Q4 – The functional groups in fructose proved a challenge for only the weakest candidates, with mistaking the carbonyl group for “aldehyde” being the most common error. Please note that to prepare new candidates for the 2016 syllabus, the markscheme was later altered to include the correct naming of functional groups following IUPAC guidelines. Many students could also correctly convert the structural formula into an empirical formula in Part (b) and then went on to correctly determine the percentage by mass of each element in Part (c), though sometimes only with the help of ECF. Writing the correct combustion equation was difficult for only the weaker candidates.

Q5 – A number of candidates seemed confused as to what Part (a) required, but most students could relate completeness of reaction to the value of K_c, a common error being to declare the reaction “complete” rather than “almost complete”. Obviously some candidates had covered the “compromise” conditions for the reaction in some detail and could give a thorough answer to Part (b), though candidates often failed to give reasons (forward reaction exothermic and decreases moles of gas) for equilibrium shifts. Candidates seemed less at ease with the hypothesis question in Part (c), with many stating opinion without any reference to the hypothesis, in addition quite a few failed to realise that two separate factors were required to gain full marks.

Section B

Question 8 was the most popular choice of question in Section B, with Questions 6 and 7 being of similar popularity.

Q6 – In Part (a) most candidates gained full marks, with the most common error being a failure to quote the answer to the precision specified, but the explanations of deflection, and more particularly detection, in the mass spectrometer were weak. The prediction of relative atomic radii of the isotopes, something that required the application of reason rather than recall, also proved much more challenging. Part (b) revealed that many candidates have a very weak understanding of the metallic bond with many thinking the bonding was ionic.

Even when they knew about a cation lattice and delocalized electrons, a mark was frequently dropped by failing to specify that the attraction between them was electrostatic. Most candidates wrote the correct equation in Part (c), but it is still disturbing that some students at this level cannot write even the most straightforward chemical equation. In Part (d) many students proved capable of carrying out routine stoichiometric calculations to identify the limiting reactant and use the result to find the mass of the product.

Even if the final result was incorrect quite frequently students gained some credit through the application of ECF. Only the better candidates could write an equation for the neutralisation of phosphoric(V) acid and even the routine derivation of a conjugate base from the formula of the acid proved difficult for many. In Part (e) most students could manage the correct Lewis structure, though some lost the mark through omitting the charge. Many candidates also scored well on the shape of the ion and the polarity of the P-H bond.

Q7 – Most students scored well on naming the required compound from its formula in Part (a), likewise defining structural isomers and recognising compounds related in the way, required in Part (b), were rarely a challenge. In Part (c) students could usually identify whether compounds underwent oxidation and the products formed, with the most common mistake being to fail to notice that there was excess dichromate(VI) in the case of the primary alcohol. The mechanism required in Part (d) seemed to be known to many, though many candidates continue to lose marks through a lack of precision about the start and finish points of curly arrows. Many students gained at least one mark for the definition standard enthalpy change in the first section of Part (e), though few displayed the precision required for both marks. In the second section quite a few tried to solve the enthalpy problem by calorimetry rather than using the enthalpy of reaction that had been given. Generally speaking the next section, that did require calorimetry, was better done though the calculation of the amount of reagent and using the mass of liquid rather than solid for the heat evolved proved a challenge for some. Many candidates correctly combined their results, sometimes invoking Hess' Law, in the final section, though many candidates benefited from the application of ECF.

Q8 – In Part (a) almost all candidates could correctly identify the equation as an oxidation reaction and justify their choice. Assigning oxidation numbers to particular species proved slightly trickier, with many no knowing that elements always have an oxidation state of zero.

Combining the half equations also provided a bit of challenge with many equations having residual electrons, though most students could correctly identify the reducing agent. The aqueous solubility of oxygen gas in Part (b) was poorly explained, with the discussion being most frequently in terms of polarity rather than invoking hydrogen bonding. The electrolysis question in Part (c) was generally well answered, though most relied on “completing the circuit” to obtain the salt bridge mark with few showing any comprehension of the way in which this was achieved. Both the property responsible for the ordering of the periodic table and the relationship of electronic structure to position in the periodic table, required for Part (d), were well known and it was rare for a student not to gain full marks. Similarly in Part (e), most students correctly drew the curve that would result from a more effective catalyst. Many also seemed to be aware of the basic idea of how to find the reaction rate, though correct use of the terms “tangent” and “gradient” was rare and many failed to note it referred to “initial rate”. Most students could also identify an appropriate alternative method for monitoring the rate. In the final section most students could accurately label the axes of a Maxwell-Boltzmann curve and many could also use it to explain the effect of a catalyst, though some weaker students confused this with the effect of temperature and constructed a second curve.

Recommendations and guidance for the teaching of future candidates

- Train students to read questions carefully to determine what precisely is being asked for, then paying attention to the mark allocation and command terms used in determining what would be an appropriate response.

- Work through previous examination papers paying attention to details of the mark scheme.

- Explain to students the basic ideas behind time management in the answering of a long examination paper.

- 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. They also need to be able to accurately relate appropriate observations and to draw inferences from these.

- Encourage candidates to set out calculations logically and be aware that credit for correct technique in later stages will gain credit, in spite of errors at a prior stage, through the application of ECF.

- Practice explaining both familiar and unfamiliar chemical phenomena in terms of the underlying chemical principles and the behaviour of particles at a sub-microscopic level.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7

Mark range:	0 - 8	9 - 16	17 - 21	22 - 27	28 - 32	33 - 38	39 - 50

General comments

The following are some statistical data based on 27 respondents (from 287 schools).

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
2	6	18	1	0

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	2	24	1

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	0	5	7	13	2
Presentation of paper	0	0	4	8	8	7

Candidates found this examination more straightforward than that set in November 2013 and many performed well. Most seemed well prepared and attempted every part of their chosen options. The most popular options were A, B, and D; C and F were the least popular. Many of the weaker candidates appeared to choose Option E while some chose either Option C or F.

In many cases these candidates tried to answer questions with limited specific chemical knowledge of the option itself and hence performed poorly. It is really important that candidates are taught their chosen options and not left to self-study. Many candidates with a biology background tend to rely on their biological knowledge; candidates choosing Option B (Human biochemistry) or Option D (Medicines and drugs) must be prepared for specific chemistry questions. Many of the stronger candidates tended to opt for Options A, D and G and performance here was generally of a very high standard.

The most common "option combinations" were BD, AB, AD, BE and AG.

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

- How a change in ligands affects the colour of a transition metal complex
- Comparing structures and formulas clearly
- Genetic information in DNA
- Correctly assigning hydrogen bonds in A–T
- Electrode equations in electrolysis
- Environmental impacts of the chlor-alkali industry
- Inorganic catalysis mechanisms
- Construction of a photovoltaic cell
- Hydrogen bonding in Kevlar®
- Specific medical uses of morphine
- Side effects of caffeine
- Greenhouse effect
- Multi-stage distillation
- Effect of antioxidants on photo-oxidation
- Oxidation of heme

Comparing substitution reactions of chlorobenzene and (chloromethyl) benzene

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

- IR
- NMR
- Calculation of the number of C=C bonds in a fatty acid
- Structures of dipeptides from amino acids

- Characteristics of enzymes
- Properties of aluminium
- Potency of diamorphine compared with morphine
- Modification of penicillin side-chains
- Environmental impact of NO_x
- Effect of O_2 and O_3 on UV light
- Contribution of CFCs to ozone depletion using free radical equations
- Food sources and nutrients
- Effect of halogens on acidity of carboxylic acids

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

Option A - Modern analytical chemistry

Candidates found this option quite straightforward and there were many average to excellent answers.

Question 1

In general, most were able to deduce the molecular mass of the compound and how it is found. Unfortunately, some gave an account of the mechanism of fragmentation rather than giving *information about this particular compound.* Part (a) (i) asks about the mass spectrum; some candidates made the mistake of mentioning the IR spectrum at this point. It was encouraging to see the + sign normally included in any discussion of fragments in (a) (ii). The functional groups present and absent were usually identified correctly and most deduced why the compound could not be propanoic acid. Although, we allowed candidates to say that there was no OH bond present, they should be more careful to specify that it is the bond between the O and the H atoms that is not present. Care still needs to be taken in drawing structures, as in (b) (iii), to ensure the correct bond linkage. Many gave structures with an –OH group even though it had been ruled out in the previous part. Most were able to score well on the ^{1}H NMR question although there were some inaccuracies in the chemical shifts suggested.

Question 2

Atomic Absorption was usually correctly identified and good answers were given in (b) when the calibration curve was mentioned. The answers to (c) (i) were rather patchy with few recognizing that there is a *replacement* of ligands and few mentioning that colour is caused by movement of electrons between d-orbitals. This was not quite the “usual” *why are TM complexes coloured?* type of question. Most gave a good answer to (c) (ii).

Question 3

Although (b) was usually answered correctly, many only scored one of the two marks available for (a). Some candidates described how to carry out paper chromatography instead of explaining how the separation takes place.

Option B – Human biochemistry

This was one of the most popular options.

Question 4

Questions about iodine number have appeared on many occasions and it was disappointing that this was answered poorly. Candidates need to learn this and be careful not to muddle units (for example using amount instead of mass). In (b), the number of moles of iodine and fatty acid were often correct and then the final mark was lost with an extraordinary answer, 20, 2 or 3 for instance. It was difficult to understand the logic of the calculations at this point.

Question 5

Candidates must remember that they are describing *carbon-carbon* double bonds; just “double bonds” does not score. Few candidates scored all four marks because some obvious similarities, such as *same number of carbons* and *both contain COOH group* were omitted. Some candidates found it helpful to tabulate the answer.

Question 6

Part (a) (i) was relatively straightforward but there were some interesting errors such as only one tripeptide given, only one dipeptide given, and incorrect peptide linkages. Part (ii) was answered well. The explanation in (b) often lost a mark because the protein was not broken down by concentrated $HCl(aq)$. The rest was generally answered with a good deal of confidence although there were two common errors. First that when the amino acids were in a given buffer solution they would move under the influence of a potential difference and then ***stop moving*** *at their isoelectric point.* Secondly, that a current was applied instead of a potential difference. Candidates should think through their answers to make sure they give the steps in the correct order.

Question 7

In (a), encoding is determined by the base *sequence* and each sequence encodes for one amino acid. Unfortunately many candidates described base pairs and how nucleotides are connected rather than how information is encoded. The mark in (b) was invariably gained but whilst adenine was usually correctly identified in (c) and sometimes that there are two hydrogen bonds involved, the positioning and linking of the hydrogen bonds was less than perfect. This included hydrogen bonding to a carbon atom on the ring rather than to nitrogen. There were no “tricks” here; the structure could be copied directly from the Data Booklet in the correct orientation.

Question 8

This question was generally well done although some candidates need to note that *three* characteristics are required for the two marks.

Option C – Chemistry in industry and technology

As is previous sessions, this was one of the least popular options.

Question 9

The reason for adding cryolite was well known but the electrode equations were shaky, particularly balancing the equation at the positive electrode (anode). Most had a good idea of why the anodes would need to be replaced from time to time. The strength of the alloy was understood but candidates needed to see that *two* properties were required for one mark in (b) (ii) – and *light* or *lightweight* was not accepted. In (c), the environmental impacts were not well done, very generic and not specific to this process.

Question 10

The mechanisms either drew a blank or candidates simply stated the names of the mechanisms instead of providing outlines of the two mechanisms as asked for in the question; the disadvantages were better known.

Question 11

Answers, in general, needed to be more specific with an indication of how p-type and n-type are made from silicon. For a straightforward question, performance was not good. One respondent was concerned about the meaning of “construction”.

Question 12

There were good descriptions of liquid crystals and many understood the thermal change in (b). The aspect of Kevlar® allowing it to be used as a liquid crystal was better known than that for bullet-proof jackets. Candidates needed to recognize the *strong* hydrogen bonding *between* chains.

Question 13

Most were familiar with nanotechnology and there was a fair understanding of its development and use.

Option D – Medicines and drugs

This was one of the most popular options.

Question 14

Candidates needed to recognize that the question asks about the *medical* use of morphine and its derivatives. Although many candidates struggled to give two advantages most scored the mark for disadvantages. Part (b) was usually answered well except by the candidates who got it the wrong way round.

Question 15

One similarity was straightforward, but correct differences were more difficult for candidates.

Question 16

The amine was usually identified correctly in (a) but in (b) one of the side effects given was often a variation on *stimulant* and thus no mark was scored.

Question 17

The role of Florey and Chain did not seem to be too well known with many incorrectly listing large-scale production. In (b), the side-chain modification was better known than the working of penicillins. Whilst many had the correct general idea of the importance of the beta-lactam ring in (c), a precise explanation was needed.

Question 18

The ways in which viruses differ from bacteria were well answered but, in (b), how antiviral drugs work was less well described. The AIDS problem had clearly been discussed but some of the answers lacked focus.

Question 19

This was answered poorly and many referred to combinatorial chemistry. The reference to drug design was almost always ignored.

Option E – Environmental chemistry

This was offered by more candidates than in previous sessions.

Question20

In part (a), lightning was usually answered correctly but the *high temperature* aspect of the internal combustion engine was often omitted. Most scored in (b), although air pollution was not accepted, and a catalytic converter was the most popular answer to (c).

Question 21

We often ask about the greenhouse effect and candidates should have prepared themselves better for this. The answers were disappointingly poor. There were still many references to “reflection”, “trapping” and “bouncing” of energy/light. Methane was a popular choice for (b), run a close second by CFCs.

Question 22

There was a reasonable appreciation of the effect of O_2 and O_3 on UV light but the distinction between bond order 2 in O_2 and 1.5 in O_3 (or similar) was often not made. There were some good answers to (b) and most were consistent about the use of dots (•) to signify radicals. It is worth noting, however, that the question includes the words “using equations”. Candidates who did not use equations did not score any marks.

Question 23

Those who actually answered a question about multi-stage distillation scored well but a significant number chose to explain primary, secondary and tertiary treatment of water. Osmosis generally scored well. In both cases, however, disadvantages were not necessarily based on the correct process.

Question 24

The equation caused some difficulty for many students; electrons were omitted on the left-hand side, incorrect products were given and equations were left unbalanced. In (b), few understood the significance of the loss of nitrates.

Option F – Food chemistry

This was one of the least popular choices.

Question 25

This was answered well and the loss of marks either came from the omission of *carbon-carbon* in (c) (i) and/or the omission of *two* possible types of degradation. Two had to be given to score the mark.

Question 26

Shelf life and factors affecting it were well understood and many managed the free radical reaction in (b). The behaviour of antioxidants in (c) was less well known.

Question 27

Only a few were able to explain how meat becomes discoloured but most were able to state how to minimize oxidation in part (a) (ii). Most scored three of the four marks available for the comparison of structures in part (b).

Option G – Further organic chemistry

This was offered by more candidates than in previous sessions and those who attempted this option generally gave a good account of themselves.

Question 28

In part (a) most were able to give the correct order of acidity and many were able to explain why the halogen substituent would increase the acidity of the acid. In (b) (i), the correct answer was usually given but the common error in (ii) was not to state that a *solid* or *precipitate* is observed. In (c), those who were able to identify the cyanohydrin A were, in general, able to score the last two marks although some quoted *water* rather than an *aqueous acid* for the last. Candidates need to learn the mechanism for the dehydration reaction in part (c). Full marks were rare and candidates need to place curly arrows carefully, paying particular attention to their beginnings and endings. In part (d) there were good explanations but *because of the inductive effect* is not a suitable explanation for the charge on the intermediate being reduced/stabilized.

Question 29

The order of reactivity in part (a) (i) was usually correct but in (ii) candidates had not appreciated that the question is about the *rate at which they (the halogen atoms) are substituted by reaction with aqueous sodium hydroxide*. Part (b) (i) provided some good answers although the most likely box to be wrong was the reaction type with ethanol. Part (b) (ii) was answered well.

Recommendations and guidance for the teaching of future candidates

- Read the question carefully and write the answer legibly, keeping within the box. Examiners can only see (and therefore mark) what is written within the box. If they cannot read what you have written no marks can be awarded.

- If you erase an answer, the remains of the first attempt can show up on the scan and “stray” bonds are seen meaning a possible remark. It is probably better to rewrite the answer on an additional sheet – and say so in the answer box. You should always refer examiners to work presented on an additional sheet.

- In general, the box should be more than sufficient for an answer gaining full marks. There is no *need* to fill the box. Indeed, writing more (incorrect) answers may decrease the score for the correct answers. For instance, if you are asked for two reasons and give three, one of which is wrong or contradicts a previous correct answer, only one mark is likely to be scored.

- Pay attention to Command terms and their meanings. Practise writing clear and succinct answers using correct scientific terminology.

- Learn the required organic reaction mechanisms, paying close attention to the positioning of curly arrows.

- Learn from past question papers and mark schemes, ignoring the “accept” or “allow” guidance to examiners. These are less than perfect answers. Develop strategies for planning and writing coherent responses.

- Ensure that the Options are taught rather than asking students to rely on some of the current textbooks. Consider integrating the learning and teaching of options within the Core teaching.

- Ensure that the chemical processes of biological concepts are well understood

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 18	19 - 22	23 - 26	27 - 30	31 - 40

General comments

The following are some statistical data based on only 27 respondents.

Comparison with last year's paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
4%	16%	69%	4%	4%

Level of difficulty

Too easy	Appropriate	Too difficult
4%	92%	4%

Suitability of question paper in terms of

	Very Poor	Poor	Fair	Good	Very Good	Excellent
Clarity of wording	0%	0%	15%	23%	50%	12%
Presentation of paper	0%	0%	8%	28%	36%	28%

Based on the G2 comments teachers in general found this to be a fair paper and it appears to have been well received. Compared to previous sessions there were very few concerns raised by teachers. There were no references to any questions being duly problematic or off-syllabus. The general consensus amongst examiners this year was that candidate performance certainly appeared reasonably good across all options though some felt it was a relatively easy and straight forward paper. The paper appeared balanced overall, though Option B appeared easier according to G2 comments.

In most options there was a good smattering of easy marks. However there were a number of equally challenging sub-questions in each option, and the paper certainly tried to bring out more of the chemical principles in Options A, C and G.

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

- Mass spectrometry - fragmentation
- Deduction of correct chemical shifts in ^{1}H NMR spectroscopy
- Electrolysis of aluminium – half-equation at positive electrode (anode)
- Mechanism of homogeneous catalysis
- Explanation on a molecular level of the effect of temperature increase on liquid crystals
- Explanation of the way mild and strong analgesics prevent pain
- Functional groups in general
- Side effects of caffeine consumption
- Role played by Florey and Chain in the development of penicillin
- The Greenhouse Effect
- Advantageous properties of hydrocarbons and hydrofluorocarbons over CFCs
- Oxidation processes associated with the discolouring of red meat involving the colourant heme
- Importance of international agreement on permitted artificial colourants in food
- Grignard reagents
- Organic reaction mechanisms
- Explanation of the order of stability of carbocations

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

Option B was very well answered by candidates and some specific questions in Options A and D. The performance on Option G was noticeably weaker this session. Many candidates demonstrated a good ability to perform stoichiometric calculations, discuss core analytical techniques such as chromatography and electrophoresis and many made good attempts to interpret spectra, though few scored full marks.

- IR spectroscopy
- Paper chromatography
- Iodine number calculation
- Dipeptide formation
- Electrophoresis
- Fatty acids
- Nanotechnology
- Differences between bacteria and viruses
- Anti-viral drugs
- Formation and depletion of ozone
- Shelf-life
- GM foods

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

Option A – Modern analytical chemistry

This with Option E was close to the third most popular option on the paper, and in general often attracted some of the stronger candidates. Performance was reasonably good and there were a number of good discriminating questions embedded which made the option overall well-balanced from an assessment perspective. Some candidates gave only general statements as answers to questions rather than answering the actual questions posed (for example Question 1 (a) (i), (ii), (c) (ii)).

Question 1

In (a) (i) many candidates associated the molecular ion peak with the molar mass of the compound. Some stated incorrectly that the mass was 74, instead of stating that the molar mass was 74 g mol^{-1}. (ii) proved problematic for a number of candidates and the difference between the loss of radicals and the positively charged fragments remaining was often lost. Greater emphasis on this difference in the teaching of this part of the curriculum on fragmentation might be worth exploring further with cohorts.

In (b) (i), most candidates identified the presence of the C=O and the absence of the C=C groups on the IR spectrum.

In (ii), although a large number of candidates stated that there is no broad absorption in the 2500-3300 cm^{-1} range, equating this to the absence of the OH bond in the IR spectrum, surprisingly some gave a more limited range of 3200-3600 cm^{-1} and associated this with the absence of hydrogen bonding. Although Table 17 of the Data Booklet does not refer specifically to the broad nature of the OH absorption in the 2500-3300 cm^{-1} range for carboxylic acids, it might be worth pointing this feature out in the teaching of IR spectroscopy, based on careful analysis of real spectral examples of carboxylic acids. In (iii), the most common mistake involved candidates drawing isomers including the OH group, which scored no marks. One G2 comment claimed that drawing an ester is not part of the syllabus. However, esters are mentioned explicitly in AS 10.1.11.

In (c) (i), nearly all identified the correct region of the EMS, namely radiowaves. (ii) proved to be a good discriminating question. Many knew that compound I had one hydrogen environment and compound II had three hydrogen environments, but only the better candidates scored the second mark. The most common mistake involved stating that compound I had a chemical shift range 0.9-1.0 ppm for the six methyl hydrogens. Many candidates clearly did not realise that the methyl groups in propanone are adjacent to the carbonyl, so hence have a higher value for the chemical shift, i.e. 2.2-2.7 ppm.

Question 2

This question was often well done and most identified AA as the correct analytical technique. The better candidates also scored full marks in (b), mentioning the idea of the construction of a standard calibration curve and the associated measurement of absorption from the water sample. Candidates who had seen this experiment in a laboratory setting clearly knew exactly what was involved.

Question 3

Parts (a), (c) and (d) were well done. In (d) some candidates stated that solubility is a factor. However solubility depends on conditions and is not a factor per se. In (b) although often candidates stated that different components have different affinities for the two phases, some did not mention the two phases and others did not refer to comparative movement to score the second mark (*e.g.* components very soluble in the mobile phase will travel further /*OWTTE*). One G2 comment stated that the command term Explain was not appropriate for this question. This was discussed at GA and the senior examining team felt that this indeed was the most appropriate command term for the nature of the question asked.

Option B – Human biochemistry

This was the second most popular option on the paper after Option D and generally performance was very satisfactory.

Question 4

The better candidates gave the correct definition of iodine number, namely the mass in grams of iodine reacting with 100 g of fat. This is the precise definition of iodine number that should be emphasised to candidates in the teaching programme. Some candidates incorrectly stated amount in grams instead of mass in grams of iodine, which showed poor understanding of the inherent difference between mass, measured in grams, and amount, measured in moles. The iodine number calculation on calculating the number of C=C in eicosapentaenoic acid was well answered and full marks were typically scored.

Question 5

The majority were able to list two health problems associated with a diet that is low in dietary fibre.

Question 6

In (a) most candidates drew either the general formula of a 2-amino acid or drew the structure of a specific 2-amino acid. In (b) (i) the structures of the two dipeptides formed by the reaction of glycine with valine were usually correctly represented and water was identified by almost all.

In (c) electrophoresis was well understood as a biochemical analytical technique. However some candidates did not read the question carefully and dropped the first mark for not stating that hydrochloric acid needed to be added to separate the individual amino acids.

Question 7

The correct answer to (a) was that it is important to have a diet that contains essential fatty acids as such acids maintain good health. In (b), few scored all four marks, though many did manage to score three marks. The most common mistake involved candidates not understanding the fact that the omega-6 and omega-3 nomenclature comes from the closest C=C on the sixth carbon from the methyl end in the case of linoleic acid and the third carbon from the methyl end in the case of linolenic acid.

Option C – Chemistry in industry and technology

A number of candidates chose this option in N14 and performance was similar to Option A, with the better, well-prepared candidates doing quite well. The option had a number of good discriminating questions also. Of those that did attempt this option many appeared to have a solid grasp of the subject matter tested.

Question 8

In (a), most were able to write the correct half-equation for the cathode though incorrect states were commonly seen, *e.g.* (aq). The anode half-equation was not well known. Both parts of (b) were well done. In (ii), incorrect answers included malleability and light mass.

Question 9

Homogeneous catalysis was usually identified in part (a). In (b), few got the correct mechanism for Fe^{2+}(aq), namely the fact that there is a change in the oxidation state. The command term, outline needs to be differentiated from state. Correct disadvantages were usually identified and for Fe(s) most knew that the mechanism involved reactants being adsorbed onto the surface. Outline is an objective 2 command term, as given on P.11 of the guide and equates to giving a brief account or summary. Hence simply stating heterogeneous for the mechanism was incorrect for Fe(s) for example. Candidates need to pay close attention to the command terms as part of their examination preparation.

Question 10

Few scored all four marks in this question. Some candidates hedged their bets stating that fuel cells are expensive and lead-acid batteries are cheap. Although this is correct candidates should only use this type of comparison for either one advantage or one disadvantage.

Question 11

An understanding of liquid crystals was generally conveyed. Some candidates stated that liquid crystals show properties of liquids and solids simultaneously which did not score as they did not mention the crystalline state explicitly for solids. In (b) only the really top-tier candidates were able to explain the question asked on a molecular level *i.e.* the fact that thermal agitation disrupts the directional order of the liquid crystal and as a result the rotation of plane polarized light is disrupted. This question proved to be possibly one of the hardest questions on the paper overall for candidates.

Question 12

Both parts of question 12 were reasonably well answered, though a small minority of candidates either did not give the 1-100 nm range or failed to give correct units here. In (b) some vague answers such as “may cause environmental destruction” were cited, which did not score.

Option D – Medicines and drugs

This was by far the most popular option. Performance did vary quite a bit. The stronger candidates did well on this option but it was disappointing at the lack of chemistry conveyed by some of the weaker candidates, in particular functional groups. Far too many of the weaker candidates were overly dependent on biological principles. The emphasis here must be on applying core chemical concepts to the associated applied topics on medicines and drugs embedded within this option and candidates should not simply depend on biological principles and general information related to medicines and drugs in order to perform at an acceptable academic level on this option in a chemistry paper.

Question 13

Although the question on mild and strong analgesics, (a), is a question that has been asked previously a myriad of times, few surprisingly scored all four marks. Candidates occasionally discussed types of medication rather than mode of action. For mild analgesics many did not state the fact that these analgesics work by intercepting the pain stimulus at the source itself. The suppression of the production of prostaglandins often was not alluded to. For strong analgesics the most common mistake involved candidates not referring to opioid receptors in the brain.

(b) proved no problem for candidates though some stated incorrect functional groups or classes (alcohol and carboxylic acid were common incorrect answers). Please note that to prepare new candidates for the 2016 syllabus, the markscheme was later altered to include the correct naming of functional groups following IUPAC guidelines.

In (c), most candidates scored at least one mark. For the advantage few stated the fact that morphine is a strong analgesic.

Question 14

The comparison between the structures of diazepam and fluoxetine hydrochloride proved to be a real challenge for the weaker candidates. Most knew that both contain benzene rings but many stated that diazepam contains an amino group which is incorrect. Many of the better candidates used correct terminology such as phenyl groups. Although the difference between functional groups and class is not a feature of the current programme, with the onset of the new Chemistry programme which emphasises this inherent difference many teachers may wish to mention this difference even in the current programme, although currently candidates are not penalized for stating alcohol instead of hydroxyl for example.

Question 15

In (a), the most common mistake was candidates stating an amide instead of the amino group. In (b), careful reading of the wording of the question was essential, as candidates were asked to state two side-effects. Hence answers such as increased mental alertness and concentration did not score, nor did stimulant. Other vague answers such as leads to a heart attack were also deemed incorrect and more precise answers such as increasing the heart rate were required.

Question 16

Lots of incorrect answers were seen on this question, such as statements claiming that penicillin was discovered by Florey and Chain. The most common mistake involved attributing the large-scale production of penicillin to Florey and Chain. This is incorrect and is in fact attributed to Moyer and Rousseau. In (b) the most common mistake seen was claims that penicillin breaks down cell walls. This is totally incorrect - penicillin does not break down existing cell walls – it only interferes with the production of new ones. Many candidates also did not mention the fact that due to damage cells absorb water and burst. Most knew that modification of the side-chain overcomes resistance by bacteria.

Question 17

This question proved to be a life-line for candidates with a strong knowledge of biology and in both parts many candidates scored full marks. Many candidates gave overly lengthy answers here and more concise answers could easily have been given such as bacteria are larger than viruses and bacteria have cell walls unlike viruses in part (a).

Option E – Environmental chemistry

Performance on this option was better than in some previous sessions though journalistic type answers were still widespread, especially on the greenhouse effect in Question 19 (a).

Question 18

In (a), the most common mistake involved candidates not mentioning the high temperature condition for the internal combustion engine in cars/planes/industrial furnaces. Both (b) and (c) were very well answered though some referred to the depletion of the ozone layer in (b).

Question 19

The greenhouse effect has been asked on several occasions in the past and there have been widespread references to the performance of candidates on this question in previous subject reports. Hence it was extremely disappointing and surprising to see such poor answers.

Journalistic type answers were common and vague terminology such as bounced and reflected were often used. In addition answers were sometimes unclear – for example some candidates did not mention incoming solar radiation and just blankly alluded to the involvement of UV rays. In contrast (b) was well answered. The most common mistake involved candidates stating NO_2 instead of N_2O, a classic mistake on IB Chemistry papers.

Question 20

This question related to the formation and depletion of ozone in the stratosphere by natural processes. The most common errors in (a) were failure to mention the necessity for UV light to form the oxygen radicals and inconsistent use of the dot in equations to represent radicals.

(b) was exceptionally poorly answered. Many just repeated the question. Most candidates tried to approach the question by stating that both alternatives do not contain chlorine. This did not score and what was required involved mention of the fact that both alternatives do not produce chlorine radicals in UV light as one property. A comparison between C-H bond enthalpy and C-Cl bond enthalpy also was rarely seen.

Question 21

In (a), few candidates scored full marks. Precise answers stating that incineration produces dioxins while landfills do not for example was required. Some candidates did not adhere to the command term used in the question *i.e.* compare. In (b) the better candidates scored both marks and most scored at least one. Some incorrectly referred to leakage into the soil instead of leakage into the water table.

Option F – Food chemistry

Fewer candidates attempted this option in N14 compared to previous sessions. However of the candidates who did attempt it, there was evidence that they were reasonably well prepared.

Question 22

(a) was found to be an easy entry-point two marks for candidates taking this option. In (b) (i), the better candidates stated ester. The weaker candidates incorrectly suggested either alcohol or carboxylic acid. Water was universally known in (ii). (c) was well answered though some did not score full marks by suggesting that hydrogenation is a degradation reaction which is incorrect.

Question 23

An understanding of shelf-life was correctly conveyed in (a) (i). (ii) proved no problem. In (b), a large majority of candidates were able to state two traditional methods such as preserving with sugar, fermentation, salting *etc*. Some gave current methods instead of traditional methods.

Question 24

This question was very poorly answered and the wording of the question was often ignored *i.e.* the fact that there had to be reference to oxidative processes. This meant that candidates had to invoke the Fe^{2+} to Fe^{3+} oxidation in (i). In (ii), nearly all scored full marks. Candidates struggled with part (b). Another G2 comment stated that the marks allocated to this question might not be suitable. However, four different marking points were used in the markscheme, equating to a ***[3 max]*** allocation.

Question 25

This question involved candidates suggesting two concerns of growing and eating GM foods. This was well done overall. Most cited concerns such as possible links to allergic reactions and the potential risk to health of changing diet. Vague answers such as harmful to health did not score.

Option G – Further organic chemistry

This was the least popular option on the paper in N14. Even the better candidates did not fare well with some of the questions this session and the organic reaction mechanism proved problematic as more detailed explanations required on carbocations and the effect of halogen substituents on the acidity of carboxylic acids were not given.

Question 26

(a) (i) was well done by the better candidates only, but most candidates only scored one mark in (ii) and no marks in (iii). In (iv) even the equation for the Grignard reagent formation was found to be difficult. (b) (i) was well done, though some candidates did not realise that an imine forms. In (ii) although the correct colour was often stated few mentioned the fact that this yellow product is in fact a precipitate, suggesting perhaps that they not have seen this in the laboratory or as a simulated experiment in a video. (c) was very poorly answered and the cyanohydrin was often not identified. In (ii) the reaction mechanism threw a number of candidates. Common mistakes included ignoring the curly arrow from the lone pair specifically on the oxygen in OH and failure to show the approach of the curly arrow from the lone pair on the oxygen of H_2O. (d) was very poorly answered. Some knew that there was an inductive effect but did not understand what this meant, namely that through the positive inductive effect the alkyl groups reduce the charge on the carbon atom.

Recommendations and guidance for the teaching of future candidates

- Options should be taught in class and are an integral part of the teaching programme. It is critical that the recommended time is devoted to cover the two options thoroughly and in depth. Although less than in M14 there was evidence that some subject areas were not covered by a small minority of schools. Students who are left to learn material independently can struggle with the options.

- It is critical that core chemical principles are brought to the fore in the Options, especially those which have often a twin biological focus *e.g.* Options B, D and F. In addition core chemistry should always underpin applied topics.

- Candidates should always look at the associated marks allocations in questions. Candidates should not have to use extra continuation sheets if they tailor their answers to the space provided.

- Students struggle with questions that require explanations or questions involving multiple steps. Candidates need to fully understand the various command terms and teachers should take time to review command terms throughout the year with students to make sure they understand how to answer questions.

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

- Candidates should be fully au-fait with formal definitions and organic reaction mechanisms.

- It is imperative that laboratory work lies at the heart of the IB Chemistry Diploma programme. Ideally candidates should be exposed to a rich experimental experience in the laboratory where suitable facilities are available. Where this is not the case other resources such as simulated experiments should be sourced if facilities allow. If an analytical technique is required by the Option and students are required to know the steps (for example chromatography and electrophoresis) then it should be performed in class or by simulation. It was clear that many candidates had little to no experience with these methods based on their answers.