May 2015 subject reports

Chemistry Time Zone 1

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 32	33 - 44	45 - 55	56 - 65	66 - 76	77 - 100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 31	32 - 43	44 - 53	54 - 64	65 - 74	75 - 100

Internal assessment

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 8	9 - 16	17 - 22	23 - 27	28 - 33	34 - 38	39 - 48

The range and suitability of the work submitted

For May session schools this was the last time that the candidates were to be assessed using the Design, DCP, CE, MS and PS criteria along with their associated aspects.

As to be expected at this stage in the internal assessment scheme's life cycle there was little significant change in the range and suitability of the work submitted. As always, in addition to much fine work from schools where the students has been given appropriate opportunity to achieve, there were examples of weak practise with students being set prescriptive and simplistic tasks that did not lend themselves to attainment against the criteria.

Although many examples of good practice were seen many schools did carry on with approaches to the Design assessment which were unimaginative and will need radical change with the new internal assessment scheme to be assessed from May 2016 session onwards. Many schools assessed the Design criterion through two theory only exercises with no follow up implementation. This has to change since the new Individual Investigation requires data to be collected and analysed.

Other schools did allow students to carry out their plans but had set very narrow tasks so that all students essentially designed the same research. It will be disappointing if the new model continues to yield such a narrow range of very similar investigations based on the rate of reaction of magnesium or calcium carbonate with hydrochloric acid and the heat of combustion of alcohols. These tasks are too familiar from pre-IB work and also easily found on the internet. When compared to the interesting student centred projects encouraged in other subject groups it has not been to the credit of IB Diploma Chemistry that whole cohorts of extremely able students have been set such narrow and unchallenging hurdles to overcome in the name of internal assessment. This has been one of the major drivers for the very significant changes now being implemented.

A small number of schools did show that they were adapting proactively to the new requirements by setting one or even two student centred individual projects that were assessed by the old criteria. These schools showed that the new individualised approach is possible to facilitate. Successful projects were usually quite simple in experimental design but generated personalised data that ensured the final report was clearly the result of the students' own endeavour.

Candidate performance against each criterion

Design

Achievement against the Design criterion was often good with the first and third aspects being best fulfilled. Most students were able to phrase a suitable research question and identify the relevant variables and similarly many planned to take measurements based on five or more values of independent variable. The attainment against the second aspect of Controlling Variables was lower with many students either not controlling identified variables at all or controlling inappropriately, such as using air conditioners to maintain room temperature rather than thinking how to control reaction temperature.

A common weakness was that a large number of students wrote up their designed procedures with insufficient attention to detail for the reader to understand exactly what was to be done and how variables were going to be manipulated or controlled. Not including details on how standard solutions were to be made up, what volumetric glassware is to be used, not stating how to make up a salt bridge in an electrochemical cell or forgetting to think about drying an electrode in an electroplating investigation were the commonest weaknesses. The new Individual Investigation where the students will have actually carried out and refined their procedures should see an improvement in this consideration.

There was often an ambiguity in language in the research question or identified variables with students using the term “amount” when they should be specific as to whether they are referring to moles, mass, volume of solution, etc. Another linguistic confusion was in the use of the terms “dissolving” and “reacting” with students discussing the dissolving of magnesium ribbon in acid or similar. These are issues that will be considered as part of the new Communication criterion.

Data collection and processing

Achievement against this criterion was generally good although some students had been over-rewarded for simply determining a simple mean, plotting the raw data on axes with no further quantitative processing (often just presenting the raw data logger output) or for presenting an inappropriate bar chart.

Aspect 1 saw the highest fulfilment with most students able to clearly present raw data with uncertainties and relevant qualitative data included. When the tasks allowed there was good achievement in aspect 2 as well with enthalpy calculations being especially productive. There were few challenging graphical processing such as determining and activation energy evidenced though. Aspect 3 continued to be the most demanding aspect with only a minority of students successfully propagating uncertainties and also quoting final answers to an appropriate number of significant figures was not uniformly achieved. Also many graphs were poorly presented with either unsuitable best-fit lines (Excel’s polynomial function was often poorly used to generate curves with false minima or maxima) or improperly labelled axes.

Conclusion and Evaluation

Conclusion and Evaluation continued to the end to be the most challenging of the criteria and few candidates achieved the top level across all three aspects. This is not surprising since this criterion requires students to really understand what their collected data signified and this is higher order thinking that cannot be readily sourced from textbooks or websites.

In Aspect 1 it was common for candidates to compare their results to literature values where appropriate and a significant number were then then able to identify whether the difference indicated the presence of system error or could be explained by random error alone. This is an important consideration that will still be applicable to the new Individual Investigation

An issue that will be confronted more often by teachers with the new Individual Investigation how to assess Evaluation when the student-led investigation does not involve the determination of a quantity that can be compared to literature and a percentage error calculated but instead involves the determination of a trend. In such cases the student should try and describe the nature of trend and compare to how this compares to accepted theory. For example even a SL student can conclude whether the rate of a reaction increases in direct proportion with concentration of one of the reactants or not. This can then be compared to the literature expectation and the likely impact of systematic or random errors discussed.

For Aspect 2 many candidates identified a good number of relevant procedural limitations or weaknesses although once again only a small minority of candidates were able to insightfully comment on the direction and relative significance of the sources of error.

Most candidates achieved at least partial in Aspect 3 with some relevant suggestions as to how to improve the investigation although a significant minority were only able to propose superficial or simplistic modifications such as simply suggesting more repetitions to be carried out or for unspecified more precise apparatus to be used.

Manipulative Skills and Personal Skills

All schools entered marks for these criteria.

Application of ICT

Most schools had checked the five ICT requirements at least once on the 4PSOW.

Recommendations for the teaching of future candidates

From May 2016 the Internal Assessment framework changes fundamentally and teachers must avail themselves of the guidance given in the Subject Guide and Teacher support Material.

Advice that arises from the current session but can be projected on to the new framework is as follows.

- Encourage students to choose a research question that has a degree of challenge, is of interest to them and one where they do not know at the outset what the outcome will be.
- A good research question will probably try to determine a trend or relationship. Students should avoid simple comparative analysis of supermarket brands or other systems with a non-chemistry relevant independent variable.
- Students should include some background theory to set the context of their investigation.
- With a ten hour time allocation to facilitate meaningful enquiry it is expected that students will collect significantly more data than is currently the case in Design assessments.
- It is sensible for students to always be encouraged to make a statement related to the safety, environmental or ethical impact of their study.
- Encourage students to reflect on data while carrying out the research so that they can actively make the decision to modify the procedure or collect more data if needed. This is a good indicator of true engagement and candidates can record such decisions being made.
- When analysing their data students should show appreciation of the impact of measurement uncertainties. This could be evidenced through the propagation of errors

using a sensible protocol through a calculation, the drawing of a graph with appropriate best fit line and quite possibly the inclusion of error bars and always the appropriate use of significant figures. Since the Individual Investigations will take many different forms the teacher will have to decide what constitutes the appropriate treatment of uncertainties applicable to that research.

- If the research includes the analysis of secondary data students should still show consideration the associated uncertainty.
- When concluding, students should draw a conclusion and discuss its methodological validity but should also compare it to expect outcomes (if any) based on accepted theory.
- If the outcome is quantitative then the comparison to a literature value, calculation of percentage error and discussion of the impact of systematic and random errors is still the expectation.
- In addition to possible modifications students should also reflect on possible extensions to their research.
- The Communication criterion will introduce new requirements. The students' designed procedures should be reported in past tense and include sufficient detail for the reader to be able to reproduce the experiment in principle.
- Although there is a requirement for more data and more reported detail there is a 12 page length limit. This means that students have to be intelligently concise and the current trend for hugely repetitious use of cut and paste for calculations or procedural details and the inclusion of pages of data-logged data should be avoided.
- There will be an increased focus on the proper referencing of sources used for background theory, procedural instructions or literature vales. This is a hugely important consideration that has to be stressed clearly to the students.
- Do not encourage the students to write up reports using the criterion titles as report sections. In particular Personal Engagement is a criterion to be assessed across the whole report and is not an introductory section.
- Written feedback or annotations on the student's work as to how the marks were awarded is of great value to moderators as they try to support a sensible interpretation of the assessment criteria.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 10	11 - 16	17 - 23	24 - 27	28 - 30	31 - 34	35 - 40

The range and suitability of the work submitted

The number of candidates who answered the paper was 5915. The paper consisted of 40 multiple choice questions on the Subject Specific Core and the Additional Higher Level. The exam was done without calculator or data booklet. Some candidates did not answer every question.

Only 70 teachers gave feedback on the G2 format from a total of 415 schools. The percent comparison with last year's paper is as follows.

Much easier	A little easier	Of similar standard	A little more difficult	Much more difficult
0	17	59	13	4

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

	Too easy	Appropriate	Too difficult
Percent Level of difficulty	2	96	2

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

	Very poor	Poor	Fair	Good	Very good	excellent
Clarity of wording	0	1	16	29	46	9
Presentation of the paper	0	0	6	26	46	23

Respondents commented that the paper had a mix of easy to fairly hard questions, having a good spread on all topics. The distribution of the marks was similar to last year; the paper was only slightly easier than last year's but not by much.

Teachers seemed in general to respond favourably to the paper. A few individual questions, namely 3, 9, 24, 28 and 36 were strongly commented on and these are discussed below. The difficulty index (percent of candidates responding the correct answer) ranged from 26.81% (suggesting none were too difficult) to 91.94% with some very easy questions and the rest in-between. The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from -.04 and 0.54.

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

Question 3

Students found this question to be one of the most difficult ones, with only 26.81% correct answers. Most candidates answered D, a molecular compound which would have no chloride ions present (the other three were ionic). Students had to address the question of ionic versus molecular structure, which was straight forward as well as the quantitative aspect.

Question 8

Although several teachers had concerns about this one, overall it was a fair question with half the students answering it correctly. Surprisingly a quarter of the students incorrectly identified chloride ions acting as Lewis acids.

Question 9

Students found this question on dative (coordinate) covalent bond to be somewhat difficult with 44.65% correct answers. However, choices A and B were commonly selected. In A, the carbon octet is full and cannot bond with the lone electron pair on NH_3; in B, the reaction of Cl_2 with C_2H_2 would be an addition reaction with covalent bond between C and Cl.

Question 16

This was a fair question with half the students answering it correctly. It was a definition question on the standard enthalpy of formation of liquid methanol but almost 40% of the candidates selected choice A where carbon is given in the gaseous state, not its solid under standard conditions.

Question 20

Students found this question to be somewhat difficult with 42.15% correct answers. However, almost 40% of the candidates chose A, namely that for a first-order reaction, the reactant concentration decreases linearly with time (rather than exponentially); this suggests the importance of reading the statements more thoroughly.

Question 24

This was a somewhat difficult question with 43.80% correct answers and 22.69% of students choosing either C (oxygen) or D (nitrogen). Presence of CO_2 in the air causes pH of unpolluted rain water to be approximately 6 (due to formation of H_2CO_3) in many parts of the world.

Question 28

Students found this question to be somewhat difficult with 41.96% correct answers. The salt in each of the other three choices is neutral (made up of strong acid and a strong base) whereas the effect of the high charge density of the aluminium ion in the complex ion formed, $[Al(H_2O)_6]^+$, produces an acidic solution.

Question 36

Students found this question one of the more difficult ones with 32.32% correct answers. Tertiary halogenoalkanes undergo S_N1 reaction mechanism in which the rate of reaction is only first order with to the concentration of the halogenoalkane; thus choice C was the correct answer.

Recommendations for the teaching of future candidates

- Candidates need to be reminded that they should choose the best answer to each question.
- Candidates should be advised on how to approach a multiple-choice examination and, at the end, to have left no question unanswered.
- Candidates should not spend more than about one minute on each question in the first instance and those candidates who find the topic 1 questions to be testing should leave those for later in the time allocation.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 11	12 - 16	17 - 18	19 - 21	22 - 23	24 - 30

The range and suitability of the work submitted

The number of candidates who answered the paper was 7734. The paper consisted of 40 multiple choice questions on the Subject Specific Core and the Additional Higher Level. The exam was done without calculator or data booklet. Some candidates did not answer every question.

Only 94 teachers gave feedback on the G2 format from a total of 560 schools. The percent comparison with last year's paper is as follows.

Much easier	A little easier	Of similar standard	A little more difficult	Much more difficult
0	14	49	21	3

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

	Too easy	Appropriate	Too difficult
Percent Level of difficulty	3	91	6

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

	V poor	Poor	Fair	Good	V good	excellent
Clarity of wording	0	1	12	32	48	7
Presentation of the paper	0	0	6	26	48	20

Respondents commented that the paper had a mix of easy to fairly hard questions, having a good spread on all topics. The distribution of the marks was similar to last year.

Teachers seemed in general to respond favourably to the paper, although several commented on a heavy emphasis on organic chemistry. There were four questions on the topic as typically in the past years; other questions with organic molecules were on stoichiometry and bonding rather than organic chemistry per se. A few individual questions, namely 4, 10 and 16 were strongly commented on and these are discussed below. The difficulty index (percent of candidates responding the correct answer) ranged from 10.82% suggesting a couple of questions were very difficult to as high as 87.92% with some very easy questions and the rest in-between. The discrimination index (indication of the extent to which questions discriminated between high and low-scoring candidates) ranged from -0.10 and 0.58.

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

Question 4

Students found this question one of the more difficult ones, with only 28.15% correct answers. Most candidates answered D, a molecular compound which would have no chloride ions present (the other three were ionic). Students had to address the question of ionic versus molecular structure, which was straight forward as well as the quantitative aspect.

Question 9

This question was straight from the Assessment Statement 4.2.10 and some thought it was a tough but fair question. Only 22.10% answered it correctly. Both silicon and silicon dioxide have giant covalent structures, but the most common answers were B and C suggesting that students think these are linear molecules.

Question 10

Students found this question on dative (coordinate) covalent bond to be difficult with 35.13% correct answers. However, choices A and B were commonly selected. In A, the carbon octet is full and cannot bond with the lone electron pair on NH_3; in B, the reaction of Cl_2 with C_2H_2 would be an addition reaction with covalent bond between C and Cl.

Question 14

Students found this question also to be difficult with 35.83% correct answers. C was by far the most common answer suggesting that students were aware of combustion being an exothermic process but not neutralization.

Question 16

Students found this question to be the most difficult question with only 10.82% correct answers. This was very surprising considering this was a definition question on bond enthalpy which involves the energy needed to break one mole of the bonds to form separated atoms with reactants and products in the gas state.

Question 21

Students found this question to be difficult with 38.16% correct answers; about 28% of students chose either C (oxygen) or D (nitrogen). Presence of CO_2 in the air causes pH of unpolluted rain water to be approximately 6 in many parts of the world.

General comments for future teaching

- Candidates need to be reminded that they should choose the best answer to each question.
- Candidates should be advised on how to approach a multiple-choice examination and, at the end, to have left no question unanswered.
- Candidates should not spend more than about one minute on each question in the first instance and those candidates who find the topic 1 questions to be testing should leave those for later in the time allocation.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 12	13 - 25	26 - 35	36 - 45	46 - 55	56 - 65	66 - 90

The range and suitability of the work submitted

The following are some statistical data based on 70 respondents (from 415 schools).

Comparison with last year's paper

Much easier	A little easier	Similar standard	A little more difficult	Much more difficult
0	5	39	18	3

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	62	8

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	7.14	17.14	21.43	47.14	7.14
Presentation of paper	0	2.86	7.14	30	44.29	15.71

Candidates, in general, found this paper more difficult than last year's although there was not the same spread of marks at the lower end and there were many fewer students scoring 80+ marks.

There were a number of comments about the amount of organic chemistry. *Pro-rata* on hours taught would give 15 marks for topics 10 and 20 together. By judicious choice of section B questions, candidates could have offered as few as 8 and as many as 19 marks. The paper may have had the appearance of more than usual organic chemistry because organic reactions were used as examples to test other concepts.

Another commented that there was too little mathematics. Choice of questions could have offered between 17 and 27 marks out of 90.

Similarly, the number of marks for Periodicity fitted the general setting template.

In general, we aim to ensure that the whole Core and AHL is covered by papers one and two.

We recognize that the space allotted for answers in this session was not sufficiently large after introducing the new font but this will be improved.

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

There was considerable variation in performance but some of the repeated weaknesses were:

- Following through calculations as in Q1
- Drawing clear Lewis structures
- Understanding the difference between *intra*-molecular and *inter*-molecular bonding
- Understanding the bonding in a carboxylic acid and its conjugate base
- Writing equations to show pH of aqueous solutions (Q2)
- Quantitative equilibrium calculations (Q3)
- Describing metallic bonding
- Defining *average bond enthalpy*
- Using data to calculate ΔH values accurately
- Drawing repeating units of polymers
- Structure of allotropes of carbon
- Free radical mechanism of alkane bromination
- Electrolysis products and equations
- Definition of *standard electrode potential*
- Calculation using Born-Haber cycle
- Half equations for oxidation of ethanol to ethanal and full equation with dichromate ions
- Organic Chemistry, in general
- The action of optical isomers on plane-polarised light
- Clear explanations of sigma and pi-bonding
- Calculation of pH from solution data
- Calculation of oxidation numbers as in Q7a(ii)

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

The areas which seemed well understood were:

There were very few errors in the Kc expression in Q3

- Collision theory;
- Gaseous molecules affecting direction of equilibrium change;
- Calculation of relative abundance of an isotope;
- Understanding the major source of error in a calorimetric experiment;
- Identifying an oxidizing agent;

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

Question 1

It was suggested that, in the second paragraph, we should have explicitly stated that “0.795 g of *hydrated* ethanedioic acid was dissolved…” We agree that this would have clarified even more the question but we believe the sense is clear from the actual question for any student with practical experience. Another teacher suggested that the question was too easy. This was not apparent in the answers seen with very few candidates getting all the way to the end without mishap.

Most had little problem with (a) but some averaged all three readings. In (b) candidates found the calculation at the beginning of the paper difficult and many gave up too early in the sequence. “Error carried forward” marks were available even if an error was made early on. In (c), most were able to identify hydrogen bonding successfully. The diagrams of the Lewis structure of ethanedioic in (d) acid were, in general, poor; the most common error was to omit the lone pairs on the O of –O–H. Very few candidates were able to give a good explanation of electron delocalization and the differences in bond lengths in ethanedioic acid and the ethanedioate ion. As one respondent suggested, candidates would have benefitted from drawing out the Lewis structure of $^{-}OOC–COO^{-}$. We did not ask for this but there was nothing preventing them from doing so.

Question 2

In (a) sodium oxide was answered better than phosphorus(V) oxide (a direct reference to Assessment Statement 13.1.1) although there were many instances of NaO. In (b) there were the usual suggestions that covalent bonds are weaker than ionic bonds. Candidates find the distinction between *inter*- and *intra*-molecular bonding very difficult to grasp. Some didn’t realize that Na_2O is ionic. Answers about electrical conductivity usually gained one of the two marks available so there may have been an element of guesswork here. Many answers to (c) gained only one mark for knowing that one would be acidic and the other basic. There was very poor understanding of the equations needed and the explanation of the equilibria involved.

Question 3

The definitions of rate of reaction in (a) were poor with many referring to a measure of time rather than a change in concentration. The collision theory was described successfully for the most part with “frequency of collisions” less frequently mentioned. In (c) (i) most realized that the number of moles of gases is important and thus gave a correct answer. Whilst the K_c expression was often given correctly in (ii), the calculation of equilibrium mole concentrations was more testing, particularly that for $[O_2]$. Many were able to answer (iii) correctly. In part (d) many suggested that it is good to make more of something rather than relating this to a reduction in costs.

Question 4

Most were able to quote the electron configuration of copper correctly; but some gave [Ar] $4s^1$ $3d^9$ when they were specifically asked for the *full* configuration. A few, inevitably gave $3d^9$ $4s^2$. In (b), few related the difference in mass to a *property* and most did not give the comparison; “the same number of electrons and protons” was more popular than “the same electron configuration”. The descriptions of metallic bonding were disappointing; the mark for electrostatic attraction was rarely scored and many confused “nuclei” with “cations/positive ions”.

Section B

This is the last May session in which there will be a choice of questions on Paper 2. The new syllabus offers no choice.

In this session there was very little difference in the “popularity” of the questions.

Question 5

There was poor understanding of the transformation in (a). When defining the *average bond enthalpy* in (b), the notion of “gaseous” was frequently omitted and very few mentioned the bonds being in similar compounds. In the calculation, many omitted the C–C bond and many did not work from a properly balanced equation which led to disaster. Nearly every candidate attempting this question was able to suggest “heat loss”. In (d) the usual errors were made; the name was the wrong way round, water was missing from the equation and wrong products (such as pentanoic acid) were suggested. In (e) (i) the diagrams were poor but water was usually given correctly. Most gave condensation as the type of polymerization. The key to gaining marks in questions such as (f) (i) is to start with a balanced equation, [1 mark], and then set the calculation out correctly and tidily. Part marks cannot be given if the examiner cannot follow what the candidate is doing. Many correctly gave “negative” in (ii) but the explanations lacked clarity. Most gained a mark in (g) for knowing three allotropes but the description of structures was poorly done. The [4] (marks) for this part gives some idea of the amount of detail expected.

Question 6

Candidates found it difficult to write the equation in (a) and the mechanisms in (b) (i) ranged from really good to no understanding. Many opined the production of •H in the first propagation step. A significant number of candidates suggested a mechanism involving ions despite *free radical* begin stated in the stem. Most were able to give methanol in (ii). Few scored full marks for (c); the answer needed to be thought through carefully. In (d) the electrodes were often reversed or the equations unbalanced. Few understood the significance of the water present in the answers to (ii). A high percentage of candidates gave the correct answer to (e) but (f) was poorly answered. Either the standard hydrogen electrode or standard conditions were omitted in (i) and the standard of diagrams in (ii) was very poor indeed. Little care seemed to have been taken over their presentation; it was not clear what, if anything, was in the beakers and electrode connections were shown actually in the solutions. In (iii) some did not notice that the voltmeter was digital but most gave the number of significant figures correctly. In (iv) many suggested repeated readings but few stated that an average omitted must be taken. In (g), those who didn’t draw out the cycle tended to get the answer wrong. Examiners cannot give part marks if they cannot work out what is being done. There was one mark for a correct Born-Haber cycle. Very few gained the mark for dividing the chlorine value by 2.

Question 7

The idea of “reflux” was usually given for the production of ethanoic acid in (a) but ethanal was less clear. We accept that perhaps we should have phrased (a) (ii), “Determine the *average* oxidation number of carbon in …” In practice, this was one of the best answered parts and caused few difficulties. Few had any idea how to attempt the half-equation in (iii) and the overall equation in (iv). Although the mechanism in (b) has been set on numerous occasions, candidates are still not taking care over the start and finish of the curly arrows and the intermediate is drawn poorly. It must have partial bonds and the sign must be outside the square brackets. Some candidates offered an S_N1 mechanism. In (c) (ii), the orders were usually successfully deduced but many omitted to give the overall rate expression. In part (ii), quite a number of candidates unaccountably ignored the instruction and used any experiment but No 3. The units were frequently wrong or omitted. The molecularity was answered satisfactorily. In (d), candidates frequently stated that the molecules have mirror images but not that these mirror images are non-superposable. "Chiral" was a popular correct answer. There seemed to be little understanding of a polarimeter with some suggesting that the crystals themselves rotate. In (e) the equations were poor and few were able to identify the reagent. Most descriptions in (f) would have been improved with a careful and clear diagram. Part (g), the relative abundance of ^{79}Br was well done except by those who tried to do it "by inspection"; this usually led to the wrong answer.

Question 8

There is a difference, which candidates should note, between "not fully dissociated" and "partially dissociated" when describing a weak acid. The latter is correct; the former is not accepted as it could mean anything between 1% and 99%. In (ii), many did not state the difference in behaviour of the two acids. Many gained the first mark in (b) for finding the concentration of ethanoic acid. Thereafter either full marks was obtained – or there was total confusion. The equivalence point in (c) was better known than the pK_a where an explanation was expected. The best candidates annotated the graph. Almost all candidates identified phenolphthalein in (ii) correctly but in (iii) any answer that did not begin with an equation was likely to score zero. In questions such as (d) (i), candidates should avoid writing a balanced equation (and there were many) unless the actual answer is clearly indicated. Many were able to identify the stronger acid with the correct reason but in (iii) there were few successful conclusions, many not having recognized that a buffer solution was formed. In (e), most were able to explain why chlorine is in group 7, but the explanation for the period, when it was given, often omitted the idea of *occupied* shells. In (f), it was disappointing to note that many thought SCl_2 to be linear and $SClF_5$ trigonal bipyramidal or square pyramidal. Two respondents commented that the column headed "polarity" was confusing; although we could have expressed this more clearly, the candidates did not seem to have a difficulty with this.

Recommendations for the teaching of future candidates

- Write legibly and take care over your answers. Examiners cannot award marks if they cannot read what have been written. Careful, organized work pays dividends.
- Set out calculations carefully if you want part marks.
- Do not write out the question again as part of the answer. It wastes time and uses up space in the box.
- Draw dot/cross diagrams carefully. Group the dots in pairs.
- Read the question and avoid careless errors.
- Do not write outside the box. Write on continuation sheets and annotate the question

paper to draw the examiner's attention to the continuation.

- Use accurate scientific terminology.
- Practise past papers.
- Make sure to balance equations not only by atoms but also by charge.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 19	20 - 25	26 - 31	32 - 37	38 - 50

The range and suitability of the work submitted

The G2 comments suggest the paper was of a similar standard to last year, with a few respondents feeling it was a little easier and some feeling it was a little more difficult. All respondents felt the wording and clarity of the paper was at least fair and more than 50% felt it was very good or excellent.

On the whole there were a large number of very poor responses on a paper that was very straightforward. Basic recall of chemical definitions and concepts was limited as was the ability to apply these ideas. Many scripts had large sections left blank.

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

- Following through calculations as in Q1
- Understanding the difference between intra-molecular and inter-molecular bonding
- Describing metallic bonding
- Defining average bond enthalpy
- Free radical mechanism of alkane bromination
- Electrolysis products and equations
- Half equations for oxidation of ethanol to ethanal and full equation with dichromate

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

Candidates could generally answer well questions related to:

- atomic structure -such as writing correct ionic formulae and drawing Lewis structures
- calculation of enthalpy of reaction using bond enthalpies
- equilibrium
- Collision theory
- Identifying an oxidizing agent

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

Question 1

This beginning of this question to state the uncertainty and to calculate the average volume added were well done and most students could also calculate the number of moles added. However, many candidates began to lose marks from this point onwards. Some could identify the ratio and correctly state the moles of ethanedioic acid, but fewer realized they needed to multiply 10 to get back to the original solution. The next step, to calculate the M_r was only correctly completed by a handful of students. Those that were correct with the molar mass always could calculate the moles of water- many students just guessed an answer though.

The intermolecular force was correctly described as hydrogen bonding- however there was some instances when it seemed unclear whether students realized this was between molecules and instead they seemed to suggest it was a bond between hydrogen and oxygen in the molecule. Some candidates could correctly draw the Lewis structure but a number of those lost marks for omitting the lone pairs on oxygen.

Question 2

Part (a) and (b) of the question were based on the free radical substitution of methane and typical marks were 0/5 or 5/5, as it required the stating of a mechanism that has been on the syllabus and on examination papers for many years. Students generally had little idea- but some had obviously learned it well. The students who gained some marks often lost marks for creating hydrogen radicals. The rest of the question was based on redox and (c) which asked for the equations at the electrodes during the electrolysis of sodium bromide was done very badly indeed. These half-equations are in the data booklet and yet very few students could come up with the correct equations. Some students had NaBr at both electrodes. However many students did correctly identify bromine as the oxidizing agent in (d).

Question 3

This question was very straightforward and based on kinetics- but few scored all the marks available as their ability to correctly define rate of reaction and describe the collision theory was limited.

Question 4

This question focused on atomic structure and metals was very accessible. Many students could correctly state relative mass and charge of the subatomic particles- but it was disappointing to see the number of students who could not. Units were not penalized which meant that more students gained marks than would otherwise have been the case. Many students could calculate the protons and neutrons in the copper isotope but few could explain how the physical properties would vary (mass is not a property) and few could clearly explain why the chemical properties were identical. Explanations were often far too vague. Two properties of copper were asked for in and many could give one- again answers were often very vague- such as "it conducts" without specifying what it was conducting.

Question 5

This was not a popular question with few candidates choosing it. Some who chose it did very well but most scored poorly. Students needed to write an equation for the hydration of ethene which was generally answered well and then state the conditions, which were less well known. Applying Avogadro's law to work out the volume of ethanol was only correctly answered by a few. The definition for bond enthalpy was not well known, however many candidates could calculate the energy change using bond enthalpies with some success- although there were few completely correct answers as bonds were forgotten or incorrectly multiplied.

Question 6

This was by far the most popular question. As before the definition was poorly done and many students defined electronegativity as just attraction for electrons- or energy change in gaining an electron. However, many could at least half explain why the atomic radius decreased. In (c) some students could write a correct equation for the addition of sodium oxide to water but very few could correctly write an equation for phosphorous(V) oxide with water, following on few could then correctly state a sensible pH for the solutions formed. Suggesting methods to distinguish between strong and weak acids was reasonably well answered but many student lost marks for the imprecision in their answers. Stating "see if it conducts" and "add pH paper" were common answers without predictions of the expected results. Identification of BF_3 as a Lewis acid was not always explained well as students mixed up proton donation and electron pair donation. In (f) the description of the bonding and structure of sodium chloride was not well done- although there were a few strong candidates who had little problems with this question. Most candidates could correctly state the ionic formulae though. The last part of this question asked for a Lewis structure of PCl_3 and most did this well- although some forgot the lone pairs on the chlorine atoms. Most could then correctly state a bond angle- although there were a number of candidates who stated 120°. Few candidates could explain why the molecule was polar.

Question 7

This was the least popular question however many who chose it were successful in parts. Part (a) that required a calculation of M_r was quite well done. However (b) that asked for the isomer of C_5H_{12} with the lowest boiling point was not well answered. Identification of the methods to produce ethanal or ethanoic acid was done well by the strong candidates and others just guessed. Deduction of oxidation numbers and then writing of redox equations was not well answered. However (d) and (e) about equilibrium were answered well by many candidates- although there were again some very poor answers.

Recommendations for the teaching of future candidates

- Students should complete practice examination papers and take careful note of the corresponding mark schemes. However they should look carefully at the new syllabus and make sure they know what has been removed and added in.
- Write legibly and take care over the answers. Examiners cannot award marks if they cannot read what is written.
- Set out calculations carefully to gain part marks.

- Draw dot/cross diagrams carefully- including all lone pairs.
- Do not write outside the box. Write on continuation sheets and annotate the question paper to draw the examiner's attention.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 14	15 - 19	20 - 24	25 - 30	31 - 35	36 - 50

The range and suitability of the work submitted

The following are the statistical data based on 70 respondents.

Comparison with last year's paper

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
0	7	63	20	3

Not applicable = 7%

Level of difficulty

Too easy	Appropriate	Too difficult
0	92	8

Suitability of question paper in terms of clarity and presentation

	Very Poor	Poor	Fair	Good	Very Good	Excellent
Clarity of wording	0	3	14	29	47	7
Presentation of paper	0	1	9	32	44	14

Based on the G2 comments teachers in general found the breadth of the paper to be fair, reasonably-balanced and it appears to have been well received. The applied nature of the paper was praised. One teacher commented that some material was not mentioned explicitly in the study guide. It must be stressed that no one textbook or revision guide forms the basis of the actual curriculum and examination questions are based exclusively on the chemistry curriculum from the guide.

There were no references to any questions being duly problematic or off-syllabus which is encouraging to read – the interpretation of a small number of possibly perceived borderline syllabus questions are addressed in the section below in the individual Options. The general consensus amongst examiners was that the paper was accessible though the performance at the upper-end was not as strong as previous. Most options had a number of easy entry level type questions and this helped a number of the weaker candidates.

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

- MRI – explanations on a molecular level
- GLC
- Zwitterions
- HDL and LDL
- Liquid crystals in general
- Process underpinning the manufacture of the expanded form of polystyrene
- The membrane chlor-alkali electrolytic cell
- Idea of a Lewis base
- Combinatorial chemistry
- Solubility product calculations
- Discussion of the relative contributions of carbon dioxide and dinitrogen monoxide to global warming
- Soil chemistry
- Hydrolytic and oxidative rancidity
- D/L convention
- Inherent stability of carbocations
- Difference between the various reaction types in organic chemistry
- Difference between activating and deactivating groups

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

- Energy-wavelength relationship and wavelength-velocity calculation
- Interpretation of core spectroscopic techniques in analytical chemistry in general – IR, MS and ^{1}H NMR
- Idea of conjugation
- Difference between hydrophobic and hydrophilic
- Polarity
- Functional groups
- Chemistry underpinning enzyme-catalysed reactions

- Annealing
- Anti-viral drugs
- Potency of diamorphine over morphine
- The ozone layer – bond order of ozone and oxygen
- Definition of shelf life
- Idea of an emulsion
- Difference between the solubility and polarity of anthocyanins and carotenes
- Organic reaction mechanisms
- Grignard chemistry

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

Option A

This option was popular with many of the better candidates and many gave answers of a high quality. Overall the option appeared to be highly accessible with a good smattering of easy to more challenging questions.

Question 1

Most candidates knew that energy is inversely proportional to wavelength. Some gave an incorrect mathematical equation. In (b), IR was usually identified as the region of the EMS for the bonds present in an organic compound and many knew that the visible region of the EMS can be used to obtain information on the concentration of Cr^{3+} ions in industrial waste waters. The most common error was UV. (c) (i) was poorly answered and protons were often not even mentioned. Very few candidates scored full marks here. In (ii), candidates typically were able to outline the information that MRI scans provide about the body, namely to provide a 3D image of an organ *etc*.

Question 2

This question focused on some of the fundamental spectroscopic techniques (MS, IR and ^{1}H NMR) used in analytical chemistry. The better candidates did well on this question though few scored full marks. In (a), the most common mistake was omission of the positive charge in (i). One G2 comment stated that isotopic effects in mass spectra with regard to the determination of the molecular ion peak would confuse students. This generally was not the case and although most got the C_4H_8 formula a large majority of candidates simply did not read the question correctly which specifically asked for the formula of the molecular ion. In (ii) the correct formulas of the fragments were usually given. In (b), C=C was usually cited as the correct structural formula in (ii). The weaker candidates struggled with explaining the doublet in (iii). Cyclobutane was obtained by a large number of candidates in (iv). In (c) (i), the better candidates scored all three marks. In (ii), an understanding of the fingerprint region was poorly conveyed. There were two parts to this question – an outline of what happens on a molecular level when radiation in the fingerprint region is absorbed and how this region is used in chemical analysis. One G2 comment referred to the fact that the fingerprint region is not explicitly mentioned in the guide. Although this is true per se AS 3.2 does require a description of how the information from an IR spectrum can be used to identify bonds, and it would be assumed that the fingerprint region would be discussed in the context of teaching IR spectroscopy as part of the IB chemistry programme.

Question 3

It was somewhat surprising that such a high proportion of candidates gave incorrect responses to parts (a) (i) and (ii) though part (b) was well answered and some good explanations were given stating that sample II has lower retention times since the molecules on average have greater kinetic energy. On G2 stated that the GLC given was not properly represented. However the GLC involves area normalization which is standard practice experimentally for GLC and the same amount of propan-1-ol was added to both samples as a reference.

Question 4

In this question the word light/radiation required for the mark was often missing as was reference to electron delocalization/conjugated system. The stronger candidates did however usually mention conjugation. Again here it was the case that the question was not carefully read. The question asked for an explanation of the colour of the pigment with reference to the molecular structure and hence the need to refer to the extensive conjugative system present. Disappointingly quite a large tranche of candidates tried to craft their answer incorrectly on supposed occupied d-orbitals of magnesium, which showed very poor chemical understanding as magnesium is not a transition metal!

Option B

This was a highly popular option and candidates showed a good knowledge of biochemistry. In several of the questions, performance was strong. There were no G2 comments on this option.

Question 5

Performance on this question varied greatly between the stronger and weaker candidates. The weaker candidates typically lost marks for not identifying the cation and zwitterions in (iii), and charges were frequently omitted. In addition some candidates incorrectly placed the positive charge on the hydrogen instead of the nitrogen. Although based on Henderson-Hasselbalch calculations the correct answer is actually both the cation and the zwitterion, the markscheme gave a high degree of latitude here and the structural formula of the cation or the zwitterion alone (the latter as the dominant form) was accepted. This also was an example of a question where incorrect bond linkages were commonly seen. In (b) the markscheme was quite generous and mention of the structural nature of collagen scored. However, it would have been nice to have seen more precise answers such as “collagen gives strength to tendons” *etc*. Answers such as “protects bones” did not score.

Question 6

In this question few candidates scored full marks and there were several parts where candidates dropped marks. In (a), although most stated that fats are less polar, few gave correct answers for the similarity or difference in structure. In the latter case, partial answers such as “phospholipids have phosphorous” were often stated but more comprehensive comparisons were needed i.e. “phospholipids have phosphate groups and fats are made from three fatty acids”. As regards the similarity in structure, loose language was often used e.g. “both are glycerol” instead of stating that “both fats and phospholipids are made from glycerol”. In (b), few stated that HDL has more protein and less cholesterol, again failing to read the question which asked about a distinction based on composition. Many also mixed up LDL and HDL in terms of the effect on health. In (c), many candidates thought incorrectly that iron ions act as ligands instead of their ability to form complex ions. In (ii), oxidation states were often guessed incorrectly and a number simply wrote charges *e.g.* Fe^{2+} instead of +2, which is the oxidation state.

Question 7

This question was well answered. In (a), the most common mistake was candidates stating that F is actually testosterone instead of stating that its structure is similar to testosterone. A number did not mention the increase in muscle mass and simply referred to improved performance, thereby repeating the question. (b) was well done, though answers had to be given in terms of functional groups and many missed this point. Some stated that G has hydroxide which is incorrect – it has the hydroxyl group.

Question 8

Overall this question was well answered. In (a) many did not refer to the areas of low and high concentration in the graph. (b) and (d) were very well answered. In (c), the most common mistake was candidates not drawing the second curve going to the same maximum.

Option C

After G probably the least popular of the options and high quality responses were rarely seen.

Question 9

In (a) (i), many candidates calculated the average oxidation state to be +8/3, but few very able to comment correctly on this value, namely the fact that the ore contains iron in two different oxidation states, namely +2 and +3. The equation for the reduction of magnetite to iron was well done, though some evidence of incorrectly balancing of equations was seen. This was predicted based on some G2 commentary. In (b) annealing was well understood.

Question 10

One teacher commented that part (a) seemed too easy for two marks. Candidates generally scored well on the first part of this question though the weaker candidates often did not draw molecules with the irregular arrangement in space and hence only scored half marks. Some did not include eight molecules. In (b) (i), reference to the CN bond was often omitted. (b) (ii) proved a real challenge whereby candidates had to explain why a liquid-crystal device may be unreliable at low temperatures. Several different answers were allowed here on the markscheme ranging from molecules becoming more ordered to molecules unable to change orientation as they approach the fixed arrangement of the solid state to the increase in viscosity of the medium (leading to an increase in the LCD response time). In (c), very few scored all four marks though many did score half marks. The markscheme was quite expansive for this question and a suitably labeled diagram also could have been used to explain many of individual marking points. Diagrams were used to good effect by some of the better candidates in supporting their written answers.

Question 11

Part (a) was very poorly answered and few knew that pentane or a volatile hydrocarbon needed to be added. In (b), vague answers such as stating “light” instead of “reduced density” were seen.

Question 12

It was surprising how poorly candidates did on the membrane chlor-alkali electrolytic cell. Few scored full marks on (a). In (b), some thought that sodium instead of sodium hydroxide formed at **M**. In (c), correct equations were often given but at incorrect electrodes or incorrect equations such as the reduction of sodium ion were cited. In (d), many candidates were aware that the diaphragm is made of asbestos but few stated that the membrane cell has its membrane is made from PTFE. Overall a very poorly answered question which showed weak understanding of this part of the syllabus.

Option D

This was by far the most popular of the options and was generally quite accessible for candidates. There were some G2 comments which stated that the questions this year on Medicinal Chemistry sometimes drew on basic chemical concepts from the core and that nicotine administration would have challenged some students and may not have been formally covered in classroom teaching. It must be emphasized that core chemical concepts form the platform for the effective teaching of the applied nature of several of the topics covered in the options and core topics are an intrinsic part of such chemistry. Although this will be greatly enhanced in the new chemistry syllabus, even in the current syllabus this aspect still is valid and is linked to the interpretation of some of the assessment statements seen in the options. As regards the methods of administering nicotine, this question is based on AS D.1.3, which mentions a description of the different methods of administering drugs. According to P.11 of the guide a description involves giving a detailed account so the question is securely on the syllabus in this context and in fact nearly all candidates scored full marks here.

Question 13

For (a) (i), many candidates appeared not to be versed with the concept of a Lewis base. In (ii), very few referred to the fact that nicotine passes into the bloodstream within seconds of a cigarette being smoked by dissolving in the aqueous medium in the body. Again the markscheme was generous here and “passing through the lungs” was accepted, an answer widely cited by candidates. In (iii), the most common answers were patches and gum. “By injection” was only accepted if NicVAX was stated. In (b), THC was usually identified. Some incorrect answers included marijuana and TLC! In (ii) a number did not relate the specific effect to a named disease and many just wrote down any effect which came to mind, hoping that this would be acceptable on the MS!

Question 14

This question was based mainly on viruses and anti-viral drugs. Candidates with a strong biology background did well here. (a) was well answered though some candidates simply gave the difference between a virus and bacteria, and failed to read the question. Answers such as “DNA” and “protein” scored full marks. In (b), the cell was frequently omitted. In (c), mutation was often mentioned but answers such as “AIDS mutates” were not accepted – there had to be reference to HIV. Some candidates misunderstood the term “mutation” and some incorrect explanations were seen on scripts.

Question 15

Many candidates were able to give a correct reagent for the conversion of aspirin to its sodium salt. Incorrect answers included NaCl, Na and incorrect chemical formulas for sodium carbonate. In (a) (ii), the increase in aqueous solubility was necessary and increase in solubility alone did not suffice. This threw a number of candidates. The markscheme for (b) (i) was quite broad and most candidates scored one for the two similarities, though some did not understand that benzene is different to benzene ring and that $-C_6H_2$ is not the phenyl group, which is actually $–C_6H_5$. As regards the difference, as previously hydroxide was not accepted for hydroxyl. Some candidates mixed up ethers with esters. In (c), many scored both marks though a few did not mention the non-polar nature of diamorphine.

Question 16

As has been the case in many previous examinations, combinatorial chemistry remains a challenge for candidates. Some teachers felt that this question was quite difficult and students with a biochemistry background may have an advantage. One teacher commented that combinatorial chemistry is a topic only partially covered in many of the IB chemistry texts that support the programme. Many of the assessment statements in D9 are objective 3 in nature and some comprehensive discussion is required in the teaching of combinatorial chemistry for this reason. The wording of the question in (a) was crucial where reference had to be made to the condensation reaction between a series of amino acids. Hence candidates had to state that a variety of (poly)peptides are produced. Many scored at least one mark in part (b), but ore precise scientific descriptions were rare *e.g.* molecular modeling of pharmacophores *etc.* Some of the upper-tier candidates did however manage to score full marks on Question 16.

Option E

A reasonably popular option in some schools as in previous sessions but one which had a number of challenging parts. Soil chemistry was found to be difficult for candidates and few seemed prepared for this topic.

Question 17

Q was only identified by the stronger candidates and even then few stated that waste needs oxygen to decompose. The ionic equation for the reaction of calcium ions with phosphate ions proved a real minefield. It was highly disappointing at HL that so many candidates did not know what the formula and charge of the phosphate anion actually is. Some gave phosphite and several gave phosphide. Core chemistry underpins all options and candidates need to be prepared to apply some basic chemical principles to the various topics in the options. This aspect will be further enhanced in the new chemistry syllabus, but performance of candidates in this particular question shows the importance of this even in the current syllabus. In (ii), candidates often used the ionic equation in (i) to write the solubility product expression and hence had an incorrect inverse equation. Many also did not realize that the activity of a species in the solid state is unity. In (iii), incorrect K_{sp} expressions in (ii) threw some candidates and others could not deal with the math involved in the solution to the equation. Many thought the final answer was x and not 3x for $[Ca^{2+}]$. Of course the stronger candidates scored all three marks on this question. In (c), misreading of the question was common which specifically asked for a non-chemical reason for the decrease in oxygen concentration *i.e.* an increase in the temperature of the water.

Question 18

There were three G2 comments on Question 18. One teacher stated that (a) (i) may be off-syllabus. This was discussed during the compilation of the paper by the paper authoring team and during Grade Award. It was agreed that the question is a completely valid to be posed to candidates as the equation relating the wavelength with the speed of light is given in the data booklet and in addition this relationship underpins some of the topics covered in the teaching of Option E. Another G2 stated that it would have been better if a variety of Lewis (electron dot) structures were included in the question. This was discussed during Grade Award and it was felt that this would have over-complicated the question. In the guide, it is explicitly stated that N_2O is a greenhouse gas (TN for AS E.3.2), so this should have been known. Furthermore, in order for a species to be IR active there must be a change in the dipole moment associated with the characteristic vibrational mode. Although nitrogen dioxide, NO_2, is bent it has a centre of symmetry so its symmetric stretch will be IR inactive. In contrast, N_2O which is linear is non-centrosymmetric and hence its symmetric stretch for example will be IR active due to change in the dipole moment. This would also rule out NO_2 as an answer to the question. Parts (a) and (b) were well answered though some candidates incorrectly gave NO_2 instead of N_2O. Candidates had no idea how to answer (c) and all sorts of stock, off the shelf answers on the greenhouse effect were muted and scored no marks. One teacher stated that (c) may be confusing to students. However although candidates performed very poorly on this question, the question is based on AS E.3.2 from the guide, which is an objective 3 assessment statement. The effects of the greenhouse gases (including N_2O) and their dependence on their respective abundances coupled with their ability to absorb heat radiation is explicitly cited in the TN for this assessment statement so is firmly on the syllabus.

Question 19

Soil chemistry proved a highly challenging topic for candidates. In (a) harvesting was only occasionally mentioned though most knew that fertilizers can replace soil nutrients. In (b) (i), although many candidates stated that fulvic acid contains COOH, few stated that there are many such groups which was required to answer this question. Once more hydroxide was stated incorrectly for hydroxyl. Hydrogen bonding was only mentioned by half the candidates. One teacher stated that only humus is covered in most IB chemistry textbooks and not fulvic acid. Once more this is an example of a case it must be stressed that the guide per defines the syllabus and not any particular textbook. Candidates should be prepared for questions of an applied nature in questions. Both (ii) and (iii) were extremely poorly answered and virtually no student scored the two marks in (iii).

Question 20

Part (a) was very well done and it was nice to see reference to and discussion of bond order in many of the answers seen on scripts. In (b), few were able to give two correct equations. Inconsistency of the representation of radicals was seen on some scripts.

Option F

Unlike previous years, candidates did not perform as well on this option in May 2015. Slightly fewer candidates also attempted this option compared to recent sessions. There were no G2 comments on this option.

Question 21

In (a) candidates had no difficulty describing what a food is but some did not state that a nutrient is obtained from food, even though most knew that a nutrient provides energy *etc.* In (b) (i), the similarity between the structure of a saturated fat and an unsaturated fat was poorly answered and few stated that both are made from glycerol. With respect to the difference, reference to the carbon-carbon double bond was often omitted. In (ii), the most common incorrect answer was the *cis* fat, instead of the *trans* fat as the factor which increases the melting point of oils and fats other than degree of saturation. Most candidates had little difficulty with (c) though many gave just specific examples of either minerals or vitamins. The question asked specifically for types.

Question 22

The meaning of shelf life was sometimes vaguely conveyed and its relationship to best-before date was often incorrectly answered. In (b), few scored full marks though many scored one mark for correctly identifying hydrolytic rancidity and oxidative rancidity.

Question 23

In (a) the idea of an emulsion was well understood though some stated that oil and vinegar actually mix instead of stating that there is an apparent mixture (or better still an emulsion formed). In (b), although most stated that lecithin has both polar and non-polar parts often the associated interactions of these specific parts with vinegar and oil was not stated.

Question 24

The same general comments apply here in part (a) as in Q4 in Option A. In (b), some excellent answers were seen and differences in polarity and solubility were correctly outlined. Many students seemed to have an outline understanding of the CIP convention, though many lacked the language skills to communicate their knowledge succinctly. The ordering of groups by atomic mass rather than atomic number seemed a common misapprehension and many referred incorrectly to molecular mass. In (d), few managed to score both marks. D/L and d/l were often mixed up and few realized that there is actually no relationship between the (+) and (-) and D/L conventions.

Option G

Option G was only attempted by a small number of students, and overall this proved to be a highly challenging option in parts. There were no G2 comments on this option.

Question 25

In (a), HBr usually was correctly identified but addition was often stated which was not enough to score the mark for the type of reaction, where electrophilic addition was required. Some incorrectly stated electrophilic substitution. The mechanism for the conversion of but-1-ene to 2-bromobutane was answered better perhaps compared to previous sessions though some careless errors were sometimes seen such as curly arrows not originating on the lone pair of the bromide ion *etc.* Few could explain why 2-bromobutane is the major product and knowledge of carbocation stability was very weak. Mention of Markovnikov's Rule was not sufficient. Only the stronger candidates referred to the greater inductive effect of $–CH_2CH_3$ plus $–CH_3$ compared to $–CH_2CH_2CH_3$.

Question 26

In (a), many candidates simply did not read the question which specifically asked for an equation. Few gave adequate explanations for phenol, namely that the lone pair on oxygen on the phenoxide anion delocalizes around the benzene ring so the charge density decreases. In (b), many guessed (correctly) that 4-nitrophenol is more acidic and some knew that the nitro group is electron withdrawing. However few scored the final mark, stating that the H^+ leaves more easily.

Question 27

The equation for the reaction of maleic anhydride with water was well answered. In (b) many candidates did not score the one mark here as they had to name two functional groups, not one, again clear misreading of the question. In (c), the most common incorrect answer stated was substitution, which was not sufficient – nucleophilic substitution was required.

Question 28

Grignard chemistry was well known. In (b) the type (namely tertiary) of alcohol was asked, not the IUPAC name of the compound. This threw some candidates.

Question 29

A number of marks were dropped on this question. In (a) (i) concentrated was required for the nitric acid and sulfuric acid reagents. In (ii), some candidates mixed up NO_2^+ with NO_2^-. In (b) the difference between activating and deactivating groups was often misunderstood.

Recommendations for the teaching of future candidates

- Options should be taught in class and are an integral part of the teaching programme. Only one option will need to be taught for the May 2016 examination. It is critical that the recommended time is devoted to cover the two options thoroughly and in depth. Although less than in May 2014 there was still some evidence that some options were not covered by a small minority of schools. Students who are left to learn material independently can struggle with the options.
- It is critical that core chemical principles are brought to the fore in the Options, especially those which have often a twin biological focus e.g. Options B, D and F. In addition core chemistry should always underpin applied topics.
- Candidates should always look at the associated marks allocations in questions. Candidates should not have to use extra continuation sheets if they tailor their answers to the space provided.
- Students struggle with questions that require explanations or multiple steps. Candidates need to fully understand the various command terms and teachers should take time to review command terms throughout the year with students to make sure they understand the relevance of command terms in answering questions. This was certainly a feature of this session on this particular component where many candidates did not have a clear appreciation of the command terms.
- Candidates should prepare for the examination by working through past examination questions and carefully studying the mark schemes provided.
- Candidates should be fully au-fait with formal definitions and organic reaction mechanisms.
- It is imperative that laboratory work lies at the heart of the IB Diploma chemistry programme. Ideally candidates should be exposed to a rich experimental experience in the laboratory where suitable facilities are available. Where this is not the case other resources such as simulated experiments should be sourced. If an analytical technique is required by the option and students are required to know the steps then it should be performed in class or via an online computer-generated simulation.
- Students can benefit from specific practice in identifying bonds stating, for example, carbon-carbon double bonds rather than simply double bonds.
- Students should be exposed to the skill of writing balanced chemical equations.
- Many students still use class names instead of functional group names. Again this will be a feature of the new chemistry syllabus but it is worth flagging even at this stage for best practice.
- Although there are several very good textbooks on the market to support the teaching of the IB Diploma Chemistry programme, it must be stressed that no one textbook or revision guide forms the basis of the actual curriculum. Teachers should emphasise to students that examination questions are based exclusively on the chemistry curriculum from the guide and this is the spine for the effective delivery of the programme. Textbooks, revision guides and other resources (online, laboratory-based etc.) can be invaluable to teachers and students in supporting this delivery of the actual curriculum from the guide but the guide itself should always be used as the primary reference.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 6	7 - 12	13 - 15	16 - 19	20 - 23	24 - 27	28 - 40

The range and suitability of the work submitted

General comments

Some candidates demonstrated a good understanding of concepts, however, a large proportion of the scripts were of poor quality indicating that many candidates were not well prepared for the paper.

Option D was the most popular option among SL candidates this session, followed by options E, F and B. The least popular option was C. Each option had several straight-forward marks to be gained and a few marks that discriminated at the top end.

In terms of skills, the answers were mostly focused on answering the question asked, a good proportion of candidates could name functional groups correctly, and candidates did attempt to provide explanations when requested. However, the use of terminology was not always precise and the explanations were often not detailed enough to meet the requirements of the markscheme.

Feedback from teachers through the G2 forms showed that 86% of the 94 respondents judged the paper to be of appropriate difficulty, and 13% judged it to be too difficult. 56% of the respondents saw the paper as of similar standard to last year's paper while 17% saw it was a little more difficult, 6% saw it was much more difficult and 6% judged it to be a little easier. With the average mark being a little higher than last year, it was certainly a slightly more accessible paper overall. 85% of respondents found the clarity of the wording to be at least good and 90% found the presentation of the paper to be at least good. The questions were seen accessible to candidates with learning support and/or assessment access requirements by 96% of respondents, and accessible irrespective of candidates' religion, gender or ethnicity by 100% of respondents. In the G2 forms, some teachers commented that it was good to see questions that connected chemical concepts to daily life, and others thought the paper made good use of the data booklet.

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

- How MRI produces information about the body
- Deducing the structural formula from the mass spectrum
- The fingerprint region in IR spectra

- Understanding the process of paper and column chromatography
- Deducing the structure of an amino acid at given pH
- Distinguishing between the composition of HDL and LDL cholesterol
- Describing chemical reactions with balanced equations
- Calculation and explanation of non-integral oxidation states
- Relative contributions of greenhouse gases to global warming
- Sources of PCBs
- Reasons for soil degradation by pesticides and fertilizers
- Relation between shelf life and best-before date
- Explaining the reactions by which foods become rancid
- Advantages of using vitamin C and β-carotene as antioxidants
- Explaining the relative stability of primary and secondary carbocations
- Predicting and explaining the acidity of alcohols and phenols

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

- Identifying the bond responsible for a specific IR absorption from the spectrum
- Identification of functional groups
- Comparing the polarity of fats and phospholipids
- Effects of HDL and LDL cholesterol on health
- Short-term effects of nicotine consumption
- Tolerance to drugs
- Methods of administering nicotine in nicotine replacement therapy
- Recognizing the properties of analgesics
- Replacement of soil nutrients using fertilizers
- The difference between saturated and unsaturated fats
- Definitions that are regularly tested

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

Option A – Modern analytical chemistry

Question 1

(a) Most students scored the mark but only a few of them stated the quantitative relationship (inverse proportionality).

(b) About half the candidates answered this correctly.

(c)(i) Few of the candidates could explain on the molecular level how MRI could give information about the body. Less than half of the candidates related the technique to detecting protons and very few candidates clarified that protons in different environments absorbed different frequencies of radio waves.

(c)(ii) Generally well answered but some candidates just said "gives an image of the body" which is already given in the question.

Question 2

(a)(i) More than half of the candidates obtained the molecular mass from the spectrum. About a third of the candidates identified C_4H_8 as the molecular formula but only a few candidates remembered to include the positive charge on the molecular ion and scored the second mark.

(a)(ii) About a third of the candidates identified the correct fragments. It was disappointing to see candidates suggesting fragments that did not match the masses of the peaks.

(b)(i) Most candidates obtained the mark for stretching and bending of the molecule. About a third of the candidates scored a second mark, usually for the change of dipole moment.

(b)(ii) Very well answered.

(b)(iii) Only a few candidates deduced the correct structural formula consistent with the data.

(c)(i) Less than half of the candidates knew the functions of the components of the double-beam IR spectrometer.

(c)(ii) Only a small proportion of candidates mentioned that the fingerprint region could be compared to spectral libraries to identify the compound. And very few candidates knew that the fingerprint region was due to bending (rather than stretching) as bending requires less energy. Some G2 forms commented that this question went beyond the syllabus. Section A.3.4 covers the analysis of IR spectra, and focuses on the identification of bonds and functional groups, hence the question is only borderline on the syllabus.

Question 3

This question was badly answered. The majority of candidates did not identify the mobile and stationary phases in paper and column chromatography, and did not identify them as partition and adsorption chromatography correctly.

Option B – Human Biochemistry

Question 4

(a)(i) About a fifth of the candidates knew the reason why amino acids are called 2-amino acids. Some candidates attributed the '2' to the position of the R group and others to the presence of two functional groups.

(a)(ii) About half of the candidates were able to identify arginine as the amino acid with the empirical formula $C_3H_7ON_2$.

(a)(iii) It was disappointing that about half of the candidates could not identify two amino acids with a hydrophobic side-chain.

(a)(iv) The markscheme includes both the zwitterion and the cation, as both species exist in equilibrium at pH 4.0 (with the zwitterion having a higher concentration). Very few candidates gave the structure of the cation of valine. Some gave the structure of the zwitterion, however, the majority of candidates copied the structure of valine from the data booklet, a structure that does not exist in solution.

(b) About a quarter of the candidates understood what was required by the question and gave the six tripeptide chains using three-letter abbreviations to represent the amino acids. Many candidates gave lots of detail for just one tripeptide.

(c) About three quarters of the candidates stated the function of collagen correctly. Some candidates thought it provided the body with energy and others seemed to confuse it with keratin stating that it builds hair and nails.

Question 5

(a) About half the candidates seemed familiar with the structures of fats and phospholipids, but only few gave the detailed answers expected by the markscheme. Some of the answers were far too general such as stating “both contain C, H and O” for the similarity in structure.

(b)(i) About a third of the candidates scored the mark by stating an accurate structural difference between vitamin D and cholesterol. Some answers were not specific enough about the numbers and types of rings.

(b)(ii) Only a few candidates were able to distinguish between the composition of HDL and LDL cholesterol, but the majority of candidates understood their effects on health well and gained the second mark. There was a comment on a G2 form that this question went beyond the syllabus, however, the question is covered in part B.4.2 (“outline the difference between HDL and LDL cholesterol”) and has also appeared in a past paper.

(b)(iii) Most candidates correctly gave calcium as one of the two elements.

Question 6

(a) Generally well-answered. Some candidates thought hormone F was testosterone.

(b)(i) Many candidates were good at identifying and naming functional groups. Some did not pay attention that the question required specific mention of functional groups and offered general comments that did not gain marks.

(b)(ii) There was good understanding shown by many candidates. Preventing ovulation was the most common point mentioned. Some incorrect answers included “releasing the FSH and LH hormones” or ”stopping the hormones from working” rather than preventing their release. It is important that students understand the process while learning it.

Option C – Chemistry in industry and technology

Question 7

(a)(i) This was a challenging question but some candidates managed to calculate the average oxidation state of iron as +8/3, and very few were able to deduce that both +2 and +3 oxidation states were present in the ore.

(a)(ii) It was disappointing that most candidates could not give a correct equation for the reduction, considering that both reactants and one product are already given in the question.

(a)(iii) Some candidates gave the higher reactivity of aluminium as the reason why it could not be extracted by the use of reducing agents.

(b) Some candidates understood the process of annealing and its effect on steel.

Question 8

(a) Well answered by many, although some candidates left the question blank. Candidates were more likely to align molecules in the same direction, but only some of them kept the arrangement of the molecules random and hence received the second mark.

(b)(i) The majority recognized that the alignment is due to the polarity, but only a few candidates attributed that to the CN bond.

(b)(ii) Quite well answered about the role of the pentyl group in the liquid-crystal properties of the compound.

(b)(iii) The better students were able to explain why a liquid-crystal device is unreliable at low temperature.

Question 9

(a) Manipulating the atoms using an atomic force microscope was not well known.

(b) With the help of the given diagram some candidates were able to estimate a reasonable length. The range of length accepted in the markscheme was generous.

Question 10

(a)(i) Some candidates identified two functional groups in the monomer.

(a)(ii) About half of the candidates described how the expanded form of the plastic could be manufactured.

(b) Most candidates were able to score one or two marks. “Good shock absorber” was a popular answer. Candidates should be encouraged to use precise terminology such as “has low density” instead of “light”.

Option D – Medicines and drugs

Question 11

(a)(i) Candidates generally knew the short-term effects of nicotine. A few candidates were giving very general answers, indicating that they did not study this option.

(a)(ii) Most of the candidates referred to lung cancer but surprisingly only a few candidates clarified that it is tar and other toxic substances that cause this.

(b)(i) For two marks, candidates were expected to explain that nitrogen uses its lone pair to accept a proton or act as a Lewis base (core concepts underlying the option material). Only a few candidates were able to score both marks. Many candidates scored one mark by identifying that nicotine contains amino groups that are basic. Some weaker candidates thought that 'basic' referred to the simplicity of the molecule.

(b)(ii) Rather than discussing nicotine's solubility in aqueous medium, most candidates discussed how nicotine entered the blood at the lungs (which was allowed in the markscheme).

(c)(i) A well answered question on tolerance.

(c)(ii) Most candidates mentioned nicotine patches and nicotine gum for nicotine replacement therapy. Some teachers commented in the G2 forms that this is not required explicitly in the programme guide, however, the candidates were very familiar with the concept and it was a very well answered question.

Question 12

(a) Most candidates stated that a virus contains DNA or RNA, however fewer candidates gained the second mark for the protein coat.

(b) More than half of the candidates showed a good understanding of how antiviral drugs work.

(c) Most candidates talked about the rapid mutation of viruses, however, only a few talked about viruses destroying T-helper cells as a difficulty associated with the development of drugs for the treatment of AIDS. A number of candidates discussed the high cost of such drugs that was irrelevant to the question. Some candidates confused AIDS with HIV.

Question 13

(a) Most candidates matched the analgesics to the properties successfully.

(b) Most candidates identified two similarities and one difference between diamorphine and morphine. For the difference, it was necessary to mention both the hydroxyl groups in morphine and the ester groups in diamorphine.

Option E – Environmental chemistry

Question 14

(a) The idea of decreasing oxygen concentration due to the aerobic decomposition of organic matter was not well understood and only a few candidates scored the marks on this question.

(b)(i) About half of the candidates identified the nitrate and phosphate ions as the ions added to the river due to the use of fertilizers.

(b)(ii) Only a few candidates related the pollutants to eutrophication gaining one mark, and very few understood how this resulted in a decrease of dissolved oxygen. Some candidates simply stated that an increase in algae decreased oxygen concentration in the water, which was not enough for the second mark.

(c) A few candidates recognized thermal pollution as the non-chemical reason for the decrease in oxygen concentration. The majority of candidates gave “biological” reasons such as the increase in the number of fish or the decomposition of dead algae. But they failed to note that these reasons are also “chemical” as oxygen is used up as a reactant in respiration and decomposition.

Question 15

(a)(i) Many candidates could calculate the wavelength correctly, while some made a power of ten error and some left the question blank. Several G2 forms expressed a concern that this question went beyond the syllabus and calculations are not required, even though the equation $c = f\lambda$ and the electromagnetic spectrum are given in the data booklet. It was pleasing to see more than half of the candidates solve the question correctly reflecting good application skills.

(a)(ii) Since the question is about global warming, most candidates identified the absorption to be in the infrared region.

(b) It was surprising that about three quarters of the candidates did not recognize the correct oxide of nitrogen that is a greenhouse gas, as its formula is stated in the programme guide. The most common incorrect answer was NO_2.

(c) It seems that the majority of candidates had not covered the relative contributions of greenhouse gases to global warming, although it is clearly required in the programme guide. Many candidates simply explained how a greenhouse gas contributes to global warming which did not answer the question. There were a few good answers though.

(d) This question required the candidate to select the consequences of global warming that would have a direct effect on food production. Some candidates did a better job than others. Some had simplistic answers that did not gain any marks.

Question 16

(a) The majority of candidates knew how to replace soil nutrients, but many forgot to mention harvesting or removal of crops.

(b) This question required application of core concepts. Less than half of the candidates mentioned hydrogen bonding. Most of the candidates selected the correct groups (OH and COOH). Some candidates incorrectly called OH as hydroxide and did not gain the mark as a result.

(c) Very few candidates stated a correct source of PCBs.

(d) The effects of pesticides and fertilizers on the soil were poorly understood and very few candidates scored any marks on this part-question.

Option F – Food chemistry

Question 17

(a) Some good answers for distinguishing between a food and a nutrient. Some candidates were not clear that a food is not everything that is ingested, and others did not mention that a nutrient is obtained from food.

(b)(i) Many candidates are still forgetting to specify that the difference is in carbon-carbon double bonds. This is important as both fats contain carbon-oxygen double bonds.

(b)(ii) Many good answers. Some candidates did not read the question carefully and answered in terms of adding hydrogen. Some mentioned *cis-trans* isomerism but did not specify that the *trans* fats have higher melting points.

(c) The answers to this straight-forward question about nutrients were often disappointing. It seems that many candidates did not know the types of nutrients the body needs to function. Some candidates gave specific nutrients rather than the types.

Question 18

(a) More than half of the candidates gave a good explanation of shelf life gaining the first mark. A common error was to state that the food spoils after the shelf life, which is not necessarily the case. Only a few candidates gained the second mark by stating that the best-before date was shorter than the shelf life. The majority of candidates thought the best-before date was the same as the shelf life. The second part of this question (best before date) is borderline on the syllabus.

(b) Some candidates gained a mark for naming both processes by which food becomes rancid. However, candidates rarely explained the reactions correctly.

(c)(i) Most candidates were not able to state an advantage of using vitamin C and β-carotene as antioxidants. Some had an idea, but often it was not detailed enough to satisfy the markscheme requirements.

(c)(ii) Some of the disadvantages of using synthetic antioxidants were too general. Many candidates understood the needs and difficulties in regulating their use internationally.

Question 19

(a) Many candidates stated “solution” or “homogeneous mixture” instead of “emulsion”. They did not seem to appreciate the difference.

(b)(i) There was a generally good understanding of the action of an emulsifier.

(b)(ii) Most candidates scored one mark for recognizing the polar and non-polar ends of the emulsifier. Some also clarified that the non-polar end attracted the oil and the polar end attracted the vinegar gaining the second mark.

Option G - Further organic chemistry

Question 20

(a) Less than half of the candidates gave the correct reagent and type of reaction, although it is a straight-forward question.

(b)(i) Some candidates drew the curly arrows and the carbocation intermediate correctly. However, many candidates are still performing poorly when it comes to reaction mechanisms. These need to be practiced.

(b)(ii) The majority of candidates did not offer an explanation – they simply stated Markovnikov's rule - and hence did not score any marks on this part-question.

(c) Some candidates gave the correct equation and reaction conditions.

(d) Not well answered by the majority of candidates. A common mistake was giving the mono-substituted iodoalkane.

Question 21

(a) It was disappointing that very few candidates used correct chemistry in explaining why phenol is more acidic than ethanol.

(b) Most candidates did not gain any marks on this part-question. Very few predicted that 4-nitrophenol was more acidic than phenol. Some said that the nitro group was electron-donating!

Question 22

(a) More than half of the candidates gave the correct reagent and condition for the formation of the Grignard reagent, which was pleasing.

(b) Less than half of the candidates identified the correct reagents.

Recommendations and guidance for the teaching of future candidates

The IB diploma programme is designed as a two-year programme. Standard level Chemistry requires 150 hours of instruction time, within which the options need to be allocated 15 teaching hours each (besides the time spent on related lab activities). This will of course change in May 2016 where only one option will need to be studied. Students who study an option on their own or rush through an option fail to reach the required depth in their answers.

- Refer to the Core material in the teaching of the options to clarify the chemical basis behind the knowledge. Related core concepts are often tested in the options.
- Encourage candidates to give specific details and avoid general answers.
- Encourage students to read the question carefully and identify what is required. There were cases in this paper where the students did not answer the question asked.
- Insist on thorough explanations throughout the course. This serves to deepen students'

understanding and give them a better chance of meeting all the required points in the markscheme.

- Advise candidates to use the correct terminology as far as possible.
- Pay attention to command terms. In particular, the command term compare requires mention of both items being compared for each point.
- Some candidates list more than one answer hoping the examiners will choose the correct answer. This is not encouraged because a correct response followed by an incorrect response nullifies the mark.