May 2015 subject reports

Chemistry Time Zone 2

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 31	32 - 42	43 - 53	54 - 66	67 - 77	78 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 30	31 - 42	43 - 52	53 - 63	64 - 74	75 - 100

Internal assessment

Component grade boundaries

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

The range and suitability of the work submitted

For May session schools this was the last time that the candidates were to be assessed using the Design, DCP, CE, MS and PS criteria along with their associated aspects.

As to be expected at this stage in the internal assessment scheme's life cycle there was little significant change in the range and suitability of the work submitted. As always, in addition to much fine work from schools where the students has been given appropriate opportunity to achieve, there were examples of weak practise with students being set prescriptive and simplistic tasks that did not lend themselves to attainment against the criteria.

Although many examples of good practice were seen many schools did carry on with approaches to the Design assessment which were unimaginative and will need radical change with the new internal assessment scheme to be assessed from May 2016 session onwards. Many schools assessed the Design criterion through two theory only exercises with no follow up implementation. This has to change since the new Individual Investigation requires data to be collected and analysed.

Other schools did allow students to carry out their plans but had set very narrow tasks so that all students essentially designed the same research. It will be disappointing if the new model continues to yield such a narrow range of very similar investigations based on the rate of reaction of magnesium or calcium carbonate with hydrochloric acid and the heat of combustion of alcohols. These tasks are too familiar from pre-IB work and also easily found on the internet. When compared to the interesting student centred projects encouraged in other subject groups it has not been to the credit of IB Diploma Chemistry that whole cohorts of extremely able students have been set such narrow and unchallenging hurdles to overcome in the name of internal assessment. This has been one of the major drivers for the very significant changes now being implemented.

A small number of schools did show that they were adapting proactively to the new requirements by setting one or even two student centred individual projects that were assessed by the old criteria. These schools showed that the new individualised approach is possible to facilitate. Successful projects were usually quite simple in experimental design but generated personalised data that ensured the final report was clearly the result of the students' own endeavour.

Candidate performance against each criterion

Design

Achievement against the Design criterion was often good with the first and third aspects being best fulfilled. Most students were able to phrase a suitable research question and identify the relevant variables and similarly many planned to take measurements based on five or more values of independent variable. The attainment against the second aspect of Controlling Variables was lower with many students either not controlling identified variables at all or controlling inappropriately, such as using air conditioners to maintain room temperature rather than thinking how to control reaction temperature.

A common weakness was that a large number of students wrote up their designed procedures with insufficient attention to detail for the reader to understand exactly what was to be done and how variables were going to be manipulated or controlled. 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 new Individual Investigation where the students will have actually carried out and refined their procedures should see an improvement in this consideration.

There was often an ambiguity in language in the research question or identified variables with students using the term “amount” when they should be specific as to whether they are referring to moles, mass, volume of solution, etc. Another linguistic confusion was in the use of the terms “dissolving” and “reacting” with students discussing the dissolving of magnesium ribbon in acid or similar. These are issues that will be considered as part of the new Communication criterion.

Data Collection and Processing

Achievement against this criterion was generally good although some 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) or 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. When the tasks allowed there was good achievement in aspect 2 as well with enthalpy calculations being especially productive. There were few challenging graphical processing such as determining and activation energy evidenced though. Aspect 3 continued to be the most demanding aspect with only a minority of students successfully propagating uncertainties and also quoting final answers to an appropriate number of significant figures was not uniformly achieved. Also many graphs were poorly presented with either unsuitable best-fit lines (Excel’s polynomial function was often poorly used to generate curves with false minima or maxima) or improperly labelled axes.

Conclusion and Evaluation

Conclusion and Evaluation continued to the end to be the most challenging of the criteria and few candidates achieved the top level across all three aspects. This is not surprising since this criterion requires students to really understand what their collected data signified and this is higher order thinking that cannot be readily sourced from textbooks or websites.

In Aspect 1 it was common for candidates to compare their results to literature values where appropriate and a significant number were then then able to identify whether the difference indicated the presence of system error or could be explained by random error alone. This is an important consideration that will still be applicable to the new Individual Investigation

An issue that will be confronted more often by teachers with the new Individual Investigation how to assess Evaluation when the student-led 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. In such cases the student should try and describe the nature of trend and compare to how this compares to accepted theory. For example even a SL student can conclude whether the rate of a reaction increases in direct proportion with concentration of one of the reactants or not. This can then be compared to the literature expectation and the likely impact of systematic or random errors discussed.

For Aspect 2 many candidates identified a good number of relevant procedural limitations or weaknesses although once again only a small minority 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 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 of future candidates

From May 2016 the Internal Assessment framework changes fundamentally and teachers must avail themselves of the guidance given in the Subject Guide and Teacher support Material.

Advice that arises from the current session but can be projected on to the new framework is as follows.

- Encourage students to choose a research question that has a degree of challenge, is of interest to them and one where they do not know at the outset what the outcome will be.
- A good research question will probably try to determine a trend or relationship. Students should avoid simple comparative analysis of supermarket brands or other systems with a non-chemistry relevant independent variable.
- Students should include some background theory to set the context of their investigation.
- With a ten hour time allocation to facilitate meaningful enquiry it is expected that students will collect significantly more data than is currently the case in Design assessments.
- It is sensible for students to always be encouraged to make a statement related to the safety, environmental or ethical impact of their study.
- Encourage students to reflect on data while carrying out the research so that they can actively make the decision to modify the procedure or collect more data if needed. This is a good indicator of true engagement and candidates can record such decisions being made.
- When analysing their data students should show appreciation of the impact of measurement uncertainties. This could be evidenced through the propagation of errors using a sensible protocol through a calculation, the drawing of a graph with appropriate best fit line and quite possibly the inclusion of error bars and always the appropriate use of significant figures. Since the Individual Investigations will take many different forms the teacher will have to decide what constitutes the appropriate treatment of

uncertainties applicable to that research.
- If the research includes the analysis of secondary data students should still show consideration the associated uncertainty.
- When concluding, students should draw a conclusion and discuss its methodological validity but should also compare it to expect outcomes (if any) based on accepted theory.
- If the outcome is quantitative then the comparison to a literature value, calculation of percentage error and discussion of the impact of systematic and random errors is still the expectation.
- In addition to possible modifications students should also reflect on possible extensions to their research.
- The Communication criterion will introduce new requirements. The students' designed procedures should be reported in past tense and include sufficient detail for the reader to be able to reproduce the experiment in principle.
- Although there is a requirement for more data and more reported detail there is a 12 page length limit. This means that students have to be intelligently concise and the current trend for hugely repetitious use of cut and paste for calculations or procedural details and the inclusion of pages of data-logged data should be avoided.
- There will be an increased focus on the proper referencing of sources used for background theory, procedural instructions or literature vales. This is a hugely important consideration that has to be stressed clearly to the students.
- Do not encourage the students to write up reports using the criterion titles as report sections. In particular Personal Engagement is a criterion to be assessed across the whole report and is not an introductory section.
- Keep an electronic copy of the work if samples for moderation need to be electronically uploaded instead of sent by courier.

Written feedback or annotations on the student's work as to how the marks were awarded is of great value to moderators as they try to support a sensible interpretation of the assessment criteria.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 14	15 - 19	20 - 23	24 - 28	29 - 32	33 - 40

The range and suitability of the work submitted

8869 candidates submitted this paper, a 3% increase on 2014.

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 212 respondents (from 847 schools).

Comparison with last year's paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
1	8	39	40	9

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	1	82	18

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	3	10	27	45	15
Presentation of paper	0	1	4	26	43	26

In the general comments, the paper was thought to be well-rounded, very fair, difficult, not difficult, tougher, more challenging and time-consuming; in fact there was little agreement except that some of the questions were "tricky".

There was a complaint about the 3-dimensional representation of molecules in questions 13 and 34. We would expect candidates to be able to interpret diagrams such as this as well as the more usual representations.

As it turned out, the paper produced a much lower mean mark than last year. That having been said, there was a full range of marks from 4 to 40 with a fairly regular distribution.

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 85.78% to 16.55% (May 2014 for comparison, 95.37% to 36.12%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.57 to 0.15 (May 2014, 0.59 to 0.11), the higher the value, the better the discrimination.

The following comments were made on selected individual questions:

Question 1

This question was found to be difficult, as many candidates did not add the number of protons to the number of electrons. They missed the word “total” in the stem. What was surprising was the percentage of candidates giving answer A (22%).

Question 2

Although this might have seemed unfamiliar, nearly 50% gave the correct answer. Many thought this was too challenging for an early question. The examination questions are, and have been for many years, presented in topic order. Those candidates who find the more mathematical manipulation testing should, perhaps, be advised the tackle the questions in a different order.

Question 3

This question may have appeared a little more daunting than usual; it required candidates to think clearly about the units and carry out dimensional analysis. Whilst 46% gave the correct answer, nearly 37% gave answer D.

Question 10

Well over 50% of the candidates gave the correct answer but a significant number (31%) gave answer A thus rejecting representation III.

Question 11

Most candidates were able to dismiss B and C but getting the correct answer required them to transfer their knowledge of steric hindrance (or alkane branching) to a different situation. 54% gave the correct answer whilst 30% gave D.

Question 12

Whilst 70% gave the correct answer, a significant number (17%) missed the axial lone pairs and thought the molecule to be tetrahedral.

Question 13

Although delocalization in amide is not covered in the syllabus, answer C was also accepted here as there is significant double bond character in the nitrogen to carbon (of the carboxamide group) bond. The question will be amended before publication.

Question 14

This question involves reasonable arithmetical manipulation (subtraction and division by two). Over 68% gave the correct answer but nearly 20% forgot to divide by 2.

Question 15

It should have been clear to candidates that liquid ethanol would require more than bond enthalpy data provided they knew the definition of the latter. 65% gave the correct answer.

Question 16

It is accepted that candidates should not have come across tetrachloromethane, CCl_4, it having been banned for many years. They were not expected to know that it is a liquid at room temperature and the question can be answered correctly without this knowledge. A standard enthalpy change of formation must start from the elements so only C and D are possible. Carbon is not a gas under standard conditions so answer C is excluded. Nearly 47% gave the correct answer.

Question 20

Over 34% confused the units with those of a first order reaction.

Question 24

There was some concern that students would not know that $AlCl_3$ has an incomplete octet. In fact, this was chosen less often than all the other answers.

Question 25

This was a legitimate test of assessment statement 18.1.3. The nature of the mathematics in Chemistry is not tied to Mathematical Studies.

Question 26

Candidates should be able to make an approximation of the inter-conversion of K_a and pK_a values. 69% of the candidates found no difficulty with this question.

Question 31

We accept that this is a difficult question but many candidates will have come across the reaction in their laboratory work – and they should know that an equation must be balanced for charge as well as for species. It was the third most difficult question on the paper but there do need to be questions that will differentiate the grade 7 candidates from those who achieve grade 6.

Question 32

Candidates found this question tough – but it was fair, the data was set out in the conventional way and all candidates had to do was to apply the rules they had learnt and the understanding gained. Only 24% gave the correct answer whilst most (36%) chose B.

Question 33

The most popular, but wrong, answer was C (42%) showing that candidates had not appreciated the formation of H_2. Many gave answer B but candidates should know that copper is deposited from aqueous solution. It is true that this question requires a lot of thought and it turned out to be the fourth most difficult question on the paper.

Question 34

We expect candidates to be able to interpret 3-dimensional diagrams as well as the more normal representations. Please note that we used names for the functional groups as they appear in the new syllabus. Hydroxyl is not an acceptable functional group here as it is part of the carboxyl group.

Question 39

This question tested assessment statement 20.6.3. The question was poorly answered with 30% choosing A and 41% B. It was the most difficult question in the paper answered correctly by only 17%.

Question 40

79% gave the correct answer (D) and it was the fourth easiest question on the paper.

Recommendations for the teaching of future candidates

- 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.
- Candidates should not spend more than about one minute on each question in the first instance and those candidates who find the topic 1 questions to be testing should leave those for later in the time allocation.

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 - 21	22 - 24	25 - 30

The range and suitability of the work submitted

6072 candidates submitted this paper, a 5% increase on 2014.

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 133 G2 returns (from 851 schools).

Comparison with last year's paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
2	11	61	17	2

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	1	93	6

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	1	11	28	47	14
Presentation of paper	0	0	6	23	47	23

In the general comments, there was not good agreement about whether the paper was fair, “tricky” or challenging. On balance the overall marks showed that the paper was more difficult than previous years. One respondent commented that there were fewer questions on acids and bases and another that it was light on topic 3. In fact there were two questions on each topic, in line with the number of hours in the Guide.

Another commented that sometimes there were four questions on a page when three might have been better. The examination preparation department will consider that comment.

Finally, it suggested that the candidates might have found the questions “tricky” because they didn’t read them carefully. Candidates should always be advised to read the questions carefully.

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 92.99% to 19.11% (May 2014 for comparison, 90.66% to 30.24%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.59 to 0.18 (May 2014, 0.58 to 0.21), the higher the value, the better the discrimination.

The following comments were made on selected individual questions:

Question 1

This question was found to be difficult as many candidates did not add the number of protons to the number of electrons. They missed the word “total” in the stem. What was surprising was the percentage of candidates giving answer A (31%).

Question 2

This might have taken some time and was, perhaps, more challenging for those reliant on calculators. Nearly 68% of the candidates, however, gave the correct answer.

Question 3

Candidates found this to be relatively straightforward with 73% giving the correct answer.

Question 4

This question may have appeared a little more daunting than usual; it required candidates to think clearly about the units and carry out dimensional analysis. Answers A and D were each chosen by about 40% of the candidates.

Question 10

One respondent would have preferred “hydronium” ion although the ion was made clear by the formula. Over half the candidates gave the correct answer.

Question 15

There was one concern about how students of mathematical studies might fare with this question. The arithmetic is straightforward and, in the event, nearly 64% gave the correct answer.

Question 16

It should have been clear to candidates that liquid ethanol would require more than bond enthalpy data provided they knew the definition of the latter. 52% gave the correct answer.

Question 19

K_c expressions often leave much to be desired so it was encouraging to see that this was the easiest question on the paper with 93% of answers correct.

Question 21

Whilst 42% correctly identified CCl_4 the most popular wrong answer (38%) was the H^+ ion.

Question 24

We accept that this is a difficult question but many candidates will have come across the reaction in their laboratory work – and they should know that an equation must be balanced for charge as well as for species. It was the most difficult question on the paper but there do need to be questions that will differentiate the grade 7 candidates from those who achieve grade 6.

Question 25

Questions such as this have been set in the past and we would expect a chemist at this level to have a rudimentary knowledge of metals in an activity series, particularly those as far apart as iron and copper. It was disappointing that less than 50% got this right.

Question 26

There were no comments about this question but it is worth noting that over 56% chose answer D.

Question 27

We expect candidates to be able to interpret 3-dimensional diagrams as well as the more normal representations. Please note that we used names for the functional groups as they appear in the new syllabus.

Question 28

One respondent commented that the absence of UV light was not relevant. The condition was mentioned to exclude the possibility of a substitution reaction.

Question 30

There was a suggestion that we should have used the phrase “minimize random error” instead of “minimize random uncertainty”. That is a fair point but it didn’t seem to worry the candidates, 75% of whom gave the correct answer.

Recommendations for the teaching of future candidates

- 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.
- Candidates should not spend more than about one minute on each question in the first instance and those candidates who find the topic 1 questions to be testing should leave those for later in the time allocation.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 12	13 - 24	25 - 33	34 - 44	45 - 56	57 - 67	68 - 90

The range and suitability of the work submitted

The paper was generally accessible and allowed 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. There were 847 schools entered for this session and teacher’s impressions of the paper were conveyed by the 212 G2 forms returned. 96% of the respondents considered the level of difficulty appropriate and 2% too easy. In comparison with last year’s paper, 57% felt that it was of similar standard, 27% thought that it was easier and 16% were of the view that it was more difficult. Clarity of wording was considered good or better by 91% and the presentation of the paper was thought to be good or better by 95%. A number of respondents commented that the size of the answer box was too small for some questions and this will be taken into account in the preparation of future papers. Teachers, who commented that it is difficult to evaluate the question paper without having access to the markscheme, are encouraged to become examiners. The general impression from the G2 forms was that that the paper had an appropriate range of questions in terms of level of difficulty and topics covered. As per IB examination rule, ECF marks were widely given throughout the paper to ensure that candidates were not unduly penalised. Questions 7 and 10 were the most popular questions in Section B.

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

- Construction of best fit straight lines for a thermometric titration.
- Calculation of absolute entropy for H_2 in J mol^{-1} K^{-1}.
- Explanation of how a mixture of propanoic acid and sodium propanoate acts as a buffer solution.
- Predicting state symbols in electrolysis.
- Determination of pH from K_b values and sketching a titration curve.
- The structures of isomers of transition metal complexes.
- Explanation of molecular polarity.
- Redox equations.
- Definition of standard electrode potential.
- Explanation of the acidity of magnesium chloride.

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

- Recognition that heat loss is a major source of error in thermometric titrations.
- Calculation of percentage error.
- Identification of the rate determining step in a reaction mechanism.
- Calculation of enthalpy and free energy changes.
- Definition of the terms buffer solutions, activation energy and Lewis base.
- Explanation of free radical and S_N2 mechanisms.
- Explanation of the effect of a change in volume on the composition of an equilibrium gaseous mixture.
- Writing the expression for Kc and finding equilibrium concentrations.
- Explanation of the action of catalysts on the rate of chemical reactions.
- Writing an electronic configuration using a box type representation.
- Definitions of Lewis acids and bases.
- Describing acid-base trends of period 3 oxides.
- Drawing *cis* and *trans* isomers of but-2-ene

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

Question 1

Some teachers commented that thermometric titrations are not listed in the syllabus nor are they included as prescribed experiments for the new guide. A similar question was asked in a past examination and thermometric titrations are covered in Topic 5. The intention is that any data based questions should be accessible to all students, who have the appropriate practical experience. It is not intended that such questions will be constrained to experiments on this list. Many students were unable to draw a best fit line for the thermometric curve and some were imprecise in reading the volume of acid needed for neutralisation. Most candidates were able to calculate the concentration of acid added including the correct unit. Many candidates were able to calculate the enthalpy changes and the percentage error although some did not read the questions carefully and either did not gave the enthalpy change per mole or gave the percentage inaccuracy to more than the required two significant figures.

Question 2

Although most candidates were able to define the rate of reaction, some of weaker candidates gave imprecise answers which did not refer to concentration of the reactants or products and the "the time for the reaction to go to completion" was not an uncommon response. Most candidates realized that the surface area would decrease but, as in previous sessions, lost marks as they did not refer to the reduced "frequency" of collisions. Most candidates were able to identify the rate determining step and correctly state that the reaction would be first order with respect to hydrogen however only a minority could explain their answer in sufficient detail *i.e.* that H_2 was involved only once in the formation of the intermediate before the rate determining step.

Question 3

Most candidates were able to calculate the enthalpy, free energy and entropy changes, although a significant number gave the incorrect units for the latter. The use of the Gibbs free energy equation requires consistency of units since ΔH°_{f} and ΔG°_{f} were given in kJ whereas S° was given in J. This needs reinforcing in class as it tends to be a common error from session to session. The calculation of the absolute entropy of hydrogen proved to be more problematic, with many not taking into account that there are two moles of hydrogen in the reaction.

Question 4

Most candidates were able to give a definition of buffer solutions including the detail that pH does not change significantly when small amounts of acid or alkali are added. The explanation of the action of buffers proved to be more challenging with only the stronger candidates giving a complete response in terms of protonation of the conjugate base and increased dissociation of the acid. The calculation of equilibrium concentrations from pK_a values was better done than in previous sessions, but still proved too difficult for many. The need to change the units of concentration of propanoic acid made this an additional obstacle in this demanding question.

Question 5

Many student gave two features of a homologous series although marks were lost by stating that they had "the same" rather than "similar" chemical properties. Some of the weaker candidates confused physical and chemical properties. The free radical mechanism was generally well known with a dot used to identify the radicals and the three steps correctly identified. Marks were lost in a significant number of cases as only one propagation step was given and it was not uncommon to see a hydrogen free radial formed instead of the bromine or the ethyl free radicals. A significant number of students described the mechanism in words rather than equations and, although this was accepted in the markscheme, responses were less successful in explaining the mechanism fully. Others lost marks as they did not explicitly refer to the reaction between ethane and bromine but instead used methane as the alkane and chlorine as the halogen.

Question 6

Many candidates were able to give the correct half-equation to describe the reaction at each electrode, but few were able to provide the correct state symbols. The question referred to the electrolysis of molten salt, yet aqueous products were commonly given. This highlights the need to read the question carefully. Some students started with the metal and chlorine gas as the reactants in the half-equations, and others stated the correct half-equations but at the wrong electrodes. Most candidates were able to give reasons for the use of aluminium instead of iron but “lighter” was a common incorrect response instead of the more correct “less dense”. Some teachers have commented that 6.b. was not included in the guide but it is covered in the teacher notes for Assessment statement 4.4.2.

Section B

Question 7

Most candidates were able to give two characteristics of a dynamic equilibrium and explain the effect of changes in volume on the position of equilibrium but many had difficulty giving a complete explanation of the equilibrium shift resulting from the removal of ammonia. Candidates were expected to include a reference to the value of K_c or the reduced rate of the reverse reaction when justifying their answer. The definition of activation energy was well known but some lost a mark in their explanation of catalyst action as they did not refer to an alternative pathway in their explanation for the lower activation energy. The explanation of why lower temperatures were not used in the Haber process was also incomplete with many not considering the economic disadvantages of a slow reaction rate. Similarly many did not explain why high pressure was expensive in terms of energy or building costs. Most were able to deduce the equilibrium constant but many lost a mark in the calculation of K_c as they used the initial concentrations of nitrogen and hydrogen. Some teachers identified an inconsistency in the question in that the total number of moles of gas under the conditions stated in the question was not consistent with the ideal gas equation however this did not appear to be a problem for the candidates. (However, the ideal gas law cannot be applied here as under these conditions ammonia would be in its supercritical state.) Most candidates were able to define Lewis bases but the definition of weak Brønsted-Lowry bases proved to be more problematic as many did not refer to partial ionisation in their response. Most students were able to identify the conjugate acid-base pairs. The calculation of the pH of an ammonia solution proved to be challenging with many confusing K_a and K_b. Others did not recognize that since it is a weak base, $[NH_3]$ at equilibrium is approximately equal to starting concentration (0.100 mol dm^{-3}) or that $[NH_4^+] = [OH^-]$. (The examination paper was rescaled for candidates sitting the examination in Spanish (due to the error in the question) and candidates close to a boundary given particular attention.) Only the strongest candidates were able to gain full marks for the pH curve although many recognised that the pH would be 1 before any ammonia was added given that HCl is a strong acid. A significant number had the final pH above 11 and did not allow for dilution of the 0.1 mol dm^{-3} ammonia solution. Many correctly identified a possible indicator.

Question 8

Most candidates were able to draw an arrow in the box diagram for the electron configuration of chromium, but few gave a complete description of the nature of metallic bonding and did not refer to the attraction between the Cr^{3+} cations and the delocalized electrons. Candidates were more successful in explaining malleability in terms of Cr^{3+} cations sliding over one another. Most candidates were able to use oxidation numbers in naming Cr_2O_3 but the explanation of ionic bonding was incomplete with only limited reference to the electrostatic attraction between the oppositely charged ions. Students continue to struggle to understand that conductivity of molten ionic compounds is due to mobile ions not electrons. Most candidates were able to deduce the oxidation number in the complex ion and give the answer using the correct notation. The nature of the ligand-chromium bond was well known and the explanation of the colour of transition metal complexes was stronger than in previous sessions with only a minority referring to the emission of light. Some teachers have commented that trans/cis-isomers of the complex ions is not specifically stated in the guide but many students were able draw two possible isomers. The representation of 3D structures could have been clearer although this was not explicitly penalized. Redox half-reactions continue to challenge many with only the stronger students being able to gain both marks and deduce the correct overall equation. Some teachers commented that the question was too demanding as students had to construct two half-equations in order to get to the overall redox equation, but the $Cr_2O_7^{2-}/Cr^{3+}$ half-reaction is given in table 14 of the current data booklet. The majority of candidates identified the conversion of I^- to IO^{3-} as oxidation and many able to identify the increase in oxidation number. The workings of a voltaic cell was generally well understood but the definition of the term standard electrode potential was often incomplete with the reference to standard conditions of the hydrogen electrode often missing.

Question 9

Most candidates knew about the relative conductivities of magnesium chloride and phosphorous trichloride and were able to relate it to bonding. The third mark was however more problematic as many continue to equate conductivity to mobile electrons rather than ions. The pH of solutions of aqueous chlorides was not generally well known with only a small number of candidates gaining full marks. An explanation of the acidity of magnesium in terms of the charge density of the Mg^{2+} ion proved to be particularly challenging. One teacher commented that the reaction of PCl_3 and water is not mentioned in the guide but it is included in the teacher note to Assessment statement 13.1.1 of the current guide (although it is not in the new guide which will be assessed for the first time in May 2016). The acidity of the period 3 oxides was generally well known but many struggled to give balanced equations to describe the reactions of sodium and phosphorous(V) oxide with water, with many confusing the reaction of sodium oxide with that of sodium giving hydrogen as a product. Most candidates were able to give correct Lewis structure and shapes and bond angles but marks were lost, as in previous session due to missing lone pairs either on the central atoms or the Br and F atoms. It should be noted that it is difficult to award ECF marks in these questions so students need to avoid careless errors. Many struggled to give a complete explanation of the polarity of the two compounds as although the molecule was identified as being asymmetrical, few stated that the P–Br and S–F bonds are polar. Only a minority of students stated that a covalent bond was an attraction between nuclei and a pair of electrons and many were unable to identify the s-orbital from hydrogen and the p/sp^2 orbital from carbon as the overlapping orbitals in the covalent bond. The hybridisation of oxygen was generally well known as was sigma and pi bonding.

Question 10

Most candidates were able to give the full structural formula but marks were lost by some as they gave the condensed formula rather than the full structural formula as demanded by the question. Most were able to apply IUPAC rules and name A but some omitted the “di” from dibromobutane. The colour change observed when but-2-ene reacts with bromine was well known, but knowledge of the economic importance of the polymerisation of alkenes was limited with many candidates restricting their answers to identifying specific plastics such a polythene. Many responses included incorrect references to nylon and margarine. Most candidates were able to identify the repeating unit of poly(but-2-ene). The explanation of the S_N2 mechanism was more successful than in previous sessions although a common error was a curly arrow originating from the hydrogen atom in the hydroxide ion rather than the oxygen. Most candidates were able to explain the higher reactivity of the hydroxide ion compared to the water molecule in terms of charge but only a minority referred to the attraction between the nucleophile and low electron density of the carbon atom. The naming of 2-methylbutanenitrile was generally well done although small errors were accepted and the reagents needed for the hydrogenation of 2-methylbutanenitrile were also generally known. A number of candidates omitted the branching methyl group in the amide formed with ethanoic acid and confused aldehydes with ketone and only a small minority referred to the carbonyl group. Most candidates identified only hydrogen bonds in compound C and did not refer to the dipole-dipole forces or van der Waals’ forces also present or explicitly compare the relative strength of the different intermolecular forces in the two molecules. Some incorrectly referred to covalent bonding in their explanation. The equation for the complete combustion of compound C was generally well known. The term stereoisomer was well understood but many candidates did not refer to the restricted rotation around a double bond. Most candidates were able draw the structures of *cis* and *trans* but-2-ene.

Recommendations for the teaching of future candidates

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

- Graphical representation of experimental data. Students should be more precise in their explanations for changes to reaction rates. Explanations referring to “more collisions” should be developed further to include “more frequent collisions” or “number of collisions per unit time”.
- More precise explanations of the factors which lead to attraction in ionic, metallic and covalent bonding.
- More precision in identifying the state symbols in equations in electrolysis and in the description of the particles which carry the charge when different substances conduct.
- Electrons are not involved in the conductivity of molten or aqueous ionic compounds.
- Pay close attention to whether a question requires full structural formulas rather than condensed structural formulas.
- Explain shifts in equilibrium due to changes in concentration with reference to the need for a constant value for K_c or the relative rates of the forward and backward reaction

instead of simply referring to Le Chatelier's Principle
- Working must be shown for all calculations so that the chances of obtaining ECF marks are maximised.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 18	19 - 24	25 - 29	30 - 35	36 - 50

The range and suitability of the work submitted

Teacher's impressions of the paper were conveyed by the 133 G2 forms that were completed, 93% of the respondents considered the level of difficulty of the question paper appropriate, 5% too difficult and 2% too easy. In comparison with last year's paper 63% felt that it was of a similar standard, 19% thought that it was easier and 11% were of the view that the paper was more difficult. Clarity of wording was considered good or better by 87%, and the presentation of the paper was thought to be good or better by 90%, and less than 1% considered it poor.

The general impression from the G2 forms were positive, and that the paper had an appropriate range of questions. Several schools expressed a concern that the boxes for the answers were in some cases too small after the new formatting, this is being looked at and should be resolved. ECF was widely applied and throughout the paper to ensure that the candidates were not unduly penalized.

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

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

- Graphical analysis
- Bonding and structure
- Electrolysis
- Application of chemical knowledge to everyday life and industrial processes
- Chemical equations and stoichiometry
- Quantitative calculations
- Questions which needed a background of practical work
- Organic reaction conditions
- Drawing diagrams

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

Topics generally well answered included:

- Atomic structure
- Kinetics
- Construction of K_c expressions
- Calculation of A_r value from isotopic data
- E_a and catalysts
- Some definitions

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

Section A

Question 1

Some teachers commented that thermometric titrations are not listed in the syllabus nor are they included as prescribed experiments for the new guide. A similar question was asked in a past examination and thermometric titrations are covered in Topic 5. The intention is that any data based questions should be accessible to all students, who have the appropriate practical experience. It is not intended that such questions will be constrained to experiments on this list. Most candidates were not able to access the first mark with by construction of lines of best fit. Some drew a 'dot to dot' curve, but with most just providing a construction line dropping down from the maximum point on the graph, which did allow them to access the second mark. There was some transferred error for 1aii), but many were not able to carry out the calculation. Scoring for the temperature difference was dependent upon on the candidate's annotations, with a few extending the line of best fit back to the y axis. In the calculation of enthalpy change, the total mass of the solutions was often incorrect, but some salvaged the subsequent marks. The calculation of percentage error was generally done well, but a good third of the candidates failed to read the question stem and did not give the answer to two significant figures. The concept of heat loss in the experiment was well understood, but the solution was very often too vague.

Question 2

The question on the structure of atoms generally scored well. The workings of the mass spectrometer was less well known; with many getting confused with the role of the magnetic and electric fields. The calculation of the A_r was done very well.

Question 3

There were very few carefully drawn correct diagrams as well as too many diagrams showing half-cells. The importance of the solution being molten was not appreciated. The equations did pick up marks, but it was extremely rare for candidates to access the mark for the correct state symbols. Far too many associated electrical conductivity in molten compounds with mobile electrons. The awareness that mobile ions are responsible for conductivity was poorly understood. The difference between 'lightness' and density is still confused.

Question 4

This question tended to be well answered. The most common errors were that some candidates stated that homologous series have the same empirical formula, and that the difference between “the same” and “similar” were confused. The knowledge of the free radical substitution was very good, with the three processes of initiation, propagation and termination quoted often, although some only gave the first and last, the equations for propagation were most likely to be incorrect.

Section B

Question 5

This was, by far and away, the most common choice for Section B.

The conditions for an equilibrium system were well known, and the K_c expression was almost universally correctly given, the incidence of curved brackets was very low. With the description of the effect of changing conditions, the increase in volume change generally scored, but the answers for the removal of ammonia were far too general to be given credit. It is pleasing to note that most candidates are aware of the importance of using the word “‘minimum”, as well as the effect of a catalyst, with most giving perfect answers. The drawing of the Maxwell-Boltzmann energy distribution curve suffered from poor draughtsmanship. Too many curves did not start at the origin and lacked correct labels. An appreciable minority drew the energy/reaction co-ordinate graph. The knowledge of the compromise conditions for the Haber process was often confused, particularly with regard to why high pressure is not used, where far too many answers lacked the depth required. Occasionally the word “pair” was missing for the definition of a Lewis base, and with the definition of a weak Brønsted-Lowry base most candidates failed to appreciate the difference between partially/slightly ionized and “not completely” ionized, the part of proton acceptor was also often missed out. With the description of the experiment to show the difference between a strong and weak base, many scored two out of the three available; the concept of a fair test, and the importance of equal concentrations was rarely appreciated.

Question 6

Probably the least popular option. The drawing of the diagram of chloromethane was generally excellent, as was the prediction/recall of the shape and bond angle. With the reasons for polarity, the concept of bond polarity was well understood, but the idea of asymmetry resulting in a dipole was less clearly appreciated. The construction of the chemical equation was disappointing, as was the description of the three types of bonding, very often missing the important point, in that they are attractions. With the calculation of volume of hydrogen, it was quite rare to get a fully correct answer. The biggest error was to use an incorrect value for the number of moles of hydrogen in the equation $pV=nRT$, by failing to halve the moles of hydrogen. The use of $pV=nRT$ also caused problems with units. The acid base nature of oxides of a period were generally well known. In contrast, the construction or recall of correct chemical equations for the reaction with water was a weakness.

Question 7

The few who opted for this option, showed a good knowledge. The drawing of structural formulae and naming was good. The reagent and conditions for the reaction was less well recalled. In 7ci, most students scored at least one mark, but lost the second. There was a lack of awareness of the importance of the system being aqueous in the conversion to the alcohol and a fully correct answer was very rare, as was the identification of the functional group. In the volatility question, most were aware of hydrogen bonding, but the fact that C also has greater other forces due to its greater mass was not present in most answers. The gaseous mark was often present, but the averaging over a range of compounds was not. With the calculation of enthalpy quite a few candidates benefitted from transferred error, from an incorrect equation.

Recommendations for the teaching of future candidates

- Encourage the candidates to give answers in sufficient depth. In a number of cases they lost credit, not because they did not know the work, but because they failed to give a complete answer.
- The drawing of poor and rushed diagrams also squandered marks. We are fully convinced that the majority of candidates had the knowledge to access the marks available, but through imprecise and often difficult to see diagrams, lost valuable marks that could be the difference between the levels awarded.
- Although this will no longer needed in May 2016, candidates should take time to read all the alternative questions carefully to ensure that they maximize their ability to score, as there was evidence that some changed their mind well into a question.
- Graphical analysis is a weakness, more opportunities to use this skill should be found to enable students to practice more practical situation like question 1.
- The balancing of equations and stoichiometry can be improved to enable candidates to access all marks.
- The difference between electrolytic and electrochemical cells and Maxwell-Boltzmann distribution graphs and enthalpy level diagrams should be made aware.
- More real life context type of questions (TOK linked and problem based learning questions) should improve the skills and understanding of Chemistry, as well as use of many experiments, both real and virtual, that are accessible on the internet.
- Teachers should be aware that use of past papers and feedback provided by IB to prepare candidates is a very useful tool, even with the change in syllabus, most of the topics will still be relevant.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 15	16 - 21	22 - 26	27 - 32	33 - 37	38 - 50

The range and suitability of the work submitted

The paper was of a very similar standard to last year with almost all teachers feeling that it was of a manageable length and represented an appropriate level of difficulty. No particular issues were identified with regard to clarity. Some points were raised with regard to interpretation of the specificity of material in the subject guide, but all material was considered covered by the Guide (and Teacher Notes). There were comments on the use of command terms and students need to be aware that “outline” tends to be used for single mark questions where less depth in the response is required compared to a similar question being set as “explain” for two or three marks. Comment, perhaps justifiable, was also made about inadequate space being left for answers, and indeed quite a number of students made use of additional sheets – much preferable to continuing outside of the box where material may be lost as a result of the scanning process.

A question arose about the fact that mark schemes are not available to be commented on using G2 forms. This is because in the early stages of marking these are being continually updated to respond in an appropriate manner to student responses encountered, hence they could not be published in a compatible time frame. Teachers are however welcome to join the teams of examiners or comment on mark schemes after their publication.

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

- Awareness of reasons why an internal standard may be required in ^{1}H NMR spectroscopy
- Recalling, in the context of mass spectrometry, that chlorine comprises a mixture of isotopes
- Predicting the iodine number from a molecular formula
- Describing the structure of a single strand of DNA
- Writing equations for industrial processes
- Describing the structural differences between thermosetting and thermoplastic polymers
- Explaining photovoltaic processes
- The difference between therapeutic index and therapeutic window
- Formulating redox half equations
- Describing hybridization of atoms in a structure and the consequences of this on ring strain
- Factors affecting the impact of greenhouse gases
- Soil chemistry
- Recalling metabolic issues related to *trans*-fats
- Explaining the action of emulsifiers
- Specific thermochemical evidence for a delocalized description of the bonding in benzene
- The influence of the inductive effect of substituents on the acid strength of carboxylic acids

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

- Correlation between tables of specific absorptions and spectra
- The complementary relationship between colour and absorbed light
- The concept of R_f
- Differences in aerobic and anaerobic respiration
- The function of hormones related to sexual development
- The toxicity of mercury and its compounds
- The scope of nanotechnology
- The nature of side effects
- The structure and action of morphine and diamorphine
- The mental effect of stimulants
- Identifying CFCs as ozone depleting chemicals and identifying a source of these pollutants
- The relative strengths of the bonds in O_2 and O_3
- Identifying the molecule that combines with fatty acids to produce oils and fats
- The effect of *trans*-fats on LDL cholesterol levels
- Knowing that the structure of benzene involves electron delocalization
- Writing mechanisms for chemical reactions
- Identifying an addition-elimination reaction

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

Option A

This option was quite popular with many candidates producing answers of a high quality.

Question 1

Candidates generally performed well on this question, with the recognition of UV-Vis spectroscopy and the identification of a particular type of chromatography causing the most errors.

Question 2

Many students recognized that the simplicity of the NMR spectrum determined which structural isomer the compound was. Sometimes students managed to identify the structure, but were unable to explain the way in which the NMR spectrum supported this. The splitting patterns were not clear as they were not necessary for identifying the compound, though one was given in part (b), with the reason it was a triplet being quite well answered. Few were aware of the problems of fluctuating fields that can require the inclusion of an internal standard, something that is unnecessary in other forms of spectroscopy, but almost all students knew an advantage of using TMS as this standard.

Question 3

Very few realized that chlorine is a mixture of isotopes and molecular ion peaks at 62.5 were usually referred to. Many students also seemed unaware that fragmentation at a double bond is unlikely. The identification of likely IR absorption bands and the underlying molecular changes were both well answered.

Question 4

It was not particularly well done and it seemed that most students were not particularly familiar with HPLC (there are good resources available on the internet), but a minority who seemed familiar with the technique, or the closely related GLC, scored well. In part (c) very few students discussed the interaction of the component with both the mobile and stationary phases.

Question 5

Both molecules involve conjugated bonds/delocalized electrons but only about half the students pointed out that in molecule A the system is much more extensive than in molecule B, hence its absorption is in the visible region. There seemed to be a good understanding of the complementary relationship between the absorbed and the observed colours, with the marking scheme allowed quite a lot of latitude owing to lack of precision in the data book spectrum.

Option B

Quite a popular option, though perhaps slightly less so than in previous years, that attracted answers of a rather variable standard.

Question 6

Many students misread the first part of the question and gave details of how chromatography is carried out. Those that did read the question often failed to gain full credit either through forgetting to mention that the protein needs heating with the acid, or though failing to mention which bonds were being hydrolyzed. Candidates generally scored quite well on the remaining parts of the question.

Question 7

The nature of the bonding in these two polymers of glucose was generally quite well known, though some thought that one or the other also involved 1.6 linkages. Aerobic and non-aerobic respiration appeared to be even better understood. Answers were often far more detailed than were necessary for the limited number of marks and mistakes were rare.

Question 8

Quite a few candidates were aware of the benefits of linolenic acid, though identifying the number of carbon-carbon double bonds present, and using this to calculate the iodine number, was rather more challenging.

Question 9

Generally students were well aware of methods of increasing the nutrient value of foods, though a significant number quoted “nutritional supplements” even though this was given in the stem of the question and they are taken in addition to foods, rather than affecting the food itself.

Question 10

Many candidates successfully identified the required structural features of the compounds, though “hydroxide” was frequently incorrectly used for “hydroxyl” and many students seem to think that any six-membered ring can be referred to as a “benzene ring”. The gland secreting aldosterone was less well known although in the Teacher Notes in the Guide with all the endocrine glands appearing with about equal frequency. The role of testosterone or progesterone were very well known though sometimes inadequately communicated.

Question 11

Many students discussed the structure of DNA as a whole rather than that of a single strand, as requested in the question. Nevertheless in the course of this many gave enough detail to gain some credit. The role of restriction enzymes and the polymerase chain reaction seemed well known, though the order of these was less clear. Details of the separation and detection of the fragments were however often less accurate. A significant minority of students attempting this question displayed some confusion with proteins and the electrophoresis of their component amino acids.

Option C

Probably the least popular of the options and good quality responses to it were rather rare.

Question 12

A relatively straightforward question that revealed the ongoing issues that many candidates have with regard to writing balanced equations. A significant number of students confused tempering and quenching.

Question 13

Candidates generally scored well on the first part of this question with the toxicity of mercury and its compounds being widely known and students often being able to identify a second reason for the phasing out of the older techniques. For many the equations however proved more challenging and it was unusual to award both marks.

Question 14

With a wide range of acceptable answers to the first part of the question it was surprising how frequently students failed to identify any of these; “producing greenhouse gases” doesn’t really explain a change in behavior unless it is linked to greater public awareness of these issues, or the delay in the production of these that occurs from the use as a feedstock. In the second part of the question only a few students knew that thermosetting polymers such as phenol-methanal have crosslinks between the chains.

Question 15

In their answers students often failed to link specific structural elements of biphenyl nitriles with the desirable properties for an LCD material. The functioning of an LCD was however better known, with some quite detailed responses for which candidates often gained good credit. The mechanism for the generation of a potential difference by photovoltaic cells however seemed less well understood.

Question 16

Probably the question on which candidates scored best in this option. Most could quote the definition of nanotechnology and could identify uncertain health effects as a potential concern. Many also knew the difference in the structure of the walls and ends of nanotubes, though the reason for the high tensile strength of bundles of these was less widely appreciated.

Option D

Undoubtedly the most popular of the options and one which attracted responses of wide-ranging quality.

Question 17

Many students confused “therapeutic window” with “therapeutic index”, but most adequately explained the nature of side-effects. Dimethicone was often correctly identified as an anti-foaming agent, but this converts small bubbles into large bubbles, which can then be expelled. Hence whilst this decreases “bloating” it will increase, rather than decrease, “flatulence”.

Question 18

Many candidates described morphine (strong analgesic) rather than discussing an advantage of the drug. Most could also identify disadvantages, but sometimes referred to issues applicable to any substance, such as the problems of overdosing. The structural difference between morphine and diamorphine, and why this makes the latter more potent, were well known.

Question 19

The ability to construct a redox half-equation connecting a given starting material and product was disappointingly rare. The colour change was better explained though many students failed to specifically identify the species involved or their oxidation states. An encouraging number of students were aware of the role of the C-H bond absorption in IR based intoximeters, though frequently mention of the importance of the absorption intensity was omitted.

Question 20

Most students knew of the effect of caffeine and amphetamines, but it was amazing how few could draw the correct structure of a molecule whose name was given.

Question 21

Many students could correctly explain the mode of action of penicillins, but often explanation of the strain in the bond angle failed to go into the required depth concerning the hybridization of the atoms in the four-membered ring. An encouragingly large number of candidates could explain how chiral auxiliaries are used in drug synthesis, but sometimes their response to the first part of this question failed to identify why it is sometimes necessary to use such an elaborate procedure. Many students could give the mode of action of antiviral drugs, though sometimes these responses lacked the required precision.

Option E

Probably the most popular of the options after Option D and another one which also attracted responses of wide-ranging quality.

Question 22

Many students could identify another greenhouse gas and a source, usually CFCs, but it was surprising how many did not read the “other”! It was disappointing how few students could accurately explain the greenhouse effect – the term “reflect” was used too often and, in addition, many continue to confuse it with ozone depletion and acid rain. Only a handful of students could identify the factors that affect how much various gases contribute to the overall effect. In the final part of the question a major weakness was a failure to link an effect with a consequence.

Question 23

The relative strength of the bonds in oxygen and ozone was well known, along with the link between this and the frequency of radiation absorbed. Students were also very familiar with the sources of CFCs and the role of these in ozone depletion. The equations involved with the catalysis of ozone depletion by nitrogen(II) oxide were however a significantly greater challenge.

Question 24

The term BOD was relatively well understood, as was reverse osmosis, though those who chose to describe multi-stage distillation seemed to only have a rather vague appreciation of the process. Many candidates failed to note the “economic factors” in the final part of the question and hence failed to identify economic consequences of issues raised, such as possible toxic emissions.

Question 25

Soil chemistry continues to pose major challenges to students studying this option and few could give a detailed description of CEC. In the second part of the question hardly any showed an appreciation of the role of bacteria in soil processes and again candidates showed their inability to write a balanced equation for a conversion given the reactant and product.

Option F

Whilst Option F seems to be gaining in popularity it still ranks well behind the most popular options. Although there were occasional good responses, candidates tackling this option often produced low scores.

Question 26

Most students correctly identified the compound that combines with fatty acids in triglycerides, but explanations of the lower melting points of *cis*-isomers usually lacked precision. The relationship between *trans*-fats and HDL/LDL levels and disorders arising from an unhealthy ratio of these seemed well known, but the difficulty in metabolizing these was rarely mentioned. Candidates either knew, or did not know, the mechanism for free-radical oxidation of fats with very few gaining partial marks; most however could identify a factor relevant to reducing its rate.

Question 27

Many students correctly identified the required structural differences, though sometimes they displayed an inadequate command of appropriate chemical terminology in communicating them. Many were also aware of the free-radical scavenging behavior of vitamin E.

Question 28

Though appreciation of the issue of complementary colours was widespread, hardly any candidates identified **both** absorption bands in the visible region. In the next few parts of the question many students lost marks by failing to answer fully, not referring to the *extensive* conjugation or the *large number* of *carbon-carbon* double bonds, as well as referring to temperature, rather than *increased* temperature, as a factor in the rate of oxidation. Lack of polarity was widely given as a reason for the fat solubility of carotenoids, though lack of groups able to form hydrogen bonds might have been more accurate (many quite polar molecules, such as $CHCl_3$, are insoluble in water). The features that lead to phospholipids acting as emulsifiers were often known, but again students tended to lose marks because their answers did not contain enough detail of their interaction between the phases present.

Question 29

Many students seemed to have an outline understanding of the CIP convention, though often they lacked the language skills to communicate this knowledge fully and clearly. The ordering of groups by atomic mass rather than atomic number seemed a common misapprehension, though in practice the results are the same.

Option G

Option G was only tackled by a small number of students, though these students often seemed to score well on it.

Question 30

This was disappointingly answered with students frequently losing marks through a lack of precise wording. The carbons are arranged in a *regular* hexagon (equal bond lengths is the only factor that discriminates it from the Kekulé structure, which would also be planar with 120^{o} bond angles). Relatively few students could quote a specific piece of thermochemical evidence to support the fact that the benzene ring does not comprise alternate single and double bonds. Students generally failed to specify *concentrated* H_2SO_4, in spite of the hint to "*precisely* identify". The mechanism part of the question was however encouraging well done with many students gaining full marks. The relative reactivities of substituted benzenes was generally known, although it was rare for the explanation of the enhanced reactivity of methylbenzene to gain both marks.

Question 31

Although the mechanism of the reaction was well done, few could appreciate that the presence of a high concentration of Br^- might affect the final stage so as to produce CH_3-CHBr-CH_3; disubstituted products abounded!

Question 32

Almost all candidates correctly identified the addition-elimination/condensation reaction but the structure of the cyanohydrin was only slightly less well known. Credit was given for students who gave the acid anhydride as the product from reacting the hydroxyacid with ethanoyl chloride, even though reaction with the hydroxyl group would be far more rapid than that with the carboxylate group. Many students tried to explain the effect of the hydroxyl group on acid strength through the effect of additional H-bonding on solubility (which would have the effect of making the hydroxyacid weaker) rather than invoking the inductive effect of the group. The product of the Grignard reagent reaction was less well known, but more candidates were aware of the reactants required to produce it.

Recommendations for the teaching of future candidates

- Encourage students to read questions, and introductory paragraphs carefully, along with the number of marks available, to help identify the required focus and appropriate depth. Where students are asked for a comparison both things, similarities and differences, need to be mentioned.
- Train students to be specific in identifying bonds stating, for example, *carbon-carbon* double bonds rather than simply double bonds.
- Give students practice in writing balanced equations to convert given reactants into given products.
- Provide students with plenty of practice at using appropriate vocabulary to accurately, and concisely, describe and explain chemical phenomena.

- Ensure that students have ample opportunity to work through past papers and then use mark schemes to grade these so as to ensure they become familiar with the level of detail required.

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 - 24	25 - 28	29 - 40

The range and suitability of the work submitted

93.99 % of the teachers who responded felt the paper was appropriate in terms of level of difficulty. 70.68% felt that the paper was of similar standard to last year's paper with 11.28% feeling that the paper was a little more difficult than last year. In terms of clarity of wording, 45.11% felt it was very good. Overall, this was thought to have been a fair paper. There were some comments from teachers around interpretation of the specificity of material from the subject guide particularly in option B. Option G was also thought to be slightly more challenging than in previous exam sessions. Some comments arose with regard to questions in Options C and D being less applied and more based on recall of facts.

Options B, D and E were the most popular options. There seemed to be a greater number of candidates answering options A and F with options C and G being tackled by only a small number of candidates.

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

- Specific types of chromatography
- Recalling the existence of chlorine isotopes in the context of mass spectroscopy
- Protein hydrolysis
- Definition and calculation of iodine number
- Alloying steel and the effect on physical properties.
- Principles of liquid-crystal displays
- Difference between therapeutic window and therapeutic index.
- Constructing redox half-equations involving organic molecules
- Factors which affect the impact of greenhouse gases
- Processes of aerobic and anaerobic decomposition of organic material
- Explaining the differences in melting points of *cis* and *trans* fatty acids
- Antioxidant action
- Action of emulsifiers

- Thermochemical evidence for the delocalized structure of benzene
- Relationship between Inductive effect of substituents and acidic strength of carboxylic acids

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

- Analytical techniques
- Identifying bonds responsible for peaks in the IR spectrum
- Concept of R_f value
- Function of progesterone and testosterone in the human body
- Field of nanotechnology
- Nature of side-effects
- Use of dimethicone in antacids
- Identification of functional group differences in morphine and heroin.
- Effect of stimulants on mental concentration
- Formation and depletion of ozone
- Source of ozone-depleting pollutants
- The effect of *trans* fatty acids on LDL cholesterol levels
- Relationship between absorbed wavelengths of light and complementary colour
- Bonding in benzene

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

Option A

This was a more popular option this year. Performance on this option was good and there were a fair number of high quality papers.

Question 1

Candidates did well on this question although the specific type of chromatography was often not given. The order of increasing frequency of radiation associated with the spectroscopic technique was well done. The most common error was the omission of the specific type of chromatography.

Question 2

Many candidates did elicit the correct structure although the most common error was the incorrect positioning of the carbonyl group. The number of H environments was often established but the ratios of atoms was not seen very often. Many did score a mark for stating a correct shift associated with the methyl group.

Question 3

The first and second marking points were rarely scored as most students did not recall that chlorine exists as a mixture of isotopes. The most common molecular ion peak stated was 62.5

instead of both 62 and 64. A common incorrect response in this question was to suggest fragmentation at the double bond with the production of the CH_2 fragment. The identification of possible IR absorption bands and the effect of IR radiation being absorbed by molecules was well done by most candidates. It was clear that most candidates understood that bond stretching/bending occurred when IR radiation is absorbed but there were fewer correct references to the change in bond polarity which was required for the second mark.

Question 4

This was well done with the H atom being the most common answer. Many were able to relate the lighter and darker regions of an MRI image to the idea of different hydrogen environments. The explanations as to why MRI is less harmful to the patient than X-rays were often too general.

Option B

This was a popular option with some wide-ranging responses.

Question 5

A large number of candidates misinterpreted the question and described in detail how the process of chromatography would separate the amino acids. Candidates who interpreted the question correctly, often did not mention that the protein had to be heated with acid and did not refer to the peptide bonds being broken in this hydrolytic process.

The R_f value was often not actually calculated but the correct formula for its calculation did score the mark.

Question 6

This questions was generally well done. The difference in structures of amylose and cellulose was well known although the mention of 1-6 linkages in cellulose was mentioned in some cases.

Question 7

The benefits of linolenic acid were reasonably well known especially its effect on lowering LDL cholesterol and many candidates scored full marks for in this part of the question although in some cases, one of the marks was not achieved due to LDL not being specified. The definition of iodine number sometimes proved challenging with some confusion of mass and moles of iodine. The expected definition of the iodine number is the mass in grams of iodine reacting with 100g of oil. Overall, students did find the calculation of the iodine number challenging.

Question 8

Many students were able to state at least one way of increasing the nutritional content of food with genetic modification being a common answer. A common incorrect suggestion in this question was to suggest the use of nutritional supplements which was already given in the stem of the question.

Question 9

Many students were able to name the functional groups in aldosterone but often were not able to identify both of the functional groups present in both steroid hormones. There were a fair number of references to the ‘hydroxide’ group instead of hydroxyl. The endocrine gland was often not correctly identified although the function of progesterone of testosterone was often answered correctly albeit not always precisely.

Option C

This was probably one of the least popular options with some variable performances overall.

Question 10

It was pleasing to see a good number of correctly balanced equations here. The precise explanation of how alloying of steel affects physical properties was rarely seen. The correct description of how quenched steel is tempered was rarely seen with the most common answer being heated and rapidly cooled.

Question 11

Many candidates did achieve at least one mark, usually referring to the increasing demand of crude oil as a raw material linked to demand for wider variety of products. Any other reasons were often inadequately communicated. There were many responses referring to the ‘production of greenhouse gases’ with no further qualification with respect to the shift in behavior. The second part of this question produced answers which often failed to precisely address the advantages and disadvantages of the use of plastics versus cardboard specifically for packaging.

Question 12

Many candidates knew the essential feature that a liquid-crystal molecule must have for the display being turned off and on but the description of the principles of a liquid-crystal display device was often poorly presented and not clearly understood.

Question 13

A correct definition of nanotechnology was often seen and many candidates knew the difference between the arrangement of carbon atoms at the sides and at the ends of carbon nanotubes. Reference to the presence of strong covalent bonding between the carbon atoms to explain the high tensile strength of the bundles of nanotubes was not seen in most scripts.

Option D

This was the most popular option in the paper with very variable responses. Many responses lacked the required precision in some of the more descriptive questions and often exhibited less than adequate application of the chemistry required for this option.

Question 14

Many candidates confused the definition of “therapeutic window” with “therapeutic index”. The nature of a narrow therapeutic window was also not well understood although the nature of side-effects was well articulated. The role of dimethicone as an anti-foaming agent was well understood overall. It was correctly identified as an anti-foaming agent where small bubbles are converted into larger ones and then released. This decreases ‘bloating’ and increases rather than decreases ‘flatulence’ which was seen quite often as a response in the use of dimethicone.

Question 15

Many candidates focused their response on the description of morphine as a strong analgesic rather than on the advantage of using morphine although the disadvantages of its use were well known. The structural differences between morphine and diamorphine were often well known.

Question 16

It was rare to see a correct redox half-equation showing the oxidation of ethanol to ethanal. The identity of the green ion formed during the ethanol oxidation was also rarely given. Many candidates did well in identifying the role of C-H bond absorption in IR intoximeters although the relationship between IR absorption and ethanol concentration was rarely addressed.

Question 17

Many candidates knew the effect of both caffeine and amphetamines on increased mental alertness. The structure of phenylethylamine was often not drawn correctly.

Question 18

Many students were able to explain how penicillins work as antibacterial agents although sometimes the answers lacked clarity. The reason for the modification of the side-chain of penicillin was often linked to bacterial resistance but did not specifically address how it actually affects the action of penicillin. Candidates were often unclear on the different ways that anti-viral drugs can work and although they usually managed to achieve one of the two marks, many explanations lacked the precision in terms of their mode of action.

Option E

This was a popular option which also exhibited a wide variety of responses.

Question 19

Many candidates identified another greenhouse gas with methane and CFCs being the most popular answers.

Most candidates identified abundance as a factor which influences the relative greenhouse effect of a gas but failed to identify as second factor. Few candidates were able to clearly articulate the effect and the consequences of increasing amounts of greenhouse gases. In addition, there was often confusion with ozone depletion and acid rain.

Question 20

The equations for the formation and depletion of ozone was generally very well known. Many identified CFC's as ozone-depleting substances and their source but a second example was rare to see.

Question 21

The term BOD was generally well understood although there were a fair number of references as it being the amount of oxygen needed by aquatic life. The correct products of anaerobic and aerobic decomposition of organic material containing nitrogen and sulfur were rarely seen.

The process of reverse osmosis was often clearly described unlike the process of multi-stage distillation which was not well understood. Many students obtained one mark for an economic factor which needed to be considered on the building of a new waste incineration plant although often, they went onto discuss non-economic factors and hence rarely scored the second mark.

Option F

This option was more popular than in recent years. Although individual questions were attempted with some success, the overall performance on this option did result in lower marks.

Question 22

Most students correctly identified glycerol as the compound which combines with fatty acids to form triglycerides. Students often described the difference between *cis* and *trans* isomer but did not always refer to the packing of the molecules. Many candidates knew one effect on health of consuming *trans* fatty acids with answers often referring to the greater risk of heart disease. Common incorrect effects on health of consuming *trans* fatty acids were that they were 'difficult to break down' or 'difficult to digest'. These statements are not synonymous with *trans* fatty acids being 'hard to metabolize'.

The conditions for hydrogenation of oleic acid were well known.

Question 23

Many students scored one mark for the similarity in structure between synthetic and naturally occurring antioxidants but the differences rarely scored any marks as candidates often compared the two structures of the natural antioxidants rather that natural ones with the synthetic ones. The role of vitamin E as a free radical scavenger was rarely correctly described although the health benefits of consuming foods containing antioxidants were generally well known.

Question 24

Most candidates appreciated the idea of carotenoids absorbing specific wavelengths of light but rarely referred to the visible region. The idea of the transmission of light of complementary colour was alluded to but often not clearly explained. Factors which increase the rate of oxidation of carotenoids need to be more specific such as ‘higher temperature’ although light as a factor was often correctly stated.

Question 25

Candidates often described how an emulsion was made in the first part of the question. Many answers did refer to the features that lead to phospholipids acting as emulsifiers but were often not able to clearly articulate this precisely in the context of this question.

Option G

Only a small number of candidates answered this option. Overall, there were some very successful responses.

Question 26

Candidates generally could provide some of understanding of the benzene structure and bonding although the explanation often lacked precision or were incomplete. Few candidates described the structure as a *regular* hexagon. Many candidates could identify a specific piece of thermochemical evidence which supported the fact that the bonds in the benzene ring were not alternative single and double bonds. In a number of responses, there was reference to an enthalpy change being less exothermic but with no indication as to which specific enthalpy change this referred to.

Question 27

There were quite a number of correct mechanisms although marks were often lost for incomplete placement of curly arrows. A very common answer to the question on predicting the most likely product to be formed in the presence of a high concentration of bromide ions was a disubstituted bromine product rather than CH_3-CHBr-CH_3.

The name of an alcohol used to produce propene was correctly stated for the most part although the correct reaction type was rare to see.

Question 28

Most candidates correctly identified the reaction as condensation/addition-elimination although the structure of the cyanohydrin formed was rarely given.

A common response to the explanation of the effect on acid strength by a hydroxyl group centred around the additional hydrogen bonding on solubility rather than the electron-withdrawing effect of the hydroxyl group. The structure of the product from the Grignard reaction was rarely stated although some candidates did manage to provide the correct reactants needed to produce Grignard reagent.

Recommendations and guidance for the teaching of future candidates

- It is important to ensure that the appropriate time is dedicated for the teaching of each of the two options (one option only in May 2016). It was interesting that in a fair number of papers, there was a large disparity in terms of performance of each of the two options possibly suggesting that one of the options might not have been taught formally and left up to the students to work on independently. Whilst independent work is encouraged, some students did have some clear difficulties in terms of their understanding of some of the material hence ideally a well-balanced approach to option coverage in terms of formal and independent work is strongly encouraged.
- The option work should provide students with many opportunities for the application of the core chemical principles such as the writing of redox half-equations especially involving organic molecules.
- There should also be an emphasis of ongoing practice of answering past exam questions on each option including the development of strategies for planning and writing coherent responses bearing in mind the number of marks for each question. This also provides opportunities for continuous review of material.
- Candidates do need to become more familiar with command terms and depth of answers expected from each one, particularly those from Objective 3. Further practice in writing clear explanations using the correct scientific terminology is also strongly encouraged.
- Candidates do need to be more familiar with organic mechanisms with particular focus on the positioning of curly arrows and drawing of organic structures.