CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-18	19-34	35-48	49-59	60-69	70-79	80-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-33	34-46	47-57	58-68	69-79	80-100

Internal assessment

Component grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-15	16-21	22-27	28-31	32-37	38-48

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-15	16-21	22-27	28-31	32-37	38-48

General comments

Pleasingly many of the moderators commented that the standard of work submitted for moderation of Internal Assessment was an improvement on previous sessions with an increasing proportion of schools implementing the assessment regulations and criteria successfully. The new 4/IA cover sheet probably helped since it acted as a much needed checklist for teachers prior to submission of their moderation samples. While a sizeable minority of schools continue to misinterpret the assessment scheme, the problems mainly arose where teachers were new to the IB Diploma or were teaching IB Diploma Chemistry in the same class as other different assessment systems and were therefore not prioritising the applicability of their schemes of work to the Group 4 IA criteria.

The range and suitability of the work submitted

In general the work submitted was suitable for assessment. As in previous years there were some schools that submitted simplistic experiments that were not appropriate for IB Diploma candidates or generated too few data. It is recognised that many students start the IB Diploma Programme with a minimal experience of practical investigative work and such simple tasks may be appropriate early in the course in order to train them in the required skills. However these tasks should not be predominant on the 4PSOW nor should they form the basis for assessment.

Similarly some teachers' instructions gave far too much assistance to the candidates in fulfilling the assessment criteria. Common examples included:

- Pl (a): far too specific aims given that did not allow candidates opportunity to focus further.
- Pl (b): too much information given regarding materials, apparatus, and even procedural steps. An investigation that requires the teacher to specify the equipment or methodology is not appropriate for assessment of Pl (b).
- DC: candidates explicitly told which data to record with supplied data tables (happily a less common occurrence this session).
- DPP: candidates instructed on which data to graphically plot or given step-by-step guide to calculations.
- CE: students being instructed to respond to a series of set questions.

Both Pl(a) and Pl(b) should evoke different responses from different candidates within the same class. A uniform set of responses is an indication that an investigation might not be appropriate for assessment of Pl(a) or Pl(b). It was a concern that some classes submitted near identical procedures that appeared to have come from commercially available laboratory manuals, web-based sources or possibly even directly from the teacher.

It would be pleasing to see more investigations that give the opportunity to more able students to stretch themselves and apply their knowledge. For example, for many Higher Level candidates, a planning exercise to see which factors affect the rate of a reaction is quite undemanding, with the hypothesis being extremely straightforward since the background theory is so well known.

There are frequent examples where students were submitting excessively long reports for relatively straightforward investigations, in some cases the length of an Extended Essay! Such students are certainly well motivated and it is a shame that their energies are being expended unnecessarily and it is likely that this is a symptom of undue stress over the assessment process and confusion between the demands of Group 4 IA compared with other subject groups and the Extended Essay. The teacher should clarify that in Chemistry the objective should be to write a clear and concise report that logically presents and interprets its findings. A long report should only arise in cases where an open-ended investigation has generated sufficient data to merit such treatment.

There was very little evidence of the use of data-logging techniques in the samples sent for assessment. The fact that very few students refer to data-logging in planning activities indicates that they are not yet familiar with the technology concerned. There is no reason why data-logging cannot be incorporated successfully into planning or CE assessment tasks. In the context of a wider individual investigation data logging can still even be a part of DC and DPP assessment as long as there is scope for the individual candidate to demonstrate their contribution to the collection and processing of the data.

It is of concern that a small but significant number of schools each year are using co-authored reports in order to assess the five written criteria. It is essential that students are solely assessed on their individual contribution to any activity used for assessment of the written criteria. Even more seriously, identical reports were submitted by two or more students without acknowledging the joint nature of the work. This is academic malpractice and can result in IBCA being notified by the moderator. Such occurrences should be identified by the teacher concerned and the work should not contribute to the final assessment of the candidates involved.

Candidate performance against each criterion

Planning (a)

Where teachers had set an appropriate open-ended task the candidates were generally able to formulate a focussed research question. Similarly nearly all candidates were citing a meaningful hypothesis with a reduction in the number of students who were simply predicting that "the experiment will work". However in many cases the hypothesis was either not explained at all or was explained in superficial terms as opposed to citing and applying chemistry concepts. In most schools the students displayed a suitable understanding of the terms *control*, *dependent* and *independent* in relation to variables. Where candidates seemed unaware or confused as to their meaning it was often reflected throughout a school's sample, indicating that these terms have not been appropriately defined for the students.

Planning (b)

This criterion was fulfilled to a similar extent as in previous years. Candidates generally selected suitable equipment and devised appropriate strategies for carrying out investigations. A common weakness in Pl (b) is the lack of control of variables even though candidates have identified variables to be manipulated or controlled when addressing Pl (a). The commonest example of this omission was that students failed to control reaction temperature when undertaking a kinetic study of a significantly exothermic reaction. Another failing of a large number of candidates was the absence of quantitative information regarding reactant concentrations, masses, volumes, etc. That said, the resulting data generally indicated that sensible quantities were used and environmentally damaging excesses were avoided. One other reason for incomplete fulfilment of Pl (b) was that the candidates often did not plan to collect sufficient data. Very few candidates considered the assessment of reproducibility through replication or the assessment of uncertainty through calibration of experimental set-up with a known standard. Also a disappointingly large number of candidates failed to plan for a suitable number of trials in order to properly investigate, ideally through graphical means, the effect of changes in the independent variable upon the dependent variable.

Data Collection

Most candidates' performance was generally good with candidates independently able to present data in suitably constructed tables with appropriate column headings and units. The most common failings still related to the first aspect with uncertainties often being left out and frequent inconsistency in the use of significant figures. Also candidates still overlook the opportunity to record qualitative data when it is clearly present and significant (e.g., the evidence of incomplete combustion in an enthalpy of combustion determination).

Fewer teachers than previously were prone to over-reward their students in purely qualitative DC tasks with full marks being given for poorly phrased observations that either lacked detail or were not primary observational statements.

Data Processing and Presentation

Most schools had appropriately assessed DPP in quantitative tasks and the overall standard was satisfactory, although maximum levels of achievement were not frequent. An increasing, although still not large, proportion of HL candidates were able to propagate errors correctly through a calculation. Very few SL candidates were able to give any form of assessment of uncertainty in a derived result and appreciation of significant figures was also often lacking. The TSM 1 should be referred to for guidance in this area.

The quality of graphing improved but was still variable. There were many effective examples of graphical processing of data but common failings were the inability to construct a best-fit line, inappropriate sketch graphs when a greater accuracy of plotting was required, as well as the poor use of Excel. Contemporary versions of Excel can be used to great effect in DPP but the normal expectations of graphing , i.e. labelled axes with units, best-fit lines and curves, etc, must still be observed, as well as the candidate's individual contribution being evident. A graphing program that does not permit user control over the processing or output is not suitable for assessment of this criterion. Few candidates were given tasks that allowed further processing of graphical data such as finding a gradient or intercept through extrapolation.

Conclusion and Evaluation

This is still an area where candidates do not score particularly well. Although more candidates than previously compare their results to literature values where appropriate, this criterion also requires a valid conclusion with an explanation that is based on the correct interpretation of the results and this is often missing. Alternatively many candidates' conclusions revealed that they had not understood the purpose of the investigation and there was very little evidence that candidates made any attempt at background reading or research in order to interpret their findings.

Most candidates attempted to evaluate the procedure and list possible sources of error, although often this evaluation was superficial, with comments frequently restricted to human error and lack of time. Candidates should be attempting to identify reasonable systematic errors and simplistic investigations may make this task difficult. Even where candidates had successfully determined a total % uncertainty for DPP very few then used this information to assess if the final result was explainable by random error or required the consideration of systematic errors. Some candidates were able to make appropriate suggestions to improve the investigation following the identification of weaknesses, although many were only able to suggest simplistic or non-specific improvements, such as to "use more accurate equipment".

Manipulative skills

In general, the practical programmes provided adequate scope for assessment of this criterion.

The Group 4 Project

Nearly all schools provided evidence for participation of individual candidates in the Group 4 Project for each of the candidates in the sample. Most schools used the Group 4 Project as an ideal opportunity to stimulate group collaboration within an interdisciplinary framework and assess the Personal Skills criteria, but did not award grades for the written criteria. This is a sensible approach to be encouraged in view of the concerns cited earlier regarding co-authored work.

Recommendations for the teaching of future candidates

The following recommendations are made for the teaching and assessment of future candidates:

- ensure that students are solely assessed on their individual contribution to any activity used for assessment of the written criteria.
- ensure that candidates have the opportunity to achieve criteria, and hence should not provide too much information/help for the Planning (a), Planning (b), Data Collection, Data Processing & Presentation and Conclusion & Evaluation criteria.
- consult TSM 1 on the Online Curriculum Centre regarding the consideration of errors and uncertainties.
- encourage candidates to form a hypothesis that is directly related to the research question.
- encourage candidates to consider repeat trials, calibration or generation of sufficient data to undertake graphical analysis, when designing procedures for Pl (b).

- when assessing the CE criterion, require candidates to evaluate the procedure, list possible sources of random and systematic errors, and provide suggestions to improve the investigation following the identification of weaknesses.
- teachers should not assess for a particular criterion if an investigation does not meet all aspects of the particular criterion.
- if candidates need to be introduced to the skills required for investigative practical work through simple introductory experiments that do not fully meet all aspects of a criterion, then it is important that the marks generated are not included on the form 4/PSOW.
- evidence for participation in the Group 4 Project by each candidate in the sample must be submitted with evidence of individual contribution.
- teachers must refer to, and follow, instructions found in the chemistry subject guide, the Teachers Support Material on the online curriculum centre, and instructions provided in the up to date *Vade Mecum* before submitting work for moderation.

Recently the IBO has published the IB Learner Profile (available on the OCC) which is the IBO Mission Statement translated into learning outcomes for the 21^{st} century. Although no single component of the IB Diploma is expected to address all of the Profile it is clear that the practical scheme of work in Chemistry can play a full role in a school's integration of the Learner Profile in its curriculum.

For example the IB Learner Profile describes *Inquirers* who develop their natural curiosity and acquire the skills necessary to conduct inquiry and research and show independence in learning, as well as *Thinkers* who exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems. These are qualities that are not engendered by routine prescriptive class practical sessions but can truly be encouraged by extended individual practical investigations where each student has their own unique research question to investigate. It is worth teachers using a meaningful proportion of the prescribed teaching time to undertake such investigations.

The Profile also states that IB Learners should be *Knowledgeable* in that they explore concepts, ideas and issues that have local and global significance, and *Communicators* who understand and express ideas and information confidently and creatively in a variety of modes of communication as well as being able to work effectively and willingly in collaboration with others. The Group 4 Project is certainly one important activity, amongst others, that should be used to address these qualities.

It is hoped that future sessions will show that Chemistry teachers are playing their part in fostering these and other IB Learner Profile qualities within their Practical Schemes of Work.

Higher level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-9	10-16	17-23	24-26	27-29	30-32	33-36

General Comments

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level material (AHL), including 15 questions common to Standard Level Paper 1, 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.

Teachers' impressions of this paper were conveyed by the 169 G2 forms that were returned. No doubt many of the general responses were influenced by the missing periodic table. In comparison with last year's paper over three-quarters of respondents felt it was of a similar standard; of the remainder, more considered it a little more difficult than a little easier. Nearly all thought the level of difficulty was appropriate. Both syllabus coverage and clarity of wording were considered good by about half and satisfactory by the remainder. The presentation of the paper was considered good by over one third and satisfactory by nearly one third; almost one third considered it poor.

It is appropriate here to consider the impact on candidates of the missing periodic table which should have appeared on the reverse of the front cover of the question paper. The fact that the question paper was put in front of candidates with this serious omission is greatly regretted by the IBO. Candidates and teachers may wonder how such an omission could have occurred and may query whether the checking procedures in place are sufficient. They should be reassured that there are such procedures in place and that they are being reviewed in the light of this occurrence. At the Grade Award meeting, participants carefully considered what steps should be taken to mitigate the effect on candidates. They considered the questions proposed for deletion in the G2 forms and agreed that there were four questions (4, 6, 7 and 10) in which candidates who had access to a periodic table would have had significant help or reassurance, and these were deleted. The overall performance of candidates on Paper 2 was carefully scrutinized, but it was not considered that the periodic table issue had caused any measurable impact in that paper. Following Grade Award the results of schools and individuals were scrutinized for evidence of under performance on paper 1, those candidates that displayed underperformance on paper 1 compared to their performance on other components and their predicted grade had a special consideration procedure applied to them which resulted in some borderline students being awarded the higher grade.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 94% to 35% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.44 to 0.00. (The higher the value, the better the discrimination).

Comments were made on the following questions.

1 Units for relative atomic and molecular masses

Neither term has units, as stated in A.S. 1.2.3

8 Knowledge of colours not on syllabus / more than one possible answer

A.S. 3.3.1 requires knowledge of the reactions of halogens with halide ions, so a displacement reaction in which iodine appears should be known as one in which a coloured substance is formed. Some respondents consider that white is a colour; the IB chemistry view on this is made clear in A.S 13.2.1, where the existence of coloured (in contrast to white) compounds is given as a characteristic of transition elements.

11 Ionic/covalent bonding in aluminium sulfide

Whether this compound is purely ionic or has considerable covalent character is not relevant to the nature of the question. Candidates are not expected to be familiar with the compound, but just to treat its bonding as ionic and make a correct choice on this basis.

12 Hydrogen bonding in methanol

It was suggested that hydrogen bonding would only occur in liquid methanol, so that states of matter should have been included in the question, or perhaps that there should have been a reference to room temperature. It is not considered that this extra information would have helped candidates, who are expected to make their choice from knowledge of structures, so that they can identify the key as the only response in which hydrogen is bonded to a very electronegative element.

13 "Boiling point" is more precise than "volatility"

This may be true, but this question tested understanding of the later and not the former. The term appears in A.S. 4.5.2

16 How can the volume of a cylinder of gas be doubled?

By raising the piston! It certainly was not a problem for candidates (89 % got it correct).

18 No distinction made between system, surroundings and universe entropy

It is expected that candidates should assume that system is meant – this is the term used in A.S. 6.5.1

19 Bond enthalpies quoted are actual, not average

While it is true that in this question all the values are for actual bonds, the term *average bond enthalpy* appears in the syllabus, and is also used as the heading in Table 10 of the Data Booklet, from which the data is taken. The wording was not an issue for candidates.

20 Units of kJ or kJ mol^{-1}

Practice varies here, and many candidates will be familiar with both units, although may not appreciate the reasons for using one rather than the other. The IB chemistry view is that both may be used in questions, and that candidates should always understand that the given enthalpy change value is for molar quantities of reactants and products (with coefficients, where applicable).

21 Question not fair for candidates familiar with exothermic definition of lattice enthalpy

Although the IB allows for both exothermic and endothermic definitions to be used by candidates, they are expected to be familiar with using the endothermic version, as this is used in Table 14 of the Data Booklet. All four responses offered were endothermic ones, so the choice was to be made on the basis of correct formulas. The suggestion that some candidates were disadvantaged is not accepted.

25 Meaning of amount not clear

Response C included the term "amount", which has a precise meaning in chemistry (amount of substance in moles). However, as this was an incorrect response, those who interpreted it to mean something else, such as mass or volume, would not have been disadvantaged.

28 Candidates might not be familiar with distinguishing between strong and weak acids using heat of neutralization

The syllabus (A.S. 9.2.3) requires candidates to describe experiments, but does not prescribe which ones. The neutralization method certainly works, and some candidates will have done such experiments in their practical work. To accept response D would make this the most difficult question on the paper, as nearly as many candidates chose response B. As the only difference between responses B and D is the inclusion or exclusion of the neutralization method, it was decided to accept both responses.

32 More than one iron half-cell

It was suggested that because there are three possible half-cells involving iron, B may also be a possible correct response. Candidates were expected to assume that the iron half-cell referred to was the one involving Fe(s) and Fe^{2+}(aq), corresponding to the only possible one for magnesium. Any candidates who assumed that the cell referred to was that involving Fe^{2+} and Fe^{3+} might have considered response B to be correct. However, candidates are asked to choose the best answer, rather than the correct answer, so as response D would always be correct, they should choose D. Fewer than 5 % of candidates chose response B.

33 Two correct responses because anode not specified

It was suggested that response B would be correct if the anode were inert. The IB chemistry view is that in the process of electroplating the anode should be made of the metal to be plated (copper), in which case response B would be incorrect. As response D is correct no matter what the electrode, it is considered that this is the best answer.

35 Requires understanding of physics concepts

The A.S. being tested (19.3.3) may also be familiar to students of physics, but is clearly part of the chemistry syllabus.

38 Answer depends on whether TMS is included

Candidates are expected to assume that in considering the ^{1}H NMR spectrum of a compound any peak due to TMS should not be included. Although it was suggested that the inclusion of wording such as "excluding the peak due to TMS" would have avoided any ambiguity, this is not accepted. TMS is not mentioned in the syllabus (only in Option G), so its inclusion would have led to other, justifiable, criticisms.

39 No correct answer / answer depends on meaning of "typical"

All the listed characteristics are found amongst a great variety of free radicals. However, A.S. 20.2.2 requires candidates to be familiar with free radicals involved in the reactions between alkanes and halogens. All of these radicals are formed by homolytic fission and are uncharged, so candidates should reason that II and III are correct. Those who identify these two as typical will choose response C. Those who go on to consider the presence of a lone pair of electrons would realise that halogen radicals, but not alkyl radicals, have them, and so reject this as not a typical characteristic.

40 Possible misprint in response D

Response C is the key (this is the only one in which the dehydrated compound loses two hydrogen atoms and one oxygen atom). The distractors should have been rejected for different reasons, response D because it is an impossible formula. It is accepted that it would have been better to have chosen a distractor with a correct formula.

Higher level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-14	15-29	30-41	42-50	51-60	61-69	70-90

General comments

This paper indicated a very broad range of capabilities of candidates. Some candidates struggled with even the most basic concepts while others demonstrated an excellent depth of understanding of the higher-level course. It produced a range of responses from almost full marks to zero. In general, answers lacked precision in terms of wording used and explanation were often vague and repetitive. There were some schools where candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank.

Candidates must pay particular attention to the number of marks allocated to the question and write their answers accordingly. Calculations must be shown clearly and should be checked for accuracy, significant figures and units where appropriate.

The 140 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, three-quarters felt that it was of a similar standard, while the remainder of respondents were equally divided between difficult and easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage was considered good by half and satisfactory by the remainder of respondents. Clarity of wording was considered good by over half and satisfactory by the remainder of respondents. The presentation of the paper was considered good by two-third and satisfactory by the remainder.

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

- Explanation of physical properties in terms of bonding and structure
- Writing acid-base reactions, particularly Lewis acid-base reactions
- Significant figures
- Correct naming of organic compounds
- Formation of σ and π bonds
- Calculation of the standard free energy change
- Writing ionic half-equations
- Calculation of K_c value
- Graph to show how the vapour pressure changes with temperature
- Addition and condensation polymerization
- Working of an indicator and a buffer solution
- Mechanism for a nucleophilic substitution reaction
- Explanation of differences in ionization energy

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

- Explanation of spontaneity based on a ΔG^0 value
- Calculation of ΔH_c^0 and ΔS_c^0 value
- Writing K_c expression
- Writing structural formulas of isomers
- Stoichiometry calculation including limiting reagent
- Drawing Lewis structures
- Application of Le Chatelier's principle
- Oxidation of alcohols
- Electron configurations
- Hess's law

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

Section A

Question 1

(a) Most candidates managed to balance the equation correctly.

(b) Most candidates managed this calculation but a common error was using values of reactants minus products rather than the other way around and not using the coefficients from the balanced equation.

(c) A number of candidates managed this calculation but some failed to convert units from J to kJ. Some candidates lost marks for not paying attention to standard temperature (298K), significant figures and units in the final answer.

(d) The majority of the candidates were able to use their answer for free energy correctly when determining spontaneity of the reaction at 298K. Candidates were able to gain the marks, even when (c) was incorrect as *error carried forward* was applied.

(e) The majority of the candidates were able to apply Hess's Law correctly; a small number either obtained the incorrect sign for the enthalpy change value, or left out the coefficient involved in the calculation.

Question 2

(a) The question specifically asked for the answer to two decimal places, some candidates did not pay attention to the instruction and lost the third mark. Often the value was calculated for TlBr, rather than $TlBr_3$ as stated in the question.

(b) The majority of candidates did not realize that both H and Br have isotopes and that, in calculating the average relative molecular mass of HBr, one must average out not only the *isotopic masses* but also the *percentage abundance* of each isotope.

(c) Most candidates were successful in stating the full electronic configuration of the bromide ion but with a minority referring to the bromine atom.

(d) Most candidates identified the symbol of the ion with 2+ charges and a configuration of $1s^2 2s^2 2p^6$ as Mg^{2+}. The common error was the omission of the charge.

(e) Majority of the candidates were able to correctly identify species that are iso-electronic with Mg^{2+}, although there were some strange responses.

Question 3

Many candidates demonstrated a good knowledge of stoichiometric calculations. A common omission, however, was not converting from kg to g in determining the amount of substance (in moles). Some candidates failed to recognise the limiting reactant as Fe_2O_3 while others did not pay attention to significant figures. Working was not always set out which prevented some candidates of gaining marks through *error carried forward*. Surprisingly, a number of candidates converted 30 kg as 0.03 g and 5.0 kg as 0.005 g.

Question 4

(a) The definition of oxidising agent in terms of electron transfer was generally well known. A significant number of candidates gave incorrect oxidation numbers for chromium and only a few candidates stated the *change* in oxidation number as *3*.

(b) Writing correct half and overall equations proved challenging for the majority of candidates. Common mistakes were H_2 instead of $2H^+$ and the correct number of electrons in the half equation. The candidates demonstrated poor understanding in terms of writing an overall redox equation.

Question 5

(a) Stating two characteristics of a homologous series was generally done well. Common errors, however, included stating that homologous series differ by CH_2 rather than subsequent members in a series differ by CH_2, boiling points change/same physical properties, rather than stating that there is a gradual change in physical properties, and stating that they have same formula instead of same general formula.

(b) Some candidates suggested the use of HBr, H_2 or Cl_2 as chemical test to distinguish between alkenes and alkanes, which were not acceptable. Frequently physical properties such as boiling and melting points or infrared absorption bands were suggested. The colour of the reagent bromine water should be stated before and after the reaction in order to clearly distinguish between alkanes and alkenes. Bromine water decolorizes on addition to alkenes; however, a common answer was that it turns clear – the difference between decolorized and becoming clear should be stressed.

(c) The oxidation products of alcohols was generally done well. Several candidates generalized and simply gave functional groups formed (aldehydes, ketones and carboxylic acids) instead of the actual organic products formed in each case.

Section B

Question 6

(a) Most candidates stated the correct equilibrium expression.

(b) The catalyst for the contact process was generally well known, although Fe, Ni, H_2SO_4, and even $Cr_2O_7^{2-}$, were given by many candidates. The effect of the catalyst was correctly stated and explained by many candidates. Although the effect of the catalyst on the value of K_c was well known, a correct explanation in terms of both forward and reverse reactions being equally affected was less common.

(c) The effect of increased temperature on the kinetic energy of particles was generally well known but many did not refer to activation energy or more *energetic* collisions. Many candidates stated that there would be more collisions instead of more *frequent* collisions.

(d) Candidates generally had a good understanding of the Le Chatelier's principle. The most common error was the omission of the term *gas* when explaining the impact of a pressure change on the position of equilibrium.

(e) Most candidates correctly identified the reaction as exothermic based on the data provided.

(f) This calculation proved challenging for the majority of candidates and demonstrated poor knowledge of equilibrium concepts. Common mistakes were not calculating the number of moles of SO_2 and O_2 at equilibrium, conversion to concentration values and stating an incomplete answer for the value of K_c. Candidates were able to gain some marks, even with an incorrect answer as *error carried forward* was applied.

(g) Many candidates could correctly identify the specific intermolecular forces for propanoic acid and pentane, a relationship between intermolecular forces and enthalpy of vaporisation was not always stated. An upward trend was often shown in the graph of vapour pressure versus temperature; however, a curve was rarely shown. Many gave graphs without axes being labelled or depicting temperature changes during changes of state. Few could explain the trend shown in the graph in terms of overcoming the intermolecular forces.

Question 7

(a) Many candidates were able to draw the correct Lewis structures, although often poorly drawn, and sometimes missing the non-bonding electron pairs. The omission of square brackets and the negative charge for BF_4^- was frequently observed.

(b) Some candidates with the correct Lewis structures made errors in the shapes and bond angles: XeF_4 sometimes appeared as tetrahedral, PF_5 with a bond angle of 72° or pyramidal, and BF_4^- as square planar. Partial names or missing angles deprived some candidates of full marks.

(c) Many candidates incorrectly defined hybridization as the promotion of electrons rather than the mixing/combining of atomic orbitals, but the type of hybridization shown by nitrogen in the examples given was well answered.

(d) Description of the sigma and pi bonds was generally done well and some gave clear diagrams to show the overlap either along the inter-nuclear axis for a sigma bond or sideways overlapping of parallel p orbitals for a pi bond. Many candidates, however, correctly stated the composition of single and double bonds in terms of sigma and pi bonds but a few candidates gave detailed description which was not required.

(e) Many candidates were able to state that magnesium's valence electron was in a higher energy level/ further from nucleus than that of fluorine. Few, however, mentioned the increased shielding effect. The equation for the third ionization of magnesium was often written without state symbols. Few candidates recognised that an increased nuclear charge was responsible for higher third ionization energy for magnesium compared to fluorine.

(f) Poor answers were common in this part. When explaining why magnesium has a higher melting point than sodium, the metallic bond was not specifically referred to; atomic rather than ionic radii was compared and number of electrons was compared without reference to delocalised electrons. Magnesium oxide was often classified as covalent when explaining its high melting point. Of those candidates that correctly classified it as ionic, many then proceeded to contradict their answers by mentioning intermolecular forces. With sulphur dioxide, too many candidates referred to the strength of covalent bonds, rather than intermolecular forces.

Question 8

(a) (i) A surprising number of candidates could not define pH.

(ii) Titration curves were reasonably well drawn, although some did not clearly label the pH at the start, equivalence and end of titration. Some students failed to produce a suitable profile for the graph.

(iii) Many candidates correctly calculated the pH using *K* a while some made careless mistakes. Many candidates, however, did not give an approximate pH value at the equivalence point, hence not fully answering the question.

(b) While many candidates had some understanding of indicators, few could give a clear, well-expressed answers in terms of equilibrium between HIn and In^{-} + H^{+}, two colours and the equilibrium shifts in the presence of acid and base. The choice of a suitable indicator was well answered, although a reason in terms of colour change around equivalence point was not always clearly given.

(c) The majority of candidates gave reagents for an acidic, rather than a *basic* buffer. Only the most able candidates stated NH_3 and NH_4Cl or correct quantities of HCl and NH_3. Many could explain the impact of the addition of a small amount of acid; however, an appropriate equation was not always given.

(d) Bronsted acids were well understood, but Lewis acid definitions often lacked the word *pair* (of electrons). Lewis acid theory was poorly understood as shown by many incorrect examples and/or equations.

(e) While many candidates correctly identified aluminium chloride solution as acidic, few could explain it in terms of hydrolysis of a highly charged cation or an equation.

Question 9

(a) This part produced some poor answers. In particular, the structures of the monomers of the condensation polymers often had incorrect functional groups although the repeating unit was given in the question.

(b) Many candidates recognised the need for a double bond in the monomer for an addition polymer, but did not specify between carbon atoms. The requirement for two functional groups on the monomer for a condensation polymer was not well understood.

(c) Many candidates chose a more complicated isomer (rather than the ester, methyl methanoate), involving more than one type of functional group, hence making it difficult to give a systematic name.

(d) Although many candidates correctly identified methanol as the reagent needed for esterification to convert ethanoic acid to methyl ethanoate, many could not state the conditions for the process, namely heat and acid catalyst. Discussion of the two physical properties that differ for the weak acid and the ester was done well. Many candidates were able to deduce the areas under the peaks for the proton NMR spectrum of ethanoic acid and methyl ethanoate.

(e) The majority correctly named and defined an optical isomer, however the test for distinguishing between two such isomers was often lacking specific detail, such as the use of *plane polarised* light and the rotation (not bending) of plane polarized light in *opposite* directions. Similarly, many candidates gave correct structures for the isomers of C_4H_9Cl, but the tertiary, rather than a primary isomer was commonly chosen to undergo nucleophilic substitution via an S_N2 mechanism. Of those that correctly chose a primary isomer, only the most able candidates could give a correct mechanism. Curly arrows were shown starting at and/or finishing at the wrong point and transition states did not always show two partial bonds as well as a negative charge.

Recommendations and guidance for the teaching of future candidates

Candidates and teachers are advised to bear in mind the following points.

- Teachers are strongly advised to refer to past examination papers and their mark schemes to assist candidates with examination preparation.
- Candidates must know the meaning of the different action verbs that appear in the assessment statements and in the examination papers.
- Candidates must read the question carefully and address all points. Working must be shown for all calculations so that the chance of obtaining ECF marks is maximized.
- Candidates must ensure that they cover a sufficient number of different points to cover the full range of marks assigned to each question.

Higher level paper three

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	39-50

General comments

There was a wide range in the quality of the answers given. The paper discriminated well between candidates. Strong candidates were able to gain high marks whereas some very weak candidates produced some very poor answers or simply left blank spaces. There was no evidence that it was easier to gain marks on any one particular option and although there were some exceptions it was noticeable that most candidates scored similar marks for both options irrespective of what the actual options were.

136 G2 forms that were received gave teacher's perceptions of the paper 68% felt that the paper was of a similar standard to last year while just over 20% felt it was a little easier and 10% more difficult. The level of difficulty almost 90% found it to be appropriate with most of the remainder felt it was too difficult. Over 90% felt that the syllabus coverage, clarity of wording and presentation of the paper were satisfactory or better and at least 50% of these thought they were good.

Parity Between Options

One of the common themes of the G2 comments and other teacher discussion about paper 3 is the parity or perceived lack of parity between the options. Presently, parity between options is designed into the papers during the writing process as it is a requirement that all options have approximately an equal distribution between questions that assess objectives 1 and 2 and those that assess objective 3. It is also considered carefully during paper editing meetings. However, if there is enough evidence to support a suspicion of unfairness to candidates it is possible to apply a moderating factor to compensate disadvantaged candidates. In order to assess the performance of students on different options a random sample of just under 15% of the total candidature had their mark for each option recorded and compared. We then compared how each option's mean mark compared to the same students' performance on paper 2.

The mean mark across all the options on paper 3 was 12.98. For individual options the highest mean score was 15.64, all the other options' means were much closer to the overall, the range being from

11.5 to 14.43. In order to allow for student ability we compared each mean option mark with the same students' mean paper 2 mark by finding the ratio between them. Overall the ratio of the mean option mark : mean paper 2 mark was 0.27. Using this measure the ratios for options fell between 0.30 and 0.24. The option that scored 15.64 as an average mark fell within the range of the other options.

All of these data have a high standard deviation (slightly less than half the value) therefore we should be cautious when we use them to predict how difficult students found the options at the individual or school scale. Paper 3 also assesses different subject knowledge and different skills to paper 2 so it is not expected that marks on paper 2 should be strong predictor of performance on paper 3. On balance, it was felt that the differences in the values described above fall well within an acceptable range and therefore no intervention was necessary.

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

This examination revealed some weaknesses in candidates' knowledge and understanding in all Options. These included:

- Option B – antiviral drug action and calculations involving partial pressure.
- Option C – practical details of electrophoresis, structures of proteins and triglycerides.
- Option D – ion exchange method of water purification and the action of sunscreens.
- Option E – the correct use of Ellingham diagrams.
- Option F – lead-acid batteries and calculations involving half-life.
- Option G – the workings of a double beam spectrometer and the correct choice of chromatographic technique.
- Option H – the need for concentrated acid(s) for both the nitration of benzene and the elimination of water from an alcohol.

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

Some candidates displayed an excellent knowledge and understanding of the material tested. As has become the norm, candidates from schools where all the candidates answered questions on the same two options tended to perform much better than those who selected a mixture of options. This strongly suggests that schools that teach two options thoroughly are preparing their students much better than those who allocate little teaching time to the option or allow their students to study a variety of options on their own. One of the ways in which this manifests itself is that some candidates are still giving simplistic or 'journalistic' answers rather than chemical answers to questions and thus failing to score some or all of the marks.

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

Option B – Medicines and Drugs

B1

In part (a) most candidates were able to identify two correct effects. A minority of candidates lost the mark through writing too many effects, some appearing in both lines. The chemistry behind the breathalyser was not well known in part (b). A general point that candidates should be aware of is that when a colour **change** is asked for, then both starting and finishing colours should be clearly identified.

B2

Some high scores were seen in this question, though rarely full marks. Most candidates correctly identified nicotine, but the short-term and long-term effects sometimes overlapped. A general point to note is that in questions that require a specified number of answers (here, "two" was in bold), candidates should not provide more than the requested number, nor include a list containing several answers appearing opposite one bullet point.

B3

It proved difficult for candidates to score highly in this question, although all but the weakest could differentiate between viruses and bacteria. Answers were generally not specific enough. For example, some wrote that bacteria were ‘living’ but did not explain what they meant by ‘living’. Similarly in parts (b) and (c) the answers given were often rather vague, although the best candidates did show a good understanding of the methods of action of acyclovir. Although the drug acyclovir is not named in the syllabus, candidates are expected to have encountered it before (its structure appears in the Data Booklet). However, it is accepted that the wording of the question would have been better as "Suggest how a drug such as acyclovir can act as an antiviral".

B4

Many candidates gave good answers for the disadvantages of the three stated anesthetics but were less certain about how to apply Dalton’s Law of Partial Pressures in part (b). Some tried to solve the problem using the General Gas Equation taking the value of R from the Data Booklet and some candidates also experienced problems with units – omitting the unit of atmospheres in part (i) or including a unit in part (ii).

B5

There is considerable confusion among some candidates regarding the different types of isomerism shown by some drugs. Many confused racemic mixture with cis- and trans- isomerism and the answer cis-platin was often given wrongly as an example of a drug where a racemic mixture could result in unwanted or dangerous side effects.

Option C - Human Biochemistry

C1

In part (a) most candidates attempted to draw the dipeptide, but mistakes were frequent, such as the inclusion of an extra O between CO and NH. Candidates should be encouraged to draw such structures in full, following the pattern of those in the question, and always to check that each atom has the correct number of bonds. Such a check would have avoided mistakes such as –N–H–. Condensation was well known, but the other product was often a complex organic molecule rather than water. In part (b) few students were familiar enough with electrophoresis to score full marks, while others unnecessarily wrote about protein hydrolysis. Unfortunately, some answers read rather like electrolysis ("a current is passed through the solution and the ions move to opposite electrodes"). In part (c) the primary structure and types of interaction in proteins were well known, but the role of hydrogen bonding in maintaining the secondary structure was not.

C2

Part (a) was poorly answered, with many candidates seemingly having little idea of a triglyceride structure. The reason for the change from liquid to solid on hydrogenation was much better answered although some omitted to connect the fact that the molecules are able to pack closer together will result in stronger van der Waals’ forces of attraction.

C3

Most candidates were able to give a good discussion about the effects of a competitive inhibitor on an enzyme catalysed reaction. Some then failed to score both marks in part (b) either by not showing how they had arrived at the position of K_m or by not showing that the competitive inhibition graph must not exceed V_{max}.

C4

Provided that the candidate read the question carefully and labelled one nucleotide then identified the parts from a different nucleotide this question presented few problems. Answers which listed the parts as 'sugar' or 'base' were accepted as well as those which were more specific and gave pentose or ribose for the sugar and guanine or adenine for the base.

Option D - Environmental Chemistry

D1

The probable effects of global warming were well-known although candidates must show some broader knowledge and not base the whole of their answer just on rising sea-levels and its causes. The effects on climate, agriculture and biodiversity etc. should also be included.

D2

A surprising number of candidates did not know that the two main uses of fresh water are for industry and agriculture. Some gave the Atlantic Ocean and the Pacific Ocean as the two locations that hold most of the Earth's water rather than oceans and glaciers. This question asked for **two** locations and many candidates listed more than two which meant that they were penalised if any in the list were wrong. In part (b) very few candidates seemed completely familiar with ion exchange, and some of those who did know wrote about water softening rather than deionization. The concept of biological oxygen demand asked in part (c) was familiar to most candidates, although quite a few thought it referred to the demand by living marine creatures for oxygen. Some omitted to state that it is measured over a specific time period (usually five days) and at a specified temperature, while others mentioned high BOD values as characteristic of pure water.

D3

The main source of photochemical smog is not 'car exhausts' but the internal combustion engine. This is a good example of where a journalistic answer is not acceptable. Most candidates knew the differences in the contents of the two types of smog and listed correctly in part (b) some of the major primary pollutants in both. Similarly in part (c) most candidates knew about thermal inversion but although many talked about the pollutants being 'trapped' they did not go on to then state that this means that the pollutants become more concentrated or longer lasting.

D4

The need for sunscreens to contain conjugated double bonds or considerable delocalisation of electrons was not well-known and part (a) was not answered well by many candidates. In part (b) candidates simply had to list two out of four substances and one got the impression that for many candidates this was a guess rather than a deduction.

Option E - Chemical Industries

E1

Most candidates managed to mention three factors for choosing a location for a chemical industry.

E2

Most candidates knew the raw materials for making iron from iron ore in the blast furnace in part (a) but were less knowledgeable about the conversion of iron to steel in part (b). The environmental impact of aluminium production in part (c) produced some rather vague answers and few mentioned that aluminium production has a significant effect on global warming as the carbon electrodes are oxidized to carbon dioxide as well as in the production of the large amount of heat and electrical energy necessary.

E3

Most knew that the most important use of petroleum other than as a fuel is as a feedstock for other compounds, particularly plastics. In part (b) a surprising number did not know why crude oil contains sulfur. For part (c) either the fact that sulfur poisons the catalyst in refining processes or that when it burns it forms sulfur dioxide which leads to acid rain was accepted.

E4

This question demanded straightforward recall on how a diaphragm cell works and most candidates were familiar with it and scored well.

E5

Many candidates were unable to use Ellingham diagrams correctly and relate the spontaneity of reactions with ΔG values, consequently only relatively few candidates scored well on this question.

Option F - Fuels and Energy

F1

A surprising number of candidates did not state that a desirable characteristic of an energy source is that the energy must be released at a controllable or reasonable rate although other characteristics were also acceptable for the marks to be gained in part (a). In part (b) there were many examples of answers where fission and fusion were confused, leading to many responses about explosion risks. Most candidates' answers about tidal energy indicated lack of familiarity ("tides only happen twice a day").

F2

Some answers like 'the sun needs to be shining' similarly indicated a lack of familiarity of the use of photovoltaic cells. Only a few candidates mentioned that a battery or storage facility would be needed in the absence of light and 'cost' without being specific to cost of production or running costs was sometimes given. Otherwise this question tended to be answered rather well.

F3

Candidates either did or did not know how a lead-acid battery works and this was reflected in the marks awarded.

F4

Although the question clearly stated 'pumped' storage some candidates wrote about electrolysing water to hydrogen and then releasing the energy by burning the hydrogen. Most had a good understanding of the advantages and disadvantages of pumped storage of energy.

F5

Most candidates gained some marks for this question but lost marks through generalizations rather than precise answers. For example high-level radioactive waste is not only highly radioactive but also stays radioactive for a long time. Similarly it is not simply buried underground but is first vitrified or encased in concrete etc. The calculation in part (c) was straightforward involving an equation given in the Data Booklet but proved too difficult for some students and others who got the numerical value correct omitted to also write years as the unit.

Option G – Modern Analytical Chemistry

G1

Most candidates had few, if any, problems with this question.

G2

Although most candidates were able to label the parts of the double beam infrared spectrometer relatively few were able to describe correctly the function of the monochromator, M. Similarly in part (iii) relatively few knew that the detector works by converting the radiation into an electronic signal then compares the intensities of the sample radiation with the reference or control radiation to determine the absorption at particular frequencies. In part (b) most candidates knew that the vibrations of the molecule are excited to a higher level when the molecule absorbs infrared radiation but some omitted to state that the dipole moment of the molecule also changes. Part (c) was generally answered well.

G3

Some candidates seemed unaware of the reasons for choosing a particular type of chromatography and not many realised that column chromatography is preferred when larger amounts of the sample are being separated. HPLC is more useful than GLC for separating different sugars as the high temperatures involved in GLC would decompose the sugars. Most were able to answer part (c) on paper chromatography well.

Option H – Further Organic Chemistry

H1

The free radical substitution reaction of chlorine with ethane to form chloroethane was generally well-known although some candidates misread the question and used methane instead of ethane. Part (c) caused more problems. Some did not state the crucial fact that the UV light in the ozone layer breaks the C-Cl bond causing radicals or explain that chlorinated alkanes are normally unreactive which is why they reach the ozone layer unaltered in the first place.

H2

Although most candidates knew that a mixture of nitric acid and sulfuric acid is needed to nitrate benzene some lost one of the marks by omitting to state that they need to be concentrated. The equation to form the electrophile, NO_2^+, was known by many candidates and it was pleasing to see that many could use curly arrows correctly to describe the mechanism in part (c). In part (d) there was a misprint on the paper as part of the question had been omitted. Even so many candidates correctly deduced the structure of the product, 1,3-dinitrobenzene, when nitrobenzene is nitrated. Part (e) was a good discriminator with strong candidates giving good answers and part (f) was straightforward for those who knew the reaction to alkylate benzene using halogen carriers.

H3

In part (a) the use of concentrated sulfuric or phosphoric acid was required and some candidates omitted to state 'concentrated'. Good candidates were able to describe the mechanism well in part (b). The most common error of those who made a good attempt but lost marks was to omit the charge on the intermediates.

Recommendations and guidance for the teaching of future candidates

There is still a need to repeat some of the advice given in previous chief examiner's reports.
Specifically:

- Read the question carefully and answer the question asked paying particular attention to the action verb(s) used.
- Give answers that involve proper chemistry and not superficial or 'journalistic' answers.
- Do not give a long list when asked for a specific number of examples.
- Prepare two options thoroughly. Candidates should know and understand **all** the topics of two options.
- Candidates should write concisely and endeavour to confine their answers to the spaces provided on the question paper. If they do need extra space then usually it is better to continue the answer in the white space below the question rather than write a few words on a separate answer sheet. If they must use continuation sheets, then they should indicate in the booklet that the particular answer is continued elsewhere.
- Do not repeat the question or include irrelevant information.
- Write legibly and draw diagrams and mechanisms as clearly and carefully as possible with correct labelling.
- Practise with past papers. Particular attention should be given to honing the skills of: writing correctly balanced equations; setting out calculations in a logical way and showing the working; the correct use of curly arrows in organic reaction mechanisms and the inclusion of the correct charge for ions and organic intermediate compounds/transition states.

Standard level paper one

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-10	11-14	15-17	18-20	21-23	24-26

General comments

This paper consisted of 30 questions on the Subject Specific Core (SSC) 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.

Teachers' impressions of this paper were conveyed by the 187 G2 forms that were returned. No doubt many of the general responses were influenced by the missing periodic table. In comparison with last year's paper, about two-thirds of respondents felt it was of a similar standard; of the remainder, more considered it a little more difficult than a little easier. Nearly all thought the level of difficulty was appropriate. Both syllabus coverage and clarity of wording were considered good by about half and satisfactory by the remainder. The presentation of the paper was considered good by over one third and satisfactory by nearly one third; almost one third considered it poor.

It is appropriate here to consider the impact on candidates of the missing periodic table which should have appeared on the reverse of the front cover of the question paper. The fact that the question paper was put in front of candidates with this serious omission is greatly regretted by the IBO. Candidates and teachers may wonder how such an omission could have occurred and may query whether the checking procedures in place are sufficient. They should be reassured that there are such procedures in place and that they are being reviewed in the light of this occurrence. At the Grade Award meeting, participants carefully considered what steps should be taken to mitigate the effect on candidates. They considered the questions proposed for deletion in the G2 forms and agreed that there were four questions (5, 6, 7 and 10) in which candidates who had access to a periodic table would have had significant help or reassurance, and these were deleted. The overall performance of candidates on Paper 2 was carefully scrutinized, but it was not considered that the periodic table issue had caused any measurable impact in that paper. Following Grade Award the results of schools and individuals were scrutinized for evidence of under performance on paper 1, those candidates that displayed underperformance had a special measures procedure applied to them which resulted in many borderline students being awarded the higher grade.

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 91% to 42% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.41 to 0.00. (The higher the value, the better the discrimination).

Comments were made on the following questions.

2 Missing state symbols

The current policy is not to include additional material that does not help candidates in their choice.

8 Knowledge of colours not on syllabus / more than one possible answer

A.S. 3.3.1 requires knowledge of the reactions of halogens with halide ions, so a displacement reaction in which iodine appears should be known as one in which a coloured substance is formed. Some respondents consider that white is a colour; the IB chemistry view on this is made clear in A.S 13.2.1, where the existence of coloured (in contrast to white) compounds is given as a characteristic of transition elements.

9 Ionic/covalent bonding in aluminium sulfide

Whether this compound is purely ionic or has considerable covalent character is not relevant to the nature of the question. Candidates are not expected to be familiar with the compound, but just to treat its bonding as ionic and make a correct choice on this basis.

11 Hydrogen bonding in methanol

It was suggested that hydrogen bonding would only occur in liquid methanol, so that states of matter should have been included in the question, or perhaps that there should have been a reference to room temperature. It is not considered that this extra information would have helped candidates, who are expected to make their choice from knowledge of structures, so that they can identify the key as the only response in which hydrogen is bonded to a very electronegative element.

15 Bond enthalpy has no meaning for ionic compounds

This is true, and for those candidates unsure of the correct response it is a valid way of eliminating B as a possible correct response.

16 Units of kJ or kJ mol^{-1}

Practice varies here, and many candidates will be familiar with both units, although may not appreciate the reasons for using one rather than the other. The IB chemistry view is that both may be used in questions, and that candidates should always understand that the given enthalpy change value is for molar quantities of reactants and products (with coefficients, where applicable).

19 Convoluted / not on syllabus

It is agreed that there was a lot of unfamiliar information for candidates to read and digest. However, the question tested A.S. 7.1.1, and was correctly answered by 78 % of candidates, with a discrimination index of 0.31, so was considered to have worked well.

21 Meaning of amount not clear

Response C included the term "amount", which has a precise meaning in chemistry (amount of substance in moles). However, as this was an incorrect response, those who interpreted it to mean something else, such as mass or volume, would not have been disadvantaged.

24 Meaning of "increase in pH"

It was suggested that this was ambiguous. The meaning is completely clear – an increase in pH means from a lower to a higher value (say, from 4 to 6), so means a decrease in $[H^+]$.

26 More than one iron half-cell

It was suggested that because there are three possible half-cells involving iron, B may also be a possible correct response. Candidates were expected to assume that the iron half-cell referred to was the one involving Fe(s) and Fe^{2+}(aq), corresponding to the only possible one for magnesium. Any candidates who assumed that the cell referred to was that involving Fe^{2+} and Fe^{3+} might have considered response B to be correct. However, candidates are asked to choose the best answer, rather than the correct answer, so as response D would always be correct, they should choose D. Fewer than 5 % of candidates chose response B.

27 Two correct responses because anode not specified

It was suggested that response B would be correct if the anode were inert. The IB chemistry view is that in the process of electroplating the anode should be made of the metal to be plated (copper), in which case response B would be incorrect. As response D is correct no matter what the electrode, it is considered that this is the best answer.

Standard level paper two

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-22	23-28	29-34	35-40	41-50

General comments

Overall, the candidates found the paper to be accessible. There was a good range of marks which indicates that the paper had been set at an appropriate level. The number of candidates leaving whole questions un-attempted was small though, as usual, some of what was written gained few or no marks. Explanations of chemical phenomena continue to be a source of some difficulty and candidates do not always look at their answers to calculations critically.

Teachers impressions of the paper as measured by G2 showed that of 166 respondents 70% thought the paper was a similar standard to last year, just under 20% though it was a little easier and the remainder thought it was a little more difficult. As for the suitability of the paper 94% found it to be of an appropriate difficulty, 4% thought is was too difficult and the remainder too easy. The syllabus coverage was felt to be good by half the teachers that responded and 45% found it satisfactory and only 5% poor. The clarity of wording was thought to be good by 56%, satisfactory by 42% and poor by 2%. The presentation of the paper was considered good by 60%, satisfactory by 39% and poor by only 1%.

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

There was considerable variation as to the quality of answers between schools. Perhaps some sections of the syllabus had not been covered or candidates had been left to read them up on their own. The sections which this paper highlighted were:-

Organic Chemistry – Question 8 was attempted by only a minority of candidates and Q5 was very low-scoring especially the description of a simple chemical test that the candidates should have seen or carried out.

Definitions – atomic number and atomic mass were often defined as the number of particles in an element rather than in an atom. There are three parts to the symbol $\Delta G^{\ominus}$. These must all be mentioned in a definition.

Periodic Trends – explanations are often very vague.

Catalysis – the name of the catalyst used in the Contact Process was often not known. Explanations of how a catalyst works often lacked clarity, especially in indicating that the rates of the opposing reactions are increased equally.

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

Questions were generally answered well in the following areas:

- Calculations in general (Q1(a)&(b), Q2(b), Q3(a)&(b))
- le Chatelier's Principle (Q6(d))
- Intermolecular forces (Q7(c)(ii), Q7(d))
- Lewis structures (Q7(c)(i))

However, although a lot of answers scored some marks, these were fewer than the candidates would have scored had they developed their arguments more fully. In calculations no process marks could be awarded when only an incorrect final answer was shown. Explanations involving le Chatelier's Principle were not sufficient to explain the effects of changes in conditions on the position of equilibrium. The relationships between intermolecular forces and physical properties were not fully explained.

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

Section A

Question 1

(a) Very few candidates drew out the structure of the alkene to check on the numbers of each type of bond present. As a result the numbers of C-C and C=C bonds were sometimes incorrectly chosen. Also the numbers of O-H and C=O bonds were often given as 4 and 3 rather than 8 and 6 having forgotten that a water molecule has two O-H bonds and carbon dioxide has two C=O bonds. A number of candidates gave the final answer from an incorrect subtraction i.e. 'formed' – 'broken'.

(b) This was generally correct. The answer 'endothermic' was expected as a consequence of a positive answer in (a) but candidates should know that combustion is invariably exothermic. This was rarely referred to.

(c) This was generally well done. Candidates had been well drilled in Hess's law calculations. The most common error was to use only 1 x -242 $kJmol^{-1}$ for the contribution made by the hydrogen.

Question 2

(a) Many candidates lost the marks for giving imprecise definitions, especially in giving 'element' rather than 'atom' or 'nucleus'. In (ii) there was sometimes a confusion between 'mass number' and simply 'mass'.

(b) The most common error in this part was to find the relative molecular mass of TlBr. A number of candidates did not give the final answer to two decimal places as asked for in the question. Some used the relative atomic masses from the data book rather than their calculated values.

(c) Some wrote 'Mg' without the charge.

(d) Candidates who got part (c) correct generally gave correct answers. A few listed other 2+ ions from Group II.

Question 3

(a) There were a number of approaches to this question, some very convoluted, giving varying degrees of success. Provision of units often clarified the method. The most common error was a failure to convert kilograms to grams before calculating the number of moles of each reactant. Nevertheless, the concept of the limiting reagent seemed to be well understood.

(b) Most candidates who had made an attempt at (a) were able to score the marks here, sometimes consequential to some incorrect calculation in part (a).

Question 4

(a) This was mostly well known, especially (i) but some candidates were unable to follow this through and state what an oxidising agent was in terms of electron transfer.

(b) The change in oxidation number was often known but not expressed in a way which answered the question. The oxidation number changes (or decreases) by 3. An explanation for calling this a reduction is that the oxidation number has decreased or that the chromium has gained electrons.

Question 5

It was clear many schools spend very little time discussing organic chemistry as this question was poorly answered.

(a) The characteristics of a homologous series were often described in very nebulous terms e.g. 'they differ by a carbon atom', 'they have similar boiling points'. A number of candidates suggested that the members of such a series have the same empirical or molecular formula rather than a general formula.

(b) A large proportion of candidates failed to realise that a visible simple chemical test was required. Some suggested measuring a physical property, especially boiling point or melting point. Many candidates gave reactions, particularly addition reactions for alkenes, using hydrogen or a hydrogen halide. Where bromine or bromine water was suggested the observation in each case was not always described. The use of acidified $KMnO_4$ was rarely suggested.

Section B

Question 6

This was by far the most popular choice of question in Section B.

(a) Most candidates scored the mark for the expression of K_c. A few had an addition sign in the denominator.

(b) The majority of candidates failed to identify the catalyst for the Contact process correctly. Iron, hydrogen, oxygen and even 'heat' were among the suggestions made. Candidates were aware that a catalyst does not change the position of equilibrium and hence K_c and that the catalyst provides an alternative pathway for a reaction with a lower activation energy thus speeding up the reaction. They often omitted to say that both the forward and reverse reactions are sped up equally.

(c) The basic principles of the collision theory were well known but candidates often omitted to give any reference to time; 'more frequent collisions' or 'more collisions per unit time' is required rather than simply 'more collisions'.

(d) Le Chatelier's Principle was also well known. For part (i) the direction of change was usually correct but many answers did not refer to the reaction moving to the side with fewer molecules of gas. In part (ii) the direction of change was usually correctly stated but explanations were often not clearly expressed and in part (iii) the effect of a catalyst was known but the equal effect on the rates of the opposing reactions was often missing.

(e) Most candidates were able to state that the reaction is exothermic; the relationship to the change in equilibrium constant with temperature was frequently unclear.

(f) Very few candidates gave an answer which included all the features of the symbol $\Delta G^{\ominus}$. 'standard', 'free energy' and 'change'. Part (ii) was often correct. For part (iii), the change in spontaneity was stated but the explanations using the positive and negative quantities were often not clearly argued. Some candidates used calculations but did not ensure that the two quantities to be combined were in the same units.

Question 7

This question was attempted by about a third of the candidates, generally not very successfully.

(a) This part of the question proved to be particularly low-scoring. Effects were often detailed descriptions of trends rather than explanations. In (i) few candidates mentioned the increased electron shielding in magnesium. In (ii) the model of metallic bonding proved to be very difficult for candidates to use or explain.

(b) The classification of the oxides was not clear, often simply stated as a general trend. The term amphoteric was not widely used. The reactions chosen were often of the elements rather than their oxides. In many cases the equations produced did not balance.

(c) The Lewis structure for water was usually correct and the shape of the water molecule was well known. Explanations for the bond angle often lacked clarity. It must be emphasised that the VSEPR theory refers to repulsion by electron pairs not by atoms. A surprisingly large number of answers gave water as O-H-O. "Like dissolves like" may be a useful aid-memoire but is not a suitable expression to use as the answer to an examination question, unless explained in further detail.

(d) This was generally well known, though some answers showed a lack of understanding of the relative strengths of the different types of intermolecular force. Some candidates still persist in relating phase changes to bond breaking.

Question 8

This question was attempted by a very small percentage of the candidates, probably because part of it was concerned with Organic Chemistry.

(a) Most candidates were able to identify a strong acid and a weak acid. A number of them thought that these could be distinguished using a simple titration with an indicator, often thinking that the weak acid would require less base for neutralisation.

(b) The word 'amphoteric' was generally known but the possible equations required were rarely correct.

(c) Most candidates knew which solution was the more acidic but were unable to carry out the calculation successfully.

(d) Few candidates had an adequate knowledge of both the composition and behaviour of a buffer solution though most were able to score one of the marks available for this part.

(e) Usually ethene was the only monomer correctly identified.

(f) The mark for addition polymerisation was sometimes gained, but rarely the one for condensation polymerisation, in particular the need for the monomer to have two functional groups.

(g) Only a few candidates correctly named and drew the structure for methyl methanoate. Other plausible isomers were sometimes seen but rarely named correctly. Many answers were missing one or more atoms.

Recommendations and guidance for the teaching of future candidates

The most important recommendation for teachers is that all the core curriculum is fully covered. The deficiencies which are highlighted from session's cohort are:-

- Basic definitions
- Periodicity and trends in physical properties
- Calculations
- Organic Chemistry
- Experimental observation of practical work and/or demonstrations
- Poor examination technique

Work using past examination papers as a teaching aid would assist candidates to gain more of the marks they deserve. Many candidates appeared to lose marks in areas where they showed some knowledge but lacked the necessary precision and detail in their answers. In many cases candidates must learn to answer the question that is asked.

The mark allocation for a question or part of a question should be used as a guide to the depth of the answer required. Thus 2 marks will not be awarded if a one-word answer is given.

Candidates should ensure that their answers are sensible. Thus in the question on the production of copper, kilograms of reactants are not likely to produce only a few milligrams of copper.

In calculations, working should always be shown. A correct answer will score all of the marks available but without working no marks can be awarded for any of the steps taken on the way to an incorrect answer if these are not shown. Also units should always be given and a sensible approach needs to be taken towards significant figures.

Candidates should be advised to learn definitions accurately and to make sure that equations balance.

Standard level paper three

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-13	14-17	18-21	22-25	26-29	30-40

General comments

The range of marks awarded was very wide; the best candidates showed a thorough command of the material and a high level of preparation, but this session there were many candidates who seemed unfamiliar with the material in the options and scored very poorly. Hardly any candidates attempted more than two options.

Teachers' impressions of this paper were conveyed by the 156 G2 forms that were returned. In comparison with last year's paper, two-thirds thought this year's paper to be of a similar standard, with slightly more of the remainder considering it more difficult rather than easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage and clarity of wording was considered satisfactory by nearly a half and good by most of the rest. The presentation of the paper was considered good by over a half and satisfactory by the remainder.

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

This examination revealed weaknesses in candidates' knowledge and understanding in all Options. These included:

- Option A – organic reaction mechanisms
- Option B – antiviral drug action
- Option C – practical details of electrophoresis, structures of triglycerides
- Option D – ion exchange method of water purification
- Option E – comparison of cracking processes

- Option F – electrochemistry

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

Once again there were some excellent scripts seen from some candidates, probably from those who had been taught specific options, rather than from those who had been allocated little teaching time or who had made their choice of options on the day of the examination. It is clearly in the candidates' interests that teachers cover two options thoroughly, rather than allow their students to study a variety of options on their own.

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

Option A – Higher Physical Organic Chemistry

A1

This was well answered by most candidates, although a minority listed the correct techniques but in the wrong order. Some of the weaker candidates gave weighing and titrating as a method of obtaining molecular mass.

A2

Selecting the correct wavenumber ranges was well done by most candidates. The commonest error was making the wrong choice for the O–H bond.

A3

Generally this question was poorly answered, with high scores being rare. The mechanisms in part (a) were usually set out untidily, and there were many common errors, the most significant being the omission or careless drawing of curly arrows, the charges being omitted or shown in the wrong place, attack by KOH rather than by ^{-}OH. The prediction of rate expressions in part (b) was better attempted, although with some candidates scoring consequentially from mechanisms in part (a) that were in the wrong order. Part (c) was the best answered, with most candidates choosing the correct bonds from Table 10 to justify their choice.

A4

Most candidates scored well in this question, although with some confusing concentration and rate. Very few left blanks or drew random lines.

A5

In part (a) there were many correct answers, although several errors were noted, including missing or incorrect charges on the ions formed, and the inclusion of H_2O in the K_b expression. Although many correct final answers were seen in part (b), a minority of candidates seemed to have little idea of how to proceed, and generally the calculations were poorly laid out.

Option B – Medicines and Drugs

B1

In part (a) most candidates were able to identify two correct effects. A minority of candidates lost the mark through writing too many effects, some appearing in both lines. The chemistry behind the breathalyser was not well known in part (b). A general point that candidates should be aware of is that when a colour change is asked for, then both starting and finishing colours should be clearly identified.

B2

Some high scores were seen in this question, though rarely full marks. Most candidates correctly identified nicotine, but the short-term and long-term effects sometimes overlapped. A general point to note is that in questions that require a specified number of answers (here, "two" was in bold), candidates should not provide more than the requested number, nor include a list containing several answers appearing opposite one bullet point.

B3

In part (a) most candidates knew that bacterial cell walls were affected by penicillins. In part (b) many candidates referred to the effects of antibiotics on diseases or humans, rather than on bacteria; a less common error was to state that broad-spectrum antibiotics were effective against more bacteria, instead of against a greater variety of bacteria. In part (c) most candidates mentioned the development of resistance, but several suggested that it was human beings rather than bacteria that developed the resistance. Candidates should avoid the use of journalistic terms such as "super-bugs" and "good/friendly" bacteria, as such terms are not credited on their own.

B4

It proved difficult for candidates to score highly in this question, although all but the weakest could differentiate between viruses and bacteria. Answers were generally not specific enough, although the best candidates showed understanding of the methods of action in parts (b) and (c). Although the drug acyclovir is not named in the syllabus, candidates are expected to have encountered it before (its structure appears in the Data Booklet). However, it is accepted that the wording of the question would have been more appropriate as "Suggest how a drug such as acyclovir can act as an antiviral.", as knowing exactly how this particular drug acts is not specified on the syllabus.

Option C - Human Biochemistry

C1

In part (a) most candidates attempted to draw the dipeptide, but mistakes were frequent, such as the inclusion of an extra O between CO and NH. Candidates should be encouraged to draw such structures in full, following the pattern of those in the question, and always to check that each atom has the correct number of bonds. Such a check would have avoided mistakes such as –N–H–. Condensation was well known, but the other product was often a complex organic molecule rather than water. In part (b) few students were familiar enough with electrophoresis to score full marks, while others unnecessarily wrote about protein hydrolysis. Unfortunately, some answers read rather like electrolysis ("a current is passed through the solution and the ions move to opposite electrodes"). In part (c) the primary structure and types of interaction in proteins were well known, but the role of hydrogen bonding in maintaining the secondary structure was not.

C2

Part (a) was poorly answered, with many candidates seemingly having little idea of a triglyceride structure. The reason for the change from liquid to solid on hydrogenation was much better answered.

C3

The influence of molecular structure on vitamin solubility was well known, although few answers referred to the formation of hydrogen bonds with water molecules.

Option D - Environmental Chemistry

D1

Most candidates scored several marks in this question, but full marks were rarely seen. Many incorrect equations involving SO were seen, and also C + O → CO. Some answers lacked specific details, for example "scrubbing" without "alkaline", and the use of a catalytic converter to remove sulfur oxides was not accepted.

D2

In part (a) many candidates believed that drinking and washing were main uses of fresh water, although rather more knew the locations of most of the earth's water. A few mentioned underground aquifers and water vapour in the atmosphere. In part (b) very few candidates seemed familiar with ion exchange, and some of those who did know wrote about water softening. The concept of biological oxygen demand was familiar to most candidates, although quite a few thought it referred to the demand by living marine creatures for oxygen, while others mentioned high BOD values as characteristic of pure water.

Option E - Chemical Industries

E1

Most candidates managed to mention three industry location factors.

E2

Parts (a) and (b), about the blast furnace, were generally well answered, but the conversion to steel in part (c) was not.

E3

The comparison of aluminium with iron was not well answered. Some thought that iron was more reactive than aluminium; the term "lighter" was not accepted as being equivalent to "lower density".

E4

Good answers to this question were rare; typically most candidates scored 1 or 2 marks in parts (a) and (b) but few in part (c), where the details of the two cracking methods were not known.

Option F - Fuels and Energy

F1

Part (a) was well answered by the majority of candidates. In part (b) there were many examples of answers where fission and fusion were confused, leading to many responses about explosion risks. Most candidates' answers about tidal energy indicated lack of familiarity ("tides only happen twice a day").

F2

Photosynthesis was well known, although the need for chlorophyll was omitted by a surprising number (light was given as a catalyst). Candidates found it difficult to score highly in part (c), although most knew what biomass was. A significant number wrote about ethanol rather than its production from biomass. Part (b) was surprisingly poorly answered with unbalanced equations and the use of oxygen as a reagent.

F3

Most candidates scored a few marks here, although some attempts were penalised through lack of precision. For example, "cost" was not accepted as a disadvantage of photovoltaic cells without a reference to cost of production, in contrast to running costs. Many candidates believe that such cells produce no electricity in the absence of direct sunlight.

F4

Very few candidates could write a correct equation, even though the lead-containing reactant and product were both given; many did not include electrons, even though a half-equation was asked for.

Recommendations and guidance for the teaching of future candidates

In addition to the usual advice about reading the questions carefully and paying attention to mark allocations and action verbs, candidates are advised to bear in mind the following points in this paper:

- practise the careful drawing of curly arrows in organic reaction mechanisms,
- realise that for most substances containing covalent bonds, melting and boiling involve the breaking of intermolecular forces and not covalent bonds
- practise writing a variety of equations, paying careful attention to balancing and the inclusion of charges and electrons where appropriate
- practise setting out calculations in a logical way, including a few words to indicate what process is being used
- do not give a long list when asked for two or another specified number of answers
- avoid the use of journalistic language, such as "super-bugs" instead of "penicillin-resistant bacteria", "friendly bacteria" instead of "beneficial bacteria", and use correct scientific terms, such as "of lower density" instead of "lighter"

Finally, some advice that is not specific to chemistry:

- The number of lines for a question part is meant to suggest the amount of space for a typical response, although some candidates write answers that are longer than the spaces available. Such candidates should complete their answers in the white space below the lines where possible, in preference to writing a few words on a continuation sheet. If they must use continuation sheets in this way, then they should indicate in the booklet that the particular answer is continued elsewhere.

