November 2016 subject reports

Chemistry

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 16	17 - 30	31 - 42	43 - 53	54 - 64	65 - 75	76 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 27	28 - 40	41 - 52	53 - 63	64 - 74	75 - 100

Internal assessment

Component grade boundaries

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

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 good as evidenced by very many schools and teachers should be proud of their efforts to provide students with the opportunity to truly become independent learners who showed curiosity, engagement and a sense of ownership in their Individual Investigations.

Overwhelmingly the work presented involved hands-on primary data collection. The most common topic areas were rate of reaction studies (pleasingly this was usually a bit more developed than the old standards of effect of acid concentration on reaction with calcium carbonate or magnesium) and many investigations in food chemistry which reflects the real world stimulus for ideas. Studies into factors effecting the oxidation of Vitamin C or red wine abounded and appear to be the new “old standards”!

Similarly to May session 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.

A small number of schools did not give their students sufficient opportunity for independent learning. Some moderators did reflect that there were some geographical clusters where many schools in a given region had not met the challenge of the new requirements. The moderators here reported many schools showing no marking annotations and as many again with very limited comments. In other cases, teachers included comments that were not supported by evidence such as praising very good suggestion for improvement when none had been included. One moderator commented on a common weakness from schools in one country where quite a number of reports used unsuitable surveys as a source of raw data.

Candidate performance against each criterion

Personal Engagement

The overwhelming majority of students managed to achieve at least one point for Personal Engagement with many securing both marks. There were slightly less cases than in the May session of the students’ efforts to justify their choice of research question and topic spilling over into overlong and contrived narratives of early childhood holidays or school excursions. That said the wine oxidation studies mentioned earlier did frequently start with stories of their parents extreme fondness for wine! These non-scientific preambles should be kept to a minimum.

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 five trials specified in the old internal assessment framework.

Exploration

The achievement in Exploration was variable.

In many cases a suitable topic was identified and a relevant research question was described. Many research questions fell into the category of determining how a measurable independent variable effected an identified dependent variable and these generated reports that were easily assessable with the IA criteria. Weaker research questions were those simple brand analyses of food, cleaning or pharmaceutical products. Any trends identified would be explainable in terms of business principles (manufacturers decide the composition rather than being the outcome of solely scientific principles). There are possible fruitful avenues available by studying commercial products but these really only open up if a student can link some component of the product composition (which they can experimentally determine or read from the packaging) to a chemical or physical property of the product.

Very often the background information was overlong (up to 6 sides were reported) and 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.

In terms of taking into consideration the significant factors that may influence the relevance, reliability and sufficiency of the collected data the responses of the candidates was extremely varied. A good number of students clearly controlled relevant variables, selected a suitable number of values of independent variable and repeats in order to establish reliability and sufficiency. However an equal number of students didn’t carry out repeats and most significantly failed to correctly identify or control key variables with the result that their data did not properly answer their research question. Electrolysis experiments were poor in this regard with students failing to measure or monitor current or not drying electrodes prior to massing. Also selecting pH as the dependent variable in a rate investigation led to misunderstandings in the subsequent interpretation as students mistakenly assumed a linear relationship between pH and hydrogen ion concentration.

Most students showed some awareness of **safety**, ethical or environmental issues relevant to their methodology although in many cases this was confined to a quite basic measures such as gloves and safety glasses when also they should have been considering other issues such as safe disposal of chemicals. Consequently achievement was limited. A very significant issue for some schools was the absence of any expectation towards safety, environmental and ethical. Although the criterion descriptor does state “Where appropriate” it is envisaged that in most cases it is considered appropriate. This session we saw without comment the reaction of sodium metal (with pictures showing large lumps and corresponding flames) and the use of teeth, human fluids, animal bones without any clarification on ethical, safety concerns.

Analysis

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

Many students recorded qualitative observations and sufficient data related to the independent and dependent variables so that they could subsequently carry out sufficiently meaningful process and interpretation. Fewer students though recorded the data regarding the control variables such as reaction temperatures or reactant amounts. It is this wider data that can provide valuable context for the evaluation of the procedure.

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. Often the numerical calculations were demanding and it is important to note here that teachers **must check through calculations** when assessing Analysis. On a significant number of occasions apparently sophisticated and lengthy calculations had been awarded the highest level by the teacher but when spot checked by the examiners revealed themselves to contain major errors (such as calculating the heat generated in combustion calorimetry using the mass of the alcohol consumed rather than the mass of water being heated) that significantly affected the conclusions drawn. These oversights did then lead to the downward adjustment of the Analysis mark.

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

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

- Sensible protocols on propagation of errors through numerical calculations such as 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 R2 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, others who presented graphed data with inappropriately chosen Excel polynomial graph lines (ski jumps and water slides often appeared to be present!), those who carried out inappropriate statistical treatments such as T-tests on a minimum of data and there are still quite a number of students who present numerical results to an excessive number of significant figures.

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. Also many students 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 new IA places the responsibility on the student and part of the independent learning task is for students to be aware of the criteria up front and for us to challenge them at an early stage of the process as to whether they think their proposed investigation gives them chance to fully satisfy the criteria and counsel them accordingly.

Evaluation

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

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

The descriptors regarding limitations and improvements/extension are those that tend to score lower. 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. Many suggested limitations were limited to issues that should have been addressed during design or by doing a pilot. Suggestions for improvements usually included more repetitions even at times when these had been acceptable. Specific improvements that were also related to previously identified limitations were less common. Moderators saw some interesting extensions but also others that were paying lip service to the requirements and were too simplistic, e.g. changing the compound.

Communication

As in the May session the Communication criterion was in most cases quite well fulfilled and 3 marks was the most common outcome. The using of citations and references was far greater than in the old framework and was generally impressively done.

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

Many reports were mostly concise and most of them did meet the 12 page limit which did prove sufficient for even the most sophisticated investigations. Some students did include lengthy appendices in order to circumvent the page limit ruling but this is not an acceptable strategy since examiners do not have to read the appendices so vital marks could have been lost. Most of the reports were relevant although the one common area of weakness was the inclusion of too much general background information that wasn't focused on the Research Question.

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.

Recommendations for the teaching of future candidates

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

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

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.

Further comments

Recommendations for procedures, forms

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

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

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 15	16 - 20	21 - 24	25 - 29	30 - 33	34 - 40

General comments

The number of candidates who answered the paper was 1919. The paper consisted of 40 multiple choice questions on the Subject Specific Core and the Additional Higher Level material. The exam was done without calculator or data booklet. A small minority of candidates did not answer every question; there is no penalty for a wrong answer.

The overall analysis suggest the paper was very slightly harder than that set in November 2015.

22 teachers gave feedback from a total of 325 schools. Apart from those for whom the comparison was not applicable (9%) 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	73	14	5

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

	Too easy	Appropriate	Too difficult
Level of difficulty / %	0	95	5

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

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	0	0	9	27	41	23
Presentation of the paper	0	0	5	18	45	32

In general, the paper seems to have been well received; "paper was of good standard", "similar standard to last May", "wording was overall very good" and "individual questions were all fair and of an expected level of difficulty". There was also the comment that students might have struggled with time management because "the balance between straight-forward, moderate and challenging questions was a little bit towards the challenging end". We particularly appreciate the last comment as we try to set questions that are appropriate for students of all abilities. There need to be some that will discriminate the grade 7 candidates from the grade 6.

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

There are often requests for a separate periodic table so that candidates do not have to keep flipping back pages for the information. We prefer not to do this as there is always the possibility that the periodic table might be "lost in transit". There is, however, no reason why candidates should not simply detach the front page of the question paper.

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

As this was the first November examination of the new syllabus, there were questions on unfamiliar topics. This was to be expected.

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 36.34% to 93.01%. The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from 0.16 and 0.74.

The following comments are made on individual questions:

Question 5

This was the easiest question on the paper with a 93% success rate.

Question 9

This had a low success rate (36%) with an almost similar number of candidates choosing D. Candidates should have been able to work out that Co(III) is $3d^6$.

Question 13

This was answered correctly by 73%. The next most popular answer was **C**; the candidates should have considered the conductivity more carefully.

Question 16

The common error was **D**, forgetting the factor of “2”. Only just over half gave the correct answer.

Question 17

The most popular incorrect answer was **B** where the candidates did not read the sign carefully.

Question 19

61% had a good grasp of the factors involved in determining lattice energy.

Question 20

77% recognized that change in mass is not a factor.

Question 21

There were some concerns expressed about the use of the term “potential energy” – but this is commonly use. The question had an 80% success rate.

Question 23

Candidates need to have noticed that one of *R* and a negative sign are missing from the slope (gradient). It would, perhaps, have been unfair to test *only* the absence of a negative sign.

Question 25

This type of question is usually found to be more difficult but, in the event, nearly 65% gave the correct answer.

Question 27

59% gave the correct answer but 31% thought both hydrogen and carbon dioxide would be given off.

Question 34

It was pleasing to see nearly 76% answer this correctly. The distinction between “hydroxide” and “hydroxyl” is important.

Question 36

Candidates should be prepared for esters, such as propyl methanoate, being presented either as –COOR or $–CO_2R$ and in “either direction”. The same would apply to the presentation of acids as either –COOH or $–CO_2H$.

Question 37

Candidates are asked to choose the best answer. We accept the criticism that a negative and positive angle of rotation could be deemed “different”. We would normally refer to equal angles but in opposite directions. This is the correct use of mathematical language.

Question 38

We apologise for the missing word (“out”) in the first sentence. This will be corrected when the paper is published. A concern was raised about the wording but nearly 71% gave the correct answer.

Question 39

This question is in the syllabus (11.3) and does not require knowledge of the operating principles of the mass spectrometer. Candidates might not have seen the term “molecular ion” being referenced as M^+ before – but the question is unambiguous. This is a standard abbreviation and has been used in past examinations papers and mark schemes.

Question 40

This was one of the easiest questions on the paper with an 82% success rate.

Recommendations and guidance for the teaching of future candidates

- Candidates need to be reminded that they should choose the best answer to each question.
- Candidates should be advised how to approach a multiple-choice examination and, at the end, to have left no question unanswered.
- Candidates should spend no more than about one minute on each question in the first instance and those candidates who find anything mathematical to be challenging should leave those for later in the time allocation.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 14	15 - 17	18 - 20	21 - 23	24 - 30

General comments

The number of candidates who answered the paper was 2131. The paper consisted of 30 multiple choice questions on the Subject Specific Core. The exam was done without calculator or data booklet. Up to 1.5% of candidates did not answer any one question even though there is no penalty for a wrong answer.

25 teachers gave feedback from a total of 273 schools. Apart from those for whom the comparison was not applicable (20%) 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	4	28	40	8

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

	Too easy	Appropriate	Too difficult
Level of difficulty / %	0	84	16

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

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	0	0	16	16	52	16
Presentation of the paper	0	0	12	12	48	28

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

Whilst it was noted that the examination paper was of a similar standard to May 2016 and November 2015, two comments said that “some of the questions were towards the more challenging end of the spectrum” and “only the very best and able students will do well, therefore appropriate”. We appreciate these comments as we try to set questions that are appropriate for students of all abilities. There need to be some that will discriminate the grade 7 candidates from the grade 6.

One or two respondents would like candidates to be allowed to use calculators. All “calculation” questions are set out in such a way that no calculator is necessary (see Q15) as, in general, we are testing the thought process. The most “complicated” manipulations generally involve multiplication or division by 2 or 3 or powers of 10 (see Q 2 and 13 for instance).

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

There are often requests for a separate periodic table so that candidates do not have to keep flipping back pages for the information. We prefer not to do this as there is always the possibility that the periodic table might be “lost in transit”. There is, however, no reason why candidates should not simply detach the front page of the question paper.

There were comments about translation issues of which we are aware and which we are trying to solve. When setting the papers (in English) we try very hard to write English that will translate without causing ambiguity. We clearly need to make more progress.

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

As this was the first November examination of the new syllabus, there were questions on unfamiliar topics. This was to be expected.

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 23.32% to 67.31%. The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from 0.18 and 0.76. There was a huge increase of poor results from new schools.

The following comments are made on individual questions:

Question 2

This was only answered correctly by 35% of the candidates but, unusually, the three distractors were almost equally popular.

Question 4

This was comparatively well answered (54%).

Question 6

31% correctly gave **A** but *more* candidates gave distractor **B** showing that they do not know that $4s^2$ electrons are lost first.

Question 8

Nearly 60% gave the correct answer but some gave D, presumably confusing “<” with “>”.

Question 10

This was found to be the second easiest question on the paper (63%).

Question 12

The most popular answer (44%) was **D** but a significant minority gave **C** (and to a lesser extent **B**). Perhaps the way to approach this question is to look at the “conductivity”; only **A** (which has a low melting point) and **D** meet the criterion of “none”.

Question 13

This was adjudged the second hardest question on the paper. All answers were very similar in their appeal to the candidates. The most common error was **D** where the factor of two was missed from an otherwise correct answer.

Question 15

42% answered this correctly but 32% chose **B**. Candidates need to pay attention to the sign of the answer.

Question 20

Only 41% gave the correct answer but 34% thought both hydrogen and carbon dioxide would be given off.

Question 21

This question needs careful reading – and 57% managed this successfully.

Question 22

This question also requires careful reading and over 54% successfully answered it.

Question 23

It was pleasing to see 56% answer this correctly.

Question 27

We apologise for the missing word (“out”) in the first sentence. This will be corrected when the paper is published. Nearly 53% gave the correct answer.

Question 28

IHD is quite clear in section 11.3 of the syllabus and, as one of the new features of the programme, was likely to be examined. There are ways to answer questions such as this without having to remember a formula.

Question 29

This question is in the syllabus (11.3) and does not require knowledge of the operating principles of the mass spectrometer.

Question 30

This was the easiest question on the paper with a 67% success rate.

Recommendations and guidance for the teaching of future candidates

- Candidates need to be reminded that they should choose the best answer to each question.
- Candidates should be advised how to approach a multiple-choice examination and, at the end, to have left no question unanswered.
- Candidates should spend no more than about one minute on each question in the first instance and those candidates who find anything mathematical to be challenging should leave those for later in the time allocation.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 28	29 - 39	40 - 49	50 - 60	61 - 70	71 - 95

General comments

This was an accessible paper with a wide range of marks, the best candidates could shine and the mean mark was in the region of 55 out of 95. There were strong scripts where candidates displayed an excellent knowledge of the subject. There was, however, a worrying minority where it seemed that students, even after two years of study, had failed to grasp even the most basic chemical concepts. A small percentage (around 2%) of candidates scored 10 or fewer marks.

The number of candidates who answered the paper was 1952. For the first time in the November session there was no choice in paper two which allowed a “mixed topic” approach to the questions. The lack of choice did not seem to bother the candidates most of whom made it through to the end even though there were five more marks than in previous years. Over 98% of the candidates attempted the penultimate part question, Q 7b(i).

22 teachers gave feedback from a total of 325 schools. Apart from those for whom the comparison was not applicable (14%) 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	9	50	27	0

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

	Too easy	Appropriate	Too difficult
Level of difficulty / %	5	95	

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

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	0	0	9	27	45	18
Presentation of the paper	0	0	5	27	36	32

In general, the paper seems to have been well received and there were comments such as “straightforward paper that would reward students who had worked hard and prepared well”, “great progression of questions, pulling in different topic areas to a single question” and “similar standard to May 2016”.

There was concern that in at least one country potassium dichromate(VI) and phenolphthalein are banned for use in schools as they are classified as carcinogens. There are many resources on the internet where “virtual” demonstrations can be seen using these chemicals. If we were to delete all carcinogens, possible carcinogens or “dangerous” chemicals from the syllabus there would be very little left to examine. The “notion of safety” teaching includes the precautions taken for the safe handling/use of chemicals.

One respondent commented that it would be good to see some question parts “worth, maybe, 4 or 5 marks”. There is such an argument – but the converse is often made, that a candidate can lose a lot of marks all at once. It would certainly make candidates write more carefully so that they might gain part marks. In Q 2 c (iv) many did not gain any marks because it was not possible to discern what was meant by random figures, calculations and jottings.

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

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

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

- Analysis of resonance structures
- Bromination of an alkene mechanism
- Unit conversions (power of 10 errors)
- Le Chatelier’s to explain change in cell potential
- Interpretation of rates
- Plots of Maxwell-Boltzmann distributions and correctly labelled axes
- Interpretation of the hydrogen emission spectrum
- Diagrams of the formation of sigma and pi bonds
- Lewis (electron dot) structures
- Ionic equations for electrolysis and prediction of products of electrolysis
- Drawing 3-D optical isomers and their mirror images
- Presenting solutions to numerical problems in which steps are explained and follow in some logical sequence
- Inversion caused by SN1 and SN2 reactions
- Errors in experimental work
- Buffers and their mechanism
- Purity of chemicals

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

- Deduction of equilibrium expression and the effect of changing pressure on the position of equilibrium
- Drawing structures of alkanes and alkenes
- Describing a bond between a ligand and a transition metal ion
- Routine calculation of amount of substance from its mass and formula
- Using ΔG to predict spontaneity
- Distinguishing between a strong and weak acid
- Choosing an indicator
- Calculation of relative atomic mass from isotopic composition data
- Toxic hazards of sulfur dioxide
- Deduction of limiting reagent

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

Question	Comment
1 a (i)	This was generally answered well although there were incidents of carelessness with formulas, brackets and indices. A few tried to calculate a value but the source of the numerical data was usually unclear.
1 a (ii)	Most gave the correct answer for the shift in equilibrium but many forgot that K_c only changes with temperature.
1 a (iii)	Many answered this correctly but it was quite common to omit the C–C bond (346 kJ mol^{-1}) from the bonds formed. The other common error was to reverse the subtraction. There were also careless arithmetical errors.
1 b (i)	This was answered well.
1 b (ii)	Curiously, HL candidates normally referred to average bond enthalpies whilst SL candidates with a slightly different question seemed to spot the difference in state which is the more significant factor.
1 b (iii)	Candidates generally had the “right idea” but need to be more specific in relating answers such as this to the number of moles of *gas*.
1 b (iv)	The common error was to forget that the units are not immediately compatible. Dimensional analysis is important in negotiating such questions.
1 b (v)	There were some good answers outlining the effect on $-T\Delta S$ on ΔG. Some, however, tried to explain the effect of $T\Delta S$ (without the negative sign).

1 c	It was encouraging to see very few errors of format. Ethane-1,2-diol caused more problems than ethene.
1 d	There was a small minority of candidates who scored zero because they gave the distinct impression that covalent bonds would be broken. There is a common confusion of intra- with inter-molecular bonding. A common loss of a mark was not comparing the strengths of the intermolecular forces.
1 e	There were many correct answers but candidates need to be aware that spelling mistakes in names are often forgiven whilst errors in formulae are not. It was common to omit the acid medium of dichromate(VI) ions.
1 f	Only good candidates were successful in this part; many could not predict the splitting pattern.
2 a	Many correctly framed their response in terms of differences in the degree of dissociation. Some who chose to discuss pH or conductivity did not state “for solutions of equal concentration”.
2 b	Candidates were tempted to repeat the question (just saying it is more convenient) but many gained the mark because pH is just simpler to use than dealing with a wide range of hydrogen ion concentrations to various powers of 10. “Easier for calculations” was not accepted.
2 c (i)	For a titration involving a weak acid and strong base, it is a mystery why candidates should not have turned automatically to phenolphthalein. Many candidates who did could not copy the spelling accurately. Nevertheless, 80% scored one mark.
2 c (ii)	90% calculated this correctly but …
2 c (iii)	… but only 50% could take their answer to (ii) and divide it by 2.
2 c (iv)	Fortunately, many did not see the relevance in using their answer to (iii) in this calculation and many could answer this successfully. The two common errors were to forget the factor of 40 and end up with 1.76% – and to work out the % purity assuming the compound to be anhydrous (50.4%). Sometimes a combination of both errors was seen (1.26%).
2 d	The answers to this were poor. Negative signs were missing or doubled (put both on the structure and outside the bracket). Candidates must draw these diagrams carefully, pairing the electrons and avoiding misleading marks on the paper. If in doubt, candidates should draw it again on an extra sheet (and say so in the answer box).

2 e	It was typical not to recognise that resonance led to an intermediate bond length with many giving 143 pm as the answer.
2 f	Many got the idea of a dative bond forming – but only very few realised the possibility of forming two such bonds.
3 a	(aq) was a common state, sometimes (g) and on occasions we saw H_2. Some forgot the state symbol altogether. 70% scored the mark.
3 b	Most recognised the problem with SO_2 but some seemed to think sulfur itself to be the problem. “Causing acid rain” or “environmental pollutant” were not accepted as answers in the context of the question.
3 c	There were some good answers to this although many missed the significance of the 2:1 ratio.
3 d	Despite a very simple plotting, some points were mis-plotted. Many did not recognise the significance of drawing the line through the origin and there were some free-hand lines. A ruler or straight edge is an essential piece of kit.
3 e (i)	Whilst it was usually recognised that the reaction was first order, “linear” was a common answer – which could also be zero order. It was important to talk about “proportionality” (preferable) or “linear increase”.
3 e (ii)	Unaccountably, even though (i) was correct, sodium thiosulfate was often omitted from the rate expression. Some candidates misread the question and give the answer “2” as the overall order.
3 f	The best answers used the best-fit line drawn. Some calculated a gradient using two points [1 max] and other took averages of times (concentration against time is non-linear) and scored zero.
3 g (i)	Most candidates could plot curves of appropriate shape although, in future examinations, we may need to pay more attention to the beginning and ending of the curves. Many did not realise that they needed to label the axes or omitted “kinetic” from the *x*-axis.
3 g (ii)	Students often only clearly identified one of the two factors (proportion with $E \geq E_a$ or increased collision rate), but students identifying the first of these often fortuitously gained the second mark by following this with phrases such as “hence there is a greater frequency of effective collisions”, even though collision frequency was not explicitly identified as a separate factor.

3 h	Answers included general statements about results being less accurate (a repeat of the question) rather than a shorter reaction time with a consequent larger percentage error in timing. Some chose cooling of reaction mixture during course of reaction (which was accepted).
4 a	Only 70% of the candidates gained the mark; some reversed atomic and mass numbers – and others found numbers of unknown provenance.
4 b	This was answered well but a disappointing number of candidates lost a mark by failing to note the required precision for the answer. 24.3 or 24.2 abounded.
4 c	Comparatively few candidates scored this mark. We would expect candidates to be aware of impurities in the chemicals used in schools by reading the labels on the bottles. Some recognised that there would be impurities but very few recognised the flame colour of sodium which, even if not specified in the guide, is a disappointing reflection on a candidate's chemical experience.
4 d (i)	The common omission was not to make clear that the energy levels are closer together (at higher frequency).
4 d (ii)	Only about 40% of the candidates scored this mark and they did not always give the name.
4 e	Many candidates did not read the question properly and went into auto-pilot writing an equation for the formation of magnesium oxide. Those that did attempt the correct equation often gave hydrogen as a product.
4 f	Some thought Al_2O_3 to be amphiprotic and SiO_2 to be amphoteric or neutral rather than (weakly) acidic.
4 g	This is a "suggest" question so is asking candidates to speculate about chemistry they might not have been taught. Many gave the "correct" answer, Mg_3N_2, but other answers were accepted provided they involved magnesium and other elements present in air. The formula had to be written correctly.
4 h	It was worrying to see many candidates describe the structure of magnesium oxide as covalent. "Ionic" does not earn the mark for a *description* of the bonding but it was pleasing to see "electrostatic attraction of oppositely charged ions" occur in many answers.
4 i (i)	This was poorly answered with equations producing ions or equations at the wrong electrode. Many did not remember that chlorine is bi-molecular and few spotted that the magnesium formed is in the liquid state.
4 i (ii)	Normally correct with a 90% success rate.

4 i (iii)	This was answered poorly with some writing equations again rather than stating the products. Some neither realised the significance of very **dilute** nor the aqueous component.
4 j	"Any two of three" saved many from losing a mark. The pressure of hydrogen was usually somewhat shaky. In general, the knowledge was disappointing.
4 k (i)	This was answered well although some reversed the equation.
4 k (ii)	Over half the answers were correct, but many looked up incorrect electrode potentials (Cu^+/Cu was common) or combined the electrode potentials incorrectly.
4 k (iii)	Some thought that the cell potentials do not vary. Many recognised that the cell potential would increase and some could explain this in terms of the equilibrium principle. One or two gave good explanations based on the Nernst equation.
5 a	This was a high-scoring question. The errors tended to occur in propene with incorrect distribution of bonds (and some chose to do pentane/pentene or even butane/butene).
5 b (i)	Some answers were good, some really poor. Without suitable annotations of the diagrams, this was not often successfully answered. Many relied on the examiner to decide what was meant.
5 b (ii)	Generally well done although if errors were to be made it was in the number of sigma bonds.
5 c (i)	Candidates found the equation more challenging than the necessity for UV light. One of the most common errors was to include hydrogen as a product. Some thought we were asking about the reaction of propane with HBr. Other errors included carelessness such as omitting HBr from the products and an incorrect number of H atoms.
5 c (ii)	This part had a 70% success rate and the loss of marks could usually be attributed to carelessness, such as the incorrect number of hydrogen atoms or writing bromine as Br.
5 c (iii)	Many students gained this mark by correctly identifying substitution and addition reactions. A number were fortunate that the mark was not deducted for incorrect adjectives.
5 d	There are very few mechanisms in the current guide and these must be learnt and understood. Typically, there was a lack of care about the start and end of

	curly arrows although this seemed to be better than in the past. In the first step of the mechanism, the curly arrow showing Br leaving was often missing. In other cases, the curly arrow from the double bond started from a carbon atom. The final mark was for the arrow to start at the negative sign or a lone pair on the Br^{-} (and go to C^{+}). It frequently started "somewhere on the B".
6 a	Marks were lost identifying the wrong isomer and for poor representations of the mirror image.
6 b	This was a difficult question that successfully challenged the top candidates. Few were aware that S_N2 would give (almost) 100% inversion, whereas S_N1 would give (approximately) 50%. Those that had some idea often attributed 75% to S_N2 and 25% to S_N1. It is not quite as simple as that! Many, however, scored the mark for suggesting that the reaction involves both mechanisms.
6 c	Differences in the reactivity of bromine and iodine led candidates in the wrong direction. Many answered correctly in terms of bond lengths or strength of bonds.
7 a	Many were able to calculate the pH correctly although some only scored the second mark by converting an incorrect [H+] to pH. The assumptions given were generally valid.
7 b (i)	The graphs, in general, were poor. They needed to be sketched with a clear vertical range at equivalence with pH > 7. The value of pK_a seemed to be left to the examiner's interpretation on occasions instead of being clearly annotated on the *y*-axis. Candidates must take care in their presentation.
7 b (ii)	Many candidates did not give an equation (with an equilibrium sign), as requested, so the explanation was not easy thereafter. Most were unable to give a truly acceptable explanation of how a buffer works in the context of the question.

Recommendations and guidance for the teaching of future candidates

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

There is no particular length to a question in 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.

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

- Only write in the box. Examiners cannot see what is written outside the box so it will not be marked. If you need more space, write on a continuation sheet and write “see continuation sheet” in the answer box.
- Write legibly. If an examiner cannot read your (correct) answer it will gain no marks. Draw diagrams carefully. If you make a mess of the first attempt, draw a new one on an extra page. Amended diagrams do not always scan very well.
- Do not write out the question. It wastes space in the answer box (and it wastes time!).
- Make sure you leave enough time for later marks. Remember that the questions (1, 2, 3 etc) may not be of uniform length.
- Read the question carefully to make sure that you answer it – and not what you would like the question to be.
- Make sure you are familiar with the Data Booklet well in advance of the examination. You will always be asked to use it and time saved there can be used to write answers.
- Draw Lewis structures very carefully and don’t leave extraneous dots/marks on the paper which can be mistaken for electrons. Don’t forget to include all non-bonding (lone) pairs and any charges.
- 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.
- Take notice of units, significant figures and decimal places.
- If you are asked to make a comparison or predict a difference, then you need to mention both compounds.
- Learn the shapes of s- and p-orbitals and how they form sigma and pi-bonds.
- You should be aware of the “list principle”. If you are, for instance, asked for one reason and you give two, one of which is correct and the other incorrect, you will score no marks.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 20	21 - 26	27 - 32	33 - 38	39 - 50

General comments

This generally seemed to be a fairly accessible paper that enabled even weaker candidates to produce respectable totals, though there were also a few more challenging questions. Some concerns were expressed that the paper did not provide a comprehensive coverage of the syllabus, but teachers should note that in reviewing this all of the compulsory sections (Paper 1, Paper 2 and Section A of Paper 3) need to be taken into consideration, not just one of these in isolation. Some teachers were also concerned that local regulations prevented them from carrying out certain reactions, such as those involving potassium dichromate(VI), but there are online videos of many reactions that can be used to offset such difficulties. Although one feedback form commented that more time would be helpful, there seemed to be little sign that students were short of time as the “no response” level of the last questions on the paper was not unusually high.

There were quite a lot of strong scripts where the candidates displayed an excellent knowledge of the subject, however there were an increasing worrying minority of scripts from new schools that seemed to indicate the students concerned had failed to grasp even the most basic chemical concepts. The more open-ended questions, introduced as part of the “nature of science” and environmental topics new to the syllabus, seemed to prove more challenging. Teachers should note that NoS content is now a compulsory part of the examination papers. In addition the setting of examination questions is only carried out in reference to the current subject guide and does not take into account how any material is covered in the various IB Chemistry textbooks.

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

- Deducing intermolecular forces in particular substances and explaining boiling point differences in terms of these
- Memorising oxidising reagents used in organic synthesis
- Analysing the results of titration calculations
- Resonance
- Writing balanced equations and making deductions from these
- Drawing accurate Maxwell-Boltzmann distribution curves at different temperatures
- Reactions of Group 1 & 2 metal oxides with water
- Describing the structure and bonding in simple metal compounds
- Electrode reactions for the electrolysis of molten electrolytes
- Writing balanced equations for the halogenation of an alkane

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

- Writing equilibrium constant expressions for a given equilibrium
- Predicting the effect of changing pressure on the position of equilibrium
- Calculating amount of substance from volume and concentration, and applying this to deducing the limiting reagent
- Recognising toxic hazards of sulfur dioxide

- Plotting data on a graph
- Calculating relative atomic mass from isotopic composition data
- Knowing the periodic trend in the acid-base character of oxides
- Drawing structural formulae of simple alkanes and alkenes
- Writing balanced equations for the halogenation of an alkene
- Recognising substitution and addition reactions

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

Question 1

Q1a(i) Most candidates deduced the equilibrium expression, though a few tried to calculate values for it, though the source of numerical data used was unclear.

Q1a(ii) Only a few candidates made a mistake in the shift in equilibrium position, but about half of the candidates forgot that pressure/concentration has no effect on the equilibrium constant value.

Q1a(iii) Whilst quite a lot of candidates produced the correct answer, there were a variety of different mistakes. Amongst those commonly encountered were forgetting the C-C bond in the product and reversing the reactants and products in calculating the final answer.

Q1a(iv) This was well answered with about equal numbers noticing the change in the state of the product and making generic comments about bond energies being average values.

Q1b Quite a lot of candidates correctly calculated the required oxidation states, with both producing approximately the same number of errors. What was encouraging was that very few candidates used incorrect formats (for example 2-).

Q1c This question was slightly more challenging. Whilst quite a few students correctly identified that the diol could form intermolecular hydrogen bonds, which are significantly stronger than the dispersion forces in ethene, a disappointingly large minority of students produced answers that indicated they believed boiling involved the breaking of covalent bonds.

Q1d Very few students correctly identified a reagent that can oxidise an alcohol to a carboxylic acid. Even if they did know a correct answer, many students tried to write down the formula of dichromate(VI) or manganate(VII) ions, or their potassium salts; these were usually incorrect. Another common mistake was forgetting that dichromate(VI) requires acidic conditions. Candidates should note that giving two answers, one correct and the other incorrect (for example “manganate(VII) ions and oxygen”) results in a mark of zero.

Question 2

Q2a Many students correctly framed their response in terms of differences in the degree of dissociation, but the sizeable minority who chose to discuss pH or conductivity failed to state “for solutions of equal concentration”, which is a critical condition.

Q2b A fairly open ended question in which about half the candidates gained the mark, usually by stating that "normal numbers" (pH values are not integers as many stated) over a limited range were easier to interpret. Students should note that stating that pH values are more convenient is simply repeating the information given in the question.

Q2c(i) One of the better answered questions on the paper, showing most students know how to combine concentration and volume to find the amount.

Q2c(ii) In spite of having correctly answered the previous part and having been given the required equation, many candidates tried to calculate the amount from the mass of impure acid used in preparing the solution, assuming it was pure, in spite of the fact that the next part of the question asks them to calculate the purity!

Q2c(iii) About 20% of students found the correct value. Common mistakes were miscalculation of the molar mass, or using that of the anhydrous acid, and forgetting the factor of 40 resulting from taking a 25 cm^3 sample from a litre of solution.

Q2d Only a few students gained any credit for this question, usually framing their answers in terms of resonance structures. Almost all students who gained this first mark also gained the second by suggesting a bond length between that of a single and double bond.

Question 3

Q3a A very simple question that was poorly done. Even when they correctly identified X as water, many lost the mark by forgetting to give the state symbol.

Q3b Generally well done with many students being aware of the possible health effects of sulfur dioxide, though a significant minority seemed to believe sulfur itself posed similar problems.

Q3c This was surprisingly well done with most students calculating the amounts of the two reagents and usually going on to use the mole ratio to confirm that HCl was in excess, with many giving the amount in excess, even though this was not required.

Q3d Almost every candidate scored the first mark for correctly plotting the points, but many squandered the second mark by failing to use a ruler to draw the best fit line or ensuring that this went through the origin.

Q3e Most students managed to use the graph to correctly determine the rate, but in some cases they forgot that this was the reciprocal of time rather than the time itself (neglecting the factor of 10^3). Others found correct values of the rate by using the gradient of the line. One common mistake was averaging the time for 0.03 & 0.09 mol dm^{-3} solutions to obtain a value of 48 s, ignoring the fact that a graph of concentration -v- time is non-linear.

Q3f(i) The criteria for the shapes of the graphs were very generous so, in spite of the fact that many did not start at the origin, were not asymptotic to the x-axis and did not have even approximately equal areas, most students gained this mark, though occasionally T_1 and T_2 were interchanged. Labelling the axes proved more of a challenge with many students forgetting to do this and others writing "Energy" rather than "Kinetic Energy" for the x-axis.

Q3f(ii) Students often only clearly identified one of the two factors (proportion with $E \geq E_a$ and increased collision rate), but students identifying the first of these often fortuitously gained the second mark through phrases such as *“hence there is a greater frequency of effective collisions”*, even though collision frequency was not explicitly identified as a separate factor.

Q3g Just under half the candidates correctly recognised problems with heat loss/temperature control, or accurately noting the end of the reaction/reaction time.

Question 4

Q4a About half the students gave the correct answer, whilst most of the others had the subscript and superscript interchanged.

Q4b Very well done, though a disappointing number of students lost a mark by failing to note the required precision for the answer.

Q4c One can speculate on whether candidates did not read the second sentence, or did not believe they had been asked to do something so simple, but less than half produced a correct equation.

Q4d The trend from basic to acidic was generally well known, though awarding the second mark was less common as many did not point out the amphoteric nature of aluminium oxide and a few still confuse amphoteric (ability to dissolve in both acids and bases) with amphiprotic (ability to both donate and accept hydrogen ions).

Q4e Only a handful of candidates gave the correct answer (Mg_3N_2) but many more gained the mark by suggesting compounds ($Mg(OH)_2$, $Mg(NO_x)_2$, $MgCO_3$) that indicated some valid chemical logic had been applied to the question.

Q4f Over half of the students gave the bonding as ionic (it is however disappointing that so many predicted covalent bonding for a simple binary metal compound), but the question asked them to describe the bonding (a lattice held by electrostatic attractions between anions and cations), not just to identify the type of bond, and many failed to note this.

Q4g This was very poorly answered even without taking account the requirement for correct state symbols (the electrolyte temperature must be above the melting point of magnesium). Frequent errors were reversing the anode and cathode reactions and/or the reactants and products, though students also regularly placed electrons on the wrong side and forgot chlorine is bimolecular.

Question 5

Q5a Another question that was very well answered. Almost everyone drew a correct structure for the alkane, but the alkene produced a few more mistakes.

Q5b(i) About a quarter of the students gained full marks on this, with the equation proving more challenging than the necessity of UV light. One of the most common mistakes was including hydrogen as a product.

Q5b(ii) About two thirds of the students wrote a correct equation for the reaction of propene with bromine.

Q5c Many students gained this mark, though a few gave answers for one of the two reactions, such as bromination or halogenation, that could be applied to both. Many would have lost the mark if incorrect adjectives had been penalised ("nucleophilic substitution" for example was allowed as "substitution").

Recommendations and guidance for the teaching of future candidates

- Training candidates to read the question carefully with regard to what exactly it is asking, the command term used (and the implications of this, taking into account the number of marks available) as well as any specification of the units or precision of the answer.
- Practicing writing answers to questions frequently asked so as to avoid making mistakes that have previously been problems, particularly with regard to the precise use of language.
- Preparing students for the more open-ended "nature of science" and environmental questions.
- Setting a variety of more demanding and "non-standard" stoichiometric and thermochemical calculations, plus routine work on the basics such as writing correct formulae, balanced equations and isotope notation.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 13	14 - 17	18 - 22	23 - 26	27 - 31	32 - 45

General comments

This examination paper proved to be highly interesting at a number of levels. Based on the 22 G2 comments received the majority of teachers found the paper to be of an appropriate standard (86%) in terms of level of difficulty, though 14% were of the opinion that the paper was too difficult. 34% thought the paper to be of a similar standard to N15, but 41% found it to be marginally more difficult, which was telling (the remainder found it to be considerably more difficult). It would have been more informative perhaps if teachers were asked to compare this paper with the M16 paper as this would have provided more comparative statistical data, as M16 was the first session which involved assessment of the new Chemistry curriculum. Some teachers in fact carried out this comparison from a qualitative perspective and stated that the paper was largely of a similar standard to M16, though with a definite smattering of considerably challenging questions. Based on feedback from examiners although some stated that the paper was fair, of a similar standard to previous papers, a significant number did articulate also that the paper may have been slightly more challenging than the M16 paper. This was also mirrored by some of the more specific G2 comments received from teachers. Some of the comments included: “generally a suitably challenging paper”, “a fairly accessible paper with a few weird questions”, “NOS and international mindedness were good", "good syllabus coverage in Option D, which allowed the very best students to shine, but would be most challenging for the average student. Good progression of ideas within a question”, “some challenging parts on writing nuclear equations involving neutron capture which favours those who take Physics” etc.

Overall it did appear that the paper was largely accessible with Questions 1 and 2 in Section A considered to be good entry level questions assessing the new syllabus. This was reflected in a solid performance by the candidature in Question 1. However, performance on the experimental based question, Question 2, was deemed by the majority of examiners to be of a very poor standard and not what one would expect from Chemistry HL candidates for a question based on a routine chemistry experiment in the laboratory. One teacher commented on Question 2 – “The experimental coursework tested was gravimetric analysis which is straightforward, though the assumptions of the experiment may be challenging for some of the students”. General consensus amongst the senior examination team was that the poor performance in Question 2 by many candidates may in part be correlated to a lack of exposure to a comprehensive experimental programme which is the engine room of any rigorous chemistry curriculum. This may also mirror the poorer performance in the IA in N16.

In Section B, Option A in this session was found to be slightly more difficult than some of the other options and was compounded perhaps by assessment of some of the newer sub-topics on the programme, which candidates were not prepared for. This was also noted previously in the subject report on P3 in M16. The most popular option was D, followed by B, C and then A. Approximately 50% of candidates chose Option D. The general feeling amongst the examination team was that overall performance appeared to be down especially at the upper end with performance amongst top tier Grade 7 candidates noticeably weaker this session. Many candidates were not prepared for questions of an experimental nature, failed to tackle NOS type questions and often struggled on questions which involved integration of core chemical concepts with the more applied topics across the options. This was often most evident in Option D on Medicinal chemistry. In addition, for many candidates misreading of many questions did appear to be an issue on this particular paper and greater understanding and emphasis on command terms needs perhaps to be focused on. Questions which particularly highlight these points include Questions 2(b), 7, 9(b), 11(b)(iv), 27(a) and 27(b).

As regards the clarity of wording on the paper, the following were the statistics: excellent – 14%, very good - 46%, good - 14%, fair – 9%, poor - 18% (possibly because of the functional groups questions). The corresponding data for the overall presentation of the paper was: excellent – 27%, very good - 36%, good - 27%, fair – 9%, poor - 0%.

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

- Many candidates really struggled with the questions based on experimental work, which was a real surprise at HL and strongly suggests that many may not have been fully exposed to a comprehensive laboratory programme, which is an essential feature of the new Chemistry curriculum. This was particular evident in Question 2 in Section A. Many candidates failed to simply understand the nature of many of the laboratory-based questions in Question 2 and it appears that a high percentage of candidates may not have been previously challenged in the programme with such experimental based questions.
- Many of the weaker candidates (and even some of the better candidates) also struggled with NOS-based questions, again a key characteristic of the new curriculum.
- One of the features of the new P3 is the integration of core concepts with applied material. Some candidates struggled with fundamental chemical concepts on this paper – in particular functional groups, chromatography, the idea of a repeating unit and stoichiometry.
- Candidates often had difficulty understanding the various command terms in questions. In addition, questions where two things had to be contrasted proved highly challenging.
- In Option A – Materials, the following were poorly understood: zeolites, the HIPCO process, nanocatalysts, the Bragg equation, superconductors, the Fenton and Haber-Weiss reaction mechanisms.
- In Option B – Biochemistry, difference between functional groups and classes, drawing a repeating unit, applying IUPAC rules for the systematic nomenclature of amino acids were the most problematic.
- In Option C – Energy, the following sub-topics were found to be challenging – biofuels, the microbial fuel cell and DSSCs.
- In Option D – Medicinal chemistry, functional groups, explanation why cold water is needed in the aspirin synthesis and gas chromatography proved to be the most problematic sub-topics.

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

- Many of the candidates performed well on Question 1, the data-based question in Section A.
- Candidates managed to solve the majority of the mathematical based questions throughout the paper with a high degree of proficiency.
- In Option A, electrolysis was very well done. Candidates were well prepared for the numerical-based problems in Option A.
- In Option B candidates performed strongly throughout and had a good understanding of lipids, amino acids, gel electrophoresis, carbohydrates and colour associated with anthocyanins. Most candidates also did reasonably well on the buffer question (though only the better candidates scored full marks).
- In Option C, any question involving a simple calculation was well answered. Concepts related to specific energy were also well answered.
- In Option D, candidates appeared to be well prepared for topics such as ring strain,

antibiotics, experimental yield and radioisotopes.

Overall candidates performed better on questions related to factual information and simple numerical calculations but had greater difficulty with questions where an application or interpretation or NOS was involved, not to mention any question based on experimental work.

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

Section A

Candidates performed well in general on Question 1 but many had great difficulty with the experimental-based question, Question 2. SL candidates perform comparatively better than HL candidates (considering their overall time allocation for the IA and the overall performance).

Question 1

One teacher commented that the first question on the paper appeared to be designed to catch out students. Candidates did reasonably on this question and most found it fairly accessible as an entry level question. Deduction of the two oxidation states of chlorine in HOCl and Cl_2 was very well answered. A minority of candidates gave incorrect notation such as writing charges i.e. 1+ and 4+ instead of +1 and +4. Some used oxidation number notation instead of oxidation state notation, e.g. I and IV. This was not penalized but technically IUPAC does distinguish between the two terms. Many scored full marks for (a) (i), (ii) and (iii) but a large majority failed to convert g to mg in (iii). In (b), correct sketches of the graph of CT versus pH were usually seen, though a common error involved candidates putting pH on the *y*-axis instead of on the *x*-axis. Few gave the 3 times ratio in (b) (iii) i.e. the fact that the values at pH 9.0 are 2.9 times the values at pH = 6.0. Predicting how the concentrations of HOCl and OCl^- change with an increase in the pH of the disinfected water proved very problematic in (iv). There were some G2 comments on part (c). One teacher stated that it was unclear as to which part of the syllabus the question assessed, and another asked whether a range of answers would be accepted. Part (c), which had an international mindedness focus was very well answered and most candidates referred to plastic pollution to score the mark. A wide range of additional answers were accepted such as “plastic bottles use up petroleum/non-renewable raw material”, “chemicals in plastic bottles can contaminate water”, “prolonged storage in plastic bottles can cause contamination of water”, “plastic water bottles are sometimes reused without proper hygiene considerations”, economic considerations such as “greater production/transport costs” etc.

Question 2

This question was overall very poorly answered and shows that many candidates are not being exposed to a solid experimental programme which is an integral part of the new IB Chemistry curriculum. In part (a), the idea of heating to constant mass was beyond most candidates and few could even state that step 5 had to be repeated which one would have thought would have been a very easy mark to gain. In (b) surprisingly there were a significant number of HL candidates who had no idea that the soot came from the incomplete combustion of the gas and who referred to the crucible burning or charring, or CO_2 from the air reacting with the flame, though better candidates did mention soot or incomplete combustion to score M1. An incredibly large number of candidates did not state explicitly that the value of **x** will be lower for M2, failing to read the question! Again in (c) the stronger candidates scored full marks though many candidates did gain at least one mark for stating that there are no impurities in the hydrated salt.

Section B

Option A – Materials

Few candidates attempted this option and performance in general of those that did attempt it was poor. However there was evidence of some good skills at handling electrolysis calculations. On balance it looked like a more challenging option, with harder questions than some of the other Options. There were a number of new type sub-topics thrown in the mix which candidates did not appear to be prepared for. Interestingly some of these sub-topics were flagged explicitly in the subject report for M16.

Question 3

Both parts were well answered in relation to bonding.

Question 4

Candidates made a good attempt at this question and the calculations in parts (a), (b) and (c) in particular were well executed. Fewer candidates were able to obtain the 3.01 mol e^- in part (d) and few were able to deduce the charge on the indium ion and the formula of indium sulfate in part (e). A common error was to write +3 (which is oxidation state notation) instead of 3+ for charge.

Question 5

Part (a) referred to the excellent selectivity of zeolites as catalysts. The question was marginally better answered than a similar question on zeolites in M16, but few still scored full marks. Most had an idea about the cage-like structures of zeolites but few then went on to state that only reactants with the appropriate geometry fit inside these cavities. As in M16, (b) (i) on the HIPCO method for the production of carbon nanotubes was really very poorly understood. Surprisingly, even part (ii) proved problematic, a question which asked for one benefit of using nanocatalysts compared to traditional catalysts in industry. One would have thought that coming up with the greater selectivity of nanocatalysts due to their pore size would have been a common and logical answer. This was not the case.

Question 6

As in Option B, candidates struggled with what was asked for specifically, namely a repeating unit in part (a). Polymeric representations were sometimes given and some candidates failed to include the continuation bonds even when trying to write the repeating unit per se. A minority were able to deduce the 100% percentage atom economy for the polymerization of 2-methylpropene. (c) (i) was beyond most candidates where they had to suggest why incomplete combustion of plastic is common in industrial and house fires. Part (ii) also proved to be too challenging for candidates. (d) (i) was well answered and candidates were able to draw the molecular structures of the propane-1,3-diol and benzene-1,4-dicarboxylic acid monomers. In (ii), candidates were asked to deduce the name of the linkage formed on polymerization between the two monomers and to name the inorganic product. Most got the ester linkage but some gave the formula for water and not its name. Candidates need to learn in particular how to spell ester, as writing “esther” could be interpreted as the hedging of one’s bets between an ester and an ether!

Question 7

This question focused on lyotropic and thermotropic liquid crystals, a topic previously asked. The question however involved candidates outlining the specific difference between the two types and hence no credit was awarded when only one type of LC was described. Few scored both marks.

Question 8

This question assessed aspects of X-ray diffraction. Parts (i) and (ii) of (a) on the Bragg equation were poorly answered. The calculations in part (b) were better answered but even then few candidates were able to deduce the correct number of chromium atoms per unit cell, namely 2.

Question 9

The Meissner effect was well articulated in (a). Few were able to outline a difference between type 1 and type 2 superconductors.

Question 10

As in M16, knowledge of the Fenton and Haber-Weiss reaction mechanisms was virtually zero! Candidates also struggled describing the process of adsorption in (b) (i). The structure of the complex ion was correctly drawn by the better candidates in (b) (ii).

Option B – Biochemistry

This was the second most popular option and candidates conveyed a good solid knowledge of biochemistry. In several of the questions, performance was strong.

Question 11

Similar to Option A, in (a) one of the main problems was that candidates did not read the question – names were asked for. Another incorrect answer commonly seen was “glycosidic link” instead of “ester link”. In (b) (i) and (ii) both marks were usually scored. In (iii) candidates had to actually calculate the P/S index of beef fat and soybean oil and hence a ratio did not score. In (iv) although many candidates were able to link the P/S index of greater than 1 to the higher proportion of polyunsaturated fatty acids, a significant majority did not link this aspect to a health consideration i.e. the fact they reduce the risk of cardiovascular disease. In (b) (v) one out of two was the most common score, usually for candidates stating that molecules of cotton seed oil have greater surface area or are more closely packed. There were few references to chain length.

Question 12

In (a), most candidates were able to state the raw materials involved i.e. namely carbon dioxide, water and the sun. In (b) (i), candidates had to justify why both molecules are carbohydrates. Many stated "because both have the formula $C_x(H_2O)_y$" which scored the mark. Others simply stated that because the molecules contain carbon, oxygen and hydrogen which scored zero. Another error involved writing hydroxide instead of hydroxyl. In (ii), candidates had to distinguish the two molecules in terms of their functional groups. One G2 comment stated the following "Whoever wrote this question has not paid close enough attention to the new syllabus and the difference between functional group and class. Both molecules have a carbonyl functional group, one is an aldehyde and the other is a ketone, but these are classes of groups and not functional groups". It should be noted that by careful reading of the question no names were in fact required here so if a candidate wrote that X contains CHO and Y contains RCOR', then the mark would have been gained. In (c) (i), lots of errors were evident e.g. writing polymeric structures instead of the repeating unit, failing to include continuation bonds, drawing continuation bonds with oxygen on both ends, missing hydrogens and incorrect bond connectivities. In (c) (ii) most candidates scored at least one mark for an advantage (e.g. biodegradable nature), but only the better candidates gave a disadvantage of using starch, which was surprising.

Question 13

The wording of the question was "State the IUPAC name for leucine". One G2 comment stated that leucine is in fact the IUPAC name for the chemical with CAS number 61-90-5, whereas the systematic name is in fact 2-amino-4-methylpentanoic acid. This comment is valid to a degree, as technically there is no such thing as a formal IUPAC name, but rather IUPAC is a naming system whereby IUPAC rules are applied to systematically name a compound. It would have been more precise if the question was written as "Apply IUPAC rules to give the systematic name for leucine", which is closer to the wording of the guide, in line with this distinction. Few candidates could write the systematic name applying IUPAC rules for the trivial name, leucine. Common errors included writing 2-methyl instead of 4-methyl, writing amine instead of amino and writing pentan-1-oic acid instead of pentanoic acid. In the question on gel electrophoresis, several candidates had the net direction of the spots reversed and several had the spots in the correct order but not in a linear format. (b) (ii) proved challenging and few stated the fact that glycine and isoleucine have different molar masses so move with different velocities. In (c), most candidates scored two out of the three allocated marks. The last mark proved troublesome and the most common error involved giving the percentage of carboxyl ionized as 10% instead of 9.1% i.e. the factor 1/10 was used instead of 1/11. This proved to be a good discriminating question.

Question 14

In part (a) (i), most candidates were able to estimate the K_m values of the two enzymes. In (ii) precise answers were rarely conveyed i.e. glucokinase as it is not saturated with the substrate at normal concentration of blood glucose. Many stated incorrectly that the enzyme in question was hexokinase. In (b) (i) while many knew what product inhibition meant very few specifically referred to glucose-6-phosphate. In (ii), the allosteric binding site was well known though some thought incorrectly that this was the active site.

Question 15

In (a) the majority were able to state that the phosphate group is the name of the component of DNA responsible for the migration of its fragments to the positive electrode in gel electrophoresis. (b) proved to be a real challenge even for the better students. Candidates could have scored the mark here by expressing the answer in several different ways e.g. for stating a technique such as X-ray crystallography etc., for stating that the bacteria is able to grow in the absence of phosphorus or even for stating reproducible data. There were a number of G2 comments on this NOS question, where teachers felt that it was not clear what was expected. This was discussed at length during the grade award meeting and it was agreed unanimously that this NOS based question was totally reasonable. Many candidates still do not appear to be fully prepared to use basic critical thinking skills in the application of NOS style questions and clearly need to be challenged to a greater extent in this area. Practice on past questions from the specimen and M16 examination papers might be the first port of call to enhance these skills or exploring further NOS based questions often found in the wide range of textbooks now available on the market written specifically for the new IB Chemistry programme or enhancement of NOS style active learning in the classroom on a day to day basis.

Question 16

Part (a) was well done and most mentioned either conjugation or delocalization of electrons. (b) was also very well answered. In (c), the better candidates scored full marks. Some of the weaker candidates misunderstood the difference between the colour absorbed and the complementary colour.

Option C – Energy

This was the third most popular option on this paper and it was encouraging to see candidates choose this new option on energy, though it may take another few sessions for more candidates to opt for it. Performance was satisfactory in certain topics of this option, in particular specific energy, cell potentials and fusion. However knowledge of some of the newer sub-topics such as the microbial fuel cell and DSSCs was sketchy, a trend also seen in M16.

Question 17

All of parts (a) and (b) were well done on balance. Some candidates had difficulty converting J to MJ however. In (b) (ii) the factor 4 was often omitted. Other mistakes included candidates simply multiplying 32.0 km by 4 to give 128.0 km, namely failing to consider units, as 32.0 has units of km dm^{-3}, and therefore to determine the distance 4.61×10^{-1} dm^3 had to be multiplied by 128.0 km dm^{-3} to give a final answer of 59.0 km.

Question 18

In (a) candidates usually tended to know that the octane number tends to increase with more branched alkanes. Fewer candidates seemed to know that with longer alkanes the octane number tends to decrease. In (b) the better candidates were able to deduce the equation for the conversion of heptane to methylbenzene. Some gave an incorrect formula for heptane (hexane or octane were often incorrectly written!). The hydrogens frequently were not correctly balanced and hydrogen rarely was given as a product.

Question 19

This question was similar to that asked in M16 and candidates were much better prepared for this question in November. The majority linked increasing concentration of atmospheric carbon dioxide to increased acidity, so scored at least one mark. Many were able to support this by outlining the processes involved. 19 (b) required candidates to describe the changes that occur at the molecular level when atmospheric carbon dioxide absorbs infrared radiation emitted from the Earth's surface. The majority mentioned the asymmetric stretching of bonds or the fact that the OCO bond angle changes. Some gave very nice well annotated diagrams describing the various modes of vibration and correlated these to the presence or not of a net dipole moment i.e. the fact that a dipole moment is generated by an asymmetric mode of vibration in carbon dioxide. Virtually no candidate gave the technically more correct answer i.e. the fact that the photon is re-emitted in a random direction.

Question 20

The question on biofuels proved to be a challenging question for candidates. Only the top tier candidates were able to state the equation for the complete transesterification of the triglyceride with methanol. Sight of the correct formula for glycerol was rare (a surprise at HL!) and correct balancing was often ignored. A few candidates managed to get almost the correct products but drew a structural formula for glucose and connected the Hs and not the Cs.

Question 21

The half-equations for the reactions taking place at both electrodes for the microbial fuel cell proved to be extremely challenging for all candidates, even though this is a new topic on the syllabus and one would have thought that candidates would have been better prepared on foot of comments made in the M16 subject report on fuel cells. In (b) (i), a lot of guess work was invoked by candidates for the difference between a concentration cell and a standard voltaic cell. The Nernst equation in (b) (ii) was very well done though some candidates did not express the cell potential to three significant figures as instructed to do so in the question. In (b) (iii), although many stated that the reaction in (b) (ii) was more spontaneous, some did not give a reason i.e. the fact that $E > E^{\ominus}_{cell}$. As in M16, knowledge of DSSCs was again very sparse, especially in relation to the role of the electrolyte solution containing iodide and triiodide ions.

Question 22

In (a) (i) many candidates scored at least one mark for stating that the product has higher binding energy per nucleon. M2 was only sometimes scored and usually as an accept statement for stating that the mass is converted to energy. More precise answers such as the fact that lighter elements than Fe can fuse with a loss of mass and release vast amounts of energy were rare. The most common correct answer in (a) (ii) was for stating that the helium products are not radioactive. In (b) the calculations involving the decay constant were very well done, though some candidates did not include the correct units, day-1 in (i) for the ^{31}P decay constant, λ. In (c) (i), most candidates stated that the molecular shape of uranium hexafluoride is octahedral. A small minority stated square bipyramidal. This is technically incorrect as a square bipyramidal stereochemistry involves two elongated bonds, which is not the case for uranium hexafluoride. This was accepted however, but no mark was awarded for candidates stating square pyramidal which has a coordination number of five. It was highly surprising at HL that so many candidates could not answer (c) (ii). Many incorrectly stated that UO_2 is covalent/molecular.

Option D – Medicinal chemistry

This was the most popular option. Overall performance was satisfactory on this option though there were a few challenging questions e.g. the NOS-based question, Question 29 (a). As 50% of the candidature this session chose Option D, there were as expected several G2 comments on this Option. Most teachers stated the fact that this Option is now far more difficult than in the previous syllabus, where the questions were highly predictable. Some of the G2 comments included “Option D questions seemed significantly more difficult than previous sessions in general”, “Medicinal chemistry seems more difficult with the new syllabus, with a much more medical orientation. It seems like the test was prepared by someone with a high degree of medical background. Gone are the days when candidates were asked about the story of the discovery of penicillin”, “I am seriously debating with myself whether I should keep on teaching this option or go to Energy which seemed much more straight forward. I do not like the medical emphasis to this Option on the new syllabus”. It should be noted here that one of the criticisms of the previous syllabus from feedback gained from various stakeholders was that the previous Option D syllabus highly favoured candidates with a biology background, was too predictable in nature in terms of the range of examination questions asked, had a narrow series of sub-topics within the syllabus and lacked proper integration with core chemical concepts, as opposed to biological concepts. Many of these concerns have been addressed in the new curriculum for Option D and it is important that candidates are prepared in particular for the more chemistry-based focus of the Option, which links core chemistry with a number of the applied areas of Medicinal chemistry. This spirit of the new syllabus for this Option was very much captured in the questions posed to candidates in N16.

Question 23

Most candidates did reasonably well on this question. Part (a) (i) was well answered though some candidates simply stated that the four-membered ring had 90^o bond angles instead of stating that the bond angles are 90^o instead of 109.5^o or 120^o. In part (ii) most candidates had little difficulty identifying the three carbon atoms in the four-membered ring. Some incorrectly included the nitrogen atom. It should be noted that the five-membered ring also is slightly strained but it was the business end of the penicillin molecule that was required, i.e. namely the three beta-lactam ring carbon atoms. In part (b) some good answers were given to part (i), but some candidates thought that clavulanic acid in fact reacts with penicillin to produce a more potent antibiotic which is not attacked by the enzyme. Another common error involved candidates stating that the R group/side-chain of penicillin changes. The majority of candidates scored full marks in part (ii).

Question 24

Part (a) was very well answered and the majority of candidates stated the fact that since zanamivir is taken orally, its bioavailability is low. In part (b), candidates had to deduce the name of the functional group in oseltamivir which changes into a carboxyl group in the body. Writing either ethoxycarbonyl, a carbonyl group attached to oxygen or even ester would have scored the mark. A number of incorrect answers were given which included the ether group, the amino group or the amido group. An answer of carbonyl alone did not score however as the drug contains in fact two carbonyl groups, so a more precise answer was required. In many cases here it looked like candidates were hedging their bets by choosing one of the functional groups in oseltamivir, without really knowing the precise chemistry involved.

Question 25

Part (a) was very well answered and most candidates were able to determine the correct percentage experimental yield of the product aspirin after recrystallization. In (b), only the better candidates correctly linked low temperature with the ability of aspirin to crystallize out of solution. This was surprising as one would have thought that this would be well known if a candidate had been exposed to at least some organic syntheses as part of a comprehensive experimental programme in the laboratory. The standard of response given in (c) however was much better and often both marks were scored for the two differences between the melting point data of the crude and recrystallized products.

Question 26

The question on why the development of ranitidine was based on a detailed knowledge of the structure of histamine proved to be a good discriminator at the upper end of the candidature, though there were some G2 comments on this question where some teachers felt that this question was either too challenging or was at the margins of the syllabus or that candidates with a biology background would have been at an advantage. Confusion of terminology and lack of articulacy often meant the one mark was not scored even though candidates frequently had some idea of what was involved i.e. the fact that ranitidine inhibits histamine binding to the H2 receptors. Some candidates thought incorrectly that ranitidine and histamine react together. In (b), most stated proton pump as the site of action. A few mentioned just stomach or intestine which did not score. Incorrect terminology such as protein pump also was penalized in this question as it showed weak chemical understanding. The role of a chiral auxiliary in the synthesis of esomeprazole in (c) was very well executed by the majority and a high proportion of candidates gained both marks here. This question was done much better than in previous sessions and this was encouraging to see as the lack of understanding of a chiral auxiliary was flagged in previous subject reports.

Question 27

In (a) what threw many candidates was the command term “compare and contrast”. For example many candidates stated that diamorphine has two ethanoate groups but did not contrast this to morphine which has none. For the similarity, common mistakes included writing the phenol group instead of the phenyl group and writing benzene or arene instead of a benzene ring. An arene in fact is an aromatic hydrocarbon and neither methadone nor diamorphine are arenes. In addition benzene is C_6H_6, so is not a functional group. It should be noted also that there are no phenyl groups in diamorphine as phenyl is $–C_6H_5$. This was not duly penalized but writing phenyl is technically incorrect in this context. Equally the question asked for functional group names and not the class. Hence candidates should not be stating that methadone contains a ketone. For the difference, candidates had many choices in terms of citing the functional group differences between the two drugs. A wide range of answers was accepted, although some were not technically chemically precise e.g. alkenyl was accepted for diamorphine even though in diamorphine the >C=C< group is a divalent substituent whereas the alkenyl group is technically a monovalent substituent (such as $–CH=CH_2$, $–CH_2CH=CH_2$, etc.) i.e. the fragment, containing an open point of attachment on a carbon atom, that would form if a hydrogen atom bonded to a doubly bonded carbon is removed from the molecule of an alkene; alkene is the class and is not a functional group etc. In (b) outlining one withdrawal symptom that an addict may experience proved no problem for the majority of candidates. Here candidates had to focus on the nature of the command term (in this case outline as opposed to list). Hence a candidate ideally should have written an answer of “experience fever” for example instead of simply listing the symptom i.e. “fever”. Candidates were not duly penalized for this but it is a point of note for teachers when preparing candidates for future examinations.

Question 28

In (a) the most common error involved candidates inverting the mass number, *A*, and the atomic number, *Z*, for the nuclear symbol, ${}^{A}_{Z}X$. Use of incorrect notation for the sub-particles involved or the radiation emitted also was also common. Many candidates wrote N instead of n for a neutron in (a) (i). Few candidates had the idea of decay of technetium-99m during transportation in (b). In (c) most candidates stated that other than half-life one of the reasons why technetium-99m is so useful in medical diagnosis is the fact that it emits gamma radiation or has a low radiation dose. The idea that the transition metal is versatile with a wide range of oxidation states and so can bond to a range of biologically active substances was rarely conveyed. In (d) low-level radiation was stated by most.

Question 29

Part (a) proved to be a minefield for virtually every single candidate and candidates clearly need infinitely greater exposure in the delivery of the programme at the coal-face to NOS style questions. Many simply misunderstood the question entirely and referred to the increased potency of newly-discovered drugs. Surprisingly for HL candidates the principles of gas chromatography were poorly understood. In (b) (ii) many scored full marks however though a minority confused the idea of molecular ion peak with base peak, which relates to the peak of greatest intensity in a mass spectrum.

Recommendations and guidance for the teaching of future candidates

Legible handwriting should be encouraged – there was strong evidence of a noticeable number of scripts this session where examiners struggled greatly in trying to decipher what was in the responses.

It is critical that core chemical principles are brought to the fore in the Options, especially those which have often a twin biological focus e.g. Biochemistry and Medicinal chemistry. Core chemistry should always underpin applied topics. This is a major feature of the new curriculum.

Candidates should always look at the associated marks allocations in questions. Candidates should not have to use extra continuation sheets if they tailor their answers to the space provided. This session far too many candidates wrote lengthy answers and used extra continuation sheets which were simply not required.

Candidates struggle with questions that require explanations or multiple steps. Candidates need to fully understand the various command terms and teachers should take time to review command terms throughout the two years with candidates to make sure they understand how to answer questions. This was certainly a feature of this session.

Candidates should prepare for the examination by working through past examination questions of the new syllabus (as they come on stream) and carefully studying the markschemes provided.

It is imperative that laboratory work lies at the heart of the IB chemistry programme. Ideally candidates should be exposed to a rich experimental experience in the laboratory where suitable facilities are available. Where this is not the case other resources such as simulated experiments should be sourced. If an analytical technique is required by the option taken and students are required to know the steps then it should be performed in class or by simulation.

Candidates should get ample practice at writing balanced equations.

Many candidates still use class names instead of functional group names. Distinction between the two is a feature of the new syllabus.

The inherent difference between a repeating unit and a polymer should be stressed.

Bond connectivity should be emphasized.

Note that according to IUPAC van der Waals forces are the attractive or repulsive forces between molecular entities (or between groups within the same molecular entity) other than those due to bond formation or to the electrostatic interaction of ions or of ionic groups with one another or with neutral molecules. The term includes: dipole–dipole, dipole-induced dipole and London (instantaneous induced dipole-induced dipole) forces.

Candidates should understand the difference between benzene, benzene ring, arene, phenol and phenyl.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 8	9 - 11	12 - 15	16 - 18	19 - 22	23 - 35

General comments

Students were generally well prepared to answer questions in all options reflecting better preparation for paper 3 than in past sessions. This was probably facilitated by the reduction of the number of options to one in the new syllabus.

Nevertheless, there was a mix of performance levels this session. While there was a good proportion of well-prepared candidates, we also saw a large increase in the numbers of retake candidates and candidates from new schools who generally performed poorly bringing the average grade lower than last November.

Options B and D were the most popular: answered by 38% of candidates each (B was more popular in the Spanish scripts and option D was more popular in the English scripts). Option C was answered by 18% of the candidates and Option A was answered by only 6% of the candidates.

In Section A, many candidates showed good data analysis and communication skills when answering Question 1. They were often able to analyse and deduce relationships from data and sketch reasonable graphs illustrating trends. However, the analysis was not always detailed enough and many candidates were satisfied with identifying an increase or decrease without looking for more detail such as a constant ratio or a constant increase. For example, we saw more straight-line graph sketches of CT value against pH in Question 1(b)(ii) than curves of increasing gradient (which is clearly obvious from a close inspection of the data).

The experimental question was mostly poorly answered (although comparatively better than at HL). It is clear that a large proportion of candidates need to spend more time in the lab using standard apparatus and analyzing data during the course. This would avoid errors such as thinking that the crucible burned when it turned black on the outside in part (b) of question 2 (as mentioned by a considerable number of candidates), and it would give students the practical experience needed to recognize soot formation due to the incomplete combustion of Bunsen burner gas for example.

As expected, candidates performed better in stating and explaining familiar concepts and conducting familiar calculations, but they struggled more when presented with novel situations. A good example was the role of clavulanic acid in Question 16(b)(i) where only the stronger candidates deduced that its beta-lactam ring reacted with beta-lactamase leaving penicillin's beta-lactam ring intact. Many candidates said clavulanic acid altered penicillin's side-chain showing a lack of understanding.

Feedback from teachers (28 responses) was that it was a fair and approachable paper that was quite demanding. Teachers welcomed the data analysis required by Question 1, although they felt that some candidates would find it challenging.

68% of respondents found the paper of appropriate difficulty while 32% found it too difficult. When comparing with last year's paper 25% found it of a similar standard, 36% found it a little more difficult, 18% found it much more difficult than last year's paper while 21% of respondents did not comment because last year's paper belonged to the old syllabus and they could not compare.

For the presentation of the paper the feedback from teachers was positive with 21% excellent, 43% very good, 18% Good and 18% fair. However, there were some concerns about the clarity of wording (11% of teachers who responded thought it was poor) and this will be specifically mentioned in the detailed analysis. There were no issues regarding any bias or the accessibility of the paper.

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

- The determination of the empirical formula of a hydrate experimentally.
- Unit conversion -specifically converting grams to milligrams (although converting joules to megajoules was not as much of a challenge to candidates).
- Explaining how zeolites act as selective catalysts.
- Calculating atom economy.
- The incomplete combustion of PVC.
- The health concerns of using volatile plasticizers.
- Thermotropic and Lyotropic liquid-crystal materials.
- Deducing the repeating unit of a polymer given the monomer.
- Stating the IUPAC name of an unfamiliar organic compound.
- Complex calculations in novel situations.
- Relative abundance and effectiveness of water vapour as a greenhouse gases
- The equation for a transesterification reaction.
- Enzyme inhibition in new contexts.
- An alternative green chemistry source of shikimic acid.

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

- In the Options, candidates performed better when questions were based on factual information than when interpretation was required.
- Many candidates showed satisfactory skills at analyzing the data in question 1 and answering questions concisely.
- Types of bonding.
- Calculation of the P/S index of a fat.

- The raw materials needed for photosynthesis.
- Advantages and disadvantages of bioplastics.
- Octane number of alkanes.
- How transesterification improves the properties of the fuel.
- Determination of the energy density and specific energy of a fuel.
- Radioactive decay calculations
- Ring strain in the beta-lactam ring.
- Antibiotic resistance.
- Calculating percentage experimental yield.
- Analyzing melting point data.
- The action of mild analgesics.
- Withdrawal symptoms of heroin addiction.

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

SECTION A

Question 1

(a)(i) Well answered in general. Some candidates lost the mark as the sign was not included and others did not manage to determine the oxidation state correctly. Most candidates used the correct notation for oxidation states.

(a)(ii) The majority of candidates scored this mark. Some lost the mark by using imprecise language.

(a)(iii) About half of the candidates obtained this mark. Those who didn't made a wrong conversion of units.

(a)(iv) This question was generally well answered where many candidates scored as a result of ECF from (a)(iii). However, some candidates lost the mark by not referring to the data in the table to support their answer.

(b)(i) While a significant number of candidates got this mark, replies showed it was found more challenging than (a)(i).

(b)(ii) Generally well answered. Few candidates presented the wrong curve. Those that failed to score usually labelled the axes incorrectly. Although the curve should have had an increasing gradient, the markscheme accepted straight-line graphs that were frequently seen in scripts. Some candidates only plotted the points but did not draw the trend line, which is required in a sketch.

(b)(iii) Only stronger candidates were able to establish the 3/2.9 ratio or any ratio at all. Some candidates just stated CT values at pH 9 were higher than values at pH 6, which was not sufficient, and others suggested a constant increase between pH 6 and pH 9, which was clearly inaccurate. Others missed what the question required and discussed the changes in CT values with temperature at each pH.

(b)(iv) Poorly answered by the majority of candidates. Most candidates predicted that the concentration of HOCl increased at higher pH. Some feedback from teachers was that the question was too challenging as it involved two equilibria that involved HOCl. While it was challenging, stronger candidates were able to predict the concentration changes correctly by focusing on the equilibrium that involved H^+ ions.

(c) A well answered questions, where pollution was by far the most popular answer.

Question 2

Many candidates did not show evidence that they were familiar with the experimental procedure of heating a hydrate in a crucible to determine its empirical formula, and performance on this question was generally disappointing. It is worth noting that this type of lab is explicitly mentioned in Section 1.2 of the syllabus and there are many exercises available that can train candidates to process and evaluate the data obtained from such an experiment.

(a) Poorly answered with only stronger candidates obtaining one or the two marks. Usual mistakes resulted from not interpreting correctly that “further work” was needed once trial 2 results were collected. The most common incorrect answer was to clean the crucible and repeat the trial.

(b) About a third of the candidates realized that the blackness was due to the deposition of soot on the crucible. It was worrying to observe the number of candidates that considered the crucible could get burnt. The effect on the value of x was a discriminating point that only the strongest candidates were able to deduce.

(c) Many candidates were able to score one mark.

SECTION B

Option A

Question 3

(a) About half the candidates answered this question correctly.

(b) Very well answered.

Question 4

(a) A well-answered question.

(b) Quite well answered.

(c) Only stronger candidates were able to calculate the mass of indium deposited by one mole of electrons.

(d) Very few candidates were able to calculate the number of moles of electrons required to deposit one mole of indium.

(e) Very poorly answered. Although indium is in Group 13 of the Periodic Table, candidates who did not have an answer in part (d) gave a charge of “2+” instead of “3+”.

Question 5

(a) More candidates than in previous sessions were able to correctly describe zeolites’ structure and scored the first mark. The second mark was only scored by stronger candidates.

(b)(i) A question where very few candidates fully scored. However, quite a few obtained one mark through the correct equation for the CO.

(b)(ii) About a third of the candidates obtained a mark here, very often by making reference to a valid economic reason.

Question 6

(a)(i) Mostly well answered.

(a)(ii) Most candidates could not deduce the repeating unit correctly even though they had the correct monomer in part (i).

(b) About a third of the candidates obtained this mark, while many stated a value lower than 100% without any justification and many did not attempt to answer.

(c)(i) Many candidates scored here very often by identifying insufficient oxygen.

(c)(ii) Very poorly answered with only a few candidates relating structure to solubility in fatty tissues.

Question 7

(a) About a third of the candidates could score one mark usually correctly relating to ranges in concentration and temperature. The distinction between solutions and pure substances was rarely seen.

(b) Most candidates addressed this question poorly. While they could often realize disorder increased they failed to provide any satisfactory explanation.

Option B

Question 8

(a) About a third of the candidates scored this mark. Some missed this mark as the question asked for names and they gave the water formula instead. A common mistake was “glycosidic linkage”.

(b)(i) More than half of the candidates identified coconut oil as the oil with the lowest iodine number. Some candidates did not give a reason for their choice and a few did not understand the significance of low iodine number and chose soybean oil.

(b)(ii) Over a third of the candidates scored this mark. Some candidates did not relate the likelihood to become rancid to the carbon-carbon double bonds.

(b)(iii) More than half of the candidates were able to calculate the P/S index correctly. A common mistake was to include linoleic acid only for soybean oil.

(b)(iv) While many candidates correctly stated that the value involved a greater proportion of polyunsaturated fatty acids -or converse argument- they missed this mark as they suggested very vague health related benefits.

(b)(v) A discriminating question. Many candidates managed to secure the first mark by stating that cotton seed oil had stronger London forces. A common mistake was to state that corn oil had more carbon-carbon double bonds, which was excluded by the question as the oils had similar iodine numbers. Some teachers found this question unfair as it did not give the candidates any hint of the reason cotton seed oil had a higher melting point that corn oil. However, the command term used in the question was “suggest” which was appropriate, and while very few candidates were able to deduce that cotton seed oil must have longer chains, all reasonable suggestions were accepted by the markscheme.

Question 9

(a) Half the candidates scored full marks.

(b)(i) Less than half of the candidates justified why both molecules were carbohydrates. Common incorrect answers included stating that they were both made up of carbon, hydrogen and oxygen, and stating that they had the same molecular formula.

(b)(ii) About half of the candidates obtained this mark. Both X and Y had the same carbonyl functional group, but its location was different. The most common answer was that X was an aldehyde and Y was a ketone, which was accepted. Some feedback from teachers found this question badly worded since both compounds had the same functional group.

(c)(i) Few candidates scored here. A common mistake involved simply copying the structure instead of modifying it as a repeating unit. A common incorrect answer was to draw the dimer showing “OH” groups on both sides.

(c)(ii) Most candidates fully scored with even very weak candidates obtained one mark, usually the first one by recognizing the material is biodegradable.

Question 10

(a) This was a discriminating question but 10% of the candidates were able to state the name for leucine using IUPAC rules. Some candidates did not state the names of the substituents in alphabetical order, but this was not penalized.

(b)(i) A well answered question with even weak candidates obtaining at least one mark. Common mistakes included reversing the directions of movement and placing amino acids at different heights (not in a straight line).

(b)(ii) Not well answered, candidates focused mostly on isoelectric point and pH values not addressing the question properly and failing to realize the relevance of size.

(c) A fifth of the candidates determined the number of different tripeptides that can be made from twenty different amino acids correctly. Some feedback from teachers was that this was a probability question and outside the syllabus. Such questions have appeared in past papers, and while it is not focused on chemical concepts, stronger candidates coped well with it.

(d)(i) The majority of candidates identified hydrogen bonds as the interaction responsible for holding keratin in a helical secondary structure.

(d)(ii) Poorly answered supporting the notion that functional groups and classes deserve better attention. A common wrong answer was the carboxyl and amine groups that are found in amino acids but not in the polypeptide. Feedback from teachers suggested that the question asking for plural functional groups was poorly worded and confusing for candidates since the answer was the carboxamide group.

Option C

Question 11

(a)(i) Many good answers. However, weaker candidates struggled with the conversion of units.

(a)(ii) Well answered by the majority of candidates.

(b)(i) About a third of the candidates were able to calculate the volume of gasoline that is equivalent to the energy in the lithium ion battery.

(b)(ii) This was a discriminating question. While most candidates multiplied the distance by four, only a fifth of the candidates used the volume found in part question (b)(i).

Question 12

(a) Most candidates related higher octane to the branching of an alkane. Fewer candidates scored the second mark about octane number decreasing as alkane length increases.

(b) A fifth of the candidates were able to give a correct reforming equation. Feedback from some teachers expressed concern that methylbenzene and heptane are not necessarily familiar to students. This is a fair point.

Question 13

(a) Most candidates scored at least one mark usually from stating acidity increased or pH decreased. About half of the candidates mentioned the formation of carbonic acid but only few candidates showed the formation of HCO_3^- and H^+, or mentioned the shift in the equilibrium as the concentration of CO_2 increased in the atmosphere, which was disappointing. Sometimes arguments were vague. It was disappointing to see the number of candidates relating CO_2 to acid rain and trying to explain the situation from this wrong stance.

(b)(i) There were better answers to this question than in May 2016 and many candidates obtained one mark for the "vibration of bonds" or the "bending of the molecule" which were generously accepted this session. However, answers should be more specific explaining what actually occurs such as "O-C-O bond angle changes" or "asymmetric stretching of bonds". Well-annotated diagrams are a good way of communicating these changes. The change is dipole moment was mentioned by about a third of the candidates.

(b)(ii) This was a discriminating question and only about a third of the candidates obtained the mark. A large number of candidates either did not tackle the question or simply discussed carbon dioxide without mentioning water vapour, reflecting a poor understanding of water vapour's effectiveness and abundance as a greenhouse gas.

Question 14

(a) This topic continues to challenge candidates and only stronger candidates managed to fully score. While many struggled with the correct structure of the ester, glycerol was better presented than in the past.

(b) Well answered by 60% of candidates. The most common answer was the lower viscosity than vegetable oils.

Question 15

(a)(i) Many candidates obtained one of the two marks by explaining the increased binding energy per nucleon in the product and only stronger candidates also considered the mass loss. However, explanations sometimes revealed some misconceptions in this topic.

(a)(ii) About 40% of candidates gave an advantage of fusion as a source of energy.

(b)(i) About half of the candidates were able to calculate the decay constant. However, quite a few candidates lost the mark as they neglected to include the unit of the decay constant as required by the question. There were also some power of ten errors.

(b)(ii) Half of the candidates were able to determine the fraction of the radioactive isotope remaining correctly.

Option D

Question 16

(a)(i) A third of the candidates were able to outline what is meant by "ring strain" successfully. Feedback received from some teachers expressed concern that the term "ring strain" may not be familiar to candidates. This term is often used when describing the importance of the beta-lactam ring in textbooks and past paper markschemes, and most candidates appeared to be familiar with it, even if some of them gave incomplete answers like “angle of 90°” failing to score the mark.

(a)(ii) Half of the candidates labelled the three carbon atoms in the beta-lactam ring.

(b)(i) Many candidates showed evidence of a shallow understanding of the topic with only stronger candidates presenting solid arguments addressing the question. A common incorrect answer was that clavulanic acid created a modified side-chain for penicillin.

(b)(ii) Many candidates fully scored here. Those who didn’t usually presented vague arguments or failed to use subject specific terms.

Question 17

(a) A well-answered question.

(b) 40% of candidates deduced that the ester is the functional group in oseltamivir that changes into a carboxyl group in the body.

(c) 30% of candidates presented valid alternative sources of shikimic acid. Feedback from several teachers found the information required by this question too specific. However it is part of section D.6 of the programme guide (“Explanation of how green chemistry was used to develop the precursor for Tamiflu (oseltamivir)”).

Question 18

(a) More than half of the candidates were able to calculate the percentage yield correctly.

(b) 30% of the candidates recognized that crystallization of aspirin occurs. Some answers were rather disappointing making reference to melting points and not addressing solubility.

(c) Very well answered with even weaker candidates obtaining at least one point, usually the one referring to the higher melting point of the recrystallized compound.

(d) Very well answered.

Question 19

(a) 40% of the candidates scored here, while many candidates were not able to analyze the situation when presented in an unfamiliar way.

(b) Generally a well-answered question. Statements like “stomach wall” were insufficient but most candidates referred to the proton pump.

(c) 40% of the candidates gave a correct equation involving aluminium hydroxide.

Question 20

(a) Most candidates scored one mark losing the second due to incorrect use of names of functional groups.

(b) Very well answered.

Recommendations and guidance for the teaching of future candidates

- Please provide enough opportunities for hands on work during the course. Candidates need to be familiar with different experimental techniques and be able to process data and evaluate the results.
- Please encourage candidates to be precise when analyzing data, for example identifying a constant ratio or a constant increase, rather than just identifying that there is an increase or decrease.
- Please provide opportunities for candidates to explain phenomena clearly and give reasons for their answers. Help them to avoid vague arguments that rarely score marks.
- Please provide opportunities for analyzing novel situations related to the option material, and continue to refer to the Core concepts in explaining the material covered in the options for greater depth and understanding.
- Please provide opportunities for converting units.
- Please provide opportunities for plotting and sketching graphs and analyzing data.
- Please continue to encourage correct use of conventions.