Diploma Programme

November 2017 subject reports

Chemistry

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 17	18 32	33 44	45 55	56 66	67 78	79 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 14	15 27	28 39	40 51	52 61	62 73	74 100

Internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 3	4 6	7 10	11 13	14 16	17 19	20 24

Recommendations for procedures

The majority of schools followed the correct process of uploading the individual investigation reports. There were occasional omissions or mistakes, however. When entering the IA criteria marks, there is a space for teacher comments about their marking. If the report itself does not feature the teachers marking feedback then please take advantage of this space since the information is most useful to the moderators.

Teachers should note that the within the system for e-marking internal assessment there was facility for a 4IAF feedback report to be written only for schools where the marking of one or more candidate report was deemed to be outside of the acceptable margins of tolerance. If a school has not received a feedback report this year then that means that the samples marked showed close enough agreement between the teacher’s and moderator’s marks that the teacher’s marks could be supported.

The range and suitability of the work submitted

The range of work in terms of suitability for the assessment by the IA criteria was varied. Some moderators commented that the standard was generally good with many students being given the opportunity to independently investigate interesting research questions that enabled appropriate achievement against the assessment criteria. However other moderators marked samples comprising very often of investigations which were simple hands-on traditional closed tasks, others where students were working on same topic and simply changing one variable, working on well-established laws or simply presenting the write up of a prescribed practical.

A quite widespread problem was that the material often failed to show primary correction by the teacher, even when for example some calculations were clearly wrong. Comments in these cases were seldom supported by evidence and usually too succinct. Quite a few schools are clearly struggling with few resources resulting in investigations which were superficial qualitative comparisons rather than more rigorous quantitative analysis.

Overwhelmingly the work presented involved hands-on primary data collection. The most common topic areas were combustion calorimetry investigations, rate of reaction studies, investigating buffer systems and once more very many investigations in food chemistry. These range from excellent investigations focused on an appropriate independent variable, quite often involving suitable quantitative analysis based on redox titrations of vitamin C, ethanol, metal ions, etc. to some overly simplistic reports where the student looked qualitatively at the change in appearance of a foodstuff on oxidation or carried out a simple comparison of supermarket brands.

Similarly to the May session very few students presented reports based on secondary data using models, simulations or databases. Although each session we have seen only a very small number of such types of investigation, certainly amounting to no more than a few percent of the total investigations submitted, those we have seen have often been very good and attained very well against the criteria. The fear expressed by teachers has been that such investigations have limited capacity to take into consideration measurement uncertainty. This is often a valid consideration. Such investigations work best when there is more than one source of data available so that the variance between sources can be evaluated. In this manner, this session saw one student compare physical properties through homologous series based on more than one database source and another student carried out a research into deviations from ideal gas behaviour using three different online van der Waal’s calculators that gave slightly different outputs that were then considered.

Candidate performance against each criterion

Personal Engagement:

The overwhelming majority of students managed to achieve at least one point for Personal Engagement.

A continuing weakness is that the student’s justification of their choice of research question and topic spilling over into overlong and contrived personal narratives.

The commonest limitation to achievement was where students failed to show genuine curiosity by presenting a very undemanding research question where the outcome too self-evident, such as determining how the mass of alcohol combusted affects the heat energy evolved, whether time current passes affects the mass change of an electrode during electrolysis or a trivial brand analysis such as comparing different antacids. Where students presented a research question that reflected a question that they genuinely appeared interested in answering and couldn't already be expected to know the answer then credit was easily given.

The second part of the descriptor regarding personal input and initiative is evidenced across the whole report and here the outcome was again variable. A good number of students did show plenty of **personal input and initiative** in the designing and implementation or presentation of the investigation but it was not uncommon for students to simply repeat a commonplace school investigation with a procedure that had not been adapted or extended in any way. Another indication that students were not fully engaged was when there were clear limitations in the initial methodology that could have been quickly and easily addressed during the process but the student made no attempt to do so. It was a pity to see students fail to generate any meaningful data and teachers should monitor the process to help students reflect and modify their investigations while they still have the chance.

Successful students evidenced input by applying a known technique to an interesting real world situation and then by fully using their time to carry out trials at plenty of values of independent variable as well as including repeats.

Exploration

The achievement in Exploration was variable.

In many cases a suitable topic was identified and a relevant research question was described. Many research questions fell into the category of determining how a measurable independent variable effected an identified dependent variable and these generated reports that were easily assessable with the IA criteria.

Weaker research questions were those simple brand analyses of food, cleaning or pharmaceutical products. Any trends identified would be explainable in terms of business principles (manufacturers decide the composition rather than being the outcome of solely scientific principles). There are possible fruitful avenues available by studying commercial products but these really only open up if a student can link some component of the product composition (which they can experimentally determine or read from the packaging) to a chemical or physical property of the product. Also within food chemistry students often chose mode of cooking such as boiling v microwave v steaming as the independent variable. Interesting but as a non-quantifiable independent variable it did limit subsequent opportunity achievement against Analysis and Evaluation criteria.

As in previous sessions it wasn't uncommon to find investigations more than one research question was proposed. These investigations often lost focus and it is better for students to concentrate on answering a single clear research question in depth. Another common weakness that led to the Research Question being considered not fully focused was the use of not properly defined terms such as "efficiency" and "suitable". For example a student posed the question "To what extent is simple distillation a suitable process for purifying ethanol mixtures?" Suitable in terms of what criteria? Cost, safety, energy demand, degree of separation? It needed clarification

The quality of the background information was mixed. Frequently it was of general character rather than addressing the specifics of the chosen research question or methodology. Very often there were descriptions of chemicals and applications in contexts that in no way related to the Research Question. The top level descriptor requires the background information to be entirely appropriate and relevant so teachers should advise students to keep it focused. Students should be encouraged to include detail such as balanced chemical equations or properly drawn chemical structures where relevant.

In terms of taking into consideration the significant factors that may influence the relevance, reliability and sufficiency of the collected data the responses of the candidates was extremely varied. A good number of students clearly controlled relevant variables, selected a suitable number of values of independent variable and repeats in order to establish reliability and sufficiency. However an equal number of students didn't carry out repeats and most significantly failed to correctly identify or control key variables with the result that their data did not properly answer their research question. Electrolysis experiments were again especially poor in this regard with students showing a range of common failings such as the poor understanding that fixing voltage does not hold current constant when changing concentration of the electrolyte, the poor drying of electrodes – re-drying and reweighing to constant mass is need, the time left for electroplating is frequently too short for significant masses to be deposited.

Other frequently seen weaknesses included students not paying attention to fact that an ionic compound was hydrated when calculating its molarity and the imprecise volumetric work to make up solutions using measuring cylinders and beakers rather than graduated pipettes and volumetric flasks.

Most students showed at least some awareness of **safety**, ethical or environmental issues relevant to their methodology. In many cases this was confined to a quite basic measures such as gloves and safety glasses but an increased number of candidates did consider safe and environmentally appropriate disposal of reagents. Safety issues should specifically address the chemicals involved in the investigation as well as their disposal. It was refreshing to see some schools considering green chemistry. However, some schools continue to poorly consider safety regulations, e.g. student collecting water sample in contaminated areas with dead rats or an investigation that returned a positive test for the presence of salmonella.

Analysis

The overall achievement for Analysis was diverse with marks distributed across the mark range.

Many students recorded qualitative observations and sufficient data related to the independent and dependent variables so that they could subsequently carry out sufficiently meaningful processing and interpretation. Fewer students though recorded the data regarding the control variables such as reaction temperatures or reactant amounts. It is this wider data that can provide valuable context for the evaluation of the procedure. Other students included the expected qualitative data in the method, but such anticipated results do not always match those obtained during the collection of actual data, therefore this practice shouldn't be encouraged. Also note that while including uncertainties in the list of materials may be a good strategy, recorded data should include them as well.

We saw that a common approach to processing was simply to average the dependent variable data and then plot a graph against the independent variable to see the nature of the relationship. Very often this was done well enough to award good credit.

Other common data processing approaches were quantitative determinations based on titrations and calorimetry calculations. In some cases the numerical calculations were demanding and it is important to note here that teachers **must check through calculations** when assessing Analysis. On a significant number of occasions calculations had been awarded the highest level by the teacher but when spot checked by the examiners revealed themselves to contain major errors that significantly affected the conclusions drawn. These oversights did then lead to the downward adjustment of the Analysis mark.

Other common areas of weakness were in rate of reaction investigations where students didn't actually calculate a rate at all and contented themselves with comparative comments on reaction time and many occasions where students presented inappropriate bar charts rather than a properly constructed graph.

There was a variety of evidence presented towards the consideration of the impact of measurement uncertainty on the analysis. These included

- Sensible protocols on propagation of errors through numerical calculations such as that outlined in Topic 11.1 of the Chemistry Guide and the TSM, half range determinations or standard deviations on a sufficiently large data set.
- Well-constructed best fit graph lines.
- Error bars on graphs.
- Maximum or minimum slopes.
- Appropriate consideration of outlier data.
- Consideration of equation of a graph line and the R2 value.
- Consistent significant figures and decimal places.

No investigation needed to include all these features to achieve full credit and many students were able to reach at least the middle band descriptor in this regard.

Some of the weaknesses that arose in this area included: a significant number of students who made no attempt to propagate uncertainties through calculations; students who present numerical results to an excessive number of significant figures; absolute uncertainties with different units being added; error bars were incorrectly determined; the use of statistical methods with very few data continues to be a weakness; the poor consideration of R^2 value with some students claiming correlations were strong with values as low as 0.07.

Many, but far from all, students were able to interpret their processed data so that subsequently a conclusion to the research question could be deduced although in a significant number of cases the interpretations were often merely prose descriptions of the data and in other cases there was no interpretation at all. When interpreting a graph a common mistake was to describe linear negative slopes as inversely proportional and any deviation from linearity in a positive slope was termed exponential. Also many students simply presented a complicated Excel graph line equation without any appreciation of what it may be indicating as an underlying trend. Analysis of subtleties like y-intercept are extremely rare. Many lines of best fit are poorly drawn often using the polynomial trendline function.

It is worth noting that some students achieved poorly across Analysis since their designed methodology was too limited **and only a small amount of data was collected and the consequent processing and consideration of uncertainties was unchallenging.** The IA places the responsibility on the student and part of the independent learning task is for students to be aware of the criteria up front and for us teachers to challenge them at an early stage of the process as to whether they think their proposed investigation gives them chance to fully satisfy the criteria and counsel them accordingly.

Evaluation

Evaluation this continues to be the most challenging criterion and one that teachers tend to over reward. Many conclusions simply described results and made limited use of scientific context.

Many students failed to correctly describe or justify their conclusion through relevant comparison to the accepted scientific context. For this part of the descriptor students should either be making the comparison of their experimentally determine quantities to readily available literature values or referring to whether any trends and relationships identified were in line with accepted theory, ideally by referring back to their original background information. It was surprising how few students achieved this successfully.

Students did focus on identifying weaknesses and limitations although these were usually procedural (why the planned method was not properly implemented) and few were methodological (why the designed method itself was flawed or limited). Very few investigations addressed systematic and random errors in details while some students referred to them but failed to identify them in their specific investigation.

The aspect of the criterion concerning suggestions for improvements and extensions were a general weakness. The suggestion for improvement was often confined to suggesting more repetitions even at times when these had been acceptable. Specific improvements that were also related to previously identified limitations were less common. Moderators saw only a few interesting extensions and generally any suggestions for extension (and often there were none) were rather trivial (try a different fruit for example in a vitamin C titration) or an impractical suggestion maybe using equipment never found in school laboratory.

Communication

The Communication criterion was in most cases quite well fulfilled with the majority of students securing 2 or 3 marks.

Most reports were clearly presented with an appropriate structure and many students gained credit for coherently presenting the information on focus and outcomes. Common weaknesses were for insufficient detail to be included in the description of the methodology and for students to not present at least one worked example calculation so the reader could understand how the data was processed.

Many reports were mostly concise and most of them did meet the 12 page limit which did prove sufficient for even the most sophisticated investigations. Some students did include lengthy appendices in order to circumvent the page limit ruling but this is not an acceptable strategy since examiners do not have to read the appendices so vital marks could have been lost. Other reports included unnecessary cover sheets or indexes/contents pages.

Most of the reports were relevant although the one common area of weakness was the inclusion of too much general background information that wasn’t focused on the Research Question. Many reports included pictures of chemicals, equipment and layouts that were totally unnecessary, e.g. a photograph of a common titration set up.

With regard to the use of terminology and conventions many students proved inconsistent in their use of labelling graph axes, units, decimal places and significant figures although in most cases understanding was not greatly hampered. Also there was frequent ambiguity in the use of the word amount and reference to weight not mass.

The using of citations and references was usually seen although it was common for it not to be clear where and if a cited source had actually been used. Sometimes a bibliography appeared to be an artificial add on and there was no evidence the student had read the sources listed.

Recommendations for the teaching of future candidates

- Students should develop investigations that seek to answer research questions related to chemical principles and to avoid research questions whose answer is known beforehand.
- Encourage students to only use background information that is specific to their research question.
- Encourage students to reflect on data while collecting it so they have the chance to modify methodology if the data are proving insufficient or erroneous.
- It will be good practice in future for students to give a safety and environmental evaluation in any investigation involving hands on practical work even if it is to show that safety and eco-friendly disposal have been evaluated but no special precaution is then required. Some schools have considered implementing methodologies using lower quantities of chemicals to preserve the environment and this is encouraged.
- Encourage students to describe briefly in a paragraph the process of developing their methodology. This narrative will help explain the amount of data collected and give insight into the decision making of the student that in part evidences Personal Engagement.
- Ensure students record all relevant associated data and not just the independent and dependent variable data.
- When evaluating methodology encourage a consideration of underlying factors affecting the validity of the method such as range, sample size, use of an alternative reaction system to study the same phenomenon, etc.
- Methodologies should be written in sufficient detail so that the reader could in principle repeat the investigation and also so that an idea of the associated uncertainties can be

gained.
- Where relevant to the analysis students should present at least one worked example calculation so the reader could understand how the data was processed.
- Encourage students to interpret results quantitatively wherever possible. This will also provide a sound foundation for high quality conclusions.
- Students should consider suggestions for improvements that are related to previously identified limitations and that should be realistic and specific to their investigation.
- Discourage the inclusion of appendices.
- Title pages, indexes and content pages are unnecessary and should be discouraged.

When assessing the students work teachers should:

- Carefully check methodology for any missing key variables that would invalidate the conclusions being drawn.
- Carefully check calculations for errors that would affect the conclusions being drawn.
- Apply the model of best fit marking of the criteria evenly and not prioritizing some descriptors over others when awarding marks.
- Leave evidence of their assessment decisions for the moderator to understand the thinking behind the marks. Hand written annotations on the report scripts are fine for this purpose.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 10	11 16	17 22	23 26	27 29	30 33	34 40

General comments

The number of candidates who answered the paper was 2117, an increase of over 12% on last year. The paper consisted of 40 multiple choice questions on the Subject Specific Core and the Additional Higher Level material. A small minority of candidates did not answer every question; *there is no penalty for a wrong answer.*

The overall results suggest the candidates found the paper easier than that set in November 2016.

27 teachers gave feedback from a total of 377 schools. Apart from those for whom the comparison was not applicable (4%) the approximate percent comparison with last year's paper is as follows:

Much easier	A little easier	Of similar standard	A little more difficult	Much more difficult

0	11	74	11	0

As to the percent level of difficulty, the following answers were given:

	Too easy	Appropriate	Too difficult
Level of difficulty / %	0	100	0

Suitability of question paper in terms of clarity and presentation (approximate %):

	V poor	Poor	Fair	Good	V good	excellent
Clarity of wording	0	0	19	22	30	30
Presentation of the paper	0	0	11	19	33	37

In general, the paper seems to have been well received; although concern was expressed by a small minority (just under 12%) about the accessibility of the examination to those with learning support and / or assessment access requirements. Schools are responsible for claiming extra time and other help on behalf of entitled candidates.

There was a comment that questions 13, 15, 33 and 38 required “quite a bit of thinking time which is a disadvantage to ESL students”. We aim to encourage candidates to think and do our best to make the language accessible to ESL students. ESL candidates can use a pocket dictionary. Calculators are not allowed in paper 1 and it is essential that candidates practise past papers without a calculator. Any calculation required is always “easy”; very low multiples such as those in question 4.

There was a comment that there was a lot of reading across the 40 questions. We do not agree with this comment; we take pains to use the minimum number of words without losing clarity in the question.

We were pleased to see the opinion that the questions would “find out regurgitators”.

Candidates should expect structural formulas to be either in 3-D (as in questions 34 and 38) or in 2-D (as in questions 14 and 37).

As far as time management is concerned, the standard response time has been 1.5 minutes per question for some time and is common to all the Group 4 subjects.

The order of questions in paper one follows topic order so candidates who are troubled by the more mathematical questions that can occur early in the paper should be advised to leave them until later.

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

The difficulty index (percent of candidates giving the correct answer) ranged from 40.91% (N16: 36.34%) to 96.46% (N16: 93.01%). The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from 0.09 (N16: 0.16) to 0.63 (N16: 0.74). The marks ranged from 0 to 40 with 9 scoring 10 or less. The mean mark was 29.4.

The following comments are made on individual questions:

Question 1

We apologise for the error showing 6.01×10^{23} in D. It will be corrected to 6.02×10^{23} in the published version of the paper. The most common wrong answer was C, presumably by those candidates who had not noticed that there are two ammonium ions in the formula.

Question 4

This was answered well (91.5%), most candidates coping with the small amount of manipulation needed.

Question 5

The second easiest question on the paper with 96% success rate.

Question 8

Over 40% of the candidates thought that melting point increases across period 3 – but that is not the whole story.

Question 10

About 10% of candidates thought the oxidation numbers to be different in the two complexes.

Question 11

The common error was to reverse propanol and propanal.

Question 14

Nearly 50% of the candidates gave A as the answer, missing the four hydrogens attached to the benzene ring. It was the "hardest" question on the paper.

Question 16

This required some mathematical rearrangement so it was pleasing to see a 56% success rate. The most common error was B.

Question 18

The most common error was B. We would expect candidates to know that Mg, in group 2, would have a charge 2^+.

Question 19

Nearly 83% answered this correctly. There is a lot of reading and questions such as this are likely to be tabulated in the future.

Question 22

This was found to be the easiest question on the paper.

Question 23

The most common error was A, the reverse of the correct answer.

Question 24

The most common error was B, a muddle between changes in pH and $[H^+]$.

Question 25

This was one of the more testing questions with many giving the answer as B, thinking the dilution was 10:100 instead of 10:1000.

Question 29

Many thought B to be the correct answer, not recognising it as an acid-base reaction.

Question 30

Many thought D to be the correct answer, not realising that MnO_4^- is reduced to Mn^{2+}.

Question 31

We would expect candidates to be able to answer this question successfully after studying the program for two years. Nearly 62% gave the correct answer, C, although D was entered by 19%.

Question 32

A significant number of candidates thought the answer to be A, presumably confused with $KMnO_4$.

Question 34

Despite the 3-D representation of the molecule, over 90% gave the right answer.

Question 37

Candidates needed to see that there are two chiral centres in this molecule and then deduce that there would be four optical isomers. In the event, it was the second hardest question on the paper with a 47% success rate.

Question 38

Incorrect answers were fairly evenly split between A and D.

Question 39

Candidates needed to identify a compound with hydrogen atoms in four different environments.

Question 40

Nearly 80% answered this correctly.

Recommendations and guidance 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 how to approach a multiple-choice examination and, at the end, to have left no question unanswered.
- Candidates should spend no more than about one minute on each question in the first instance and those candidates who find anything mathematical to be challenging should leave those for later in the time allocation.
- Ensure the whole syllabus is taught as every topic is examined in this paper (as in all papers).

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 20	21 23	24 30

General comments

The number of candidates who answered the paper was 2309. The paper consisted of 30 multiple choice questions on the Subject Specific Core. Up to 2.5% of candidates did not answer any one question *even though there is no penalty for a wrong answer.*

27 teachers gave feedback from a total of 280 schools. The approximate percent comparison with last year's paper is as follows:

Much easier	A little easier	Of similar standard	A little more difficult	Much more difficult
0	11	78	11	0

As to the percent level of difficulty, the following answers were given:

	Too easy	Appropriate	Too difficult
Level of difficulty / %	0	96	4

Suitability of question paper in terms of clarity and presentation (approximate %):

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	0	0	19	37	33	11
Presentation of the paper	0	4	15	22	37	22

In general, the paper seems to have been well received. There were some general comments.

It was noted that questions 1 – 3 are slightly challenging for those who aren't very mathematically able. As the questions are always presented in topic order, candidates have the option to start elsewhere in the paper and come back to these early questions later. Calculators are not allowed in paper 1 and it is essential that candidates practise past papers without a calculator. Any calculation required is always "easy"; very low multiples such as those in question 3.

One commented that we should allow more time for the paper. The standard response time has been 1.5 minutes per question for some time and is common to all the Group 4 subjects.

Another commented that some questions were too difficult for special educational needs candidates. Schools can apply for extra time on behalf of these candidates and, in the case of questions such as 26, it may be possible to ask in advance for models.

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

The difficulty index (percent of candidates giving the correct answer) ranged from 24.43% (N16: 23.32%) to 82.03% (N16: 67.31%). The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from 0.29 (N16: 0.18) to 0.66 (N16: 0.76). The marks gained ranged from 0 to 30 with 10% scoring 7 or less. The mean mark was 15.6.

The following comments are made on individual questions:

Question 1

We apologise for the error showing 6.01×10^{23} in D. It will be corrected to 6.02×10^{23} in the published version of the paper. The most common wrong answer was C, presumably by those candidates who had not noticed that there are two ammonium ions in the formula.

Question 2

This was the most difficult question on the paper with a success rate of less than 25%. The most common answer was B.

Question 3

Nearly half the candidates gave the right answer but there was a significant number of blank answers.

Question 4

The common error was to forget the “1” in front of $C_6H_{12}O_6$.

Question 5

This turned out to be the easiest question on the paper with an 82% success rate.

Question 6

Inevitably the most common wrong answer was C.

Question 9

Whilst 58% gave the correct answer, opinion was fairly evenly divided between the others.

Question 11

Distractor B was the most common error here.

Question 12

Only 35.9% gave the correct answer suggesting that the vast majority of candidates think that *ions* move when a metal conducts electricity. One commented that choice III was ambiguously worded; we did not consider it so.

Question 14

For a question requiring some manipulation, this was done well (67%).

Question 15

The most common wrong answer was A, the reverse of the correct answer.

Question 16

The most common wrong answer was D.

Question 17

Many thought the answer to be C, not realising that an increase in temperature would only increase the rate, not the loss in mass.

Question 18

One respondent was concerned that the gaseous state of CO_2 would confuse candidates. In the event, the most common wrong answer was B showing that the confusion was the relationship between pH and $[H^+]$.

Question 19

This was one of the more testing questions with many giving the answer as B, thinking the dilution was 10:100 instead of 10:1000.

Question 21

A significant number of candidates thought the answer to be A, presumably confused with $KMnO_4$.

Question 22

Many thought B to be the correct answer, not recognising it as an acid-base reaction.

Question 25

This had the highest number of “no responses”.

Question 26

Candidates need to be ready for this sort of representation of molecules. In the event, it was the third easiest question on the paper.

Question 28

This was answered correctly by only 38% with A and C being popular choices.

Question 29

This was thought to be confusingly worded but the wording is clear although only answered correctly by 38% of the candidates. The rest of the answers were fairly evenly spread between the distractors.

Question 30

Nearly 60% answered this correctly.

Recommendations and guidance 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 how to approach a multiple-choice examination and, at the end, to have left no question unanswered.
- Candidates should spend no more than about one minute on each question in the first instance and those candidates who find anything mathematical to be challenging should leave those for later in the time allocation.
- Ensure the whole syllabus is taught as every topic is examined in this paper (as in all papers).

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 14	15 28	29 38	39 49	50 59	60 70	71 95

General comments

This was an accessible paper with a very wide range of marks from 3 to 95, the latter being particularly pleasing to see. In fact, 29 candidates scored 90 or more and the mean mark was in the region of 56 out of 95. There were strong scripts where candidates displayed an excellent knowledge of the subject. There was, however, a worrying minority where it seemed that students, even after two years of study, had failed to grasp even the most basic chemical concepts. A small percentage (around 1.5%) of candidates scored 10 or fewer marks.

There is evidence that candidates found it difficult to finish the paper, with the % attempting each part question falling in the region of question 8.

29 teachers gave feedback from a total of 377 schools. Apart from those for whom the comparison was not applicable (3%) the approximate percent comparison with last year's paper is as follows:

Much easier	A little easier	Of similar standard	A little more difficult	Much more difficult
0	7	69	17	3

As to the percent level of difficulty, the following answers were given:

	Too easy	Appropriate	Too difficult
Level of difficulty / %	0	93	7

Suitability of question paper in terms of clarity and presentation (approximate %):

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	0	3	10	24	31	31
Presentation of the paper	0	0	21	10	34	34

In general, the paper seems to have been well received and there were comments such as "good spread of topics", good paper for testing application and not catching students out", and "well-designed paper".

One respondent commented that there was "no full coverage of topics". When the papers are authored, care is taken to balance the marks with the time allocated for teaching each topic.

Another commented that there was insufficient space provided for questions using the command term "explain". We would agree with this and will do our best to increase the space for such questions for papers which are still in production.

There was also a comment that the paper will be difficult for a child having dyslexia and / or other learning disabilities. It is important that schools apply for any extra help allowed for such candidates.

It was noticeable that some candidates, whilst continuing on an extra page, did not refer the examiner to the extra page. It is really important that candidates write “see extra sheet” in the answer box.

Teachers should be aware that paper authors set question papers by reference to the current subject guide and do not consider how material is covered in Chemistry text books.

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

- Showing how data is gained from graph extrapolation
- Setting out calculations clearly and succinctly
- Determining empirical formula from combustion data
- Explaining shapes of rate curves obtained under different conditions
- Explanations for trends in ionization energies across a period and melting points down a group
- Understanding weak acids and conjugate bases
- Hydrogen spectrum
- Understanding difference between the trend in melting points of Groups 1 and 17
- Explaining the products of electrolysis of aqueous solutions
- Drawing 3-D representations of chiral compounds
- Remembering that a nitration mixture needs concentrated acids

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

- Calculation of relative atomic mass
- Calculation of molar mass from $pV = nRT$
- How to determine molecular formula from empirical formula
- Determining orders of reaction, writing rate expressions, calculating rate constants
- Reaction of phosphorus(V) oxide with water
- Oxidation states
- Calculation of K_c and factors affecting equilibrium
- Calculation of acid and base dissociation constants
- Reaction taking place during complex ion formation

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

Question 1

There have been data-based questions in paper 2 in the past but, in fact, there was very little data manipulation. Most of the question required direct interpretation of the data and calculations where a good deal of “error carried forward” was allowed. In general, candidates made a good attempt at this.

(a). We hoped that candidates would extrapolate two lines to cut the *y*-axis at the same point. Many scored the mark although very few had shown any lines on the graph. A worrying number thought the initial temperature to be that of the first data point.

(b). Again, we hoped for an extrapolation but there were few examples – although candidates scored quite well.

(c). Very rarely was a "correct" volume of ethanoic acid used – and it was not possible to relate the volume used to the graphs as no lines were drawn. The moles of NaOH were generally calculated correctly.

(d)(i). A lot of "error carried forward" was allowed here from the incorrect volume in (c) here but many did not add the two volumes. Some added 273 to the *difference* in temperature.

(d)(ii). Plenty of "error carried forward" here with many scoring [2]. But, the sign had to be negative!

(e). The idea of the weak acid was generally scored but very few commented on the energy required to ionise the weak acid.

(f)(i). The question is about "collision theory" – so collisions must be mentioned in the answer which needs to explain the shape of curve **X**. This has nothing to do with curve **Y** to which many made comparison.

(f)(ii). Some candidates lost a mark here because it was not clear which, of **X** and **Y**, had the greater concentration / amount.

Question 2

(a). Candidates who understood "describe" generally answered this well. Those who misread it for "explain" generally did not score.

(b). Some opined that "hydrogen jumped down" – but the mark was only awarded if electrons were specified. There was testing "error carried forward" if the candidate had described the absorption spectrum.

(c). This was generally answered well but it is difficult to understand the mindset of those who gave only one decimal place in the answer.

(d)(i). Candidates found this very difficult indeed. The most common mark gained was M1 for finding the moles of carbon / CO_2. Thereafter, many seemed to misread menthol for methanol. Sometimes it was possible to award the final mark if some data about moles of C, H and O had been given.

(d)(ii). This was answered well by many and the mean mark was 1.5 out of 2. Some forgot to convert the temperature to K.

(d)(iii). The mark here was awarded if the candidate used the correct calculation even though the answers in (i) and (ii) were incorrect. Over 20% of the candidates, however did not attempt this part. Even so, 60% did score the mark.

(e)(i). For the most part this was done well with a 90% success rate.

(e)(ii). Well done for the most part but some carelessly reversed the indices.

(e)(iii). Many (80%) managed this part well and errors were carried forward from the previous two parts.

Question 3

(a). There was a suggestion that we should have referred candidates to section 8 of the data booklet. This was not necessary as the trend was given in the question. Candidates did not have a firm grasp of this although many scored the mark for the "increase in number of protons".

(b). Candidates were either well-prepared or seemed to have little idea. In Group 17, there were many answers suggesting an increase in atomic radius could be the explanation.

(c). 50% of the candidates scored this mark.

(d)(i). This was generally well-answered.

(d)(ii). Oxidation state should be stated "sign then number".

(e). There were many good explanations but candidates should be sure to specify "pair" of electrons.

Question 4

(a). This was generally well answered (at the 70% level overall). Common errors were to omit the lone pair on P in PF3 (thus leading to incorrect molecular geometry and bond angles) and the lone pairs on F in either or both (only penalised once).

(b). This was well done in general with many giving explanations which were not required. Of course, two answers had to be given, one for PF3 and the other for PF5.

(c). This was answered with an 80% success rate. Candidates should be aware that the answer is sp^3 and not sp_3 (although no penalty was exacted).

Question 5

(a). Errors were usually arithmetical or the "2" factor(s) were missed or the subtraction effected the wrong way round.

(b). Candidates had the same success rate with this as with (a) above.

(c). There were some good answers. Some candidates, however, incorrectly referred to positive entropy, S, rather than positive entropy change, ΔS, and others suggested high temperatures would make ΔG negative rather than $T\Delta S > \Delta H$ (at the reaction temperature of 298K).

Question 6

(a)(i). Apart from careless errors such as [I] and [H], this was generally well done. Another error was to forget to include the [HI] coefficient as a power to its concentration term in the K_c expression.

(a)(ii). This was correctly answered at the 90% level – but arithmetic errors were disappointing.

(a)(iii). The answer was required in kJ and needed a negative sign in the final answer; both were common errors.

(a)(iv). Candidates needed to appreciate that there are the same number of gaseous moles on each side of the equation and hence pressure change has no effect. The idea of movement in the endothermic direction was quite well understood but not always made clear.

(b)(i). This was generally well answered. Some candidates missed the negative sign from HCO_3^-

(b)(ii) and (iii). Learning a definition of a conjugate base is not required – but candidates should be able to explain what is meant by one. They found it difficult to express themselves. Some candidates answered in (ii) that the conjugate base differed by a proton from the conjugate acid. Others gave rather muddled explanations and showed that they did not understand the concept by their answer to (iii).

(c)(i). The mean mark was 2 out of 3 with many good answers. Typical challenges were in obtaining the correct value of $[H_3O^+]$ from the given pH, forgetting the power of 2 in the numerator of the K_a expression – and arithmetic errors.

(c)(ii). Those who managed (i) were generally able to get an answer.

(d). Even weaker candidates made an attempt at this and the mean mark was 1.1 out of 2. In general, candidates found it difficult to structure their answers.

Question 7

(a). The answers were very variable with some backwards and some with I^- and Ni^{2+} on different sides of the equation.

(b). Some candidates assumed the question was asking about the same electrodes as Q7a. Those that gave the direction correctly had more trouble with a reason.

(c). There were many correct answers. Arithmetic errors were disappointing as was the use of incorrect electrode potentials.

(d). Generally correct but some wrote a half equation so it was not clear which species was the answer.

(e) This was disappointingly answered. There were many suggestions that sodium would be produced at the negative electrode and equations were often written the wrong way round – or at the wrong electrode.

Question 8

(a)(i). Some candidates wanted to use bromine (often an answer, just to a different question) and many did not acidify their reagent. In general, we try not to ask for two answers for one mark; we apologise that this one slipped through.

(a)(ii). There were two ways in which candidate lost marks. They did not report the colour change and /or they referred to primary and secondary instead of secondary and tertiary.

(a)(iii). Candidates either knew the concepts and were able to score [4] or they had no idea and guessed – invariably wrongly. In retrospect, too many marks were allocated to this.

(a)(iv). This was generally well done.

(a)(v). This type of diagram seems to be improving although there are still some candidates who do not draw the two enantiomers as mirror images.

(b). Some candidates used chlorine in place of bromine and other hydrocarbons in place of ethane. Some did not identify the three steps, some omitted the second propagation step or produced H•. This is one of the few mechanisms that should be learnt – and applied to the chemicals in the question.

(c). This was poorly answered overall. Some candidates had absolutely no idea and others omitted “concentrated” and sometimes sulfuric acid as well.

(d). 50% of the candidates scored this mark but 14% of the candidates did not attempt this question. We would expect formation of the electrophile to be part of the teaching of benzene nitration.

(e). One respondent commented that there was doubt about whether this was a substitution or elimination reaction. The latter is no longer in the syllabus and, in any case, would require ethanolic solution. The question was generally well answered but the accuracy of the curly arrows was an issue. They need to start from the C–Br bond (not on the C) and on the negative charge or lone pairs on the oxygen on ^{-}OH. Some examples of S_N2 were seen which gained partial credit.

Recommendations and guidance for the teaching of future candidates

We give a reference to the data booklet in many questions but candidates should not assume that because there is no reference, the data booklet is not needed. In general, the data booklet should be a candidate's constant companion during the two-year course.

There is no particular length to a question in these papers. The questions flow in a logical way and candidates should pace themselves by the number of marks (just over one minute per mark) rather than by the number of questions.

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

- Only write in the box. Examiners cannot see what is written outside the box so it will not be marked. If you need more space, write on a continuation sheet and write "see continuation sheet" in the answer box.
- Take care over your handwriting and write legibly. If an examiner cannot read your (correct) answer it will gain no marks. Draw diagrams carefully. If you make a mess of the first attempt, draw a new one on an extra page. Amended diagrams do not always scan very well.
- Do not write out the question. It wastes space in the answer box (and it wastes time!).
- Make sure you leave enough time for later marks. Remember that the questions (1, 2, 3 etc.) may not be of uniform length.
- Look at the number of marks available and try to make the same number of points in your answer.
- Read the question carefully to make sure that you answer it – and not what you would like the question to be.
- Make sure you are familiar with the data booklet well in advance of the examination. You will always be asked to use it and time saved there can be used to write answers.
- Draw Lewis structures very carefully and don't leave extraneous dots/marks on the paper which can be mistaken for electrons. Don't forget to include all non-bonding (lone) pairs and any charges.
- Learn to use all terms, such as molecules, atoms, ions, nuclei, correctly.
- Write out calculations neatly and in a logical manner. If marks for working are to be awarded, the examiner needs to be able to read and understand what you are doing.
- "Keep going" with calculations as errors are carried forward so that a correct method in a later part of the question is rewarded. Show all steps in a calculation.
- Take notice of units, significant figures and decimal places and check that you have not made an avoidable mathematical error.
- Check the sign of your numerical answers.
- If you are asked to make a comparison or predict a difference, then you need to mention both compounds.
- Do not ignore organic chemistry; it will always be examined.
- You should be aware of the "list principle". If you are, for instance, asked for one reason and you give two, one of which is correct and the other incorrect, you will score no marks.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 6	7 12	13 17	18 23	24 29	30 35	36 50

General comments

Over 2350 candidates from 280 schools sat this paper, with approximately equal numbers of English and Spanish scripts and 12 scripts in Japanese. The paper contained questions that varied in difficulty and was able to discriminate well between candidates. A good proportion of candidates performed well, their answers reflecting good understanding of concepts, effective communication skills and care in reading questions. Most candidates showed skill at the more straightforward calculations and unit conversions.

The majority of candidates seemed to find the paper accessible and attempted the majority of questions several scoring 40 to 50 marks. However, it was a concern that the number of candidates leaving totally unanswered questions is still startling high in Spanish.

Organic chemistry was not answered as well by a good number of candidates indicating that this area may be receiving less coverage in some schools. About 25% of the candidates who answered the Spanish scripts and about 10% of those who answered the English scripts left the organic question blank.

We received 30 responses from teachers about the paper (16 English, 13 Spanish and 1 Japanese). The respondents gave positive comments about the paper that it was well designed and tested the students' knowledge and understanding. There was a comment that topic coverage should be better and another comment that explanation questions needed to have larger answer boxes. When the papers are authored, care is taken to balance the marks with the time allocated for teaching each topic. 83% of the respondents judged the paper as of appropriate difficulty while 17% judged it as too difficult. When comparing the paper to the November 2016 paper, 7% judged it as a little easier, 53% thought it was of a similar standard, 33% judged it as a little more difficult and 7% of respondents thought it was a much more difficult paper. The perceived increase in difficulty is supported by the statistics that show a decrease in the average mark obtained on the paper from November 2016.

73% of the respondents thought the clarity of wording in the paper was good to excellent and 83% of respondents thought the presentation of the paper was good to excellent. There were no concerns regarding any gender or religious bias in the paper, however, 3% of respondents somewhat disagreed that the questions were accessible to all candidates irrespective of their ethnicity, and 10% of respondents somewhat disagreed that the questions were accessible to all candidates with learning support and/or assessment access requirements. IB Coordinators can apply for special arrangements for candidates who experience vision difficulties or have other special educational needs.

Specific concerns about wording, presentation and accessibility will be discussed in the section about individual questions.

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

- Using a thermometric titration graph to extrapolate and extract data.
- Knowing what mass to use in calorimetric calculations.
- Explaining trends in ionization energy and melting points.
- Remembering to include the lone pairs of outer atoms when drawing Lewis structures
- Explaining molecular polarity.
- Calculating the empirical formula from combustion data, where calculation of oxygen is required.
- Accurately stating the meaning of terms, such as conjugate base.
- Deducing the conjugate base of a given species.
- Qualitative organic tests, reagents and observations.
- Accuracy in naming oxidising agents.
- ^{1}H NMR spectroscopy.

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

- Interpretation of reactivity series.
- Voltaic cells.
- Lewis structures.
- Molecular geometry.
- Applying the ideal gas equation to the calculation of molar mass, including converting temperature to Kelvins.
- Applying Le Chatelier's principle to changes brought about by altering equilibrium conditions.
- Identifying amphiprotic species.
- The mechanism of free radical substitution.
- The strengths and weaknesses of the candidates in the treatment of individual questions.

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

Question 1

(a). 40% of the candidates extrapolated the line and obtained a correct answer based on the graph. Quite a few candidates did not extrapolate and simply gave the temperature of the lowest data point, 22.8℃.

(b). Almost all candidates scored the mark (the average mark on the question was 0.9), as the highest point on the graph was in the markscheme range, so it was correct even if the lines were not extrapolated.

(c). The average mark on this question was 0.6 out of 2 possible marks. Many candidates obtained the amount of sodium hydroxide correctly but used an incorrect volume of ethanoic acid required for the "end point", which needed to be obtained at the intersection of lines in the graph. The most common incorrect volumes used were 30.0 cm^3 and 45.0 cm^3. A few candidates also misread the x-axis scale.

(d)(i). Almost all candidates benefitted in some way from ECF on this question and, with the help of this, about a quarter of candidates attained full marks. The major source of confusion was the mass to use in $q = mc\Delta T$. Many candidates did not add the two volumes of solution together. Quite a few candidates lost a mark by incorrectly stating an answer in J, instead of kJ – the required unit.

(d)(ii). With the help of error carried forward, some candidates achieved full marks. However a significant number lost a mark for not including a negative sign for the enthalpy change. The average mark on this question was 0.5 out of two possible marks.

(e)(i). One of the worst answered questions on the paper. Many candidates did not read the question carefully and thought a comparison of Curve X and Curve Y was required, though some of them salvaged a mark by communicating the concept that reaction rate depended on collision frequency. Those who did correctly interpret what was being asked found that clearly communicating the shape of the curve in terms of reaction rate was a challenge, let alone explaining it in terms of changing concentrations and the effect this had on collision frequency. Some candidates referred to "more" collisions without reference to time.

(e)(ii). Many candidates made statements about changes in conditions without stating whether they were referring to Curve X or Curve Y. Some candidates also wrote "a difference", without stating whether it was an increase or a decrease in the chosen variable. When it came to the variable about a third of the candidates realised that the significantly different final volumes meant that the amount of limiting reagent (usually assuming one reagent) was the underlying difference. Temperature was the most common incorrect variable, though more creative ones, such as presence of a catalyst or reactivity series placement did occur. The average mark on this question was 0.2, making it one of the most discriminating questions on the paper.

Question 2

(a). Many candidates used incorrect terminology or seemed to be confused about the concept. Some candidates talked about "increasing number of electrons" instead of the more fundamental and relevant "increasing number of protons". Nevertheless quite a few managed to gain a mark, though achieving the second one was rare. Only a small proportion of candidates mentioned the decrease in radius along a period. The average mark was 0.5 out of 2 possible marks.

(b). A lot of confusion about what the question was asking, with many giving answers that appeared to assume they were explaining an ionisation energy trend. Even when candidates realised the question was about melting point, many seemed unsure of the nature of the forces that needed to be overcome, with intermolecular forces often being mentioned. The average mark was 0.5 out of 2 possible marks.

(c). About a third of the candidates gave the correct equation for the reaction of phosphorus(V) oxide with water. Some candidates had the correct reactants and products but failed to balance the equation.

(d). Many candidates explained the origin of the spectrum, instead of describing it – a confusion of command terms. Some candidates described the energy levels instead of the spectrum. Almost all candidates who did describe the spectrum seemed to be aware it was a line spectrum and a few mentioned the convergence. The average mark was 0.5 out of 2 possible marks.

(e)(i). 70% of candidates correctly identified manganese as the strongest reducing agent.

(e)(ii). A number of candidates wrote cell diagrams and many of those who wrote equations gave the half equations at the electrodes, often correctly, rather than the cell reaction asked for. Those giving the cell reaction often did so correctly. The average mark was 0.3.

(e)(iii). The majority of candidates realised the need for a wire and a salt bridge, though a few lost marks by not labelling the latter or drawing a salt bridge that does not dip into the solutions. Many correctly identified the electron flow in the wire, taking into account ECF from Q2e(ii), but the direction of ion flow was very poorly done. Most candidates gave a single direction for ion flow instead of identifying directions for cations and anions separately. The markscheme of this question was lenient as the wording of the question was rather vague. The average mark achieved was 0.9 out of 2 possible marks.

Question 3

(a). Generally well done, though there were quite a few candidates who omitted the lone pairs on the fluorine atoms and hence benefitted from ECF to gain a mark for the second structure. Few candidates however would have gained the mark for PF_4^+ if the charge and brackets had been required. The shapes were generally well known, though a few candidates gave PF_3 as planar. The average mark was 2.3 out of 4 possible marks.

(b). Again candidates, over and above second language issues, found it difficult to clearly account for the polarity of PF_3 using its bond polarity and the lack of symmetry. The explanations were often incomplete and 80% of candidates did not gain the mark.

Question 4

(a). This calculation was beyond all but the most able candidates. The vast majority gained one mark by correctly calculating the amount of carbon dioxide. It was surprising that most candidates did not obtain the amount of hydrogen correctly. Very few candidates were awarded ECF for obtaining the simplest ratio from the incorrect amounts of C, H and O. Most candidates were trying to “guess” the formula rather than calculate it. Some candidates confused “menthol” with “methanol”. The average mark achieved was 0.7 out of 3 possible marks.

(b). Many candidates gained both marks for this questions, though a few had problems with powers of ten. It was encouraging to see that the majority of candidates realised the need to convert the temperature to K. The average mark was 1 out of 2 possible marks.

Question 5

(a). Generally well done, especially the effect of temperature change, as some candidates found it difficult to explain why volume change had no effect on the hydrogen iodide equilibrium. Explanations that stated "volume/pressure of reactants and products are the same" were not accepted. The average mark was 0.7 out of 2 possible marks.

(b)(i). Quite well answered with 50% of candidates being able to identify two amphiprotic species.

(b)(ii). This mark was rarely gained and again clarity of expression was the problem. Most candidates seemed to have a good general idea of what a conjugate base was but the problem, even for native speakers, was using words precisely to express this accurately. A significant number also stated that it "*differs* by one H^+ from the acid" rather than "has one *less* H^+ than the acid". The average mark on this question was 0.3.

(b)(iii). This was the most challenging question on the paper, answered correctly by only 10% of the candidates. The vast majority of candidates gave water instead of O^{2-} as the conjugate base of OH^-.

(c). Some teacher respondents commented that "evaluate this hypothesis" was rather vague for ESL candidates. Indeed many answers lacked clear statements that the hypothesis was not valid. This question dealt with the nature of science and the markscheme was generous offering many ways of scoring the marks. Most candidates realised that HCl refuted the hypothesis and, in addition, a reasonable number gained a second mark by implying it contradicted Brønsted-Lowry theory or that the student should use a broader selection of acids to test his hypothesis. The average mark on this question was 0.8 out of 2 possible marks.

Question 6

(a)(i). This was a discriminating question. Only about a fifth of the candidates realised an oxidation reaction would distinguish between the compounds and could correctly identify an appropriate reagent. Some candidates forgot to state that the dichromate(VI) was acidified.

(a)(ii). Many candidates who had answered part (a) correctly failed to gain the 2 marks because they did not answer all parts of the question. Those who gave the correct colour change often did not explain this in terms of the nature of the hydroxyl group and vice versa. A number of candidates also thought A was a primary alcohol, failing to recognise that the –COOH involved another C-C bond. Weaker candidates left this question blank. The average mark on this question was 0.4 out of 2 possible marks.

(a)(iii). Most candidates showed a weakness in predicting NMR spectra. A number of candidates scored a mark for one of the numbers in the first column; gaining full marks as a result of understanding the underlying principles was rare. A quarter of the candidates left this question blank. The average mark was 0.9 out of 4 marks. Four marks out of 50 on one sub-topic of the programme was probably not suitable and will be avoided in future sessions.

(b). Almost all candidates scored some marks, with the initiation process being the best known, and some candidates gained full, or nearly full, marks. The average mark was 1.6 out of 4 possible marks.

Recommendations and guidance for the teaching of future candidates

- Give students more practice at writing explanations using correct chemical terminology.
- Teachers are advised to coach students in appropriate interpretation of graphs.
- More practical work in the laboratory will give students confidence in determining appropriate data analysis, interpreting graphs, and in describing qualitative observations.
- Students need to understand the difference between the different command terms and use them to frame an appropriate answer.
- Ensure all parts of the syllabus receive coverage including organic chemistry and spectroscopy.
- Provide more practice on predicting ^{1}H NMR spectra.
- Candidates should understand the chemical reactions instead of memorising equations.
- Train students to write out calculations neatly and in a logical manner allowing the examiner to award partial marks if a mistake is made.
- Help students interpret the precise wording of examination questions with regard to what is required and what would be an appropriate depth of response, taking into account the number of marks and the space left for the answer.
- Train students to write only in the box and refer the examiner to a continuation sheet if one is used. We are still seeing parts of answers outside the boxes.
- IB Coordinators can apply for special arrangements for candidates who experience vision difficulties or have other special educational needs.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 7	8 15	16 19	20 24	25 30	31 35	36 45

General comments

Based on the 29 G2 comments received, the majority of teachers, 93%, found the examination paper to be of an appropriate standard in terms of level of difficulty with only 7% considering the paper too difficult. 62% of the teachers stated that the paper was of a similar standard to N16. 24% considered it more difficult than N16. Only 7% considered the paper slightly easier (the remainder felt that the paper was much easier).

Many of the general G2 comments received reflected a paper that was well received, balanced and relatively unproblematic. The N17 paper was found to be more accessible than in N16 and teachers stated that their students largely commented positively on the accessible nature of the data-response question in Section A compared to previous sessions. Students appeared to have a greater chance of gaining incremental, scaffolding marks in all three questions in this Section. One teacher considered that the syllabus coverage of Option B on Biochemistry was poor.

Based on feedback received from examiners, general consensus was that the overall paper was highly accessible with a good spread of easy and challenging questions throughout each Section and Option. Most examiners deemed the paper to be less challenging than in N16. In particular, in Section A, many of the questions had a number of relatively straight-forward marks in each of the three questions which made Section A overall quite accessible to candidates. In addition, most examiners commented that the overall performance of candidates in N17 was better than in N16. Performance was better in several key areas, including the data-based question, numerical calculations (which were particularly well executed this session), integration of core, chemical concepts into the applied sub-topics in the Options and candidates connecting the environmental chemistry strand across the programme in all four Options. NOS based questions still appear problematic for candidates however.

A small number of centres did not attempt Section A at all. As regards the clarity of wording on the paper, the following were the statistics, based on G2 feedback: excellent – 28%, very good - 31%, good - 24%, fair – 17%, poor - 0%. The corresponding statistical data for the overall presentation of the paper was as follows: excellent – 35%, very good - 31%, good - 24%, fair – 10%, poor - 0%. Out of the total number of G2 responses, 11% considered that the questions were not accessible to Special Education Needs students. 4% also considered that the questions were somewhat not accessible to all candidates irrespective of their ethnicity. This was discussed during the Grade Award meeting and the IB wishes to remind all teachers and IB coordinators that if any learner has any specific Special Education requirements that they should ensure that the IB are informed directly in advance of an examination in order to give all learners the maximum support possible.

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

- NOS based questions – involving logical thinking and application of basic chemical knowledge to everyday situations.
- Intermolecular forces of attraction.
- Drawing structural formulae with correct bond connectivities.
- Basic chemical nomenclature.

Section A

- Outline of how current flows in an electrolyte.

- Writing the correct chemical formula of magnesium hydroxide and magnesium chloride.

Option A – Materials

- Explanation of Inductively Coupled Plasma (ICP).
- Superconductors.
- Solubility product calculation.

Option B – Biochemistry

- Explanation why linoleic acid releases more energy per gram than fructose.
- Importance of linoleic acid for human health.
- Explanation how pH change causes loss of activity of an enzyme.
- Role of cis and trans-retinal in vision.

Option C – Energy.

- NOS based question on “carbon footprint”.
- Concise scientific explanation of the Greenhouse effect.
- Calculation of mass defect.
- Transesterification reaction.
- Mode of action of a dye-sensitized solar cell (DSSC).

Option D – Medicinal Chemistry

- Explanation of how a fuel cell breathalyser works.

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

There was strong evidence that candidates demonstrated multiple skills and conveyed competency in several core areas of the programme:

- Numerical calculations – very well executed this session compared to previous years – on balance suggested a stronger cohort than in N16.
- There was a marked improvement in the overall performance in Section A, especially involving the data-based question. Interpretation of graphical and tabular data was in addition very good.
- Integration of the core fundamental chemistry sub-topics within the Options.
- Environmental chemistry.
- Interpretation of IR spectroscopy.

Section A

- Understanding of the meaning of correlation coefficient.
- Uncertainty calculations.
- Interpretation of graphical and tabular data.

Option A – Materials

- Intermolecular bonding in Kevlar®.

Option B – Biochemistry

- Finding the value of the Michaelis constant graphically.
- Idea of a competitive inhibitor.

Option C – Energy

- Calculation of specific energy.
- Renewable energy sources.
- Calculation of half-life.

Option D – Medicinal Chemistry

- Determination of the percentage of a sample remaining after radioactive decay.
- Interpretation of IR spectroscopy.
- Chiral auxiliaries.
- Functional group names.
- pH buffer calculations.
- Explanation of the importance of the beta-lactam ring in the mode of action of penicillin.

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

Section A

Section A in N17 was found to be very accessible to candidates with most gaining at least some marks in all three questions. This was a welcome change to previous sessions and shows that the performance on the data-response question appears to be improving coupled with perhaps an increased integration of laboratory work in the delivery of the curriculum across many centres. There was evidence of some excellent answers in Section A.

Question 1

(a)(i). 50% of candidates were able to sketch a correct graph. The most common errors included sketches where axes were not labelled, incorrectly putting *I* as the independent variable on the *x*-axis, or plotting *I* versus *d*, representing a line (instead of a curve) of decreasing slope.

(b)(i). 70% of candidates were able to explain the significance of the -0.9999 correlation coefficient, namely that it is indicative of a negative correlation.

(b)(ii). Over 90% of candidates stated the correct equation of the straight line obtained using the given data. A small minority attempted to answer this question by giving just one set of *x* and *y* data points, which of course is not the general equation of a line. Likewise, the general mathematical equation of a straight line, $y = mx + b$, was not accepted, as the question mentioned the fact that the equation had to be formulated using the given data set.

(b)(iii). Candidates were asked to outline how the current flows in the sodium chloride solution. As the command term was "Outline" only a brief explanation was required, namely that ions move across the electrolyte. Only 40% of candidates equated current flow to the movement of ions across the electrolyte however – candidates often concentrated on electron movement in the external circuit, around the wire.

There were several G2 comments on Question 1. One teacher stated that there was no evidence that any of the questions were based on a prescribed experiment in the syllabus. It should be noted that although the experimental question Section A may assess various sub-topics across the curriculum, the question per se may involve NOS based elements and may not necessarily be based on a prescribed experiment. Another teacher also stated that the voltaic cell would not produce any measurable electric current. In the simple voltaic cell, at the anode Zn(s) is oxidised to Zn^{2+}(aq) ions and at the cathode H^{+}(aq) ions are reduced with the production of H_2(g). This simple voltaic cell set-up based on standard electrode potentials in fact results in a standard electrode cell potential of 0.76 V. The experiment was in fact validated independently in two different chemistry laboratories and although the current held for only a short period of time, a current was in fact registered consistent with this movement of ions across the electrolyte. Other G2 comments on Question 1 included teachers stating that the question was too focused on mathematical concepts. It should be noted that measurement and data processing is a topic on the syllabus (Topic 11 in the Core) and is clearly an integral component of any data-based question.

Question 2

(a). 30% of candidates did not manage to state the correct balanced equation. Common errors included incorrect coefficients or incorrect formulae for magnesium hydroxide and magnesium chloride, where formulae involving Mg in a +1 oxidation state such as MgOH and MgCl were frequently written. One G2 comment stated that students may not be clear whether to give a word or chemical equation or both in 2(a). It should be noted that when candidates are required to state an equation, typically a balanced chemical equation is required. An examination of previous examination papers would be useful in this context in the preparation of future candidates.

(b). Was well done and many candidates were able to suggest two variables.

(c). The uncertainty in the pH change was calculated correctly by 80% of candidates.

(d). Proved more challenging though a high percentage did manage to score at least one mark. The fact that the number of tablets was not controlled was the most common answer as expected, followed by the fact that the uncertainty meant A and C could not be distinguished. Very few commented on the number of trials i.e. noting that each measurement was conducted once. Several candidates stated that the composition of the tablets themselves differs – this was not accepted. Likewise, answers such as stating that “the time frame is too short since some antacids could be long-acting drugs” was also not accepted unless this was qualified by reference to the presence of a gelatinisation/delaying agent. The markscheme allowed several different answers for this discussion question and the question proved to be a good discriminating question at the Grade 6/Grade 7 boundary.

Question 3

(a). Surprisingly, a number gave a value outside the range such as -19 or -20 ^{o}C, thereby losing a relatively easy mark.

(b). Was very well done however and most estimated the percentage to be 28%. Another G2 comment stated that phase diagrams and freezing point depression are not part of the syllabus. Although this is true this is not the purpose of this question in Section A where candidates should be able to interpret graphical representations in an unknown context.

(c). Proved problematic for 35% of candidates. Common errors included using integer values to deduce the molar mass of the hydrated sodium chloride crystals, not expressing the final answer to two decimal places or incorrectly calculating the molar mass.

(d). Candidates had to suggest a concern about spreading sodium chloride on roads. Only 30% scored the one mark, which was very disappointing. All sorts of vague and strange answers were articulated, such as the generation of chlorine gas, making the roads more slippery etc. Answers such as “causing type damage”, “economic/environmental issues” also were not accepted, unless the latter was specified in detail e.g. “increase in costs in road budgets from local councils” was acceptable.

Option A – Materials

It is disappointing that this Option still has not appeared to have gained traction amongst candidates with only 3% of candidates opting for the materials Option this session. Of those examiners who did mark this Option general consensus was that grades were either very low, suggesting that candidates self-taught themselves the option or else were actually above average.

Question 4

(a). 50% of candidates managed to outline the composition of an alloy. It should be noted here that an alloy is a mixture of a metal with other metals or non-metals and as such can be homogeneous or heterogeneous, whereas a composite can only be heterogeneous involving a reinforcing phase embedded in a matrix phase.

(b). 40% of candidates were able to outline why an alloy is usually harder than its components by referring to its structure. An explanation of Inductively Coupled Plasma (ICP) Spectroscopy proved very difficult for candidates and only 23% scored all three marks here.

Question 5

Many candidates managed to gain at least one mark for suggesting why it might be worth using a more expensive catalyst to increase the rate of a reaction. Greater selectivity was the most common answer.

Question 6

(a). As in Question 5, many scored at least one mark for outlining the properties of a substance should have, to be used as a liquid-crystal in a liquid-crystal display. Typical answers included “being polar”, and “being chemically stable”. Superconductors were very poorly understood, with only 25% achieving both marks.

(c). Focussed on the HIPCO process. Some candidates managed to secure some salvage marks here, typically scoring one mark for part (ii) for mention of the idea of a larger surface area on which carbon nanotubes form.

Question 7

Parts of this question were very accessible for candidates and some parts were challenging.

(a). The flexible nature of LDPE was often cited.

(b). It was surprising how poorly candidates faired on where they had to describe how the monomers of addition polymers and condensation polymers differ. Hydrogen bonding was well known however as the type of intermolecular bonding responsible for the strength of Kevlar®.

(d). Most candidates understood that in spectrum B, there is a C-F absorption at 1000-1400 cm^{-1} for PTFE.

(e). 30% of the better candidates were able to deduce a correctly balanced equation for the complete combustion of two repeating units of PVC.

Question 8

One G2 comment stated that this question was visually confusing. This was discussed during Grade Award and it was concluded that the representations shown were typical representations used in several textbooks and other sources.

(a). 40% of candidates managed to calculate that there were four cobalt atoms within the unit cell.

(b). Half of the candidature determined the correct edge length. Part (ii) proved more challenging and only one-third determined the correct density of cobalt.

Question 9

(a). Many secured the mark for stating the name of one method, other than precipitation, that can be used to remove heavy metal ions from solution in water, e.g. chelation, ion exchange etc. Some mentioned “electrolysis” which was also accepted. Although solubility product questions have appeared on previous examination papers, the question posed in N17 proved considerably more challenging, with only 27% of candidates scoring all three marks.

Option B – Biochemistry.

This was the second most popular option taken by approximately 26% of candidates. The disparity between candidate's grades for this option was noticeably high. However, even though there were a handful of candidates who displayed a poor understanding of biochemistry, a significant number did manage to achieve average or above average grades.

Question 10

(a)(i). 80% candidates determined the empirical formula of linoleic acid.

(a)(ii). Frequently candidates referred to the C=C double bond as an explanation why linoleic acid releases more energy per gram than fructose. Only 40% of candidates gave a correct explanation such as the fact that linoleic acid is less oxidized.

(b). 60% of candidates scored all three marks. The most common error involved using a 1:1 ratio instead of 1:2 for the ratio of linoleic acid:iodine (2 marks could still be achieved as ECF applied).

(c). A minority scored hardly any marks here at all as they tried to answer the question in terms of general answers such as "source of energy" etc. Others scored at least one mark for mentioning the fact that linoleic acid will decrease the risk of heart disease. Some candidates also gave more journalistic responses citing good and bad cholesterol. Others mentioned HDL or LDL but not cholesterol per se. This question generated some G2 comments where it was stated that this question is not strictly on the syllabus and requires memorization of very specific details. This was discussed at length during Grade Award and it was concluded that the question in fact was fair as the structure of linoleic acid was actually given in the stem of the question and is also shown in Section 34 of the Chemistry data booklet. In addition, "Discussion of the impact of lipids on health ….. " is a statement on the syllabus in Topic B.3 and a wide variety of answers were included in the markscheme.

Question 11

Most candidates managed to determine the value of the Michaelis constant, K_m, by annotating the graph. A very small minority were slightly careless when deducing the value for ½ V_{max} however.

(b). 65% of candidates scored both marks, one mark for similar shape and one mark for competing for the active site with the substrate. For M1, "similar structure" was accepted (especially for ESL candidates, whose first language may not be English) but technically this is not quite the same as "similar shape". This should be a point of note for future teaching of this sub-topic in the curriculum. Most could draw the curve on the graph showing the effect of the presence of the malonate inhibitor on the reaction rate. 20% incorrectly drew a curve showing non-competitive inhibition.

(c). Many candidates failed to see that this was a four-mark question. Most mentioned the fact that the conformation altered scoring M1 and that there is an exchange of protons for M3.

However very few stated explicitly that the amino groups or the carboxyl groups in the side-chains react (M2) and that the hydrogen bonds are altered (M4).

Question 12

According to IUPAC a condensation reaction is a reaction (usually stepwise) in which two or more reactants (or remote reactive sites within the same molecular entity) yield a single main product with accompanying formation of water or of some other small molecule, e.g. ammonia, ethanol, acetic acid, hydrogen sulfide. Some candidates failed to read the question which asked for a general description of such a reaction and instead gave an example of an equation of a condensation reaction such as the formation of a dissacharide. This yielded 1 max.

(b). A high percentage of candidates did not score the mark here for the structure of galactose as frequently incorrect bond connectivities were shown or hydrogen(s) was/were omitted. This point has been well articulated in previous subject reports and is a feature that candidates should be on the alert for when drawing structures, especially in the Biochemistry and Medicinal Chemistry Options.

(c). Only 25% of candidates scored both marks. Virtually nobody mentioned the fact that the London forces are weakened between the polymer chains in the plastic. "Breakdown by bacteria" was the most common explanation given for biodegradable plastics. Many stated that starch-based plastics are broken down easily but did not mention bacteria or microorganisms per se.

Question 13

This question asked for an outline of the interactions of the phosphate groups in DNA with water and with surrounding proteins (histones). There were lots of misinterpretations of bonding interactions conveyed in answers. Few really understood the correct type of bonding interaction involved (e.g. hydrogen bonding for DNA with water and ionic bonding for DNA with proteins). Many resorted to purely guesswork and had little idea of what was involved.

Question 14

Perhaps the mention of cytochromes in the question stem was off-putting. 60% did manage to state the correct half-equation for the reduction of molecular oxygen to water in acidic conditions. However, only one-half of the candidature was able to outline the +2 to +3 change in oxidation state of the iron ions in the heme groups that occurs when molecular oxygen is converted to water. Future candidates should also be reminded that 2+ represents a charge but +2 represents the oxidation state i.e. the values of oxidation state are denoted by Arabic numerals with a preceding sign - PAC, 2014, 86, 1017 (Toward a comprehensive definition of oxidation state) (IUPAC Technical Report).

Question 15

Many knew that vitamin D is mainly non-polar. However, few mentioned the fact that it forms London forces with fats.

(b). Only the better candidates answered the question in terms of the role that *cis*- and *trans*-retinal play in vision. Most gained some credit but answers were often convoluted and the sequence of events was often mixed up. The absorption of light was rarely mentioned in the context of answers. One G2 comment stated that this was a challenging question. 43% managed to gain all three marks.

Option C – Energy

Approximately 26% of candidates chose the Energy Option and several calculations were particularly well executed. Performance on Option C was broadly similar to the overall performance on Option B.

Question 16

Most candidates correctly calculated the specific energy for octane. Some candidates did not express their answer in $kJ\ kg^{-1}$. Although not formally penalized, a minority gave a negative sign for specific energy.

(b). Although 80% of candidates scored the mark some did not explicitly answer the question and omitted to state which fuel was actually most useful, even though they often had the fundamental rationale necessary to support their decision. The command term “Comment” is quite specific in the guide, i.e. you are required to give a judgement based on a given statement or result of a calculation.

(c). 90% could state the name of one renewable source of energy other than wood. The most common examples were wind and solar.

Question 17

(a). Was poorly done and few scored all three marks. Many candidates did not read the question carefully and failed to even include an equation. An answer with the organic product written as a full or condensed structural formula was required. Some candidates simply gave a molecular formula for the organic product which did not score. The most common salvage mark was for “cracking”. Balancing the equation also proved problematic for those candidates who did manage to write an equation with the correct reagents through cracking etc.

(b). Involved a NOS based question where candidates had to outline one difficulty in quantifying the idea of our “carbon footprint”. This proved to be very challenging though 30% did manage to score the mark.

(c). Was based on the greenhouse effect, a question that has appeared on several past examination papers. Few scored all three marks. There was the usual crop of loose jargon type answers (such as “bounced” etc.). Keywords were often mentioned out of context and explanations were often long-winded and off-the-point. For such a fundamental global topic at HL it was disappointing that HL candidates could not express the effect in a concise, scientific fashion.

Question 18

(a)(i). Was often well done with respect to the difference between fusion and fission in terms of their respective nuclei. However not many stated that both increase in binding energy per nucleon.

(a)(ii). Many gained one mark for stating that no radioactive waste was produced. Some just stated that no waste was produced which was not deemed sufficient. Answers that mentioned “large amounts of energy released per unit mass” were rarely cited. The estimation of the half-life of ^{228}Ac was very well answered with 70% of candidates getting the correct answer. In part

(c)(i). Although many secured an ECF mark for energy released, most lost M1 for the loss in mass. Loss of mass was found by adding or subtracting mass per kg for each particle (and even then these were sometimes incorrectly combined). Very few candidates multiplied by the amount, in mol, of Ac, and even fewer multiplied by Avogadro’s constant.

(c)(ii). Even fewer scored the mark here for the energy released. Many candidates did not realise that 7/8ths of ^{228}Ac decays.

(d). Approximately 40% of candidates mentioned “production of radicals”.

Question 19

(a). The transesterification reaction proved challenging. There were all sorts of errors evident – incorrect formulas for the ester product, failure to recognize that glycerol is formed and failure to balance the equation.

(b). Was based on how the DSSC works. This was done better than in recent sessions, but even still only 57% of candidates managed to gain all three marks, which was somewhat disappointing as poor performance of this new sub-topic on the Chemistry curriculum has been flagged in previous subject reports.

Question 20

Many scored all three marks for the half-equations taking place at the anode and cathode of the direct methanol fuel cell (DMFC) and for writing a correct balanced overall equation.

(b). Most candidates managed to score at least one mark. Often this was for referring to the emission of carbon dioxide as a disadvantage.

Option D – Medicinal Chemistry

This was the most popular option taken by candidates in Section B (51%) and in general the standard of responses was very satisfactory across this Option.

Question 21

(a). Although many scored both marks, several candidates failed to identify Hf in the nuclear equation. The decay product was often incorrectly labelled as Lu or Yb. Beta was sometimes also written incorrectly on the reactant side of the nuclear equation.

(b). Was very well answered.

(c). Only the better candidates scored both marks in explaining the low environmental impact of most medical nuclear waste. The majority gained one mark for stating that there is low radioactivity. A handful, yet still surprising number of candidates misinterpreted (c) and seemed to think that the question was asking for an explanation of the hazards associated with medical nuclear waste.

Question 22

The interpretation of the IR spectra was generally well done. The most common mistake involved candidates not relating the OH absorption explicitly to either phenol or the carboxyl functional group.

(b). Was very well answered and most candidates gained both marks here.

(c)(i). Many scored this mark for stating methylation, but a surprising number simply described the structural difference between the analgesics.

(c)(ii). A high percentage of candidates scored full marks.

Question 23

Nearly all candidates outlined the difference between the therapeutic index in animal studies and the therapeutic index in humans. A minority gave incorrect inverted expressions for the respective ratios. Chiral auxiliaries were much better understood than in previous sessions and a high percentage of candidates managed to score full marks here. Surprisingly a significant number of candidates thought that they were starting with Taxol in the synthesis!

(c). A few stated “injection”; this was insufficient as injection into the bloodstream was required.

Question 24

Some candidates failed to read the question and gave functional group formulae instead of functional group names. Others incorrectly cited class names, such as ketone instead of carbonyl etc. The most common error was candidates writing ester for ether. Other incorrect answers seen were benzene and phenyl. Other answers were accepted, though some not strictly correct. For example, some candidates stated that both structures contain the alkenyl functional group. The alkenyl group is technically a monovalent substituent (such as $–CH=CH_2$, $–CH_2CH=CH_2$, *etc.*) i.e. the fragment, containing an open point of attachment on a carbon atom, that would form if a hydrogen atom bonded to a doubly bonded carbon is removed from the molecule of an alkene. Others stated that both contain the amino functional group. In the context of these two structures this also is not strictly correct, as although oseltamivir contains an amino group, zanamivir actually contains the guanidine group.

Question 25

(a). Few scored both marks though many scored M1 for stating that ranitidine reduces stomach acid production by binding to H2 receptors in the cells of the lining of the stomach or that it prevents histamine molecules binding to H2 receptors and thereby triggering acid secretion.

(b). Nearly all candidates used the Henderson-Hasselbalch equation and a high percentage deduced the pH. Some used the inverted form of the concentration (i.e. log {[HA]/[A^-]}, resulting in an incorrect result for the pH as 5.05.

Question 26

The importance of the beta-lactam ring in the action of penicillin was well explained. Most mentioned the fact that the ring is strained and hence, opens up easily. A small number of candidates did not score M3 as they forgot to refer to transpeptidase per se or the enzyme responsible for bacterial cell wall formation.

Question 27

This question was poorly answered by a significant number of candidates. There were many references to the use of potassium dichromate and colour change. Of those who described the fuel cell method, most knew that ethanol was oxidized to ethanoic acid scoring M1, but many then failed to mention the fact that the current is actually proportional to the concentration of ethanol. Some of the better candidates discussed the answer by writing correctly balanced chemical equations for the oxidation and reduction processes.

Recommendations and guidance for the teaching of future candidates

- Legible handwriting should be encouraged – there was strong evidence again of a noticeable number of scripts this session where examiners struggled greatly in trying to decipher what was written in several responses.
- 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. Biochemistry and Medicinal chemistry. Core chemistry should always underpin applied topics. This is a major feature of the new curriculum.
- Candidates should always look at the associated mark allocations in questions. Candidates should not have to use extra continuation sheets if they tailor their answers to the space provided. This session once more far too many candidates wrote lengthy answers and used extra continuation sheets which were simply not required.
- Candidates often struggle with questions that require explanations or multiple steps. Candidates need to fully understand the various command terms and teachers should take time to review with candidates command terms throughout the two years of the programme to ensure they understand how to answer questions.
- Candidates should prepare for the examination by working through past examination

questions of the new syllabus (as they come on stream) and carefully study the markschemes provided. In addition, it is critical that candidates are continuously challenged throughout the delivery of the programme on NOS-based type questions. Candidates need exposure to data-based scientific problems involving unfamiliar situations, and be able to interpret graphical representations, critique and interpret data and draw logical conclusions involving scientific methodologies.

- It is imperative that laboratory work lies at the heart of the IB chemistry programme. Ideally candidates should be exposed to a comprehensive 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 an analytical technique is required by an Option and students are required to know the steps, then ideally the technique should be performed in class or via a simulation.
- Environmental chemistry should be integrated in linked topics throughout the delivery of the programme. This strand is also present across all four options and is of prime importance in the syllabus. Consideration of Aim 8 of the programme is worth emphasizing in this regard.
- Candidates should get ample practice at writing balanced equations and nuclear equations.
- Some candidates still use the class names of organic compounds instead of functional group names. Distinction between the two is a feature of the new syllabus. The inherent difference between an ester and an ether should also be stressed.
- Bond connectivities should be emphasized.
- Note that according to IUPAC, van der Waals forces are the attractive or repulsive forces between molecular entities (or between groups within the same molecular entity) other than those due to bond formation or to the electrostatic interaction of ions or of ionic groups with one another or with neutral molecules. The term includes: dipole–dipole, dipole-induced dipole and London (instantaneous induced dipole-induced dipole) forces.
- Candidates should always use the precise values of the atomic masses in Section 6 of the data booklet, round numbers correctly, and state answers to calculations to an appropriate number of significant figures including addressing the issue of significant figures when dealing with logarithmic entities. Rounding should be discouraged after each step or prior to reporting a final value in a problem. Significant figures associated with logarithms need to be handled carefully. For example, it is the number of digits in the mantissa part of a logarithm (i.e. the decimal part) that conveys the number of significant figures for a logarithmic entity (e.g. for a solution with $[H_3O]^+ = 1.0 \times 10^{-3}$ mol dm^{-3}, the pH should be correctly reported as the $-\log_{10}(1.0 \times 10^{-3}) = 3.00$, since the concentration has two significant figures, so 3.00 as the logarithmic entity has two significant figures in the decimal, mantissa part; the integer characteristic part of the logarithm is not considered here. This is best practice mathematically for logarithms which are commonplace across the syllabus in questions related to pH and buffer solutions in particular.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 4	5 9	10 13	14 17	18 20	21 24	25 35

General comments

We saw a variety of performance levels on this paper. Many candidates were well prepared for the paper and a few had answers that were excellent. However, there were also a significant proportion of candidates who did not manage to achieve a satisfactory mark in the paper. Their answers were very weak indicating that the option may have not been covered during the course and/or their practical programmes were not fully supportive for developing much needed skills based on the prescribed laboratory curriculum. In Spanish the number of students not receiving any mark was lower and this is very encouraging. Section A included a data analysis exercise. The performance on this section was still rather poor overall, although many candidates did very well on this section. Candidates performed better this on Section A this session even when some sub-parts were perhaps still challenging for many students.

93% of the teachers found the paper of appropriate difficulty with 7% describing it as too difficult. When compared to last year's paper 57% of the teachers felt it was of a similar standard, 10% felt it was a little easier, and 33% felt it was a little more difficult. In terms of clarity of wording 80% of the teachers felt that the paper was good to excellent while 17% felt it was fair, and 3% thought it was poor. The presentation of the paper received similar comments with 87% describing the paper as good to excellent, 10% describing it as fair, and 3% describing it as poor. 90% of teachers agreed that the questions were somewhat to strongly accessible to all candidate with learning support and/or assessment access requirements and 100% of the teachers felt the questions were accessible to all candidates irrespective of their religion, belief system, and /or gender. Teachers are reminded that special education students can apply for additional time to take the exam and potentially the use of molecular modelling kits when molecular diagrams are too challenging.

Some teachers commented about all topics not being covered on the exam. It is not possible to cover every statement within the syllabus on each exam but each sub-topic is represented in approximate relative amounts based on the hours given to teach the content. Papers are also set to a strict markscheme to provide for consistent marking between examiners.

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

- Correctly graphing a negative correlation.
- Mobility of ions in solution.
- Balanced equations.

- Controlled variables in a specific scenario.
- Composition of composites.
- Metallic structure.
- Application of Inductively Coupled Plasma (ICP) Spectroscopy.
- Relating physical characteristics (melting point, permeability, conductivity, elasticity, brittleness) of a material to its bonding and structures (packing arrangements, electron mobility, ability of atoms to slide relative to one another).
- Deduction of equations for the production of carbon atoms from HIPCO.
- Discussion of the properties needed for a substance to be used in liquid-crystal displays (LCD).
- Discussion of some implications and applications of nanotechnology.
- Discussion of the impact of lipids on health, including the roles of dietary high-density lipoprotein (HDL) and low-density lipoprotein (LDL) cholesterol, saturated, unsaturated and trans-fat and the use and abuse of steroids.
- Calculation of the iodine number of fats.
- Explanation of the difference between condensation and hydrolysis reactions.
- Description of the role of starch in biodegradable plastics.
- Relationship of the properties and functions of monosaccharides and polysaccharides to their chemical structures.
- Application of the relationships between charge, pH and isoelectric point for amino acids and proteins.
- Determination of the energy density and specific energy of a fuel from the enthalpies of combustion, densities and the molar mass of fuel.
- Discussion of the reforming and cracking reactions of hydrocarbons and explanation how these processes improve the octane number.
- Calculations of the carbon dioxide added to the atmosphere, when different fuels burn and determination of carbon footprints for different activities.
- Explanation of the molecular mechanisms by which greenhouse gases absorb infrared radiation.
- Identification of features of the molecules that allow them to absorb visible light.
- Deduction of equations for transesterification reactions.
- Solving buffer problems using the Henderson–Hasselbalch equation.
- Explanation of the different ways in which antiviral medications work.

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

- State the equation of a line obtained using the data.
- Propagation of uncertainties in processed data.
- Interpreting validity of a conclusion.
- % of water in a hydrate.
- Explanation of fusion and fission reactions in terms of binding energy per nucleon.
- Discussion of the storage and disposal of nuclear waste.
- Determination of empirical formula.
- Haworth projections representing the cyclic structures of monosaccharides.
- Solution of radioactive decay problems involving integral numbers of half-lives.
- Description of the use of salicylic acid and its derivatives as mild analgesics.

- Description and explanation of the use of strong analgesics.
- Discussion of experimental foundations for therapeutic index and therapeutic window through both animal and human studies.
- Discussion of drug administration methods.
- Identifying with correct names functional groups in structures.
- Explanation of the importance of the beta-lactam ring on the action of penicillin.

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

Section A

Students did much better on section A this session. There were several comments from teachers about the data question – some indicating it was suitable and a welcome change and other indicating it was too challenging and students do not have sufficient practice problem to prepare. Teachers are able to model their own practice problems using from the template of the exams to provide additional practice problems for their students and share them on the PRC.

Question 1.

(a). Many wrong answers where students showed a straight line for I vs d.

(b)(i). Many correct answers. Those who didn't score usually was due to stating the correlation was inverse rather than negative or showing the general equation $y = mx+b$. This question aligns with topic 11.2.6.

(b)(ii). Mostly well answered.

(b)(iii). Very poorly answered. Most candidates seemed not to correctly interpret the question with many references to the external circuit rather than the solution. Ions were rarely mentioned. Many students are certainly more familiar with a voltaic cell diagram with two compartments and a salt bridge. Quite a few candidates in Spanish referred to mobile ions but due to NaCl being ‘molten’ not in an aqueous solution. There was a teacher comment about the construction of the cell being unfamiliar to students. The point of Section A is for students to interpret data both familiar and unfamiliar, not only from the expected laboratory experiences but from other data sources. Examiners repeated the experiment as indicated in the script and were able to collect the data from the exam.

Question 2.

(a). While many candidates provided correct answers, it was disappointing the serious mistakes many students made in particular when writing compound formulas or unbalanced equations.

(b). Many candidates referred to time (not properly addressing question) and active ingredients. Concentration of antacids was fairly common. Candidates needed to realize pH initial values were well within uncertainties range (something they usually overlook in IA). Some referred to poorly calibrated pH meter which wasn't a variable, confirming the difficulty observed in IA that some students have in correcting classifying variables. Students continue to use amount for volume or concentration. Amount is number of moles and students tend to use it in a more generic manner when asked for variables which is incorrect.

(c). A well answered question. Some candidates tried to use the (max-min)÷2 value. Students who struggled with this tended to give ±0.01 as the answer.

(d). Most candidates managed to score at least one mark. Many candidates referred to time (not properly addressing question) and active ingredients. The fact that the number of tablets was not controlled was the most common answer as expected, followed by the fact that the uncertainty meant A and C could not be distinguished. Very few commented on the number of trials i.e. noting that each measurement was conducted once. Several candidates stated that the composition of the tablets themselves differs – this was not accepted. Students continue to use amount for volume or concentration which is not accepted. Amount is number of moles and students tend to use it in a more generic manner when asked for variables.

Question 3.

(a). Many candidates got this mark. However, a significant number of students lost the mark by stating 20. A comment was made that this question was outside the syllabus. The questions in Section A are data based questions and are about the ability to interpret given data from tables or graphs. Specific knowledge about freezing point depression was not required.

(b). A well answered question.

(c). Many good answers with students scoring at least one mark, either by correctly giving M_r or through ECF. Few candidates ignored the question providing more or less than 2 decimal places answer.

(d). Many students obtained this mark. Those who didn't often presented vague arguments such as “affect the environment” or presented incorrect answers including “acidic” or “toxic salts”.

Option A.

Very few candidates attempted this option with only approximately 4% of papers containing student responses. Many of the responses were weak.

Question 4.

(a). Quite a few candidates scored the first mark, but presented wrong/incomplete arguments and therefore, lost the second.

(b)(i). Not well answered with candidates providing incomplete arguments or wrong ones.

(b)(ii). While many candidates scored here, in general it wasn't as well answered.

(c). Very poorly answered. Some candidates managed to score 1 mark, usually by making reference to sample injected into argon but showed a shallow understanding of technique and often confused it with other techniques.

Question 5.

Many candidates scored here but quality of arguments was in general weak.

Question 6

(a). Poorly answered. However, quite a few candidates obtained one mark usually by providing the second equation correctly.

(b). Quite a few candidates scored here. However, a bit disappointing as this question has often been asked in previous sessions.

(c). Similar situation as 6b.

Question 7

(a). Not many candidates scored here with “chemically stable” and “LC phase that is stable over suitable temperature range” were the most popular arguments.

(b)(i). Quite a few candidates scored here. The answers were in general of limited quality though and the use of subject specific vocabulary on the weak side.

(b)(ii). Many candidates stated the letter correctly but failed to present correct value and therefore, lost the mark.

(c). Not well answered. Candidates presenting $(-C_2H_3Cl-)_2$ were an exception.

Option B.

This was the most popular option with approximately 39% of candidates attempting Option B. Many students appeared well prepared. A comment was made that some topics were missing from the exam from Option B. It is not possible to cover every statement within the syllabus on each exam but each sub-topic is represented in approximate relative amounts based on the hours given to teach the content.

Question 8

(a)(i). A well answered question, where only weak candidates didn't score.

(a)(ii). Poorly answered. Many candidates referred to this essential fatty acid in terms of energy, and/or presented general and vague arguments.

(b)(i). Many correct answers with addition being the most popular. Some students lost the mark as they referred to either oxidation or reduction only. Weaker students suggested “esterification” or “hydrolysis”.

(b)(ii). Even weak candidates obtained at least one mark by calculating the correct number of moles. Quite a few established the ratio as 1:1, and perfect scores were uncommon.

(c). Quite a few candidates obtained at least one mark but fewer both. Arguments based on "source of energy" were quite common which were not accepted. A comment was made about this requiring memorization of specific details. Students were not required to memorize the structure of linoleic acid, it was given in the stem of the question as well as in the data booklet. "Discuss the impact of lipids on health…" is the syllabus statement that was used and the markscheme accepted answers as basic as "essential fatty acid" or "decreases risk of stroke".

Question 9

(a). A significant number of candidates were able to identify the formation of water. That said, many lost the first mark usually by stating the specific example described in stem rather than describing the reaction in general.

(b). Most candidates were familiar with the correct structure. Many candidates lost the mark due to incorrect bond linkages, missing hydrogens, sloppy, or careless drawing.

(c). Not very well answered. A significant number of candidates referred to hydrocarbons on their own and not as part of a plastic (only accepted for M2). Arguments presented were often incomplete and not making use of subject specific terminology. It was rare to find correct references to IMFs.

Question 10

(a). Many students scored the first mark but very few made reference to IMFs so the second mark was rarely awarded.

(b). A well answered question.

Question 11

Few candidates fully scored, but most obtained at least 1 mark usually by stating the enzyme denatured. Weaker candidates described the curve without addressing mechanism or chemical reactivity. Arguments referring to acidic/basic/ionizable/COOH/carboxyl/NH_2 /amino groups in the R groups/side chains «react» "and "ionic/H-bonds altered" were quite uncommon.

Option C.

This was a fairly popular option with approximately 21% of the candidates selecting Option C.

Question 12

(a). Many candidates lost the first mark due to stating wrong values instead of M_r (C_8H_{18}) =114.26 but obtained the second through ECF. Some did not convert the answer to the correct units.

(b). Not as well answered as expected with many incomplete arguments or using "'it' is more useful" when question involved both octane and wood.

(c). A well answered question. Weak candidates lost mark by stating water/air/heat failing to use subject specific vocabulary.

Question 13

(a). Many candidates scored one mark by referring to correct process. Correct equations were less abundant and few candidates fully scored. At times this resulted from stating conditions but failing to give the correct name/symbol of an appropriate catalyst.

(b). Not well answered. Most answers didn't fully address question and were of a vague nature.

(c) Some students identified global warming with ozone depletion. Many answers were very journalistic scoring no mark as lacking required specificity

(d). Poorly answered question which was a bit disappointing as it has often appeared in previous sessions.

Question 14

(a)(i). Many candidates obtained at least 1 mark, usually through the first argument in MS. General and vague replies were common.

(a)(ii). Many good answers.

(b). Many students correctly scored here.

Question 15

(a). Many students providing answers from the biological perspective not addressing question and structure.

(b). This continues to be a challenging topic for most students, with quite a few not even attempting it while others showing some general idea but failing to correctly address the question. However there has been an improvement over previous session. Some students had correct structures but did not balance the equation. Some responses did not have correct bond linkages in the structures. Some responses named the compounds instead of drawing structures.

Option C.

Question 16

Many students obtained at least one mark with "«isotopes» have short lives" and "low activity/radioactivity" being quite popular. Some students did not receive the mark because they described more hazardous products.

Question 17

(a). Most students scored at least one mark by stating compounds "at the site of injury/source of pain".

(b)(i). Many candidates scored through "methylation" or by presenting arguments that provided an acceptable explanation. The use of correct reagent wasn't as common as desired. However, fewer candidates referred to hydroxide instead of hydroxyl which is encouraging.

(b)(ii). Many candidates fully scored with "interact with opioid receptors in the brain" and "give a feeling of pleasure/euphoria «that the person craves»" being quite popular. Quite a few candidates presented arguments related to addiction, but these were in general vague.

Question 18

(a). A well answered question.

(b). A well answered question.

Question 19

(a). Many candidates fully scored while the rest often obtained at least one mark. This is an improvement over previous sessions. Naming an 'ester' was a common mistake with weaker candidates.

(b). Many good answers. Those that scored only 1 mark usually did so through "by preventing the virus from leaving the host cell". Weaker candidates lost the second mark as failed to correctly discuss the idea of "inhibiting".

Question 20

(a). A significant proportion of candidates scored at least one mark, usually using in their arguments one of the two first marking points. Quite a few candidates lost the second mark ("prevents parietal cells from releasing/producing acid") as made no reference to parietal cells. Weaker candidates entirely confused the mechanism with that of other antacids.

(b). This continues to be a challenge for many candidates but was answered better than in previous sessions. The most common mistake was to invert the concentrations in Henderson's equation. In this case students scored 1 mark due to ECF.

Question 21

While perfect scores were not too common, most candidates scored at least one and often 2 marks.

Recommendations and guidance for the teaching of future candidates

- Please provide enough opportunities for hands on work during the course including all of the prescribe experiments.

- It is important to allocate sufficient class time to cover every part of the option in detail. The class time allocated for covering the option should be 15 hours.
- Use discussion in class encouraging students to reflect on concepts and their applications to help them answer objective three questions.
- Apply and reinforce related core concepts while teaching the option. Questions on paper 3 often include applications of the core concepts.
- Provide opportunities for analyzing results and evaluating experiments during the course as well as hands on laboratory work related to the Options. Laboratory experience is necessary to be familiar with the proper use of apparatus, and for providing opportunities for analyzing and evaluating data.
- Hold Nature of Science and Theory of Knowledge discussions when opportunities arise.
- Insist on detailed answers that offer good explanations and on the use of correct terminology.
- Encourage students to read the question more than once and to pay attention to the command term used. Students should be familiar with all command terms and their expectations. For example, if “compare” is the command term, the candidate must refer to both items to be compared in their answer.
- Insist candidates draw structural formulas carefully and have practice as needed for each Option.
- Remind candidates to:
    - Write out calculations clearly and show all their work. This gives the examiner the ability to award partial marks and error carried forward marks, especially if the final answer is incorrect.
    - Make sure they write in a legible manner and use a pen that does not leak through the paper.
    - Do NOT write outside the box. The examiners cannot see it.
    - make a reference in the answer box if they use extra pages. Label the work on the extra page clearly with the correct question and part designation.
    - think about the sign when they write down a number.
- Train students to be specific in their answers and to read questions carefully to ensure that they answer every part of the question.