Chemistry

Timezone 1

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 - 16	17 - 31	32 - 43	44 - 54	55 - 66	67 - 78	79 - 100

Standard level overall

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 15	16 - 28	29 - 42	43 - 54	55 - 64	65 - 77	78 - 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 - 22	23 - 26	27 - 31	32 - 36	37 - 40

Standard level paper one

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 10	11 - 14	15 - 18	19 - 21	22 - 25	26 - 30

Higher level paper two

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 13	14 - 27	28 - 35	36 - 46	47 - 56	57 - 67	68 - 90

Standard level paper two

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

Higher level paper three

Grade:	1	2	3	4	5	6	7

Mark range:	0 - 6	7 - 13	14 - 18	19 - 23	24 - 27	28 - 32	33 - 45

Standard level paper three

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 4	5 - 9	10 - 13	14 - 17	18 - 20	21 - 24	25 - 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 number of candidates who sat this paper was 5921 from 436 schools. The average mark scored was 25.29 out of 40. This is 3 marks higher than May 2018. The marks ranged from 0 to 40 with 76 candidates scoring 9 or less, compared to 198 who scored 9 or less in 2018. There were only 6 questions where less than 50% of candidates did not get correct.

There were 53 teachers who took the time to review the paper and send feedback after the examination. They generally felt the paper was fair, perhaps a bit easier than last year. The range of questions was good with the only concern being wording of some questions, making them tricky. The statistics given below back these observations.

Teachers commented that questions which required mathematical manipulation without the use of a calculator were simpler and more easily handled this year. Specific concerns for G2's will be addressed in individual question analysis

Teachers also sent the following feedback:

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	N/A
4%	28%	60%	8%	0%	0%

Clarity of wording

Very poor	Poor	Fair	Good	Very good	Excellent
1.89%	1.89%	16.98%	24.62%	43.40%	9.43%

Presentation

Very poor	Poor	Fair	Good	Very good	Excellent
0%	0%	11.32%	22.64%	45.28%	20.75%

The table below lists the questions from least to most difficult where the difficulty index is the percentage of candidates giving the correct answer. It also 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).

There is a much larger range in the discrimination index on HL P1 than on SL P1.

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
15	178	201	266	**5146**	7	88.75	0.23
38	295	**4940**	72	484	7	85.20	0.21
19	244	618	75	**4856**	5	83.75	0.37
10	**4702**	433	642	18	3	81.10	0.33
11	342	**4639**	399	412	6	80.01	0.28
21	660	318	260	**4555**	5	78.56	0.39
20	398	**4538**	529	328	5	78.27	0.35
40	**4387**	348	504	553	6	75.66	0.38
39	485	**4378**	788	141	6	75.51	0.41
7	389	774	263	**4368**	4	75.34	0.37
3	899	104	428	**4360**	7	75.20	0.42
34	547	**4342**	664	233	12	74.89	0.51
36	965	331	**4223**	275	4	72.84	0.43
6	379	555	**4149**	709	6	71.56	0.28
14	**3969**	1613	83	130	3	68.45	0.50
32	1342	189	300	**3963**	4	68.35	0.44
29	1029	**3870**	553	343	3	66.75	0.50
13	**3862**	679	914	334	9	66.61	0.57
2	**3848**	1446	461	38	5	66.37	0.46
4	203	1716	**3791**	84	4	65.38	0.47
12	855	559	648	**3724**	12	64.23	0.40
33	321	**3640**	1359	464	14	62.78	0.51
23	**3444**	1090	239	1017	8	59.40	0.59
30	1267	660	458	**3407**	6	58.76	0.42
8	899	**3394**	1397	103	5	58.54	0.39
24	438	1804	165	**3386**	5	58.40	0.70
27	490	445	**3376**	1478	9	58.23	0.51
26	**3329**	741	997	726	5	57.42	0.55
28	697	712	**3326**	1057	6	57.36	0.50
17	**3173**	1424	531	667	3	54.73	0.30
22	834	**3137**	779	1040	8	54.10	0.52
18	1045	560	**3135**	1053	5	54.07	0.50
5	827	**3041**	1160	766	4	52.45	0.50
16	205	758	1921	**2911**	3	50.21	0.54
1	**2448**	2263	110	973	4	42.22	0.34
37	1053	1658	**2336**	737	14	40.29	0.16
31	**2313**	621	1883	973	8	39.89	0.48
9	993	**2282**	991	1521	11	39.36	0.47
35	1788	**2156**	1040	800	14	37.19	0.49
25	**1653**	1720	1156	1265	4	28.51	0.24

Number of candidates : 5798

The areas of the programme and examination which appeared difficult for Reactions of acid with active metals and carbonates.

- Reactions of acid with active metals and carbonates.
- Recognizing cyclic compounds existing as *cis* and *trans* isomers.
- Differentiating between protic and aprotic solvents.
- Ranking compounds in order of increasing boiling points.
- The requirements of a standard hydrogen electrode used as a base measurement.

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

- Use of Hess's Law.
- Writing measurements with correct uncertainties.
- IUPAC nomenclature
- Understanding how collision theory influences rate of reaction.
- The concept of charge and ionic radii size influencing the strength of a metallic bond.

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

Question 1

A few G2 forms suggested that candidates could have chosen A or B. However, homogeneous and heterogeneous mixtures are usually represented in such a way while only option A shows a clear separation in the mixture. We will avoid schematic diagrams in the future for this type of questions.

Question 2

The concept of using volume ratios of gases as mole ratios in balanced equations was well answered.

Question 3

Well answered and straight forward.

Question 4

Some candidates had ground state configuration of Cr as $4s^2 3d^4$ rather than $4s^1 3d^5$

Question 5

52% of candidates could identify the element for successive ionization energies with no clear misconception based on the other choices.

Question 6

A well answered question regarding finding principal energy level and valence electrons from position on the periodic table

Question 7

Another well answered question with 75% correctly ranking elements according to atomic radii. One G2 form stated that this question was repeated in paper 2.

Question 8

Stating the 4s electrons are lost first in forming the Fe(II) ion was done correctly by 58% but with a low discrimination index.

Question 9

Ranking compounds in order of increasing boiling points proved challenging. There existed a number of misconceptions based on the incorrect answers chosen. Wrong answers were evenly distributed.

Question 10

More than 81% of candidates could correctly apply IUPAC nomenclature for an inorganic substance.

Question 11

The concept of charge and ionic radii size on the strength of the bond was answered well but had one of the lowest discriminatory indices on the paper.

Question 12

This question on delocalized electrons was also well answered.

Question 13

Identify carbons with sp, sp^2, and sp^3 hybridization was well answered.

Question 14

Answered correctly by 66%, this question relating specific heat capacity to temperature rise was handled better by higher scoring candidates.

Question 15

Nearly 89% of candidates answered this Hess Law question correctly. This topic was obviously well covered.

Question 16

Higher scoring candidates had more success understanding enthalpy and entropy decreases

Question 17

One G2 comment asked if enthalpy of atomization was on the syllabus. This Topic 15.1 question was answered correctly by 54% of candidates but did not differentiate well between higher and lower scoring candidates.

Question 18

One G2 form queried if visible spectroscopy is on the core syllabus and therefore should candidates be aware of monitoring a reaction via colour change. However, 6.1 clearly states that following change in colour is one method of following reactions.

Question 19

This question on collision theory was one of the best answered in the exam.

Question 20

More than 78% of candidates correctly identified a first order reaction graph.

Question 21

Another well answered question on rate mechanisms.

Question 22

Candidates scored well while one teacher thought it was a trick question and particularly tough. Relationship between *K* values on reversed equations should be understood.

Question 23

The higher scoring candidates did better on identifying the direction of spontaneity given a positive ΔG.

Question 24

This had the highest discriminatory index on the exam. Most of the incorrect answers indicated that a basic solution would have **$[OH^-] = 1.0 \times 10^{-13}$ mol dm^{-3}** rather than **$[H_3O^+] = 1.0 \times 10^{-13}$ mol dm^{-3}**.

Question 25

This question on reactivity of acids with carbonates and metals (first bullet point in Topic 8.2) confused higher and lower scoring candidates alike and was the worst answered question in paper 1. One teacher commented "The question does not seem clear. They would all react with acids, but what does "most acids" mean?".

Question 26

Identifying a Lewis acid seemed relatively easy for the majority of candidates.

Question 27

Strength of conjugate bases appeared to be another good discriminator, with higher scoring candidates performing better.

Question 28

57% of candidates correctly identified products of electrolysis at the anode with the incorrect answers being split by the remaining 43%

Question 29

One G2 form thought the question was awkwardly worded, implying oxidation is occurring in two places rather than one. This was one of the better answered question with a relatively low discriminatory index.

Question 30

Majority of candidates answered this correctly with the most common mistake being omission of time as a factor affecting electrolysis quantities.

Question 31

This was a poorly answered question on the standard hydrogen electrode. Many candidates believed what was **not** required was a Pt electrode material.

Question 32

Another relatively high scoring question on IUPAC nomenclature.

Question 33

Markovnikov addition was handled much better by higher scoring candidates.

Question 34

75% of candidates could correctly identify the oxidation of a primary alcohol to form carboxylic acid.

Question 35

Identifying protic from aprotic solvents was poorly done my most candidates.

Question 36

73% of candidates knew that benzene did not react the same way as alkenes.

Question 37

Cis and *trans* isomerism on cyclic alkanes was poorly answered. This had the lowest discriminatory index on the test and all incorrect answers were fairly evenly distributed.

Question 38

More than 85% of candidates were able to identify a correct uncertainty, however not a good discriminating question.

Question 39

Graphical representation of catalysis was also well answered.

Question 40

The vast majority of candidates knew that IR spectroscopy can be used to identify functional groups.

Recommendations and guidance for the teaching of future candidates

- Continue to challenge students to apply concepts in new situations.
- Practice problem solving so that students are confident and can apply concepts with accuracy and speed.
- Encourage students to give their reasoning for their choices in multiple choice questions.
- Candidates should be encouraged to answer all questions. If they are not sure of the answer, they should eliminate incorrect answers and then guess one of the remaining answers, as there is no penalty for incorrect answers.
- Candidates should be made aware that the questions appear in the order of the topics in the syllabus, and that the average time allocated for each question is 1.5 minutes.

Standard level paper one

General comments

The number of candidates who sat this paper was over 8180 and the average mark scored was 16.11 out of 30 which was slighter higher than the average mark in May 2018 (15.43 out of 30).

There were 616 schools which took the exam and 61 G2 forms completed. Teachers who sent feedback generally found the paper appropriate with a good coverage of topics. Several teachers expressed concern over the clarity of questions but thought that the paper had a range of difficulties. Some commented that the paper had a few too many "trick" questions which didn't test chemistry. One commented: *"For instance, knowing to multiply K values or find a reciprocal does not allude to knowing what K values represent in an actual reaction or knowing to look at exponents does not confirm knowledge of pH values only tricks."*

These overall impressions are only somewhat supported by the statistics:

Approximately 62% felt that the paper was of similar difficulty to last year with 21% viewing it as slightly easier and 17% a little more difficult. This edges a bit more towards easier than last year.

Approximately 72% of respondents said the suitability of the paper in terms of clarity and presentation was good to excellent with 20% viewing it as fair and 8% as poor. This compares to only 2% stating poor clarity on last years' paper one. Specific concerns for G2's will be addressed in individual question analysis.

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). This year's paper had a small range in the discrimination index with nearly all question in the 0.3 to 0.6 range.

Question	A	B	C	D	Blank	Difficulty Index	Discrimination Index
14	411	435	620	6423	22	81.19	0.37
28	660	6272	204	747	28	79.28	0.25
2	79	160	1917	5733	22	72.47	0.35
17	5440	428	357	1664	22	68.77	0.37
7	748	1011	5266	863	23	66.57	0.30
29	840	5186	1493	368	24	65.55	0.47
20	753	1010	5063	1063	22	64.00	0.46
3	1896	224	837	4933	21	62.36	0.57
15	419	501	2191	4781	19	60.43	0.51
22	973	205	1987	4716	30	59.61	0.59
12	894	4704	1313	968	32	59.46	0.25
25	2225	406	691	4560	29	57.64	0.45
27	1403	4425	1478	556	49	55.93	0.65
5	4390	429	640	2427	25	55.49	0.56
21	1928	4334	949	678	22	54.78	0.57
11	2181	4208	1093	404	25	53.19	0.49
13	4185	3197	179	331	19	52.90	0.55
4	4007	2194	919	764	27	50.65	0.58
18	1087	3857	1407	1536	24	48.75	0.57
10	1375	3796	812	1899	29	47.98	0.58
23	1423	1183	3683	1590	32	46.56	0.40
6	471	3439	3578	404	19	45.23	0.55
16	2026	674	3484	1705	22	44.04	0.44
1	3471	2714	248	1455	23	43.88	0.35
24	325	3016	3423	1122	25	43.27	0.52
19	858	3575	437	3012	29	38.07	0.55
9	1401	2736	1618	2128	28	34.58	0.36
8	2691	1073	1726	2389	32	34.02	0.46
26	1259	2347	2676	1596	33	33.83	0.47
30	1077	2370	2137	2287	40	28.91	0.43

Number of candidates : 7911

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

Question 1

A few G2 forms suggested that candidates could have chosen A or B. However, homogeneous and heterogeneous mixtures are usually represented in such a way while only option A shows a clear separation in the mixture. We will avoid schematic diagrams in the future for this type of questions.

Question 2

This question was well answered while one teacher commented that using 1 as a coefficient in a “sum the coefficients” question seemed tricky.

Question 3

Well answered and straight forward.

Question 4

The idea of *P* vs 1/*V* as being non-linear was the most common mistake, with just over 50% of candidates earning this mark.

Question 5

Almost 56% of candidates could find a 1:1 ratio as an average of 2 items, however many had ^{79}Br and ^{80}Br with an average mass of 79.90

Question 6

A large number of the candidates had ground state configuration of Cr as $4s^2 3d^4$ rather than $4s^1 3d^5$

Question 7

A well answered question regarding finding principal energy level and valence electrons from position on the periodic table.

Question 8

Very disappointing results with a large percentage of the candidates thinking metals have a high electron affinity.

Question 9

Ranking compounds in order of increasing boiling point proved challenging. There existed a number of misconceptions based on the incorrect answers chosen being close to evenly distributed.

Question 10

Identifying resonance structure had one of the highest discriminatory indices. Only the higher achieving candidates had much success with this.

Question 11

Fairly well answered with the most widely held misconception being that ionic compounds conduct electricity in the solid state.

Question 12

The concept of charge and ionic radii size on the strength of the bond was answered well, but had the lowest discriminatory index on the paper.

Question 13

Answered correctly by 53%, this question relating specific heat capacity to temperature rise was handled better by higher scoring candidates.

Question 14

83% of candidates answered this Hess Law question correctly. This topic was obviously well covered.

Question 15

This question on enthalpy change was also well answered.

Question 16

One G2 form queried if visible spectroscopy is on the core syllabus and therefore should candidates be aware of monitoring a reaction via colour change. However, 6.1 clearly states that following change in colour is one method of following reactions.

Question 17

One teacher pointed out that the question should have stated for a fixed mass of calcium carbonate. However, this question was one of the highest scoring so it did not cause confusion.

Question 18

Not scored well and a couple of teachers thought it was a trick question and particularly tough. Relationship between *K* values on reversed equations should be understood.

Question 19

This was very poorly answered and had one of the highest discriminatory indices. More candidates thought that a basic solution would have **$[OH^-] = 1.0 \times 10^{-13}$ mol dm^{-3}**, rather than **$[H_3O^+] = 1.0 \times 10^{-13}$ mol dm^{-3}**

Question 20

One teacher thought this was a tricky question if candidates did not think of impurities in the combustion. However, 64% of candidates answered correctly.

Question 21

One G2 form thought the question was awkwardly worded, implying oxidation is occurring in two places rather than one. This question also had a relatively high discriminatory index.

Question 22

This question on identifying oxidizing agents was well answered by high scoring candidates, but not handled well by low scoring candidates.

Question 23

46% of candidates correctly identified products of electrolysis at the anode with the incorrect answers being split by the remaining 54%

Question 24

One G2 comment stated “the functional group by definition is an aldehyde, however, students must assume that the H should be considered as an 'R group in order to call it a carbonyl”. However, aldehyde was not an alternative answer, with the main misconception considering the C=O as a carboxyl rather than carbonyl.

Question 25

57% of candidates could correctly apply IUPAC nomenclature.

Question 26

Only 33% of candidates could identify the mechanism type with a large confusion between electrophilic addition and substitution.

Question 27

The largest gap between high scoring and low scoring candidates was on this question about oxidation of alcohols.

Question 28

80% of candidates could correctly identify uncertainty.

Question 29

Graphical representation of catalysis was also well answered.

Question 30

IHD was the worst answered question on Paper 1, with a low discriminatory index so handled poorly by all candidates.

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Recommendations and guidance for the teaching of future candidates

- Candidates need to be reminded that they should choose the best answer to each question and to leave no questions unanswered.
- Ensure the whole syllabus is taught as every topic is examined in this paper. It appeared that IHD was poorly treated this year.
- Questions in paper one follow the order of the guide so candidates can begin at a topic they are confident in if Stoichiometric Relationships (Topic 1) is not their strongest choice.
- Candidates should read questions carefully and pay special attention to anything which is in bold.
- Approach the teaching of chemistry from the chemistry perspective and not from memorizing tricks. Eg: K_c values for reactions which are multiples or reverses of one another.

Higher level paper two

General comments

50% of examiners and 21 % of G2 forms felt that paper 2 was more difficult than last year. There were 53 G2 forms submitted from 436 schools. The mean was 4 marks lower than last year but the paper was out of 90 instead of 95 marks.

While a few G2 comments thought the paper fair and of a similar standard to last year the bulk of comments pointed towards the paper being more difficult. Some specific concerns included beginning the paper with an organic question, too many questions revolving around benzene, the use of difficult and/or unfamiliar terminology, and confusing instructions in questions, such as "by annotating your graphs" but also supplying an answer box. There were a few comments from teachers that their students would not know what a dimer or adduct was. One teacher stated "Using terminology such as "active nitrating agent" seems unnecessary." Specific G2 comments will be addressed in individual questions.

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

- Stereochemistry and organic chemistry in general
- Mechanism for nitration of benzene
- Distinguishing between real and ideal gases.
- Confusing terms, such as atoms and ions, electrons and electron pairs, emitted and reflected.
- Identifying carboxylic acids form dimers due to hydrogen bonding.
- Plotting pH titration curves and finding p*K*a from the curve.
- Explanation of the action of a buffer by using equations
- Gibbs free energy change and equilibrium constant relation $\Delta G^{\ominus} = -RT \ln K$

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

- Deducing signals in a ^{1}H NMR spectrum
- Drawing structure of isomers
- Identifying homolytic fission and its condition
- Identifying wave number in an IR spectrum
- Calculating $[OH^{-}]$ given pH of solution
- Enthalpy calculations based on Born-Haber cycle and enthalpies of formation
- Calculations involving relative atomic mass
- Connection between atomic structure and chemical properties.
- Lewis structure and associated shapes of molecules
- Plotting relative values of successive ionization energies
- IUPAC nomenclature

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

Question 1

(a) Many identified two correct peaks but quite a few less the correct ratio.

(b) Generally well done, although some candidates repeated the formula of the 1,4-isomer structure or drew the wrong bond, e.g. benzene ring to H rather than C on CH_3.

(c)(i) The production of NO_3^- was a common answer.

(c)(ii) Performance was fairly good by schools covering the topic while others had no idea. There were many careless steps, such as omission or misplacement of + sign.

(d)(i) Very well done, with a few making reference to a catalyst.

(d)(ii) Some candidates lost one mark for the bond originated from H in CH_3 instead of C. Some teachers thought the use of the word “substituted alkane” made the question more difficult than it should have been.

(e) One of the most poorly answered questions on the exam with only 10% of candidates earning this mark. Some candidates just answered ‘yes’ or ‘no’ on whether the organic product is a racemic mix and very few mentioned the absence of a chiral carbon. One teacher though the use of benzene in this question made it unnecessarily tough, stating “the optical activity of benzene has not been covered due to the limited chemistry of benzene included in the specification. An aliphatic compound here would test the understanding of enantiomers without the confusion of adding benzene”. Candidates should recognize that carbon in benzene cannot be the centre of optical activity and look for chiral carbons in the substitution chains.

Question 2

(a) Most candidates could identify a wavenumber or range of wavenumbers in the IR spectrum of benzoic acid.

(b) Less than half the candidates identified x-ray crystallography as a technique used to measure bond lengths. There were many stating IR spectroscopy and quite a few random guesses.

(c) Again less than half the candidates could accurately give a physical piece of evidence for the structure of benzene. Many missed the mark by not being specific, stating ‘all bonds in benzene with same length’ rather than ‘all C-C bonds in benzene have the same length’.

(d) Very poorly answered with only 1 in 5 getting this question correct. Many did not show **all** the bonds and **all** the atoms or either forgot or misplaced the negative sign on the conjugate base.

(e) This question was a challenge. Candidates were not able to explain the intermediate bond length and the majority suggested the value of either the bond length of C to O single bond or double bond.

(f)(i) Generally well done with a few calculating the pOH rather than the concentration of hydroxide ion asked for.

(f)(ii) Most earned at least one mark by correctly stating the products of the reaction.

(g) Another question where not reading correctly was a concern. Instead of identifying the atom that is oxidized and the atom that is reduced, answers included formulas of molecules or the atoms were reversed for the redox processes.

(h) The other question where only 10% of the candidates earned a mark. Few identified hydrogen bonding as the reason for carboxylic acids forming dimers. There were many G2 forms stating that the use of the word “dimer” is not in the syllabus, however the candidates were given that a dimer has double the molar mass and the majority seemed to understand that the two molecules joined together somehow but could not identify hydrogen bonding as the cause.

(i) Very few candidates answered this part correctly and scored the mark. Common answers were H_2SO_4, HCl & Sn, H_2O_2. In general, strongest candidates gained the mark.

Question 3

(a) Generally well done with a correct plot of ionization energies.

(b) The majority answered correctly stating same number of valence electrons as the reason. Some candidates stated same size or similar ionization energy but the majority scored well.

(c) Many candidates lost one or two marks for missing “electrostatic forces” between “oppositely charged ions”, or “lattice”. Some candidates’ answers referred to covalent bonds and shapes of molecules.

(d)(i) Good performance with typical error being in the calculation for the first equation, ½O2 (g) → O_2^- (g), where the value for the first electron affinity of oxygen was left out.

(d)(ii) Many candidates earned some credit for ECF based on (d)(i).

(d)(iii) Average performance with answers using atomic size rather than ionic size or making reference to electronegativities of K and Na.

(e) An average of 1.1 out of 3 earned here. Many candidates could write a balanced equation for the reaction of sodium oxide with water but not phosphorus(V) oxide. Mediocre performance in identifying the acid/base nature of the solutions formed.

(f) The majority earned one or two marks in finding a % yield.

(g)(i) The average was 2.2 out 3 for this question on enthalpy of formation. Enthalpy calculations were generally well done.

(g)(ii) The majority of candidates referred to “bond enthalpy values are average”, rather than not valid for solids or only used for gases.

(h) Some candidates recognized that ozone had a resonance structure but then only compared bond length between ozone and oxygen rather than bond enthalpy.

(i) Few candidates could distinguish the cause for difference in behaviour between real and ideal gases at low temperature or high pressure. Many answers were based on increase in number of collisions or faster rate or movement of gas particles.

(j) Na_2O was a common formula in many candidates' answers for the product of the reaction of sodium peroxide with water.

(k) The vast majority of candidates could correctly state the oxidation number of carbon in sodium carbonate.

Question 4

(a) There were a couple of comments claiming that this NOS question on "why to store hydrogen peroxide in brown bottles" is not the syllabus. Most candidates were quite capable of reasoning this out.

(b)(i) Most candidates could plot a best fit line and find the slope to calculate an average rate of reaction.

(b)(ii) Good performance but with answers that either typically included only $[H_2O_2]$ with first or second order equation or even suggesting zero order rate equation.

(b)(iii) Fair performance; errors including not starting the two curves at the origin, drawing peak for T2 above T1, T2 finishing below T1 or curves crossing the x-axis.

(b)(iv) The majority of candidates earned at least one mark, many both marks. Errors included not annotating the graph with E_a and referring to increase of kinetic energy as reason for higher rate at T2.

(b) (v) A well answered question. Very few candidates had problem with nomenclature.

(c) One teacher suggested that "stored" would have been better than "sold" for this question. There were a lot of irrelevant answers with many believing the back reaction was an acid dissociation.

(d) It is recommended that candidates use the relative atomic masses given in the periodic table.

Question 5

(a) Majority of candidates understood weak acids do not fully dissociate.

(b) The average score was 1 out 3. Many could not suggest why it is dangerous to mix chlorine with vinegar. Most students gained at least one mark for stating that "chlorine gas will be produced" but couldn't link it to equilibrium ideas.

(c) (i) Most candidates correctly drew the Lewis structure of chloramine. Some left off lone pair electrons.

(c) (ii) Mostly correct with a surprising number stating sp or sp^2 hybridization.

(c) (iii) Generally well done with some candidates misinterpreting the bond angle from the stated geometry.

(c)(iv) "Ionic bond", "hydrogen bond" and "intermolecular forces" were some common answers.

(d)(i) Quite poorly done with many candidates not indicating a vertical drop but rather a weak acid/weak base curve. Some did not have the correct location for the equivalence point.

(d)(ii) Generally well done although a number of candidates chose bromothymol blue as a suitable indicator for weak base with a strong acid.

(d)(iii) Nearly 30% of candidates did not attempt to answer this question about buffer equations. It was also poorly answered because equations were not used to explain buffer action or the dissociation equations for the base and acid were given rather than their reactions with H^+ or OH^-.

Question 6

(a) Done fairly well with common mistakes leaving in the $4s^2$ electrons as part of Fe^{2+} electron configuration, or writing $4s^1 3d^5$

(b) This was poorly answered and showed a clear misconception and misunderstanding of the concepts. Most of the candidates failed to explain why the complex is coloured and based their answers on the emission of light energy when electrons fall back to ground state and not on light absorption by electrons moving between the split d-orbitals and complementary colour transmitted of certain frequencies.

(c) Many candidates wrote the nuclear notation for iron as Z over A.

(d) This question on average atomic mass was the best answered question on the exam. A few candidates did not write the answer to two decimal places as per instructions.

(e) Very few candidates scored M1 regarding the lemon juice role as electrolyte. Some earned M2 but a lot of answers were too vague, such as 'electrons move through the circuit', etc.

(f)(i) Only 50% of candidates earned this relatively easy mark on calculate EMF from 2 half-cell electrode potentials.

(f)(ii) Average performance; typical errors were using the incorrect value for n, the number of electrons, or not using consistent units and making a factor of 1000 error in the final answer.

(f)(iii) This question was left blank by quite a few candidates. Common errors included not using correct units, or more often, calculation error in converting ln K_c into K_c value.

Question 7

Very few answers were correct, even for stronger candidates. Many failed to formulate the correct half equation for the reaction at the anode and used the nitrate ion instead of oxidation of H_2O. Some candidates lost one of the marks for using equilibrium arrows in an electrolysis equation.

Recommendations and guidance for the teaching of future candidates

- Place an emphasis on the importance of using accurate scientific terminology, e.g. when to use ionic radius or atomic radius, the meaning of an equilibrium arrow.
- The focus on correct use of sections in data booklet as required in questions.

- The organic chemistry and mechanisms topics to be given more weight and time in teaching and learning.
- Spectroscopy techniques to be given more weight and time in teaching and learning, and more practice.
- Encourage students to read questions more carefully and plan for the answer. Be sure to pay attention to bold terms.
- Practice sketching and analysing pH titration curves.

Standard level paper two

General comments

This was a generally accessible paper that allowed students to demonstrate their understanding. 46% of respondents on the 57 G2 forms received felt the paper was of a similar standard to last year or easier and 42% felt it was a little more difficult. 68% of respondents felt the difficulty was appropriate and 32% felt it was too difficult. The fact that some teachers found it more difficult could have been because of the use of organic molecules to test general chemical concepts in questions 1 and 2. Also there was concern about the use of the words dimer in question 2c and adduct (an unfamiliar word to most students and teachers) in question 4c- however this did not seem to impact student performance in this question. There was a good range of ability shown by students but unfortunately there were a large proportion of students who were completely under prepared, 27% of students obtained 10 marks or less (i.e 20% or less) on this paper.

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

- Analysis of NMR spectra
- Structure of organic molecules and Free radical substitution reactions for aromatic compounds
- Balancing and constructing equations, especially acidic and basic oxides with water and predicting the properties of the solutions
- Equilibria and Le Chatelier's principle.
- Accurate description of ionic bonding
- Lewis structures and VSEPR geometries
- Drawing best fit lines and graphing
- Drawing Maxwell Boltzmann distribution curves and showing the effect of temperature
- Recognizing hydrogen bonding in different situations.
- Maxwell-Boltzmann distribution curves.
- Electrochemical cells

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

- Free radicals
- Naming compounds.
- Calculating mass percentages and stoichiometry
- Calculating relative atomic mass
- Determining oxidation numbers
- Calculation of enthalpy change of reaction using enthalpies of formation
- Definition of a weak acid
- Structural isomerism.

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

Question 1

(a) Most students gained M1 but very few gained M2, suggesting that the correct answer of 2 signals may have been a guess.

(b) Another isomer of xylene was generally correctly drawn, but some candidates drew the original compound.

(c)(i) Drawing or describing the homolytic fission of bromine was generally done well.

(c)(ii) Very few students gained 2 marks finding hard to apply their knowledge of free radical substitution to a benzene containing compound. Many thought that the bromine will attach to the benzene ring or would substitute the alkyl group twice and not produce HBr.

Question 2

(a) Most failed to score a mark for the conjugate base of benzoic acid as either they didn’t show all bonds and atoms in the ring and/or they did not put the minus sign in the correct place. Some didn't read the question carefully so gave the structure of the acid form.

(b)(i) Many students could correctly calculate the hydroxide concentration, but some weaker students calculated hydrogen ion concentration only.

(b)(ii) Most students earned at least one mark for writing the correct products of the combustion of benzoic acid but the balancing appeared to be difficult for some.

(c) Very few students answered this question correctly, thinking benzoic would bond with the hexane even though it was a non-polar solvent. It was very rare for a student to realize there was intermolecular hydrogen bonding.

Question 3

(a)(i) Disappointingly many students did not realise that sodium oxide was held by ionic bonds, many said it was covalent or metallic bonding. The ones that knew it was ionic failed to describe it adequately to earn the 2 marks.

(a)(ii) Very few students could correctly write out the two equations and so often were unable to realise it was acid/base behaviour that would differentiate the oxides.

(b) Many candidates were able to correctly calculate the % yield but some weaker candidates just used 5.0/5.5 to find %.

(c)(i) The calculation of the enthalpy change using enthalpies of formation was generally answered well but common mistakes were students forgetting to multiply by 2 or adding extra terms for oxygen.

(c)(ii) Most students didn't gain a mark and "values are average" was the most common incorrect answer. The fact this was an ionic compound did not register with them. Some students did gain a mark for stating that the substances were not in a gaseous state.

(d) Some students correctly identified sodium hydroxide as the correct product, but hydrogen, oxygen and sodium oxide were common answers.

(e) Oxidation number of +4 was often correctly identified.

Question 4

(a) The explanation that the brown bottle prevented light causing a decomposition of the chemical was well answered but some incorrectly suggested it helped to stop mixing up of chemicals e.g. acid/water/peroxide.

(b)(i) The graphing was disappointing with a surprising number of students missing at least one mark for failing to draw a straight line or for failing to draw the line passing through the origin. Also some were unable to calculate the gradient.

(b)(ii) The drawing of the two curves at T1 and T2 was generally poorly done.

(b)(iii) Explaining why temperature increase caused an increase in reaction rate was generally incorrectly answered with most students failing to mention "activation energy" in their answer or failing to annotate the graph.

(b)(iv) Many could correctly name manganese(IV)oxide, but there were answers of magnesium(IV) oxide or manganese(II) oxide.

(c) Suggesting why peractic acid was sold in solution was very poorly answered and only a few students mentioned equilibrium and, if they did, they thought it would move to the left to restore equilibrium.

(d) Calculating the % by mass was generally well answered although some candidates started by using rounded values of atomic masses which made their final answer unprecise.

Question 5

(a) The definition of a weak acid was generally correct.

(b) Explaining why it was dangerous to mix chlorine with vinegar was not well answered but most students gained at least one mark for stating that "chlorine gas will be produced", but couldn't link it to equilibrium ideas.

(c)(i) The Lewis structure of chloramine was correct for strong candidates, but many made the mistake of omitting electron pairs on N and Cl.

(c)(ii) The molecular geometry and bond angles often did not correspond to each other with quite a few candidates stating trigonal planar and then 107 for the angle.

Question 6

(a) The nuclear symbol notation was generally correct. However, some students swapped atomic and mass numbers and hence lost the mark.

(b) Calculation of RAM was generally correctly calculated, but some candidates did not give their answer to two decimal places while they should use the provided periodic table.

(c) Very few students gained the 2 marks available for explaining the potential generated in the lemon as they didn't realise it was the lemon that acted as the electrolyte and allowed ions to flow. Some were able to gain a mark for explaining that electrons moved from iron to copper as iron is more reactive.

Recommendations and guidance for the teaching of future candidates

Considerable numbers of the candidates seemed ill prepared for the examination, especially questions from Topics 10 and 11. Schools must spend more time on these or they should consider the sequence of topics and not leave those particular topics till the very end. Drawing best fit-lines should have also been covered in practicals, so more practical work would be beneficial.

Also, ensure students learn correct terminology so that they can accurately explain and describe chemical concepts such as bonding.

Higher level paper three

General comments

Many candidates were well prepared and performed well on this paper, although some appeared quite unfamiliar with the subject material. The mean score was 19.11 out of 45.

53 teachers submitted G2 forms following the examination. 94% of respondents (50 teachers) have rated the difficulty of the paper as appropriate. 3.77% (2 teachers) rated it as too difficult. 38 respondents said that the paper was of similar standard to last year, 11 said it was a little more difficult and none thought it was much more difficult. Only 2 thought the paper was a little easier than last year.

Significantly, 13 of these teachers felt that the clarity of wording was below par (4 stating it was poor and 9 that it was fair). However, they were more than balanced by teachers who rated the clarity of wording positively. Similarly, 11 respondents thought the presentation of the paper was poor (1) or fair (10), while 13 said presentation was good, very good (20) or excellent (9).

Most candidates answered Section A and one option from Section B, although there were a small number who did not attempt Section A. Most candidates confined themselves to only one option. Option D was the most popular, followed by Options B and C. Very few answered Option A, although one school had candidates who were well prepared for this option.

Candidates seemed to have had adequate time to answer all questions.

Many candidates did not display the depth of knowledge that IB expects. Responses often indicated that phrases had been memorized with little understanding shown of the processes involved.

Candidates were often not specific enough or scientific enough in their use of terminology. In many cases, answers were either too general or too superficial and attention to detail was generally lacking.

Candidates had difficulty articulating answers, not just including the right key words, but also determining what information was necessary to answer the question and what facts were related to the question but not necessary for scoring marks.

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

- Explanation of why some groups sublime
- Explanation of which elements have greater density using graphical data and Section 25 (activity series) in the data booklet
- Explanation of ease of oxidation of s-block and d-block elements using graphical data and Section 25 in the data booklet
- Estimating the maximum temperature from a graph
- Explanation of limiting and excess reagent use or independent and dependent variables

- Explanation of assumptions in enthalpy calculations using experimental data
- Explanation of Cooper pairs
- Determining the number of atoms in a unit cell
- Explanation of liquid-crystal behaviour at very low and very high temperatures
- Polydentate ligands
- Drawing a repeating unit of starch
- Calculating energy released when starch is combusted
- Writing an equation for the hydrolysis of a triglyceride
- Showing a particular functional group on a diagram (option B and D)
- Drawing 3D structures to show spatial relationship of enantiomers
- Explanation of relationship of melting point to length of carbon chain in fatty acid
- Explanation of competitive inhibition
- Calculating ratio of acid-base conjugate pairs to create a buffer of known pH
- Explaining why fission reactions release energy or nuclear binding energy per nucleon versus nuclear binding energy
- 1H NMR splitting patterns
- Deducing mass of carboxylate ion
- Explaining how a polarimeter differentiates between enantiomers

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

- Describing trends in the graphs provided
- Distinguishing between homogeneous and heterogeneous catalysts
- Identifying addition polymers
- Identifying chiral carbons
- Electrophoresis
- Annotating a Michaelis-Menten plot

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

Section A

There were many G2 comments about Section A. This section consists of data analysis of an unfamiliar topic and questions relating to practical activities with which candidates should have had some experience. Candidates should expect to have a question on new material which requires them to think analytically. Some respondents liked Section A, and thought it was “challenging but not

Question 1

There were some comments that the graph was difficult to read and should have been made clearer for students. Considerable effort had actually gone into the production of the graph. Most candidates seem to have been able to interpret it sufficiently well.

(a) Most candidates correctly identified the group of elements most likely to undergo sublimation but did not score for the reason as they referred to low melting and boiling points, rather than the smallest difference between these temperatures. There were several G2 comments that “the group of elements” was a confusing requirement as elements could be grouped in many ways, including for instance, from B to Ne. The Chemistry Guide clearly states that a group on the periodic table refers to a vertical column of elements. A few complaints were received about the inclusion of a question on sublimation, but the question was designed to make candidates think, and did not require knowledge of phase diagrams.

(b) Required candidates to consider density trends. Most candidates correctly described trends across periods 4 and 5 but had difficulty predicting and explaining whether lanthanoids or actinoids would have the higher density. Many said that actinoids would have higher density because they have more protons and neutrons / greater atomic number / greater mass with no further detail about having similar bonding and hence similar volume. Some G2 comments complained about the inclusion of lanthanoids and actinoids in this question. However, the Chemistry Guide clearly states that these terms should be known.

(b)(iii) most candidates scored at least 1 mark for comparing the s-block and d-block metals and most drew a line with a negative slope.

(b)(iv) Although many here failed to score because the line crossed or touched one of the axes. A few sketched a graph reminiscent of first ionization energy against atomic number.

Question 2

This question clearly indicated whether candidates had gained an understanding of the processes involved in calorimetry experiments or had simply followed instructions.

(a) Nearly everyone correctly estimated 100s as the time when powdered zinc was added to the beaker.

(b) Most scored the mark in for stating that point Y either indicated the maximum temperature or the end of the reaction.

(b)(i) Stating the maximum temperature that should be used in calculations was less well answered, with answers between 63 and 65, or 78 commonly given instead of the correct answer of 73°C. Most candidates managed to score the second mark for stating “no heat loss”.

(b)(ii) Many candidates struggled to explain their choice of which reagent should be in excess. This question proved quite difficult with many candidates seeming to confuse independent and dependent variables.

(b)(iii) Explaining the assumptions made when using values for m and c was challenging in. Many referred to the accuracy of the data when using m = 25.00g or said that no mass was lost during the reaction. Most knew that the value of c used was for water and suggested that the water was pure, but did not say that the specific heat of solution was assumed to be the same as that of water.

(b)(iv) Most scored a mark for predicting how the calculated enthalpy value would compare with the theoretical value.

Section B

Option A – Materials

Question 3

Most candidates correctly identified the type of bonding and the colour of the emission spectrum of lithium, but frequently referred to the ICP-OES spectra of ^{6}Li and naturally occurring lithium as being the same, rather than similar and thus failed to score the mark in (b)(ii). A better method was selected by most candidates.

(c) The calculation in was done well.

(d)(i) Candidates had some difficulty describing the Meissner effect, with several responses using the terms repelling or repulsion instead of opposing and expulsion. Correct terminology is required.

(d)(ii) Poor expression was also evident in responses explaining the formation of Cooper pairs, with very few candidates scoring full marks.

(e) Most candidates had difficulty determining the number of atoms in lithium in a unit cell, even with a diagram provided. However, ECF marks were frequently scored.

Question 4

(a) Most candidates correctly stated one difference between heterogeneous and homogeneous catalysts. Few gave a second difference even though the question is worth 2 marks.

(b) Most explained well how elastomers increase tyre traction.

(c) but had difficulty applying their knowledge to outline why polychlorinated dibenzofuran is considered dioxin-like but is not classified as a dioxin.

(d) Some candidates failed to score the mark as they did not give a reason for classifying polybutadiene as an addition polymer.

(e) Most candidates were able to state a factor considered when making green chemistry polymers.

Question 5

(a) Identifying a chiral carbon atom was answered reasonably well.

(b) Explaining effects of very low and very high temperatures on liquid-crystal behaviour proved difficult for most candidates. Responses lacked the required detail about intermolecular forces between molecules.

Question 6

Describing the structure and bonding of a carbon nanotube was generally answered satisfactorily, although some candidates simply said the bonding was covalent with no further detail. There were some vague responses for applications of carbon nanotubes when specific details were needed to score the mark in (b).

Question 7

(a) There were several incorrect responses that products were more ordered than the reactants.

(b) Proved very challenging with very few candidates knowing the number of coordinate covalent bonds EDTA forms with a nickel ion.

Option B – Biochemistry

Question 8

(a) Candidates were required to draw the structure of the repeating unit of starch given the ring structure as a starting point. This proved extremely difficult with very few candidates scoring a mark. Commonly, the structure of α-glucose was given, or an attempt was made to draw a polymer. Naming the type of linkage formed was answered well.

(b) Also proved challenging, with many candidates unable to write an equation for the hydrolysis of a starch molecule $(C_6H_{10}O_5)_n$. The n was often omitted from otherwise correct equations or the product was incorrectly given as $(C_6H_{12}O_6)_n$.

(c) The incorrect mass was frequently used when calculating energy released from combustion of starch in a calorimeter. Those who used the mass of water correctly frequently stopped when energy in kJ or J was calculated, and did not seem to notice that the question asked for the energy to be calculated in kJg^{-1} so a further calculation was required.

(d) Responses to explain how including starch in plastics makes them biodegradable were sometimes lacking in detail. Some candidates simply said that "starch is soluble in water". Some said that "starch can be broken down/hydrolyzed" but omitted the key words "by bacteria or microorganisms".

Question 9

(a) Candidates were challenged to draw a circle around the functional group formed between the two amino acids in a dipeptide. Commonly the central C=O or the N-H groups were circled instead of the amide. Some candidates then named the functional group as a ketone or amine, however most candidates stated "peptide" here and scored a mark.

(b) Most candidates correctly deduced the positions of the two amino acids after electrophoresis.

(c) Was very poorly answered. Many candidates had difficulty drawing a 3D structure and showing the spatial relationship of two enantiomers. An incorrect amino acid residue was often used, or incorrect bond connections drawn.

Question 10

(a) Candidates had difficulty explaining the melting points of fats in terms of length of carbon chain, and referred instead to an explanation of saturated and unsaturated fat structures.

(b) Quite a few candidates had no idea how to write an equation for the acid hydrolysis of a given triglyceride. Many struggled with the structure or molecular formula of glycerol. Some created products of $(R\text{-}O\text{-}CO\text{-}OH)_3$ and alkanes, even though the question told them that triglycerides are esters of glycerol and fatty acids. Some got the products almost correct but wrote O-H-CO-R for the fatty acid so failed to score the first mark. Some forgot to balance the equation.

(c) Outlining an effect of *trans*-fatty acids on health was generally answered well, with only a few vague answers.

Question 11

(a) Very few candidates scored the first mark. Two absorption bands were required but most candidates only mentioned one. However, most candidates scored the second mark for stating the colour of β-carotene.

(b) Most candidates gave good answers to suggest how a combination of chlorophyll *a* and carotenoids is beneficial for photosynthesis.

Question 12

(a) Most candidates correctly sketched a curve to show the effect of a competitive inhibitor on a Michaelis-Menten plot

(b) Many scored 1 out of 2 for stating that the inhibitor causes a slower reaction rate. The calculation of the ratio of a conjugate acid-base pair to create a buffer with a specific pH was poorly done. Some candidates wrote a ratio without indicating which compound each value referred to and thus could not score. Many candidates used the concentrations of 0.1 mol dm^{-3} for both compounds and could not proceed.

Question 13

Explanations of why ascorbic acid is soluble in water and retinol is not were poor. Very few referred to the ability to form hydrogen bonds with water. Some said "hydroxide" instead of "hydroxyl" and thus failed to score a mark. Commonly, candidates scored 1 mark for saying that ascorbic acid has many hydroxyl groups and retinol has a long hydrocarbon chain.

Question 14

(a) Candidates had difficulty outline the meaning of genetically modified organisms with many simply repeating the question by stating modified DNA without including technology or engineering techniques.

(b) Outlining one benefit of using GMOs was well answered.

Option C – Energy

Question 15

(a) Calculations of specific energy of methane and the maximum electric energy output in parts (a) and (b)(i) were done well.

(b)(ii) Suggesting reasons for hydroelectric power having higher efficiency but lower relative use than other energy sources in was not answered well by most candidates. Often the reasons for higher efficiency were given in vague terms that did not meet the detail required.

(c)(i) Required candidates to circle a fractionating tower to show where the methane fraction could be withdrawn. Despite the expectation that candidates know methane is a gas at room temperature, there were many varied answers to this question.

(c)(ii) Required products of fractional distillation of crude oil to be ranked according to decreasing volatility. This should have been able to be worked out from first principles and did not have to be memorized as one G2 respondent suggested.

(d)(i) Many candidates scored the first mark for stating that methane is tetrahedral. Further details to explain how methane absorbs IR radiation were generally insufficient. Many candidates referred to "dipole movements" despite dipole moment being in the stem of the question.

(d)(ii) Most candidates correctly answered comparing methane's atmospheric abundance and greenhouse effect to that of carbon dioxide.

Question 16

(a)(i) Required candidates to write a nuclear equation for a fission reaction with the question indicating that ^{235}U was bombarded with a neutron to produce ^{144}Ba and ^{89}Kr. Despite this, some candidates did not include the initial neutron or omitted neutrons completely.

(a)(ii) Outlining why the fission reaction releases energy was challenging. Some candidates simply said the reaction was exothermic. Some said that the products were smaller than the reactant. Very few candidates referred to binding energy per nucleon.

(a)(iii) The calculation of the energy released in was done reasonably well. Some candidates answered this very well and scored full marks. However, many scored 1 or 2 marks out of 3 through ECF marks. Common errors were incorrect calculation of mass in amu, or omission of converting amu to kg. Here, it was apparent that good setting out of calculations was effective in scoring for partially correct responses.

(b) The meaning of critical mass was answered reasonably well with most candidates scoring at least 1 out of 2.

(c) The calculation of time taken for radioactivity to fall to 10% of its initial value was answered very well.

Question 17

(a) One G2 respondent was concerned that "Research Octane Number" was used instead of "Octane Rating", but most candidates correctly outlined how higher octane fuels affect engine performance.

(b)(i) Some candidates did very well and deduced the half-equations occurring in a DEFC as illustrated in a flow chart. A few used equilibrium arrows and lost a mark. Some candidates failed to balance the half-equations.

(b)(ii) Was answered well.

(b)(iii) Few candidates could outline why aqueous ethanol is used in a DEFC,

(c) Most could suggest one environmental disadvantage of producing biodiesel from renewable resources.

Question 18

(a) Candidates struggled to express themselves adequately in comparing the change in electrical conductivity of metals and semi-conductors as temperature increases. Many scored 1 mark for stating the effect of increasing temperature, but very few scored any marks for the explanation.

(b) Generally answered well with most candidates able to suggest one advantage of a DSSC over a silicon based photovoltaic cell.

Option D – Medicinal chemistry

Question 19

(a) Many candidates scored a mark for naming a functional group that differentiates salicylic acid from aspirin. Some incorrectly said ether or carboxylic acid. Many candidates also scored for identifying the absorption band although 1700-1750 was a popular incorrect answer.

(b)(i) There was considerable confusion with indicating protons responsible for ^{1}H NMR signals. Often entire functional groups were circled or carbon atoms and not hydrogen atoms were circled.

(b)(ii) There was also great difficulty in identifying the splitting pattern of the signals. It was rare to see both signals identified as singlets.

Question 20

(a) Most candidates correctly identified the feature in penicillin responsible for its antibiotic activity.

(b)(i) Most candidates could outline how bacteria inactivate the antibiotics.

(b)(ii) Outlining how the structure of penicillin has been modified was less well answered, with many candidates referring to functional groups rather than the side chain or R group.

Question 21

(a) Responses were mixed with some candidates easily writing an equation for the neutralization of stomach acid with $CaCO_3$. Others failed to score for having incorrect products such as H_2CO_3 or CaCl, or for using sulfuric acid instead of hydrochloric for stomach acid.

(b) Many candidates correctly outlined how drugs such as omeprazole and ranitidine regulate acid secretion.

Question 22

(a)(i) Required candidates to identify the functional group in a diagram of the structure of oseltamivir that can be converted to a carboxylate by hydrolysis. This was very challenging with many varied parts of the structure circled. Many circled the amide group. Candidates who selected the ester had to be careful to not include the ring structure as well.

(a)(ii) The challenge continued where the expected mass of the carboxylate ion was required. Some candidates chose values that exceeded the molar mass of oseltamivir itself, and some chose 45. There were very few correct answers.

(b) Many candidates referred correctly to increased solubility of the salt in water while some mentioned bioavailability but did not realize that a salt will also form in the stomach.

(c) Most candidates scored the first marking point when explaining the development of resistant virus strains but almost no-one scored the second mark. Many candidates were confused between bacteria and viruses and gave explanations about bacterial resistance and natural selection.

Question 23

(a) The question asked candidates to explain how opiates provide pain relief. This was difficult and was poorly answered by many. As this has been asked many times over the years, it would be an advantage to candidates to practise answering past examination questions.

(b) The explanation that required a discussion of the difference in structure of codeine and morphine, and how this affects their ability to cross the blood-brain barrier was challenging. Many scored for saying "codeine is less polar". Some also scored for saying that "morphine has more hydroxyl groups" but others provided less detail and could not be awarded any marks.

Question 24

(a)(i) Most candidates correctly determined the % of technetium-99m remaining after 24.0 hours. Some candidates did not read the question properly and forgot to convert to a percentage.

(a)(ii) A common incorrect answer was to give Tc as a product or to give an incorrect symbol for beta radiation. Most candidates scored a mark for the correct mass number of the product and beta radiation.

(b)(i) Low level nuclear waste was poorly outlined with many superficial responses. Many candidates only gave half the required answer.

(b)(ii) Outlining the disposal of LLW was also challenging with many candidates saying that it should be put in a container without saying the container should be shielded.

(c) Suggesting why MRI is less dangerous than using X-rays and radiotracers was mostly answered well, but some candidates were confused and linked longer wavelengths with higher energy.

Question 25

(a) Some candidates had difficulty identifying the chiral carbon in a methadone structure, with quite a few varied answers. However, many managed to mark the correct carbon.

(b) Very poorly answered. Few scored any marks at all when outlining how a polarimeter can be used to differentiate between enantiomers. Many referred to the light or the enantiomers themselves being rotated.

Recommendations and guidance for the teaching of future candidates

- Students should be encouraged to write legibly and to clearly set out calculations. Some handwriting was very difficult to decipher which makes it very difficult for examiners to award marks when the wording of the response is not exactly as expected.
- Students should be advised to use appropriate chemistry terminology and expressions so that there is no ambiguity about the meaning of the answer.
- Students should learn how to write appropriate chemical and nuclear equations for the processes studied in the options.
- Students should practise drawing organic molecules using wedge-dash conventions and ensuring correct bond connections are made between atoms.
- Students should be encouraged to understand the processes involved in laboratory experiments and not to just follow the instructions without thinking about what they are doing.
- Students should work through past examination questions and markschemes carefully. Candidates need exposure to data-based scientific problems involving unfamiliar situations. They must be able to interpret graphical representations, critique and interpret data and draw logical conclusions involving scientific methodologies.
- Students should be trained to read the question very carefully and then direct their answer to the requirements of the question. Command terms should be emphasized throughout the teaching of the course.

Standard level paper three

General comments

This appeared to be a rather more accessible paper than last year's with candidates scoring slightly higher, but the overall ability of candidates was very similar to previous cohorts. The achievement levels on Section A and Section B were overall very similar, though the latter varied widely (more than a factor of 2) between the different options.

About 10% of candidates are getting scores of under 10%; in contrast <0.1% achieved a mark over 90%. This seems a most unsatisfactory outcome for a course.

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

- Questions that require an understanding of practical methodology
- Awareness of the terms "lanthanoids" and "actinoids"
- Applying the concept of constant heat loss to compensate for cooling in thermochemical investigations
- Drawing the repeating unit of a starch molecule
- Writing an equation for starch hydrolysis
- Reasons why starch containing polymers are biodegradable
- Writing an equation for triglyceride hydrolysis
- Explaining aqueous solubility in terms of the ability to form sufficient hydrogen bonds
- An awareness of reasons for and against hydroelectric power generation
- Writing nuclear equations for fission reactions
- The characteristics and safe storage of low-level nuclear waste

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

- Relative reactivities of the s- and d-block metals
- Deducing the point at which a reaction starts from a graph of a physical property against time
- Deducing the type of bonding in a binary compound from the electronegativities of the elements involved
- The differences between homogeneous and heterogeneous catalysts
- The tubular nature of nanotube molecules and their use to reinforce composite materials
- The bond linking glucose monomers in starch
- Calorimetric calculations
- The peptide bond and being able to identify it in a molecule
- The negative health effects of *trans*-fats
- Locating appropriate data in the data booklet and using it to calculate specific energy
- Relating high octane numbers to a reduced tendency for auto-ignition

- The action of penicillin, how some bacteria resist it and ways in which it is modified to overcome this
- Writing an equation for the reaction of a carbonate with an acid
- Calculating the volume of gas produced by reacting a given mass of carbonate with excess acid
- The action of Omeprazole and Ranitidine
- The mechanism by which strong analgesics provide pain relief

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

Section A

Question 1

(a) Some candidates appeared to be unfamiliar with the term “sublimation”. Whilst most students correctly identified the noble gases as the group most likely to sublime there were a variety of other answers. Many students referred to “low melting and boiling points” rather than identifying the difference between these as the key factor.

(b)(i) Most students realised that density peaks around the middle of each of these periods, though a significant minority seemed unaware of the significance of “periods” and just reported the overall general increase in density.

(b)(ii) Poorly answered. Some students seemed unaware of the terms “lanthanoids” and “actinoids”. Many others just stated the actinoids because they had greater atomic masses, without adding that the bonding, and hence the volume occupied by each atom, would be similar to the lanthanoids. Others responded in terms of the given data, but this required rather more justification than just stating “as can be seen from the graph”.

(b)(iii) Almost all candidates gained some credit on this question and many obtained full marks. Students were generally aware that s-block elements are more reactive than d-block ones and hence are more easily oxidised. Many correctly linked this to lower melting points and densities. Often a causal relationship was implied (more reactive because of their low density/mp) but this was not penalised. A significant minority of students referred to only one of the physical properties; not reading the question fully?

(b)(iv) Most students sketched a negative correlation between IE and radius, but then many lost the mark by drawing a line that met an axis; it is not possible for either to have a value of zero.

Question 2

(a)(i) Almost all candidates identified 100 s as the time at which the reaction was initiated.

(a)(ii) Many students gained this mark through stating this was the highest temperature recorded, though even more took advantage of the acceptance of the completion of the reaction, expressed in many different ways. Very few answered that it was when heat loss equalled heat production.

(b)(i) Even though almost all students recognised 100 seconds as the start time of the reaction less than 50% chose the extrapolated temperature at this time. Predictably the most common answer was the maximum of the graph, followed closely by the intercept with the y-axis. With regard to reasons, again relatively few gained the mark, though most who did wrote “no loss of heat”, even though it was rare to find this preceded by “the temperature that would have been attained if …”.

(b)(ii) The correct answer depended on whether students considered the object of the additional trials was to investigate the effect of a new independent variable (excess copper(II) sulphate) or to obtain additional values of the same enthalpy change so they could be averaged (excess zinc). Answers that gave adequate reasons were rare.

(b)(iii) Again relatively few gained these marks for stating that it was assumed the density and specific heat of the solution were the same as water.

(b)(iv) Only about a third of the students correctly deduced that loss of heat to the environment means that the experimental value is lower than the theoretical one, though other answers, such as “higher because linear extrapolation over-compensates for the heat losses” were also accepted.

Section B

Option A

Very few candidates (<5%) attempted this option and most who did only achieved low marks.

Question 3

(a)(i) Many students correctly used the data tables and chart to deduce the bonding is ionic.

(a)(ii) Only a few students were aware of the connection between electron pairing and magnetic properties.

(b)(i) Surprisingly few candidates referred to the fact that the two spectra shown are almost identical.

(b)(ii) Again relatively few students were able to suggest ICP-MS as a more appropriate alternative.

(c) About half the candidates who attempted this were able to calculate the amount of lithium being formed and hence the time required.

Question 4

(a) Many students were aware of the fundamental difference between homogeneous and heterogeneous catalysts, but only a few could identify another difference to obtain full marks.

(b) Whilst some students realised that elastomers would increase the area of road in contact, hardly any linked this to their fundamental property of deforming under stress.

(c)(i) This was a question that highlighted a perennial problem; students appearing to know the answer but not having sufficient command of the English language to express it accurately. A number did identify similar toxic effects as the reason for being “dioxin like”.

(c)(ii) Only a few students linked this to the toxin entering the food chain.

Question 5

(a) A few students correctly named the nitrile group as being the one responsible for the polarity of the liquid crystal molecule

(b) Very poorly answered with candidates failing to link the change in liquid crystal properties to changes in molecular motion.

Question 6

(a) Most students were aware that nanotubes have a tubular structure, but answers to the bonding were rarely detailed enough to gain the second mark.

(b) Only a few students gained this mark and they usually gave the use of nanotubes for a reinforcing.

Section B

Option B

Biochemistry was quite a popular option with about 25% of students tackling it. Though there were some high scores, most seemed to find it quite challenging.

Question 7

(a) Hardly any students were able to draw the required repeating unit, but in contrast almost all knew that the monomers were joined by a glycosidic linkage.

(b) It was very unusual to find a candidate who could give a correct equation for starch hydrolysis.

(c) Nearly half the students correctly calculated the enthalpy change and some of these went on to find the value in $kJ\ g^{-1}$. The most common mistakes were to use the mass of starch rather than the mass of water and adding 273 to the temperature change.

(d) Whilst many could quote from 7b, that starch undergoes hydrolysis, very few linked this to a biochemical mechanism. Other factors, relating to the reduction of intermolecular forces between the polymer chains were also rarely encountered.

Question 8

(a) Many candidates correctly circled the bond between the amino acid residues, though in some cases their circle missed out key atoms. Many correctly identified it as a peptide or amide linkage.

(b) Most candidates seemed to realise that phenylalanine would be neutral and hence unaffected by the field, but many failed to realise that the negative charge of the aspartic acid anion would cause it to move to the left, not the right.

Question 9

(a) A classic instance of candidates answering the question they thought (or hoped?) they had been asked rather than the one that was asked. Almost all answers referred to the differing amounts of saturated and unsaturated fatty acids present, totally ignoring the fact that the question clearly stated "*their saturated fatty acid composition*", where the relative lengths of the chains was the key point. Nevertheless some who went on to discuss the nature of the intermolecular forces between the chains gained some credit.

(b) A disappointingly small number of candidates gained any marks for deducing the equation for the hydrolysis of the given lipid.

(c) Almost all students were aware of negative health effects of *trans*-fats, though quite a few lost marks by just stating "*cholesterol*" without specifying HDL or LDL.

Question 10

Another instance where candidates insist on discussing water solubility in terms of polarity or hydrophilicity rather than its fundamental dependence on the presence of sufficient groups that can form hydrogen bonds to water. A few however gained a mark through pointing out the significance of the –OH groups in ascorbic acid and the long hydrocarbon chain in retinol.

Option C

This was more popular than Option B, attracting about 30% of the candidates. There were many questions that students appeared to have difficulty in answering, though a handful scored well.

Question 11

(a) About half the candidates were able to locate the appropriate data and use it to calculate the specific energy of methane.

(b)(i) Many students were aware that methane is the major component of natural gas and could use the efficiency data to calculate the electrical energy available from methane.

(b)(ii) This seemed to cause quite a lot of difficulties, especially as some students appeared totally unaware of what hydroelectric power was, with a number discussing it as if it were some kind of fuel. The most usual mark gained was from discussing environmental concerns as a reason for its decreased use.

(c)(i) Having been given it is a gas, it is difficult to know why probably only about a third of the candidates could identify where methane would appear on a fractionating column.

(c)(ii) Again surprisingly poorly done. Firstly there appeared to be some confusion about the term "*volatility*" with listing in the reverse order being quite common. Secondly many seemed unaware of the nature of "*asphalt*" as it was the one most frequently misplaced.

(d)(i) Comprehensive answers were rare. Many students gained a mark for correct statements about methane's molecular geometry or polarity, though quite a few totally disregarded the instruction to refer to these. Some seemed aware of the link to vibrational motion and the better ones also identified the need for a change in dipole moment.

(d)(ii) Quite a few candidates were aware of the relative atmospheric abundances of carbon dioxide and methane as well as their relative potency for enhancing the greenhouse effect.

Question 12

(a)(i) Only about a third of the candidates could write the nuclear equation for the requested fission reaction.

(a)(ii) Only about a quarter of the candidates could explain the release of energy, usually in terms of the change in nuclear binding energy.

(b) Less than half the candidates could correctly explain "critical mass" with even fewer combining the definition as the minimum mass for a sustainable fission reaction with the required clarification in terms of neutrons creating a chain reaction.

(c) Another question that created far more problems than anticipated with only about half gaining the mark. Many students appeared not to realise that 6.25% is 1/16, hence the amount remaining after 4 half lives.

Question 13

(a) Over half the students could relate a high octane number to a reduced tendency for auto-ignition, though this was usually referred to as "knocking".

(b) A question that gave the opportunity for a variety of different approaches. This challenge was beyond all but the best students, though there were a number of well argued responses.

(c) Many students did not take into account "production from renewable resources" and answered in terms of the combustion of biodiesel, though about a third correctly identified the area of land biofuel crops require.

Option D

This was by far the most popular option attracting over 40% of the candidates. There was a range of marks with better prepared candidates scoring well on a number of quite familiar questions, though it also seemed to be the preferred option of many weaker candidates.

Question 14

Many students could correctly identify a difference between the given structures and state a region in the IR spectrum where this would absorb.

Question 15

(a) Most students could identify the beta-lactam ring as the structural feature responsible for penicillin's activity.

(b)(i) The action of penicillinase/beta-lactamase was less well known with only about a third of students gaining this mark.

(b)(ii) Most students were also aware that changing to the side chain of penicillin is often used to counter resistance, though many benefitted from the decision to accept "*R*-" without any mention of the data booklet structure.

Question 16

(a)(i) About two-thirds of the candidates could write an equation for the reaction of calcium carbonate with an acid. It was refreshing to find that "H_2CO_3" was only rarely encountered as a product.

(a)(ii) It was encouraging that over half the students were able to calculate the volume of gas produced from a given mass of calcium carbonate.

(b) Many students correctly remembered the modes of action of Omeprazole and Ranitidine, though needless to say a few confused these and weaker students thought they acted like conventional antacids.

Question 17

(a)(i) Many students erroneously identified the amide as the required group, failing to realise that its hydrolysis would give the carboxylate ion of the side chain lost to the drug.

(a)(ii) About a third of the candidates realised that producing a salt would increase the drug's aqueous solubility, though many just stated "*increased bioavailability*" without explaining how this came about.

(b) Another question where well argued responses were rare, though many students gained credit for mentioning the ease of mutation and the speed of reproduction of viruses.

Question 18

(a) Most candidates correctly remembered the mode of action strong analgesics, though some had difficulty expressing it clearly.

(b) Many candidates identified the relevant structural difference from the data booklet structures and could use these to explain the difference in the ability of the drugs to reach the brain, though some were confused as to whether this was favoured by aqueous solubility. This again was more frequently discussed in terms of polarity than the ability of –OH groups to form hydrogen bonds.

Question 19

(a) Most candidates just listed items that low-level nuclear waste was likely to comprise, rather than giving two of its radiation characteristics (low activity, non-penetrating radiation, short half-life).

(b) There appeared to be very limited awareness of the need to store low-level waste in shielded containers until the radiation falls to a negligible level.