# Chemistry

*Timezone 2*

*To protect the integrity of the examinations, increasing use is being made of time zone variants of examination papers. By using variants of the same examination paper candidates in one part of the world will not always be taking the same examination paper as candidates in other parts of the world. A rigorous process is applied to ensure that the papers are comparable in terms of difficulty and syllabus coverage, and measures are taken to guarantee that the same grading standards are applied to candidates' scripts for the different versions of the examination papers. For the May 2019 examination session the IB has produced time zone variants of Chemistry.*

# Contents






International Baccalaureate
Baccalauréat International
Bachillerato Internacional

# Grade boundaries

## Higher level overall

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 17 | 18 - 33 | 34 - 47 | 48 - 58 | 59 - 69 | 70 - 80 | 81 - 100 |

## Standard level overall

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 16 | 17 - 32 | 33 - 45 | 46 - 57 | 58 - 67 | 68 - 78 | 79 - 100 |

## Internal assessment

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

## Higher level paper one

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 10 | 11 - 16 | 17 - 23 | 24 - 27 | 28 - 31 | 32 - 35 | 36 - 39 |

## Standard level paper one

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 7 | 8 - 12 | 13 - 18 | 19 - 21 | 22 - 23 | 24 - 26 | 27 - 30 |

## Higher level paper two

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 13 | 14 - 27 | 28 - 38 | 39 - 48 | 49 - 57 | 58 - 67 | 68 - 90 |

## Standard level paper two

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 8 | 9 - 17 | 18 - 21 | 22 - 27 | 28 - 32 | 33 - 38 | 39 - 50 |

## Higher level paper three

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 8 | 9 - 16 | 17 - 22 | 23 - 27 | 28 - 31 | 32 - 36 | 37 - 45 |

## Standard level paper three

| Grade: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Mark range: | 0 - 5 | 6 - 10 | 11 - 14 | 15 - 18 | 19 - 22 | 23 - 26 | 27 - 35 |

# Higher/standard level internal assessment

## The range and suitability of the work submitted

The overwhelming majority of the work submitted was appropriate for assessment using the IA criteria and was the outcome of students being given sufficient opportunity for independent open-ended investigation with very little of the work appearing to be prescriptively directed by the teacher. Unusually this year we did see a small number of investigations submitted that had no chemistry content and were solely within the realms of Biology or Physics. Maybe this reflected some confusion with the Group 4 Project, where students are free to work outside of their normal discipline. However for the Internal Assessment component we do expect the Individual Investigations to be firmly grounded in the realms of Chemistry. Pleasingly there were fewer concerns raised by examiners where schools had submitted samples in which all students had studied similar aspects of the same topic.

Overwhelmingly the work presented involved hands -on primary data collection with a small proportion based on secondary data from databases. Although each session we see only a very small number of such types of investigation those we have seen have often been very good and attained very well against the criteria. The concern expressed by teachers has been that such investigations have limited capacity to take into consideration measurement uncertainty. This is often a valid consideration and certainly such investigations work best when there is more than one source of data available so that the variance between sources can be evaluated. Investigations based on models and simulations were extremely rare.

Within the traditional laboratory-based investigations the most common topic areas were food chemistry and kinetics followed by investigations based on calorimetry or electrochemical cells. Within food chemistry there was more variety than in previous sessions. Vitamin C based investigations were not quite as numerous as in previous years, although still popular, while the next most popular topic related to calcium ion determinations.

Most investigations involved a significant quantitative component, and this has been an area of improvement. Within kinetics for example more students are going beyond a qualitative evaluation of the effect of a factor on rate and are actually looking to establish a quantitative relationship or carry out significant processing to determine the rate constant, rate equation or Activation Energy.

There was the usual range of overly narrow brand analyses such as iron content in diet supplements or antacid tablet comparisons and other investigations where the independent variable appeared to be a random collection of available substances with no obvious link between them.

## Candidate performance against each criterion

### Personal Engagement:

The overwhelming majority of students managed to achieve at least one point for Personal Engagement. A continuing weakness is that the student's justification of their choice of research question and topic spilling over into overlong and contrived personal narratives. Some of the narratives were barely credible such as a candidate who professed a long-standing fascination with the gas syringe. Also, some teachers seem to consider Personal Engagement to be a section of the report and require students to write it up before beginning their research. It is actually a holistic criterion assessed using evidence across the whole report.

The commonest limitation to achievement was where students failed to show genuine curiosity by presenting a very undemanding research question where the outcome is too self-evident such as determining the gas constant R or a trivial brand analysis such as comparing different antacids. Where students presented a research question that reflected a question that they genuinely appeared interested in answering and couldn’t already be expected to know the answer then credit was easily given.

The second part of the descriptor regarding personal input and initiative is evidenced across the whole report and here as in previous sessions the outcome was again variable. 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. Less highly achieving candidates showed themselves not to be 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.

## Exploration

The achievement in Exploration was variable although most students were able to achieve at least middle band fulfillment of the assessment criterion.

In many cases a suitable topic was identified and a relevant research question was described with the research question often falling into the category of determining how a measurable independent variable effected an identified dependent variable. These research questions achieved well against the assessment descriptor and also frequently facilitated a successful fulfillment of Analysis and Evaluation criteria. However it wasn't uncommon to have long introductions justifying personal interest to be followed by a research question totally unrelated to previous context which is something that reduces how well focused the research question is considered to be. Another weakness was where students posited overly ambitious research questions that could not be answered by their methodology. This was especially prevalent in the food and nutrition-based investigations where the Research Question often related to health effects in the body whereas the methodology simply measured the content of substances such as vitamin C, caffeine or calcium in a range of sources or under different cooking conditions. In such cases it is the Research Question that can be more easily rephrased so as to be in harmony with the ensuing practical investigation. Students should be challenged to reflect on what exactly their methodology is testing or measuring and discouraged from stating Research Questions with ambiguous terms such as “efficiency” and “suitable”.

The quality of background information was uneven. Some candidates provided a very relevant theoretical context, including relevant chemical equations, that was directly related to the research question in hand. In many other cases though the background was only focused on the wider topic so was subsequently too broad or actually unrelated to the research question under investigation. A common weakness was illustrated by a report of an investigation on the effect of tea on iron uptake in the body. There was a large section on iron and haemoglobin and another large section on tea (chemical and non-chemical) but crucially they were not linked together to discuss how tea may affect iron uptake.

The aspect of the Exploration criterion that is most challenging is to design a methodology that addresses the research question and takes into consideration the significant factors that may influence the relevance, reliability and sufficiency of the collected data. Here students need to consider the range and frequency of the tested independent variable, the number of repeats and the control of other influencing variables. Only a minority of students achieved this fully. Common weaknesses included ignoring the control of variables in the procedure even though they had been earlier identified as relevant, implementing poorly considered methodologies such as using a beaker without a lid for calorimetry investigations or failing to consider the control of temperature in experiments lasting several days.  Calorific determinations of foodstuffs usually ignored moisture content and similarly the many investigations based on the alcohol homologous series failed to recognize the alcohols are not 100% pure and most probably have significant water contents that can be allowed for. A significant number of investigations had otherwise appropriate methodologies but the students had determined quantitative relationships based only on two or three changes of independent variable, which is insufficient. There were many investigations based on Beer's law but few students understood that its linearity does not hold at very low and very high concentrations and this needs to be considered. As in previous sessions some students had invalidly determined the absorbance values of suspensions where Beer’s Law of course does not apply.

Other frequently seen weaknesses included poor attention to drying in experiments where massing products was crucial, not calibrating instrumentation such as pH meters and most commonly imprecise volumetric work to make up solutions using measuring cylinders and beakers rather than graduated pipettes and volumetric flasks. Some students used surveys to collect data. This is rarely appropriate as a methodology in Chemistry.

The proportion of reports featuring meaningful awareness of safety, ethical or environmental issues relating to the use and disposal of equipment and materials was high. A few moderators noted that there have been a number of biochemistry related crossover investigations where animal or human products such as blood, saliva and even in one case urine have been used. These products have to have been ethically sourced (they often break the IB policy) and handled safely. In many cases it would be sensible to guide students to an alternative investigative direction to avoid such material. The number of schools that encouraged students to work with green chemistry including using much smaller quantities of reagents appeared to be low.

## Analysis

The overall achievement for Analysis was similar to previous sessions with most students securing some credit for recording data however the subsequent processing was understandably varied. Many students recorded qualitative observations and sufficient data related to the independent and dependent variables so that they could subsequently carry out sufficiently meaningful processing and interpretation. Fewer students than previously presented unhelpful photographs as qualitative data which was also encouraging.

Only a minority of students recorded the data regarding the control variables such as reaction temperatures or reactant amounts. It is this wider data that can provide valuable context for the evaluation of the procedure. Other students included the expected qualitative data in the method, but such anticipated results do not always match those obtained during the collection of actual data, therefore this practice shouldn't be encouraged. Also note that while including uncertainties in the list of materials may be a good strategy, recorded data should include them as well so always encourage the recording of uncertainties in the raw data. Where students often missed out recording uncertainties was in the molar concentration values of reactant solutions used. As ever a frequent omission was not recording the initial and final volumes in titrations but only the total volume used.

A common approach to processing was simply to average the dependent variable data and then plot a graph against the independent variable to see the nature of the relationship. Very often this was done well enough to award good credit. Other common data processing approaches were quantitative determinations based on titrations and calorimetry calculations. In some cases the numerical calculations were demanding and it is important to reinforce the message given in previous sessions' reports that teachers must check through calculations when assessing Analysis. Yet again on a significant number of occasions calculations had been awarded the highest level by the teacher but when spot checked by the examiners revealed themselves to contain major errors that significantly affected the conclusions drawn. These oversights very often lead to the downward adjustment of the Analysis mark.

Weaker candidates interpreted results qualitatively with no actual calculations. In other instances teachers significantly over-rewarded processing that was limited to very simple calculations, including averages of very dispersed values or outliers included, leading to at best a bar graph that added little/no value. Another fairly common weakness was the invalid plotting of scatter plots (or even bar charts) with trendlines when the independent variable was non-continuously measurable.

A weakness for mid-range achievement was seen in rate of clock reaction investigations where students did some valid calculation work but wrongly considered 1/time to directly be the average rate itself. Either the students should acknowledge that it is 1/time and label axes and tables accordingly or they should go further to derive the rate by calculating the change in concentration and then dividing that by the time.

Treatment of uncertainties continued to prove challenging with many students using statistical approaches not justified by the low number of collected values. They were many investigations that didn't report uncertainties at all and a significant proportion of other reports showed standard deviations with very few trials. Generally speaking we do not expect standard deviation calculations in most chemistry analyses.

It wasn't uncommon to find very dispersed values and the student ignoring this fact. Students are expected to identify outlying data and to critically decide how to deal with them in the processing of data. One common weakness is that some students failed to realize the collected data were within the uncertainty range and could hence not support the later interpretation.

Many students were able to interpret their processed data so that subsequently a conclusion to the research question could be deduced although in a significant number of lower attaining reports the interpretations were often merely prose descriptions of the data presented earlier. Where students did try to extract a quantitative relationship from their graph, a number revealed misconceptions such as describing a negative correlation as inverse and it was noticeable that the teacher did not pick up on this in their comments. Possibly in response to last year Subject Report it was less common for students to simply present a complicated Excel graph line equation without any further interpretation.

## Evaluation

Evaluation is the most challenging criterion to be fulfilled since an appreciation of the significance of their findings and the limitations of the methodology requires deep reflective thinking skills. The achievement against the descriptors of this criterion were similar to previous sessions with only a small proportion of students attaining the top band.

The first strand of the criterion usually yielded some credit since most students were able to make a statement that drew a conclusion consistent with their processed data. However for many this was limited since it was an overstatement of an observed trend but actually not clearly supported beyond the bounds of the measurement uncertainty.

Achievement against the second aspect of Evaluation was poor with many students failing 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 determined quantities to readily available literature values or referring to whether any trends and relationships identified were in line with accepted theory, ideally by referring back to their original background information.

Most students did identify weaknesses and limitations although these were mainly procedural (why the planned method was not properly implemented) and few were methodological (why the designed method itself was flawed or limited). Yet again only the higher achieving students evaluated errors in the terms of systematic or random. These distinctions are outlined in Topic 11.1 of the Chemistry Guide and their use should be promoted.

The aspect of the criterion concerning suggestions for improvements and extensions were a general weakness. Often the weaknesses were superficial (more repeats, use a digital probe, have a second student help) and few addressed meaningfully methodological issues such as calibration, range or adapting the method to reduce systematic error. Extensions continue to be poorly addressed and often omitted. One moderator commented that material revealed quite a few teachers misinterpret extensions as suggested applications to broader context such as industry. In fact, it is intended that suggested extensions should address the question of what the student would do if they were given the same time again to take their investigation further or deeper.

## Communication

The Communication criterion was in most cases well fulfilled with many students earning at least three marks.

Many 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. It is not sufficient to simply present a few equations of relevance but not to show how they were actually used with the authentic data. Also, raw data was not always clearly presented.

Reports were mostly concise and most of them did meet the 12 page limit however some students persist in including lengthy appendices in order to circumvent the page limit ruling. Other reports included unnecessary cover sheets or contents pages.

Most of the reports were relevant although the one common area of weakness was the inclusion of too much general background information that wasn't focused on the Research Question as discussed in the section on Exploration earlier. A significant number of reports included pictures of chemicals, equipment and layouts that were unnecessary, e.g. a photograph of a common titration set up or revealed poor practice such as the absence of safety glasses. Some schools uploaded images in grey-scale although the report had made reference to colour such as different coloured data series and trendlines. It was not possible to properly follow the analysis in these cases

With regard to the use of terminology and conventions many students proved inconsistent in their use of labelling graph axes, units, decimal places and significant figures although in most cases understanding was not greatly hampered. A few schools in one region had not encouraged SI units or IUPAC nomenclature, a fact which impacted attainment in this criterion

The using of citations and references was usually seen although it was common for it not to be clear where and if a cited source had actually been used. Note that proper referencing is necessary to establish the academic honesty of the work. It is not though a part of the Communication criterion so does not impinge on the mark

## Recommendations and guidance 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 describe briefly in a paragraph the process of developing their methodology. This will help explain the amount of data collected and give insight into the decision making of the student.
- Encourage students to only include background information that is specific to their research question.
- Encourage students to reflect on data while collecting it so they have the chance to adapt or extend their procedural phase if the data are proving insufficient or erroneous.
- It is good practice for students to give a safety and environmental evaluation in any investigation involving hands on practical work even if it is to show that safety and eco-friendly disposal have been evaluated but no special precaution is then required.
- Encourage procedures to use lower quantities of chemicals to preserve the environment.

- Ensure students record all relevant associated data and not just the independent and dependent variable data.
- Address topics 11.1 and 11.2 of Measurement and Data Processing before students embark on their Individual Investigations.
- Methodologies should be written in sufficient detail so that the reader could in principle repeat the investigation.
- Where relevant to the analysis students should present at least one worked example calculation so the reader could understand how the data was processed.
- Encourage students to interpret results quantitatively wherever possible. This will also provide a sound foundation for high quality conclusions.
- Encourage students to evaluate errors in terms of being systematic or random. These distinctions are outlined in Topic 11.1 of the Chemistry Guide.
- Students should consider suggestions for improvements that are related to previously identified limitations and that should be realistic and specific to their investigation.
- Students should communicate using the internationally accepted scientific conventions such as SI units and IUPAC nomenclature.
- Title pages, indexes, content pages and appendices are unnecessary and should be discouraged.

## When assessing the students work teachers should:

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

# Higher level paper one

## General comments

The paper was sat by nearly 11,000 candidates (a 5% increase on last year's numbers) with a mean mark of 30.25. The mean mark in last year's paper (May 2018 Time Zone 2) was 26.62 which echoed other available data that this year's paper was more straight-forward.

We received feedback about the examination paper from 201 teachers which is appreciated. Most teachers commented that the paper was appropriate, well-balanced, clear and covered a wide variety of concepts. The paper was seen as fair and the coverage of topics was seen to be excellent. Some teachers commented that they appreciated the focus on application of concepts. Teachers generally found some questions to be straight-forward, while others were thought provoking and required further in-depth knowledge of the topics. Teachers commented that candidates completed the paper within the time allocated. Many also found the level of the paper appropriate, while a few teachers were concerned whether the paper was a little too easy to discriminate well at the top end. Teachers also commented that there were fewer questions requiring mathematical manipulation and that the math was simple enough to do without a calculator. This helped candidates to complete the paper within the allocated time.

There were several positive comments regarding presentation, and clarity of wording and diagrams.

Teachers also sent the following feedback:

### The best description of the difficulty of the paper

| Too easy | Appropriate | Too difficult |
|---|---|---|
| 8.46% | 90.05% | 1.49% |

### The best description of the difficulty of the paper in comparison with last year's paper

| Much easier | A little easier | Of a similar standard | A little more difficult | Much more difficult |
|---|---|---|---|---|
| 3.06% | 25.00% | 62.24% | 9.18% | 0.51% |

### Clarity of wording

| Very poor | Poor | Fair | Good | Very good | Excellent |
|---|---|---|---|---|---|
| 0.00% | 1.49% | 14.93% | 29.85% | 37.31% | 16.42% |

### Presentation

| Very poor | Poor | Fair | Good | Very good | Excellent |
|---|---|---|---|---|---|
| 0.00% | 0.00% | 10.95% | 26.87% | 37.31% | 24.88% |




International Baccalaureate
Baccalauréat International
Bachillerato Internacional

The table below lists the questions from least to most difficult. It shows the numbers of candidates who selected each of the options A-D and the discrimination index for each question (how well the question discriminated between high-scoring and low-scoring candidates).

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 34 | 85 | 116 | 140 | 10457 | 7 | 96.78 | 0.07 |
| 9 | 100 | 109 | 10213 | 377 | 6 | 94.52 | 0.13 |
| 17 | 10194 | 48 | 533 | 25 | 5 | 94.35 | 0.15 |
| 28 | 166 | 91 | 410 | 10131 | 7 | 93.76 | 0.16 |
| 4 | 288 | 163 | 270 | 10080 | 4 | 93.29 | 0.15 |
| 2 | 203 | 237 | 271 | 10078 | 16 | 93.27 | 0.15 |
| 1 | 335 | 262 | 9729 | 473 | 6 | 90.04 | 0.21 |
| 12 | 256 | 9617 | 678 | 249 | 5 | 89.01 | 0.28 |
| 21 | 197 | 837 | 9544 | 220 | 7 | 88.33 | 0.25 |
| 10 | 545 | 546 | 358 | 9345 | 11 | 86.49 | 0.28 |
| 3 | 1068 | 321 | 9234 | 173 | 9 | 85.46 | 0.28 |
| 7 | 430 | 781 | 9183 | 407 | 4 | 84.99 | 0.26 |
| 33 | 9173 | 676 | 793 | 155 | 8 | 84.90 | 0.34 |
| 37 | 624 | 9132 | 542 | 499 | 8 | 84.52 | 0.38 |
| 29 | 598 | 989 | 8947 | 263 | 8 | 82.80 | 0.37 |
| 39 | 357 | 1268 | 8826 | 345 | 9 | 81.68 | 0.40 |
| 5 | 1391 | 385 | 234 | 8784 | 11 | 81.30 | 0.30 |
| 15 | 451 | 1426 | 8752 | 169 | 7 | 81.00 | 0.36 |
| 13 | 8372 | 1475 | 455 | 492 | 11 | 77.48 | 0.43 |
| 22 | 8318 | 1386 | 653 | 438 | 10 | 76.98 | 0.50 |
| 24 | 179 | 890 | 8292 | 1437 | 7 | 76.74 | 0.42 |
| 26 | 211 | 8220 | 1652 | 714 | 8 | 76.08 | 0.42 |
| 19 | 7982 | 106 | 216 | 2488 | 13 | 73.87 | 0.28 |
| 35 | 2209 | 7817 | 562 | 205 | 12 | 72.35 | 0.38 |
| 16 | 1124 | 7738 | 1069 | 866 | 8 | 71.61 | 0.48 |
| 36 | 696 | 922 | 1498 | 7659 | 30 | 70.88 | 0.41 |
| 14 | 293 | 422 | 7652 | 2433 | 5 | 70.82 | 0.47 |
| 25 | 457 | 7503 | 1296 | 1541 | 8 | 69.44 | 0.45 |
| 6 | 7450 | 2841 | 98 | 408 | 8 | 68.95 | 0.38 |
| 11 | 1692 | 7319 | 1260 | 519 | 15 | 67.74 | 0.56 |
| 38 | 289 | 7249 | 2786 | 465 | 16 | 67.09 | 0.49 |
| 40 | 1082 | 1177 | 1341 | 7194 | 11 | 66.58 | 0.51 |
| 32 | 823 | 2787 | 367 | 6818 | 10 | 63.10 | 0.46 |
| 27 | 6684 | 819 | 2787 | 506 | 9 | 61.86 | 0.37 |
| 23 | 1272 | 2336 | 6675 | 510 | 12 | 61.78 | 0.61 |
| 8 | 483 | 2543 | 6241 | 1511 | 27 | 57.76 | 0.57 |
| 31 | 990 | 897 | 2754 | 6153 | 11 | 56.95 | 0.52 |
| 30 | 6105 | 800 | 2475 | 1415 | 10 | 56.50 | 0.57 |
| 20 | 2818 | 774 | 1629 | 5574 | 10 | 51.59 | 0.61 |
| 18 | 2286 | 696 | 1231 | 6586 | 6 | 21.16 | 0.25 |

**Number of candidates : 10805**

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

- Deducing how molecular speeds vary for different gases at the same temperature.
- The way a catalyst works.
- Deducing the strongest oxidizing agent using standard electrode potentials.
- Deducing the products of the electrolysis of an aqueous solution.
- Deducing the oxidation state of the metal ion and the charge of the complex ion.
- Calculating $K_c$ after deducing the equilibrium concentration of a product.
- Effect of temperature on water dissociation and its pH.
- Deducing the hydrocarbon with the lowest boiling point.
- Identifying the analytical technique that involves breaking covalent bonds.
- Identifying the appropriate number of significant figures for the answer of a calculation.

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

- Naming a branched alkane.
- The formation of stable ions.
- Identifying the reaction with the greatest increase in entropy.
- Deducing the oxidation state of sulfur in different molecules.
- Deducing the numbers of sub-atomic particles in an ion.
- Balancing an equation and obtaining the sum of the coefficients.
- Calculating the amount of product using a balanced equation.
- Determining the numbers of sigma and pi bonds in a molecule.
- Deducing the order with respect to each reactant from experimental data.
- Factors affecting the strength of metallic bonding.

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

### Question 1

90% of the candidates were able to deduce the amount of a product given the amount of another product and the balanced equation.

### Question 2

93% of the candidates balanced the equation for the combustion of propene and obtained the sum of the integer coefficients.

### Question 3

85% of the candidates were able to deduce the new volume of a sample of gas after the pressure was halved. The most commonly chosen distractor was the value that assumed a direct proportionality between volume and pressure.

### Question 4

93% of the candidates deduced the correct numbers of protons, neutrons and electrons in the sulfide ion.

### Question 5

81% of the candidates identified the transition the emits the least energy in the given four transitions in the hydrogen atom (which was n=4 to n=3). The most commonly chosen distractor was A (n=2 to n=1) which means these candidates did not realize that the energy levels in the hydrogen atom converge at higher energy.

## Question 6

69% of the candidates understood how colour is produced in transition metal complexes. The most commonly chosen distractor was B, which also recognized the involvement of the split d-orbitals, however stated that colour is produced when light is emitted when electrons fall between split d-orbitals.

## Question 7

85% of the candidates know the trends in ionization energy and ionic radius down Group 17. The other distractors were equally chosen by the remainder of the candidates.

## Question 8

This was one of the most challenging questions on the paper and it discriminated well between high scoring and low scoring candidates. 57% of the candidates were able to use the formula of the compound to deduce the oxidation state of the metal ion and the charge of the complex ion. The most commonly chosen distractor was B where the charge of the complex ion was correct but the charge of the metal ion was not. Some teachers commented that the question was challenging but reasonable.

## Question 9

One of the most straight-forward questions on the paper about how lithium forms its most stable ion.

## Question 10

A straight-forward question about factors affecting the strength of metallic bonding answered correctly by 86% of candidates. The distractors were almost equally chosen by the rest of the candidates.

## Question 11

This was a highly discriminating question. 67% of the candidates identified the species that has a square planar molecular geometry. One teacher commented that this was a difficult recall question. However, the intention here is not to memorize shapes but rather to use VSEPR theory to deduce the shape.

## Question 12

89% of the candidates deduced the numbers of sigma and pi bonds in HCN correctly. The most commonly chosen distractor (C) had the correct number of sigma bonds but only one pi bond.

## Question 13

77% of the candidates deduced the hydridization of carbon and oxygen in methanal. A teacher commented that it was unusual to ask for the hydridization of oxygen, however, this is a reasonable application of the concept.

## Question 14

Only 70% of the candidates chose the correct calculation of the enthalpy change using bond enthalpy data. The most commonly chosen distractor (D) reversed the signs.

## Question 15

81% of the candidates identified the activation energy of the reverse reaction. The most commonly chosen distractor was B, the activation energy of the forward reaction.

## Question 16

72% of candidates chose the correct equation that represents lattice enthalpy. Many candidates chose A, where the ionic compound (NaCl) was gaseous, and others chose distractor C, where the ions produced were aqueous. The discrimination index for the question was quite high.

## Question 17

94% of the candidates chose the change with the greatest increase in entropy.

## Question 18

This question generated debate among teachers. It extended the concept that equal amounts of gases at the same temperature have the same distribution of kinetic energy curve, to the molecular speed distribution among particles. Candidates had to know that kinetic energy is calculated based on speed and mass of the molecule to deduce the answer.

Some teachers welcomed the question as a "good challenge to students' thinking", others thought it was difficult and a couple felt it was outside of the syllabus.

It was by far the most challenging question on the paper with only 21% of candidates obtaining the correct answer. The majority of candidates chose distractor D which did not take note of the fact that the gases were at the same temperature and hence had the same average kinetic energy.

## Question 19

74% of the candidates chose the correct combination to give the greatest rate of reaction. The most commonly chosen distractor was D where "smaller surface area of same mass of $CaCO_3(s)$" was chosen. It seems these candidates confused "surface area" with "particle size".

## Question 20

This was surprisingly one of the most challenging questions on the paper and discriminated very well between high scoring and low scoring candidates. It tested understanding of the role of the catalyst. 52% of candidates chose the correct answer (a catalyst changes the mechanism of the reaction). The most commonly chosen distractor was A (a catalyst decreases the activation energy of the forward reaction but not the reverse).

## Question 21

88% of the candidates deduced the order of the reaction with respect to each reactant based on the experimental data of initial rate and concentrations of reactants.

## Question 22

77% of the candidates applied Le Chatelier's Principle correctly. The question had a high discrimination index.

## Question 23

This was a challenging question with the highest discrimination index on the paper. 62% of the candidates were able to deduce the equilibrium concentration of IBr and calculate the equilibrium constant correctly. The most commonly chosen distractor was B where the stoichiometric ratio was not taken into account when calculating the equilibrium concentration of IBr.

## Question 24

77% of the candidates were able to calculate the pH of the aqueous solution of NaOH. The most commonly chosen distractor was D (pH = 13) which was probably selected because NaOH is a strong base.

## Question 25

69% of the candidates identified $CO_2$ as the gas responsible for the acidity of unpolluted rain. The majority of the candidates that answered incorrectly chose nitrogen oxides (C) or sulfur dioxide (D).

## Question 26

There was a mistake on this question and it had to be annulled (39 marks paper). Grade boundaries were lowered accordingly. The x-axis was incorrectly labelled as "volume of weak acid" instead of "volume of strong base". We sincerely apologize for this mistake which will be corrected before publication.

## Question 27

This is one of the more challenging questions on the paper. 62% of the candidates obtained the correct answer. The most commonly chosen distractor was C, where the increase in the concentration of $H_3O^+$ was recognized by applying Le Chatelier's principle but the effect on pH was incorrect.

## Question 28

94% of candidates identified the compound that contains sulfur with an oxidation state of +6.

## Question 29

83% of the candidates were able to identify the electrode equations given the cell reaction. The most commonly chosen distractor B had the correct half-equations at the opposite electrodes.

## Question 30

This was a challenging question with a high discrimination index. 57% of the candidates identified the strongest oxidizing agent given the standard electrode potentials. The most commonly chosen distractor was $Al^{3+}$ (C).

## Question 31

Another challenging question with a high discrimination index. 57% of the candidates were able to identify the electrode products during the electrolysis of concentration KBr (aq). The most commonly chosen distractor was C where K was the product at the cathode (instead of $H_2$). Some teachers commented that the data booklet was needed to solve this question and others said “concentrated” was vague. But the effect of concentration is clearly stated in the syllabus and does not need the data booklet to be determined. As for the cation, potassium is known as a reactive metal according to the periodic trends and should have been easy to recognize as more reactive than hydrogen. Similar questions have appeared in past papers.

## Question 32

Surprisingly, this was one of the challenging questions on the paper. Only 63% of the candidates chose dimethylpropane as the compound having the lowest boiling point. The most commonly chosen distractor was pentane (B) which did not take into account the effect of branching on the strength of London dispersion forces.

## Question 33

85% of the candidates chose free-radical substitution as the type of reaction occurring between methane and chlorine in sunlight.

## Question 34

This was the easiest question on the paper. 97% of the candidates recognized the correct IUPAC name of the compound.

## Question 35

72% of the candidates chose B (a nucleophile must have a lone pair of electrons). The most commonly chosen distractor was A (a nucleophile must have a negative charge). Some teachers commented that both answers A and B are correct. However, the word “must” in the question means B is the only answer. Candidates are aware that some nucleophiles like water are neutral. Moreover, the definition of a nucleophile is clearly stated in the syllabus (topic 10.2).

## Question 36

71% of the candidates identified 1,2-dibromoethene as having two configurational isomers. The most commonly chosen distractor was C which was the only saturated halogenoalkane, indicating that these candidates may have confused the term with “conformational” isomers.

### Question 37

85% of the candidates identified the secondary alcohol as the product of the reduction of a ketone. The other three distractors (primary alcohol, ether and carboxylic acid) were chosen almost equally by the remaining candidates.

### Question 38

Candidates found this question relatively challenging and only 67% chose the answer with two significant figures. The most commonly chosen distractor was C which expressed the answer to three significant figures.

### Question 39

82% of the candidates identified the bonds present as the information that can be deduced from an infrared spectrum. The most commonly chosen distractor was B (the number of hydrogen environments).

### Question 40

This question challenged candidates to think about analytical techniques more deeply. 67% of the candidates recognized that mass spectrometry involves breaking covalent bonds. The most commonly chosen distractor was X-ray crystallography (option C).

## Recommendations and guidance for the teaching of future candidates

- The important thing is for students to understand the concepts in order to be able to apply them in different situations. Reflection and connections across topics help with this. Also using different approaches to ask questions about a concept so that the students do not memorize a specific method/answer but rather apply their understanding to each question.
- Problems that requires multiple steps should be practiced.
- Students should be reminded to read the question carefully to make sure they do not miss valuable information. For example, when answering question 18 many students missed that the information that the gases were at the same temperature.
- Redox seems to be an area that needs more practice. Many students do find it challenging to use standard electrode potentials and to deduce electrolysis products.
- Practice writing answers to calculations to the correct number of significant figures throughout the course.

# Standard level paper one

## General comments

The paper was sat by nearly 8,000 candidates, approximately 6100 candidates in English, 1500 candidates in Spanish and 200 candidates in French. The mean mark was 20.90 which was higher than the mean mark in May 2018 (17.25) indicating that this year's paper was more approachable.

We received feedback about the examination paper from 146 teachers which is highly appreciated. Teachers commented that they found the paper fair with a good coverage of the syllabus. Some questions were straight forward while others required more thought and discriminated well between candidates. The paper included some interesting questions and gave candidates opportunities to apply concepts in unfamiliar situations. Teachers reported that candidates were generally pleased with the paper.

Teachers also sent the following feedback:

### The best description of the difficulty of the paper

| Too easy | Appropriate | Too difficult |
|---|---|---|
| 4.79% | 95.21% | 0.00% |

### The best description of the difficulty of the paper in comparison with last year's paper

| Much easier | A little easier | Of a similar standard | A little more difficult | Much more difficult |
|---|---|---|---|---|
| 2.13% | 23.40% | 65.25% | 9.22% | 0.00% |

### Clarity of wording

| Very poor | Poor | Fair | Good | Very good | Excellent |
|---|---|---|---|---|---|
| 0.68% | 0.68% | 12.33% | 30.14% | 39.04% | 17.12% |

### Presentation

| Very poor | Poor | Fair | Good | Very good | Excellent |
|---|---|---|---|---|---|
| 0.68% | 0.00% | 10.27% | 25.34% | 38.36% | 25.34% |

The table below lists the questions from least to most difficult. It shows the numbers of candidates who selected each of the options A-D and the discrimination index for each question (how well the question discriminated between high-scoring and low-scoring candidates)

| Question | A | B | C | D | Blank | Difficulty Index | Discrimination Index |
|---|---|---|---|---|---|---|---|
| 27 | 102 | 150 | 218 | 7311 | 8 | 93.86 | 0.14 |
| 18 | 209 | 277 | 397 | 6903 | 3 | 88.62 | 0.28 |
| 2 | 280 | 336 | 293 | 6875 | 5 | 88.27 | 0.26 |
| 5 | 317 | 249 | 362 | 6860 | 1 | 88.07 | 0.29 |
| 15 | 344 | 6854 | 470 | 118 | 3 | 88.00 | 0.23 |
| 9 | 209 | 236 | 6746 | 593 | 5 | 86.61 | 0.29 |
| 21 | 6648 | 234 | 498 | 394 | 15 | 85.35 | 0.33 |
| 13 | 223 | 179 | 932 | 6447 | 8 | 82.77 | 0.39 |
| 3 | 1097 | 337 | 6197 | 149 | 9 | 79.56 | 0.39 |
| 1 | 450 | 372 | 6136 | 822 | 9 | 78.78 | 0.40 |
| 4 | 1272 | 385 | 5846 | 277 | 9 | 75.05 | 0.53 |
| 26 | 5799 | 1016 | 641 | 326 | 7 | 74.45 | 0.43 |
| 8 | 710 | 848 | 5771 | 457 | 3 | 74.09 | 0.39 |
| 12 | 402 | 5620 | 414 | 1346 | 7 | 72.15 | 0.41 |
| 30 | 561 | 1300 | 5514 | 384 | 30 | 70.79 | 0.49 |
| 23 | 592 | 1271 | 5482 | 425 | 19 | 70.38 | 0.51 |
| 6 | 468 | 703 | 1315 | 5298 | 5 | 68.02 | 0.55 |
| 25 | 5285 | 618 | 1241 | 617 | 28 | 67.85 | 0.59 |
| 10 | 879 | 918 | 710 | 5264 | 18 | 67.58 | 0.39 |
| 11 | 1008 | 5110 | 1030 | 620 | 21 | 65.61 | 0.43 |
| 17 | 5088 | 147 | 370 | 2170 | 14 | 65.32 | 0.43 |
| 14 | 405 | 742 | 5043 | 1595 | 4 | 64.75 | 0.52 |
| 28 | 252 | 4838 | 2339 | 350 | 10 | 62.11 | 0.58 |
| 22 | 2016 | 4653 | 468 | 639 | 13 | 59.74 | 0.30 |
| 20 | 502 | 4542 | 1364 | 1371 | 10 | 58.31 | 0.46 |
| 19 | 648 | 1676 | 4502 | 951 | 12 | 57.80 | 0.52 |
| 24 | 1032 | 1844 | 485 | 4413 | 15 | 56.66 | 0.49 |
| 7 | 3572 | 1396 | 2123 | 684 | 14 | 45.86 | 0.56 |
| 29 | 1596 | 3023 | 568 | 2577 | 25 | 33.09 | 0.33 |
| 16 | 1468 | 616 | 1448 | 4248 | 9 | 18.85 | 0.13 |

**Number of candidates : 7789**

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

- Deducing how molecular speeds vary for different gases at the same temperature.
- Identifying that elements in the same period have the same highest energy level occupied.
- Deducing the hydrocarbon with the lowest boiling point.
- Calculating the pH of a solution of NaOH.
- Identifying the compound responsible for the acidity of unpolluted rain.
- Determining the direction of ion flow in the salt bridge of a voltaic cell.
- Identifying the appropriate number of significant figures for the answer of a calculation.

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

- Naming a branched alkane.
- Writing the equilibrium constant expression.
- Balancing an equation and obtaining the sum of the coefficients.
- Deducing the numbers of sub-atomic particles in an ion.
- Identifying the activation energy in a reaction profile.
- The formation of stable ions.
- Determining oxidation state.
- Applying Hess's law.

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

### Question 1

This was one of the easier questions on the paper. 79% of the candidates were able to deduce the amount of a product given the amount of another product and the balanced equation.

### Question 2

Very well answered. 88% of the candidates balanced the equation and added up the integer coefficients correctly.

### Question 3

80% of the candidates were able to deduce the new volume of a sample of gas after the pressure was halved. The most commonly chosen distractor (A) was the value that assumed a direct proportionality between volume and pressure.

### Question 4

75% of the candidates were able to calculate the molar concentration of the NaOH solution. The question had a good discrimination index.

### Question 5

A well answered question. 88% of the candidates deduced the correct numbers of protons, neutrons and electrons in the sulfide ion.

### Question 6

This question discriminated well between high scoring and low scoring candidates. 68% of the candidates chose the correct transition that emits visible light (n = 3 to n = 2). The most commonly chosen distractor C was the only other option that involved emission.

### Question 7

A challenging question with a high discrimination index. 46% of the candidates chose the correct answer A (the highest energy levels occupied have the same numerical value for all elements in the same period). A high proportion of candidates chose C (orbitals occupied have the same value ....) and a significant proportion chose B (energy sub-levels occupied have the same value ...).

### Question 8

74% of the candidates chose the correct trends for ionization energy and ionic radius down Group 17.

### Question 9

One of the most straight-forward questions on the paper about how lithium forms its most stable ion. It was answered correctly by 87% of the candidates.

## Question 10

A question about factors affecting the strength of metallic bonding answered correctly by 68% of candidates. The distractors were almost equally chosen by the rest of the candidates.

## Question 11

66% of the candidates identified $BF_3$ as having an incomplete octet of electrons. The distractors $NF_3$ and BrF were chosen in equal numbers, and the distractor $SF_2$ was chosen by the least number of candidates.

## Question 12

72% of the candidates identified $CH_4O$ as having hydrogen bonds between its molecules. The most commonly chosen distractor was $CH_2O$, the only other option containing oxygen.

## Question 13

It is pleasing that 83% of the candidates were confident in applying Hess's law to obtain an expression for the standard enthalpy change of reaction. The most commonly chosen distractor (C) had the correct coefficients but one of the signs was incorrect.

## Question 14

65% of the candidates chose the correct expression for determining the enthalpy change using bond enthalpies. The most commonly chosen distractor (C) had the signs reversed. The question had a good discrimination index.

## Question 15

Well answered. 88% of the candidates chose the correct arrow representing the activation energy of the forward reaction.

## Question 16

This was by far the most challenging question on the paper, answered correctly by only 19% of the candidates. Some teachers thought this was beyond the scope of the syllabus while others thought it was a question requiring thought. To be able to answer, candidates needed to connect kinetic energy to the speed and mass of the molecule.

## Question 17

65% of the candidates chose the correct combination to give the greatest rate of reaction. The most commonly chosen distractor was D where "smaller surface area of same mass of $CaCO_3$(s)" was chosen. It seems these candidates confused "surface area" with "particle size".

## Question 18

One of the easiest questions on the paper. 89% of the candidates chose the correct $K_c$ expression.

## Question 19

The question discriminated well between high scoring and low scoring candidates. 58% of the candidates were able to calculate the pH of the aqueous solution of NaOH. The most commonly chosen distractor was B (pH = 3) where the students determined pOH but did not complete the calculation. It is interesting that these candidates did not seem to notice that NaOH is a base and should have a higher pH.

## Question 20

This was one of the challenging questions on the paper. 58% of the candidates identified carbon dioxide as the cause of acidity in unpolluted rain. The rest mainly chose either nitrogen oxides (option C) or sulfur dioxide (option D), the causes of acidity in polluted rain.

## Question 21

It is pleasing that 85% of the candidates identified the species containing nitrogen with the highest oxidation state.

## Question 22

A challenging question about direction of ion flow in a salt bridge. 60% answered correctly and the option with the opposite directions of flow of ions (A) was the most commonly chosen distractor.

## Question 23

The question about electrode reactions discriminated well between high scoring and low scoring candidates. 70% of the candidates selected the correct electrode reactions given the cell reaction. The most commonly chosen distractor had the same reactions at the opposite electrodes.

## Question 24

Surprisingly, this was one of the challenging questions on the paper. Only 57% of the candidates chose dimethylpropane as the compound having the lowest boiling point. The most commonly chosen distractor was pentane (B) which did not take into account the effect of branching on the strength of London dispersion forces.

## Question 25

The question involving a sequence of organic reactions discriminated well between high scoring and low scoring candidates. 68% chose the correct compound.

## Question 26

74% of the candidates chose free-radical substitution as the type of reaction occurring between methane and chlorine in sunlight.

## Question 27

This was the easiest question on the paper. 94% of the candidates recognized the correct IUPAC name of the compound.

### Question 28

This question about choosing the answer to a calculation with the appropriate number of significant figures discriminated well between high-scoring and low-scoring candidates. Candidates found this question relatively challenging and only 62% chose the answer with two significant figures. The most commonly chosen distractor was C which expressed the answer to three significant figures.

### Question 29

This question was answered in two different ways. 33% of the candidates chose the correct answer (D) considering what would be true about a mass-volume graph for silicon samples. However, 39% chose distractor (B) as they considered the silicon samples in the previous question which did not show a directly proportional relationship. Both answers were accepted as we agree that the wording was ambiguous (it will be amended before publication).

### Question 30

71% of the candidates identified the bonds present as the information that can be deduced from an infrared spectrum. The most commonly chosen distractor was B (the number of hydrogen environments).

## Recommendations and guidance for the teaching of future candidates

- Provide plenty of opportunities for students to apply concepts in new situations. Try to use different approaches to ask questions about a concept so that the students do not memorize a specific method/answer but rather apply their understanding to each question.
- Encourage students to reflect on concepts to deepen their understanding and to relate new concepts to previous knowledge. This would help them tackle questions such as the direction of flow of ions in a salt bridge and the distribution of molecular speeds.
- Many students need a better understanding of the factors affecting the strength of London dispersion forces.
- Students need more practice in applying the rules for significant figures.
- Standard level students need more practice in pH calculations including the incorporation of $K_w$.

# Higher level paper two

## General comments

In general, this paper was perceived by teachers as being of an appropriate level (≈ 81%) while the other approximately 20% considered it to be difficult. Candidates did well in the exam with a mean mark (and grade) clearly above M18.

The comments of teachers and examiners alike -arising at a first sight of the paper and before seeing the markscheme - centered on it being different to other papers in several ways. On the positive side it was felt to require less challenging mathematical skills leaving more room for chemistry-related concepts, so that chemistry knowledge, rather than maths skills, were rewarded. There was a consensus that the questions required more critical thinking, correct understanding of concepts and appreciation of NOS. As a negative aspect, some teachers felt that the absence of organic chemistry mechanisms or straightforward stoichiometry could be confusing for the candidates. Some teachers of ESL students did complain about a certain lack of clarity in the wording of a few questions. Regarding ESL students, it was observed that as more explanations were required, they did struggle with this in some of the questions.

Actually, this paper had the same or at least a very similar amount of stoichiometry questions, but these were spread out among other questions, applied to specific situations. Similarly, most topics were very well integrated in questions related to compounds or elements, an outstanding example of this being question 1.

This exam is back to 90 marks and in general candidates appear to have been able to complete the exam in the allotted time.

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

- Periodic trends, notions of periodicity.
- Properties of isotopes.
- Balancing redox equations.
- Estimation of uncertainties.
- Plotting graphs: few students were able to draw the appropriate titration curve inflexion or correct pressure vs time for gases at different temperatures.
- Conformational isomerism.
- Nitric oxide (NO) catalyzed decomposition of ozone.
- Reaction conditions for oxidation.
- Applying $E^{\ominus}$ values to potential situations to evaluate their feasibility.
- Applying equilibrium concepts to practical situations.
- Kinetics: relating a rate expression to a proposed mechanism.

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

- Atomic structure.
- Using IUPAC nomenclature for simple compounds.
- Calculation of the exact mass of $N_2O$ considering isotopic ratios of N.
- Bonding, dot structures, shapes, intermolecular forces, hybridization.
- Equilibrium: predicting changes in position of equilibrium without further analysis.
- Acids and bases: general definitions and calculations of $H^+$/ pH.
- Interpretation of spectra: most students could correctly locate the peaks and signals in respectively an IR and $^1$H NMR spectra and use the data booklet to identify functional groups.
- Energetics: calculation of enthalpy using bond enthalpies and entropy.
- Distinguishing between types of experimental error.
- Calculations in general.

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

### Question 1

An integrated question that very nicely combined many aspects of the curriculum.

(a) All candidates were able to write the correct reactants/products for combustion of ethyne, but a few failed to balance correctly.

(b)(i) Most drew correct Lewis structures for ethyne, though some drew ethene

(b)(ii) Surprisingly very few explained the difference in bond length/strength looking at electrons shared and just gave the shorter/triple or longer/single bond answer.

(b)(iii) Good to see that most candidates identified the specific IMF correctly.

(c)(i) Most candidates gave the correct IUPAC name.

(c)(ii) Candidates were able to calculate the $\Delta H$ of the given reaction correctly; a few inverted the calculations or made mathematical errors.

(c)(iii) Generally well done, most common error was stating that the enthalpy change was "larger" without the indication that it was an exothermic change or the sign.

(c)(iv) Interpretation of spectra was very good and the few candidates that lost marks with $^1$H NMR data rather than IR, for example simply mentioning two signals for B. However, most candidates that attempted this question got full marks.

(c)(v) The stronger candidates were able to predict the splitting pattern correctly, others inverted the answer, but many others repeated the information for protons with the given chemical shift, which is unexpected since wording was straightforward.

(d)(i) Candidates seemed to be confused by the prompts, reagent and conditions, so often included the acid among conditions. Careless errors were common such as the wrong charge on the dichromate ion. Few candidates suggest permanganate as an option.

(d)(ii) Most candidates were able to calculate oxidation state of carbon in B.

(d)(iii) Candidates did not understand that they must mention the IMF responsible for the solubility. Most candidates explained the polarity of the aldehyde and water but did not mention that this results in permanent dipole-dipole interactions; many did mention H-bonding. The mention of the lone pair on O atom and short hydrocarbon chain were very rare.

## Question 2

(a) Students were able in general to relate more moles of gas to increase in pressure.

(b) Few students were able to relate the effect of reduced pressure at constant volume with a decrease in concentration of gas molecules and mostly did not even refer to this, but rather concentrated on lower rate of reaction and frequency of collisions. Many candidates lost a mark by failing to explain rate as collisions per unit time, frequency, etc.

(c)(i) Though the differential equation was considered to be misleading by teachers, most candidates attempted to answer this question, and more than half did so correctly, considering they had the graph to visualize the gradient.

(c)(ii) Most students were able to identity step 1 as the RDS/slow but few mentioned unimolecularity or referred vaguely to $NO_2$ as the only reagent (which was obvious) and got only 1 mark.

(d) Many students drew a lower initial gradient, but most did not reflect the effect of lower temperature on pressure at constant volume and started and finished the curve at the same pressure as the original one.

(e) Almost all candidates identified the inaccurate pressure gauge as a systematic error, thus relating accuracy to this type of error.

(f) The graph was generally well done, but in quite a few cases, candidates did not mention that increase of rate in the catalyzed reaction was due to $E$ (particles) > $E_a$ or did so too vaguely.

(g)(i) Candidates were able to calculate the $\Delta S$ of the reaction, though in some cases they failed to multiply by the number of moles.

(g)(ii) Though the question asked for decomposition (in bold), most candidates ignored this and worked on the basis of a the $\Delta H$ of formation. However, many did write a sound explanation for that situation. On the other hand, in quite a number of cases, they did not state the sign of the $\Delta H$ (probably taking it for granted) nor explicitly relate $\Delta G$ and spontaneity, which left the examiner with no possibility of evaluating their reasoning.

## Question 3

(a)(i) Candidates sometimes failed to identify how ozone works in chemical terms, referring to protects/deflects, i.e., the consequence rather than the mechanism.

(a)(ii) Many candidates recalled the first equation for NO catalyzed decomposition of ozone only. Some considered other radical species.

(b)(i) All candidates, with very few exceptions, answered this correctly.

(b)(ii) Most candidates were able to calculate the accurate mass of $N_2O$, though quite a few candidates just calculated the mass of N and didn't apply it to $N_2O$, losing an accessible mark.

(b)(iii) Many students realized that neutrons had no charge and could not affect IE significantly, but many others struggled a lot with this question since they considered that $^{15}N$ would have a higher IE because they considered the greater mass of the nucleus would result in an increase of attraction of the electrons.

(c) Mixed responses here; the explanation of higher IE for N with respect to C was less well explained, though it should have been the easiest. It was good to see that most candidates could explain the difference in IE of N and O, either mentioning paired/unpaired electrons or drawing box diagrams.

(d)(i) Most candidates identified resonance for this given Lewis representation.

(d)(ii) Though quite a number of candidates suggested a linear shape correctly, they often failed to give a complete correct explanation, just mentioning the absence of lone pairs but not two bonds, instead of referring to electron domains.

(d)(iii) Hybridisation of the N atom was correct in most cases.

## Question 4

(a) It was expected that this question would be answered correctly by all HL candidates. However, many confused the A-Z positions or calculated very unusual numbers for A, sometimes even with decimals.

(b)(i) This is a NOS question which required some reflection on the full meaning of the periodic table and the wealth of information contained in it. But very few candidates understood that they were being asked to explain periodicity and the concept behind the periodic table, which they actually apply all the time. Some were able to explain the "gap" idea and other based predictions on properties of nearby elements instead of thinking of periodic trends. A fair number of students listed properties of transition metals in general.

(b)(ii) Generally well done; most described the cell identifying the two electrodes correctly and a few did mention the need for Re salt/ion electrolyte.

(b)(iii) Generally well answered though some students suggested physical properties rather than chemical ones.

(c) Many candidates chose to set up voltaic cells and in other cases failed to explain the actual experimental set up of Re being placed in solutions of other metal salts or the reaction they could expect to see.

(d)(i) Almost all candidates were able to name the compound according to IUPAC.

(d)(ii) Most candidates were able to answer this stoichiometric question correctly.

(e)(i) This should have been a relatively easy question but many candidates sometimes failed to see the connection with Mn or the amount of electrons in its outer shell.

(e)(ii) Surprisingly, a great number of students were unable to balance this simple half-equation that was given to them to avoid difficulties in recall of reactants/products.

(e)(iii) Many students understood that the oxidation of $Fe^{2+}$ was not viable but were unable to explain why in terms of oxidizing and reducing power; many students simply gave numerical values for $E^{\ominus}$ often failing to realise that the oxidation of $Fe^{2+}$ would have the inverse sign to the reduction reaction.

## Question 5

(a)(i) As expected, many candidates were able to distinguish between strong and weak acids; some candidates referred to "dissolve" rather than dissociate.

(a)(ii) More than half the candidates were able to deduce that carbonate was the conjugate base but a significant proportion of those that did, wrote the carbonate ion with an incorrect charge.

(b) Many students gave generic responses referring to a correct shift without conveying the idea of compensation or restoration of pressure or moles of gas. This generic reply reflects the difficulty in applying a theoretical concept to the practical situation described in the question.

(c) Most candidates calculated the pH of the aqueous $CO_2$. Some candidates attempted to use the Henderson-Hasselback equation and others used the quadratic expression to calculate $[H^+]$ (these two options were very common in the Spanish scripts) getting incorrect solutions. These answers usually ended in pH of approx. 1 which candidates should realize cannot be correct for soda water.

(d)(i) This was an easy question, especially the identification of the type of bond between H and O, yet some candidates interpreted that the question referred to intermolecular bonding.

(d)(ii) A significant number of candidates omitted the "equilibrium" involved in the dissolution of a weak base.

(d)(iii) This is another stoichiometry question that most candidates were able to solve well, with occasional errors when calculating $M_r$ of hydrogen carbonate.

(d)(iv) Mixed responses, more attention should be given to this simple calculation which is straightforward and should be easy as required for IA reports.

(e) This was a good way to test this topic because answers showed that, while candidates usually knew the topic in theory, they could not apply this to identify the Lewis and Bronsted-Lowry bases in the context of a reaction that was given to them. In some cases, they failed to specify the base, $OH^-$ or also lost marks referring just to electrons, an electron or H instead of hydrogen ions or $H^+$ for example.

(f) Most students that got 1mark for this titration curve was for the general shape, because few realized they had the data to calculate the equivalence point. There were also some difficulties in establishing the starting point even if it was specified in the stem.

### Question 6

This was mostly HL organic chemistry.

(a) Most candidates were able to draw the monomer correctly. Some candidates made careless mistakes writing $C_6H_6$.

(b) Another calculation which most candidates were able to work out, though some failed to convert $\Delta G$ given value in kJ $mol^{-1}$ to J $mol^{-1}$ or forgot the negative sign. Some used an inappropriate expression of *R*.

(c) The strong candidates were generally able to see the similarity between the two reactions but unexpectedly some could not identify “electrophilic” as a similarity even if they referred to the differences as electrophilic substitution/addition, so probably were unable to understand what was being asked.

(d)(i) Candidates were given the products of the addition reaction and asked about the major product. Perhaps they were put off by the term “forms” and thus failed to “see” the chiral C that allowed the existence of enantiomers. There was some confusion with the type of isomerism and some even suggested cis/trans isomers.

(d)(ii) If candidates seemed rather confused in the previous question, they seemed more so in this one. Most simply referred to isomers in general, not seeming to be slightly aware of what conformational isomerism is, even if it is in the curriculum.

(e) Quite well answered though some candidates suggested an aldehyde rather than the alcohol, or forgot that C has two hydrogens apart from the -OH. In other cases, they left a Br there.

## Recommendations and guidance for the teaching of future candidates

Work on the importance of taking all the necessary time to read a question carefully: an example is question 2(g)(ii) in which “decomposition” was highlighted yet ignored by about 50% of the students. Similarly, candidates were told that $NaHCO_3$ has a pH of 7, but started their graphs at pH 4; in 4 c, more than half the candidates made a voltaic cell (the materials to use were specified to make things clearer), and when chemical properties were required many students gave physical properties (when they did know the chemical properties since many had mentioned them out of context in 4(b)(i)).

Also work on taking time to understand what is being asked rather than rush to answer a question with “learnt” answers. This happened in 5(a) where candidates just answered the direction of equilibrium with a generic justification or in 2(b) just limited to a decrease in rate and the less frequent collisions, instead of really thinking of the situation and dealing with it.

When teaching definitions, be sure that students can identify the definition in action in specific examples.

In addition to understanding the mathematical value of a table of redox potentials, ensure students understood the competition in terms of oxidising and reducing agent power.

The use of graphs as a way of describing a phenomenon must be accurate. For example, more than half the candidates, including strong ones, plotted a curve for 2(d) where the pressure of an equimolar amount of $N_2O$ at a lower constant temperature reached that of the one at a higher temperature over time. In many cases the only difference found was a lower initial gradient but starting from the same initial pressure.

Understand that attention should be paid to how curves are drawn in graphs since these details represent data points.

Be aware of the units of constants to be sure to convert data to the appropriate unit (J/kJ, etc.), such as the case for $\Delta G$ unit in kJ to be used with $R$ value in J.

Check their answers when possible to make sure they are reasonable.

Candidates should answer questions in the allotted box or use extra pages.

## Further comments

The paper was better answered than was predicted initially by teachers. Topics were spread out across the different aspects involved in all chemical phenomena and their applications, instead of keeping each topic within a box. This is a much more realistic and interesting approach to the teaching of chemistry.

The question on Rhenium is just an example of how to use the periodic table to predict properties of an element we are unfamiliar with. This is the aim of introducing some NOS - oriented teaching as it encourages deeper reflection and understanding of available tools so we can take full advantage of them.

# Standard level paper two

## General comments

The paper was sat by 7912 candidates, 77% of whom wrote the paper in English, 20% wrote it in Spanish and 3% wrote it in French. The mean mark achieved was 23.28 out of 50 possible marks, while the mean mark last year was 19.74. The mean grade was also higher this session. Some teachers however suggested that the paper was more challenging.

A good performance was seen in many scripts. Many candidates showed understanding and were able to apply concepts in a variety of situations. Answers were often precise and included sufficient detail. However, some candidates seemed to be reciting learned information that was not appropriate to the question, using imprecise language and sometimes contradicting themselves. The calculations in the paper were relatively straight-forward and almost all candidates handled them well.

145 teachers sent feedback about the paper. They commented that the paper focused on the application of concepts in unfamiliar situations as well as including some familiar questions. There were many positive comments about the paper in terms of coverage, variety of concepts, appropriateness of level, interesting questions, linking concepts, the focus on the application of concepts and requiring students to think and reflect. Some teachers wanted to see less organic chemistry on the paper and others thought more was needed. Some teachers also wanted to see more stoichiometry. It is worth pointing out that the number of marks allocated for each topic in a paper is proportional to the number of teaching hours allocated for that topic in the subject guide.

Teachers generally thought the paper was fair and approachable, though some teachers felt it was rather challenging for less able students, as reflected in the statistics below. It appears that candidates managed to complete the paper within the allotted time and there were no complaints from students. This was confirmed by the fact that most candidates answered all the questions on the paper and blank questions were only seen in the scripts of very weak candidates.

Teachers also sent the following feedback:

### The best description of the difficulty of the paper

| Too easy | Appropriate | Too difficult |
|---|---|---|
| 1.38% | 86.90% | 11.72% |

### The best description of the difficulty of the paper in comparison with last year’s paper

| Much easier | A little easier | Of a similar standard | A little more difficult | Much more difficult |
|---|---|---|---|---|
| 0.71% | 5.71% | 58.57% | 30.71% | 4.29% |

### Clarity of wording

| Very poor | Poor | Fair | Good | Very good | Excellent |
|---|---|---|---|---|---|
| 0.69% | 2.07% | 12.41% | 39.31% | 31.72% | 13.79% |

### Presentation

| Very poor | Poor | Fair | Good | Very good | Excellent |
|---|---|---|---|---|---|
| 0.69% | 0.69% | 9.66% | 34.48% | 33.10% | 21.38% |

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

- The role of intermolecular forces in vaporization.
- Conditions needed to oxidize ethanol to ethanal.
- Explaining solubility based on intermolecular forces.
- Comparing the ionization energies of isotopes.
- Identifying non-metal oxides as acidic.
- Writing the formula for the conjugate base of an acid.
- Applying Le Chatelier's Principle in unfamiliar situations.

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

- Writing a balanced equation for complete combustion.
- Drawing simple Lewis structures.
- Comparing bond lengths.
- Naming an aldehyde.
- Using bond enthalpies to determine enthalpy change for a reaction.
- Identifying a compound based on its IR and $^1H$ NMR spectra.
- Determination of the oxidation state of an element in a compound.
- Recognizing a systematic error and realizing that repetition would not reduce the error.
- Calculating relative atomic mass.
- Calculating percentage composition, by mass, of a compound.
- Distinguishing between strong and weak acids.
- Calculating the molar concentration of a solution from the mass of solute and volume of solvent.

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

### Question 1

(a)(i) Almost all candidates recognized the products of the complete combustion of ethyne, and over two thirds managed to balance the equation. It was good to see candidates using integers for the balancing.

(b)(i) The majority of candidates drew the Lewis structure of ethyne. A few teachers commented that they did not cover alkynes assuming they are not included in the syllabus. Please check the current syllabus carefully when preparing students.

(b)(ii) A very well answered question. The vast majority of candidates understood that triple bonds are stronger than single bonds and result in a shorter bond length. It was disappointing, however, to see a considerable number of candidates stating that ethane has a double bond.

(b)(iii) Some candidates could not relate evaporation of a liquid to the breaking of its intermolecular forces and gave irrelevant answers such as "evaporation". Other candidates gave general answers such as "the intermolecular forces" or used the term "van der Waals' forces" which did not gain credit as too vague. The current guide is clear that "London/dispersion forces" is the appropriate term to use for instantaneous dipole-induced dipole forces. Less than 40% of the candidates scored the mark. It was disappointing to see some candidates state "covalent bonding" as the type of interaction that must be overcome when liquid ethyne vaporizes. Some teachers thought the wording of the question may have been vague and candidates may have been confused about what was meant by the "type of interaction".

(c)(i) About 60% of the candidates stated "addition" as the type of reactions that compounds containing carbon-carbon double bonds underwent. It was disappointing to see a variety of answers including substitution, condensation and combustion showing a total lack of understanding. Some candidates gave specific types such as "bromination" or "hydration" which did not receive the mark.

(c)(ii) 60% of the candidates were able to name compound B as ethanal. Some candidates did not recognize it as an aldehyde and gave names related to carboxylic acids or other homologous series. Other candidates called it methanal.

(c)(iii) Candidates were confident in using average bond enthalpies for calculating the enthalpy change for the reaction. Mistakes included forgetting to include the breaking of the O-H bonds in water and reversing the signs.

(c)(iv) Reasonably well answered. About half of the candidates showed understanding of the relation between stability and the enthalpy change from the same starting materials. ECF was applied in this question based on the answer in part (iii).

(c)(v) The majority of candidates handled this question competently and nearly half of the candidates obtained both marks. They obtained the value of the absorption from the spectra provided and compared it to the values in the data booklet to deduce the identity of the product. Common mistakes included not identifying the peaks and signals precisely (for example C=O instead of CHO for $^1H$ NMR signal at 9.4-10.0 ppm). Some teachers commented that the TMS signal should not have been included as the SL do not know about it. Other teachers commented that using the 'actual' rather than an ‘idealized’ IR spectrum may have caused confusion due to the peak at around 3400 $cm^{-1}$ which could be confused for O-H in alcohols. Thankfully both of these answers were hardly seen in the scripts. The peak at 3400 $cm^{-1}$ was not at all broad and did not confuse the majority of students. Please note that real spectra are usually used in examination papers, and it is worth encouraging students to check more than one peak to confirm their deductions.

(d)(i) Surprisingly, this question was not answered well by the majority of the candidates. However, it did discriminate well between high-scoring and low-scoring candidates. Common mistakes included incorrect formulas (such as $K_2CrO_7$), missing the acidic conditions and stating “reflux” instead of “distillation”. Many candidates gave completely irrelevant reagents and conditions such as “oxygen, pressure and a nickel catalyst”. It is possible that some candidates did not think of “distillation” as a “condition”.

(d)(ii) About 60% of the candidates determined the average oxidation state of carbon in ethanal. A couple of teachers commented that asking SL students to determine an “average oxidation state” seems a little difficult. Please note that this term has been used in recent papers whenever there are two or more atoms of the element in different parts of the compound. There was no evidence of confusion on the part of the candidates and most answered the question well.

(d)(iii) This was a challenging question with a demanding markscheme. Most students missed the fact that ethanal can form hydrogen bonds with water. And students who did state this often achieved only 1 out of the 3 marks because they did not offer a full explanation. Some candidates stating "hydrogen bonding" showed confusion by mentioning the hydrogen of the aldehyde group. Few identified the lone pairs on oxygen as the reason for the ability to hydrogen bond. Most candidates just stated that ethanal is polar and dissolves in polar water achieving no marks. However, one mark was awarded for “dipole-dipole interactions with water”.

## Question 2

(a) About a quarter of the candidates gave the full answer. Some only gained the first marking point (M1) by recognizing the increase in the number of moles of gas. Some candidates wrote vague answers that did not receive credit such as “pressure increases as more gaseous products form” without explicitly recognizing that the reactants have fewer moles of gas than the products. Some candidates mistook it for a system at equilibrium when the pressure stops changing (although a straight arrow is shown in the equation). A teacher commented that the wording of the question was rather vague “not clear if question is asking about stoichiometry (i.e. how 200 & 300 connect to coefficients) or rates (i.e. explain graph shape)”. We did not see a discussion of the slope of the graph with time and most candidates understood the question as it was intended.

(b) More than half of the candidates obtained the mark allocated for “less frequent collisions” at lower pressure, but only strong candidates explained that this was due to the lower concentration or increased spacing between molecules. Some candidates talked about a decrease in kinetic energy and they did not show a good understanding of collision theory. Some candidates lost M1 for stating “fewer collisions” without reference to time or probability.

(c) This was a challenging question. Candidates usually obtained only one of the two marks allocated for the answer. Most of them scored the mark for a lower initial slope at low temperature, while others scored a mark for sketching their curve below the original curve as all pressures (initial and final) will be lower at the lower temperature. A teacher commented that the wording was unclear "sketch on the axes in question 2", and it would have been better to label the graph instead.

(d) This question was well answered by nearly 70% of the candidates reflecting a good understanding of the impact of systematic errors. Some students did not gain the mark because of an incomplete answer. The question raised much debate among teachers. They worried if the error was clearly a systematic one. However, a high proportion of candidates had very clear and definite answers. In Spanish and French, the wording was a bit ambiguous which caused the markscheme in these languages to be more opened.

(e) This question discriminated very well between high-scoring and low-scoring candidates. About half of the candidates annotated the Maxwell-Boltzmann distribution to show the effect of the catalyst. Some left it blank and some sketched a new distribution that would be obtained at a higher temperature instead. The majority of candidates knew that the catalyst provided an alternative route with lower $E_a$ but only stronger candidates related it to the annotation of the graph and used the accurate language needed to score M2. A common mistake was stating that molecules have higher kinetic energy when a catalyst is added.

## Question 3

(a) 60% of the candidates were aware that ozone in the atmosphere absorbs UV light. Some candidates did not gain the mark for not specifying the type of radiation absorbed.

(b)(i) Well answered. More than half of the candidates stated mass spectrometry is used to determine the ratio of the isotopes.

(b)(ii) Many candidates successfully calculated the relative atomic mass of nitrogen in the sample. M2 was awarded independently of M1, so candidates who calculated the relative molecular mass using the $A_r$ of nitrogen in the data booklet (14.01) were awarded M2. Many candidates scored both marks.

(b)(iii) This was a challenging question for many candidates, while stronger candidates often showed clarity of thinking and were able to conclude that the ionization energies of the two isotopes must be the same and to provide two different reasons for this. Some candidates did realize that the ionization energies are similar but did not give the best reasons to support their answer. Many candidates thought the ionization energies would be different because the size of the nucleus was different. Some teachers commented that the question was difficult while others liked it because it made students apply their knowledge in an unfamiliar situation. The question had a good discrimination index.

(c) Only a quarter of the candidates answered correctly. Some simply stated that $N_2O$ forms $HNO_3$ with water which did not gain the mark.

## Question 4

(a) This nature of science question generated a lot of discussion among teachers. Some in support of such questions and others concerned that it takes a lot of time for candidates to know how to answer. Some teachers thought it was unclear what the question was asking. It is pleasing that about a quarter of the candidates answered both parts successfully and many candidates gained one mark usually for "periodic trends". However, some candidates only focused on one part of the question. Quite a few candidates discussed isotopes, probably thrown off by the stem. A teacher was concerned that since transition metals are not part of the SL syllabus that Re was a bad choice, however, the question did not really require any transition metal chemistry to be answered.

(b) This question was a good discriminator between high-scoring and low-scoring candidates. It was well answered by more than half of the candidates who had obviously carried out such displacement reactions and interpreted the outcomes during the course. Some candidates did not state the obvious of dipping the metal into the sulfates.

(c)(i) More than half of the candidates named $ReCl_3$ correctly. Common mistakes included "rhenium chloride" and "trichlororhenium".

(c)(ii) The majority of candidates calculated the percentage, by mass, of rhenium in $ReCl_3$ correctly. Some rounding errors were seen that students should be more careful with.

## Question 5

(a)(i) It was rather disappointing that less than 70% of the candidates could distinguish between weak and strong acids. Many candidates referred to pH differences.

(a)(ii) A poorly answered question, though it discriminated very well between high-scoring and low-scoring candidates. Less than 40% of the candidates were able to deduce the formula of the conjugate base of $HCO_3^-$. Wrong answers included water, the hydroxide ion and carbon dioxide.

(a)(iii) This was a relatively challenging question. Only about a quarter of the candidates explained how a decrease in pressure affected the equilibrium. Some candidates stated there was no shift in the equilibrium as the number of moles is the same on both sides of the equation, not acknowledging that only gaseous substances need to be considered when deciding the direction of shift in equilibrium due to a change in pressure. Some candidates wrote that the equilibrium shifts right because the gas escapes.

(b)(i) This was one of the most challenging questions on the paper that required application of Le Chatelier's Principle in an unfamiliar situation. Most candidates did not refer to equilibrium (2), as directed by the question, and hence could not gain any marks. Some candidates stated that $NaHCO_3$ was an acid and decreased pH. Some answers had contradictions that showed poor understanding of the pH concept.

(b)(ii) Very well answered. Most candidates calculated the molar concentration correctly.

(b)(iii) Many candidates identified the bonding between sodium and hydrogencarbonate as ionic. A much smaller proportion of candidates identified the bonding between hydrogen and oxygen in hydrogencarbonate as covalent. The most common mistake was "hydrogen bonding".

## Recommendations and guidance for the teaching of future candidates

- Explanations quite often failed to score full marks. Help students practice identifying where the marks are earned in explanation questions. Sometimes there is a mark for a "guess", but usually not, so if there are two marks, two reasons are probably required, and "increases" or "shifts left" will not earn a mark by themselves.
- Remind students to read the question carefully, to ensure they are answering the question fully. For example, in part-question 2(e) students were asked to “use the graph to outline why a catalyst has this effect” and many missed the mark because they did not do so.
- Candidates sometimes regurgitated knowledge without understanding. This was seen in discussions about kinetics and intermolecular forces in this paper. It is important to stress understanding throughout the course and avoid memorization.
- Organic chemistry was covered well in many schools; however, some schools need to give more attention to this topic as their students did not seem to grasp basic concepts such as alkenes undergoing addition reactions. Organic chemistry provides excellent opportunities for applying concepts learned in other topics.
- Encourage students to write out the method of their calculation as this may enable the examiner to award partial credit for incorrect answers. Rounding should only be carried out at the end otherwise it can lead to significant errors. Encourage students to use the $A_r$ values in the data booklet.
- Give students practice in writing answers to frequently asked questions so as to avoid making similar mistakes to those made in the past, particularly with regard to the precise use of language.
- Explanations of equilibrium shifts were not always clear. More practice is needed in this area.
- Remind candidates that the term “van der Waals’ forces” is quite general and should not be used instead of London forces or instantaneous dipole-induced dipole interactions.

# Higher level paper three

## General comments

This paper identified a broad range of candidate capabilities with both the mean mark and mean grade higher than in M18. Some candidates struggled with even the most basic concepts and factual knowledge, while others demonstrated an excellent depth of understanding of the higher-level material. In general, candidates appeared to be well prepared. There were some schools where the candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank. Answers lacked precision in terms of the wording used, and explanations were often vague. Responses to questions lacked chemical detail; and some responses tended to be journalistic rather than based on chemical facts and principles.

The 200 G2 forms that were returned conveyed teachers' impressions of this paper. The comments received on the G2 forms are considered very important feedback by the IBO and are reviewed thoroughly during the grade award meeting.

In comparison with last year's paper, 96% of respondents found the examination paper to be of an appropriate standard in terms of the level of difficulty with only 4 % considering the paper too difficult.

As compared to last year's paper, 69% of respondents thought the level of difficulty was appropriate, while 23% thought that it was too difficult and 8% found it a little easier.

Clarity of wording was considered excellent by 15%, very good by 32%, good by 35% of the respondents and fair by the remainder. The presentation of the paper was considered excellent by 20%, very good by 36%, good by 31% of the respondents and fair by the remainder of the respondents.

The option D was attempted by 38.5% candidates, option B by 33%, option C by 25.5% and option A by 3% candidates.

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

There was considerable variation in performance, but some of the repeated weaknesses in each option are as follows:

### Section A

- Explaining why a relationship isn't linear in terms of chemical concepts
- Identifying significant sources of error

### Option A

- The equation for the formation of carbon nanotubes from carbon monoxide
- Comparison of addition and condensation polymerisation in terms of green chemistry

- Explaining the toxicity of transition metals

### Option B

- Contrasting the bonding responsible for secondary protein structures
- Structure of phosphatidylcholine
- Genetic code
- Organic structural formulas and connectivity errors

### Option C

- Contrasting fractional distillation and cracking
- Microbial fuel cells

### Option D

- Synthesis of taxol in terms of green chemistry criteria
- Fuel cell breathalysers
- Detection of alcohol by IR spectroscopy and awareness that O-H is abundantly present in breath due to the presence of water vapour

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

### Section A

- Suggesting ways for measuring the rate of reaction
- Suggesting sources of systematic error and their effect on the calculated rate

### Option A

- Superconductors
- Solubility product calculations

### Option B

- Explaining enzyme denaturation
- Identifying condensation reactions
- Cell membrane structure
- Describing the effect of increased LDL levels

### Option C

- Specific energy and energy density calculations
- Explaining catalytic cracking/reforming
- Nuclear reactions in general
- Suggesting ways to reduce carbon emissions
- Effect of temperature on semiconductor conductivity

### Option D

- Therapeutic window and therapeutic index
- Morphine and diamorphine
- Antivirals drugs and difficulties associated with solving the AIDS problem
- Stoichiometric calculations
- Use of the Henderson-Hasselbalch equation

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

## Section A

### Question 1

(a) This part was correctly answered by the majority of the candidates.

(b)(i) A surprising number of candidates gave evidence for the non-linearity but then did not go on to explain why, giving no reasons or causes rooted in chemical theory. The command term "suggest" involves proposing a solution or hypothesis. Here the instruction "suggest why" indicates that the reason has to be explained.

(b)(ii) The candidates who examined the data and quoted it in their answer generally scored the mark but several candidates did not refer to the data table.

(c)(i) Several candidates missed that this question was based on the equilibrium and it will shift to the left in presence of chloride ions.

(c)(ii) Majority of the candidates scored two marks but some struggled with the conversion of grams to milligrams.

### Question 2

In general, this question was done well, indicating that it is advantageous when candidates can draw on their practical experience.

(a) This part proved to be challenging for some candidates whereas other candidates were able to draw a tangent at 20 sec and then calculate the rate. A significant number of candidates calculated the average rate and achieved one mark.

(b) Majority of the candidates stated another property, which could be monitored correctly. The most common error was changes in temperature, which was stated by some candidates.

(c)(i) This part was about the systematic error and was answered correctly, but many candidates failed to state how the error affected the calculated rate. Many candidates confused this with the concept of a random error and identified the uncertainty of reading the syringe, which is incorrect.

(c)(ii) This part was well answered by most candidates although some candidates did not read the question clearly and commented on the stopwatch not working properly or not being accurate.

# Section B

## Option A - Materials

### Question 3

Most candidates were able to obtain at least one mark on this question but struggled with the distribution of the nematic liquid crystal phase.

### Question 4

(a) Many candidates did reasonably well in this question but some struggled with the number of electrons required.

(b) Most candidates did not seem to understand any advantages of using plasma technology rather than regular mass spectrometry.

(c) This question was reasonably answered with many candidates receiving a mark for the action of a catalyst. The terms adsorbed and desorbed were often missing.

(d) Most candidates were awarded one mark for how alloys conduct electricity. Some struggled with describing why they are harder than pure metals.

(e) Carbon nanotubes proved to be difficult for the majority of the candidates. Hardly any candidates stated an equation for the formation of carbon nanotubes from carbon monoxide.

### Question 5

(a) Few candidates scored at least one mark although most either scored both or none for this polymer structure. Some did not read that only four monomer units are required.

(b) Almost all candidates received the mark for identifying the correct absorption band for polychloroethene.

(c) This was a well-answered question; with most candidates identifying at least one method plasticizers affect the properties of plastic.

(d) Several candidates wrote vague answers as to why the addition of plasticizers is controversial.

(e) Candidates seemed to have difficulty in comparing addition and condensation polymerisation with regard to green chemistry.

(f) Several candidates struggled to draw the full structural formula of the peptide linkage formed during the polymerisation of the two reactants.

### Question 6

(a) The number of atoms in the unit cell was correctly calculated by most of the candidates.

(b) Majority of the candidates managed to get three marks in determining the density of the calcium.

### Question 7

(a) The question about superconductor was well answered by the candidates.

(b) Some candidates struggled to outline the difference in the behaviour of Type 1 and Type 2 superconductors when the temperature is lowered.

### Question 8

(a) The candidates seemed to have difficulty in outlining why heavy metals are toxic.

(b) Majority of the candidates managed to get two marks in determining the maximum concentration of lead(II) ions using solubility product constant.

(c) This was not well answered by most of the candidates.

## Option B – Biochemistry

### Question 9

(a)(i) This question was well answered with many scoring the mark although there were quite a few incorrect responses that answered “beta-helix” rather than “beta-pleated sheet”.

(a)(ii) Almost all the candidate’s stated hydrogen bonding as the similarity between the 2 types of secondary structures but lost marks on the difference between them.

(b) This question was well answered where most candidates received one mark for identifying that the enzyme will denature with an increase in temperature. However, many candidates did not continue with the explanation that the shape of the active site changes.

(c) Many candidates stated correctly that Vmax remains unchanged but only some mentioned that a higher substrate concentration was required to reach Vmax for the second mark.

(d)(i) Many candidates received two marks for this part while some candidates only suggested one reason or repeated the same reason (for example - heat and energy from the sun) even though the question clearly asked for two reasons.

(d)(ii) The candidates struggled with this part and gave journalistic or vague answers that cannot be awarded marks. Atom economy was mentioned correctly by a few candidates.

### Question 10

(a)(i) Several candidates stated correctly that $pK_a2$ should be used with a reason whereas others wrote pKa1, which was incorrect.

(a)(ii) Majority of the candidates calculated correctly the pH of the glutamine solution while other candidates managed the ECF mark from part a (i).

(b) This part was poorly answered by many candidates and was unable to state that genetic code is a sequence of bases in DNA and each codon codes for an amino acid. Often complex answers were written which were incorrect.

### Question 11

(a)(i) Almost all the candidates struggled with this part. Although the phosphodiester was a challenging mark it could be awarded in both the protonated and deprotonated form. The two ester groups were required for the second mark. Candidates were not able to draw correctly for both marks, and many left this question blank.

(a)(ii) This part was very well answered.

(b) This question was another one where the first part was fairly well answered, but the explanation or second mark was often not correct or incomplete.

(c) Many candidates missed the idea of a long or large non-polar chain when describing the structure of vitamin E. Simply stating non-polar chain was not sufficient for the mark.

(d) Candidates were required to state one effect of increased LDL. Majority of the candidates scored well on this part. High cholesterol is not an acceptable answer but was frequently seen.

### Question 12

(a) This was reasonably answered although there were some candidates who stated ester or hemiacetal, which is incorrect.

(b) This part was very poorly answered. Majority of the candidates had no idea about the reason whether the six-membered ring was an alpha or beta isomer.

(c) This question was poorly answered. Many candidates lost marks due to sloppy drawing and incorrect bond linkages. Some candidates did not separate the two monosaccharides as instructed.

### Question 13

(a) This part was fairly well answered with the majority of the candidates managed one mark. The second mark was missed because the candidates did not write extensive conjugated system or extensive delocalised bonding system.

(b)(i) Many candidates managed one mark by describing the graph and stating that the affinity of other sites for oxygen increases/cooperative bonding. Several candidates missed that it was a sigmoid/S-shaped curve.

(b)(ii) Many candidates were able to sketch another line to show the effect of an increase in body temperature on the oxygen saturation of haemoglobin.

## Option C - Energy

### Question 14

Many candidates performed well on this question, especially when identifying an advantage of tidal power. The candidates who struggled tended to either give vague or journalistic answers especially for the disadvantage of tidal power.

### Question 15

(a) This part was not well answered. Many candidates didn't answer the question as instructed. Candidates required two correct statements, either about fractional distillation or cracking as a process for one mark.

(b) This part was very well answered by most candidates with the correct number of significant digits as specified in the question.

(c) Candidates responded well to at least one mark of this question. There were several different ways to earn the two marks possible. The most common way candidates earned marks were by identifying the use of a catalyst and then the idea of the compound reforming into a smaller or branched compound. Very few candidates discussed the idea of purification or separation into individual compounds, which is another important part of this process.

## Question 16

(a)(i) This part was well answered.

(a)(ii) This part was also fairly well answered although some candidates missed the concept of minimum mass to sustain a chain reaction.

(a)(iii) This part saw some reasonable answers, but some other candidates wrote very vague or general answers.

(b) This was a well-answered question with most candidates referring to fusion having less or no radioactive waste.

(c) Most of the candidates were able to state correctly the mass difference between reactants and products and $E = mc^2$.

(d) Many candidates were able to calculate the half-life of an isotope correctly.

## Question 17

This question was well answered, and many candidates received either one or both marks.

## Question 18

(a) This part was fairly well answered with most candidates receiving one of the two marks. There were many candidates who stated asymmetric stretching and bonds vibrate but missed writing polarity and dipole changes, which deprived them of the second mark.

(b) This part was reasonably answered although there were many candidates who gave vague answers that did not receive marks.

## Question 19

(a) The question on microbial cell invited varied responses. Half equations for the oxidation of glucose or reduction of oxygen were rarely written. PEM/membrane separates two half- reactions and allows proton transfer from anode to cathode was missed by most of the candidates.

(b) The cell potential was correctly calculated by several candidates with some candidates managed an ECF mark for an error in the calculation. Unfortunately, the ln $Q$ part was frequently wrong due to candidates forgetting to square the denominator.

(c) Most candidates were able to state one difference between a primary and a secondary cell.

### Question 20

(a) Several candidates managed one mark to show conductivity of semiconductors on increasing the temperature but were unable to show that generally conductivity decreases for metals when the temperature is increased.

(b) The question on dye-sensitized solar cell invited mixed responses. While most candidates correctly stated that dyes absorb light but several failed to mention that electrons from the excited dye pass to TiO2/semiconductor.

## Option D – Medicinal Chemistry

### Question 21

(a) Most candidates receive one mark for this question, mainly for the therapeutic window. Some candidates inverted the ratio as ED50/TD50 for therapeutic index.

(b) This part was reasonably well answered with some very good answers.

### Question 22

(a) This was a very well answered question. Even weak candidates were able to identify one correct absorption band present in an infrared spectrum of aspirin.

(b)(i) A significant number of candidates were able to calculate the mass of aspirin correctly.

(b)(ii) A significant number of candidates were able to calculate the percentage purity of aspirin correctly although some managed an ECF mark.

(c) This part was reasonably answered by most candidates.

(d) This part was well answered by the majority of the candidates.

### Question 23

(a)(i) Some candidates were not confident enough in their answers to receive a mark while others confused the action of ranitidine which blocks H2 receptors with omeprazole which is a proton pump inhibitor.

(a)(ii) While most candidates were awarded at least one of the two marks possible for this question some of the descriptions were too vague or incomplete to receive a mark.

(b) This was generally a well-answered question. Most candidates who did not receive the mark inverted the concentration of the conjugate base/concentration of the acid in the calculation.

### Question 24

(a) Candidates responded fairly well to this question. Candidates who did not receive a mark were either too vague or discussed anti-bacterial methods.

(b) Most candidates were awarded at least one of the two marks possible for this question. Some student responses were too vague or discussed the social and political issues surrounding the AIDS crisis. There were also some responses, which only talked about AIDS extensively with no mention of the virus.

### Question 25

(a) The synthesis of taxol in terms of green chemistry criteria invited varied responses. While some candidates were precise in their answers but others lost focus and wrote something about green chemistry.

(b) The operation of a polarimeter to distinguish between enantiomers was generally well handled by the candidates while some missed stating to measure the angle/direction of rotation.

### Question 26

(a) The most frequent response was the short half-life, followed by the emission and detection of gamma radiation.

(b) Most candidates were able to calculate the percentage of technetium-99m correctly.

### Question 27

(a) While many scored the first marking point, full marks were rarely seen. Many candidates mixed up this and a dichromate breathalyser.

(b) Most candidates incorrectly identified O-H, failing to realise it is unsuitable due to its abundant presence in the breath.

## Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding mark schemes to assist candidates with examination preparation.
- Teachers should ensure that definitions covered in the assessment statements for each option are well known by candidates.
- Candidates should be given guidance as to the level of depth expected in responses to questions. Journalistic answers to questions will not suffice.
- Candidates need to read questions carefully to ensure they answer appropriately and precisely.
- Teachers should encourage candidates to note the number of marks allocated to a question and correlate this to their response to ensure it is sufficiently detailed. This will enable candidates to avoid just writing rambling statements, hoping that they will pick up marks somewhere in their answer.
- Candidates should read questions carefully to avoid missing parts of the question. Chemical equations should be given wherever possible to support the processes discussed in options.
- Candidates must know the meaning of the different command terms that appear in the assessment statements and in the examination papers.

- Teachers should emphasise the importance of clearly set out calculations Significant figures should be considered in all calculation type questions. Candidates should read questions carefully to avoid errors in units.
- Candidates must be instructed to use the chemistry data booklet during the chemistry course so that they are familiar with what the chemistry data booklet includes and practise determining the molecular formulae for the compounds, the structures of which are given in the booklet.
- Some candidates are writing more than one answer hoping the examiners will pick up the correct answer. This is not encouraged because a correct response followed by an incorrect response nullifies the mark of that question.
- Candidates should write legibly so examiners can read responses.

# Standard level paper three

## General comments

We received detailed feedback from 144 teachers this session. Most of the teachers (97%) found the paper of appropriate difficulty with 3% describing it as too difficult. When compared to last year's paper 74% of the teachers felt it was of a similar standard, 7% felt it was a little easier, and 19% felt it was a little more difficult. In terms of clarity of wording 88% of the teachers felt that the paper was good to excellent while 10% felt it was fair, and 1% thought it was poor. The presentation of the paper received similar comments with 91% describing the paper as good to excellent and 8% describing it as fair. Teachers are reminded that special education students can apply for additional time to take the exam if they have a need for extended time and potentially the use of molecular modelling kits when molecular diagrams are too challenging to visually interpret.

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

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

- Reading unfamiliar data tables and applying their knowledge to data interpretation.
- Stoichiometry- especially when applied to unfamiliar situations.
- Accurate molecular drawings.
- Learning and giving textbook definitions.
- Green chemistry principles.

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

- Questions that involved recall versus explanations
- Identifying reaction types
- Calculations with specified significant figures
- Nuclear equations
- Identifying greenhouse gases
- Identifying IR absorption bands

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

## Section A

In general, student performance on Section A has improved this session. It is important to note that the content tested in this section comes from the core material. Students are expected to be able to interpret data in tables and graphs that is based on core concepts as well as discuss laboratory skills based on the prescribed practical program.

### Question 1

(a) Most candidates did well on this question, identifying the correct experiment by number or beverage.

(b)(i) Many candidates struggled with this question, answering it from a mathematical perspective rather than explaining why the rate would decrease over time from a chemical perspective. There were several possible correct answers (reaching equilibrium, acid concentration decreasing, solution becoming saturated with lead ions, etc.…)

(b)(ii) This question required students to recognize the rate of lead dissolving did not increase with acidity and to refer to data in the table for the reason. Some students did not refer to data in the table and did not receive the mark because they did not have a reason, other students compared the rate of lead dissolving with temperature increasing which did not answer the question.

(c)(i) This question was an equilibrium question. Many students received 1 mark for either concentration of lead decreased, or lead chloride was produced and quite a few recognized that the explanation was the reaction shifted to the reactant or left side for the second mark.

(c)(ii) Most students receive one mark for this question, and many receive both marks. The most common mistakes involved incorrect conversions from gram to milligrams or milligrams to grams.

### Question 2

(a) This question was challenging for many students. Quite a few candidates did draw a tangent line at 20s for 1 mark, show a slope/gradient calculation of the line for 1 mark, and had a reasonable final value for the final mark. Some candidates only found the average rate by finding the ratio of the value at that data point and received one mark (16/20=0.80 $cm^3\ s^{-1}$). Candidates also received one mark if they had a correct answer with no work since the question clearly asked students to show their work.

(b) The reaction rate was originally monitored by measuring the volume of $CO_2$ produced. Students needed to propose another method for this reaction, with a reason, that could be used to measure the rate. There were several possible correct answers and most students received at least one mark with many receiving both marks. The most common incorrect answer involved changes in temperature.

(c)(i) This question was asking about a systematic error. There were several possible correct answers for the error, but students also needed to clearly identify a specific error and if the rate increased or decreased for the second mark. Many students confused this with the concept of a random error and identified the uncertainty of reading the syringe which is incorrect. Teachers need to reinforce the concept of systematic versus random errors.

(c)(ii) This question was well answered by most candidates although some students did not read the question clearly and commented on the stopwatch having problems or not being accurate.

## Section B

Of the four choices Option C was the most popular with approximately 36% of the students attempting this option. Option D was the next most attempted with approximately 33% followed by Option B with 26% of the candidates attempting this option. Once again Option A was the least attempted selection with only about 5% of the candidates attempting it. Core concepts may also be included in the options when they are directly related to the topics being tested.

### Option A

### Question 3

Most students were able to obtain at least one mark on this question. The distribution was the most challenging part.

### Question 4

(a) Many students scored at least one point typically the 1st mark with many obtaining the 2nd and 3rd marks as well. If students struggled it was typically with the second mark where the number of electrons was required.

(b) This was question was not answered well. Most candidates did not seem to understand any advantages of ICP-MS or how to describe them.

(c) This question was reasonably answered with many candidates receiving a mark for the action of a catalyst. Teachers should remind students to use the terms adsorb/desorb with this type of process, not absorb.

(d) Most candidates were awarded M1 for how alloys conduct electricity. Some struggled with describing why they are harder than pure metals. Teachers should remind student to use proper terminology such as atoms or ions not nuclei for this type of answer.

(e) This was a very poorly answered question. Very few candidates knew the correct balanced equation or gave an equation that was not balanced.

### Question 5

(a) Quite a few candidates scored at least one mark although most either scored both or none for this polymer structure.

(b) Almost all students managed who attempted this question received the mark for identifying the correct absorption band.

(c) This was a well answered question, with most candidates identifying at least one method plasticizers affect the properties of plastic.

(d) Many students received a mark for this question although some did not because their answers were too vague.

## Option B

### Question 6

(a)(i) This question was quite well answered with many scoring the mark although there were quite a few incorrect responses that answered “beta-helix” rather than “beta-pleated sheet”.

(a)(ii) The similarity in bonding between the 2 types of secondary structures was answered well but the difference was not. Most students were not descriptive enough to receive the second mark or simply repeated the idea of proteins containing an alpha-helix and beta-pleated sheets rather than describing something different about them.

(b) This was another question where most candidates received one mark for identifying that the enzyme will denature with an increase in temperature. However, many candidates did not continue with the explanation of the active site shape changing or substrate molecules not longer fitting into the active site.

(c)(i) While many candidates did receive two marks for this question some candidates only suggested one reason or repeated the same reason (for example - heat and energy from the sun) even though the question clearly asked for two reasons.

(c)(ii) Students tend to struggle with these questions and end up giving journalistic or vague answers that cannot be awarded marks. It is important for teachers to instruct students to give more specific answers directly related to the topics presented.

### Question 7

(a)(i) This was very poorly answered. Although the phosphodiester was a challenging mark it could be awarded in both the protonated and deprotonated form. The two esters should have been much more straight forward mark, and both were required to receive the second mark. Students struggled with proper structural drawings for both marks and many students simply left this question blank. The functional groups did need to be drawn out in their full structural form to receive the mark as indicated in the question.

(a)(ii) This question was well answered.

(b) This question was another one where the first mark was fairly well answered but the explanation or second mark was often not correct or complete.

(c) This question was not well answered even though it has appeared on previous tests. In any cases the students did not give the relative energy density or the reason. It is important that candidates read question carefully and responds completely to each question as asked.

(d) This question was also not answered well even though it has appeared on previous tests. Many students missed the idea of a long or large non-polar chain when describing the structure.

(e) Students were required to state two effects of increased LDL. High cholesterol is not an accepted answer but still frequently seen. Many students also repeated similar answers that could not receive the same mark.

## Question 8

(a) This was reasonably answered although there were some students who responded with ester or hemiacetal which is incorrect.

(b) This question was very poorly answered. Many students lost marks due to sloppy drawing and incorrect bond linkages. Some students did not separate the two saccharides as instructed.

## Option C

## Question 9

Many candidates performed well on this question especially when identifying an advantage of tidal power. The students who struggled tended to either give vague or journalistic answers especially for the disadvantage of tidal power.

## Question 10

(a) This question was not well answered. Many candidates didn't answer the question as asked. Candidates needed two correct statements, either about fractional distillation or cracking as a process for 1 mark.

(b) This question was very well answered by most students and many answered with the correct number of significant figures as specified by the question.

(c) Students responded well to at least one mark of this question. There were several different ways to earn the 2 marks possible. The most common way students earned marks were by identifying the use of a catalyst and then the idea of the compound reforming into a smaller or branched compound. Very few students discussed the idea of purification or separation into individual compounds which is another important part of this process.

## Question 11

(a)(i) This question was well answered.

(a)(ii) This question was also fairly well answered although some students missed the concept of maintaining a chain reaction.

(a)(iii) This question was reasonable answered by many students, but some gave very vague or general answers.

(b) This was a well answered question with most student referring to fusion having less or no nuclear waste. There were many different possible correct answers.

(c) This was a well answered question with most students solving for the number of years correctly.

## Question 12

(a) This question was not well answered as many students missed the idea of the system being a large/extensive/extended or containing many alternating single and double bonds. Although fewer students than expected received a mark, examiners did note there were more student who wrote about conjugation or alternating single and double bonds (but were missing the idea of the system being large) which is an improvement from previous sessions.

(b) This question was well answered, and many candidates received one or both marks. Some candidate who did not receive marks were too vague, especially with the limitation.

## Question 13

(a) This question was well answered.

(b) This question was fairly well answered with most students receiving one of the two marks. There were many students who mentioned the information in M1 (asymmetric stretching and bonds vibrate) or M2 (polarity and dipole changes) more than one time but could only receive one mark. Teachers need to remind students each mark is a different topic or concept.

(c) This question was reasonably answered although there were many students who gave vague answers that did not receive marks. Carbon cannot be “filtered out” and the process of “carbon capture or scrubbing” is different from filtering.

## Option D

## Question 14

(a) Most students receive one mark for this question and therapeutic window was probably the more successfully mark. Teachers need to remind students not to refer to lethal dose for therapeutic index. Some students forgot to mention the 50/50% when explaining therapeutic index or inverted the ration as ED50/TD50.

(b)(i) This was not a particularly well answered question even though it has been seen in previous exams. Many students confused it with the idea of solubility and passing through the blood brain barrier which was 1(b) (ii).

(b)(ii) This question was reasonably well answered with many students receiving at least one of the two marks.

## Question 15

(a) This was a very well answered question. Even weak candidates were able to identify one correct wavenumber.

(b)(i) This was a fairly well answered question with most students receiving both marks and many receiving one mark.

(b)(ii) This was a reasonably well answered question but quite a few students still struggled with what should have been a basic calculation, even when using ECF from the previous question.

(c) This question was reasonably answered by most students although some candidates confused the modification of aspirin into an ionic salt with the modification of the side chain of penicillin.

(d) This question was well answered.

(e) This question was not very well answered by some students. Some students gave vague answers or responses not related to the concept of Green chemistry.

### Question 16

(a)(i) This question was not very well answered even though it has been seen in previous scripts. Some students were not through enough in their answers to receive a mark while others confused the action of ranitidine which blocks H2 receptors with omeprazole which is a proton pump inhibitor.

(a)(ii) While most students were awarded at least one of the two marks possible for this question some of the descriptions were too vague or incomplete to receive a mark.

(b) This was in general a well answered question. Most candidates who did not receive the mark inverted the concentration of the conjugate base/concentration of the acid in the calculation.

### Question 17

(a) Candidates responded fairly well to this question. Students who did not receive a mark were either too vague or discussed anti-bacterial methods.

(b) Most candidates were awarded at least one of the two marks possible for this question. Some student responses were too vague or discussed the social and political issues surrounding the AIDS crisis. There were also some responses that did not refer to a virus but AIDS.

## Recommendations and guidance for the teaching of future candidates

- The experimental laboratory programme should be integrated with the rest of the course and students should be familiar with the application of lab techniques for all topics and the options taught. The use of computational models is becoming increasingly relevant and their use should be encouraged whenever possible.
- It is critical that core chemical principles are integrated in all of the options. Core chemistry should always underpin applied topics.
- Candidates continue to struggle with questions that require explanations, interpretations or multiple steps. Very often they addressed only one part of the question while neglecting the others.
- The interpretation of command terms continues to be an issue. Students should be provided with a list of the command terms and their definitions, so they are familiar with expectations for each individual term and how they are applied in a variety of questions

and responses. Students seem to especially struggle with compare and contrast statements which require BOTH items being discussed.

- Candidates should always look at the associated marks allocations in questions. Together with the command terms the marks provide guidance on the depth expected by examiners for each answer.
- Provide training during the course in addressing question and producing concise arguments. Superfluous comments achieve no extra mark and may lead the student to lose focus.
- Students are not required to answer questions in complete sentences. They may focus their responses as bullet points.
- Converse arguments are accepted. For ESL/EAL students this may facilitate producing their arguments.
- Handwriting continues to be a problem with some responses being illegible. The IB Coordinators should be made aware of specific situations with enough time so that special accommodations may be arranged. Students should consider they type of pen used as well since some can smear or bleed through the paper making marking more challenging when scripts are scanned.
- Bond connections should be emphasized throughout the course as well as correct organic nomenclature and different representation systems such as abbreviations, condensed format, and organic line structures. While not all of these methods are required, if students are going to use a particular representation it must be used correctly.
- Please encourage candidates to use $A_r$ values in section 6 of the data booklet, round numbers correctly, and state their answers to calculations to an appropriate number of significant figures. Discourage rounding after each step or prior to reporting their final value.
- Train students to be specific in their answers using scientific terms, e.g. 'molecules' aren't synonyms of 'groups', and to read questions carefully to ensure that they answer every part of the question. Practice in the precise use of language and chemical terms throughout the course (e.g. atom/molecule/ion/particle) when writing answers to questions.
- Throughout the course, draw your students' attention to the implications of concepts as they are related to the environment. Suggestions are provided in the right-hand column in the programme guide. This should dissuade students from producing journalistic or vague answers.
- Please provide enough opportunities for hands on work during the course including all of the mandated labs.
- It is important to allocate sufficient class time to cover every part of the option in detail. The class time allocated for covering the option should be 15 hours.
- Use discussion in class encouraging students to reflect on concepts and their applications to help them answer objective three questions.
- Use discussion in class encouraging students to reflect on concepts and their applications to help them answer objective three questions.