May 2017 subject reports

Chemistry Timezone 1

Overall grade boundaries

To protect the integrity of the examinations, increasing use is being made of timezone variants of examination papers. By using variants of the same examination paper candidates in one part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the Examinations papers. For the May 2017 session, the IB has produced timezone variants of Chemistry SL/HL Papers 1, 2 and 3

Standard level TZ1

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-27	28-38	39-49	50-59	60-70	71-100

Higher level TZ1

Grade:	1	2	3	4	5	6	7
Mark range:	0-15	16-27	28-40	41-52	53-63	64-74	75-100

Higher level and Standard level 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

The range and suitability of the work submitted

The range of work in terms of suitability for the assessment by the new I.A. criteria was similar to May and November 2016 with a large number of candidates presenting work which was the outcome of independent enquiry and showed evidence of curiosity, engagement and a sense of ownership of their Individual Investigations. Teachers and support staff in the many schools that encouraged such varied investigations should be commended greatly on their efforts since the facilitation of such opportunities for sizeable classes is a logistical and organizational challenge.

Overwhelmingly the work presented involved hands-on primary data collection. The most popular were rate of reaction studies, redox titrations and combustion calorimetry with very many of these investigations being related to food chemistry. The most successful of these investigations had identified an independent variable that was continuously measurable (such as concentration, mole fraction, temperature, etc.) and also a dependent variable that could be measured quite precisely using techniques commonly available in a school laboratory such as temperature measurements, acid-base or redox titrations, gas volume measurements, mass changes, etc. It was seen that some schools have increased the range of options available to students to good effect by acquiring a spectrophotometer or some extra data logger probes such as those determining carbon dioxide or oxygen concentrations in the atmosphere.

There were however many less successful investigations. A significant number of students did not identify a suitable independent variable and focused simply on comparative assays of brands of cleaning product, pharmaceuticals or strains of fruit and vegetables. Other students showed quite a bit of imagination but struggled to generate usable data when they had tried to develop their own measurement technique such as using digital photography to quantify colour or to somehow evaluate strength or quality of odour. We don't want to stifle creativity but teachers should monitor such projects closely to see if meaningful data is being generated and if necessary redirect the student while there is still opportunity to do so. It is a pity for an enthusiastic student to generate in the end no usable results which consequently does make achievement against some of the criteria, especially Analysis, more limited.

Similarly to the May and November 2016 sessions few students presented reports based on secondary data. Models and simulations yielded an extremely low number of investigations and the few database orientated investigations were generally weak with little data presented - which counters the purpose of using a database rather than generating primary data. Some moderators expressed that they felt that teachers would more readily promote such investigations if separate expectations of secondary data investigations were sent out to schools. Although this thinking is understandable it is important to state that the assessment criteria and associated expectations have to be the same for all types of investigation submitted for IA. Teachers are advised to look at the expanded Teacher Support Material for examples of what can be achieved in this area.

With regards to overall achievement the mean moderated mark per student was similar to last year with a shortfall of about half a point compared to the May 2016 mean. The magnitude of the mark readjustment through moderation again showed a significant reduction compared to the last session under the old framework in 2015 and once again teachers across the IB world should be commended.

There were variations in attainment across the two levels and also across the IB regions. The mean moderated mark for Time Zone 1 Higher Level students was 13.4 marks out of 24 whereas for Standard Level the mean was 12.3. This difference was even more apparent in Time Zone 2 schools with HL candidates being awarded a mean moderated mark of 15.6 while for SL the mean was 13.7. These differences are not surprising considering the fact that SL students have to carry out the same internally assessed task and be evaluated by exactly the same criteria despite having significantly less prior scaffolding time in their Practical Scheme of Work and also having studied the topics in less depth with a more limited opportunity to have acquired and practiced crucial data processing skills. The reasons for the differences seen between Time Zones 1 and 2 can only be conjectured and those schools whose marks are significantly short of the mean should reflect on how they are scaffolding, facilitating and assessing the Individual Investigation. It must be stressed that examiners are allocated unidentifiable reports from both levels and time zones. Similarly, from the outcome of the Individual Investigations submitted in Spanish, where the mean moderated marks were also significantly behind Time Zone 2, it is clear some schools need to reflect on their current practices and seek help from the Online Curriculum Centre and IBO authorized training such as the Category 3 Focus on IA workshops.

Candidate performance against each criterion

Personal Engagement:

The candidates were awarded either one or two marks with fairly equal frequency with a zero award being very rare.

There were less cases than in the May 2016 session of the students’ efforts to justify their choice of topic spilling over into overlong and contrived narratives relating to their early childhood experiences.

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 or whether time current passes affects the mass change of an electrode during electrolysis. 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.

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 rather than confining themselves to the simple few trials specified in the old internal assessment framework.

Exploration

Of the six-point criteria (Exploration, Analysis and Evaluation) it was Exploration that proved the most successful for students with Higher Level candidates on average securing midway between 3 and 4 points while Standard Level students averaged 3 points.

In many cases a suitable topic was identified and a relevant research question was described to a better extent than in May 2016. 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.

The quality of the background information was mixed and possibly weaker than in May 2016. Frequently it was of general character rather than addressing the specifics of the chosen research question or methodology. The top level descriptor requires the background information to be entirely appropriate and relevant so teachers should advise students to keep it focused. A common failing was that students failed to include balanced chemical equations for the key reactions associated with their investigation.

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 were similar to last year in that it 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. For example many investigations focusing on food tended to ignore relevant variables such as variety of food, moisture content and storage conditions. Another weakness was that quite a few candidates omitted reporting capacities for volume measuring instruments or used inappropriately imprecise glassware such as beakers and measuring cylinders instead of volumetric flasks and graduated pipettes. The correct choice affects uncertainty and should be carefully considered during design. Also while many students considered rightly the calibration of instruments such as pH-meters, others ignored this relevant step thereby decreasing the reliability of collected data.

Even more so than last year 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.

Analysis

The overall achievement for Analysis was close to that for Exploration although the marks were distributed widely across the range.

Most students recorded sufficient data related to the independent and dependent variables so that they could subsequently carry out sufficiently meaningful process and interpretation. Qualitative observations were often recorded although it was not uncommon to find photographs replacing, rather than supporting, written qualitative data. The interpretation of these photographs was frequently not easy and this practice should not be encouraged. Fewer students though recorded the wider data that can provide valuable context for the evaluation of the procedure such as measurements of controlled variables, for example the temperature of the reaction mixture, as opposed to room temperature, in studies of reaction rates or the current in electrolysis investigations where all too often students simply assume current is directly proportional to the voltage setting on a power pack without actually measuring for themselves. In common with other sessions a significant number of candidates reported solely processed data such as added volume of a titrant or averages instead of raw data and thereby limited their achievement.

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 (plenty of redox titrations featured which stretched the students) and calorimetry calculations. Last year it was noted that teachers needed to check calculations through carefully since moderators were uncovering serious processing errors that led to significant downward mark adjustments. This session the situation seemed much improved. Although students are still prone to processing errors these were more often identified by teachers.

Some common areas of weakness surfaced. Calculations in acid-base chemistry were often erroneous with the relationship between pH and pK_a poorly understood and some students assumed pH values were additive. In rate of reaction investigations a significant number of students didn't actually calculate a rate at all and contented themselves with comparative comments on reaction time and there were many reports where students presented inappropriate bar charts rather than properly constructed graphs. On other occasions graphs were presented but students opted for establishing average rate instead of using tangent at initial times which rather diminished the purpose of constructing the 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 outlined in Topic 11.1 of the Chemistry Guide or the TSM or standard deviations on a sufficiently large data set or square rooting sum of the squares, etc.
- Well-constructed best fit graph lines
- Error bars on graphs (this was much more common this year than in the past).
- Maximum or minimum slopes.
- Appropriate consideration of outlier data.

- Consideration of equation of a graph line and the R^2 value
- Consistent significant figures and decimal places.
- Comparison of data from different data sources (secondary data examples) to evaluate reproducibility.
- Evidence of investigation of research into the uncertainties associated with database data.

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

Some weaknesses that arose were: a significant number of students who made no attempt to propagate uncertainties through calculations, a number of candidates presented lines of best fit on graphs involving discrete independent variables which is of course not valid, frequently error bars were inconsistent with the record uncertainties while there are still quite a number of students who present numerical results to an excessive number of significant figures. More pleasingly compared to last year there appeared to be a reduction in the number of inappropriate statistical treatments such as T-tests on a minimum of data and the use of Excel seemed improved with less polynomial graph lines appearing like water slides and roller coasters!

Most 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. Less students this year simply presented a complicated Excel graph line equation without any appreciation of what it may be indicating as an underlying trend.

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 framework 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 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 the students' attainment was significantly behind those for Exploration and Analysis by about half a point on average. This is probably not surprising since it is a demanding reflective criterion requiring higher order thinking skills while the writing of the relevant report section comes at the end of the process when possibly fatigue has set in and often the submission deadline is looming large.

The first part of the criterion was fulfilled fairly well with most students able to draw a conclusion that was consistent with the data to an extent that met the 3-4 band descriptor or above.

The second part of the criterion was not well fulfilled by a large number of candidates as students failed to correctly describe or justify their conclusion through relevant comparison to the accepted scientific context. For this part of the descriptor students could possibly be making the comparison of their experimentally determine quantities to readily available literature values and/or referring to whether any trends and relationships identified were in line with accepted theory possibly by referring back to their original background information. It was disappointing how few students achieved this successfully.

The descriptors regarding limitations and improvements also were not well fulfilled by many students. Strengths were rarely addressed and limitations were usually procedural and few. Very few investigations addressed systematic and random errors in details while many referred to them but failed to identify them in their specific investigation. Suggestions for improvements usually included more repetitions even at times when the number of trials had been acceptable. Specific improvements that were also related to previously identified limitations were less common. Moderators did see a bit more meaningful emphasis on extensions being given this year which addressed a weakness from the last May session.

Communication

As in the May 2016 session the Communication criterion was in most cases quite well fulfilled and averaged midway between 2 and 3 marks. Understandably this criterion, along with Personal Engagement, saw a minimal differential between Higher and Standard Level candidates.

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 nearly all of them did meet the 12 page limit which did prove sufficient for even the most sophisticated investigations. Less students than last year included lengthy appendices in order to circumvent the page limit ruling which was good since examiners do not have to read the appendices so vital marks could have been lost. Most of the reports were relevant although the one common area of weakness was the inclusion of general background information that wasn't focused on the Research Question.

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. The using of citations and references was overall very good.

Recommendations for the teaching of future candidates

- Students should develop investigations that seek to answer research questions whose answer is not self-evident to them known beforehand.
- Encourage students to include any relevant balanced chemical equations in their introductory material so it is clear as to the reactions and processes involved in their

investigation.

- Encourage students to reflect on data while collecting it so they have the chance to modify methodology if the data are proving insufficient, unreliable or erroneous.
- It is good practice for students to give a safety and environmental evaluation for 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.
- 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.
- 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.
- 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.
- Discourage the inclusion of appendices.

Further comments

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.

Standard Level Paper 1 Timezone 1

Component grade boundaries

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

General comments

Candidates were generally well prepared and many of them performed well on this paper. 7934 candidates sat the paper and the mean score was 17.03 out of 30.

77 teachers provided feedback after the examination using G2 forms. Besides some comments about specific questions that are discussed in the section on individual questions, the feedback was positive. Teachers described the paper as "appropriate", "fair" and having a "good spread over the curriculum". Some teachers thought the timing of the paper was a little tight.

97.37% of the responses considered the paper of appropriate difficulty and 69.74% of the respondents judged the paper to be of similar difficulty to last year's paper while 19.74% saw it as a little more difficult.

As for the clarity of wording, 84% of respondents saw it as excellent, very good or good, while 14% found it fair and 1% judged it as poor. The cases involving lack of clarity are discussed in the section on individual questions. 95% of respondents found the presentation of the paper excellent, very good or good.

Notes about the examination:

- 1. Students are recommended to detach the periodic table at the start of the examination for easy reference throughout the examination.
- 2. Students are recommended to narrow down the choices and guess the answer to questions they are not sure about. There is no penalty for an incorrect answer.

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

- Emission spectra
- Reaction of oxides with water
- Deducing type of bonding from physical properties
- Electron pair geometry
- Thermochemical calculations
- Bond order
- Rate of reaction graphs
- pH of acid, base and salt solutions
- Predicting the strength of intermolecular forces in organic compounds

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

- Percentage composition by mass
- Deducing the numbers of neutrons and electrons in ions and atoms
- Identifying an element's position in the periodic table from its electron configuration
- The effect of a catalyst
- Le Chatelier's Principle
- Votaic cells

- Choosing the answer with the appropriate number of significant figures

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 29.45% (M16: 13.77%) to 82.45% (M16: 90.56%).

Question 1

This question was correctly answered by the majority of candidates. Candidates were confident in determining the percentage composition by mass.

Question 2

Over half of the candidates answered the question correctly. The distractors chosen by the other candidates were A and D. Many candidates thought mixtures must involve components in the same phase forgetting about heterogeneous mixtures.

Question 3

Over half of the candidates were able to determine the concentration of the diluted solution correctly without using a calculator.

Question 4

This question was correctly answered by over half of the candidates. The most commonly chosen distractor was A where the candidates had the wrong stoichiometric ratio.

Question 5

This was the question with the highest difficulty index. The majority of candidates were able to determine the numbers of neutrons and electrons in atoms and ions.

Question 6

This question had the lowest difficulty index. The most commonly chosen answer was C, where candidates chose the largest energy gap, neglecting the inverse relationship between energy and wavelength of photons. The other popular distractor was A, where the candidates missed the fact that the gaps between the energy levels of hydrogen decrease at higher energies.

Question 7

This question had the second highest difficulty index. The majority of candidates were confident in deducing the position of an element in the periodic table from its electron configuration.

Question 8

Nearly half of the candidates recognized sodium oxide as the oxide giving the highest pH when added to water. The most commonly chosen distractor was sulfur trioxide, which suggested that candidates were confused about the concept of pH.

Question 9

This was one of the more challenging questions in this paper. The most commonly chosen distractor was B, which suggests that the majority of candidates appreciated the significance of the electrical conductivity data but did not use the melting point data.

Question 10

This question was well answered. In the absence of the data booklet in paper one, candidates needed to use the electronegativity trends in the periodic table to answer this question.

Question 11

40% of the candidates answered this question correctly. The commonly chosen distractors were A (where candidates neglected the lone pair on sulfur) and C (where candidates did not distinguish between electron pair geometry and molecular geometry).

Question 12

This question was well answered. Candidates were able to determine the types of intermolecular forces in different compounds.

Question 13

This was one of the more challenging questions in this paper. Just under half of the candidates were able to use enthalpy of combustion and the heat released to determine the mass of fuel combusted.

Question 14

This question was generally well answered. 61% of candidates used the Hess's Law cycle provided to calculate the enthalpy change.

Question 15

This question had a low difficulty index. Only about a third of the candidates were able to deduce the order of increasing oxygen-oxygen bond enthalpy in hydrogen peroxide, oxygen and ozone.

Question 16

This was the question with the third highest difficulty index. The majority of candidates understood the effect of a catalyst on the activation energy.

Question 17

Only a third of the candidates answered this question correctly. The most commonly chosen distractor was B (selected by 46% of candidates), which displayed the increased rate (due to the doubled concentration) but neglected the stoichiometric aspect.

Question 18

This was a very well answered question. Candidates applied Le Chatelier's Principle correctly and recognized that catalysts do not affect the position of equilibrium.

Question 19

More than half of the candidates were able to identify the conjugate acid-base pair.

Question 20

45% of the candidates obtained the correct answer. The most commonly chosen distractor was B indicating that some candidates did not understand the pH scale. Feedback from teachers was that it was not fair to include ammonium chloride among the distractors as salt hydrolysis is not required of SL students. However, ammonia and the concept of conjugate acid- base pair are clearly listed in topic 8. Ammonium chloride was the least chosen distractor as SL students probably considered it a neutral salt.

Question 21

This question was well answered by more than half of the candidates. They were able to use the displacement reactions to determine the order of reactivity of the metals.

Question 22

More than half of the candidates recognized the oxidation half-equation correctly. The most commonly chosen distractor was A (the reduction half-equation).

Question 23

A very well answered question. Over 70% of candidates identified the correct statements about voltaic cells.

Question 24

This was one of the more challenging questions. Candidates had to predict the order of increasing boiling point for a group of organic compounds. 37% were able to do so. The commonly chosen distractors were A and D (both had one substance out of place).

Question 25

More than half of the candidates were able to select the correct names for the functional groups in aspirin.

Question 26

Over 60% of candidates selected the correct name for the carboxylic acid. The most commonly chosen distractor was D, which had the carbon atoms numbered in the reverse order.

Question 27

More than half of the candidates identified the molecule that contained a tertiary nitrogen.

Question 28

A very well answered question about the significance of the number of signals in an ^1H NMR spectrum.

Question 29

The majority of candidates selected the correct value for density with the appropriate number of significant figures. The most commonly chosen distractor was C (correct value with inappropriate number of significant figures).

Question 30

More than half of the candidates were able to calculate the Index of Hydrogen Deficiency correctly.

Recommendations and guidance for the teaching of future candidates

Provide opportunities for question solving and applying concepts throughout the course. Challenge the students with indirect questions and a variety of different approaches.

Remind students to read questions carefully and answer directly to what the question requires.

The concept of pH is an important one and students should be provided with plenty of opportunities to measure and predict pH of different substances and how it changes in different situations.

Provide opportunities for students to predict the strength of the intermolecular forces in different substances, including the different classes of organic compounds.

Data from kinetics experiments provides good opportunities for students to plot and analyze graphs, such as determining the rate of reaction from concentration-time graphs and using the amount of limiting reactant to predict the amount of product.

Provide plenty of opportunity throughout the course for students to draw Lewis structures including the lone pairs on all atoms.

Ensure students distinguish electron pair geometry from molecular geometry.

Students need practice in determining the bond order from the Lewis structure, including structures containing delocalized electrons, and relating it to bond strength and bond length.

Students need to be more confident of the relationships between wavelength, frequency and energy of a photon of electromagnetic radiation.

Continue to provide opportunities for students to do simple calculations without using a calculator.

Higher level Paper 1 Timezone 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-15	16-20	21-25	26-30	31-35	36-40

General comments

Many candidates were well prepared for this paper. 5884 candidates sat the paper and the mean score was 23.48 out of 40. Most candidates competently calculated different quantities without the use of a calculator, and handled quantitative questions well. They also showed good understanding of most topics. Oxidation and reduction was the topic candidates performed least well on in the paper.

We received 75 G2 forms from teachers. The feedback was generally positive and teachers described the paper as “accessible”, “fair” and “covered topics appropriately”. There were some comments about specific questions that are discussed in the section on individual questions.

93.3% of the teachers who responded considered the paper of appropriate difficulty. 78.67% of the respondents judged the paper to be of similar difficulty to last year’s paper while 14.67% saw it as a little more difficult and 4% saw it as a little easier.

As for the clarity of wording, 76% of respondents saw it as excellent, very good or good, while 13% found it fair and 11% judged it as poor. The cases involving lack of clarity are discussed in the section on individual questions. 89% of respondents found the presentation of the paper excellent, very good or good.

Notes about the examination:

- 1. Students are recommended to detach the periodic table at the start of the examination for easy reference throughout the examination.
- 2. Students are recommended to narrow down the choices and guess the answer to questions they are not sure about. There is no penalty for an incorrect answer.

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

- Emission spectra
- Explaining trends in ionization energy
- Complex ions
- Enthalpy of hydration
- Rate of reaction graphs
- S_N1 and S_N2 mechanisms
- Deducing the units of the rate constant
- Deducing values from a straight-line graph
- Predicting the pH of a buffer
- Identifying the products of the electrolysis of an aqueous solution and their relative amounts
- Chiral molecules

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

- Mass percentage
- Molecular geometry and hybridization
- Identifying species that have resonance structures
- Using Hess's law cycles
- The effect of a catalyst
- Applying Le Chatelier's principle
- pH calculations without the use of a calculator
- ^1H NMR spectra
- Calculating percentage error
- Correct choice of significant figures for the answer in a calculation

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 30.12% (M16: 19.64%) to 89.26% (M16: 92.24%).

Question 1

This was very well answered and was the question with the second highest difficulty index. Candidates were confident in determining the percentage composition by mass.

Question 2

Just over half of the candidates answered the question correctly. The distractors chosen by the other candidates were A and D. Many candidates thought that a mixture's components must be in the same phase.

Question 3

This question was correctly answered by two thirds of the candidates. The most common distractor was A where the candidates used the wrong stoichiometric ratio.

Question 4

This question was answered correctly by 41% of the candidates. The most commonly chosen distractor was C, where candidates chose the largest energy gap, neglecting the inverse relationship between the energy and wavelength of photons. The other popular distractor was A, where the candidates missed the fact that the gaps between the energy levels of hydrogen decrease at higher energies.

Question 5

This was a challenging question. The most commonly chosen answer was the distractor D, followed by the correct answer, B. In choosing D candidates did not show appreciation that an electron at lower energy requires more energy to leave the atom, and that p-electrons have a higher energy than s-electrons of the same shell. The wording of the correct answer was rather awkward and several G2 respondents commented on this fact.

Question 6

This question was correctly answered by half of the candidates. The most commonly chosen distractor was B where candidates showed appreciation of the number of shells but failed to recognize the effect of the number of protons.

Question 7

More than half of the candidates recognized sodium oxide as the oxide giving the highest pH when added to water. A few of the teachers who submitted G2 forms commented that this question was unfair as students do not know which is more basic, sodium oxide or magnesium oxide. However, this is clearly mentioned in Periodic Trends (sub-topic 3.2). It is also worth mentioning that magnesium oxide was not a popular answer- only 12% of candidates selected it. The most commonly chosen distractor was sulfur trioxide, which suggested that candidates were confused about the concept of pH.

Question 8

This question had the lowest difficulty index. Only 30% of candidates were able to deduce the charge on the complex ion although the ligands were simple ones (water and hydroxide ions).

Question 9

More than half of the candidates answered this question correctly. The most commonly chosen distractor was B, which suggests that the majority of candidates appreciated the significance of the electrical conductivity data but did not use the melting point data.

Question 10

This question was well answered. In the absence of the data booklet in paper one, candidates needed to use the electronegativity trends in the periodic table to answer this question.

Question 11

This question was very well answered. More than two-thirds of the candidates deduced the correct molecular geometry and hybridization.

Question 12

This was a challenging question and only 38% of candidates answered it correctly. The most commonly chosen distractor was D. Candidates who chose D probably counted the sigma-bonds without counting the C-H bonds on the phenyl group obtaining 10 instead of 15 sigma-bonds. Some G2 respondents commented that this question was confusing because it requested the pi-electrons instead of pi-bonds, and because the electron domains were requested per carbon while the total number of pi-electrons and sigma-bonds were requested. It required candidates to be alert and read the question carefully.

Question 13

Very well answered. Over two-thirds of the candidates recognized that ozone and benzene had resonance structures.

Question 14

This question was quite well answered.

Question 15

This question was very well answered.

Question 16

This was one of the more challenging questions. Candidates' answers were almost split equally between B (the correct equation for the enthalpy of hydration) and D (the equation for the enthalpy of solution).

Question 17

This question was well answered. The most commonly chosen distractor was B, which had the opposite signs for the enthalpy and entropy changes.

Question 18

This was the question with the highest difficulty index. The majority of candidates understood the effect of a catalyst on the activation energy. One of the G2 respondents commented that it is more accurate to state that a catalyst provides an alternative route with lower activation energy (than stating that the catalyst lowers the activation energy). It is a good point.

Question 19

Half of the candidates answered this question correctly. The most commonly chosen distractor was B, which displayed the increased rate (due to the doubled concentration) but neglected the stoichiometric aspect.

Question 20

This was a challenging question. Most candidates deduced that the reaction was zero-order with respect to hydroxide as very few selected distractors A and B. However, distractor C was commonly selected indicating that many candidates did not relate the kinetics data to the S_N1 mechanism.

Question 21

Half the candidates were able to deduce the units of the rate constant correctly.

Question 22

This was a very well answered question. Candidates applied Le Chatelier's Principle correctly and recognized that catalysts do not affect the position of equilibrium.

Question 23

This question presented the relationship between the free energy change and the temperature through a graphical representation, which most candidates found challenging to analyze.

Question 24

This question was correctly answered by two-thirds of the candidates.

Question 25

The majority of candidates were able to calculate the pH of the sodium hydroxide solution correctly.

Question 26

Two-thirds of the candidates were able to identify the base.

Question 27

This question had the second lowest difficulty index. While many candidates realized that the volume of NaOH must be less than the volume of CH_3COOH to form a buffer, less than a third of the candidates were able to predict the pH of the buffer correctly. A few G2 respondents did comment that this question could only be solved by students who had a solid understanding of buffers – especially as the pK_a value was not available. This however relates again to the understanding of the concept of pH and conjugate acids and bases.

Question 28

More than half of the candidates were able to identify the oxidation.

Question 29

This question was generally well answered.

Question 30

This was correctly answered by more than half of the candidates. However, a considerable number of candidates (30%) selected distractor A which had the wrong direction for the flow of electrons in the voltaic cell.

Question 31

This was one of the more difficult questions. 43% of candidates answered it correctly and the three distractors were chosen equally by the rest of the candidates. Both aspects, identifying the electrolysis products and their amounts, were found challenging by a considerable number of candidates. Some G2 respondents commented that it was a challenging question to solve without the standard electrode potentials and the half-equations provided in Table 24 in the data booklet.

Question 32

Many candidates were able to identify the functional groups in aspirin correctly.

Question 33

The majority of candidates were able to identify the molecule that had a tertiary nitrogen.

Question 34

Correctly answered by three-quarters of the candidates.

Question 35

Half of the candidates applied Markovnikov's rule correctly.

Question 36

This question was generally well answered.

Question 37

Less than half of the candidates were able to identify the chiral molecule. A few teachers commented on the G2 forms that it was confusing to give candidates a compound with two functional groups. This was a discriminating question for more able candidates.

Question 38

Three-quarters of the candidates calculated the percentage error correctly.

Question 39

The majority of candidates selected the answer for density with the appropriate number of significant figures.

Question 40

Correctly answered by more than half of the candidates.

Recommendations and guidance for the teaching of future candidates

- Provide plenty of opportunities for applying concepts throughout the course. Challenge students with indirect questions and a variety of different approaches.
- Provide opportunities for producing and analyzing graphs and obtaining the gradient and y-intercept from a straight-line graph.
- Students should practice writing formulas for complex ions and their compounds. They should also be able to deduce the charge on the metal ion or the complex ion from the formula.
- Ensure that students distinguish the enthalpy of hydration from the enthalpy of solution, and provide opportunities for writing equations to represent the different types of enthalpy change.
- Ensure students are confident in predicting pH values of different substances and knowing how pH relates to acidity.
- Encourage students to make connections between organic mechanisms and kinetics to deepen their understanding of mechanisms and to be able to make predictions.
- Remind students to read questions carefully and answer directly to what the question requires.

Standard Level Paper 2 Timezone 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-18	19-23	24-27	28-32	33-50

General comments

This was a fair and balanced paper that students found hard. The use of examples outside the norm which made the paper interesting seemed to make the students lose confidence and there were too many questions left unanswered. This was also seen in the G2 comments as 38% of the 76 respondents felt it was too difficult and 62 % found that it was appropriate, 59% also felt it was more difficult than last year's paper.

There were a number of very straightforward questions that were not answered well and high levels of imprecise language used by students meaning that marks could not be awarded. Students need to learn to use chemical terminology more precisely.

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

- Alloys
- Distinguishing different structures (ionic vs simple molecular) and their effect on properties
- Balancing a redox reaction in an acidic environment
- Lewis structures were not drawn correctly when needed in the thermodynamics question
- Free radical substitution mechanism
- Use of data from NMR and Mass Spectrometry to identify the structure of an organic compound
- Structure of benzene
- Ionic equations

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

- Atomic structure- calculating RAM and electron configurations
- Thermochemistry
- Stoichiometry and empirical formula calculations
- VSEPR/bond angles
- Finding the rate of reaction even without a line of best fit
- Finding oxidation states

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

Question 1

- (a) (i) This was usually answered well but students did not always explain that they were measuring a change and relatively few seemed to realise there would be a colour change.
- (a) (ii) Most candidates did not draw a line of best fit for M1 and when they did they were sketched in and curved. This then gave rise to wrong answers from rough

estimates from individual points on the graph.

- (b) Stronger candidates gained 2 marks but most only gained 1 mark as they did not give enough information using the figures in the table or forgot to link it to increased number of collisions in unit time so stating the increase in the number of collisions but not the 'frequency'.

Question 2.

- (a) Many candidates struggled to clearly describe metallic bonding and hardly any candidates gained 2 marks as they did not mention electrostatic attraction and some gave positive nuclei/atoms rather than cations in a sea of electrons. Also, they did not mention the electrons were delocalized or freely moving.
- (b) Most candidates gained 2 marks by calculating RAM to two decimal places, but weaker candidates gave answer to one decimal place or divided by 5 not 100.
- (c) This was usually done well, but a few had 48 neutrons.
- (d) (i) Many candidates wrote electronic configurations for a neutral Ti atom or forgot it was the 3d electrons that were retained not 4s.
- (d) (ii) Very few answers here were correct even for stronger candidates, so one might suspect that quite a few candidates had not reviewed/been taught about the nature of alloys. Most thought the alloy was a combination of chemical properties of the two metals which led to increased strength, not different sized metals affecting the ability of layers to slide over each other.
- (e) (i) Many correctly stated that KCl was ionic but there were a few covalent or even confusion with IMFs such as dipole-dipole.
- (e) (ii) Few students could suggest why KCl had a higher melting point than $TiCl_4$. Data was provided for them to deduce the answer; $TiCl_4$ chemistry is not to be covered.
- (f) (i) Stronger candidates gave the correctly balanced equation but weaker ones had the wrong oxide or thought chlorine and hydrogen were formed.
- (f) (ii) Most candidates could suggest that the smoke would be harmful in some way.

Question 3

- (a) Finding oxidation states was generally well done, but very few managed to balance the equation correctly as most candidates didn't appreciate that they needed to include H^+ ions on the LHS and some thought O_2 molecules were formed.

Question 4

- (a) wide variation of values was seen with many choosing 120 degrees as candidates failed to realize that nitrogen has a lone pair.
- (b) Few candidates got both marks as they failed to say the hydrogen ions would react with the hydroxide ions.
- (c) Some candidates forgot the equilibrium sign; others thought the hydrazine would decompose to ammonia gas.
- (d) Not many equations were correct and ionic. Hardly any candidates gave any observations. Only a couple of students gained 2 marks.
- (e) Some had realized oxygen would be in short supply at high altitudes so this fuel didn't need oxygen, some thought it was a low pressure effect that would affect the fuel whilst others said the gases would propel the rocket.
- (f) There were many good attempts made at this question but many errors mainly due

to the wrong structures and bonds used. Quite a few had the wrong bond energy values for the nitrogen in hydrazine or in nitrogen gas.

- (g) This was poorly done as very few students drew an energy cycle. Signs were often kept the same and some weaker candidates didn't carry forward their value from the previous part.
- (h) (i) Most candidates gained 2 out of the 3 marks as they either had wrong units for mass of oxygen or calculated wrong number of moles of hydrazine as they used 16 instead of 32 for Mr of O_2 molecules.

Question 5

- (a) Mainly either totally correct with free radical substitution found among the two answer lines but few distinguished between type of reaction and mechanism. Others left this question blank.
- (b) Most students were unable to write the propagation steps and so gave initiation steps or were inconsistent with dots on radicals. Most managed to get the mark for the termination step though.
- (c) (i) Most candidates were able to calculate the empirical formula.
- (c) (ii) Very few used the empirical formula information from the previous question and were able to interpret the NMR and mass spectrum and apply these to a chloro compound. Some gave answers with oxygen compounds which seemed to indicate that they had not covered this topic. So most either scored zero or left this question blank. If they did manage to get the structure they then had problems naming it.
- (d) The polymer could be drawn by most candidates, but marks were needlessly lost as some had C=C or had gaps between the carbon atoms or bonds left out at either end of the polymer.

Question 6

- (a) Very few correct answers as some students didn't know difference between physical and chemical evidence for benzene structure. Most failed to score a mark as mentioned bond lengths but didn't mention they were between carbon atoms.
- (b) Some candidates gained this mark but many seemed to have no idea of how the compounds would react by addition or substitution reactions.

Recommendations and guidance for the teaching of future candidates

- Effective practice with past papers and familiarity with mark schemes would help.
- Practise using terms associated with descriptions of graphs (proportional; directly proportional; inversely proportional, etc.)
- Practise more complex instrumental analysis questions (NMR/MS)
- Spend recommended time on teaching certain aspects of the programme with more time allowed for Organic Chemistry and spectra interpretation in particular.
- A focus should be placed on the use of the correct terminology and key words (e.g. electrostatic) that the students should use in their explanations.
- Emphasize the need to answer the question asked and follow instructions. For example, in Q2(b) it asked for two decimal places.

Higher level Paper 2 Timezone 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-12	13-25	26-35	36-45	46-56	57-66	67-95

General comments

Opinions about this paper ranged from "well-constructed, giving students a fair balance of easily accessible questions and challenging questions in unfamiliar situations" and "about the same level and expectation as last year's" to "completely inappropriate" and "triple the difficulty of last May or November". Whilst 67% of respondents opined that the paper was a little more or much more difficult it should be borne in mind that this only represented 12% of schools. It was certainly the intention to set some questions as "Grade 7 discriminators" to allow the brightest students to shine – and to ask about "unfamiliar" chemicals so that students could apply their knowledge and understanding to new situations.

The mean mark was in the region of 35 out of 95 so there is evidence that the paper was more difficult than May and November 2016. Because the grading is criterion referenced this will be reflected in lower grade boundaries. There is, however, concern that, even after two years of study, nearly 400 candidates scored less than 10 marks (and 36 scored zero).

The lack of choice did not seem to bother the candidates most of whom made it through to the end. Nearly 98% of the candidates attempted the last part question, Q 8 (b).

73 teachers gave feedback from a total of 409 schools. Apart from those for whom the comparison was not applicable (1%) 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	0	32	37	30

As to the percent level of difficulty, the following answers were given (approximate %):

	Too easy	Appropriate	Too difficult
Level of difficulty	0	52	48

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

	V poor	Poor	Fair	Good	V good	excellent
Clarity of wording	3	16	27	25	22	7
Presentation of the paper	1	4	19	27	34	14

There were comments about too much or too little of some particular area of the syllabus. When the papers are authored, a setting grid is used to ensure that syllabus coverage is within acceptable parameters. We aim to examine the whole syllabus over papers one, two and Section A of paper three and match the number of marks for each topic to the recommended time allocation in the Guide.

Please be aware that if an error is made in an early part of a calculation, the error is carried forward so marks are not lost in later parts of the question. In many cases, as you will have seen, we supplied an “answer” to an earlier part to help in a later calculation. On many occasions, examiners are instructed to award full credit for the correct final answer. If, however, no working is shown and the “final answer” is incorrect, only zero can be given.

We gave references to the data booklet in many questions but candidates should not assume that, because there is no reference, the data booklet is not needed. On occasions, we give data that is in the data book directly in the question. (The skill of finding data does not have to be repeatedly examined.) Similarly, we will provide data that is not in the data booklet (such as the vanadium data in Q 3 b) so that we can test understanding in an unfamiliar context. In general, the data booklet should be a candidate’s constant companion during the two-year course.

There are common questions with the SL paper; this is because we hold a G7 in SL at the same level as a G7 in HL (see Group 4 grade descriptors). There is only a difference in syllabus content.

There is no particular length to the “mixed topic” questions in the new 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.

We regret the use of the name *aniline* is question 7 (e). The name in the syllabus was changed after the paper was authored and this was missed during subsequent revisions of the paper. We make no excuse.

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, whether bearing the IB logo or not.

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

- Answering open-ended “nature of science” type questions
- Drawing a best fit line to determine rate from experimental data
- Monitoring the course of a reaction
- Describing the bonding in metals, the melting point of metals and the hardness of alloys
- Explaining why $TiCl_4$ should have a lower melting point than KCl
- Manipulation of electrode potentials
- Bond angles, electron domain geometry and hybridisation
- Explaining movement of equilibria
- Identification of suitable indicators
- Using Hess’s Law cycles
- Calculation of pH from pK_b
- Writing ionic equations
- Identifying bonds broken and calculating ΔH correctly
- Steps in the free radical substitution of alkanes
- Interpretation of MS and NMR data
- Discussing physical evidence for structure of benzene
- Mechanism for the nitration of benzene
- Equations for the catalytic destruction of ozone by NO
- Understanding that ozone depletion and global warming / climate change are different concepts

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

- Determining order of reaction from data
- Calculating relative atomic mass from isotopic composition
- Stating the numbers of protons, neutrons and electrons in an atom
- Determination of oxidation numbers
- Writing a balanced equation for the hydrolysis of $TiCl_4$
- Calculations involving ΔS and ΔH
- Calculation of standard entropy and enthalpy changes
- Calculating empirical formulae
- Understanding the purpose of the ozone layer for absorbing UV

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

Question 1

- (a) (i) Very few were able to give a good answer that would measure *change*.
- (a) (ii) Few drew a best fit line; even fewer used a ruler and there were many incorrect calculations for M2 based on individual points.
- (b) This was mostly answered well although quite a few lost the first mark for writing the general comment “rate increases as concentration increases”
- (c) There was a wide variety of answers, from the excellent to those who found the

concept of rates to be challenging.

- (d) Most candidates *described* the shape of the graph instead of relating it to an increasing rate of reaction. Only a very few recognised that one of the products could be catalysing the reaction.

Question 2

- (a) The mean mark on this question was 0.4 / 2 – which, for a "standard" question was disappointing. Many used "nuclei" for "ions" and many omitted "electrostatic". *Bonding in metals is either ionic or covalent* was a common answer.
- (b) This was universally well done with a mean mark of 1.6 / 2. There were some "catastrophic" errors such as dividing by "5" but most marks were lost by not giving the answer to "two decimal places".
- (c) There was 90% success with this question.
- (d) (i) The common error was to lose the $3d^2$ instead of the $4s^2$ electrons.
- (d) (ii) Very few gave smaller ionic radius, some mentioned more electrons. It did not seem to be clear to candidates that these two metals are adjacent in the periodic table. The question implies that a comparison with titanium is required.
- (d) (iii) We were expecting to see a gradual increase of IE over the first five and then a more significant increase for the sixth. Many candidates seemed to think they were dealing with the first ionisation energies of successive elements.
- (d) (iv) Candidates had little idea of the movement of layers of atoms.
- (e) A reasonable number realised that the ligand provides the electron pair – but the wording was often "woolly".
- (f) This is a standard question and some had clearly studied the markscheme in previous examinations. Others thought the colour to be caused by emission as electrons fall back to the lower level.
- (g) (i) This was generally answered successfully (80%).
  (g) (ii) Only a handful of candidates dared to believe that $TiCl_4$ is a simple molecule, recognising that a metal compound that is a liquid at room temperature cannot be ionic. But those who did recognise this unfortunately suggested that covalent bonds are weaker than ionic.
- (h) (i) Many managed this correctly – although some gave Ti_2O_4 with otherwise correctly balanced equations.
- (h) (ii) Well over half of the candidates were able to suggest a suitable disadvantage.

Question 3

- (a) It was encouraging to see high marks in this question with very few being penalised for incorrect format
- (b) (i) and (ii) Candidates found this difficult with many giving a complete half-equation without specifying the reductant species. Others gave a vanadium half-equation presumably not having read the question properly
- (c) (i) This was quite well done even by those who had not been successful with the two previous parts.
- (c) (ii) There were many errors in the calculation of $E^\ominus$ but most had a reasonable grasp of the calculation and deduction of spontaneity.

Question 4

- (a) Few seemed to realise that the other product would be SO_2. Suggestions included sulfur (elemental) and H_2S.
- (b) This question was designed for those aiming for the highest grades and many answers were considered suitable.
- (c) (i) and (ii) Candidates who had done poorly on other parts sailed through these calculations. The common error was not the multiply the CO values by 4.
- (c) (iii) There were more errors here as candidates did not notice that the reaction had become a decomposition which led to some answers being incorrectly given as T < 104ºC. The other common errors: not converting ΔS to kJ, not converting K to ºC. Candidates must be aware of units.
- (d) About half the candidates realised that anything involving CO was likely to be hazardous. Candidates should, however, be taught the difference between suffocation and poisoning.
  There was a teacher comment made that we should not have expected candidates to know that CO is toxic as it is not in the syllabus. We regard this as common chemical knowledge to which we would expect a candidate to have been exposed sometime in the two-year course.

Question 5

- (a) and (b) Few had noticed that there would be a lone pair on the N atom. There was no intention to mislead candidates with the diagram but the question was poorly answered by those who did not think about a Lewis structure. “Tetrahedral” was not a common answer although more correctly gave sp^3. As is common practice, no ECF was allowed in (a) and (b).
- (c) Few recognised that H^+ would react with the hydroxide ions. Some suggested that this would make more water and thus the equilibrium had moved to the left.
- (d) (i) Calculations from pK_b to pH are not often set and many thought this to be a buffer question. The question was answered well by many candidates who were performing poorly elsewhere in the paper. Many part marks were awarded where legible and logical working was shown. Examiners need to see a clear indication of what the calculation is about so there is a need for words (as well as numbers).
- (d) (ii) Phenol red, phenolphthalein and bromo*thymol* blue were common (incorrect) answers.
- (e) Very few gave an *observation* and few understood the idea of an ionic equation. If Cl^- ions were included as spectator ions, this was not penalised. A significant number read aluminium for ammonium.
- (f) Many struggled to find appropriate values of N to N bonding in N_2H_4 and in N_2. It can be useful to ensure that the same number of “single bond equivalents” have been formed as broken when checking the calculation.
- (g) Candidates need more practice in the application of Hess’s Law.
- (h) (i) and (ii) Some managed this well but others seemed to think that they were calculating the mass of water! This was generally very poorly set out and many used 16.00 instead of 32.00 for oxygen.

Question 6

- (a) This was poorly answered (at 30% success). We gave the two prompts to try to elicit both "substitution" and "«free» radical". We accepted these anywhere in the answer – but some were contradicted by the inclusion of "S_N1" or the like.

- (b) (i) The initiation reaction was often included in propagation (see list principle below). There were many incorrect equations, many producing H• and others various ionic species. Many gained an ECF mark for termination using incorrect species in the propagation steps.
- (b) (ii) Even though the formula was given, this question was poorly answered.
- (c) (i) Candidates had little difficulty with this and there was a 75% success rate. Apart from the few who had no idea what to divide by what, the most common way of losing the second mark was to give $C_2H_4Cl_2$.
- (c) (ii) Most commonly, candidates did not seem to realise that (i) and (ii) were connected – and spent time trying to carry out a full analysis of the two spectra. There was little interpretation of the spectra required except to see that the molar mass is in the region of 100 and there is a ratio of hydrogen atoms 3:1.
  Quite a number of candidates suggested various ketones or acids as a result of the "full analysis".
- (c) (iii) There were few correct answers.
- (d) Most commonly continuation bonds were omitted.

Question 7

- (a) Few were able distinguish between physical and chemical evidence. Those that attempted to discuss bond lengths frequently did not specify that they were referring to C to C (rather than C to H) bonds. Thus, "all bond lengths are equal" does not score. Perhaps it is a consequence of the normal skeletal structure used that students forget that there are hydrogen atoms present.
- (b) This was poorly answered with many unaware of alkene reactions.
- (c) There were few correct answers; many suggested electrophiles with positive charges.
- (d) Those that had learnt (and understood) this mechanism scored well. Otherwise answers were poor with a few picking up the odd part mark. There are very few mechanisms that candidates are expected to know
- (e) Many had not come across the name *aniline* and this was taken into account when determining the grade boundaries.

Question 8

- (a) It was most common to score one mark but having reacted NO• with ozone, the second equation generally did not regenerate NO•.
- (b) Candidates generally knew that ozone prevents UV radiation from reaching the earth – but some left it at "radiation" which did not score. The effect of UV radiation, however, was muddled with global warming.

Recommendations and guidance for the teaching of future candidates

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

- Read the whole examination first before answering the “less challenging” questions.
- Read the question carefully to make sure that you answer it – and not what you would like the question to be.
- Make sure you leave enough time for later marks. Remember that the questions (1, 2, 3 etc.) may not be of uniform length.
- 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.
- Make an effort with your handwriting and use a quality pen. If the 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.
- Draw lines of best fit with a ruler.
- Do not write out the question. It wastes space in the answer box (and it wastes time!).
- 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.
- Look at the number of marks available and try to make the same number of points in your answer.
- 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.
- “Answers to a previous part”, such as in Q4 c (iii) and Q5 g, give a clue to the size and *sign* of the answer you should have obtained. Consider using the values given if you are uncertain of your own. Full credit is awarded as we are only marking the method.
- Take notice of units and significant figures.
- If you are asked to make a comparison or predict a difference, then you need to mention both compounds.
- Learn to use the terms, molecules, atoms, ions, nuclei correctly.
- 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 3 Timezone 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-4	5-8	9-10	11-14	15-17	18-21	22-35

General comments

We saw a variety of performance levels on this paper. There was good performance from a significant proportion of candidates and a small proportion of candidates whose answers were excellent. However, there was also a significant proportion of candidates who did not manage to achieve a satisfactory mark in the paper, whose answers were very weak indicating that the option may have not been covered during the course.

7908 candidates sat the paper, with the majority choosing option D (42% of candidates), followed by option B (28%) and then option C (25%). Option A was only selected by a few schools (5% of the candidates).

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. The questions were not meant to be tricky nor were they designed for students who had experience of a thermometric titration. Good candidates were able to apply the concepts they learned in the course to this question, including providing reasonable answers to the nature of science (NOS) questions. Many candidates handled calculations and unit conversions well this session. There was also a good proportion of candidates drawing structural formulas accurately.

77 teachers provided us with feedback about the examination paper through G2 forms. 56 teachers saw that the paper was of appropriate difficulty while 25 teachers judged it as too difficult. When comparing the difficulty of the paper with the May 2016 paper, the following data was obtained.

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult	Not applicable
1.32%	2.63%	51.32%	27.63%	10.53%	6.58%

The marks also suggested that it was generally more difficult that the May 2016 paper.

In terms of clarity of wording and the presentation of the paper, the following data was obtained.

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0%	6.58%	26.32%	36.84%	22.37%	7.90%
Presentation of paper	1.33%	1.33%	24.00%	37.33%	25.33%	10.67%

Concerns about the clarity of wording or content in specific questions will be discussed in the section on individual questions.

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

- Analyzing results from a thermometric titration

- Choosing suitable glassware for measuring volume
- The function of a homogeneous enzyme
- Describing the plasma state and its production in ICP
- Identifying the base hydrolysis of lipids and its products
- Identifying the building blocks of carbohydrates
- Comparing carbohydrates and lipids as energy storage molecules
- Understanding the use of Haworth projections
- Deducing the formula of biodiesel
- Discussing the optimum temperature of an enzyme in terms of active sites
- The detection of elements in stars using absorption spectra
- The production of liquid hydrocarbons from coal
- The equation for converting aspirin to its ionic salt
- Explaining the effect of impurities on the melting point
- Explaining how the properties of organic compounds relate to their structure
- Green chemistry solutions for solvent waste
- Acid-base reactions of aspirin
- Green chemistry solutions to producing the precursor to oseltamivir

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

- Calculation of percentage uncertainty
- Calorimetry
- Using the bonding triangle
- Calculating electrolysis current
- Identifying catabolic processes
- Application of the relationships between charge, pH and isoelectric point for amino acids
- Predicting the solubility of vitamins from their structure
- Constructing nuclear equations
- Comparing fission and fusion
- Reagents needed for transesterification
- Comparing biodiesel with vegetable oil
- Calculation of the specific energy of a fuel from the enthalpy of combustion and the molar mass
- Explaining IR absorption on a molecular level
- Explaining global dimming due to particulates
- Identifying the therapeutic window of a drug
- Explaining the action of opiates
- Calculation of buffer pH
- Spectral analysis of molecules
- Identifying the development of bacterial resistance

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

Section A

Question 1

- (a) The majority of candidates calculated the percentage uncertainty of the volume.
- (b) Surprisingly, only a fifth of the candidates suggested measuring the volume with a more precise piece of glassware like a pipette. This was expected to be a relatively easy question as titration is a prescribed lab and students should be familiar with the glassware. The most common answer was using a more precise measuring (graduated) cylinder, however, it is difficult to achieve an uncertainty less than ±0.5 cm^3 for 25.0 cm^3 measured with a measuring (graduated) cylinder and this answer was not accepted.

Question 2

- (a) A very well answered question. Most candidates recognized that mixture B corresponded to a larger amount of acid added and hence underwent more of the exothermic reaction. Some teachers commented on G2 forms that calling points A and B on the curve “mixture A” and “mixture B” was confusing, suggesting that they are two separate experiments rather than two stages of the same experiment. Thankfully this did not seem to confuse candidates.
- (b) This was a challenging question and only 10% of the candidates provided an answer with the required detail. Many candidates did recognize that there was no more reaction occurring at C and D, but only few recognized the reason for the lower temperature at D was the larger volume of liquid. Several teachers commented that the analysis required on this question was complex. It was certainly one of the discriminating questions for grades 6 and 7 candidates.

Question 3

- Very few candidates provided the best answer in terms of the intersection of the two best fit lines. However, the majority of candidates stated that the end point was at the peak temperature (or at 35 cm^3 of HCl) and were awarded the mark.

Question 4

- It was surprising that only about a fifth of the candidates realized that sulfuric acid is diprotic and a smaller volume would be needed to neutralize the sodium hydroxide sample. A significant number of candidates thought that sulfuric acid was weaker than hydrochloric acid. Other candidates scored one mark by stating that a higher temperature would be reached with sulfuric acid.

Question 5

- (a) This was a discriminating question that raised a lot of discussion. A small proportion of candidates deduced how to process the data of the thermometric titration scoring two marks. Others scored one mark for suggesting the use of $q=mc\Delta T$ for calculating the heat released at the end point, but they did not know how to process the data correctly. A common error was mistaking the mass in the equation for the mass of the sodium hydroxide. Some candidates referred to heat as the "enthalpy of neutralization" which was not accepted. Similar questions have appeared numerous times in past paper two examinations. Several G2 respondents considered this question unfair because the thermometric titration is not one of the prescribed labs. The intention of the question was the application of concepts in a new situation; however, it inevitably favoured candidates who had conducted a thermometric titration during the course. The average mark on this part-question was 0.4 marks (out of 2).

- (b) Students who answered part-question 5(a) correctly were more likely to answer 5(b) correctly. It was more common to achieve the mark for the lower temperature rise. Many candidates simply repeated the question saying that heat losses lead to a lower calculated concentration achieving no marks.
- (c) A well answered question. Half the candidates suggested insulating the beaker, using a polystyrene cup or adding a lid. An answer that failed to achieve marks was "closed system" as such a system does exchange heat with the surroundings.
- (d) A fifth of the candidates gave a valid assumption. "Reaction goes to completion" was a common answer that was accepted in the notes in the markscheme although candidates should know that acid-alkali reactions are very fast. Another common answer that was not accepted was that no other reaction released any heat.
- (e) This was a nature of science question and a variety of reasonable answers were accepted. The most common answers were "simplifying the calculations" and "the errors do not have a major impact on the results". A fifth of the candidates scored the mark.
- (f) This was a well answered question. Most candidates recognized that the temperature rise would be too small with such a low concentration.

Option A

Question 6

- (a) Very well answered.
- (b) Most candidates stated that the bonding was ionic but very few explained why the ionic lattice was brittle.

Question 7

- (a) A third of the candidates stated that lanthanum was more reactive than carbon scoring the mark.
- (b) Stronger candidates were able to calculate the current correctly scoring the three marks. Some lost one mark for forgetting to include the stoichiometric ratio.

Question 8

- (a) Surprisingly, only a third of candidates identified the major advantage of nanoparticles as their large surface area.
- (b) Only a third of the candidates scored this mark. Some answers were too general.

Question 9

- (a) Only 10% of candidates scored this mark. Candidates did not display understanding of how homogeneous catalysts are involved in the reaction mechanism.
- (b) Quite well answered with good suggestions from many candidates.

- (c) This was a discriminating question. Only strong candidates were able to describe the plasma state and how it is produced in ICP-MS.

Question 10

- (a) About a quarter of the candidates were able to identify the plastics and their resin codes correctly.
- (b) A third of the candidates knew the difference between the structures of HDPE and LDPE, and most of these candidates scored either one or two marks while explaining the difference in their melting points.

Option B

Question 11

- (a) A third of candidates listed the building blocks of triglycerides and carbohydrates correctly. Candidates who failed to score the mark were more familiar with the building blocks of triglycerides than those of carbohydrates.
- (b) (i) Only a small percentage of candidates recognized the importance of forming hydrogen bonds with water to solubility. About half of the candidates obtained the first mark for the comparison of the structures of raffinose and linoleic acid. Some candidates only discussed one of the two molecules failing to score the second marking point.
- (b) (ii) This was a discriminating question. About a third of the candidates recognized that hydrolysis took place but very few candidates were able to score the second mark. A common mistake was to state that water was a product of the hydrolysis.
- (c) Surprisingly, this was not a well answered question, even though it is clearly mentioned in the programme guide.

Question 12

- (a) (i) This question was not answered correctly by the vast majority of candidates. Teachers commented that it was a very difficult question and should not have been included in the paper. While many candidates made a good attempt at deducing the straight chain structure of ribose, they did not manage to deduce the correct orientation of the hydroxyl groups.
- (a) (ii) A fifth of the candidates scored the mark. The most common mistake for those who attempted the question was not including the hydrogen atoms. A proportion of candidates did not attempt to answer the question, suggesting that the inclusion of the partial structures may have been confusing to them while the author thought that it would help.
- (b) A fifth of the candidates were able to describe how Haworth projections help focus on the position of attached groups. Many answers were too simplistic.
- (c) (i) Although an easy question, the majority of candidates did not read the question carefully and simply stated something related to biodegradability failing to score the mark.
- (c) (ii) This was a discriminating question and only 10% of the candidates were able to deduce the product. Some teachers commented that this question was too challenging, however it did discriminate at the top end. Stronger candidates applied their knowledge of the hydrolysis of biological polymers to this example.

Question 13

- (a) This was a very well answered question.
- (b) (i) A very well answered question.
- (b) (ii) Many candidates deduced that lysine was the amino acid that was closest to the negative electrode and gave a correct reason. The most common mistake was to select aspartic acid.
- (c) Although candidates recognized point X as the optimum temperature, only a fifth of them were able to meet the requirements of the markscheme in their answer. They needed to refer to the highest frequency of successful collisions between the substrate with the active site.
- (d) Almost all candidates identified vitamin C as the most soluble vitamin in water.
- (e) A third of the candidates were able to outline how the presence of heavy metal ions decreases the action of enzymes. Many other candidates stated that heavy metals altered the shape of the enzyme but did not provide more detail.
- (f) Only a fifth of the candidates stated host-guest chemistry as the method of removing lead ions from an individual suffering from lead poisoning.

Option C

Question 14

- (a) This was not a well understood area. Candidates more often referred to the emission spectrum of a star showing the frequencies emitted by carbon. In fact the hot star behaves as a black body emitting a continuous spectrum and carbon in the outer layers of the star absorbs specific frequencies appearing as dark lines on the star's emission spectrum.
- (b) (i) Most candidates deduced that X was boron-8. This was an improvement on previous sessions.
- (b) (ii) Only a fifth of the candidates gained the mark. Most correct answers referred to mass being converted to energy. Very few referred to the increase in nuclear binding energy per nucleon. Some candidates used the incorrect terminology "mass defect" which relates to the difference between the mass of a nucleus and the mass of its constituents rather than to the difference in mass between reactants and products, but they were not penalized for it.
- (c) More than half of the candidates scored at least one mark out of the two allocated for this question. The main reason for losing marks was providing general answers without sufficient detail, for example, "fusion releases more energy than fission" (instead of "higher specific energy").

Question 15

- (a) About a third of the candidates were able to score both marks- an improvement on previous sessions.
- (b) Deducing the structural formula of biodiesel was challenging for most candidates. This question discriminated at the upper grades.
- (c) The first part was well answered. More than half of the candidates stated that biodiesel was less viscous than vegetable oil and some of them were able to give a valid reason for this difference. Many candidates, however, continue to struggle with explanations based on intermolecular forces.

- (d) This was well answered by many candidates. More of the candidates were able to calculate the specific energy than the energy density. Some candidates calculated both quantities in different units, scoring only one of the two marks. Some teachers commented that candidates may not be familiar with the unit megajoule and it would have been better to have used the kilojoule in the question. It is a fair point that is noted for future paper setting although the unit MJ is common used in data table.

Question 16

- (a) About half of the candidates gave the equation for converting coal to carbon monoxide and hydrogen. Only few of them stated that the process required heating.
- (b) This question was hardly answered by any candidates. It seems this area of the syllabus requires more attention. The most common incorrect answer was an equation for the production of methane instead of a liquid hydrocarbon.

Question 17

- (a) This nature of science question was well answered by about 40% of candidates. Some candidates did not read the question carefully.
- (b) It was surprising that only a third of candidates answered this question about the absorption of IR radiation by different modes of stretching.
- (c) While most candidates knew that pH decreases and many gave an equation for carbon dioxide dissolving to form carbonic acid, but only 20% scored the mark by showing the dissociation of carbonic acid.
- (d) This was well understood by a third of the candidates. A common incorrect answer was in terms of global warming.

Option D

Question 18

- (a) This was well understood. The majority of candidates recognized the interval as the therapeutic window of the drug. Some candidates called it the therapeutic index, which did not correspond to the definition and failed to score the mark.
- (b) (i) A third of candidates deduced the type of reaction. The most common correct answer was methylation. Some teachers commented that it would have been better to use a reaction covered in the core part of organic chemistry like esterification in this question. Although being a fair comment, the explanation of the synthesis must be covered in option D.
- (b) (ii) The action of opiates was generally well understood and the majority of candidates were able to score at least one of the two marks. However some candidates showed confusion and incorrect terminology.

Question 19

- (a) A third of candidates explained the polarity of aspirin due to the carboxyl group. However, very few candidates scored the second mark by referring to the non-polar benzene ring in aspirin.
- (b) The equation for the conversion of aspirin to a soluble form was one of the most discriminating marks in the paper. Some candidates used a reaction with sodium hydroxide but were not able to give the correct product.

- (c) Two-thirds of candidates stated that the student’s sample was impure gaining the first mark. The second mark allocated for explaining the range of melting points was rarely scored.
- (d) Most candidates gave a correct similarity but a much smaller number gave a correct difference.
- (e) Nearly half of the candidates gave a green chemistry solution. The most common correct answer was recycling the waste solvent.

Question 20

- (a) Half of the candidates calculated the pH of the buffer correctly.
- (b) About half of the candidates recognized that aspirin was acidic and deduced that it lowered the pH of the blood. Hardly any candidate gained the second mark. Many teachers complained that this question was unfair as SL candidates are not familiar with buffer solutions or their action. Although this was intended as an extension of equilibrium and weak acids, this is a valid point and will be considered when setting future papers.

Question 21

- (a) A third of candidates understood the action of oseltamivir (at least partially). Incorrect answers often stated how other antiviral drugs worked.
- (b) This was one of the most challenging questions on the paper. Only 10% of candidates were able to outline a green chemistry method for the production of shikimic acid.
- (c) This question was well answered by 40% of candidates. Some candidates gave general answers that were not accepted.

Recommendations and guidance for the teaching of future candidates

- 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 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 lab work. Lab 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 discussions when opportunities arise.
- Insist on detailed answers that offer good explanations and on the use of correct terminology.
- For the biochemistry option, provide plenty of opportunities for writing the structural formulas of building blocks and the products of reactions.
- Encourage students to read the question more than once and to pay attention to the command term used. For example if “compare” is the command term, the candidate must refer to both items to be compared in their answer.

- Practice recent past paper questions and markschemes with students. These help students refine their exam technique, appreciate the level of detail required in markschemes and the importance of using correct terminology.
- Correct bond connectivities should be emphasized during the course (such as HO-CH(CH_3)-COOH is correct and OH-CH(CH_3)-COOH is incorrect in question 13(c)(ii)), as well as correct organic nomenclature and different representation systems.
- Please encourage candidates to round numbers correctly and state answers to calculations to an appropriate number of significant figures. Discourage rounding off too early.
- Throughout the course, draw your students' attention to the implications of concepts learnt on the environment. Suggestions are provided in the right-hand column in the programme guide. This should dissuade students from producing journalistic answers.
- Relating acidity to pH change was a difficulty for a number of candidates, which was surprising for a core concept. Please provide opportunities for using pH values and pH measurements in the lab.
- Ensure students are familiar with the format of paper 3 – we are still seeing a few scripts where the students did not answer Section A.
- Handwriting continues to be a problem with some candidates. The IB Coordinators should be made aware of specific situations with enough time so that special accommodations may be arranged.

Higher level Paper 3 Timezone 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-5	6-10	11-16	17-21	22-25	26-30	31-45

General comments

Many candidates were well prepared and performed well on this paper, although some appeared quite unfamiliar with the subject material. The mean score was 16.67 out of 45.

73 teachers submitted G2 forms following the examination. 85% of respondents (62 teachers) have rated the difficulty of the paper as appropriate. 15% (11 teachers) rated it as too difficult. These same 73 teachers said that the paper was of similar standard to last year (48 respondents), a little more difficult (17) and much more difficult (2). Only 5 thought the paper was easier than last year.

Significantly, 20 of these teachers felt that the clarity of wording was below par (3 stating it was poor and 17 that it was fair). However, they were more than balanced by teachers who rated the clarity of wording positively.

Most candidates seemed quite familiar with the concept of answering Section A and answering one option from Section B, although there were some who did not attempt Section A. Most candidates confined themselves to only one option. Option D was the most popular, followed by Option C and B (very similar in popularity). Very few answered Option A. Candidates seemed to have had adequate time to answer all questions.

There was quite a bit of concern expressed by teachers about Section A. The questions in this section combine the practical work to which candidates should have been exposed with a technique which few of them would have seen previously. In this paper the prescribed practicals were an acid-base titration and a calorimetry experiment to find the enthalpy of reaction in an aqueous solution. The thermometric titration provided the unfamiliar data. There is no expectation that thermometric titrations must now be included in the practical scheme of work. To encourage candidates to attempt all of Section A the questions were numbered separately rather than as parts of only one or two questions.

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

As stated in previous subject reports, candidates struggled with questions based on experimental work. As a teacher myself, I am reluctant to suggest that candidates are not being exposed to a comprehensive laboratory programme. Rather, I believe that students are not engaging with the experiences in the ways that we expect them to, and that we need to spend more time discussing why the instructions include certain steps so that the students understand why they have performed the experiment in the way they have.

In general, many candidates gave responses that needed interpretation by examiners. Instead of stating the answer in a simple manner, candidates wrote complex and verbose (and sometimes contradictory) statements. There is an advantage in giving short, clear answers using correct terminology.

Candidates also struggled to give lucid, articulate responses to the NOS-based questions. It seems we need to provide more NOS challenges in our teaching programmes.

The writing of half-equations and equations for various reactions were problematic.

In Section A many candidates had difficulty analysing data in graphical form, as demonstrated by their answers on the graph. A number of them provided explanations in terms of faster or slower even though time was not a variable on the graph given to them. Many could not correctly describe properties of the graph involving the gradient.

In Option A, candidates had difficulty outlining why superconductivity only occurs at low temperatures, the production of a plasma state in ICP-MS, and in the calculation involving K_{sp}.

In Option B, difficulties presented in comparing water solubility and energy storage of a lipid and a carbohydrate, explaining base hydrolysis of a lipid and in converting a cyclic monosaccharide to a straight chain structure. Candidates also had difficulty explaining enzyme function, oxygen saturation of hemoglobin and the generation of impulses from the retina to the brain.

In Option C, candidates had difficulty outlining how spectra from stars can be used to identify which elements are present, and in calculating the energy produced in a fusion reaction. Equations for the Grätzel cell, coal gasification and conversion to liquid hydrocarbons, and half-equations for a fuel cell proved challenging.

In Option D, candidates had difficulty describing aspirin structure, explaining the effect of impurities on the structure and discussing the purification of an aspirin sample based on acid-base properties and solvent extraction. Again, candidates had difficulty writing equations and half-equations.

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

- Candidates seemed to use the number of marks and the space available for answers as a guide on how much to write. Very few had additional pages attached. Those that did had often crossed out answers in the booklet and given a fresh answer on the additional pages.
- Candidates scored better on short answer questions that only involved recall.
- In all options, candidates seemed competent in the use of IR spectroscopy for structure determination.
- In Option A, most candidates had no difficulty in using electronegativity values to predict bond type, and in explaining why lanthanum cannot be produced from its oxide using carbon.
- In Option B, candidates could find the value of Michaelis constant from rate data, outline how non-competitive inhibitors affect the rate of enzyme reactions, and calculate relative proportions of nitrogenous bases in DNA.
- In Option C, candidates could identify reagents needed to convert vegetable oil to biodiesel and give the structure of the fuel formed.
- In Option D, candidates competently identified IR peaks for aspirin and salicylic acid.

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

Section A

Question 1

The majority of candidates correctly calculated percentage uncertainty but a smaller number could suggest how to improve the precision of the volume measurement. Many suggested choosing a measuring cylinder with smaller increments, but as the uncertainty is already ±0.5 this is not possible. Some suggested that measurements should be repeated but the standardisation teams felt that the question referred to a single measurement, and thus a change in glassware used was required.

Question 2

Many candidates had difficulty expressing themselves well in their responses to this question. Many responses required interpretation and it was not always obvious if candidates understood what was happening during the titration. Candidates often referred to a greater concentration of acid being added rather than more moles. Several candidates contradicted themselves in part (b) by saying “less heat was being produced and the reaction was complete”. Whilst some recognized that the endpoint had been reached and no more reaction was occurring, the requisite second point for the mark to be awarded was either missing or vaguely expressed.

Question 3

Very few candidates described extrapolating both lines of best fit to find the intersection and hence the end-point of the titration. Some candidates were confused by the graph and described extrapolation of the (net) cooling line of best fit back to the y-axis. Many gave verbose responses referring to sections of the graph where plateauing occurred before a decrease in temperature instead of simply giving the acceptable response of highest temperature. A few suggested that the end-point would be reached when the temperature had returned to its original value.

Question 4

A surprisingly large number of candidates thought that sulfuric acid is a weak acid. Several guessed that either sulfuric acid is stronger than hydrochloric or vice versa. Those who are aware that sulfuric acid is a strong diprotic acid generally scored well.

Question 5

Explanations of how to calculate the concentration of the alkali without knowing the concentration of the acid were often unclear. Candidates often referred to the enthalpy of the reaction instead of the heat released by the neutralisation reaction. The IB is quite clear about the terms to be used. Topic 5.1 of the Chemistry Guide states that enthalpy change (ΔH) is indicated in kJ mol^{-1} and calculation of heat change uses $q = mc\Delta T$. A significant number of candidates stated that *m* in this equation referred to the mass of the alkali and thus could be used to find *n*. Candidates frequently contradicted themselves in their responses giving a correct statement and its opposing incorrect statement. It is not possible to award marks in these situations.

In response to outlining why the thermometric method would always give a lower concentration, it is not sufficient to simply say there are heat losses (as this is given in the stem of the question) nor that concentration must be lower as it can never be higher.

It was anticipated that candidates would be able to suggest how heat loss could be reduced with a lid or by insulating the beaker for instance. There were some very vague and incorrect responses given. A beaker made of glass that resists heat loss is not sufficient. Others said to do the reaction in a closed system. Closed systems exchange energy with their surroundings so no mark was awarded.

Again suggesting that these questions have not been linked to their practical experiences, many candidates had difficulty stating one other assumption made in calculations of heat produced. However, the better candidates could suggest an assumption and could also say why scientists often make assumptions that do not correspond to reality.

Difficulty in expressing themselves clearly was again a problem outlining why 0.001 mol dm^{-3} solutions should not be titrated using the thermochemical method. Better candidates gave clear responses. Others said that the values would be too low without specifying which values.

Section B

Option A – Materials

Question 6

Determining the type of bonding based on average electronegativity and electronegativity difference was generally answered well, as was explaining why crystalline lanthanum bromide is brittle.

Question 7

Most candidates could explain that lanthanum is higher on the reactivity series than carbon and hence cannot be produced from its oxide using carbon.

Most candidates had difficulty using Faraday's laws to calculate current.

Question 8

The coordination number of each lanthanum atom in hcp crystal structure proved challenging. It is agreed that hcp crystal structures are not listed in the Chemistry Guide and a different crystal structure should have been included in the examination.

Most candidates scored some marks for explaining superconductivity in terms of Bardeen-Cooper-Schrieffer theory, but had difficulty outlining why superconductivity only occurs at low temperatures.

Question 9

Candidates could generally give the repeating unit of the PETE polymer, although marks were lost for missing continuation bonds or an O at both ends. Most correctly identified the class of polymer.

Outlining how homogeneous catalysts work was more difficult. Some said that the catalyst provided an alternative pathway with lower activation energy. This scored no marks as it was stated in the stem of the question. Others gave very good answers. Knowing why it is important to know how catalysts function was generally answered well.

Question 10

Several candidates correctly outlined the nature of the plasma state but had difficulty saying how it is produced in ICP-MS.

The K_{sp} calculation proved difficult. Several candidates could not identify the ions present in Sb_2S_3 and a small number could not write a correct K_{sp} expression.

Identifying a ligand to chelate antimony(III) ions in solution was generally answered well.

Question 11

Identifying which plastic belonged to which IR spectrum and their resin identification code should have been straightforward, as candidates were told that the two plastics were PETE and LDPE. A small number of candidates identified different plastics. Those who read the question properly generally answered this well.

Describing differences in LDPE and HDPE structures and melting points was generally answered well.

Option B – Biochemistry

Question 12

Explaining why raffinose is more water soluble than linoleic acid required a comparison. Not all candidates commented on both molecules. Very few candidates referred to H-bonding.

Explaining the use of sodium hydroxide to unblock kitchen drains was poorly answered. Some candidates recognised that hydrolysis was occurring. Very few stated that a salt of the fatty acid was formed or that this salt was water soluble. Common answers referred to the triglyceride being broken down into smaller chunks that could wash away.

Most candidates missed the point in explaining why linoleic acid is a more efficient energy storage molecule than raffinose, simply saying that lipids are better energy stores than carbohydrates. This is not an explanation.

Question 13

Very few candidates could deduce the straight chain structure of ribose given its ring structure. Often the hydroxyl groups were on both sides of the chain. More worryingly, frequently the hydroxyl groups were written with the H between the O and C. Most candidates recognized that ribose has a carbonyl (*aldehyde*) group at one end but some just had an O (sometimes with a continuation bond).

The majority of candidates correctly linked the two α-glucose molecules, and most could describe the advantage of Haworth projections as providing 3-D perspectives of structures.

Several candidates referred to the biodegradability of starch-based polymers despite the question specifically asking for another advantage. A wide variety of advantages were mentioned, not necessarily expressed well.

Most candidates correctly deduced the formula of the product formed when water reacts with polylactic acid. Some gave a molecular formula which was not accepted: the molecular formula does not give an indication of the nature of the product.

Question 14

This question was answered very well. Most candidates knew that the hydrolysis of peptide is catabolism. Most also answered correctly that alanine would not move during electrophoresis and that lysine would develop closest to the negative electrode. It was encouraging that candidates gave the name of the amino acid when asked for it, although many also gave the abbreviated form of Ala.

Very few candidates gave the expected response to part (c) regarding rate of reaction in terms of the enzyme's active site. Few referred to frequency of successful collisions and most simply stated that all active sites are occupied or that point X indicates the optimum temperature for enzyme activity and that the enzyme is denatured at temperatures above X.

Nearly all candidates correctly identified vitamin C as most soluble in water.

Very few candidates described the effect of heavy metal ions on enzymes in terms of interactions between R groups or tertiary/quaternary structures. If a mark was scored at all for this question it was usually for simply saying that the metal ion reacts with the enzyme.

Question 15

Many candidates correctly deduced an appropriate pH range for glycine to act as an effective buffer. Some gave the lower pH value as 8, which was not accepted.

The determination of Michaelis constant was generally answered well. Those who answered incorrectly often halved [S] instead of the halving the maximum rate.

The action of a non-competitive inhibitor was correctly outlined by most candidates. A few contradicted themselves by saying the inhibitor binds to the allosteric site or the active site. Several neglected to state that the maximum rate was reduced and thus missed out on a mark.

Most candidates correctly stated mole percentages of nitrogenous bases in DNA.

Question 16

Many candidates scored at least one mark for stating that cooperative binding occurs as oxygen binds to hemoglobin. Few gave extra detail to score the second mark.

Sketching a graph to show the effect of decreasing pH on the binding of oxygen proved a challenge for many candidates. The graph should be offset to the right which means the 100% saturation should occur at higher partial pressures of oxygen. Many candidates had the curves reaching maximum at the same pressure, or had the % saturation levelling off at lower values. Restating the effect of decreasing pH in the second part of the question was answered correctly by most candidates.

Question 17

It was very difficult to give marks for this question. Despite the stem stating that light is absorbed as 11-*cis*-retinal isomerizes to 11-*trans*-retinal, many candidates referred to this transformation as the one which releases energy to generate nerve signals. It seems that few candidates understood this process.

Option C – Energy

Question 18

Many candidates referred to emission spectra rather than absorption spectra seen in light from stars. Some mentioned both. Very few mentioned that there are black lines in the spectra or specific wavelengths that are characteristic of carbon.

Almost all candidates correctly identified the isotope that reacts with helium to produce carbon 12. However, calculating the energy produced in the fusion reaction proved very difficult for most candidates. Very few found the loss in mass and simply used the combined mass of the two reactants in their calculations. Frequently candidates omitted the conversion of amu to kg but scored ECF for then multiplying their mass value by c^2 to find the energy. Some also had arithmetic errors as they multiplied by 10^3 to convert (wrongly) kJ to J. A few of the better candidates calculated the energy produced correctly.

Many candidates scored one mark for an advantage of nuclear fusion over nuclear fission. Again there was lack of clarity in responses with many candidates simply saying that fusion produces more energy than fission instead of referring to specific energy.

Question 19

Comparing the organic dye used in DSSCs with chlorophyll gave many vague answers. Frequently candidates said both contained a transition metal at the core. Mg is not a transition metal. Central metal ions were mentioned without referring to bonds from nitrogen. Benzene rings were a commonly mentioned feature. Better candidates mentioned an extensive system of conjugated bonds.

Very few candidates could state the reduction equation in a Grätzel cell. Many attempted to state the equation for photosynthesis but often failed to balance the equation. Only a handful of answers included iodine species and most of these were incorrect.

Question 20

Most candidates could state two reagents required to convert vegetable oil to biodiesel, and could then deduce the formula of the biodiesel formed.

The calculations of specific energy and energy density were poorly done. Some candidates had them the wrong way around. Many had incorrect conversion of MJ to kJ (and thus scored one mark out of two). Some had no idea.

Question 21

Most candidates scored one mark for stating the equation $C + H_2O \rightarrow CO + H_2$. Some scored a second mark for stating that heat was required for this to occur. Almost no-one gave a response more complicated than this.

Only the very best candidates could then outline the conversion of CO to a hydrocarbon fuel.

Question 22

Most candidates had difficulty writing half-equations for a fuel cell. Frequently electrons were omitted. Some candidates had two reduction half-equations. It seemed that some candidates tried to memorise these half-equations rather than deduce them using simple rules.

Identifying a similarity of various cells was a challenge for many. We expected candidates to state that all of them produce electrical energy. Stating a difference between primary and rechargeable cells often led to responses that primary cells can only be used once whereas rechargeable cells can be used over and over, with no reference to reversible reactions.

Many candidates successfully identified a factor that affects the voltage and another that affects the current of a cell.

Question 23

Responses to the NOS question on predictions of future impacts of fossil fuel combustion were poorly expressed and difficult to award any marks to.

Despite being on the November 2016 exam many candidates had difficulty predicting which stretching mode of carbon dioxide would absorb IR. Even those who predicted correctly had difficulty explaining why, with many responses simply stating that one was polar, rather than mentioning a change in dipole moment.

Most candidates could write equations to show how increasing carbon dioxide levels affect the pH of oceans, and the majority could state the impact of particulates on Earth's temperature.

Option D – Medicinal chemistry

Question 24

Most candidates recognised therapeutic window although a few incorrectly mentioned lethal dose or therapeutic index.

The action of opiates was explained well with most candidates scoring at least one mark out of two.

Question 25

Candidates were required to look at the structure of aspirin to suggest why it is slightly soluble in water. Very few candidates referred to both the non-polar benzene ring and the polar carboxyl group. Frequently candidates stated that the O-H bond in aspirin is only slightly polar and hence the molecule is only slightly soluble.

In part (b) most candidates suggested that the student’s sample of aspirin had impurities, but very few explained why the impurities lowered the melting point. References to intermolecular forces were rare, as was mention of a crystal lattice. A few candidates made detailed comments about lack of recrystallization that resulted in the sample being impure.

Candidates very successfully identified IR peaks for aspirin and salicylic acid. The few who failed to score did not refer to peaks and instead simply compared the structures. Some stated a peak below 1500 cm^{-1}.

The purification of aspirin based on its acid-base properties and solvent extraction was very poorly answered. Commonly candidates said that aspirin was basic due to the hydroxyl group so it could be reacted with acid to separate it from the mixture.

Most candidates correctly stated that solvents could be re-used or recycled. A few gave another correct response as a green solution to organic solvent waste.

Question 26

The calculation of blood pH was correctly done by many candidates. Those who got it wrong had the ratio upside down.

Most candidates stated that aspirin would lower the pH of the blood but could not explain why for the second mark.

Question 27

There were some very good responses outlining how oseltamivir works. The best candidates described the process very well. Those who did not know tended to give incorrect responses relating to preventing the virus from reproducing.

Describing the development of the precursor for oseltamivir was poorly outlined with most candidates seeming to be unfamiliar with these details. A few stated that genetically modified organisms were involved and a few scored a mark for stating that the reaction occurred in a fewer number of steps. There were several teachers’ comments that this question is too obscure but the Chemistry Guide clearly states in D.6 “Explanation of how green chemistry was used to develop the precursor for Tamiflu (oseltamivir)”.

Many candidates gave incorrect explanations of why antibiotics can affect the environment. Frequently candidates stated that the antibiotics get into the waterways or cause ‘immunity’. Better candidates gave the correct response that bacteria develop resistance to the antibiotics.

Question 28

Most candidates correctly described the plane of polarized light rotating as it passes through a solution of an optically active compound. Some suggested that the light caused the compound to rotate.

Most recognized that if a mixture shows optical rotation that it is not racemic.

Question 29

Surprisingly few candidates could write an equation for the beta decay of yttrium-90. Many candidates used incorrect notation for the beta particle. Sr was commonly written as a product rather than Zr, or even more surprisingly, Y was both the reactant and the product. It seems that many candidates had attempted to memorize the equation rather than understand what beta-decay involves.

A very small number of candidates stated that lutetium-177 is a beta-emitter. This was required along with the reason for its usefulness for the mark to be scored so most candidates scored zero here. The vast majority of candidates stated that Lu emits alpha particles. This isotope is listed in the Chemistry Guide in D.8: “Explanation of why lutetium-177 and yttrium-90 are common isotopes used for radiotherapy based on the type of radiation emitted”.

Most candidates correctly calculated the rate constant for the decay of iodine-131 but made errors in the calculation of the time taken for 90% of the sample to decay. A typical error was to use 0.9 for the remainder instead of 0.1. An ECF mark was then frequently scored.

Many candidates had difficulty writing half-equations for a fuel cell breathalyser. Electrons were often omitted and frequently one equation involved the reduction of the dichromate ion. Candidates are not expected to memorize half-equations but are expected to be able to formulate an equation from first principles.

Recommendations and guidance for the teaching of future candidates

- Students should be encouraged to write legibly. Some handwriting was very difficult to decipher which makes it very difficult for examiners to award marks when the wording of the response is not exactly as expected.
- Students should be advised to use appropriate chemistry terminology and expressions so that there is no ambiguity about the meaning of the answer.
- Students should learn appropriate chemical equations for the processes studied in the options.
- Students should work through past examination questions and markschemes carefully. It is disappointing that similar questions in recent papers have not facilitated the answering of the questions in this examination.
- Students should be trained to read the question very carefully and then direct their answer to the requirements of the question. Command terms should be emphasized throughout the teaching of the course.
- Teachers should make sure that all aspects of an option are taught as some sub-topics

appeared to be poorly understood. Nature of Science parts of the syllabus should be covered along with the chemistry understandings.