

## CHEMISTRY

### Overall grade boundaries

#### Higher level

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 - 18	19 - 33	34 - 46	47 - 57	58 - 66	67 - 77	78 - 100

#### Standard level

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 - 17	18 - 32	33 - 45	46 - 57	58 - 67	68 - 78	79 - 100

### Higher and standard level internal assessment

#### Component grade boundaries

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

#### General comments

This was the last May examination session that worked within the old internal assessment model and there was evidence that most schools and teachers with prior experience of the current Chemistry I.A. model had successfully applied the criteria to a much greater extent than was evident a few years ago. However many new schools and teachers come into the IB world each year and it is clear that the internal assessment requirements often present a challenge for newcomers.

As in previous sessions the moderating team were working to instructions from the Principal Moderator that emphasised that teachers are the primary markers and that moderators should support the teacher wherever possible. Moderators are not primary marking and if the teachers grading is a plausible interpretation of the criteria then it should be supported.

Guidance was then given as to when and how moderators should and should not change marks as follows:

#### When to mark down

Planning (a):

- The research question, hypothesis and/or independent and controlled variables are given by teacher. Mark the relevant aspect down to 'n'. A general aim is fine if the students have significantly modified it (e.g. made it more precise).

- The hypothesis has not been explained or the explanation is clearly counter to theory as can be reasonably expected to be known by an average IB chemistry student (e.g. 'reaction rate will decrease with increasing temperature because .....'). Award 'p' for second aspect.

#### Planning (b):

- A method sheet is given which the student follows without any modification or **all** students are using identical methods. Moderator gives n, n = 0
- Teacher gives c, c, c but it is clear that the students have been told what apparatus and materials they require. Maximum moderator can award is n, c, c = 2.

#### Data Collection:

- A photocopied table is provided with heading and units that is filled in by students. Maximum moderator can give is p, n = 0.
- The teacher gives 3 (c, c), but the student has only recorded quantitative data (e.g., in titration) and qualitative data such as colours of solutions, indicator, colour change etc. are missing. Moderator gives p, c = 2. However, do not be overzealous and penalize DC every time a student does not find qualitative data to record.
- Student has not recorded uncertainties in any quantitative data. Maximum 'p' for first aspect.
- Student has been repeatedly inconsistent in use of significant digits when recording data. Award 'p' for second aspect.
- In purely qualitative DC tasks such as establishing a reactivity series. Too often the students put in a reaction equation as opposed to the observation. This cannot be supported and will reduce first aspect to 'p' or 'n' depending on how much other raw data is present.

#### Data Processing & Presentation:

- A graph with axes already labelled is provided (or students have been told which variables to plot) or students follow structured questions in order to carry out data processing. Moderator gives c, n = 1.
- No evidence of errors being propagated (HL) or total random error being estimated in any way (SL). Maximum award c, p = 2. Remember that best fit line graph is sufficient to meet requirement for error and uncertainty propagation.

#### Conclusion & Evaluation:

- Structured questions are given to prompt students through the discussion, conclusion and criticism. Depending on how focussed the teacher's questions are and on the quality of students' response the maximum award is partial for each aspect the student has been guided through. You have to be judging purely on the students input.
- Teacher gives c, c, c = 3 but the student has only indicated as a criticism that they ran out of time. Maximum moderator can give is c, n, p = 1.

#### When not to mark down

In the following cases support the teacher's stance as they are aware of their own expectations of the students.

## Planning (a):

- Dependent variable has been given by teacher or student has made no mention of dependent variable (surprisingly it is not featured in aspect 3 descriptor!)
- You disagree with the explained hypothesis but you feel that it is a reasonable application of IB level knowledge.
- The hypothesis explanation is simplistic but the only one possible within the framework of the task (e.g. Student predicts vitamin C contents of juices based on evidence supplied by packaging.) In this case support student but feedback to teacher as to poor suitability of task for meaningful hypothesis generation.
- The independent and controlled variables have been clearly identified in procedure but are not given as a separate list (we mark the whole report and there is no obligation to write up according to the aspect headings)
- There is a list of variables and it is clearly apparent from procedure which is independent and which are controlled.

## Planning (b):

- Similar (not word for word identical) procedures are given for a narrow task. Comment though on poor suitability of task on 4/IAF form.
- Do not only mark equipment list. Give credit for equipment clearly identified in stepwise procedure. Remember we mark the whole report.
- Do not insist on +/- precision of apparatus to be given in apparatus list. This has never been specified to teachers and the concept of recording uncertainties is dealt with in DC.
- Do not downgrade a teacher's mark if something as routine as safety glasses or lab coats are not listed. Some teachers consider it vital to list them each time and some teachers consider them such an integral part of all lab work that they go without saying. Support teacher's stance.

## Data Collection:

- When teacher has supplied stepwise instructions including when to record data. This criterion has evolved into assessing the written record only.
- In a comprehensive data collection exercise possibly with several tables of data the student has been inconsistent with significant digits for just one data point or missed units out of one column heading. If you feel the student has demonstrated that they were paying attention to these points and made one careless slip then you can still support maximum mark under 'complete not meaning perfection' rule. This is an important principle since often **good students responding in full to an extended task unfairly get penalised more often than students addressing a simplistic exercise.**
- Student has not included any qualitative observations and you cannot think of any that would have been obviously relevant.
- Purely qualitative DC such as in establishing a reactivity series. These are currently allowable but not recommended since they do not facilitate recording of uncertainties. Please feedback to that effect. However when marking do make sure that it is genuine raw data (see section A above).

- No table title when it is obvious what the data in the table refers to. I have seen students do all the hard work for DC and then lose a mark from the moderator because they did not title the table. Except for extended investigations it is normally self evident what the table refers to and the section heading Raw Data is sufficient. Once again 'c' does not mean perfect.

Data Processing:

- **Errors and Uncertainties**

The expectation in chemistry, as described in the TSM 1, is:

**Standard level candidates** are **not** expected to process uncertainties in calculations. However, they can make statements about the minimum uncertainty, based on the least significant figure in a measurement, and can also make statements about the manufacturer's claim of accuracy. They can estimate uncertainties in compound measurements, and can make educated guesses about uncertainties in the method of measurement. If uncertainties are small enough to be ignored, the candidate should note this fact.

**Higher level candidates** should be able to express uncertainties as fractions,  $\Delta x/x$ , and as percentages,  $(\Delta x/x) \times 100$ . They should also be able to propagate uncertainties through a calculation.

**Note:** Standard level and higher level candidates are **not** expected to construct uncertainty bars on their graphs."

**Note that a best-fit line graph is sufficient to support 'c' for the second aspect at both SL and HL.**

For both DC and DPP, if the student has clearly attempted to consider or propagate uncertainties (according to whether HL or SL) then support a teacher's award even if you may feel that the student could have made a more sophisticated effort. Please **do not** punish a teacher or student if the protocol is not the one that you teach i.e. top pan balance uncertainties have given as +/- 0.01g when you may feel that if we consider the tare weighing then it should be doubled. Moderation is not the time or place to establish the favoured IB protocol.

- **Is a graph on its own necessarily data processing?**

The current subject guide clearly states on page 25 under DPP that processing raw data includes 'converting tabulated data into graphical form' and does not require further treatment such as finding a gradient or intercept. . Maximum DPP can be awarded if the graph is properly and accurately constructed and with a suitable best-fit line as long as it has been used as an aid to interpret the data. For HL we most certainly would prefer to see quantitative results generated but I do not feel we can disallow the hundreds of rate of reaction graphs that directly plot volume of gas produced against time that we are about to mark! If the graph has been used to draw qualitative conclusions regarding relative rates then allow it to be assessed according to its merits. A diplomatic 4IAF comment advising the teacher to make greater demands on DPP in future sessions would be appropriate. The new curriculum for first exam in 2009 will tighten up the requirements in this area.

### Conclusion and Evaluation

- Simply apply the principle of complete not meaning perfect. For example if the students have identified most sensible sources of systematic error then you can support a teacher's award even if you think that you can identify one more. Do be a bit more critical in third aspect that the modifications are actually relating to the cited sources of error."

Finally the moderators were guided:

"So the broad message is be positive in your marking. Look for what is present in a piece of work and not for minor omissions. Try to avoid pettiness and remember that sometimes you can mark upwards."

## The range and suitability of the work submitted

There were a good number of schools who submitted challenging work which reinforced learning and provided a suitable opportunity for assessment. A small number of schools were still not undertaking a suitable practical scheme of work and were failing to appropriately address the assessment criteria. To a better extent than previously, schools appeared to be implementing recommendations given on the previous years 4/IAF feedback form.

Once again the issue of most serious concern was that the work of some candidates was clearly guided by teachers, fellow candidates or unreferenced sources to a level well beyond the instructions evidenced. It was unfortunately not uncommon for all candidates to choose exactly the same variables, carry out an identical procedure or follow through with identical methods in complex calculations, while the instructions provided had indicated an independent, open-ended task. At best this could be considered poor practise for failing to ensure that candidates carry out the task legitimately for themselves.

Teachers should ensure that assessment is carried out in good faith and that an individual's skills are being assessed.

## Candidate performance against each criterion

### Planning (a)

When the set-task was appropriate this criterion was generally well fulfilled with candidates able to pose a research question, make a sensible hypothesis with some level of explanation and to identify the relevant control and independent variables. Moderators did report that a significant number of candidates were unable to fulfil criterion due to being set unsuitable investigations such as those based on confirmation of laws or determinations of specific values. E.g. confirming gas laws.

### 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. Some schools were setting very simplistic tasks such as finding the density of a penny. A common weakness in PI (b) was the lack of control of variables even though candidates have identified variables to be manipulated or controlled when addressing PI (a), e.g. the failure to control reaction temperature when undertaking a kinetic study of a significantly exothermic reaction. Variables were frequently not properly controlled in electrochemical investigations, calorimetric labs and chromatography analysis. Another failing

of a large number of candidates was the absence of quantitative information regarding reactant concentrations, masses, volumes, etc. Volume measuring instruments were often omitted or the choice was inappropriate. One common reason for incomplete fulfilment of PI (b) was that the candidates often did not plan to collect sufficient data. It is recommended that five data points at least should be planned for.

An investigation that requires the teacher to specify the equipment or methodology is not appropriate for assessment of PI (b). Teachers sometimes over-plan and set up an investigation leading to only one possible procedure, and this denies candidates opportunity to achieve in this criterion. Both PI (a) and PI (b) should have evoked different responses from different candidates within the same class.

### **Data Collection**

Most candidates had been presented with suitable data collection tasks and their 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 associated qualitative data not being recorded although more candidates than previously recorded uncertainties and were consistent in the use of significant figures.

### **Data Processing and Presentation**

Most schools had appropriately assessed DPP in quantitative tasks and the overall standard was satisfactory with few schools still unwisely using purely qualitative investigations for DPP assessment. A majority of schools encouraged meaningful treatment of errors or uncertainties in DPP for Higher Level candidates.

The quantity and quality of graphs, including those generated by Excel, was improved from last year. Note that a graphing program that does not permit user control over the processing or output is not suitable for assessment of this criterion. Only a few schools persist in only presenting bar graphs which are seldom appropriate for most investigations in our field.

### **Conclusion and Evaluation**

Moderators reported that this was often the most difficult criterion for candidates to fulfil. Most candidates could compare their results to literature values where appropriate and included some level of explanation. Most candidates did attempt to evaluate the procedure and list possible sources of error although very few were able 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 completely unrealistic improvements. There still persists a trend in teachers to over-reward very simplistic evaluations or suggestions not related to cited errors.

### **Manipulative skills**

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

### **The Group 4 Project**

All schools provided evidence for participation in the Group 4 Project for each of the candidates in the sample. Many schools seemed to have undertaken stimulating and imaginative projects.

## Recommendations for the teaching of future candidates

From May 2009 session onwards the revised specifications in the new Subject Guide will apply.

- The new criteria will be marked on a scale of 0 to 6, not 0 to 3 as present.
- Candidates should be made aware of the different aspects of the new criteria by which they are assessed and evaluation of investigations using a grid of criteria/aspects with n, p and c indicated clearly is strongly encouraged.
- It is essential to ensure that candidates are solely assessed on their individual contribution to any activity used for assessment of the written criteria.
- Teachers must ensure that candidates have the opportunity to fulfil criteria, and hence should not provide too much information/help for the Design (D), Data Collection & Processing (DCP) and Conclusion & Evaluation (CE) criteria.
- All candidates, both Higher and Standard Level, need to record, propagate and evaluate the significance of errors and uncertainties.
- It is recommended not to use workbooks and worksheets with spaces to be filled in by the candidates for internal assessment as they usually provide too much information and deny the candidates the opportunity to achieve criteria.
- Candidates no longer will need to formulate a hypothesis to fulfil completely the assessment criteria, although teachers are still free to promote their inclusion.
- Candidates will need to explicitly identify the dependent variable as well as independent and controlled variables in the Design criterion.
- Candidates should be encouraged to consider repeat trials, calibration or generation of sufficient data to undertake graphical analysis, when designing procedures for Design.
- All investigations for the assessment of DCP must include the recording and processing of quantitative data.
- Teachers are encouraged to set DCP tasks that will generate a graph that will require further processing of the data such as finding a gradient or intercept through extrapolation.
- Candidates must record associated qualitative as well as quantitative raw data, where appropriate where relevant.
- Candidates must compare their results to literature values where appropriate.
- 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.

- From May 2009 there is no formal requirement to submit evidence of Group 4 Project participation. The Group 4 Project is only to be used for assessment of the Personal Skills criterion.
- The Manipulative Skills criterion is to be assessed summatively over the whole practical scheme of work. No evidence for the MS mark need be submitted to the moderator.
- Teachers must refer to, and follow, instructions found in the chemistry subject guide, the Teachers Support Material, and instructions provided in the up to date *Vade Mecum* before submitting work for moderation.

## Higher level paper one

### Component grade boundaries

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 – 10	11 - 17	18 - 24	25 - 27	28 - 30	31 - 33	34 - 40

### General comments

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) material 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 76 G2's that were returned. 51% found that it was of a similar standard, compared with last year's paper, 27% felt that it was a little easier, 5% considered the paper much easier, 15% thought that it was a little more difficult and 2% were of the view that it was much more difficult. 91% felt that the level of difficulty was appropriate, 3% thought that it was too difficult and 6% considered that the question paper overall was too easy. Syllabus coverage was considered satisfactory by 9% and good by 90%. 1% considered coverage poor. In addition, 14% felt that the clarity of wording on the paper was satisfactory and 81% felt that the wording was good and 5% felt it was poor. The presentation of the paper was considered satisfactory by 3% and good by 97%.

### 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 95.02% to 26.92%, and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.56 to 0.10 (the higher the value, the better the discrimination).

The following comments were made on selected individual questions:



**Question 1**

This question was found to be the most difficult question on the paper, with a difficulty index of 26.92%. One respondent stated that having the word atoms in bold mislead many students, even though it was felt that this actually gave candidates a strong indication as to what was actually been asked. The use of the terms "amount" and "moles" should have indicated to candidates that an answer in moles, and not molecules, was required, and "atoms" was put in bold to emphasise that candidates should consider all three atoms in the carbon dioxide molecule.

**Question 4**

This question related to the visible emission spectrum of hydrogen. One respondent raised the issue of using the term convergence. However, in the teacher's notes on 2.2.2 in the guide, it is clearly stated that an understanding of convergence is expected.

**Question 5**

In this question candidates were asked to identify the correct statement in relation to ionization energy. The correct answer was D, which states that the fourth ionization energy of an element is always greater than its third ionization energy. One respondent commented however that both answers B (second ionization energies refer to the removal of two electrons from an atom) and C (third ionization energies always involve the removal of an electron from a p-orbital) also could be correct. However, second ionization energy refers to the energy needed to remove an electron from an isolated 1+ ion whereas the third ionization energy relates to the energy needed to remove an electron from a 2+ ion. 43.48% of candidates in fact chose D as the correct answer. The question had a discrimination index of 0.43.

**Question 8**

One respondent commented that the wording of the question made it difficult to ascertain whether A or D was the correct answer. A.S. 3.3.2 requires candidates to know the meaning of "amphoteric", so that they should be able to select I and II as correct statements. Statement III should be rejected for two reasons – aluminium oxide does not dissolve in water, and because many substances that dissolve in water to form neutral solutions are not in fact amphoteric (sodium chloride, for example).

**Question 9**

Some respondents suggested that the use of the term common here was confusing in relation to the oxidation states of transition metals. In A.S. 13.2.3, it is stated explicitly that the existence of the variable oxidation states in d-block elements should be known. In addition in the teacher's notes, the common oxidation states of +2, +4 and +7 are listed for Mn. Hence, in  $\text{MnO}_4^{3-}$ , Mn is in a +5 oxidation state, which is not a common oxidation state for Mn.

**Question 20**

This was considered a difficult question by some respondents, with a difficulty index of 35.77%. A.S. 15.2.2 states that a comparison between the effect of both the relative sizes and the charges of ions on the lattice enthalpies of different ionic compounds is required. In this question, four different ionic compounds had to be considered, CaO, CaS, LiF and LiI, which was challenging, as students had to consider both size and charge effects.

Generally, the effect of charge is greater than that of size, and hence using the electrostatic model, with  $E = kQ_1Q_2/d$ , both CaO and CaS would have greater lattice enthalpies than LiF and LiI. However, comparing the size of  $O^{2-}$  and  $S^{2-}$ , since  $S^{2-}$  is larger, then the lattice enthalpy of CaO will be greatest in magnitude.

Two respondents also stated that the use of the word magnitude would have been better than highest in this question which is a valid comment.

### Question 23

Although there did not appear to be any ambiguity amongst students, one respondent suggested correctly that the question might be better worded as referring to the overall order of the chemical reaction.

### Question 24

Some candidates found this question on half-life difficult, which had a difficulty index of 45.13%. The correct answer was B = 0.4, 0.4, 0.4, 0.4, although a number of candidates opted for answer D = 0.8, 0.4, 0.2, 0.1. The question might have been better presented if the term "intervals" was put in bold to clearly emphasise what was required. However, the question was a good discriminator, with a discrimination index of 0.52, which was the third highest on the paper.

### Question 37

Some respondents felt that the presentation of this question was confusing, especially in relation to the second + sign used in answer B, which would have been better replaced by the word 'and'. The question might have been better presented also if the question asked for the identification of the organic products formed from the reaction of 2-aminoethanoic acid with 2-aminopropanoic acid. However, candidates did not appear to have a problem with this question in general, and the question had a difficulty index of 69.99%.

### Question 38

This question was satisfactorily answered by most candidates (difficulty index = 82.15%). One respondent however suggested that a competent mass spectrometrists might also be able to identify structure and hence the chemical environment from fragmentation patterns. Although it was agreed that this may be possible most students clearly understood that mass spectrometry can provide information on the relative molecular mass of a compound (D) which was clearly the best answer of the four.

### Question 39

This question related to the reaction mechanism involved in the single step conversion of chloroethane to ethanol. One comment stated that elimination reactions are not covered in the compulsory syllabus. However, it was felt that there was no ambiguity here, as answer A simply referred to the removal of HCl. Use of the term removal instead of elimination might have been a better choice for this statement.

### Question 40

Three respondents stated the fact that reduction of carboxylic acids, aldehydes or ketones are not on the syllabus, which is correct. Candidates are required to know the products formed from the oxidation of primary and secondary alcohols (A.S. 20.4.2), and from an understanding of redox as a process which is clearly on the syllabus, most candidates were

then able to subsequently identify the fact that primary alcohols can be obtained by the reduction of carboxylic acids or aldehydes using their chemical intuition. This question was fully discussed during grade award, and it was felt that the question does fall within the remit of the HL syllabus since candidates should be able to determine the answer to this type of question based on the above principle. However, the question then becomes an objective 3 type question, which would have been more applicable to be asked on Paper 2, instead of Paper 1. However, candidates scored reasonably well on this question, with approximately 63% getting the question correct.

## Higher level paper two

### Component grade boundaries

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 – 13	14 - 26	27 - 37	38 - 47	48 - 57	58 - 67	68 - 90

### 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. The most common problem in this paper often involved candidates failing to read the question. This was particularly evident in question 6.

Teachers' impressions of the paper were conveyed by the 69 G2 forms that were returned. In comparison with last year's paper, 67% felt that it was of a similar standard, 22% thought that it was a little easier, 7% a little more difficult and just 4% were of the view that the paper was much more difficult. 96% considered the level of difficulty of the question paper appropriate, 1% too easy and 3% too difficult. Syllabus coverage was considered good by 88% and satisfactory by 12%. Clarity of wording was considered good by 81% and satisfactory by 19% of respondents. The presentation of the paper was thought to be good by 96% and satisfactory by 4%.

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

This examination revealed the following weaknesses in candidates' knowledge and understanding:

- Trying to suggest a mechanism of a reaction consistent with a rate expression
- Precise definitions in general, such as first ionization energy, standard enthalpy of formation and average bond enthalpy
- Explanations pertaining to trends in ionization energy
- Salt hydrolysis and associated explanations
- Delocalization
- Explanation of physical properties in terms of structure and bonding

- Mechanism of an  $S_N2$  reaction
- Structure of optical isomers

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

Topics generally well answered included:

- Determination of the order of a reaction
- Enthalpy level diagrams
- Calculation of the pH of a weak acid
- Application of Le Chatelier's Principle
- Calculation of enthalpy change
- Difference between sigma and pi bonding
- IR and proton NMR spectroscopy

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

### Section A

#### Question 1

Candidates were very familiar with the requirements of parts (a) to (c) and order of a reaction and rate expressions were in general very well understood. Part (d) caused confusion for some candidates and in part (e), many candidates had difficulty in determining the units of the rate constant, which were  $\text{mol}^{-2} \text{dm}^6 \text{s}^{-1}$ . In part (f), suggesting a mechanism for the reaction, consistent with the rate expression turned out to be one of the most challenging questions on the entire paper. Unbalanced steps were common and some incorrectly cited the name of a type of mechanism. Some candidates often wrote a step involving three reacting species, which showed clear misunderstanding of the chemistry. Several G2 comments in fact pointed to the fact that on the syllabus, A.S. 16.2.2, the teacher's note states that examples should be limited to one- or two-step reactions. This is a valid comment and the most plausible suggested mechanism for this reaction in actual fact involves three steps. However, the vast majority of candidates did not even know how to tackle this question, and very few papers were seen where candidates even tried to suggest a mechanism based on two steps. In part (g), most candidates understood the principle of heterogeneous catalysis, and in general the enthalpy level diagram was well presented. However many candidates did fail to label the individual axes. It should be stressed that whenever a graph is required, axes must always be labelled. Some candidates also failed to recognize that the reaction in question was exothermic.

#### Question 2

This question in general was well answered. In part (a), the majority of candidates were able to calculate the concentration of nitric acid. The most common error related to candidates not recognizing the 1:2 stoichiometric ratio between barium hydroxide and nitric acid. Part (b) also was typically well answered. In part (c), for the amount of gas, a large number of candidates incorrectly used 0.01 mol, instead of 0.025 mol.

Units of volume also caused problems for many candidates, and some failed to read the question, which specifically requested to use the ideal gas equation to calculate the total volume in  $\text{cm}^3$ . Converting from  $\text{m}^3$  to  $\text{cm}^3$  posed a problem for several candidates.

### Question 3

In the definition of first ionization energy, many candidates failed to state that the gaseous state is involved. Some incorrectly wrote  $\text{Mg}(\text{g}) \rightarrow \text{Mg}^{2+}(\text{g}) + 2\text{e}$ . While many candidates correctly identified the correct sublevels when comparing the first IE's of magnesium and aluminium in part (b), they did not refer to the higher energy or further distance from the nucleus of the 3p sublevel. Few candidates recognized that removing an electron from a cation would explain the higher third IE of magnesium in part (c), but many correctly referred to the higher energy required to remove an electron from a main energy level close to the nucleus or from a full, stable main energy level. In (d), most candidates were able to write the full electron configuration of cobalt, although a few candidates wrote incorrectly the condensed (abbreviated) form, failing to read the question! The most common mistake with regards to the sub-level from which the electron is removed when the first IE of cobalt is measured involved candidates removing an electron from the 3d level, instead of the 4s level.

### Question 4

Part (a) was very well answered, although some candidates did not write an equilibrium sign. Salt hydrolysis was very poorly understood by most candidates. Although the better candidates were able to correctly identify the pH's in part (b), few of these candidates surprisingly were able to explain the choices based on sound chemical reasoning. In particular, the effect of high charge density of the metal ions was cited only by a small minority.

## Section B

### Question 5

A precise definition of standard enthalpy of formation was rarely given by candidates. Change was often omitted in the definition. In addition, accurate definitions of average bond enthalpy were rarely seen. Many candidates did not mention the gaseous state and only a small minority stated the fact that an average over several similar compounds is involved. In part (b), many candidates were able to determine the enthalpy change for the reaction, although common errors involved candidates using incorrect bond enthalpies and incorrect sign conventions for bond formation and bond breaking. In part (c), the most common error involved candidates using the enthalpy of formation of gaseous instead of liquid methanol. Le Chatelier's Principle was well understood in part (d), but some candidates did not give clear explanations for the shifts in equilibrium. In part (e), words such as standard and change often were omitted. The calculation and interpretation of Gibbs Free Energy was usually well answered by candidates, although some forgot to convert J to kJ. Surprisingly, the mechanism of the  $\text{S}_{\text{N}}2$  reaction in part (g) was poorly answered by several candidates. Many did not use curly arrows to represent the movement of a pair of electrons and the transition state (TS) with partial bonds was rarely seen. The negative charge on the TS also often was omitted.

### Question 6

In part (a), the most common mistake involved candidates not addressing the actual question. In the case of ammonia, the electron domain geometry is tetrahedral, since it involves four charge centres (electron domains) around the central nitrogen atom, whereas the molecular geometry is tetrahedral, since there are three bonding pairs and one non-bonding pair. Many candidates also were not able to explain why the bond angle in ammonia decreases from 109.5 to 107 degrees, due to the fact that in terms of repulsion lone-pair/bond-pair repulsions are greater than bond-pair/bond-pair repulsions. In part (b), again many students did not read the question, and hence failed to cite the tetrahedral electron domain geometry for  $F_2O$  or the octahedral electron domain geometry for  $ICl_4^-$ , based on the electron pair distributions, although many were able to predict the bent and square planar molecular geometries of both species. In part (c), the majority of candidates misunderstood the question and gave a description of the Lewis structure instead of giving the actual Lewis structure of chloroethene. The three non-bonding pairs of electrons around the chlorine were often omitted. The difference between sigma and pi-bonding generally was well understood, but many candidates did not relate this to chloroethene. In (c) (iii), most candidates did recognize the fact that both carbons in chloroethene involve  $sp^2$  hybridization. Application of delocalization principles proved challenging in part (d), as commented by many teachers on the G2 forms, as it involved an unfamiliar example. Candidates often did not identify the atoms/bonds involved in the delocalization and many could not give the effect of this in terms of altered bond strength or bond length. This was evident as many candidates gave the standard C=C bond length for the carbon-carbon length. Part (e) also was found to be very challenging. The vast majority of candidates gave the order, incorrectly as ethene > bromoethene > chloroethene, arguing the fact that since the electronegativity of chlorine is greater than bromine, then the dipole-dipole intermolecular forces of attraction between the molecules will be greater. However, bromoethene has stronger London-dispersion forces and hence bromoethene will have the highest value.

### Question 7

This was the least popular question in Section B and in general was very poorly answered. In parts (a) and (b), candidates struggled to explain physical properties in terms of structure and bonding, with incorrect terminology as well as insufficient detail being common. The half-equation for the oxidation of oxide ions was challenging for many candidates in part (c) and candidates did not always give sufficient information about current flow; electrons and ions were identified, but answers often did not state explicitly where these species travel. In part (d), many candidates were able to cite the correct pH of  $Al_2O_3 = 7$  and in the range 1-5 for  $AlCl_3$ , but very few were able to explain why. For example, many explained a neutral pH for  $Al_2O_3$  due to its amphoteric nature, rather than its insolubility in water. Reference to the hydrated aluminium ion was rare. In part (e), 298 K was generally well known, but 1 mol dm<sup>-3</sup> aluminium sulfate solution, instead of 1 mol dm<sup>-3</sup> aluminium 3+ ions was often incorrectly given. In part (f), the most common errors involved candidates giving reversed equations or giving two reduction half equations. Part (g) overall was very poorly answered. Although some candidates knew that a ligand involves non-bonding electron pairs, very few mentioned coordinate or dative covalent bonding. In addition, although many candidates tried to explain the fact that solutions containing the  $[Zn(H_2O)_6]^{2+}$  complex ion are colourless, based on the full 3d sublevel, whereas those containing  $[Fe(H_2O)_6]^{3+}$  which are coloured involves an incomplete d sublevel, very few were able to relate the latter to the splitting of the d sublevel into two different levels and the fact that light is absorbed due to d to d transitions.

### Question 8

Most candidates were able to explain the fact that butane contains two identical methyl groups in the same chemical environment and two methylene groups in a different chemical environment in relation to its proton NMR spectrum. In (b), the vast majority of candidates managed to explain the fact that a chiral centre is the structural feature responsible for optical isomerism. However, some candidates discussed incorrectly optical isomerism in terms of the reflection of plane-polarized light, instead of the rotation of plane-polarized light. The colour change from orange to green was generally easily identified in part (c), as was the +3 oxidation state of chromium. In (d), the four isomers were correctly identified by most candidates. Some however mixed up A and C, the two primary alcohols. One G2 comment suggested that the question would have been better phrased as: "There are four isomers which are also alcohols, with the formula  $C_4H_9OH$ ," which is a valid comment. In (e), the most common mistake involved candidates not writing three-dimensional diagrams for the optical isomers. Candidates should use where possible three-dimensional tapered bonds in answering this type of question. While most candidates correctly showed the structure of butanone, water was often omitted. In (f), reflux was often given incorrectly instead of distillation. (g) was generally well answered and most candidates were able to draw the structures of the alkenes. Many candidates in part (h) were able to correctly identify E and F, and usually were able to describe their differences in terms of IR spectroscopy. Some mentioned proton NMR but reference to MS was rarely mentioned. Only the better candidates scored full marks on this question, as since the question involved six marks, more than one technique needed to be given in order to answer the question.

### 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:

- Consider the various steps of the common organic reaction mechanisms
- Consider the units and the appropriate number of significant figures for the final answer in calculations
- Always label the axes on graphs
- Learn the common definitions on the syllabus

## Higher level paper three

### Component grade boundaries

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 – 8	9 - 16	17 - 21	22 - 27	28 - 33	34 - 39	40 - 50

### General comments

The range of marks awarded was very wide; most candidates attempted answers to all parts of their chosen options and the best candidates showed a thorough command of the material and a high level of preparation. This session it was pleasing to see more candidates who seemed very familiar with the material in the options than those who scored very poorly. It was evident that in several cases candidates did not study as much as they should, or had studied the option on their own. The most popular options were B, C and D, followed by G and H whereas very few opted for Options E and F. Hardly any candidates attempted more than two options.

Teachers' impressions of this paper were conveyed by the 50 G2 forms that were returned. In comparison with last year's paper, an overwhelming majority (81%) thought this year's paper to be of a similar standard, with most of the remainder considering it more difficult rather than easier. Most respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by 22%, poor by 2% and good by 76%. Clarity of wording and presentation of the paper was considered good by over 80%.

### 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:

- (b) An explanation of *combinatorial chemistry*.
- (c) Effect of the presence of double bonds on melting point of fatty acids; an explanation of the function of *rhodopsin*; an explanation of how the presence of mercury compounds affects enzyme activity.
- (d) Major natural and man-made sources of  $N_2O$ ; the main types of toxic chemical pollutants in water; acid rain as a source of nitrate water pollution.
- (e) The extraction and purification of silicon from silica; free-radical mechanism involved in thermal cracking and ionic mechanism in catalytic cracking.
- (f) The working of an alkaline hydrogen-oxygen fuel cell; the working of the lead acid storage battery; the use of parabolic mirrors to convert solar energy into electrical energy; mode of decay of radioactive isotopes.
- (g) Identification of analytical techniques suitable for various detections or measurements.
- (h) Reaction of 2,4-dinitrophenylhydrazine with carbonyl compounds; dehydration of alcohols; free radical mechanism for the depletion of the ozone due to the presence of chloroalkanes.



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

During this session many excellent scripts were seen, invariably from those who had been taught two options, rather than from those who seemed to have been allocated little teaching time or who had made their choice of options on the day of the examination. Good levels of knowledge, understanding and skill demonstrated in the following areas:

- The social problems associated with the misuse of heroin
- The use of cis-platin to treat cancer
- The action of competitive inhibitors on enzyme-catalysed reactions
- $^1\text{H}$  NMR spectroscopy
- The relative acidities of the substituted carboxylic acids

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

### Option B – Medicines and Drugs

#### Question 1

In part (a), redox reaction was surprisingly a common answer instead of esterification or condensation reaction. In part (b), even though the necessary information is in the Data Booklet, some could not state the differences in structure between morphine and codeine. In part (c), many candidates stated that the main advantage of using morphine as an analgesic was that it is effective. Reference to its **strength** was, however, needed for the mark. Most candidates were aware of the disadvantages of its use. In part (d), most candidates were aware of the social problems associated with the misuse of heroin.

#### Question 2

Part (a) asks for the *type* of drug, and several answered the name of a drug, and it seems the question was not read carefully. Part (b) asks for the effects of nicotine, not of cigarette smoking, yet many students answered the latter. In part (c), a common error was to state a functional group in one of them, but many did not consider the characteristics of the other compound. Also, some had difficulty in recognizing primary and secondary amine.

#### Question 3

Part (a) related to cis-platin was correctly answered by most candidates. Part (b) was partially answered correctly, with some candidates having difficulty in expressing themselves correctly. Some found the chiral nature of thalidomide difficult and the preparation of the drug as a *racemic* mixture was generally not discussed. In part (c), not many candidates had a clear idea of what is meant by combinatorial chemistry.

### Option C - Human Biochemistry

#### Question 1

Part (a) was answered well. The lower marks in (b) were due to the fact that candidates had difficulty in explaining the reason for the lower melting point. Some incorrectly suggested that the difference depends on the amount of energy needed to break a C–C single bond and a

C=C double bond, as if when melting the molecule decomposed. Also mention of 'double bond' in the difference in the structures of the molecules was not sufficient for mark – candidates must refer to the double bond between two carbon atoms. The lower performance in part (c) was either through an inability to determine the number of double bonds, or assuming that 1 mole of fat reacted with one mole of iodine or by using the  $A_r$  of I rather than the  $M_r$  of  $I_2$ .

### Question 2

In part (a), a significant number of candidates identified a methyl side chain as a functional group. Part (b) was generally only half-answered - the presence and effect of the long carbon chain was correctly identified, but the presence/influence of –OH was largely ignored. Part (c) was generally fine, but with some omissions (conversion of light into electrical impulses); the main difficulty was explaining the function of rhodopsin. Most candidates were aware of night blindness as a disease caused as a result of Vitamin A deficiency, but Xerophthalmia was less well known.

### Question 3

Once again, questions which require explaining offered more difficulty. In some cases the explanations were rather difficult to follow. In part (a), most candidates were able to describe the action of competitive inhibitors in enzyme-catalysed reactions. In part (b), only a small minority of candidates were able to explain how the presence of mercury compounds specifically affects enzyme activity and in part (c) there was some confusion with the action of detergents.

## Option D - Environmental Chemistry

### Question 1

In part (a), several candidates answered not specifying if the source was natural or man-made. Few candidates were able to give a major natural and man-made source of  $N_2O$ , and a common error was referring to the production of nitrogen dioxide instead. In part (b), many candidates did not quite understand what the question was asking and made comments about each one contributing to the greenhouse effect instead of referring to concentration and effectiveness of each greenhouse gas. In part (c), the probable effects of global warming on sea levels were well known, but few candidates gave specific effects on agriculture and biodiversity.

### Question 2

Parts (a) and (b) were generally done well although an error, which appeared a few times, was considering that the acid formed by burning coal was carbonic acid. In part (c), many candidates were able to give two methods of reducing acid rain as a result of burning coal.

### Question 3

Part (a) seems to be an easy question, yet not many were able to score the two points. Few candidates were able to give the three main *types* of toxic chemical pollutants in water, for example, some candidates mentioned specific pollutants and many students identified three heavy metals pollutants, not *types* of pollutants.

**Question 4**

This was a very straightforward question and some gave good answers but some others were confused with the order of the layers of air of different temperatures. Also, few candidates identified *surrounding hills* and *lack of wind* as factors in the formation of thermal inversions.

**Option E - Chemical Industries****Question 1**

In part (a), the function of adding limestone to the blast furnace is not just to remove any impurity, but rather silica/acid impurities – this was often not identified. ) Some weaknesses in writing correct equations for the processes were also evident. In part (b), detail was often lacking, in particular two steps were left out, namely the addition of calcium oxide or calcium carbonate, and the reaction to form slag. It felt as if the topic had been studied but it was not fully understood.

**Question 2**

This was generally done well and did not offer much difficulty, although detail was lacking in some answers regarding discussion of the two disadvantages of the use of polyurethane.

**Question 3**

This question presented no real difficulty; nevertheless some candidates were unable to answer it fully. Some were familiar with only part of the stages in the extraction and purification of silicon; for example, the middle stages of the purification process (conversion to  $\text{SiCl}_4$  and subsequent reduction with  $\text{H}_2$ ) were often omitted by candidates. Others only gave a detailed explanation of zone refining.

**Question 4**

This seemed to be a more difficult question, especially trying to show the steps of the two mechanisms. Candidates would have served themselves better if they had written more clearly – they should have dissected the question and (perhaps) answered it in tabular form.

**Option F - Fuels and Energy****Question 1**

Most responses correctly stated the desired characteristics of an energy source.

**Question 2**

This produced weak responses and offered the greatest difficulties; the ability to write correct half-equations, for both the alkaline fuel cell and the lead-acid storage battery, was poorly done.

**Question 3**

Most descriptions of the use of parabolic mirrors to convert solar energy into electrical energy lacked the necessary detail – many candidates were not able to describe how the use of parabolic mirrors eventually produces electrical energy. Again, in this case, they did not seem to really understand the process.

**Question 4**

In part (a), few candidates were able to identify the mode of decay of  $^{67}\text{Cu}$  and  $^{147}\text{Sm}$  isotopes and even less were able to write the nuclear equations. Part (b) to calculate the time taken for a certain decay was correctly answered by a high percentage of the candidates.

**Question 5**

Most candidates were familiar with the characteristics and sources of low and high level radioactive waste.

**Option G – Modern Analytical Chemistry****Question 1**

In part (a), most candidates could not correctly identify all three analytical techniques asked for in the question. In part (b), the principles behind MRI scanners were well understood by many candidates. Part (c) was answered well, although for the description of emission spectra, absorption was given first by some candidates and then they went on to explain absorption separately.

**Question 2**

Generally well answered, but many candidates were unable to give the 3.8ppm chemical shift in ethoxyethane – it was generally quoted as 1.3ppm suggesting that they did not see the presence of the O atom.

**Question 3**

Well answered on the whole, but if there was any omission it was usually that it was not stated that there is a change in dipole moment. The labelling of some diagrams could have been clearer.

**Option H – Further Organic Chemistry****Question 1**

In part (a), the reaction of 2, 4-dinitrophenylhydrazine with carbonyl compounds was generally not understood. In part (b), some listed it as a nucleophilic substitution reaction rather than addition-elimination or condensation reaction. In part (c), only a small number of candidates were able to explain its use in distinguishing between propanone and propanal - frequently when questions are related to practical work these continue to be poorly answered.

**Question 2**

In part (a), few candidates were able to give both conditions of concentrated acid and heat or high temperature needed for the mark. In part (b), few scored full marks. Many candidates had difficulty giving a description of the mechanism for the de-hydration of butan-1-ol. Few students showed the lone electron pair on the oxygen atom in the first part of the mechanism. Also, curly arrows often originated from the incorrect bonds, or still worse, originated from atoms, the carbocation was omitted and the loss of  $\text{H}^+/\text{H}_2\text{O}$  was usually given as a concerted process. In part (c), few were able to explain the why tertiary alcohol undergoes dehydration more readily than a primary alcohol in terms of the stability of the carbocation intermediate.

**Question 3**

On the whole this question was not correctly answered. Very often the explanations were very confusing. Only some candidates answered part (b) correctly (using aqueous ammonia instead of aqueous sodium hydroxide).

**Question 4**

Responses varied enormously. Few candidates were able to give the complete free radical mechanism for the depletion of ozone initiated by chloroalkanes. Usually those who attempted this question were able to write some of the equations for the different steps in the reaction correctly.

**Question 5**

The relative acidity of the substituted carboxylic acids was generally well understood. Some candidates just mentioned how the pKa values varied, but many gave reasonable explanations.

## 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:

- Give answers that involve proper chemistry and not superficial or 'journalistic' answers. Also, avoid the use of everyday or journalistic language, and use correct scientific terms, such as "of lower density" instead of "lighter", and radiation "absorbed" instead of "blocked".
- Practise setting out calculations in a logical way, showing each step, and emphasising the final answer by underlining, as well as paying attention to units and significant figures.
- When writing organic structures, check that the total number of each atom is correct, and each carbon atom has four bonds.
- Practise writing a variety of equations (including ion-electron half-equations and nuclear equations), paying careful attention to balancing and the inclusion of charges and electrons where appropriate, and following the convention of writing mass numbers above atomic numbers to the left of symbols.
- Do not give a long list when asked for a specified number of answers.

**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.

## Standard level paper one

### Component grade boundaries

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 - 7	8 - 12	13 - 17	18 - 20	21 - 23	24 - 25	26 - 29

### 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 68 G2 forms that were returned. In comparison with last year's paper, about two-thirds of respondents felt it was of a similar standard; of the remainder, many more considered it a little easier than a little more difficult. Nearly all thought the level of difficulty was appropriate.

Syllabus coverage, clarity of wording and the presentation of the paper were considered good by about almost all and satisfactory by the remainder.

### 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 89% to 19% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.62 to 0.07. (The higher the value, the better the discrimination).

Comments were made on the following questions.

#### Question 1

See Question 1 in HLTZ2 section.

#### Question 8

See Question 8 in HLTZ2 section.

#### Question 11

In this question, candidates should be able to reject A and B because of their symmetrical shapes. C and D both contain polar bonds and are unsymmetrical, so are both possible correct choices. One respondent pointed out in a G2 comment correctly that the dipole moment of C is actually greater than that of D, although no candidate is likely to have known that. It was therefore decided to accept both C and D as acceptable responses to the question.

#### Question 13

It was suggested that statements II and III were ambiguous or misleading, because it was not clear what "average energy" and "particles" were referring to. Although over half of the candidates chose the mark scheme response (D), this was the least discriminating question

on the paper. In these circumstances it was decided to delete the question. The question was replaced for the published version of the paper.

### Question 23

It was suggested that a knowledge of the pH of sodium hydrogencarbonate, or of the acid and base dissociation constants of the hydrogencarbonate ion, were needed to answer the question. It was, however, the intention of the question that candidates who did not know that this compound formed an alkaline solution should confidently be able to eliminate B on the grounds of insolubility or because it is an acidic oxide, and certainly to eliminate C and D because of their familiar acidic nature. The question was answered correctly by well over half of the candidates, it discriminated well enough, and no one distractor stood out as being much more popular than the others.

## Standard level paper two

### Component grade boundaries

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 - 7	8 - 15	16 - 20	21 - 26	27 - 32	33 - 38	39 - 50

### 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, although this session there were many candidates who scored poorly in either Section A or in their chosen Section B question.

Teachers' impressions of this paper were conveyed by the 59 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 the remainder evenly split between considering it a little more difficult and a little easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage, clarity of wording and the presentation of the paper was considered good by four-fifths or more and satisfactory by the rest.

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

This examination revealed the following weaknesses in candidates' knowledge and understanding:

- the drawing and interpretation of Maxwell-Boltzmann curves
- the application of Le Chatelier's principle
- the connection between electrical conductivity and ionic concentration
- drawing polyester structures
- confusion between covalent and ionic bonding, and between the terms intramolecular and intermolecular
- how to draw clear Lewis structures

- failure to realise that application of the VSEPR requires reference to the numbers of bonding and non-bonding electron pairs (or charge centres)
- failure to distinguish between electrolytic and voltaic cells

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

Once again there were some excellent scripts seen from some candidates, whose answers indicated knowledge and understanding across the syllabus, especially when answers to their chosen Section B question matched the quality of their answers in Section A.

Topics generally well answered included:

- empirical formula and  $A_r$  calculations
- optical isomerism
- calculation of enthalpy changes from average bond enthalpy values
- esterification reactions

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

### Section A

#### Question 1

The only G2 comments on Section A were about this question. It was pointed out that, as the concentrations of the reactants were not changed in the three experiments, then the curves on the graph should level off at the same final concentrations. In reply, it was intended that none of the curves should end up exactly horizontal, although this seemed to be the case for Experiment 3. However, since candidates should have been interested only in the initial rates at time = 0, there was no need to consider the shapes of the curves at longer times. It was also pointed out that the curves for Experiments 1 and 2 seemed to suggest that their initial rates were the same. Judging by the responses seen to (c)(ii), which were invariably correct, there was no evidence that candidates were misled by either of these minor problems. Parts (a) and (b) were generally well answered, as were (c)(i) and (ii), but in (c)(iii) few candidates drew the peak higher and to the left of the original one. In (c)(iv), the majority of candidates drew a second curve, even though the two experiments were at the same temperature. The effect of the catalyst on activation energy in (c)(v) was well known.

#### Question 2

Most attempts at (a) scored full marks, although several errors were seen – omitting any reference to oxygen, dividing by atomic number instead of by atomic mass, and dividing by 32 instead of 16 in the case of oxygen. Few errors were made in (b), other than giving the final answer to three decimal places instead of the two required by the question.

#### Question 3

Most attempts at (a) were successful, with a small minority inverting the expression or inserting a plus sign between the two terms in the denominator. It was worrying to see some expressions in which each element was shown separately, e.g. in the numerator



$[C]^2[H]^5[O][H]$ . Many candidates lost marks in (b) through incorrectly interpreting the significance of the two  $K_c$  values. In (c) marks were lost more through omissions than through errors; "State and explain two advantages..." clearly needs four points to be made, and a surprising number referred to the effect on either rate or equilibrium position, but not both, or correctly stated both effects but did not explain them. It is worth emphasising that when using the collision theory to explain increases in rate, "more collisions" without any reference to time or frequency is not sufficient.

#### Question 4

It was pleasing to see many all-correct responses to (a), but (b) was much less well answered. Although most candidates understood the connection between conductivity and the concentration of ions, many thought that hydrochloric acid was stronger than sulfuric acid, and not all recognised that ethanoic acid was a weak acid. A surprising number described sulfuric acid as a base.

### Section B

#### Question 5

This was the least popular question in Section B, but was answered very well by the better candidates; part (d) caused the most problems, with many candidates being unable to show the  $C_6H_4$  group in the polyester structure ( $C_6H_5$  and a hexagon without a circle were often seen). The only G2 comment concerned part (b), where it was suggested that the final sentence did not clearly indicate what was required. In fact, most candidates realised that the question was just a different example of the familiar conversion of ethanol to ethanal or ethanoic acid and responded accordingly, with many high scores seen.

#### Question 6

Part (a) was often well answered, although not all candidates referred to the electron arrangements of the species involved, especially those of the ions formed. In (b) it was disappointing to see Lewis structures for Br rather than for  $Br_2$ , and some Lewis structures were poorly drawn or showed electrons as dots that were too faint to clearly see. Weaker candidates tended to write about the bonds in or between hydrogen and bromine molecules rather than about the attractive forces between hydrogen bromide molecules. Some otherwise correct answers used "intramolecular" instead of "intermolecular". Part (c) proved no problem for better candidates, although  $Na_3N$  and  $ClO_2$  were occasionally seen. Answers to (d) were disappointing; apart from the errors seen, especially in the shape of the nitrite ion, many answers did not refer to the numbers of bonding and non-bonding electron pairs, even though the question asked candidates to show how the VSEPR theory could be used. Although the question did not ask for diagrams to be drawn, those that were seen were often very small or poorly drawn, with the 3-D shape of the ammonium ion not clearly shown.

#### Question 7

Again, in spite of the instruction to refer to electron arrangements, many candidates failed to do so. In (a), although many candidates wrote that Na loses an electron, there was no comparison of the numbers of filled energy levels in the two species. In (b), the comparison of Na and Mg often referred to the difference in the number of electrons lost when forming an ion, rather than to the different numbers of delocalized electrons. Better candidates did well in (c), although a surprising number had their understanding of oxidation and reduction the wrong way round.

It was disappointing to see several answers stating that the oxidation number of chlorine changed from  $-2$  to  $-3$ . Part (d) was often poorly answered, with many errors and omissions seen. These included drawing two half-cells connected by a salt bridge, labelling the electrolyte as lead bromide solution, using  $Pb^+$  instead of  $Pb^{2+}$  in the equation, omitting the power source, writing equations showing Pb losing electrons and Br gaining electrons; very few clearly distinguished between the flow of electrons through the connecting wire and the movement of the ions in the electrolyte. Five of the seven marking points in (d) could have been scored on a carefully drawn and labelled diagram, but all too often diagrams were carelessly drawn and labelled.

## 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 writing a variety of equations (including ion-electron half-equations and nuclear 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, showing each step, and emphasising the final answer by underlining
- consider the units and the appropriate number of significant figures for the final answer in calculations
- carefully consider how Maxwell-Boltzmann curves change with temperature and a catalyst
- practise applying Le Chatelier's principle in a variety of reactions
- practise writing the structures of all the types of polymer included in the syllabus
- carefully distinguish between the different types of bonding and the use of the terms atom, molecule and ion in appropriate situations
- practise drawing Lewis structures and 3-D diagrams of an appropriate size, and clearly showing the electron pairs
- practise drawing a neat and fully-labelled diagram for the electrolysis of a molten salt

### 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.

## Standard level paper three

### Component grade boundaries

<b>Grade:</b>	1	2	3	4	5	6	7
<b>Mark range:</b>	0 - 5	6 - 11	12 - 17	18 - 21	22 - 26	27 - 30	31 - 40

### General comments

A very wide range of performance was seen - there were some excellent responses and also there were a number of students that were insufficiently prepared for the paper. The major problem continues to be that candidates do not answer questions with sufficient detail and their answers can tend to be journalistic rather than based on chemical principles. All students however followed the rubric and answered two options.

Of the 68 G2s sent in 70% felt that the paper was a similar standard to last year, while the remainder were equally split between the paper being easier and more difficult. The vast majority (96%) of the teachers who responded felt the level of difficulty was appropriate, 3% felt it was too difficult and 1% too easy. Syllabus coverage was considered to be good by 72%, satisfactory by 22% and poor by 6%. For clarity of wording 81% felt it was good, 16% satisfactory and 3% poor. Finally, for presentation of the paper, 89% chose good, 10% satisfactory and 1% poor.

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

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

- The use of I.R. to identify functional groups
- The bonding in benzene
- Outlining the effects of nicotine
- Identifying functional groups and comparing structures of molecules
- Calculating heat released by foods
- Calculations using iodine number
- Rhodopsin
- Sources of  $N_2O$  and its action as a greenhouse gas
- Balanced equations
- Explaining eutrophication
- Electrolysis equations
- Equations for processes occurring in a fuel cell and lead-acid cell

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

This was an accessible paper and the candidates were familiar with the material. Some of the candidates gave very good answers and were obviously well prepared. Most students seemed able to complete the paper in the space given.

The areas which seemed well understood were:

- Mass spectrometry and NMR
- Analgesics
- Social problems caused with heroin
- Structure of fats and link of unsaturation to melting point
- Global warming
- Reduction of iron
- Extraction of aluminium
- Properties of fuels
- Fractional distillation
- Power plants

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

### Option A - Higher physical organic chemistry

#### Question 1

In (a) most candidates correctly stated the value was 88 and were able to suggest suitable fragments for the masses. However, many forgot the + charge and so lost marks. For part (b) many correctly identified butanoic acid and explained satisfactorily and many correctly identified butanal and most of these correctly stated 4 peaks in the ratio 3:2:2:1 in (c). For part (d) many students stated IR was used to find "the bonds" which was not specific enough - the correct answer was to find the functional group. Candidates were generally good at linking IR values to the correct bond, however, they did not always give adequate explanations.

#### Question 2

Most candidates correctly drew at least one correct diagram but did not always explain the diagram in (a). For (b) most students could give one piece of evidence but it was rare for students to give two correct pieces of evidence.

#### Question 3

Most students were able to correctly draw the primary isomer, however many had problems drawing the tertiary isomer. For (b) most candidates identified the slowest step, but not all were able to relate it to step one.

**Option B - Medicines and Drugs****Question 1**

Most students correctly identified hydrochloric acid, although some lost marks because they gave the formula rather than the name and for (b) the balanced symbol equation was correctly written by about half those that attempted it.

**Question 2**

In (a) many students were unable to identify esterification as the reaction type. Many could see that  $\text{CH}_3$  had been replaced by  $\text{OCH}_3$  in (b) and for (c) most candidates knew that morphine was a stronger analgesic but some failed to explain this properly, also most candidates could suggest a disadvantage of addiction or constipation. For part (d) most candidates could suggest two social problems caused by the use of heroin. Occasionally though candidates spoke about the problems to the individual instead, which they could not gain marks for, such as a loss of sex drive.

**Question 3**

Most candidates knew that it was a stimulant but they found it harder to communicate why it was a sympathomimetic drug for (a). For (b) nicotine was correctly identified as the stimulant in tobacco, by the majority. However, they were then asked to outline short and long term effects, which meant more than one effect for each was needed. Also, the effects cited were often very trivial and not acceptable as an answer. For (c) correctly identifying the structural differences proved tricky and although many were able to see the OH group in amphetamine, few were able to see the differences in the amines. In (d) the fact that caffeine is a diuretic was well known but only some candidates could correctly name the amine group.

**Option C - Human Biochemistry****Question 1**

For (a) most candidates could correctly identify the other food groups as fats, minerals and vitamins although some incorrectly suggested fibre or gave examples of particular vitamins or minerals. Most could calculate the energy per gram in (b); however few correctly calculated the temperature rise. Also, a poor use of units meant that marks were lost by students who did correctly calculate.

**Question 2**

The majority of students correctly identified an ester or triglyceride in (a) although fatty acids and soaps were common wrong answers. For (b) the majority of students correctly stated that linoleic was unsaturated, and that the double carbon bonds prevented molecules packing together and so reduced the Van der Waal's forces. Few candidates were able to do the calculation in (c) and most could not see from the formulas that linoleic acid had 4 hydrogens less than stearic acid, and so 2 double bonds. The fact that iodine is diatomic was also frequently overlooked.

**Question 3**

Generally candidates could identify the alcohol and alkene functional groups in (a) although a large number also suggested methyl. Many could suggest vitamin A was fat soluble in (b) but did not explain why or that it could not hydrogen bond with water. For (c) very few candidates correctly identified rhodopsin as the substance needed for vision. Also, few could explain that

it converted light to electrical signals and then sent this message to the brain. However most candidates could identify at least one illness caused by vitamin A deficiency

### Option D - Environmental Chemistry

#### Question 1

Candidates could correctly suggest sources of carbon dioxide in (a) although on occasions their answers were too vague, however, very few could suggest sources of  $N_2O$ . For part (b) only a few candidates could correctly explain the action of  $N_2O$  as a greenhouse gas; many incorrectly explained that it interacted with the ozone layer. In addition, very few understood it was more effective whereas  $CO_2$  was more abundant. Candidates generally did well on part (c) and could state many effects of global warming, however, some answers were far too vague.

#### Question 2

The candidates could generally name sulfuric acid as the cause of acid rain for (a) although a number suggested carbonic acid which meant they got the subsequent questions wrong as well. Part (b) was answered fairly well although a number of candidates did not balance their equations and so lost the marks. Part (c) was not answered well and candidates did not state that sulfur should be removed or suggest alkaline scrubbing or the use of fluidized beds, the answers were generally very vague.

#### Question 3

Eutrophication did not seem to be understood in depth by the majority and it was very rare for a candidate to score full marks for (a). Like many questions in this option answers were far too vague and lacked sufficient detail. For (b) the relationship between temperature and oxygen content of water seemed fairly well understood but few realised that metabolism would increase.

### Option E - Chemical Industries

#### Question 1

For (a) many candidates suggested limestone removed impurities but as the answer required was acidic impurities or silica they could not gain the mark, also they were careless when writing the equation. Most correctly stated that coke was a reducing agent and were able to write a suitable equation. Although many knew that oxygen was added to oxidise impurities of carbon for (b), there was little evidence that candidates knew that limestone was added to remove other impurities.

#### Question 2

Often candidates stated that aluminium was more reactive than iron for (a) but didn't actually answer the question as to why carbon could reduce iron but not aluminium. For (b) that cryolite was used to reduce the melting point of aluminium oxide was well known and that it would reduce the amount of energy needed.

Most candidates knew that the electrodes were made of carbon for part (c) but they had more difficulty writing the correct equations at the electrodes. Some were unable to explain that the carbon electrodes were replaced as they burnt away.

**Question 3**

Most candidates realised that air was blown through the polymer in (a) but many could not give two properties of the polymer. For (b) few candidates could give two problems with disposal of the polymer.

**Option F - Fuels and Energy****Question 1**

The majority of candidates' could list 3 desirable properties of fuels with ease.

**Question 2**

Few candidates could correctly state the equations for what happens in a fuel cell for (a) and for (b) very few candidates correctly stated the equations in the lead/acid cell. Also, very few could suggest that water was added as it was electrolysed during charging.

**Question 3**

For part (a) the candidates knew that the heat was focussed using the parabolic mirrors but few then stated that this was used to heat water to create steam that turned turbines and generated electricity. Few candidates answered the question asked in (b) and so many did not state the disadvantages of the mirrors such as the large space requirement. Many stated that they would not work when the sun wasn't shining which would affect photovoltaic cells equally. For (c) the equation for photosynthesis was quite well known as was the use as a source of food, or to convert to a fuel. Some candidates failed to suggest both as was required by the question though.

**Question 4**

Many candidates could explain that fermentation converted carbohydrates to ethanol that was then burnt. However the decay of organic matter by bacteria to produce methane was not well known.

**Recommendations and guidance for the teaching of future candidates**

- Candidates need to study each option in depth and ensure they know the equations relating to the processes they study
- Candidates should practise writing balanced equations
- Candidates need to read questions carefully to ensure they answer appropriately and precisely
- Candidates should take note of the action verb used and also the mark allocation for the question
- Candidates should prepare for the examination by practicing past paper questions and carefully studying the mark schemes provided