May 2016 subject report

Chemistry

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 32	33 - 44	45 - 55	56 - 66	67 - 77	78 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 29	30 - 42	43 - 54	55 - 63	64 - 75	76 - 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 submitted was overwhelmingly suitable for the assessment by the new I.A. criteria. The majority of schools and their staff 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. Students around the world had occupied themselves in gathering data as they studied red wine oxidizing, apples fermenting, superabsorbent polymers absorbing, bleaches decolorizing, sugars rotating the plane of plane polarized light, d-block elements catalysing, surface tensions changing with dissolved ion concentration and many more interesting and imaginative topics.

Overwhelmingly the work presented involved hands-on primary data collection in a laboratory setting and there is no problem with this approach especially since so many students had gone well beyond the overly familiar standard practical experiments. It was surprising however how few students presented reports based on secondary data. Models and simulations yielded an extremely low number of investigations although the outcome was quite good since it seemed only the really enthusiastic chemistry students were attracted to this approach. There were a few more database orientated investigations but they were unfortunately at times used in a rather inappropriate way showing extremely few data - 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 schools simply tried to follow their old favourite design tasks with all students presenting similar investigations on overly familiar themes. In a few cases schools had simply set students to do a descriptive internet based journalistic survey (such as “Drugs in the World”) with no data collection or analysis of any kind which of course is completely unsuitable for the Individual Investigation whose essence is all about data and its collection, analysis and evaluation.

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 was in many cases an over-emphasis on the first part of the descriptor and often the students’ efforts to justify their choice of research question and topic spilled over into overlong and contrived narratives of early childhood holidays, school excursions and suchlike. 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. More 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 as often found in the old internal assessment framework.

Exploration

The achievement in Exploration was often very good and it was in this planning phase that students showed the greatest engagement and imagination. Although some schools presented samples containing variations on very standard themes many students really tried to extend themselves.

In most 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. A few research questions related to comparative studies such as the relative rates of oxidation of red and white wine samples from the same wine producing region. Although the independent variable was not quantitative such researches were valid and interesting investigations and any trends identified could be interpreted in chemical terms. 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. Some students tried investigations based on syntheses or extractions. These yielded mixed results and the key to success was whether any data was generated that could be meaningfully analysed or interpreted. Just to be able to say that a compound has been successfully synthesized or extracted was not sufficient whereas if a measurable factor could have been studied that may have effected yield or purity in a synthesis or extraction then a more successful investigation would have resulted.

Very often the background information was of general character rather than addressing the specifics of the chosen research question or methodology. The top level descriptor requires the background information to be entirely appropriate and relevant so teachers should advise students to keep it focused.

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, this criterion also assesses awareness of safety, environmental, and ethical considerations” it is envisaged that in most cases it is considered appropriate. For example even in secondary data researches the student could mention the ethical issue of whether the data used is openly licensed or not. So it was a serious concern that in some cases the teachers' marking comments indicated that they felt there were no relevant safety, ethical and environmental issues for the student to comment on even when the investigations included such obvious hazards as the use of corrosive substances such as bleach and 9M sulphuric acid, the use of tetrachloromethane which is an anticipated carcinogen and needs careful handling and disposal or biochemical investigations using blood or bacteria. In these cases the fourth descriptor should have been addressed and this omission most likely would reduce the subsequent Exploration mark by a point. It will be good practice in future for students to give a safety evaluation in any investigation involving hands on practical work even if it is to show that safety has been evaluated but no special precaution is then required.

Analysis

The overall achievement for Analysis was diverse with marks distributed quite evenly across the mark bands. Awards of 1 were not unknown as some students simply presented some raw data and then passed some form of qualitative comment on it. At the other end of the range a good number of students presented some very meaningful data analysis including full consideration of uncertainties and supportable marks of 6 were seen.

Most students collected sufficient data related to the independent and dependent variables so that they could subsequently carry out sufficiently meaningful process and interpretation. Fewer students though also included associated data such as qualitative observations or 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.

The appropriateness and accuracy of the data processing was mixed and here we saw some students slip back from the standards we saw in the old framework when teachers had set up highly scaffolded prescriptive tasks that directed them into quite demanding calculations. In the new framework 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 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. In the common analyses that were trying to determine a relationship between two variables through graphical means a number of students were able to correctly identify the nature of the trend i.e. a positive linear proportionality, etc. However a number of students showed confusion between the terms. Linear negative slopes were thought to be 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.

Other common misconceptions arose in the Analysis. One was a confusion between transmittance and absorbance with % transmittance being thought to be related linearly to concentration. Another was that students too easily identified a trend in rates of reaction as reaching an “optimum” when in fact it was just a positive relationship that would have continued if the trials had been taken to higher temperatures or reactant concentrations. It appears that students are unduly influenced by enzyme kinetics.

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 proved to be the most challenging criterion which could be for a range of reasons. The top band descriptor features higher order thinking skills such as justifying conclusions and showing a clear understanding of methodological issues. Also it is possible that teachers missed the differences with the old CE criterion especially with regard to evaluating strengths as well as weakness and to suggest extensions as well as improvements. In many cases it simply seemed that students ran out of energy and space after very lengthy introductions, methodologies and analyses and what was a fluent and detailed report until that point would quite rapidly be concluded. As a consequence although some students did get into the top band the very highest mark of 6 was less frequently awarded than in the Exploration and Analysis criteria.

Many students were able to achieve well against the first part of the descriptor by describing a conclusion that was supported by the data presented and justified through the data analysis (there is cross over with the last part of the Analysis descriptor here). Some students though appeared to lose their focus through the process and after identifying some form of trend from the data they failed to then relate this back to the original research question.

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.

Many students had not addressed strengths and had solely evaluated weaknesses and here the discussion was not as strong as expected. In terms of evaluating weaknesses only a minority of students made relevant reference to systematic and random errors and very few had an appreciation of the magnitude or direction of error. In this respect the new style of work did not have the rigour of the old format. And without an understanding of systematic error few students were able to evaluate methodological as opposed to simply procedural issues. Higher achievement in this criterion requires 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.

Most students did give some sensible suggestions for improvement although as ever a number suggestions were quite superficial or impractical. Many students had failed to suggest possible extensions and further research and it seems that teachers maybe hadn't clearly highlighted this part of the descriptor.

Communication

The Communication criterion was 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.

The reports were mostly concise and most of them did meet the recommended 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 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 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 reflect on data while collecting it (trials should be carried out) 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 evaluation in any investigation involving hands on practical work even if it is to show that safety has been evaluated but no special precaution is then required.
- 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.
- 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.

Further comments

The majority of schools followed the correct process of uploading the required 4/ICCS form and the individual investigation reports. There were occasional omissions or mistakes, however. The 4/ICCS form asks for the title of the individual investigation. The space for this is just under the box for the group 4 reflections. Many students wrote the name of the G4P activity, and not the IA title. When entering the IA criteria marks, there is a space for teacher comments about their marking. If the report itself does not feature the teachers marking feedback then please take advantage of this space since the information is most useful to the moderators.

Teachers should note that the within the 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 - 21	22 - 25	26 - 29	30 - 33	34 - 40

General comments

The number of candidates who answered the paper was 15122. 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.

327 teachers gave feedback from a total of 1290 schools. Apart from those for whom the comparison was not applicable (11%) 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	10	54	24	2

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

	Too easy	Appropriate	Too difficult
Level of difficulty / %	2	94	4

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

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	1	2	17	31	33	17
Presentation of the paper	0	0	7	28	38	27

In general, the paper seems to have been well received with comments such as "good syllabus coverage", "largely as expected", "complete analysis of student's course knowledge" being used. One respondent suggested that "command terms" could be used more instead of "which", "what" for instance. Command terms are only used in papers 2 and 3.

There were comments about syllabus coverage and the absence of questions on certain topics. Questions in paper one are set to a ratio determined by the recommended teaching time for each topic. We aim to examine the whole syllabus over papers one, two and Section A of paper three. Thus, an area of the syllabus thought to be missing from paper one is likely to be covered elsewhere.

There was a comment about the phrasing of the questions. We try very hard to write concise questions which can be translated into both French and Spanish without creating ambiguities.

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 examination of the new syllabus, there were a few 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 19.64% to 92.24%. The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from 0.11 and 0.55.

The following comments are made on individual questions:

Question 1

We were happy with the use of the term “sublimation” for the (s) to (g) transition; the reverse is usually called “reverse sublimation” or “deposition”.

Question 2

Most chemists use the term “limiting reagent” when the other reagent is in excess. Answer B was achieved by about 77% of the candidates, with D being the most popular of the three distractors.

Question 3

This was poorly answered (19.64%) with the majority choosing distractor D which, whilst a true statement, is not an explanation of deviation from the ideal. It is accepted that distractor B might have been better phrased, “Forces of attraction increase the volume from the ideal” – again, not a correct answer.

Question 6

It is accepted that point D should not have been so low on the diagram. Only about 29% of the candidates gave the right answer with the others evenly divided between the distractors.

Question 10

Perhaps it would have been clearer to re-order each statement so that, for instance, A becomes: “Light of a certain colour is emitted as electrons return to lower energy levels and the complementary colour is observed.”

Question 11

We might have made the question clearer by asking, “In which species does the central atom break the octet rule?” The octet rule is found in section 4.3 of the Guide. Hydrogen is not generally considered to break the octet rule.

Question 13

This question was based on the syllabus where the nature of van der Waals’ forces is explained in the Guidance notes.

Question 14

It is accepted that the use of the word “group” might have been misleading and that “pair” might have been better.

Question 17

We accept that the question might have been better presented, “Which equation represents the average bond enthalpy of the Si–H bond in SiH_4?”

Question 19

There is no need to state that the “reaction” in question is spontaneous; we would expect candidates to realise this. The inclusion of $\Delta S_{surroundings}$ is fair as ΔG cannot be explained without an understanding of it.

Question 25

This was a direct assessment of syllabus topic 17.1.

Question 31

Nearly 65% of the candidates gave the correct answer with the most common distractor being B.

Question 32

We would expect a basic knowledge of aqueous electrolysis. Electrolysis of water doesn’t take place in significant quantities without the presence of acid. If candidates had been thinking about choosing answer D, they could have checked their knowledge against question 33 where it is given that silver is deposited rather than hydrogen evolved.

Question 33

The most popular (incorrect) answer was C (about 50% of the candidates) and only 23% correctly gave D. There is a need for questions in paper one which differentiate between grade 5, 6 and 7 candidates.

Question 35

There is a general assumption that “base” means a Brønsted-Lowry base unless *Lewis* base is specified and thus A is the better answer.

Question 38

Nearly 68% of the candidates gave the correct answer.

Question 39

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 is no need to remember a formula; just draw a diagram showing all the atoms and bonds given. Work out how many more H atoms would be needed for a saturated molecule. Divide this number by 2.

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

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 15	16 - 18	19 - 20	21 - 23	24 - 30

General comments

The number of candidates who answered the paper was 14603. The paper consisted of 30 multiple choice questions on the Subject Specific Core. 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.

291 teachers gave feedback from a total of 1494 schools. Apart from those for whom the comparison was not applicable (11%) 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
1	11	53	21	3

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

	Too easy	Appropriate	Too difficult
Level of difficulty / %	2	91	7

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

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	0	2	21	29	37	12
Presentation of the paper	0	0	11	26	42	21

In general, the paper seems to have been well received although there was not always agreement in the comments. For instance, whilst one respondent suggested there were too many “Math” questions, another said there was a “disappointing lack of Math”.

There were a number of comments about syllabus coverage and the absence of questions on certain topics. Questions in paper one are set to a ratio determined by the recommended teaching time for each topic. We aim to examine the whole syllabus over papers one, two and Section A of paper three. Thus, an area of the syllabus thought to be missing from paper one is likely to be covered elsewhere.

Although some respondents suggested we had set questions on material that is not in the SL syllabus (sub-energy levels, resonance, alkynes for instance) this was not the case.

There was a comment that some questions were difficult for SL students. Please remember that both SL and HL are examined on the Core to the same standard; hence many questions are common to both papers. HL has more material – which may or may not be harder. The SL paper needs questions that will discriminate between grade 6 and grade 7 candidates.

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 examination of the new syllabus, there were a few 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 13.77% to 90.56%. The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from 0.17 and 0.60.

The following comments are made on individual questions:

Question 1

We were happy with the use of the term “sublimation” for the (s) to (g) transition; the reverse is usually called “reverse sublimation” or “deposition”.

Question 3

Most chemists use the term “limiting reagent” when the other reagent is in excess. Answer B was achieved by about 63% of the candidates, the others being fairly evenly divided between the three distractors.

Question 4

This was poorly answered (13.77%) with the majority choosing distractor D which, whilst a true statement, is not an explanation of deviation from the ideal. It is accepted that distractor B might have been better phrased, “Forces of attraction increase the volume from the ideal” – again, not a correct answer.

Question 11

Although no respondents mentioned this, we decided, at the Grade Award, to accept both answers C and D as two Lewis structures can be drawn for the cyanide ion.

Question 12

This question was based on the syllabus where the nature of van der Waals’ forces is explained in the Guidance notes.

Question 13

It is accepted that we should have given the answers with a negative sign or rephrased the question “heat released when…” There was a comment that we should have included units with each quantity. We endeavour to include units in our markschemes but there is some discussion about whether or not their inclusion in a question such as this would make the whole thing very clumsy. The units were given in the stem of the question so candidates could have rewritten the responses with units if that would have made them more comfortable.

Question 14

This is a Hess's Law problem not a Born-Haber cycle. 60% of the candidates gave the correct answer.

Question 15

We accept that the question might have been better presented, "Which equation represents the average bond enthalpy of the Si–H bond in SiH_4?"

Question 20

Attention is drawn to the syllabus, 8.5, where it is indicated that "acid deposition has a lower pH (than that caused by dissolved CO_2), usually below 5.0.

Question 22

Nearly 53% of the candidates gave the correct answer with the most common distractor being B.

Question 23

Although the term "general formula" is used in the Guide, 10.1 the word "general" could have been omitted without loss of meaning.

Question 24

Alkynes are in section 10.1.

Question 25

Candidates should be prepared for acids, such as propanoic acid, being presented either as –COOH or –CO_2H.

Question 27

Nearly 64% of the candidates gave the correct answer.

Question 28

This question was designed to test 11.2, graphical techniques. We could have put the graph into a chemical context but that would have made it more complicated. The majority thought the answer to be B.

Question 30

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 is no need to remember a formula; just draw a diagram showing all the atoms and bonds given. Work out how many more H atoms would be needed for a saturated molecule. Divide this number by 2.

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

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 31	32 - 40	41 - 50	51 - 61	62 - 71	72 - 95

General comments

This was an accessible paper with a wide range of marks, the best candidates were able to shine and the mean mark was in the region of 46 out of 95. There is concern that, even after two years of study, over 400 candidates scored less than 10 marks (over 150 scored less than five marks).

The number of candidates who answered the paper was 14961. For the first time 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. Nearly 93% of the candidates attempted the last part question, Q 5 (c).

327 teachers gave feedback from a total of 1290 schools. Apart from those for whom the comparison was not applicable (11%) 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
1	9	48	27	5

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

	Too easy	Appropriate	Too difficult
Level of difficulty / %	2	89	9

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

	V poor	Poor	Fair	Good	V good	Excellent
Clarity of wording	1	1	17	30	36	14
Presentation of the paper	1	1	8	26	42	23

In general, the paper seems to have been well received and there were comments such as "good syllabus coverage" and "good use of command terms". There were some individual concerns about the length of the paper and the loss of choice. Others commented that there was too much or two little of some particular area of the syllabus or questions of Objective 2 or 3 type. When the papers are authored, there is a complex setting grid used to ensure that syllabus coverage and objective type are within acceptable parameters. We aim to examine the whole syllabus over papers one, two and Section A of paper three and match the number of marks for each topic to the recommended time allocation in the Guide.

Other comments:

We no longer ask candidates to write definitions but we do expect them to be able to understand and outline what is meant by certain terms such as electronegativity, for instance.

One commented that there was too much focus on new material in the syllabus; we don't accept that this was the case but it had to be expected that new areas of the syllabus would be examined.

Another commented that some parts should have been allocated more marks. In Q3 (a) (iv), for instance, there was only one mark because we considered it inappropriate to give a mark for "no", a 50:50 answer. We have tried to eliminate 50:50 marks from future examinations.

Please be aware that if an error is made in an early part of a calculation, the error is carried forward so marks are not lost in later parts of the question.

We gave references to the data booklet in many questions but candidates should not assume that because there is no reference, the data booklet is not needed. They would have found it helpful in Q 1 a (iv). The data booklet should be a candidate's constant companion during the two-year course.

There are common questions with the SL paper; this is because we hold a G7 in SL at the same level as a G7 in HL. There is only a difference in syllabus content, which admittedly contains challenging topics.

There was a comment that "context gets in the way of the chemistry". Ideally, we would set the questions in *more* context but, mindful of those who are working in their second or third language, we cut the questions down to the minimum words without losing clarity (and allowing confusion-free translation into French and/or Spanish).

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.

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

- Answering open-ended "nature of science" type questions
- The reaction of phosphorus(V) oxide with water
- Pre-combustion and post-combustion methods of minimising SO_2 levels
- Reduction of nitrobenzene to phenylamine
- Naming ethane-1,2-diol
- Recognition that fragments in a mass spectrometer have a positive charge
- The analysis of resonance structures
- Molar enthalpy changes of solution
- Splitting patterns in ^1H NMR spectra
- Mechanism for the nitration of benzene including drawing curly arrows with accurate starting and ending points
- Unit conversions (power of 10 errors)
- Le Chatelier's principle (to explain why tin(II) chloride is dissolved in dilute hydrochloric acid)
- Classification of amines

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

- Lewis (electron dot) structure of phosphine
- Deduction of equilibrium constant
- Distinguishing between alkanes and alkenes with bromine water
- Identifying a bond that produces a specific peak in an IR spectrum
- Sketching an enthalpy profile for a reaction with and without a catalyst
- Sketching a Maxwell-Boltzmann energy distribution curve at a higher temperature
- Describing a bond between a ligand and a transition metal ion
- Routine calculation of amount of substance from its mass and formula
- Calculation of empirical and molecular formulas
- Using ΔG to predict spontaneity

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

Question	Comment
1 a (i)	This was generally correct but candidates need to take care with these diagrams so that odd marks on the paper are not mistaken for electrons. The electron pairing was poor in some instances.
1 a (ii)	There were many correct answers but sp^2 was a common error.
1 a (iii)	Many answered this correctly although some talked about donating *an* electron or electrons which did not score.
1 a (iv)	Many described the polarity of the molecule not the bond; candidates must read the question carefully.
1 a (v)	There was evidence that some candidates considered that covalent bonds would be breaking. Many omitted to explain that hydrogen bonding is stronger than London forces.
1 a (vi)	There were many good answers.
1 b (i)	This was expected to be straightforward by some candidates struggled with nomenclature, muddling “molecule” with “atom”.
1 b (ii)	This was generously marked but for the future candidates should be aware of the difference between *amphiprotic* and *amphoteric.* The most common error was to muddle the term with *diprotic*. The formulas seemed to cause unexpected problems even if the first mark had been gained.
1 b (iii)	For those who understood how to do this, “0” for P_4 caused little problem. We were strict about requiring “+1” for $H_2PO_2^-$ rather than “1” or “1+”.
1 b (iv)	Commonly, candidates did not relate the previous definitions to the system under consideration (some got muddled with P_4 going to PH_3) and many carelessly lost a mark by not indicating that the current definition is an *increase* in oxidation number.
1 c (i)	Many correct answers; but some gave 0.08 having forgotten to take P_4 into account.

1 c (ii)	Most were able to gain this mark.
1 c (iii)	This was generally well done and some gained ECF marks from (ii) which illustrates the importance of showing working.
1 c (iv)	This was answered very variably; if calculation from $pV = nRT$ was done, the temperature chosen was often 298 K instead of 273 K.
1 d (i)	Less than half of the candidates gained this mark. Many did not look at the units and gave 3.75 K; the other common error was to give –3750 K showing a misunderstanding of the Kelvin scale. With hindsight, 3750 K was an unusually large number for the answer.
1 d (ii)	This was a straightforward calculation and the likely error was "over-rounding" giving PO_3. Other errors tended to be careless.
1 d (iii)	Answers were accepted that showed the correct "process" from an incorrect answer to (ii).
1 d (iv)	This was poorly answered with many candidates suggesting oxygen or hydrogen as products.
1 d (v)	Candidates found this more of a challenge with many suggesting that the acids are weak. This was the worst answered part of the paper.
1 d (vi)	This was poorly answered with many not understanding the significance of preventing SO_2 being produced (pre-combustion) and SO_2 being removed post-combustion.
2 a (i)	Candidates, in general, scored well on this question. A common careless error was to miss the "2" in the formulas.
2 a (ii)	The equation $\Delta G^o = -RT \ln K$ given in the data booklet is derived from $\Delta G = \Delta G^o + RT \ln Q$. At equilibrium, $Q = K$ and $\Delta G = 0$, hence, $\Delta G^o = -RT \ln K$. The equilibrium constant K is here given at 600°C (T = 273 + 600 K), so $\Delta G^o = -RT \ln K$ = +11.7 kJ and this ΔG^o value can be used in part (iv) at 298 K (SATP conditions). Many carried out the calculations correctly but lost the final mark by not giving the answer to three significant figures.
2 a (iii)	This was answered quite well but some candidates lost a mark by inexplicably transcribing –220.1 kJ mol^{-1} as –220 kJ mol^{-1}.

2 a (iv)	The key to success in this part was to pay careful attention to the units. The answer was often left in $kJ\ K^{-1}$ when the question asked for $J\ K^{-1}$.
2 b (i)	"Secondary" was a common, incorrect answer.
2 b (ii)	This proved to be challenging for candidates and many incorrect answers included sulfuric acid and/or tin *as a catalyst.*
2 b (iii)	There were few good answers to this and some produced NO_3^-.
2 b (iv)	This was either answered very well or very poorly. There are few mechanisms to learn in the syllabus.
2 c (i)	The standard of nomenclature was disappointing with many omitting "di". The class was generally recognised as an alcohol.
2 c (ii)	About half the candidates were able to give good reasons for their answer.
2 c (iii)	It was disappointing to see so many candidates (well over half) omit the "+" charge. This must be one of the most common errors reported in every subject report.
2 c (iv)	By contrast the vast majority of candidates got this right. It would be preferable if candidates were to draw out the bond as O–H (rather than –OH) so it is clear to the examiner.
2 d	Many candidates were well-prepared for this type of question, with quite a few gaining full marks. Others had little idea how to cope with a pK_b type calculation. "Error carried forward" marks could be awarded if correct working could be followed by the examiner. Many scored just one mark for subtracting an incorrect value of pOH from 14 for the pH value. Others were able to score one by converting pK_b to K_b.
3 a (i)	Many careless errors were displayed in these answers.
3 a (ii)	Many included $[N_2O_2]$ in the expression, not realising that, as an intermediate, it needs to be replaced by $[NO]^2$. Others gave a K_c type expression.
3 a (iii)	It would be good if candidates made it clear that only one concentration would be changed at a time. Otherwise there was a generally good understanding of the effect of concentration change on the rate.
3 a (iv)	This was challenging for weaker candidates and the reason had to reflect the answer "no". There was no credit for the answer "no" alone.

3 a (v)	The answers were, in general, very imprecise with few suggesting the need to monitor the reaction by taking measurements at different times.
3 b (i)	There were many poorly drawn diagrams and many lost marks through imprecision. Many had ΔH marked as including E_a. Candidates need to take care with these diagrams.
3 b (ii)	This mark was usually gained even on a poor diagram.
3 b (iii)	The markscheme (for one mark) was quite generous but candidates would do well to practise drawing curves that give the impression of having the same enclosed area.
3 b (iv)	This is a very standard question so it was disappointing to see so few gain full marks. “More kinetic” energy was often all that was offered for the first mark and the mark for “greater frequency of collisions” was more often gained than that for answers related to the activation energy. (Quite a number opined that the value of the activation energy changes.)
3 c (i)	Candidates expressed their answers in a wide variety of ways with few understanding the delocalisation of the pi-bond/electrons.
3 c (ii)	Many candidates were awarded a mark for *delocalisation* here if it had not been awarded in (i).
4 a (i)	To gain the mark, candidates needed to state that the ions have both the same charge (if Sn^{2+} and Sr^{2+} were explicitly written in the answer that was accepted) and the same radius.
4 a (ii)	The value –1587 was commonly used (hydration enthalpy of Sn^{2+}) and the enthalpy of hydration of Cl^{-} was quite often not multiplied by 2.
4 a (iii)	Very few seemed to understand the change in the position of equilibrium caused by an increase in hydrogen ion concentration. Many seemed to think the question related to *dilute* as opposed to *concentrated* hydrochloric acid.
4 b (i)	All errors possible were committed in the calculation of E^{o}. In the calculation of ΔG both n = 2 and n = 1 were accepted as no overall equation had been given.
4 b (ii)	This was answered well although many gained the mark as an ECF from (i).
4 c	The electron configuration with $3d^5$ was a common error. There were vague statements about the term transition metal with suggestions of different

	oxidation states or coloured compounds rather than partially complete d sub-shell. “Does not have full d-orbitals” is not precise enough.
4 d (i)	About half the candidates gave the correct answer. “Act as ligands” was not accepted as this was not a description of the bond.
4 d (ii)	It was often not made clear that the changing energy gap was between d-orbitals. Many answered this well although there were the inevitable muddles of frequency with wavelength.
4 e (i)	About half the candidates gained this mark. Many omitted the principal quantum number.
4 e (ii)	Many answers lacked clarity, many suggesting greater nuclear charge.
4 e (iii)	There were better answers to this part but many were unable to designate the two subshells from which the electrons were taken. There were many good answers about shielding.
4 e (iv)	Most candidates gave the correct answer.
5 a (i)	The majority of candidates gave the answer “isomers” but allotropes was a popular answer.
5 a (ii)	There were examples given of non-chemical tests, generally some sort of spectroscopy. If bromine water was correctly given for the test, the second mark was not awarded if it was stated that the solution went clear.
5 b	This was usually answered correctly but some gave 1700 – 1750 cm^{-1}, perhaps having misread across section 26.
5 c	About a third of the candidates answered this correctly with many giving 1.3 – 1.4 in place of 4.5 – 6.0. Many found the splitting a challenge.

Recommendations and guidance for the teaching of future candidates

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 much of what is written outside the box so there is a chance that 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
- 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 and significant figures.
- 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.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 21	22 - 27	28 - 32	33 - 38	39 - 50

General comments

The paper seemed to be a fairly accessible paper which tested basic concepts, sometimes in novel situations. There was however quite a high proportion of straightforward questions that enabled even weaker candidates to accrue respectable totals.

There were quite a few strong scripts in which the candidates displayed an excellent knowledge of the subject, however there were still a very large number of scripts that seemed to indicate the students concerned had failed to grasp even the most basic chemical concepts – it seems incomprehensible that after a 150 hour course candidates could score less than 5 out of 50.

The areas introduced as part of the new syllabus, such as "nature of science", environmental topics and physical methods for the determination of organic structures, were those that seemed to prove the most challenging. Teachers should note that NoS content is now a compulsory part of the examination papers and also that the setting of examination questions is only carried out in reference to the current subject guide and does not take into account how the material is covered in Chemistry textbooks.

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

- Unit conversion (g to kg, J to kJ, m3 to cm3 etc.)
- Being able to write correct structures of conjugate acids and bases of a species
- Calculating the oxidation state of an element in a polyatomic ion
- Answering open ended “nature of science” (NoS) questions
- Calculating of the amount of reagent in excess in a reaction
- Non-standard calorimetric calculations
- Writing equations for the reaction of acidic oxides with water and predicting the properties of the solution
- Products from addition polymerisation reactions
- Effect of isotopes on mass spectra
- Electron orbital diagrams and the shapes of atomic orbitals

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

- Drawing basic Lewis structures
- Shapes of simple molecules
- The allotropes of carbon
- Calculating of amount of a substance from its mass and formula
- Deducing the limiting reagent
- Calculating empirical and molecular formulas
- Writing equilibrium constant expressions
- Energy level diagrams
- Maxwell-Boltzmann distribution curves (though greater precision desirable)
- Equations for the complete combustion of hydrocarbons
- Deducing that molecules are isomeric
- The bromine (water) test for unsaturation
- The composition of atomic nuclei

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

Question 1

Q1a(i) Most candidates accurately drew the required Lewis structure, though predictably a few candidates (<20%?) forgot the lone pair.

Q1a(ii) Many considered the polarity of the PH_3 molecule, not the P-H bond, and others assumed that phosphorus was more electronegative than hydrogen, rather than checking it in the data booklet.

Q1a(iii) Most candidates could explain why phosphine was not planar, though most gained their marks through the second, rather less fundamental, alternative answers on the markscheme.

Q1a(iv) Candidates often scored full marks for explaining the boiling point difference, as there were a number of ways in which this could be obtained. A disturbing minority of candidates however seemed to state, or imply, that the N-H covalent bond in ammonia was the hydrogen bond and/or that boiling involved breaking the covalent bonds within a molecule.

Q1b(i) Most candidates knew two of the allotropes of carbon, though a few explored other elements.

Q1b(ii) The difference between P_4 and 4 P seemed to be generally understood, though candidates often had problems putting this into words. It is worrying how some candidates use the terms “element”, “atom”, “compound” and “molecule” fairly indiscriminately!

Q1b(iii) Most knew the meaning of *amphiprotic*, though some definitions sounded more like *amphoteric*, but the majority of candidates had problems deducing the formulas of the conjugate acid and base.

Q1b(iv) Most students knew that the oxidation state of an element is always zero, but calculating the oxidation state of $H_2PO_2^-$ proved much more challenging.

Q1b(v) For quite a few candidates, this appeared to be the first time they had come across a question with a “nature of science” (NoS) slant to it and predictably most did not know how to explore the issue. Questions of this type will now be mandatory. Many appeared to be aware of earlier definitions, especially in terms of the gain/loss of electrons, but only a handful successfully analysed the transition in question in terms of these definitions.

Q1c(i) Most students carried out this simple moles calculation correctly, though a handful used the atomic, not the molecular, mass and there were a number of “power of ten” errors.

Q1c(ii) It was encouraging how many candidates accurately deduced the limiting reagent and backed this up with an appropriate calculation.

Q1c(iii) Calculating the amount of reagent in excess proved much more challenging. Common mistakes were to choose the wrong initial amount of substance and to fail to apply the mole ratio from the equation.

Q1c(iv) This routine calculation of the volume of gas produced proved much more difficult than had been anticipated. Candidates often used 298 K (standard thermochemical temperature) rather than 273 K (STP temperature). Even when candidates did calculate the correct volume they lost the mark by not quoting it in the units requested (cm^3).

Question 2

Q2a(i) A surprising number of candidates found this routine calorimetric calculation challenging. Problems often arose from a confusion between J and kJ and, even though it says the air was heated, many candidates gave negative values for ΔT!

Q2a(ii) An encouraging number of candidates correctly calculated the empirical formula, though some multiplied, rather than dividing, by the atomic mass. Another common fault was to “over-round” the amounts and deduce an empirical formula of PO_3.

Q2a(iii) The relationship between empirical and molecular formula appeared well understood, even by candidates who produced an incorrect answer to a(ii).

Q2b(i) Very few students seemed to be able to write a correct equation for the reaction of phosphorus(V) oxide with water.

Q2b(ii) Deducing the effect of dissolving the oxide on the pH and conductivity of water proved far more challenging than was anticipated – probably less than half gave the correct response. It was anticipated that some would make the mistake of thinking acids increase pH, but many seemed to genuinely think that phosphorus(V) oxide was basic.

Q2b(iii) The reason why oxides of phosphorus do not create environmental problems, a rather open-ended environmental question really testing why those of sulfur and nitrogen do, was not well answered even though a wide variety of reasons were accepted. Many erroneously thought that phosphoric(V) acid is a weak acid.

Q2b(iv) The poor answers to this question seem to indicate that many students are unaware of the specific techniques being currently employed to reduce amount of sulfur dioxide produced by the combustion of fossil fuels.

Question 3

Q3a(i) Almost all students could correctly formulate the required equilibrium constant expression.

Q3a(ii) It was encouraging that many students realised that the value of K_c is unaffected by pressure, though quite a few candidates interpreted the question as asking about the shift in the position of the equilibrium.

Q3b(i) Most students could accurately draw the energy level diagram requested.

Q3b(ii) Almost every candidate who produced the correct diagram for the previous part, correctly added the profile for the same reaction in the presence of a catalyst.

Q3b(iii) Not quite as well answered as the previous parts, but again most students could add the Maxwell-Boltzmann curve for a higher temperature. Many however were not very accurately drawn and a more stringent markscheme would have significantly reduced the marks gained.

Q3b(iv) It seems that most candidates are aware of why reactions proceed more rapidly at higher temperatures, though many students failed to identify both of the required factors and quite a few lost marks through a failure to express themselves accurately.

Question 4

Q4a(i) Very few gave the correct name "methylpropene", though most gained the mark through answers that were accepted even though they contained redundant numbers.

Q4a(ii) Very few candidates could correctly predict the product of addition polymerisation.

Q4a(iii) Most candidates could write the correct equation for the combustion of methylpropene.

Q4b(i) The majority of candidates correctly noted the two compounds were isomeric.

Q4b(ii) The use of bromine, or bromine water, to identify carbon-carbon multiple bonds, along with the resultant colour change, was generally well known. A handful, though noticeably fewer than in the past, stated the unsaturated compound turned the reagent "clear" even though it is initially a "clear orange" colour.

Q4b(iii) Many students predicted correct differences in the IR and NMR spectra of the two molecules, though some lost a mark through not mentioning both compounds. The ^{1}H NMR spectrum was more challenging than the IR spectrum with candidates having difficulty in correlating the data in the data booklet to the three separate hydrogen environments. The imprecise, though accepted, manner in which candidates communicated their answers gave the impression that many of them had not previously seen real IR or NMR spectra.

Q4c(i) Hardly any candidates realised that the substitution of the isotope would increase the mass of ions containing the ^{13}C atom, such as the molecular ion, by one unit.

Q4c(ii) Most candidates correctly identified the structure of the ^{13}C nucleus, but the electron diagram was more of a challenge with many candidates drawing an excited state with four unpaired electrons.

Q4d It was surprising how many candidates were unable to accurately draw representations of the shape of basic atomic orbitals.

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. When comparing things, reference should be made to both. If a question is about to a particular substance or reaction, then the answer should specifically refer to it.
- Practicing writing answers to questions frequently asked so as to avoid making mistakes, particularly with regard to the precise use of language, that have previously been problems.
- Ensuring that candidates know the meanings of terms such as "element", "atom", "compound" and "molecule" and use them accurately.
- Preparing students for the more open-ended "nature of science" questions.

- Setting a variety of more demanding and "non-standard" stoichiometric and thermochemical calculations.
- Giving students more practice on questions relating to the nature of oxides.
- Applying students' knowledge of the polymerisation process to novel examples.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 19	20 - 24	25 - 28	29 - 33	34 - 45

General comments

Overall this first examination paper of the new chemistry syllabus appears to have been well received. Based on the 558 G2 comments received, a high percentage of teachers found the paper to be of an appropriate standard (79.5%) in terms of level of difficulty and the general feedback was that the paper was fair, accessible and reasonably balanced. 19.96% found the paper too difficult. Compared to last year's papers, 36.51% found the paper of a similar standard, 30.4% found it somewhat more difficult, and 14.39% much more difficult. Clarity of wording of the paper was found to be fair by 20.07%, good by 34.54%, very good by 27.67% and excellent by 7.23%. Presentation of the paper was found to be fair by 15.51%%, good by 33.39%, very good by 25.7% and excellent by 13.87%.

Candidates performed well in Q1 in Section A, but struggled with the experimental based question, Q2 in the same section. There was something for each candidate to access in questions across the paper in both sections, but at the very upper end even some of the better candidates lost marks due to the additional twists of features embedded in the new syllabus such as NOS type questions, new sub-topics and the greater emphasis on core topics in P3. Candidates did appear to have done better on the options, largely due to the fact that only one option needed to be studied. Option A was found to be more difficult and Option B perhaps easier than Options C and D, in this session. This was also expressed by some teachers.

Reaction based on the G2 comments received was favourable, which points to the fact that both candidates and teachers appear to be reasonably satisfied with this paper. However there were a few points of concern which were widely communicated – in particular teachers questioned the inclusion of an experimental question on preparation of a solution as many felt this was not one of the mandatory listed experiments. Q2 (c) also was vigorously debated and many stated that they did not know the actual precise answer to the question. The question on the advantages and disadvantages of biodegradable plastics was queried as being at the edge of the syllabus. Many of these points are addressed in the report below on the Options. Other comments included the minute detail asked for in Option A where it was felt that more thematic, overarching topics could have been included for this Option overall and also the fact that many HL Biology candidates would have been able to answer a high proportion of Option B. The naming of the sections also was strongly criticized i.e. why not Sections 1 and 2 and not Section A and Option A. Some candidates (1%) did not actually do Section A.

For many candidates misreading of some questions did appear to be an issue on this particular paper and greater understanding of command terms needs to be re-emphasised by teachers in the classroom setting. In addition, candidates need to be prepared for the integration of core chemical principles into the topics covered in the options. This is a feature greatly emphasized in the new curriculum.

The most popular option was D, followed by B and C. The least popular option was Option A. Performance on each of the options is outlined below.

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 had not been exposed to a comprehensive laboratory programme, which is an essential feature of the new curriculum. This was particular evident in Q2 in Section A. Even outlining how to prepare a solution in 2 (a) was beyond the capacity of a significant number of candidates. Many candidates failed to simply understand the nature of many of the laboratory-based questions in Q2 and it appears that a high percentage of candidates may not have been previously challenged in the programme by typical experimental based questions.
- Many of the weaker candidates (and even some of the better candidates) also struggled with NOS-based questions, again an essential characteristic of the new programme.
- One of the features of the new P3 is the integration of core concepts with applied material. Many candidates struggled with fundamental concepts from the core on this paper – in particular molecular polarity, optical isomerism, relative integration (in a 1H NMR spectrum) etc.
- Candidates often had difficulty understanding the various command terms in questions. In particular questions where one had to compare and contrast or outline advantages and disadvantages proved highly challenging.
- In Option A – Materials, the following were poorly understood: cause of electrical resistance in metallic conductors, the Bardeen-Cooper-Schrieffer (BCS) theory, explanation of how zeolites act as selective catalysts and the difference between the structures of ceramics and metals.
- In Option B – Biochemistry, drawing the enantiomers of serine, biodegradable plastics and oxygen saturation of haemoglobin and foetal haemoglobin were poorly answered.
- In Option C – Energy, the following sub-topics were found to be challenging – formation of methane from coal and steam, the role of carbon dioxide on the pH of oceanic water, the PEM fuel cell and DSSCs.
- In Option D – Medicinal chemistry, medical radioactive waste (types and methods of disposal) proved to be the most problematic sub-topic.

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

- Many candidates performed well on Q1, the data-based question on GWP in Section A.
- Candidates managed to solve the majority of simple numerical based questions throughout the paper with a high degree of proficiency.
- In Option A, magnetic properties were well understood and candidates often explained paramagnetism and diamagnetism using orbital diagrams which showed solid understanding of core concepts. The electrolysis problem on molten alumina was very well answered, and also the question on solubility product. Candidates were very well prepared for the numerical-based problems in Option A.
- In Option B, candidates performed strongly throughout and had a good understanding of amino acids, electrophoresis, enzyme-catalysed reactions, the Michaelis-Menten plot and buffer calculations. Most candidates also did very well on the R_f question on chromatography.
- In Option C, any question involving a simple calculation was very well done. Concepts related to fission and fusion were particularly well answered, and most knew the difference between n-type and p-type doping of silicon in photovoltaic cells.
- In Option D, candidates appeared to be well prepared for topics such as the antibiotic activity of penicillin, opiates and the interpretation of IR spectroscopy.
- Overall candidates performed better on questions related to factual information and simple numerical calculations but had greater difficulty with questions where an application or some degree of interpretation was involved.

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

Section A

Candidates performed well in general on Q1 but many had great difficulty on the experimental-based question in Q2.

Question 1

Some teachers felt that Q1 was too similar to the corresponding question on the specimen paper. Another G2 comment stated that that the title of the graph "graph of IR absorbances for oxygen and ozone molecules" is not quite correct as the graph also shows UV and visible light absorbances. This is a valid comment and it would have been better if IR was not stated in the title. It was also remarked that the graph is unusual as absorption is shown and not transmittance, but overall the graph is easy to understand. The better candidates had no difficulty explaining why ozone is a greenhouse gas and why oxygen is not. Some of the weaker candidates appeared confused and stated that both were not in fact greenhouse gases. Some candidates simply stated that ozone is shown in the IR region and oxygen appears in the UV region and then tried to guess whether each compound is a greenhouse gas or not. It was disappointing that more precise language was not used in responses to this question e.g. many did not even mention absorption which showed poor understanding of the actual reason underpinning why a compound is a greenhouse gas (or not). (b) (i) proved no difficulty and most gave a single value within the 1300-1500 km mol^{-1} range for CF_4. In (b) (ii), the majority of candidates stated that fluorine was more electronegative than chlorine but then failed to explain the fact that in CCl_3F, the vectorial sum of the individual dipole moments gave a net dipole moment for the molecule. This was highly disappointing to see at HL and most candidates had little understanding of the inherent difference between bond polarity and molecular polarity. One or two of the top tier candidates scored full marks by explaining their reasons using well represented sketches of both molecules with the individual vectors shown as dipole moments and showing the net resultant vector in CCl_3F, pointing towards the fluorine. This question was based on core concepts and showed that candidates were poorly prepared with regards to molecular polarity. Candidates could have explained their answer in words or using supporting sketches showing the vectorial sum of the bond dipole moments. The latter was a nice, common approach taken by the better candidates who scored full marks. The consideration of molecular geometry is essential when one discusses molecular polarity and this was largely ignored by candidates. One G2 comment stated that it would be better if dipole moments and Debyes were stated explicitly on the syllabus. However dipoles are explicitly mentioned on P.45 of the guide in the guidance section and candidates should know from the table given in 1 (b) that Debyes are the units for dipole moments. (b) (iv) was often well done, as was (b) (v), though some candidates did not indicate that the effect is large with respect to global warming.

Question 2

This question was very poorly answered, in particular part (a) where the vast majority of candidates had no idea how to prepare a solution. This is of some concern for both SL and HL candidates taking the new chemistry programme where experimental work is deemed of major importance. Imprecise accounts were often given such as candidates stating that water was used instead of deionized or distilled water. In (b) (i), most gave a correct colour change from blue to yellow, though some gave this the wrong way round. A few candidates also failed to read the question, which asked for colour change and gave a single colour such as blue or yellow. (b) (ii) was well answered and most scored both marks here. In (c) most of the answers seen referred to either random or systematic errors, suggesting that many had not actually done a titration of this nature and failed to read the wording of the question which stated that the titrations were performed very carefully. There were numerous G2 comments on Q2 overall and in particular Q2 (a) and (c). Some of these stated that the preparation of a solution is not a mandatory experiment and that the precise answer to (c) is unclear. As regards the first of these comments it should be emphasized that an experimental question of this nature is not just limited to the set of prescribed mandatory experiments on the syllabus, and key experimental skills may be assessed, within the general realms of the indicative syllabus of the programme. The preparation of a solution is one such key skill. In relation to 2 (c), the question is a hypothesis type question, based on the suggest command term. For this reason a number of possible answers were included on the markscheme (the most obvious was that the colour is difficult to detect) and several others were actually accepted (though some not strictly correct) after careful examination of several scripts during the standardization process. Another teacher commented “Q2 seems a good and fair test of student’s experimental design and practical experience and is well within the expectations for students who have done this type of work in the laboratory”.

Section B

Option A - Materials

Few candidates attempted this option (approximately 4%), though of those that did, most made a fair attempt at most questions. The Option certainly appeared to be more challenging than some of the other options. This was reflected in some of the G2 comments, where one teacher commented that compared to Option B, Option A was a lot more difficult but nevertheless stressed the importance of the inclusion of material science as an option in the curriculum. Greater syllabus coverage was suggested for this option.

Question 3

The overall redox equation for the reaction of iron(III) oxide with carbon monoxide was well known. In 3 (b), most candidates predicted that iron(III) oxide is paramagnetic due to having no unpaired electrons present whereas aluminium oxide is diamagnetic since all its electrons are paired. Some nice responses were seen to this question where candidates explained their answers in terms of orbital diagrams for the respective ions. Some incorrectly tried to craft their responses in terms of the orbital diagrams for the elements instead of the respective ions. The electrolysis calculation on molten alumina in (c) was very well done and most obtained the correct answer of 186 g. In (d) (i), few candidates gave a precise answer of the fact that it is the collisions between electrons and positive ions that is the cause of electrical resistance in metallic conductors. In (d) (ii) superconductivity and the BCS theory were only partly understood. In (e) (i), the most common mistake involved representations of multiple unit cells in a lattice instead of showing a single unit cell diagram for the simple cubic structure of polonium metal which the question demanded. Most stated the correct coordination number of six however. The Bragg equation calculation in (e) (ii) proved no problem for candidates as they had access to this equation from the data booklet.

Question 4

This question was based on nanocatalysts. In (a), the majority of candidates were able to identify one concern of using nanoscale catalysts. In (b), many candidates struggled in scoring both marks for explaining why zeolites act as selective candidates. The understanding of selectivity was poor. The HIPCO process was well known in terms of the catalyst and conditions used.

Question 5

This question was poorly answered and few scored both marks. Many described the structure of ceramics but then failed to describe how these differ from the structure of metals which contain a lattice of positive ions in a sea of delocalized electrons. Again, chemical terminology such as structure and bonding should be deemed critical elements in the holistic teaching of chemistry to candidates.

Question 6

LCDs have appeared on a number of recent papers and this question should have proved to be of little difficulty if candidates had practiced questions from previous papers. In reality in (a) often only one mark was scored. In (b) (i) and (ii), the better candidates scored full marks on Kevlar®, but some of the weaker candidates could not deduce the correct formula of the repeating unit in (b) (i).

Question 7

This question was based on PVC. In (a), most candidates scored at least one mark but typically failed to score M2 by failing to state that PVC becomes more flexible and softer when a plasticizer is added by weakening the intermolecular forces of attraction. In (b), the majority of candidates stated that hydrochloric acid which can contribute to acid rain is produced from incineration which is an environmental issue associated with the use of PVC.

Question 8

Part (a) was based on the Haber-Weiss reaction. Few scored full marks and often there was inconsistent use of the radical symbol. The solubility question in part (b) was done much better this session compared to recent sessions and it was encouraging to see a high proportion of candidates scoring full marks on this. The most common mistake involved writing an incorrect K_{sp} expression at the outset of the solution to the problem.

Option B – Biochemistry

This appeared to be the most second most popular option (31% took this Option) and candidates conveyed a good solid knowledge of biochemistry. In several of the questions, performance was strong, though at HL it was very surprising that a high proportion of candidates gave incorrect bond connectivities and were not able to draw correct 3D representations for enantiomers or correct Fischer projections. This was highly disappointing. The overall option certainly appeared much easier than the other three and candidates with a strong biology background would have done very well here on some of the questions in particular. This was mentioned in one G2 comment. The option was well received by teachers in general though some were thrown by the question on foetal hemoglobin, which is part of the new syllabus. Other G2 comments stated that the advantages and disadvantages of biodegradable plastics are not explicitly on the syllabus and that this question may be on the edge of the syllabus. This was discussed at length during GA and although there is not an explicit mention in the guide of this sub-topic per se like in the previous syllabus (where there were numbered assessment statements) it was felt that in the new syllabus the sub-topic still resides within the broad parameters of interpretation of the topics contained within the Option itself.

Question 9

In (a) (i), candidates were asked to state the name of the functional group containing the carbon to carbon double bond in the DHEA molecule. This was an unfortunate question as the correct name for this group is ethanylylidene and not alkenyl. Alkenyl is actually a monovalent substituent, such as $–CH=CH_2$, $–CH_2CH=CH_2$, etc. but here in DHEA the fragment is trivalent

>C=CH– and so has the IUPAC name ethanylylidene. Candidates that gave the answer as alkenyl or even alkene (which is strictly incorrect as this is the class) scored the mark. It would have been much better if another unambiguous functional group in DHEA from a naming perspective such as hydroxyl was chosen in the question as it is important that candidates know the inherent difference between functional group and class name as part of the new programme and either the hydroxyl or carbonyl functional group would have served this purpose easily in this instance. This was mentioned in one G2 comment which is a valid statement. In (ii), most candidates were able to identify the fused ring structure of a steroid. (b) was well done.

Question 10

In (a) the better candidates scored all three marks. The question asked specifically for structures as opposed to structural formulas – this was lost on a number of candidates, though condensed structural formulas were accepted, although not strictly correct. One G2 comment stated that three marks was too much for this question, which in hindsight is a fair criticism. In (b) (i), a large percentage of candidates scored both marks; some scored only one mark for getting Leu at the centre. In (ii), six tripeptides were typically identified though some gave twenty seven, which was accepted. The most common incorrect answer was nine. (c) (i) was very poorly answered. Wedge-dash 3D notation for the two enantiomers was rarely seen and even then often incorrect representations were drawn. Incorrect bond connectivities were widespread. Some candidates tried to draw Fischer representations but typically failed to represent the position of the substituents correctly. The L enantiomeric form of serine was correctly identified by most in (c) (ii).

Question 11

The equation for the cellular respiration of glucose and the energy calculation in (b) were both very well answered. In (c), although some candidates scored one or two marks out of the allocated four marks, few scored all four marks. Again like in Q10 (a), there were G2 comments stating that four marks was too much for a sub-topic which could be interpreted as being on the edge of the syllabus. This is a valid point and two or three marks would have been a better allocation of the marks. Most were able to sketch the correct graph showing how the rate varies with pH in (d).

Question 12

Performance in both parts of this question was excellent. The most common mistake in (a) was having the sketched curves for competitive and non-competitive crossing the given curve. Some also had the non-competitive curve decreasing again once it tailored off which is incorrect. In (b), 4.6 was sometimes incorrectly calculated as the pH, by having 2.60×10^{-3} as the numerator instead of the denominator in the equation.

Question 13

Both parts here were also well answered. In (a) some candidates thought incorrectly that A and D consist of all non-polar parts and forgot the one OH group i.e. it consists of mainly non-polar components. In (b) the most common mistake was identifying Z as chlorophyll a instead of chlorophyll b. One teacher queried how candidates could answer such a question without a ruler. Candidates (and teachers) should be familiar with the official list of allowed material that can be brought into examination centres.

Question 14

This question proved to be a good discriminator for potential Grade 7 candidates. The top tier candidates scored all three marks in (a), but even they often struggled in getting even one mark in (b). An adequate explanation as to why foetal hemoglobin has a greater affinity for oxygen was rarely conveyed. On teacher felt that the term "blood plasma" may not be widely known and biology students would therefore have an advantage. Based on the performance of candidates, the main issue with Q 14 was in fact non-familiarity of new material from the new curriculum for a vast tranche of candidates and not the wording of the question itself in (a).

Option C – Energy

It was encouraging to see so many candidates choose this new option on energy (24%). Performance was highly satisfactory in certain topics of this option, in particular nuclear energy. However knowledge of some of the newer sub-topics such as the PEM fuel cell and DSSCs was sketchy.

Question 15

In 15 (a), incorrect IUPAC nomenclature or incorrect structures were common. (a) (ii) was reasonably well answered if an acyclic hydrocarbon was chosen in (a) (i) but less so if benzene was chosen. The calculation on the specific energy of octane to yield 47.9 kJ g^{-1} was scored by virtually every candidate. In (b) (ii) few scored both marks. In (c), most candidates incorrectly wrote $C(s) + 2H_2O(g) \rightarrow CH_4(g) + O_2(g)$ for the equation showing the formation of methane from coal and steam, which showed very weak chemical understanding at HL. This again was quite surprising at this level.

Question 16

In (a), the most common mistake was simply writing alcohol for the reagent instead of a specific reagent such as methanol etc. (b) involved a NOS based question and was poorly attempted. Many candidates clearly were not prepared for this type of question.

Question 17

Parts (a), (b) (i) and (b) (ii) proved no problem for candidates. In (b) (iii), although most stated that cells can be damaged, few mentioned the fact that radicals are produced. In (c) (i), the most common mistake occurred on the mass of nucleons calculation. Some teachers felt that the mass of the helium-4 nucleus should have been given in the question. However the conversion from amu to kg is given in Section 2 of the data booklet, so could be worked out as $4 \times 1.66 \times 10^{-27} = 6.64 \times 10^{-27}$ kg. In (c) (ii) it was necessary to divide by four and to convert J nucleon^{-1} to kJ nucleon^{-1}. The unit conversion was missed by virtually every candidate except an odd few and it was decided that this would not in fact be penalized since the question was only allocated one mark.

Question 18

In this question on the effect of increasing atmospheric carbon dioxide on the pH of oceans, few gave a correct equation. Most stated correctly that the pH decreases however.

Question 19

In this question many candidates did not state that the CO bonds stretch asymmetrically resulting in a change in the dipole moment.

Question 20

Few candidates scored the two marks for the anode and cathode half-equations for the PEM fuel cell. Many just wrote the corresponding half-equations for the hydrogen-oxygen fuel cell. In (b), the better candidates were able to give one advantage and one disadvantage of a fuel cell over a lead-acid battery as an energy source in a car. Many did not realize that in the lead-acid battery water is also generated, so stating that water is non-polluting cannot in this instance be deemed an advantage of the fuel cell over the lead-acid battery.

Question 21

Part (a) which focused on n- and p-type doping of silicon was very well answered. (b) was based on DSSCs. Most candidates mentioned large surface area but few stated anything else, in particular the fact that the dye allows absorption of a wide range of wavelengths.

Option D – Medicinal chemistry

This was the most popular option, with over 40% taking it. Overall performance was very satisfactory.

Question 22

Part (a) proved slightly problematic and many did not read the wording of the question and gave stock answers from previous mark schemes. In (b) the main difficulty for candidates was that two dangers of the overuse of antibiotics were required for one mark, a point raised by several teachers. This is a fair criticism.

Question 23

One G2 commented stated that this esterification reaction is not on the syllabus. This is incorrect and the synthesis reaction for the conversion of morphine to diamorphine is explicitly mentioned on P. 160 of the guide. In part (a), incorrect by-products linked to a given reagent were frequently given. Both (b) and (c) were very well answered. In (c), some gave the range for the hydroxyl group of a carboxylic acid instead of the 3200-3600 cm^{-1} range.

Question 24

The equation for the neutralization of stomach acid with magnesium hydroxide was usually formulated correctly, though some candidates incorrectly cited MgCl for $MgCl_2$ and MgOH for

$Mg(OH)_2$. This is highly disappointing at HL, again stressing the importance of integrating core material in the teaching of applied material in the four Options. In (b), candidates were asked to compare and contrast the use of omeprazole and magnesium hydroxide. Few scored all three marks. Most knew that omeprazole is a proton-pump inhibitor and that magnesium hydroxide neutralizes the excess acid present, but few scored the mark allocated for the similarity i.e. that both compounds relieve symptoms of acid reflux.

Question 25

The question on medical radioactive waste and how each must be treated for proper disposal proved to be a real issue for candidates. Many gave low level waste as one example but then often failed to outline the correct treatment i.e. the fact it must be stored in a shielded container for example until the isotope has decayed and then can be disposed of as non-radioactive waste. Many gave high-level waste which is incorrect as this relates to nuclear reactions. A named isotope or radioactive sources would have scored the mark here. In (b) incorrect species, such as mercury, were often written and frequently the alpha particle was placed on the left side of the equation (not the right), even though the question clearly stated that alpha decay was involved. In (c), many candidates did not give specific answers such as the fact that there is selective targeting of cancer cells. Many candidates guessed the type of cancer at random and failed to understand that metastatic cancer is involved. (d) was well answered. In (e) few understood the question, and referred to risks and not ethical implications of using nuclear treatments in medicine. For example the risk of cancer to the patient is not an ethical issue, whereas the risk of cancer to the health worker is.

Question 26

In (a), although a significant percentage of candidates identified correctly the ether functional group in Tamiflu, some incorrectly stated ester and some stated carbonyl. In (b), three was typically given for the number of signals, but few got the correct relative integration. In (c) (i), many candidates failed to read the question which asked for apparatus, not a technique. In (c) (ii), the better candidates scored both marks. The most common mistake was stating that enantiomers rotate the plane of polarized light in different angles instead of stating in opposite directions but by the same angle.

Recommendations and guidance for the teaching of future candidates

- NOS lies at the heart of the new programme. Candidates need to be exposed to NOS on a constant basis throughout the delivery of the curriculum as this is an integral part of the teaching of the new IB Chemistry curriculum. Otherwise candidates may struggle with some of the questions on the examination papers which have a NOS focus.
- It is imperative that laboratory work lies at the centre 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.
- It is critical that core chemical principles are brought to the fore in all of the four options. Core chemistry should always underpin applied topics. This is a major feature of the new curriculum.

- Candidates need to be aware of the scientific method and need to be challenged on hypothesis type questions.
- Candidates continue to struggle with questions that require explanations, interpretations or multiple steps. Candidates need to fully understand the various command terms in the guide (especially the new ones) and teachers should take time to review command terms throughout the year with students to ensure that they understand how to answer questions. Lack of understanding of many command terms by candidates was certainly a feature of this session.
- 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 not required.
- Legible handwriting should be encouraged – there was certainly a noticeable number of scripts this session where examiners struggled greatly in trying to decipher what was in the responses.
- Students need practice in writing balanced equations for the conversion of reactants into products. The use of state symbols should be encouraged as best practice.
- The correct use of significant figures should be encouraged, including how significant figures are dealt with for logarithmic entities where the mantissa needs to be considered.
- Many candidates still use class names instead of functional group names. The distinction between the two is a feature of the new syllabus, so there should be some emphasis on this sub-topic.
- Bond connectivities should be emphasized – incorrect bond connectivities were widespread this session.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 12	13 - 16	17 - 19	20 - 23	24 - 35

General comments

Many candidates were well prepared for the paper and it appeared that they had covered the option material thoroughly. Option D was the most popular option this session and Option A was answered by the least number of candidates. Calculations were generally well answered in the options, reflecting an improvement in skills from previous sessions. The area that was more lacking for many candidates was explaining facts using chemical concepts.

In the new Section A of paper 3, many candidates showed good data analysis and communication skills when answering Question 1 of Section A. They were often able to analyse and deduce relationships from data. However, many candidates did not show evidence that they were familiar with the details of basic experimental techniques like making a solution and titration, and performance on Question 2 of Section A was weaker.

We received detailed feedback from a large number of teachers this session, which was pleasing. 85% of teachers found the paper of appropriate difficulty. When comparing it to last year's paper, 42% of teachers found the paper of a similar standard to last year's paper, while 25% found it a little more difficult and 18% considered the comparison to last year not applicable due to the change in the structure of the paper.

88% of teachers thought the presentation of the paper was good to excellent, and 77% fond the clarity of wording good to excellent. A frequently expressed concern was that the labels of Sections A and B and Options A and B were confusing for some candidates. However only a very small number of candidates did not complete this section A, and most of these same candidates did not score marks in Section B.

There were many positive comments from teachers about the paper being fair and a good start to the new programme. Some teachers commented that Section A should only include the prescribed labs. The section will test experimental and data analysis skills in a variety of contexts and is not limited to the prescribed labs. It will include skills from Topic 11.

Some teachers expressed concern that there was too much focus on environmental issues in the paper. Please note that the environmental theme will continue to be a prominent one due to its importance (Aim 8 of the programme). The programme guide provides many links to environmental issues relating to the core and option concepts.

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

- Interpreting general trends that include discontinuities
- Interpreting molecular dipoles
- General weakness in practical work especially in how to make a solution and errors that can occur during a titration and their impact on the outcome
- Explaining the magnetic properties of ions
- Explaining how zeolites act as selective catalysts
- The structure of an atactic polymer
- The equation for a transesterification reaction
- Nuclear equations
- The equation of the reaction between carbon dioxide and water
- The importance of the structure of the beta-lactam ring
- The reagent needed for the synthesis of diamorphine from morphine
- Comparing and contrasting the use of omeprazole and magnesium hydroxide

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 analysing the data in question 1 and answering questions concisely.
- Calculations in part-questions 10(b), 11(b)(i), 13(b)(i) and 18(b) were correctly done by the majority of candidates.
- Predicting the result of electrophoresis
- The equation for the cellular respiration of glucose
- Dependence of rate of enzyme catalysed reactions on pH
- Identifying IR absorbance ranges that would help distinguish compounds

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

SECTION A

Question 1

(a) Well answered by the majority of candidates. Some candidates did not use the information given in the stem of the question clarifying that a greenhouse gas absorbed IR radiation. In some cases, candidates had misconceptions regarding the absorption of radiation that need to be addressed.

(b)(i) Most candidates were able to predict a reasonable value for the integrated IR intensity of CF_4.

(b)(ii) Candidates' performance was disappointing on this question. Most of the candidates only went as far as to state that F was more electronegative than Cl. Very few discussed individual dipole moments adding up to give the overall polarity of the molecule or drew appropriate diagrams. In addition, many candidates failed to fully score due to poor use of subject specific terminology.

(b)(iii) Most candidates identified the positive correlation between integrated IR intensity and GWP over 100 years. Some tried to give a quantitative relationship and the markscheme generously accepted a proportional relationship (although it is not correct). Some candidates did not answer the question and gave the relationship between other quantities.

(b)(iv) About a third of the candidates were able to provide thorough enough answers. Mistakes included simply saying that there was no correlation without providing the evidence, or failing to provide a good account of inconsistencies based on the values. Some students did not look closely at the data and simply noted the positive correlation shown by some of the compounds. A statistical analysis would have yielded a weak positive correlation but this approach was rarely seen.

(b)(v) More than half of the candidates gained a mark for stating that the compounds made a significant contribution to global warming. Some only stated that they contributed to global warming without noting the large magnitude of the integrated IR intensity and GWP over 100 years and hence did not gain the mark. Only some candidates recognized the ozone depleting property of CFCs although this is part of the Core syllabus.

Question 2

(a) Many disappointing answers were given that indicated that many students either did not have the opportunity of making a solution in a volumetric flask or it was done early in the course and not remembered. Nevertheless, the markscheme included several stages and considerations like mixing the solution to make sure it is homogeneous and weighing the NaOH with an analytical balance to give candidates opportunities for obtaining the marks. Some teachers expressed concern that this was not a prescribed lab and should not have been included. However it should be emphasized that an experimental question of this nature is not just limited to the set of prescribed mandatory experiments on the syllabus, and key experimental skills may be assessed, within the general realms of the indicative syllabus of the programme. The preparation of a solution is one such key skill.

(b)(i) More than half the candidates obtained the mark. Some candidates failed to obtain the mark by only stating that the indicator becomes yellow without stating the complete colour change. Some reversed the colour change and others did not check Section 22 of the data booklet although they were directed to do so in the question.

(b)(ii) This was well answered by about a third of the candidates. Many stated that excess acid may have been used but only some stated the correct effect on the calculated concentration of the NaOH solution.

(c) This was a discriminating question and only a fifth of the candidates obtained this mark. The best answer was that the colour of the indicator would change through a series of shades of green and yellow and it may be difficult to know when the required colour of indicator is reached to stop adding acid. There were some comments from teachers that the wording of this part-question was not clear and it left the students confused about the cause of the widely differing values obtained. It was pleasing to see some of them come up with specific suggestions that did not contradict the information given in the question that the student made the solution and conducted the titration carefully.

SECTION B

Option A – Materials

Question 3

(a) Well answered by many candidates.

(b) Some candidates answered this correctly. Some used the electron configuration of the atoms rather the ions. Many did not know how to explain magnetic properties.

(c) Some candidates were able to complete the calculation correctly and others obtained only one mark usually through the relationship between charge and Faraday's constant.

Question 4

(a) Well answered.

(b) Only a few candidates addressed what the question was asking. Many simply described the structure of zeolites but they did not explain how they act as selective catalysts.

(c) A small number of candidates named a correct catalyst. The conditions for the HIPCO process were known by about a third of the candidates.

Question 5

The question asked for a description of structure but only a few candidates described the metallic structure. Less than half obtained the mark for the structure of ceramics. Many candidates suggested properties of ceramics instead hence not scoring the mark.

Question 6

(a) Quite well answered.

(b) Well answered by about half of the candidates. Some candidates mentioned magnetic field or current flowing (instead of an electric field), which is not correct.

Question 7

(a) It was disappointing to see many incorrect structures of PVC containing the wrong numbers of atoms. In general candidates knew that the arrangement is random in the atactic polymer.

(b)(i) About half of the candidates could explain the effect of adding plasticizers.

(b)(ii) Only a few candidates suggested correct substances used as plasticizers.

(c) In general candidates were able to establish that PVC doesn't degrade easily or occupies space in landfills, with stronger candidates also correctly describing hazards resulting from incineration. A common mistake was stating that PVC released Cl_2 instead of HCl.

Option B – Biochemistry

Question 8

(a) Quite well answered but some candidates gave vague answers that were not specific enough. Some teachers expressed concern that 3 marks were excessive on the health hazards of steroid abuse.

(b)(i) The correct name of the specific trivalent C=C was actually ethanylylidene – a name the students were not expected to know. The expected answer was alkenyl, but many candidates are still using the class name instead of the functional group names in the new programme. “Alkene” was not penalized for this session.

(b)(ii) Very well answered by most candidates.

(c) Also well answered with most candidates discussing the medical uses of steroids, and some discussing the detection and effects of anabolic steroids on athletes.

Question 9

(a) Although the question asked for the structure, the majority of candidates gave condensed structural formulas instead. It was surprising that more than half of the candidates did not give the zwitterion and many did not have the correct charges or general structure in some cases. Please encourage candidates to place the charge on the correct atom in the structure.

(b)(i) Well answered by many candidates- even those who did not give the correct structures in part question (a). Most candidates at least placed Leu at the centre gaining one mark.

(b)(ii) Very well answered by most candidates.

Question 10

(a) About two thirds of the candidates gave the correct equation for the cellular respiration of glucose.

(b) The majority of candidates were able to calculate the energy correctly. Candidates must use the molecular masses given in Section 6 of the data booklet.

(c) Many candidates were able to deduce reasonable advantages and disadvantages for the use of bioplastics based on their chemical knowledge. Some teachers expressed concern for allocating 4 marks for this question whilst the syllabus might have been made clearer.

(d) Well answered by the majority of candidates.

Option C – Energy

Question 11

(a) Less than half the candidates were familiar with the reforming process and suggested a correct product. Some candidates knew they had to branch the molecule but they named the branched compound incorrectly.

(b)(i) Well answered by the majority of candidates. Some candidates quoted the specific energy as a negative value, which was not penalized this session.

(b)(ii) Many candidates were able to obtain at least one mark. The most popular answers for the advantage were that ethanol is less polluting or had a higher octane rating, and the most popular answers for disadvantages were that it has a lower specific energy and it uses land that could otherwise be used for food production.

(c) This was a discriminating question that a fifth of the candidates got right. The most common incorrect answer was to give oxygen as a product (unlikely in the presence of heated coal).

Question 12

(a) Many candidates named the correct reagent and catalyst. Some candidates failed to give the name of one correct alcohol answering with the class instead.

(b) This was one of the most discriminating part questions on the paper. Candidates found it challenging to draw the structure of the ester and the glycerol. Quite a few candidates did not even attempt to write the equation.

(c) This was a nature of science question that was only answered well by about a half of the candidates. Many answers were too vague.

Question 13

(a) Only a third of the candidates was able to give the correct nuclear equation. A common mistake was to give an alpha particle as a product instead of the four neutrons.

(b) Very well answered – most candidates calculated the time correctly and identified fission products as radioactive.

(c) This was an area many students were not confident in. Some discussed increasing the binding energy instead of binding energy per nucleon.

Question 14

This question was poorly answered by the majority of candidates. Only about half of the candidates acknowledged that the pH of the oceans decreases. Some candidates stated that pH increased and some candidates did not address this part of the question. A few candidates discussed the shift in equilibrium, and few candidates gave an equation for the formation of carbonic acid, but the ionization to H^+ and HCO_3^- that was required for the mark was rarely seen.

Question 15

Rather disappointing performance by some candidates. A small percentage of candidates mentioned the change in dipole moment that occurs when IR radiation is absorbed, required for the second mark. About half of the candidates gained the first mark but many answers were rather general rather than specifying “asymmetric” stretching and clarifying what is meant by “bending”.

Option D – Medicinal Chemistry

Question 16

(a) Few candidates gave complete answers to this question. Some candidates focused on the beta-lactam ring binding to the bacterial enzyme responsible for forming the cell walls gaining the third mark, but only a small proportion of candidates discussed the strained angles and the ring opening.

(b) Most students recognized bacterial resistance as a danger of the overuse of antibiotics, but the question required a second danger and not many candidates were able to provide a different danger. Damage to beneficial bacteria was the most common second danger provided by candidates. Most candidates focused on the outcomes of bacterial resistance, which did not score the mark.

Question 17

(a) About a quarter of the students answered this part correctly. The mark for the by-product was only awarded if it matched the chosen reagent. The name of the anhydride was a challenge to some candidates. They would have obtained the mark with the structural formula instead.

(b) A very well answered question by the majority of candidates. A common mistake was choosing the absorbance range for O—H in carboxylic acids instead of alcohols and phenols. Some candidates did not read the question carefully and did not provide absorbance ranges.

(c) Well answered by about half the candidates. Most candidates stated that diamorphine crosses the blood-brain barrier more easily than morphine and many stated that diamorphine was less polar than morphine. Few were able to relate polarity to the structure and few explained that morphine was more soluble in blood and diamorphine was more soluble in lipids.

Question 18

(a) Well answered by many candidates.

(b) Very well answered by most candidates. Some candidates rounded values to an inappropriate number of significant figures leading to inaccurate answers.

(c) This was a challenging question. About half of the candidates understood that magnesium hydroxide neutralizes excess acid while omeprazole stops the production of acid, which was pleasing. However, only few candidates discussed that both cure heartburn or indigestion or increased stomach pH. The third mark was the most challenging to obtain but some candidates stated that omeprazole had a long term effect while magnesium hydroxide only had a short-term effect. Some candidates did not seem aware that the command term “compare and contrast” requires the identification of similarities and differences.

Question 19

(a) This question was poorly answered by the majority of candidates. Candidates were expected to distinguish the radioisotopes used in treatment from the materials and instruments used in radiotherapy like gloves and syringes. The treatment described by many candidates was more suitable for high-level waste from nuclear reactors rather than medical radioactive waste. Some candidates misunderstood the question that asked for “examples” and discussed “types” of waste instead. The markscheme generously accepted “low-level” and “medium-level waste” to support these candidates.

(b) Well answered by some candidates. Many missed the reference to “ethical” issues and simply discussed cancer risk for the patient, which was not awarded marks.

Recommendations and guidance for the teaching of future candidates

- It is important to stress understanding and cross-reference to core concepts when covering the options.
- Please provide enough opportunities for hands on work during the course.
- Please encourage students to give examples and write precisely when analysing data.
- Please provide opportunities for exploring the nature of science. Many suggestions are provided in the programme guide.
- Throughout the course, draw your students’ attention to the implications of concepts learnt on the environment. Suggestions are provided in the right hand column in the programme guide.
- Please reinforce the command terms during the course. For example compare and contrast requires the identification of similarities and differences.
- Insist that students give the initial and final state when a “change” is required.
- Relating acidity to pH change was a difficulty for a number of candidates, which was surprising for a core concept. Please provide opportunities for using pH values and pH measurements in the lab.
- Please encourage students to use the appropriate names of functional groups rather than the class names when requested, for example alkenyl rather than alkene.
- Please encourage candidates to use A_r values in section 6 of the data booklet, round numbers correctly and state answers to calculations to an appropriate number of significant figures.
- Train students to be specific in their answers and to read questions carefully to ensure that they answer every part of the question.