November 2015 subject reports

Chemistry

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 17	18 - 34	35 - 46	47 - 57	58 - 68	69 - 79	80 - 100

Higher level 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

This was the very 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 late stage in the internal assessment scheme's life cycle there was little significant change in the range and suitability of the work submitted. In addition to much fine work from schools where the students had been given appropriate opportunity to achieve, there were examples of weak practise with students being set prescriptive or 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 2016 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. Tasks about the rate of reaction of magnesium or calcium carbonate with hydrochloric acid or the heat of combustion of alcohols are too familiar from pre-IB work and also easily found on the internet. 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. What was disappointing though was the ordinary nature of many studies where the outcome of the research was self-evident from the outset and unchallenging. In particular this year saw a large number of students investigate the effect of time on amount of copper being deposited in electroplating.

Common areas of weakness in the Design criterion were:

- Students selecting independent variables that were not quantifiable.
- Students listing many irrelevant controlled variable such as air pressure in a titration experiment
- 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.
- Writing up their designed procedures in insufficient detail. For example, not describing how standard solutions were to be made up, which volumetric glassware was to be used, not stating how to make up a salt bridge in an electrochemical cell or forgetting to consider how to dry an electrode in an electroplating investigation. The new Individual Investigation where the students will have actually carried out and refined their procedures should see an improvement in this consideration.
- Ambiguity in language used 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, or confusing the term "dissolving" with "reacting". These are issues that will be considered as part of the new Communication criterion.

Data Collection and Processing

Achievement against this criterion was mixed and many 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. There were few challenging graphical processing appropriate to Higher Level such as determining an activation energy.

Other common areas of weakness in the DCP criterion were:

- Collecting very few data
- Neglecting relevant qualitative data or presenting data that are not relevant, e.g. mentioning the colour of solutions before titration but not changes at end point.
- Omitting relevant raw data that appear later in the processing.
- No reference to uncertainties or sensitivity of the instrument when working with data-loggers.
- Including extremely long tables of data that could have been easily replaced by a representative graph when working with data-loggers.
- Students bypassing the calculation phase completely and just making descriptive or graphical comparisons of raw data. For example in titrations some students simply compared titrant volumes, and in combustion calorimetry they just compared temperature increases.
- Not propagating uncertainties and not quoting final answers to an appropriate number of significant figures.
- 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 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 many candidates compared 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.

Recommendations for the teaching of future candidates

From 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.
- 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 candidate 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 expected outcomes 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 could be reported in past tense and should include sufficient detail for the reader to be able to reproduce the experiment in principle.

Although you might expect some more data and more reported detail in some investigations, there is also a 12 page length stipulation. This means that students have to be 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

General comments

2079 candidates submitted this paper, an 11% increase on November 2014.

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and *no* credit deducted for incorrect answers. It is therefore surprising that nearly all of the questions were left unanswered by at least one candidate.

The following are some statistical data based on 15 respondents (from 334 schools).

Comparison with last year's paper (14 comments as one was from a new school)

Much easier	A little easier	Of a similar standard	A little more difficult	Much more difficult
0	3	9	2	0

Suitability of question paper

	Too easy	Appropriate	Too difficult
Level of difficulty	0	15	0

	Very poor	Poor	Fair	Good	Very good	Excellent
Clarity of wording	0	0	1	5	7	2
Presentation of paper	0	0	1	4	7	3

There were very few comments on the paper as a whole; those who commented thought it to be good with some subtlety although some questions (unspecified) were said to be rather ambiguous. We welcome comments on ambiguity but it would be appreciated that, if they are made in the "general" comments, the question numbers are included at this stage.

There was concern from one respondent that the use of both COOH (Q1, 26 and 34) and CO_2H (Q27 and 35) in the same paper might confuse students. The statistics did not bear this out.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 94.86% to 42.74% (November 2014 for comparison, 90.51% to 37.59%). The discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.68 to 0.10 (November 2014, 0.78 to 0.21), the higher the value, the better the discrimination.

The following comments are made on selected individual questions:

Question 3

Concern was expressed about the style of the answers in this question. Answers have been expressed as fractions for many years. Nearly 69% gave the correct answer.

Question 7

This was thought to be more appropriate for the SL paper and it was indeed the easiest question on the paper in terms of correct answers (95%). It is, however, fair that there should be some questions, even on a higher level paper, that are accessible to the majority of students.

Question 8

This tested AS 13.2.7. One respondent commented that the syllabus does not make clear the specific connection between the concepts of variable oxidation number and catalytic action. This is accepted as fair comment although it would probably be included in the teaching. This seemed to be the case as nearly 70% gave the correct answer.

Question 9

Over 52% gave the correct answer but many thought the answers to be A (a bizarre concept) or C. Candidates are expected to know the structure of sodium chloride (AS 4.1.8).

Question 11

Whilst 72% correctly identified CH_2Cl_2 as the polar molecule, a significant proportion gave CO_2 as the answer. It is common to muddle polar bonds with the polarity of the molecule – or perhaps CO_2 was not thought to be linear.

Question 14

Whilst 52% gave the correct answer, a significant number did not realize that condensation (III) is exothermic.

Question 21

This was found to be the most difficult question on the paper with only 43% giving the correct answer. 35% gave C suggesting that a catalyst has no effect on the rate constant. Perhaps candidates had muddled rate constant, *k,* with the equilibrium constant, *K.*

Questions 22 and 23

It was encouraging to see that the two questions on equilibrium were amongst the best answered.

Question 24

Candidates needed to identify an atom with an incomplete octet. PCl_3 was a popular answer.

Question 26

Nearly 80% were able to match K_a with pK_a to achieve the correct response.

Question 27

Distractor C was a popular answer presumably because candidates were thinking about half neutralization.

Question 29

The graphs here were intended to be quite different as they clearly relate to two different types of titration. A and B should be immediately discounted as this graph refers to a strong acid – strong base titration. Nevertheless, 19% gave A and 17% B.

Question 30

The most common wrong answer was N suggesting an incomplete understanding of redox.

Question 32

This question generated the largest number of non-responses. Perhaps it was a question that candidates wanted to leave until other later and possibly easier questions had been attempted

– and then time ran out. In the event, it was a simple application of the "anti-clockwise" rule or "Lower Left Oxidizes Upper Right" rule giving the answer C as over 73% did.

Question 33

It is concerning that nearly 19% should think that sulfur dioxide would be produced.

Question 37

The most common error was to identify butanenitrile. Candidates need to remember that the carbon of the –CN group is counted in the chain.

Question 39

This tested AS 20.6.3. The most popular answer (46%) was A which **is** *cis*-1,2-dichlorocyclopropane rather than its geometric isomer. Candidates must ensure they read all the questions carefully, especially those that are later in the paper.

Question 40

The answer was correctly identified by 81% of candidates. There was some concern expressed about this question but the stem made it very fair – "best-fit line or best-fit curve". Candidates should first look for the general trend, in this case a curve, and then decide which curve is the best fit (C).

Recommendations and guidance for the teaching of future candidates

- In general, each question tests one specific aspect (assessment statement) of the syllabus.
- Paper one complements paper two so there is full coverage of the syllabus.
- Candidates should choose the best answer to each question.
- Candidates should be advised on how to approach a multiple-choice examination. No marks are deducted for incorrect answers so all questions should be answered.
- Use many sources of reference when preparing students. Even the best textbooks contain errors and students should be advised to read them critically.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 14	15 - 29	30 - 39	40 - 50	51 - 60	61 - 71	72 - 90

General comments

This paper identified a very broad range of candidate capabilities. Some candidates struggled with even the most basic concepts and factual knowledge while others demonstrated an excellent depth of understanding of the core and AHL material. In general, candidates appeared very well prepared. There were some schools where the candidates seemed unfamiliar with some of the subject material and left many areas of the question paper blank. Answers lacked precision in terms of the wording used and explanations were often vague and lacked chemical concepts and key points.

The 18 G2 forms that were returned conveyed teachers' impressions of this paper. The comments received on the G2 forms are considered very important feedback by the IBO and are reviewed thoroughly during the grade award meeting.

In comparison with last year's paper 83% of respondents felt that it was of a similar standard and 6% considered it a little more difficult while 11% felt that it was not applicable. 95% of respondents thought the level of difficulty was appropriate while 5% thought that it was too difficult. Clarity of wording was considered excellent by 17%, very good by 45%, good by 33% and satisfactory by 5%. The presentation of the paper was considered excellent by 22%, very good by 50%, good by 22% and satisfactory by 5% of the respondents.

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

The examination revealed the following weaknesses in candidates' knowledge and understanding.

- Determination of activation energy from the graphical data
- Electronic configuration of Cu and Cu^{+} ion
- Condensation polymerization
- Bond enthalpy calculations
- Application of Hess's law in an unfamiliar situation
- Identifying hybridization in unfamiliar species
- Calculation of equilibrium concentration of each component
- Reaction mechanism from rate expression
- Choosing appropriate acid-base indicator
- Writing balanced equations for the reactions of oxides with water

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

The areas, which seemed well understood by candidates were:

- Mole calculations
- Calculation of oxidation numbers
- Combustion reaction equation
- Electronegativity
- Thermochemical calculations

- Sigma and pi bonding
- Lewis diagrams and their shapes
- Predicting the relative boiling points of organic compounds
- Mass spectrometer
- Equilibrium position shift and equilibrium constant expression
- Identifying order from reaction rate data and rate expression
- Using data provided to produce a reactivity series
- Brønsted-Lowry theory
- Drawing isomers
- Organic reaction mechanism (substitution and elimination)
- Free radical mechanism

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

Section A

Question 1

This was a data based question based on quantitative and redox chemistry and proved difficult for some candidates. Majority of candidates were able to gain almost full marks in parts (a) and (b) by correctly identifying the oxidation states of the species and the oxidising and reducing agents. Calculation of uncertainty in part (ci) was relatively well done by many candidates. Identifying the type of error in (cii) posed some challenge to the candidates with only about half correctly identifying "systematic" and very few candidates could suggest a valid method to improve the colour interference. Most candidates handled the various calculations in the other parts of the question quite well with some candidates missing 1:3 mole ratio in part (d). Determination of activation energy in part (f), proved difficult for majority of the candidates and some candidates missed rounding it off to 3 significant digits.

Question 2

Many candidates had difficulty writing the correct electronic configuration of Cu and Cu^{+} ion. In part (b) the nature of the bonding in complex ions was well understood, though some forgot to specify the Lewis acid/base character of both species involved. Part (c) was generally well answered though a few candidates still seem to think that transition metal compounds owe their colour to their emission spectra.

Question 3

Majority of the candidates achieved full marks on part (a). Only few candidates could gain full marks in part (b) by calculating the bond enthalpy value. Many candidates missed C-C bond while others did not realise that there are 8 O-H and 6 C=O bonds. Few candidates missed that bond breaking is endothermic and bond making is exothermic. It was distressing to see a positive value of bond enthalpy for a combustion reaction, which was calculated by some candidates.

Question 4

Majority of candidates left most of this question blank, whilst others gave the structure of a polymer rather than the monomer in part (a). Part (b) was fairly well done with some problems encountered in the structural feature required in the monomers. In part (c), almost everybody got water as the other product of the reaction but few candidates missed the linkage formed in the polymer.

Question 5

The candidates almost always seemed to have the correct concepts for part (a) and a good understanding of electronegativity but on occasions failed to express these with the clarity and precision required. The periodic trends in part (b) were less well understood, with some candidates discussing factors related to ionisation energy or electronegativity rather than melting point. Part (c) revealed a great deal of confused thinking with regard to shielding and the way in which the attraction of the nucleus for the valence electrons depended on the proton: electron ratio.

Section B

Question 6

This was the second most popular question answered in Section B.

In part (a), majority of candidates failed to realise that a 1:3 ratio was required to combine the equations given and hence the consequences of this for the spontaneity of reaction and negative value of delta G. The first two parts of (b) were generally well answered, but in part (iii) many candidates did not read the question carefully and gave the same answer as to part (i) while others did not convert temperature to kelvin or changing units of entropy value. Almost all candidates in part (c) correctly identified the hybridisation of NF_4^+, but in N_2H_2 and N_2H_4 it was most frequently identified as sp and sp^2 respectively. Most candidates could explain the nature of sigma and pi bonds but very few made use of the diagrams. The Lewis diagrams required in part (c) were correctly drawn but sometimes there were missing lone pairs around fluorine. In part (d) the order of boiling point was usually correct, but it was unusual for candidates to answer in enough detail to gain full marks for the explanation; not clearly linking boiling point to the strength of intermolecular forces. Most of the candidates knew the correct order of stages in the mass spectrometer and wrote accurately what happens in each one.

Question 7

This was the most popular question answered in Section B.

Most of the candidates could correctly predict the equilibrium shift but did not read the question carefully about the effect on hydrogen. The effect of a catalyst on the equilibrium was well understood, with many candidates gaining full marks, as was the case for parts (iii) and (iv). Many candidates had difficulty in calculating the equilibrium concentrations of each component present in the mixture. In part (c), the data was analysed correctly to determine the order of reaction, the rate equation and the rate constant. Correctly determining the units of the rate constant proved difficult whereas writing a simple mechanism provided significantly greater challenge. Most candidates could determine the reactivity series, though many failed to write it in the required order. Majority of the candidates could not correctly identify the strongest oxidising agent in part (dii). The half equations for the anode reaction in the electrolysis of brine were generally well known by some whereas several candidates had no clue.

Question 8

This was the least popular question answered in Section B.

Few candidates who attempted this question answered most sections of part (a) correctly except identifying a suitable acid-base indicator, where the whole of the range fitted within the rapid pH change of both curves. An encouraging number of candidates could correctly handle the calculation of K_b and of the pH required in part (b), where the definition of a buffer solution was very well known. The Brønsted acid-base theory required for part (c) was done well. The differences between weak and strong acids in part (d) and the ratio of $[H^+]$ concentration in two acidic solutions of pH 1 and 5 were well understood by several candidates. In part (e), many candidates lost marks by incorrectly identifying SiO_2 as amphoteric and completely ignoring that Ar does not form any oxide. In part (eii), few candidates could correctly write an equation for the reaction of sodium oxide and sulfur trioxide with water.

Question 9

This was also a very popular question answered in Section B.

Several candidates who attempted this question had very good knowledge of organic chemistry and subsequently achieved full marks in part (a). It was pleasing to see that almost all candidates could draw the correct four isomers of C_4H_9Br with occasional error in identification of one primary isomer. It was impressive to observe that majority of the candidates could draw organic mechanisms accurately including curly arrows and scored well for both parts (b) and (c). Several candidates surprisingly missed that the formation of a nitrile lengthened the hydrocarbon chain and being able to write a balanced equation for the reduction of the nitrile, often failing to realise that two moles of hydrogen are required. Most candidates managed to score full marks for the final part on the free radical chlorination of ethane.

Recommendations and guidance for the teaching of future candidates

- Teachers are strongly advised to refer to past examination papers and the corresponding mark schemes to assist candidates with examination preparation
- Teachers should ensure that candidates read the questions carefully to ensure they answer appropriately and to avoid missing parts of the question. Candidates must know the meaning of the different command terms that appear in the assessment statements and in the examination papers.
- Candidates should use the number of lines and the marks as a guide as to how much to write. It should be possible to write the answers in the boxes provided and if the answer does not fit in the box, indicate that the answer is continued on a separate sheet. However, the use of continuation sheet is not encouraged and candidates should

use the space provided when possible.

- Candidates need to practice on the data-response question, which involves different facets including experimental work, uncertainty measurements, hypothesis, Aim 8 and linking of different topics across the curriculum.
- The experimental nature of chemistry should be brought to the forefront of the teaching programme including key experimental skills. There should be greater emphasis on core chemical concepts and definitions covered in the assessment statements for each topic.
- Candidates should set out calculations logically and legibly and "keep going" with calculations because error carried forward in the later part is usually awarded full marks if the method is correct. All steps in the calculation should be shown and attention must be paid to significant digits and units.
- Candidates must be instructed to use the latest chemistry Data Booklet during the chemistry course so that they are familiar with what the data booklet includes.
- Some candidates are writing more than one answer hoping the examiners will pick up the correct answer. This is not encouraged because a correct response followed by an incorrect response nullifies the mark of that question. Candidates should avoid writing rambling statements, hoping that they will pick up marks somewhere in their answer.
- Candidates should write legibly so examiners can read responses.

Higher level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 - 7	8 - 15	16 - 20	21 - 26	27 - 31	32 - 37	38 - 50

General comments

Overall the paper appeared to be slightly easier than in November 2015. Based on the G2 comments most teachers found the paper to be of an appropriate standard (100%) in terms of level of difficulty and the general feedback was that the paper was fair and reasonably balanced. There were a number of positive comments from teachers. Option A was highlighted as being pitched at a good level overall for HL candidates. The overall wording of the questions was in general praised. One teacher did comment on poor coverage of the syllabus. This was discussed during Grade Award and the Chief Examiner pointed out that every effort is made to cover the entire syllabus over the duration of the entire lifespan of the programme. It is impossible to assess every single topic in any given session, especially with the broad range of topics covered on Paper 3. Another teacher stated that it is more difficult to comprehend the 3D representations of structures and preferred the use of 2D representations in the November 2015 session. It should be emphasized that candidates must be comfortable with both types of representations as chemists. Chemical structures are three-dimensional in nature and both types of representations have their platforms in the subject domain of chemistry.

The performance may have been marginally better above the mid-range but this might be associated with the fact that some of the popular options had a number of predictable questions, in particular Option D. Overall performance appears on balance on this component to be similar to November 2014. The standard of the paper was broadly similar to November 2014 with some of the topics very similar, although approached from a different angle, which caught out some candidates, perhaps even at the upper end. In order to be successful candidates were required occasionally to “think outside the box” and use reverse arguments to the ones previously required e.g. the sunscreen question, Q4 on Option A.

Reaction based on the few G2 comments (only 18 responses) received seems highly favourable, which points to the fact that both candidates and teachers appeared to be quite satisfied with this paper. There appeared to be no question which posed a major issue for teachers which is encouraging and there did not appear to be any real off-syllabus concerns with any of the questions, though there was one isolated minor comment on Q3 (b), which is addressed later on in this report.

For many candidates misreading of some questions did appear to be an issue on this particular paper and greater understanding of command terms needs to be re-emphasized by teachers in the classroom setting. In addition, candidates need to be prepared for the integration of core chemical principles into the topics covered in the options. This will be a feature greatly enhanced in the new syllabus. This aspect is important as the core is often the platform for the understanding of topics in the options. Other transferable scientific skills such as interpretation of graphical representations needs to be enhanced. 26 (b) was exceptionally poorly done, a real surprise at HL. This type of skill can be an outcome from exposing candidates to a rich laboratory experimental programme.

Many candidates seemed well prepared and attempted every part of their chosen questions. The most popular options were A and D. Options B and G were also popular. Many of the stronger candidates opted for the combinations Options A and G or Options A and D respectively. Performance on each of the options is outlined in detail below.

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

- Practical details of the Atomic Absorption (AA) spectrophotometer.
- Outline of how the emission spectrum of a sample of gaseous element is produced.
- Abuse of anabolic steroids.
- Tertiary and quaternary structure of an enzyme.
- Comparison between rechargeable batteries and fuel cells.
- Bonding in carbon nanotubes and graphite.
- Inherent difference between a monomer and a polymer.
- Environmental implications of the use of polyethylene terephthalate (PET).
- Difference between Therapeutic Window and Therapeutic Index.
- Identification of chiral centres.

- Infrared (IR) intoximeter.
- Peroxyacylnitrates (PANs).
- Variation of Biochemical Oxygen Demand (BOD) / dissolved oxygen in water courses.
- RS notation.
- Directing effects of substituents.

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

- Interpretation of Infrared (IR) spectroscopy.
- Understanding of Gas-Liquid Chromatography (GLC).
- Difference between absorption and emission spectra.
- Enzymes.
- Functional groups in general.
- Double helical structure of DNA and application of DNA profiling.
- Basic oxygen converter.
- Understanding of tolerance.
- Difference in functionality between strong and mild analgesics.
- Antiviral drugs.
- Effects of the overuse of antibiotics.
- Explanation of the occurrence of soil salinization.
- Nutrients.
- Definition of a dispersed system.
- Organic reaction mechanisms.
- Grignard chemistry.

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

Option A – Modern analytical chemistry

This option was popular with several of the better candidates and high quality responses were often conveyed. Overall the option appeared to be accessible with a good cross-section of easy to more challenging questions, a few which served as discriminatory questions at the upper end. The biggest challenge for candidates was the wording in some of the questions such as 1 (c) and 3 (b) in particular.

Question 1

Part (a) highlighted the importance of reading the question carefully. It asked for a description of how information from an IR spectrum can be used to identify the bonds in a molecule. However, a significant number of candidates simply gave a description of bond stretching, bond bending and change in the dipole moment. Candidates who read the question carefully scored at least one mark in part (a) knowing that each type of bond absorbs a specific wavenumber of IR radiation. In (b), compound A was usually identified by the stronger candidates, though a number of candidates chose compound B. Most were able to deduce that the C=O bond corresponded to the 1760 cm^{-1} absorption in the IR spectrum. Surprisingly although many recognized that an OH bond was present often this was not correlated with the broad OH peak of a carboxylic acid in the range 2500-3300 cm^{-1}. In (c) the wording appeared to throw some candidates. Common mistakes included incorrect number of signals (4 was often cited for compounds A and B) or failure to include the area ratios. 5 was frequently quoted incorrectly for the number of signals for compound C, instead of 6.

Question 2

This question focused on AA spectroscopy. Nearly every candidate was able to state one application of AA spectroscopy, with most giving specific examples of metal ions in water samples. The uses of the fuel and the monochromatic detector in (b) was more difficult. One G2 comment queried what would be accepted on the markscheme for the fuel and monochromatic detector i.e. would answers such as “the flame results in atomization of metal ions in the sample” (for the fuel) and “measurement of absorbance” (for the monochromatic detector) be accepted? This indeed was the case and a number of answers were allowed according to the markscheme. Few gave a correct answer for the use of a monochromatic detector which converts the intensity of light absorbed into an electric signal. For the fuel the most common error was candidates stating that a fuel vaporizes the sample – this alone did not score.

Question 3

Part (a) of this question was very well answered and most candidates scored full marks. The idea of electron movement was well understood in reference to absorption and emission spectra, though some did not refer to the absorption of a photon or its release. Another error was stating “atoms” for “electrons”. Part (b) was very poorly answered and the wording of the question proved problematic for many candidates. One G2 comment referred to this point stating that the question might prove challenging for most candidates as an explanation as to how the emission spectrum of a sample of gaseous element is produced is not clearly listed under the learning objective in the guide. This was discussed at Grade Award and it was concluded that although this point may have some validity, the question is certainly open to interpretation of the syllabus per se. A few of the top-tier candidates did gain full marks. Typically however the same answer as in part (a) was repeated. Only the better candidates gave correct answers in terms of the source (e.g. application of high voltage under reduced pressure) and the fact that the sample emits a photon which then is passed through a diffraction grating. This part proved to be a highly discriminatory question. The word “how” was essentially passed over or simply not understood!

Question 4

This question focused on ultraviolet (UV) radiation. In part (a), the structural feature of molecules that absorb high energy UV radiation was well answered, with double bonds being the most common answer given. In (b), the correct answer of octyl salicylate was scored by approximately 50% of candidates. Most associated the better protection in the context of UV to conjugation i.e. the fact that in in octyl salicylate there is less conjugation and provides better protection because there is absorption of the more harmful radiation at shorter wavelength.

Question 5

Understanding of gas-liquid chromatography (GLC) was overall very good. In (a) most candidates scored full marks for correctly identifying suitable materials for the stationary and mobile phases. In addition in (b) some excellent explanations were provided on how the substances in the blood sample are separated by GLC. Part (c) asked for an outline of how the concentration of alcohol is obtained from the GLC processing unit and the majority stated that the area under the alcohol peak is proportional to its concentration. The most common error was “height of peak” instead of “area under the peak”. The final part of Question 5 involved candidates having to suggest why GLC might not be suitable for determining the concentration of sugar in the blood. A significant majority of candidates stated that the sugar would decompose at the high temperature used. A small minority omitted to state the high temperature condition of the oven in GLC and therefore scored no marks.

Option B – Human biochemistry

This was also a popular option and candidates conveyed a good broad knowledge of biochemical concepts. In several of the questions, performance was strong, though at HL it was very surprising that so many candidates gave incorrect bond connectivities for β-glucose.

Question 6

In (a) (i), it was surprising that a high percentage of candidates gave an incorrect structure for β-glucose. Hydroxyl groups were often misplaced, sometimes missing entirely and it was highly noticeable in this session the sheer number of candidates who were sloppy in adhering to correct bond connectivities as stated above. This point should be emphasized by teachers to future candidates. In (a) (ii), many did not identify the carbon atom. (b) featured on a G2 comment where one teacher wondered whether or not just writing “ether” or “glycoside” would score. This was not sufficient. In (b), although most scored the mark, some vague answers were seen such as “peptide link”, or “1,4 linkage”, instead of giving the complete answer of “1,4-glycosidic”.

Question 7

In (a), most candidates stated that vitamin C has more hydroxyl groups. However few followed this up by referring to the formation of hydrogen bonding with water. Some forgot to mention water and more thought that OH bonds themselves are hydrogen bonds! This type of misunderstanding really should not be evident on HL scripts. Part (b) was very well done and typically all three marks were scored.

Question 8

Part (a) was about enzymes and in general (i) was reasonably well done. Most knew about the induced fit model but fewer stated that the active site depends on the tertiary/quaternary enzyme structure. In (ii), denaturing was usually cited and the better candidates stated that the tertiary structure becomes disrupted. In (b), most gave correct structures. Another G2 comment queried whether the protonated main amine or side chain amine would be accepted here. A number of possible structures were accepted in the markscheme.

Question 9

All of this question was very well answered and a high percentage of candidates scored all three marks. One G2 comment wondered if for (b) an answer such as "cytochromes: transport electrons and hemoglobin: transports oxygen" would score the two allocated marks. This indeed was the case, as the command term "Outline" is Objective 2 and from P.11 of the guide is indicative of giving a brief account or summary. This is different to the Objective 2 command term, "Describe", where a detailed account is required. Careful analysis of command terms is critical in assisting candidates trying to decipher the length of responses required for particular questions.

Question 10

Like elsewhere on the paper knowledge of functional groups was well known compared to previous sessions. Future candidates however should understand the intrinsic difference between class and functional group. This aspect was not penalized up to November 2015 in the current syllabus but is a marker for future candidates to consider with the launch of the new curriculum. In (b), the medical use of anabolic steroids was well known but PEDs were not as well articulated as an example of an abuse.

Question 11

The key features of the double helical structure of DNA were generally well conveyed by candidates. Some simply mentioned "bases" instead of "nitrogeneous bases". Equally, virtually all candidates were able to state one application of DNA profiling.

Option C – Chemistry in industry and technology

This was the least popular option and overall performance was mediocre and certainly not as strong as on some of the other options. The questions on Option C during this session although firmly within the realms of the syllabus may have proved more challenging and perhaps have not been asked as frequently in the past. This made the Option more challenging judging on overall candidate performance.

Question 12

In (a) most candidates scored both marks stating cadmium as the substance used as the anode and usually potassium hydroxide or sodium hydroxide as the substance used as the electrolyte. Some ignored the wording of the question (which asked for named substances) and instead gave chemical formulas such as Cd and NaOH. The half-equations for the chemical reactions during recharging were easily identified and most scored the assigned one mark. In (c) candidates had to compare rechargeable batteries and fuel cells. Although the mark scheme was quite extensive in terms of the range of possible answers accepted very few managed to score all three marks. Most salvaged one mark for getting a difference between the two but few scored the mark allocated to similarities (e.g. "both convert chemical energy to electrical energy"). The command term "Compare" is quite explicit on P.12 of the current guide i.e. Give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout. If candidates have not adequately prepared for command terms from the guide, there is a danger that some easy marks can be lost in questions like this.

Question 13

This question focused on nanotechnology. Part (a) was poorly answered and a large tranche of candidates just gave descriptions of carbon nanotubes and graphite instead of outlining how the bonding causes carbon nanotubes to be much stronger than graphite. (b), asked for suggestions of two health concerns that arise due to the small size of the substances used in nanotechnology. This was answered somewhat better.

Question 14

In part (a), candidates were typically able to formulate at least one of two equations for reactions that occur in the basic oxygen converter, although there was a large choice of equations from which to choose. In addition most candidates scored at least one mark and often the two marks allocated for distinguishing between low-carbon and high-carbon steels.

Question 15

In (a), candidates were required to explain thermotropic behaviour in terms of the arrangement of molecules. Many scored at least one mark here and the better candidates scored full marks. In (b), the roles of the biphenyl group (making the molecule rod-shaped) and the nitrile group (making the molecule polar to allow alignment) were usually correctly explained. However the role of the long alkyl group (i.e. to ensure molecules cannot pack too closely to maintain the liquid crystal phase) was less well known.

Question 16

In (a), the majority of candidates were able to name the addition and condensation polymers. However, the difference between a monomer and a polymer was clearly not understood by a high percentage of HL candidates – several gave brackets and extension bonds for the monomer for example. In (b), increased electrical conductivity was generally cited. In part (c), candidates were asked to discuss the environmental implications of the use of PET. The non-biodegradable nature of PET was well understood but few gave other more detailed points such as the fact that subsequent combustion of PET can result in degradation products which impact the environment.

Option D – Medicines and drugs

This was the most popular option on the entire paper and performance was often strong here.

Question 17

Candidates did not understand the difference between Therapeutic Window and Therapeutic Index. This should be noted for the new syllabus. Therapeutic Index in humans is the toxic dose of a drug for 50% of the population (TD_{50}) divided by the minimum effective dose for 50% of the population (ED_{50}). In contrast Therapeutic Window, which is what the question explicitly referred to, is the range of dosages between the minimum amounts of the drug that produce the desired effect and a medically unacceptable adverse effect. Many candidates gave a definition of Therapeutic Index instead of Therapeutic Window. Even candidates that gave a definition of Therapeutic Index, often gave incorrect ratios for humans, and instead a common mistake was to give the lethal dose of a drug for 50% of the population (LD_{50}) divided by the minimum effective dose for 50% of the population (ED_{50}). This ratio refers to animal studies, and not human studies, which is what the stem of the question alluded to. Tolerance was better understood though some candidates mixed up tolerance with addiction and sometimes dependence. It should be noted that there is now consensus amongst the American Academy of Pain Medicine, the American Pain Society and the American Society of Addiction Medicine for the formal definitions of tolerance, physical dependence and addiction. The distinctions between the three terms is very clear medically and these three bodies recognize the following definitions and recommend their use. Tolerance, which is what the question demanded is a state of adaptation in which exposure to a drug induces changes that result in a diminution of one or more of the drug's effects over time. Addiction is a primary, chronic, neurobiologic disease, with genetic, psychosocial, and environmental factors influencing its development and manifestations. It is characterized by behaviors that include one or more of the following: impaired control over drug use, compulsive use, continued use despite harm, and craving. In contrast, physical dependence is a state of adaptation that is manifested by a drug class specific withdrawal syndrome that can be produced by abrupt cessation, rapid dose reduction, decreasing blood level of the drug, and/or administration of an antagonist. The better candidates had a clear understanding of tolerance stating that "a patient would need to take larger amounts of a drug to achieve the same original effect", and thereby scored M2.

Question 18

Most candidates knew that "esterification" was the type of reaction that takes place when morphine is converted to diamorphine. (b) centred on the difference between strong analgesics and mild analgesics, a question that has been seen on a myriad of past examination papers on this option. As such candidates were well prepared for the type of answer required and most scored full marks. An odd few candidates stated incorrectly that prostaglandin is an enzyme.

Question 19

In (a) (i) candidates were required to identify the two chiral carbons in pseudoephedrine. This was surprisingly difficult and many only identified one chrial centre. A significant number incorrectly stated that some of the carbon atoms in the benzene ring were chiral. In (ii), the concept of enantiomers having different physiological effects on the body was well understood and most cited thalidomide as their chosen example. Some candidates did not understand the difference between optical isomers and *cis-trans* isomers. Cisplatin and transplatin were occasionally mentioned which is incorrect as these two square planar isomers are cis-trans in nature and are not enantiomers. The idea of a chiral auxiliary was better described than in some previous sessions though there still were a number of candidates who incorrectly stated that chiral auxiliaries themselves are achiral, instead of stating that they are in fact optically active. In (c) (i) many candidates were able to state two physiological effects of stimulants, though many insisted on citing multiple examples, of which many were deemed incorrect on close examination. Candidates should note that in such cases the list principle applies in marking and incorrect answers can invalidate correct answers if more than the required number is stated. In (ii), the most common mistake was candidates stating that a sympathomimetic drug mimics the sympathetic nervous system instead of stating that it stimulates it. In (c) (iii) candidates were asked to explain why the drug in question is administered as the hydrochloride salt of pseudoephedrine. Again here, few scored full marks. Most knew that there is an increase in solubility in water (though some forgot to mention the medium, thereby scoring no marks), but only the better candidates stated that the drug molecule becomes more polar or ionic. As has been mentioned umpteen times in previous subject reports it is imperative that chemical principles lie at the heart of any discussions on medicines and drugs.

Option 20

Describing the ways antiviral drugs function has been frequently asked in the past and candidates who had done their homework using previous markschemes would have had no difficulty in scoring full marks here. The most common omission was not referring to the cell, in answers such as “inhibiting the virus entry to the cell” and “prevents the virus from using the cell to replicate”. Two effects on the overuse of antibiotics were well known – most mentioned the fact that this may lead to resistance.

Question 21

In (a) the orange to green colour change was generally given though a minority gave the colour change the other way round! Too many candidates simply gave either “oxidation” or “reduction” alone, seemingly unaware that when one process has occurred the other must necessarily have also taken place and only the better candidates stated that the type of reaction is in fact “redox”. In (b), although a greater proportion of candidates cited IR as their chosen technique, a high percentage based their answer incorrectly on IR absorption of the OH bond (which is also present in water vapour!) and not the absorption associated with the CH bond. Even candidates that correctly scored M1 often did not answer the question fully and failed to state that there needs to be a comparison of the absorption to a standard/reference. Although fewer candidates opted for the fuel cell of those that did, many scored full marks.

Question 22

Functional groups were well known this session and quite a large number of candidates were able to state the names of two functional groups present in LSD and psilocybin. Once more, some candidates failed to read the question and gave formulas instead of names. The most common errors evident were answers such as “benzene” (instead of “benzene ring”) and “phenyl”. It should be emphasized that the phenyl group is in fact C_6H_5- and although there is a benzene ring present in the two compounds, the ring in each case has more than one point of attachment so describing it as a phenyl group is strictly incorrect. Another error evident was that a large number of candidates stated that there is a tertiary amino group present in both structures. This, although not penalized, is also incorrect as the classification of the amino group common to both drugs is actually secondary.

Option E – Environmental chemistry

Not as popular an option as in previous sessions and one which had some definite challenging parts. The chemistry underpinning PANs and BOD was found to be difficult for candidates and few seemed prepared for both of these topics.

Question 23

Some of the weaker candidates struggled writing the reactants and products of an equation for a reaction occurring in the catalytic converter in (a) (i). Correct balancing proved problematic. (ii) was well answered and most referred to “provision of a large surface area”. Part (b) proved to be a good discriminating question for this option. (b) (i) was well articulated. In (ii), although many stated that nitrogen and oxygen react to produce NO_x and that as the air to fuel ratio increases the amount of air in the engine in turn increases, few stated that at very large air to fuel ratios the temperature in the engine actually drops. The high temperature condition for the reaction between nitrogen and oxygen also was frequently omitted. The formation of PANs in photochemical smog was dismally understood. Some candidates made a stab at writing equations involving radical species but typically these were completely incorrect. This was one of the most poorly answered questions on the entire paper.

Question 24

Soil salinization was well explained. In part (b), many candidates scored at least one mark and more often two marks describing the chemical functions of soil organic matter. Few scored all three marks.

Question 25

The equations for the stepwise mechanism of ozone depletion catalyzed by dichlorodifluoromethane were reasonably well known. The most common errors involved inconsistent radical representations and omission of UV in the first step. In (b), although candidates had some idea about the advantage of using hydrofluorocarbons (HFCs) as alternatives to chlorofluorocarbons (CFCs), incomplete answers were common. Many did not mention the fact that HFCs do not deplete ozone as they contain C-Cl bonds. Simply stating that HFCs do not contain chlorine alone was insufficient to score the mark. The disadvantage of contributing to global warming was rarely seen.

Question 26

The final question on Option E was very poorly answered. In (a) too many candidates failed to read the question which required candidates to give two examples of oxygen-demanding wastes. In (b), most did not answer the question posed and simply outlined the increasing and decreasing nature of the two representations on the graph without giving a proper outline of the reasons for the variation in BOD and the concentration of dissolved oxygen which is what the question demanded.

Option F – Food chemistry

This was one of the least popular choices of options this session but candidate performance was reasonably good.

Question 27

Most candidates were able to identify the unsaturated *trans* fatty acid, elaidic acid. A small minority incorrectly suggested oleic acid. Surprisingly few scored full marks in explaining why elaidic acid has a higher melting point than oleic acid in (b).

Question 28

This question was well answered. The most common error was citing “vitamins” for the nutrient essential for healthy bones, instead of the more explicit response, “vitamin D”.

Question 29

This question focused on shelf life. (a) (i) was answered correctly by essentially all candidates. (ii) also was well answered though some candidates gave the hydrogen radical instead of the R radical in the second equation for the propagation step. In (b), approximately 60% of candidates stated correctly that a lower salt content leads to higher water content. Less referred to the idea that more microbial spoilage can occur.

Question 30

In (a) the most common mistake involved stating “carotenes” instead of “carotenoids”. Although Lycopene is a carotene, Zeaxanthin is not, as a carotene is a terpenoid hydrocarbon. The presence of the two hydroxyl groups in Zeaxanthin invalidates this pigment being classified as a carotene. In (b) (i), few mentioned visible light. In (ii), many candidates stated that bromine reacts with double bonds but virtually no candidate mentioned the fact that the absorbed energy shifts to violet from green, as was required to score M2.

Question 31

The textbook definition of a dispersed system was well known. In (b) a large number of candidates stated that the hydrophobic end attracts oils and the hydrophilic end of Lecithin attracts water, but few stated that lecithin acts as an interface between the two phases in the dispersed system. Some simply mentioned the hydrophobic and hydrophilic ends of Lecithin without linking these respective ends to the associated media. In (c), although most candidates scored at least one mark, oftentimes some of the answers were partial in nature e.g. not mentioning the fact that chelating agents actually form stable complexes with metal ions or the fact that free-radical quenchers form less reactive radicals.

Question 32

Identification of chiral centres again proved to be problematic for many candidates. The six-membered ring system certainly appeared to throw candidates. RS notation was poorly understood and explained by the weaker candidates. Errors included stating “mass number” instead of “atomic number” and mixing up the (+)/(-) and RS systems completely.

Option G – Further organic chemistry

Option G was attempted by a large number of candidates. Many of the stronger candidates opted for this option and their performance overall was of a high standard.

Question 33

The mechanism for the reaction of benzaldehyde with hydrogen cyanide was generally well done, though some common errors were seen such as incorrect directions for curly arrows (e.g. going to CN^- instead of originating from CN^-), incorrect originating species for curly arrows (e.g. originating on nitrogen instead of carbon on CN^-) and failure to have the curly arrow going from the lone pair on O of the intermediate anion to H^+. Understanding of Grignard chemistry was excellent. In (c), most were able to identify the type of reaction as “elimination” and quote “concentrated phosphoric acid” as the preferred reagent. Concentrated sulfuric acid was accepted though concentrated phosphoric acid is the preferred reagent for the dehydration of an alcohol as concentrated sulfuric acid is also a strong oxidizing agent and can produce some unintended side-products. For example it can oxidize some of the alcohol to carbon dioxide and concomitantly sulfuric acid itself can be reduced to sulfur dioxide. Fewer candidates gave a correct condition (e.g. 180 ^oC). Pressure conditions was the most common error. Many candidates did not understand the difference between “reagent” and “condition”.

Question 34

Nearly all candidates correctly deduced the major product in (a), $(CH_3)_2CBrCH_2CH_3$, but in (b), a number struggled to score all three marking points. A common error was comparing a secondary with a primary carbocation instead of comparing a tertiary carbocation (more stable) with a secondary carbocation.

Question 35

This question was a good discriminating question and only the top candidates scored both marks. The lone pair on chlorine was rarely mentioned and few referred to the electron-deficient carbon attached to Cl for the Cl atom attached to the $–C_2H_4$- group.

Question 36

This question was very well answered overall. The most common error seen was stating that a ketone forms i.e. $CH_3CH_2COCH_3$ instead of the ester, $CH_3CH_2COOCH_3$, for **A**/**B**.

Question 37

In (a) a high percentage of candidates were able to write an equation for the formation of the NO_2^+ species from concentrated nitric and sulfuric acids. Some forgot to balance the equation especially when hydronium was given as one of the products, where two of the species have a stoichiometry coefficient equal to 2 (not 1). The mechanism for the reaction of benzene with the nitronium species was very well done. In (c), most knew that the nitro group is ring deactivating. Part (d) proved to be inaccessible for a large number of candidates though one or two top tier candidates did score both marks. Again this proved to be an excellent discriminating question. Many candidates did not mention the stabilization of the carbocation by the inductive effect of the methyl group.

Recommendations and guidance for the teaching of future candidates

- Legible handwriting is essential – there was certainly a noticeable number of scripts this session where examiners struggled greatly in trying to decipher what was actually written in the responses.
- Candidates should always look at the associated marks allocations in questions. Candidates should not have to use extra continuation sheets if they tailor their answers to the space provided. This session far too many candidates wrote lengthy answers and used extra continuation sheets which were not required.
- It is critical that core chemical principles are brought to the fore in the Options, especially those which have often a twin biological focus e.g. biochemistry and medicines and drugs. Core chemistry should always underpin applied topics. This will be become a major feature of the new curriculum and every effort should be made by teachers to link core chemistry to the chemistry embedded in the options as part of the delivery of the new IB Diploma Chemistry programme.
- 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 how to answer questions. This was certainly a feature of this session where unfortunately some candidates missed easy marks by not understanding the nature of some of the command terms.
- Candidates should prepare for the examination by working through past examination questions and carefully studying the markschemes provided.
- 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 an option and students are required to know the steps then it should be performed in class or observed by simulation.
- Students need practice in writing balanced equations to convert given reactants into given products.
- Many students still use class names instead of functional group names. Again this will be feature of the new syllabus so it worth flagging to teachers for future classroom delivery of the programme.
- Understand the inherent difference between Therapeutic Window and Therapeutic Index.
- Bond connectivities should be emphasized – incorrect bond connectivities were rampant this session!
- Candidates need to understand the language of chemistry e.g. the difference between “reagents” and “conditions” etc.
- Chemistry is an evolving subject, in many ways a feature of the actual nature of science. Teachers should make every effort to highlight terms that are gradually being phased out as recommended by IUPAC e.g. coordination bonding is now preferred to dative

covalent bonding, (+) (-) notation is not preferred to d and l, usage of geometric isomerism is strongly discouraged and cis-trans isomerism is the preferred term, van der Waals actually includes dipole–dipole, dipole-induced dipole and London (instantaneous induced dipole-induced dipole) forces, oxidation numbers are represented by Roman numerals and the term Stock number is no longer recommended etc. Exposing candidates to some of these ongoing universal IUPAC developments over the lifespan of a Chemistry programme leads to a richer experience of the subject for the candidate.

- As alluded to elsewhere in this subject report, candidates need to be aware of the List Principle e.g. if a [2] mark question requires two examples of animals and a candidate states "cat, dog and tree", this will only score [1 max] as the tree will invalidate one of the two correct responses i.e. [2-1] = [1 max].
- With the advent of the new curriculum, the nature of science (NOS) will play a central role in future examination papers. For example, candidates may wonder why even though nitrogen is more electronegative than carbon, the negative charge resides on the carbon in the cyanide anion (as in the organic mechanism in Q33 (a) on this paper). An aspect such as this could now be explored in the new curriculum by looking at the various possible resonance structures of the cyanide anion using a platform such as formal charge calculations at a simplistic level, which is an addition to the new curriculum. Some of the more curious candidates of course may like to explore HOMO in MO theory for this species by looking at molecular modelling type representations. This sort of scientific questioning encompassing the nature of scientific understanding will be a feature of future examination papers and teachers should try to integrate NOS into the very heart of the classroom delivery of the new programme.