CHEMISTRY

Overall grade boundaries

Higher level

Grade:	1	2	3	4	5	6	7
Mark range:	0-18	19-33	34-48	49-59	60-69	70-79	80-100

Standard level

Grade:	1	2	3	4	5	6	7
Mark range:	0-17	18-32	33-47	48-57	58-67	68-78	79-100

Standard level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-12	13-18	19-20	21-23	24-25	26-29

General Comments

This paper consisted of 30 questions on the Core 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. Because there is no penalty for incorrect answers it is always a surprise when candidates decline to answer one or more questions. On this year's paper every question was left blank by at least one candidate and one question (#30) was omitted by 53 individuals. In all, there were 463 blanks out of 24,584 possible answers (6,146 candidates times 4 responses).

The G2 forms provided teachers with an opportunity to compare this year's paper with last year's. Of the 159 G2s that were returned, 72% of the respondents indicated that the M2005 paper was of a similar standard to M2004. Of the remaining respondents, 16% felt it was a little easier while 12% thought it was a little more difficult. 97% believed the level of difficulty was appropriate while 1% stated it was too easy and 2% stated that it was too difficult. Syllabus coverage was considered good by 61% of the respondents and satisfactory by 36% (3% thought it was poor). The clarity of the wording was deemed good by 47% and satisfactory by an equal number while 6% felt it was poor. The presentation of the paper was considered good by 68% of the respondents and satisfactory by the remainder. Various comments were made about several questions, some of which will be addressed below.

Strengths and weaknesses in individual questions

The difficulty index, D, (the percentage of candidates achieving each correct answer) ranged from 93% to 24% and the discrimination index, d, (a measure of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.43 to 0. (The higher the value, the better the discrimination).

The following comments are made on individual questions, with an emphasis on those questions that seemed especially difficult for students, as indicated by low difficulty indices.

Question 11

This question, with a difficulty index of 46%, asked students to identify the bonds or forces that are broken when ethanol is vaporized (covalent bonds, hydrogen bonds or van der Waals' forces). Although more candidates selected the correct answer (H-bonds and vdW forces) than any other choice a surprising number selected an option that included covalent bonds while many others neglected the vdW forces and chose hydrogen bonds only.

Question 13

This question asked candidates to identify the changes with a large increase in spacing between particles. It was eliminated during the Grade Award process, despite having good statistics ($D = 0.61$ and $d = 0.28$), because the wording was deemed to be potentially confusing. This question had been identified as a problem by an unusually large number of teachers on the G2 forms.

Question 16

This question was the second most difficult with approximately 30% of the candidates answering it correctly. The question asked students to provide the expression for the heat change in Joules from its mass (m), specific heat capacity (c) and increase in temperature (t). The number of individuals who selected the correct answer (mct) was exceeded by the number who added 273 to the temperature change.

Question 18

This question, with a difficulty index of about 38%, sought a correct statement about the sign of ΔG° given that ΔH° and ΔS° were both negative. The largest number chose the correct answer, "It cannot be determined without knowing the temperature", almost as many individuals chose "It is negative at high temperatures and positive at low temperatures". This answer suggests that many students relied on rote memorization of a table that is included in many textbooks rather than thinking about the conditions.

Question 19

This question, which was the most difficult on the paper with a difficulty index of 24% asked candidates which measurements could be used to measure the rate of a reaction between $CaCO_3(s)$ and $HCl(aq)$. Candidates were presented with three alternative methods and asked to choose among three different combinations of two and one of all three. The difficulty index corresponds to random choice and, consistent with this, two incorrect choices drew more responses than the correct one. The discrimination index (0.30) shows that the question was answered correctly by the better students at a significantly higher rate than by others.

Question 27

This question, which had a difficulty index of 39%, asked candidates what happens when molten sodium chloride is electrolyzed. With a discrimination index of 0.04 it was answered equally well (or equally poorly) by better and poorer students. While it is possible that students may have been confused by the designation of electrodes by their signs this form of designation is specified in A.S. 10.3.1.

Standard level paper 2

Component grade boundaries

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

General comments

Overall, it appeared that the Chemistry SLP2 paper in May 2005 was reasonably accessible to most candidates. As usual however, many candidates had problems when it came to providing a valid explanation rather than when something had to be stated explicitly in the form of a definition *etc.* Nevertheless, it did appear that the paper was set at the appropriate level and a good normal distribution was evident. The following report outlines specific points in relation to the paper itself.

The areas of the programme which proved difficult for candidates

Although the level of difficulty appeared to vary from centre to centre, the following areas definitely caused problems for a significant number of candidates:

- Students often had difficulty solving numerical problems. Two prime examples of this appeared in Section A, in particular in relation to the determination of the enthalpy change in 1 (b) and the calculation of the molar mass of the hydrocarbon in 2 (b) (i). In addition, student's treatment of units and constants was weak in both these questions.
- The fluency and exactness of expression in answering collision theory questions often caused candidates to lose points, including even the better students who seemingly had a grasp of the concept. Only the best students were gaining full credit in 4 (a) and 4 (b).
- The theory of VSEPR was particularly weak. Many students were able to deduce the individual molecular geometries of SCl_2 and C_2Cl_2, but failed to understand the principles underlying the theory itself. In addition, many students did not appear to be able to rationalize the idea of an electron-domain geometry, with respect to a multiple-bonded system about a central atom.
- Molecular polarity proved to be the most difficult concept for all students to grasp, and only small minorities of the best candidates were able to rationalize the overall polarity of the molecule in terms of resultant dipole moments.
- Full and correct explanations underlying periodic physical properties such as atomic radii and first ionization energies also were found lacking in many candidates.

The areas of the programme in which students appeared well prepared

The following areas were well answered by candidates:

- calculation of empirical formulae, 2 (a)
- understanding the idea of a limiting reactant, 1 (e)
- harmful effects of CO was well understood, 2 (c)
- writing of structural formulae, 5
- determining the number of subatomic particles from a nuclear symbol, 6, (b)
- general periodic trends in physical properties, 7 (a)

- organic chemistry in general, 8

In addition, most students displayed competent basic mathematical skills. Grasp of the basic fundamental theories in the curriculum was mostly satisfactory. However, a deeper understanding of the rationale behind many theories was seldom evident, and although it could be argued that this paper is standard level, it was generally apparent that there needs to be better preparation by candidates in some of the core areas of chemistry, such as structure and bonding, physical properties, experimental observations, isomerism, exothermic/endothermic reactions and molecular polarity. Treatment of these areas by students was often far too rudimentary, and clear misconceptions were seen on several papers, in particular in relation to the role of electron pairs in VSEPR and the influence of bond dipoles in the deduction of molecular geometries.

Strengths and weaknesses in individual questions

Section A

Question 1

(a) Most candidates stated that there was a rise in temperature, but far fewer were able equate this with the idea of an exothermic reaction, as an answer to part (a). Some candidates even confused the terms exothermic and endothermic. A common mistake made was students stating that the reaction was endothermic, because heat was released in the process!

(b) The majority of candidates were able to explain that the solutions were mixed rapidly so that all the heat will be given out very quickly. However, many candidates incorrectly referred to an increase in the rate of the reaction.

(c) Only the better students were able to correctly determine the enthalpy change of the reaction. Many students were able to give an expression for the heat given out in terms of the specific heat capacity, temperature change and mass, but fewer realized that the mass was that of the solution and began complex calculations involving the relative molecular mass of KOH or HCl. Some candidates expressed the temperature as 3.5+273, and the amount of substance as 0.05 moles *i.e.* the amounts of KOH and HCl collectively. In general, few of the weaker candidates got beyond the first two points for this part of the question, not realizing the inherent difference between an experimental heat change and a molar enthalpy change. A common mistake for the first point seen on many papers was students writing $\Delta H = mc\Delta T$, instead of $q = mc\Delta T = 1463$ J. Some candidates also failed to take into account significant figures and units in this part of the question. Heat loss, and a suitable means of overcoming it, was usually correctly answered in part (c). However, some candidates, suggested using a calorimeter, without referring explicitly to using a lid or using an insulated reaction vessel. Other candidates also gave more general answers such as using a closed system, without further clarification. In addition, a few students suggested using a graph. However, this did not earn credit, as it was expected that exact detail would be given here *i.e.* at least some reference to the nature of the plot itself – *T versus t* graph.

(e) Many students answered this section correctly, and it was encouraging to see students referring to the idea of KOH acting as a limiting reactant in the reaction. Some candidates talked about the rate of a reaction being increased with a higher concentration of acid. Another common mistake was candidates stating the fact that there was no temperature change, when they probably meant that there was no change in the temperature change!

Question 2

(a) The vast majority of candidates were able to successfully determine the empirical formula of the hydrocarbon. A select few gave the formula as C_2H as opposed to CH_2. A minority also worked out the ratio, but forgot to write the formula, thereby losing the second point in the question.

(b) This caused a number of problems for candidates. Most candidates quoted $pV = nRT$, but had difficulty with respect to the choice of the most appropriate value of R, the universal gas constant, with respect to the pressure and volume parameters given in the question. As a result, students who failed to work out part (i) correctly, were not able to determine the molecular formula of the hydrocarbon in part (ii) as C_4H_8, as no ECF was invoked here. Some candidates appeared confused as to what was being specifically asked for and attempted to write the structural formula, as opposed to just simply writing the molecular formula as C_4H_8 which was asked for in the question.

(c) This was well answered by virtually every student. However a minority did refer to carbon dioxide, even though the word incomplete did appear on the question paper in bold type. Another feature of the type of answers seen in this question involved students stating that incomplete combustion of hydrocarbons produces CO, which is harmful to humans. This type of response only yielded one point, as stating the fact that CO is harmful to humans is only restating what is already mentioned in the question. Students had to refer to the toxic nature of the CO *etc*.

Question 3

(a) In this question a few candidates mentioned entropy rather than kinetic theory. Some candidates also referred to the reaction of the ammonia with air, rather than the diffusion process. A lot of candidates appeared to perceive diffusion as a movement of particles from a high concentration to a low concentration, or that it is caused by collisions with air particles. Some candidates also failed to refer explicitly to the fact that the particles or molecules of ammonia are travelling in continuous random motion.

(b) This was very well answered. One obvious omission however, was students not always stating what happened to the time. Equally, a few candidates attempted to explain this question by stating that since this is a chemical reaction, the rate would increase. The key second point here however is that the molecules of ammonia will have a greater rate of diffusion or move faster.

Question 4

(a) Many candidates were aware of the need for the correct orientation of the colliding particles, with sufficient kinetic energy for the reaction to take place. However, fewer referred explicitly to activation energy, and of those that did, many appeared confused as to what exactly activation energy refers to!

(b) Only a small number of candidates gained full credit, even though this type of question has been previously asked on more than one occasion at standard level. Most candidates stated the fact that the particles have an increased number of collisions, but only the better students related this to per unit time *i.e.* increased frequency of collisions. Students did not earn the first point, unless they mentioned explicitly time in their answers. Equally, even if activation energy was discussed, on fewer occasions, did candidates state that increased proportions of particles have energy greater than or equal to the activation energy. Some candidates again mentioned incorrectly the concept of force. Other misconceptions involve the reduction in activation energy or bond strength. Increased pressure was also sometimes used to explain the increase in rate. Some of the better candidates who clearly had a more in-depth understanding of this area included a graph to support their answer, involving $T_2 > T_1$.

Question 5

This question was very well answered. Most candidates were able to draw the structure of butane. Fewer were able to draw and correctly name the structure of 2-methylpropane. A significant minority of candidates lost credit by sketching either repeated structures (usually of butane), or by failing to include all the hydrogen atoms. Students must realize that a stick represents a methyl group in a structure and must not be perceived as a hydrogen atom. The number of students still doing this is smaller than in previous years, but surprisingly small minorities of candidates continue with this incorrect practice.

Section B:

Question 6

Both this question and Q7. were the two most popular questions of Section B. Many candidates scored highly in this question.

(a) Most candidates wrote correct formulas. A minority failed to use the given symbols and tried to produce formulae of compounds such as CO_2 *etc.*

(b) This was very well answered, with virtually every student correctly able to determine all the sub-atomic particles in the ${}^{15}_{7}N^{3-}$ ion.

(c) Students also appeared to have no problem writing the Lewis structure of $SiCl_4$, although a few candidates neglected to write the non-bonding pairs on the four chlorines in the structure. Without any doubt however, the weakest part of the entire paper involved students understanding of the principles underlying VSEPR Theory. Although, this part of Q6 involved only three points, virtually no candidate scored all three, with an alarmingly high number of candidates attempting to explain the theory, but yet failing to score even one point! The misconceptions and mistakes here were rife. Many candidates talked about repulsion between bonds or atoms; others failed to refer to the number of electron pairs about the central atom and some candidates tried to answer the question by choosing a single geometry (such as trigonal planar) and work their way through an example of same! Surprisingly then, the better candidates were able to determine the molecular geometries of SCl_2 and C_2Cl_2 as V-shaped and linear respectively. However, VSEPR Theory obviously needs a much more rigorous treatment by students and teachers in the programme as a whole. Some candidates still do not appreciate the difference between electron-domain geometries and molecular geometries. Equally, one wonders whether students really appreciate why in the Lewis structure of a multiple-bonded system, in the multiple bond about the central atom, only the sigma bonding framework is considered. This point can easily be explained and understood at a basic level, and hence should eliminate some of the confusion perceived by candidates in this area. In addition, some candidates described the structure of SCl_2 as bent linear. Although, candidates obviously understand the molecular geometry involved here (and gained the appropriate points), the term bent alone should be encouraged in class.

(d) In part (ii), most candidates appeared to understand little the idea of molecular geometry. The most common mistake involved students confusing the idea of bond polarity and molecular polarity. If students had a good three-dimensional appreciation of the geometries they deduced previously for SCl_2 and C_2Cl_2, then derivation of the molecular polarity for each compound should be relatively easy *i.e.* in each case, the molecular polarity is determined by vectorially summing the individual bond dipoles, to yield a zero or non-zero dipole moment. A variety of techniques can be used to help students in this regard, such as simple models (even using match-sticks or balloons), molecular graphics, or even using the mental concept of rope-pulling – every avenue should be explored to look carefully at a selection of molecules listed on the curriculum, with respect to determining their molecular polarities. If candidates were stronger in both VSEPR and polarity, this section of question six could have resulted in a candidate gaining an easy 9-12 points.

Question 7

This question was very popular and well answered by a significant number of candidates with many scoring highly.

(a) The vast majority of candidates in part (a) (i) and (ii) were able to state the trends in atomic radii and ionization energies for the group 1 metals and the period three elements. However, this was not surprising as this simply involved using the data booklet in each case. The real problem involved students citing an accurate explanation of the reasons underlying such trends. Although some students did get partial credit here, the vast majority did not get full points, due to the fact that a deeper understanding of the reasons was beyond a lot of candidates. A typical example of this type of partial understanding included students failing to state the fact that the full energy levels are occupied in the case of the increasing atomic radius on traversing down group 1. Equally, terms such as bigger nucleus do not equate with increasing nuclear charge. Although the paper is standard level, the really well prepared candidates did talk about concepts such as an increased shielding effect, which displayed a deeper chemical understanding.

(b) Most candidates had no trouble listing three similarities and one difference in relation to the reactions of lithium and potassium with water. Some candidates failed to read the question correctly and attempted to describe the similarities in atomic structure between Li and K. In part (ii), the reactions were well known, although equations were often incorrectly written, with a significant number of students listing H^+ as a product as opposed to H_2. A few candidates stated that the pH would be acidic or just greater than 7, but not specifically equal to or greater than 11. Students also lost points if they failed to mention the fact that LiOH or KOH was a strong base. Surprisingly, some candidates gave the reaction of Na instead of K! Another common mistake involved students writing metal oxides as the products, as opposed to the corresponding metal hydroxides.

(c) This was satisfactorily answered, with the great majority of candidates knowing that aluminum oxide was amphoteric, sodium oxide basic and sulfur dioxide acidic.

(d) The equations proved troublesome to the weaker candidates, who often had difficulty giving the correct formula of sodium oxide. There also was a tendency to cite incorrect products or additional by-products in the equations such as H_2 and H_2SO_4.

Question 8

This was the least popular of the optional questions in Section B, but interestingly was often selected by the better candidates, and consequently scored highly. The general standard of comprehension of organic chemistry was very satisfactory by those candidates who attempted this question.

(a) The nomenclature and structural formulas were well answered, although some candidates were confused in the naming of the two possible esters.

(b) Many students did mention the idea of hydrogen bonding in trying to explain the solubility of propanoic acid in water. However, a significant number failed to state the fact that propanoic acid explicitly forms hydrogen bonding with water. Some tried to explain solubility and acidity with reference to a chemical reaction. Most candidates were successfully able to write the reaction of propanoic acid with sodium hydroxide to give sodium propanoate and water in part (b) (ii). However, in part (iii), many students mentioned the fact that the two esters do not react with bromine, due to the double bonded nature of the compounds. This was not enough, as the critical point here involved the fact that there is no C=C bond present in either species. Most candidates also were able to state and explain why propanoic acid has the highest boiling point of the three compounds, citing the reason of intermolecular hydrogen bonding in the acid. Some of the better candidates even sketched a drawing of the hydrogen bonding network, and clearly did not confuse the polar covalent O-H bond with the intermolecular force which showed good understanding in this area. Additionally, nearly all candidates could identify two of the compounds as esters and most had a very good knowledge of esterification.

(c) Credit was lost by some candidates who used the term bromination as opposed to the correct answer of addition in response to the type of reaction involved. Another common mistake involved students stating discoloured instead of decolorized in relation to the observation that can be made during the reaction, on addition of the bromine.

Assistance and guidance for future candidates

The main recommendation for teachers should involve a much greater emphasis on core chemical concepts in the SL curriculum. The following areas were found to be particularly lacking in this session's SL P2:

- General structure and bonding.
- Explanation of trends underlying physical properties, such as atomic radii and ionization energies
- Collision theory
- Experimental observations
- Calculations based on enthalpy change
- Calculations involving molar mass determination

In relation to structure and bonding, many of these points have been made explicitly in the report on individual questions above. However, teachers are strongly encouraged to give a much greater emphasis on the following sub-areas:

(a) Principles underlying VSEPR Theory

(b) Difference between electron-domain and molecular geometries

(c) Difference between bond polarity and molecular polarity

A variety of different teaching techniques can be used for most of the above, depending obviously on resources available in individual schools. However aids such as simple self-constructed student models (match-sticks, balloons), commercially available 3D chemical models, molecular graphics programmes could make a huge difference in students understanding of three-dimensional shape. In addition, teachers should look more closely on how they teach molecular polarity. The main emphasis here should be on the determination of the resultant dipole moment from the vector addition of individual bond dipoles. On many papers, students were stating that SCl_2 was polar, due to the fact that it was non-symmetrical. Although, one clearly understands what the student is trying to say, this type of language can be ambiguous at a deeper level (for example SCl_2 is symmetrical, in that it involves a C_2 rotational axis), and hence teachers should try stray away from this type of argument.

Standard level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-6	7-12	13-17	18-21	22-26	27-30	31-40

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 many candidates seemed unfamiliar with the options answered and scored very poorly. Hardly any candidates attempted more than two options.

Teachers' impressions of this paper were conveyed by the 136 G2 forms that were returned. In comparison with last year's paper, three-quarters thought this year's paper to be of a similar standard, with slightly more of the remainder considering it easier rather than more difficult. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by nearly a half and good by most of the rest. Clarity of wording was considered good by over half and satisfactory by the remainder. The presentation of the paper was considered good by two-thirds and satisfactory by the remainder.

Difficulties for candidates

Many of those who chose Option A did not score well, showing difficulties with recalling the meanings of terms and providing adequate explanations; the use of curly arrows in reaction mechanisms still causes candidates difficulties. In Option D there were again many answers written in a journalistic style, and evidence of considerable confusion between the greenhouse effect and issues to do with the ozone layer. Relatively few candidates attempted Option E. Parts of Option F were problematic, with Question F3(a)(i) being perhaps the question answered least well.

Knowledge, understanding and skills demonstrated

Again, this year, there were some excellent scripts seen from some centres, mostly those where all the candidates had answered the same two Options. 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.

Strengths and weaknesses in individual questions

Option A – Higher physical organic chemistry

Question A1

(a) Most candidates managed the two marks for the structures of the organic starting material and product, but very few scored both of the other two marks – the curly arrows were often carelessly placed, and the transition state often contained two or more charges instead of the overall single minus charge needed.

(b) Most realized that the rate would increase but few actually stated that it doubled.

Question A2

Many candidates scored both marks here, although some answers referred to the difference in reactivity between chlorine and bromine, and predictably wrote that the reaction of 1-chlorobutane was faster because chlorine was more reactive than bromine.

Question A3

(a) This was often correct, with just a few failing to include the bonds responsible, or selecting the wavenumber range for acids instead of alcohols.

(b) This was well attempted, with the commonest error being to assume that the two CH_2 groups contained protons in the same chemical environment.

(c) This was also well attempted, although some answers were not precise enough to score full marks. For example, it is not sufficient to state that infrared spectroscopy identifies the types of bond present, without also stating that the bonds are the same in both propan-1-ol and propan-2-ol.

Question A4

(a) Most candidates had the correct reactants and products, but a surprising number did not balance the equation.

(b) The term *activated complex* was poorly described, and several candidates referred to activation energy in their answers.

(c) This was generally well attempted, although some answers to (c)(ii) explained the meaning of the term *molecularity* without giving its value in this example.

Option B – Medicines and drugs

Question B1

(a) Although most candidates realized that the neutralization of an acid was involved, many did not refer to the acid in the stomach.

(b) The equations required were often correct, although it was not always stated which of the two hydroxides would be the more effective. Some wrote that magnesium hydroxide would be more effective because it was a stronger base than aluminium hydroxide.

Question B2

Most candidates attempted all parts of this question, with varying degrees of success. The general problem for many was the use of too colloquial or journalistic language – "kills the pain" or "bad for the liver" are not likely to score marks.

Question B3

(a) A common error was to state that broad-spectrum antibiotics were effective against more bacteria, instead of against a greater variety of bacteria.

(b) There were many good answers with most mentioning the prevention of cell wall formation, although several of those who mentioned developing resistance to antibiotics suggested that it was human beings rather than bacteria that developed the resistance.

(c) This was not well answered, with relatively few mentions of increasing resistance to the penicillinase enzyme.

(d) The best candidates did well, although there was a tendency to describe useful bacteria with journalistic terms such as "good" and "friendly".

.

Option C - Human biochemistry

Question C1

(a) Most candidates referred to double bonds, but often not to those between carbon atoms.

(b) This question revealed several problems, including the mention of hydrogen bonding and of the breaking of covalent bonds.

(c) Some candidates seemed well practised in thermochemical calculations and scored full marks, while others scored little or nothing. Common mistakes included adding 273 to the temperature change, using 5 or 1005 instead of 1000 for the mass of water, and stopping at the experimental heat change instead of continuing to the molar enthalpy change.

(d) This was well attempted.

Question C2

(a) There were several mistakes in the answers to what was a straightforward question. It was often stated that vitamin C was water soluble but vitamin D was not, and that there was hydrogen bonding in vitamin C but not in vitamin D, without clearly stating that vitamin D was fat soluble or identifying the intermolecular forces in D. Vitamin C was described as having OH bonds/groups, without stating that there were more than in vitamin D.

Question C3

Most candidates scored at least 1 mark here, but sloppy language cost many marks. For example, the fact that anti-cancer substances can be incorporated into GM foods was acceptable, "cures cancer" was not. Others did not distinguish between crops and foods, leading to confusions such as "they last longer on the shelf because they are not attacked by insects".

Option D - Environmental chemistry

Question D1

(a) Most candidates correctly identified two greenhouse gases.

(b) Explanations were disappointing, being full of unacceptable journalistic terms. The radiation is not reflected or bounced off, but absorbed and re-radiated. The gas molecules, and especially the bonds in them, were rarely mentioned.

(c) Answers were variable, but several candidates stated that particulates absorb energy radiated from the earth's surface and so contribute to global warming.

Question D2

(a) Many candidates overlooked the "natural" in the question and gave equations involving various pollutants.

(b) Most candidates identified CFCs and a suitable source.

(c) It was good to see that many candidates realized that fluorocarbons do not release radicals, although for the disadvantage a common error was to state that "they" were flammable, without a reference to hydrofluorocarbons (fluorocarbons being non-flammable).

Question D3

(a) Most candidates seemed familiar with waste water treatment, although some errors were noted; the commonest were to omit the use of both bacteria and oxygen in secondary treatment, or to state that bacteria were removed.

(b) Errors were more prevalent here, for example the removal of metals (without the "heavy") or mentioning the removal of aluminium. There was some confusion about what was being added and what was being removed (eg adding phosphate ions to remove aluminium ions). "Nitrogen" and "oxides of nitrogen" often appeared instead of "nitrates".

Option E - Chemical industries

Question E1

Generally poorly answered, with most candidates not clearly indicating that they knew the structure of polypropene; some of those who chose to draw a diagram gave $–(–CH_2–CH_2–CH_2–)–$ as the repeating unit. Sometimes the properties given were contradictory (eg tough and flexible) and the molecular packing was sometimes overlooked.

Question E2

(a) The use of plasticizers was not well known.

(b) Most could give a common disadvantage, but not one specific to PVC.

Question E3

(b) Quite a few candidates did not refer to the given metals, and others based their answer on the presence of impurities rather than differences in reactivity.

Question E4

Good answers to this question were rare.

(a) Many candidates stated that the main impurity in iron ore was carbon.

(b) The ion-electron equations for the electrolysis of aluminium were often flawed (the wrong way round, electrons on the wrong side, unbalanced, Al^{2+} instead of Al^{3+}).

(c) A common error was to state that cryolite lowered the melting point of aluminium.

Option F - Fuels and energy

Question F1

This question was well answered by the majority of candidates.

Question F2

(a) This was poorly answered, with few references to fuels.

(b) The commonest error was to make the same point twice (e.g. direct combustion causes much pollution, then burning ethanol causes little pollution). Also cost is acceptable in an answer, but only if qualified (i.e. photoelectric cells cost little to maintain, but are expensive to produce for their power output). It is also not true to say that they do not work when it is cloudy.

Question F3

(a) This question was poorly answered by the majority. Very few identified both electrodes, not even lead, and most equations were not relevant. Reduction at the negative electrode was often given.

(b) This was better answered.

Assistance and guidance for future candidates

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

- to realize that for most substances containing covalent bonds, melting and boiling involve the breaking of intermolecular forces and not covalent bonds
- to practise setting out calculations in a logical way, including a few words to indicate what process is being used
- to avoid the use of journalistic language (especially in Option D) and use correct scientific terms (such as radiation being absorbed and emitted or re-radiated, rather than being reflected or bounced off)
- practice drawing structures for polymers with side groups (formed from monomers such as propene and chloroethene).

Any candidates taught more than the two Options required for the examination should concentrate on two as the examination approaches.

Higher level paper 1

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-10	11-17	18-25	26-28	29-31	32-34	35-40

General comments

This paper consisted of 40 questions on the Core 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. Despite the fact that there was no penalty for incorrect answers, almost every question was left blank by two or more candidates and three were omitted by more than 40 candidates.

The 151 G2 forms that were received conveyed teachers' impressions of this paper. In comparison with last year's paper, 65% of the respondents felt that it was of a similar standard, with the remainder being about evenly divided between a little easier (15%) and a little more difficult (18%). 94% indicated that its level of difficulty was appropriate with the remaining opinions being evenly divided between too easy and too difficult. Syllabus coverage, clarity of wording and presentation were judged to be satisfactory or good by more than 90% of the respondents. 18 of the 40 questions elicited specific comments from teachers and a few questions prompted criticisms by multiple individuals. Specific questions will be discussed below, with an emphasis on those questions that presented candidates with the greatest difficulty.

Strengths and weaknesses in individual questions

The difficulty index (the percentage of candidates achieving each correct answer) ranged from over 93% to 35%. The discrimination index (a measure of the extent to which questions discriminated between high- and low-scoring candidates) ranged from 0.46 to 0.

The following comments are made on those questions with difficulty indices below 46%. These are 19 (35%), 27 (37%) and 31 (45%).

Question 19

This question, which was also on SL P1, asked candidates which measurements could be used to measure the rate of a reaction between $CaCO_3(s)$ and $HCl(aq)$. Candidates were presented with three alternative methods (mass of flask and contents, pH of the mixture, and volume of carbon dioxide) and asked to choose among three different combinations of two and one of all three. It proved to be the most difficult question at both levels, with the performance at HL being better than that at SL.

Question 27

This question asked candidates to identify the solution (of HCl, NaCl, $MgCl_2$ and $AlCl_3$) with the highest pH. The correct answer, NaCl, corresponds to the substance containing the cation with the lowest charge density and, therefore, the least likely to undergo hydrolysis (A.S. 18.4.1). The question was intermediate in its discrimination (d = 0.29).

Question 31

This question was an exercise in balancing an oxidation-reduction equation;
$SO_2 + H_2O \rightarrow H_2SO_4$. It had the highest discrimination index on the paper (0.46), indicating that the stronger candidates performed significantly better on it than did the less able ones. The second most popular answer (after the correct one) placed electrons on the left side of the equation, which could have been eliminated based on a consideration of oxidation numbers. Although there are several different ways to balance redox equations, the least confusing is the ion electron method (balancing atoms of the oxidized species, oxygen, and hydrogen in that order, and using electrons to balance the charge). Teachers are encouraged to have their students practice this skill.

Higher level paper 2

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0 – 13	14 – 27	28 – 40	41 – 49	50 – 59	60 – 68	69 – 87

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 explanations 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 138 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, three-fourths felt that it was of a similar standard, with slightly more of the remainder of respondents considering it more difficult rather than easier. Almost all respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by half and good 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 over two-thirds and satisfactory by the remainder.

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

- VSEPR theory
- Colour of transitional metal compounds
- 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
- Addition polymerization
- pH of a buffer solution
- Writing a correct chemical equation.

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_f^0 and ΔG^0 value
- Writing rate expression
- Writing structural formulas of isomers
- Kinetic molecular theory
- Ideal gas equation
- Drawing Lewis structures
- Calculation of empirical and molecular formula
- Oxidation of primary alcohols

Strengths and weaknesses in individual questions

Section A

Question 1

(a) Most candidates managed the equation although some overlooked the single oxygen atom in phenol and few candidates did not use the simple whole number ratio.

(b) A number of candidates found this challenging. Common errors were omitting the negative sign and not using the coefficients from the equation.

(c) Candidates managed this calculation but a number of candidates failed to convert units from J to kJ. Quite a number used the correct method, scoring two marks but some lost both marks through units and significant figures penalties.

(d) This part was also well done although some candidates were reluctant to state that it would become even more non-spontaneous.

Question 2

(a) The calculation in this part was usually correct, although with a minority working out the ratio (C_7H_{14}) but not writing the empirical formula.

(b) Those candidates who used the molar volume of a gas at STP usually had no problem with the calculation of the molar mass of the hydrocarbon but those who used PV=nRT often ran into problems with units especially when using R in J/K.mol. Some candidates attempted to write structures in (b) (ii), confusing molecular with structural formulas.

(c) Most candidates were successful in this part but with a minority referring to carbon dioxide, even though the word *incomplete* in the question was in bold type. The weaker candidates tended to repeat the question and responded by writing that the products produced from incomplete combustion were 'harmful to humans'.

Question 3

(a) Many candidates demonstrated a good knowledge of the kinetic molecular theory. A common omission, however, was that molecules/particles are in constant/rapid /random motion.

(b) Some candidates did not refer to the change in time for detection even though they recognised that particles would gain kinetic energy. Some stated an increase in energy, rather than more specifically referring to kinetic energy or speed of particles and some wrote that rate of reaction increases.

Question 4

(a) This part was usually correct, although with a substantial minority writing a second order equation, no doubt because of the coefficient in the stoichiometric equation. A number of candidates wrote an equilibrium law expression.

(b) The definition of half-life was generally well known but some referred to the decrease in the amount of product.

(c) Some candidates thought that the half-life was proportional to the concentration.

(d) This part was out of syllabus and was therefore deleted.

Question 5

(a) Structures, naming and classification of the isomers of C_4H_9Cl was generally well done. Common errors, however, included; drawing the same isomer twice, missing hydrogen atoms, punctuation errors, for example, use of commas instead of dashes, incorrect numbering of methyl and/or chloro groups, non-alphabetical order of groups and incorrect classification of some isomers. Some candidates drew correct structures but then failed to name and/or classify them. (The mark scheme was adjusted to allow for the optical isomer but was rarely mentioned by any candidate).

(b) Some candidates gave salt as the product of nucleophilic substitution of a chloroalkane with sodium hydroxide.

(c) The primary isomer was given as often as the tertiary isomer, but the meaning of S_N1 was generally well known. In part (ii), some candidates gave an equation for the overall reaction, rather than the rate-determining step and some incorrectly gave the rate expression. Many included the hydroxide ion demonstrating a lack of understanding in this area.

Section B

Question 6

(a) Few candidates could write an equation for the reaction between ammonia and sulfuric acid. Subsequent calculation of the concentration of the ammonia solution was generally well done, albeit with errors carried forward.

(b) The candidates who recognized that the reaction was a strong acid/weak base usually had no problem but those who considered the reaction as a straight forward acid/base picked phenol red as a suitable indicator for an equivalence point of around $pH = 7$.

(c) Few candidates were affected by the discrepancy between the pK_b values in the question paper and in the data booklet, although few scored full marks. In most cases, the calculation was poorly set out, and some errors were caused by incorrectly quoting or rearranging the K_b expression and attempts to calculate *pH* rather than *pOH*. Only the most able candidates were able to calculate *pOH*.

(d) Candidates generally had a good understanding of the buffer solution as well as the composition of an acidic buffer. Calculation of the *pH* of a buffer solution, however, was poorly done with many having difficulties. Some calculated the number of moles of acid and base, but did not then realise the consequence of the excess base. Few stated that the concentration of ammonia was equal to that of ammonium ions. Others attempted to calculate *pH* based directly on the concentration of HCl given (ignoring that all of this acid would react with the ammonia). An attempt to use K_a rather than K_b was also common.

(e) Most candidates could explain the meaning of each, with the exception of a Lewis acid, but many had difficulty writing suitable equations. For example, some showed ammonia reacting as a Bronsted-Lowry acid with water. Copper ions were shown reacting as a Lewis acid with oxide ions. Often, candidates gave equations that did not include the species given and some had trouble identifying conjugate acid-base pairs.

Question 7

(a) Most candidates wrote correct formulas although several showed the charges separately from the formula of WY – the best candidates wrote $W^{3+}Y^{3-}$. Few failed to use the given symbols, and tried to produce formulas of compounds such as CO_2.

(b) This part was poorly done, with very few candidates scoring three of the several possible points. Common errors were to make no mention of a central atom or of electron pairs, and to refer to repulsion between atoms or bonds rather than electron pairs. Many, however, correctly stated that a lone electron pair exerts greater repulsion than a bonding pair.

(c) Many candidates were able to correctly apply the VSEPR principles to the examples in this part. Most Lewis structures were correct, although often poorly drawn, and sometimes missing the non-bonding electron pairs. Even those who had correct Lewis structures to work from, made errors in the shapes – PCl_3 often appeared as trigonal planar, and PCl_5 with a bond angle of 72°. In some cases, "trigonal" was often missing from trigonal pyramidal/bipyrimidal. The explanations of polarity (or lack of it) were less well done, and some attempts contained the term *electronegativity* but not *polar* or *polarity*. Only the best candidates could explain why $POCl_3$ was both symmetrical and polar.

(d) Many candidates incorrectly defined hybridization as the promotion of electrons rather than the combining of atomic orbitals. In part (ii), while many correctly compared double and single bonds in terms of bond length and strength and correctly stated the type of hybridization shown by *each* carbon atom, only the better candidates could clearly describe the formation of sigma and pi bonds in terms of orbital overlap.

Question 8

(a) The trend in ionisation energy across a period was well known and explained. In part (ii) however, some could not explain the two exceptions (Al and S). In particular, the better candidates only mentioned the electron-electron repulsion in S. Some candidates gave both exceptions but no explanations.

(b) This part produced disappointing answers. Candidates tried to explain the properties described in terms of electronic configurations rather than structure and bonding. In part (i), while some recognized a greater positive charge or more delocalized electrons in magnesium, this was not then linked to the strength of the metallic bond. In part (ii), several referred to silicon (IV) oxide instead of silicon. In part (iii), many stated that chlorine's higher boiling point was due to the energy required to break its *covalent* bond or *dipole-dipole* bond, which was not present in argon. There were many references to reactivity, along the lines of "argon has a lower melting point because it is less reactive than chlorine". Few mentioned the impact of the higher molar mass of Cl_2 on Van der Waals forces.

(c) Many candidates did not refer to bonding type of both compounds. Even the difference in conductivity was not precise ("NaCl is a better conductor than $SiCl_4$"), and the movement of ions was often missing. Many discussed aqueous solutions rather than the molten state. In part (ii), the pH of NaCl was often correctly given, but few could explain this in terms of lack of hydrolysis. Many candidates stated that NaCl is neutral because it forms NaOH and HCl when dissolved in water. The reaction of $SiCl_4$ with water was not well known and quite a number failed to predict a pH value, giving a wide range or a description such as "a low value" or "an acidic value".

(d) Many candidates gave both oxidation states shown by iron but some referred to the loss of 3d electrons before 4s electrons. Explanation of coloured d block compounds demonstrated a very poor understanding. Many described electrons jumping between energy levels rather than within split d orbitals. Many confused this with emission spectra referring to emission of colour when electrons return to ground state rather than electrons absorbing (with subsequent reflection) wavelengths of visible light.

Question 9

(a) The definition of dehydration was often given as ‘removal of water’ without reference to a compound or molecule. Many candidates omitted the word *concentrated* when quoting a dehydrating agent such as sulfuric acid.

(b) This part was well answered with the main errors being, omission of 1 in naming of 1-propanol, missing hydrogen atoms and the inclusion of an ether rather than propene as the product of dehydration.

(c) Some candidates gave too few peaks in NMR spectra, for example stating that all H atoms in CH_2 groups were equivalent in 1-propanol. In part (ii), almost all candidates gave correct IR absorptions.

(d) The addition of bromine to propene was well done, although some did not name the product while others omitted the numbers in the name of the product. Some candidates stated that the bromine solution became clear rather than colourless. Choosing the chiral carbon was very well done although some candidates did not then state the *property* that a chiral atom gives to the molecule-instead they described a chiral atom (in terms of four different groups etc)

(e) Addition polymerisation was well known but many candidates had difficulty drawing the addition polymer. Polythene was a common incorrect structure.

(f) Oxidation of alcohols was also well known in terms of products and conditions required. The main error was the omission of *acidified* when quoting an oxidising agent such as potassium dichromate. In some cases, specific conditions were missing.

Assistance and guidance for 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 correctly address all points. Working must be shown for all calculations so that the chance of obtaining ECF marks is maximised.
- Candidates must ensure that they cover a sufficient number of different points to score the full range of marks assigned to each question.

Higher level paper 3

Component grade boundaries

Grade:	1	2	3	4	5	6	7
Mark range:	0-7	8-15	16-22	23-27	28-33	34-38	39-50

General comments

As in previous years students tended to score approximately equal marks on the two options they answered. This suggests that there was good parity between the different options.

The areas of the programme that proved difficult for candidates

There is some evidence that students are not covering the details of each option fully. For example, the questions on the lead storage battery in Option F were not answered well and the problems associated with particular heavy metals in Option D were not well known. There seems to be no evidence that students who answer questions involving recall do better than those answering questions where more interpretation is required. Thus options that superficially appear to be easier such as Option B - Medicines and Drugs do not produce higher marks than Option G - Modern Analytical Chemistry. Even though it is stated every year, some students still lose marks by giving answers that are far too superficial or contain little chemistry. For example, many students still talk about the Earth reflecting the incoming radiation from the sun and omit to mention that it is the vibration of bonds within the greenhouse gas molecules that causes them to trap the longer wavelength radiation emitted from the Earth. Some students still have difficulty in explaining that for most substances containing covalent bonds, melting and boiling involve the breaking of intermolecular forces and not covalent bonds.

The levels of knowledge, understanding and skill demonstrated

Good candidates displayed both a good factual knowledge and an ability to use their knowledge and understanding to answer Objective 3 type questions. This year calculations on enthalpy of combustion (Option C), half-life (Option F) and the ability to interpret spectra (Option G) were generally all answered well by the candidates who attempted them. The paper discriminated well between candidates and the better candidates gave some excellent answers showing that they had been well prepared. Candidates from centres where students opted for different combinations of options tended to show less detailed knowledge compared to those where most candidates chose the same two options to answer. It is clearly in the candidates' interest for teachers to cover two options thoroughly rather than allow their students to study a variety of the options on their own.

Strengths and weaknesses in individual questions

Option B - Medicine and drugs

This option was generally answered well although some candidates are still providing more general answers rather than the precise answers required to score maximum marks.

Question B1

(a) Many candidates knew that mild analgesics prevent the transmission of pain at the source of the injury but fewer were able to explain how they do this by interfering with the production of substances such as prostaglandins which cause pain. Similarly in the second half of B1(a) many omitted to state that strong analgesics prevent the transmission of nerve impulses.

(b) The questions on aspirin were answered well by many candidates with only the synergistic effect of combining aspirin with ethanol causing some problems.

Question B2

This question on penicillins also distinguished well between those candidates who knew the underlying science rather than just the superficial answers. Some talked vaguely about broad-spectrum antibiotics being used when the cause of the disease was not known rather than stating that they are effective against a wide range of bacteria compared with narrow-spectrum antibiotics which are only effective against certain types of bacteria. Most knew about the effects of over prescription of penicillin in terms of increased resistance but often failed to mention that they destroy useful bacteria as well.

Question B3

(b) The chiral centre in adrenaline was identified correctly by many candidates but the question on the use of chiral auxiliaries was not answered well. Some candidates confused this with cis- / trans- isomerism and many did not state that the chiral auxilliary is itself optically active.

Question B4

(a) Many candidates did not recognise that both LSD and mescaline are hallucinogenic drugs and often had problems distinguishing between their effects.

(b) Surprisingly some candidates were unable to compare properly the similarities and differences between the structures of the two drugs. Some gave trivial answers like ‘contains a C=O bond’ rather than, for example, distinguishing between an amide and an amine or stating that mescaline contains ether groups.

Option C - Human biochemistry

Question C1

(a) Most candidates correctly stated the major structural differences between saturated and unsaturated fats although it was necessary to refer specifically to carbon when mentioning single or double bonds to gain the mark.

(b) There was less certainty as to why palmitic acid melts at a higher temperature than linoliec acid. Although the fact that linoleic acid chains are more ‘kinked’ was often mentioned an explanation as to how this affects the melting point in terms of closeness of packing and van der Waals’ forces was less forthcoming.

(c) Most students were able to calculate the calorific value of the oil correctly although a few are still confusing the mass of the sample with the mass of the water in the expression $q = mc\Delta T$.

Question C2

There were several mistakes in the answers to what was a straightforward question in C2. It was often stated that vitamin C was water soluble but vitamin D was not, and that there was hydrogen bonding in vitamin C but not in vitamin D, without clearly stating that vitamin D was fat soluble or identifying the intermolecular forces in D. Vitamin C was described as having OH bonds/groups, without stating that there were more than in vitamin D.

Question C3

Most candidates scored at least 2 marks on the benefits and concerns of using genetically modified foods, but sloppy language cost many some marks. For example, the fact that anti-cancer substances can be incorporated into GM food was acceptable, "cures cancer" was not. Others did not distinguish between crops and foods, leading to confusions such as "they last longer on the shelf because they are not attacked by insects".

Question C4

Candidates had more difficulty with this question with many not interpreting the graph correctly and omitting to include the units in the answers for $V_{\max}$ and K_m. Very few candidates gained full marks for explaining how the rate of the hydrolysis is affected by an increase in substrate concentration. Most did include some reference to ‘active sites’ on the enzyme but omitted to state that initially the rate increases due to more frequent collisions.

Question C5

For Question C5 most knew that iron is complexed with haem or haemoglobin but were less sure that the oxidation state of the iron is +2.

Option D - Environmental Chemistry

This was a popular option and was answered quite well by many candidates although there are still examples of students not giving enough chemistry in their answers to score all the marks.

Question D1

(b) Vague answers about the earth reflecting light which is trapped by greenhouse gases do not gain marks. The incoming shortwave radiation from the sun passes through the greenhouse gases to warm the earth. The Earth then radiates longer wavelength (lower energy) radiation. Rather than escaping back into space some of this is absorbed by the bonds in the molecules of the greenhouse gases. This heats the molecules and energy is re-radiated back to the Earth's surface.

Question D2

The identity and sources of pollutants that contribute to the lowering of the ozone concentration were well known but many stated that a disadvantage of both fluorocarbons and hydrofluorocarbons is that they are inflammable. In the case of fluorocarbons this is not true.

Question D3

(a) Primary and secondary sewage treatment was answered well.

(b) To gain all the marks candidates needed to refer to chemical precipitation rather than just precipitation or give a suitable equation to explain how heavy metal ions or phosphate ions are removed in the tertiary treatment of sewage.

Question D4

Although a few candidates confused photochemical smog with a reducing smog most were able to gain good marks on D4.

Question D5

Some candidates omitted to state which heavy metal their answers referred to in D5 and there were many rather vague answers or guesses as to the environmental and health effects of a particular heavy metal.

Question D6

The disadvantages of using LD_{50} as a means of expressing toxicity in D6 were generally well known.

Option E - Chemical industries

Question E1

Some candidates gave good word answers to describe the difference between isotactic and atactic polypropene then ruined their answer by drawing incorrect diagrams. The most common mistake was to put one $-CH_3$ group on every carbon atom in the chain rather than on alternate ones.

Question E2

(b) Many candidates referred rather loosely to the fact that aluminium is more reactive than iron in their answer without specifically stating that the major factor is the position of the metal in the reactivity or electrochemical series. The name and formula of the main ore of iron used in the blast furnace was well known but fewer candidates also knew the name and formula of the main impurity silicon (IV) oxide. Most candidates could give suitable equations for the reactions taking place during the electrolytic extraction of aluminium but were less clear on the role of cryolite. Cryolite is used as a solvent rather than an impurity so that aluminium ions are present in solution at a lower temperature than in pure molten alumina.

Question E4

This was a straightforward question on the chlor-alkali industry. Any two out of diaphragm, ion exchange membrane or mercury cell were accepted. Although almost all candidates gave hydrogen and its use in the Haber process as one of the products less candidates identified sodium hydroxide as the other product and they were less clear as to its industrial importance.

Question E5

This was on the doping of silicon and was generally answered well.

Option F - Fuels and energy

Question F1

(a) Some candidates were unable to give good scientific answers on the advantages and disadvantages of directly combusting biomass compared to first converting it into ethanol. Burning biomass is more efficient but more polluting than converting it into ethanol. Ethanol can be transported more readily but time is needed for the conversion.

(b) Better answers were generally given for this part concerned with the advantages and disadvantages of using photovoltaic cells.

Question F2

(a) Although the lead-acid storage battery is clearly referred to in the chemistry programme many candidates did not answer question F2 well. They did not state that one of the electrodes is made of lead (IV) oxide and many did not know that the electrolyte is sulfuric acid and were unable to write correctly the half-equations occurring at the electrodes.

(b) Some stated what they had presumably learned that the voltage produced by a cell depends on the half-cells used. Although this would be true for cells in general it does not answer this question which referred specifically to the lead storage battery. In this case the answer is the number of cells connected together. The power depends on the size of the electrodes and the amount of material used.

Question F3

Many candidates were able to answer F3 on radioactive decay correctly although a few omitted to give the units of day^{-1} when giving the value for the rate constant. Some also calculated the ratio of A/A_o correctly as 0.824 but then omitted to subtract this from one to give the fraction that had decayed as 0.176 (or 17.6%).

Question F4

Many candidates were unable to define the term *nuclear binding energy* correctly. The answers given were too vague and did not refer to separate protons and neutrons when talking about making or breaking a nucleus. Some also had problems explaining correctly the graph of binding energy against mass number in terms of conversion to nuclei with smaller or heavier mass numbers.

Option G - Modern analytical chemistry

Question G1

Most candidates who answered the questions on this option seemed well prepared and there were some good answers given. Some did confuse A and B perhaps because they had seen the electromagnetic spectrum drawn the opposite way but the question did clearly indicate how the wavelength increased. If they did incorrectly state that A was infra-red and B was ultra-violet then the principle of 'Error Carried Forward' was applied to the rest of their answers.

Question G2

(a) There are several possible isomers that could be drawn for $C_2H_4O_2$ and any two of these were accepted.

(b) The IR absorptions were easily assigned from the *Data Booklet*, although it was necessary to distinguish between the type of OH vibration occurring at 2765 and other OH vibrations.

(c) The correct structure was the structure for ethanoic acid. Marks were awarded for an explanation which was consistent with using the information given to distinguish between the two particular isomers drawn by the candidate in part (a).

Question G3

The ^{1}H NMR information asked for was generally given correctly. The most common mistake made by candidates was to interpret the splitting patterns and the chemical shifts incorrectly and to give the wrong isomer (ethyl ethanoate) as the structure in G3(c) rather than the correct structure (methyl propanoate).

Option H - Further organic chemistry

As in previous years there was considerable variation in some of the answers given for this option. Many candidates are correctly able to show the individual steps of mechanisms with good use of curly arrows and δ^+ and δ^- whilst others still give very confused answers.

Question H1

Although almost all candidates gave the correct structure for $C_6H_5CH_3$ some had problems with the propagation steps of the free radical mechanism for the chlorination of methylbenzene although the remaining parts of the question were usually answered well.

Question H2

This question on the reaction of hydrogen cyanide with propanone proved more difficult. Many of those that did know that the nitrile product is hydrolysed by acid to form a carboxylic acid omitted to include NH_4^+ in the equation for the hydrolysis.

Question H3

This question on nucleophilic substitution was answered very well by the better candidates.

(a) Most could explain the S_N1 and S_N2 mechanisms well both in terms of steric hindrance and the stability of the intermediate carbocation formed.

(b) Similarly most knew or correctly surmised that OH^- is a better nucleophile than H_2O as it is charged and more attracted the δ^+ carbon atom in CH_3Br and hence will react at a faster rate.

(c) Some of the explanations as to why CH_3Br reacts much faster with nucleophiles than C_6H_5Br were rather confused. It is one of the non bonding pair of electrons on the bromine atom which is able to delocalize with the π electrons in the aromatic ring. This creates a stronger C-Br bond (making it less likely to break) and also causes the nucleophile to be repelled.

Assistance and guidance for future candidates

Some comments that have been made in previous years are still pertinent. Some candidates still showed difficulty in answering the question(s) asked. Sometimes parts of the question were missed and at times questions were misread. This can at least in part be overcome by frequent practice in examination type questions. Students should be given regular assignments and tests from past examination and specimen papers. This will give candidates the opportunity to develop the skills of answering questions clearly, directly and completely, so that they are not penalised for failing to answer the question asked. If candidates are asked to list two properties etc. then they should not list three as they will be penalised if one of them is wrong even if the first two given are correct. When questions are asked to compare two methods and advantages and disadvantages are asked for two clearly different points should be given rather than using the same point. For example, if the fact that it is difficult to transport is given as a disadvantage of using biomass as a fuel compared to converting it first to ethanol then ease of transport should not be given as an advantage for converting it to ethanol. Students also need to be completely familiar with the action verbs and which objective they relate to.

Provide students with adequate resources to complement the teaching of the options. Apart from specific IB textbooks many chemistry books do not contain enough information to cover the options and students often seem unfamiliar with some of the basic information. It is important that students cover the whole of an option and do not try to guess which questions will be asked and thus miss out some parts of each option.

Responses to questions should demonstrate both depth and breadth. Students must ensure that they cover a sufficient number of different points to score the full range of marks assigned to each question. They must give the best chemical/scientific answer they can rather than simplistic or journalistic answers.

There must be a meaningful relationship between theory and practice – classroom presentations/discussions and practical investigations should reinforce each other.

Candidates should be advised to attempt to answer all parts of an option. Better an attempt that may provide a small amount of credit than no attempt that will give no credit at all.

Teachers are advised to cover two options thoroughly and not attempt to cover more than this unless time allows. Each year there is strong evidence that candidates from schools covering several options do less well than those concentrating on just two options.

Students should be strongly advised to answer questions on the option they have studied rather than attempt options where they feel that they have some knowledge from elsewhere. For example, students should not answer questions on Human Biochemistry, even if they have studied Biology, unless they have been specifically taught that option.

Internal assessment

Higher and standard level

Component grade boundaries

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

The moderators expressed the opinion that the general standard of internal assessment (IA) was either similar to last year or slightly improved. In view of the number of new schools being incorporated into the IB Diploma Programme it is encouraging that standards overall are being maintained or even advanced. Moderators can now access the previous year's Internal Assessment Feedback form and it is clear that many teachers are implementing the recommendations contained, although it is disappointing that a minority of schools show no such improvement and it is a concern that such feedback is either not reaching the teachers concerned or is being ignored.

Last year's feedback directed all teachers to the Teacher Support Material (TSM) available on the Online Curriculum Centre (OCC) and this is possibly the reason that many more appropriate assessment tasks were in evidence this year. However the TSM 1 material on errors and uncertainties in DC, DPP and CE has clearly not yet been implemented in many schools and this is limiting achievement against these criteria.

Overall most schools are following instructions provided in the *Vade Mecum* when compiling samples for submission to the moderator, with only a minority of schools incorrectly completing the form 4/PSOW or not submitting the correct pieces of candidate work. The one area of weakness is the frequent absence of suitable evidence of instructions given by teachers. Either the evidence is missing, and has to be requested separately through IBCA, or is too brief to be informative. It is required that a record of verbal instructions is included if the students received extra direction in this manner.

Many samples show that teachers had monitored the candidates' work carefully and provided useful feedback. In other cases, there was no evidence of feedback. Teachers often used a grid and c, p, n notation to indicate aspects achieved for each criterion. This practice helps candidates and the moderator, as the purpose of moderation is to validate teachers' assessment. Safety awareness and concern for the environment were evident in some schools but lacked in others – these concerns should be universal.

The range and suitability of the work submitted

Most schools presented a practical scheme of work of a suitable academic standard. A broad range of investigations was submitted and many schools had an interesting practical programme. The majority of the schools covered the syllabus suitably and the investigations addressed a wide range of topics. Where moderators noted some deficiency in range it usually related to the absence of experiments addressing the option topics or organic chemistry. Although it is understandable that a large proportion of the practical programme will be given over to quantitative investigations that lend themselves to assessing the written criteria, teachers should still strive to achieve a balance overall and should not abandon all qualitative experiments.

Most schools supplied evidence that a range of experimental techniques were used. In a very small number of cases there was an over-reliance on titration based experiments, which indicates a lack of suitable equipment available to the students. It has been notable that there has been no significant increase over the last few years in the use of data-logging techniques in the samples sent for assessment. This probably reflects the pragmatic consideration that it is very difficult to assess the students' individual contribution to DC and DPP when data-logging techniques have been used. However 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 into successful planning or CE tasks.

Most investigations used for assessment were appropriate for that purpose. However, a majority of schools received feedback that cited, in Section C of the form 4/IAF, at least one investigation as being unsuitable for assessment of a given criterion. Happily, fewer schools than before received feedback that reflected a comprehensive failure to implement suitable assessment tasks against any of the criteria.

There were two common reasons for investigations being deemed unsuitable. The first is that the teachers' instructions gave far too much assistance to the candidates. 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.

DC: candidates explicitly told which data to record with data tables supplied.

DPP: candidates instructed on which data to graphically plot or given step-by-step guides to calculations.

CE: students being instructed to respond to a series of set questions.

The above failings were more prevalent when schools overly relied upon commercial workbooks and worksheets with spaces to be filled in by the candidates, as they usually provide too much information and deny the candidates the opportunity to fulfil criteria for themselves.

The second common reason for investigations to be deemed by the moderator as unsuitable for use in assessment was that the task was too trivial or simplistic for IB Diploma candidates, such as the Pl (b) tasks 'Separating salt from sand' or 'Determining the boiling point of water'. Similarly investigations that yielded very few data should not have been used for DC and DPP assessment. 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. Marks generated from these simple tasks, however, should not be entered on the form 4/PSOW so that they do not contribute to the final mark and in this way no associated problem will be caused in moderation.

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)

There has been an improvement in the fulfilment of this criterion over recent years and in this session many reports were structured to clearly show the aim, hypothesis and explicit identification of the independent and control variables. There was a suitable understanding shown by many candidates 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 had not been appropriately defined for the students.

This criterion requires the provision of a broad or general investigation problem that is subsequently narrowed or focused by the candidate. A specific research question is still being given by a significant number of schools, denying the opportunity to fully achieve this criterion. Some candidates stated a hypothesis, but did not explain their reasons for it or the hypotheses were poorly worded or superficial. Too many hypotheses simply predicted the success of the candidate's proposed experiment. A hypothesis should be explainable in terms of chemistry concepts as described in the syllabus, usually at the molecular level. If no such hypothesis can be readily formulated in principle for a given investigation then the set task is probably unsuitable for Pl (a). Another significant reason for some candidates not fulfilling this criterion was that the set task was too narrow to allow the candidates to make their own decision as to which variable(s) should be the independent variable and which others should be controlled. Often these narrow tasks took the form of determining a prescribed chemical property or quantity (e.g., 'Determine concentration of ethanoic acid in vinegar').

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. An investigation that requires the provision of equipment or methodology for practical reasons is not appropriate for assessment of Pl (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 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) and / or Pl (b). It was a concern that some classes submitted near identical procedures that appeared to have come from commercially available laboratory manuals or web-based sources.

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 had been presented with suitable data collection tasks (fewer schools than in earlier years were presenting students with pre-formatted data tables) and their performance was generally good with candidates independently able to present data in suitably constructed tables with appropriate column headings and units. Although there was a noticeable improvement compared with previous years the most common failings still related to the first aspect, with uncertainties often being left out and there was 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).

Teachers were prone to over-reward their students in purely qualitative DC tasks with full reward 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. In comparison to previous sessions an increased minority of school encouraged meaningful treatment of errors or uncertainties in DPP. Only a small proportion of HL candidates though were able to propagate errors correctly through a calculation. Very few SL candidates were able to give any form of assessment if 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.

A major disappointment was the relatively small number of graphs presented for moderation and the poor quality of many that were presented. 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. labeled 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. This has clearly been recognised by most teachers since the use of data-logging techniques in DPP was not commonly evident. Although it is a pity that successful integration of data-logging into DPP assessment exercises has not yet been generally achieved, teachers are probably well advised to be cautious for the time being when it involves DPP assessment.

Very few candidates undertook further processing of the data such as finding a gradient or intercept through extrapolation. The fact that the second aspect's requirement to take into account uncertainties can be fulfilled through a suitable best-fit line should make data processing through graphing an increasingly important component of most school's programmes and hopefully the quality of graphs presented will improve as a result.

DPP was often being assessed for interpretation of qualitative data such as test-tube reactions where balanced equations were generated from a minimum of qualitative observation and lacked substantiation. These responses are more appropriate for the assessment of the first aspect of CE.

Conclusion and evaluation

As last year, this is still an area where candidates do not score particularly well. For example, it is still not common for candidates to 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. There is very little evidence that candidates make any attempt at background reading or research in order to interpret their findings. If a literature source is used then it should be properly referenced.

Most candidates did attempt to evaluate the procedure and list possible sources of error. Often this evaluation was superficial though, with comments such as "the readings must have been too low or too high" being not uncommon. 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. Many candidates were able to make appropriate suggestions to improve the investigation following the identification of weaknesses, although a significant minority were only able to suggest simplistic (frequently of type 'use a digital meter') or completely unrealistic improvements.

Manipulative skills

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

The Group 4 project

Most schools provided evidence for participation in the Group 4 Project for each of the candidates in the sample. This is an essential requirement of the IB programme. A special request had to be made for the submission of such evidence for schools failing to provide evidence. This evidence provided can take a variety of forms as stated in the IB *Chemistry Guide* (page 32). Group evidence is not appropriate when the Group 4 Project is to be used to assess any of the written criteria.

Many schools seemed to have undertaken stimulating and imaginative projects. However in a large number of cases there seemed to be little evidence of chemistry-related work have been carried out. It is required that all chemistry students undertake study that is in some way chemistry related. In some cases the Group 4 Projects do not represent the 15 hours of work that is stated on the 4/PSOW.

It is worth teachers noting that a significantly large proportion of schools use the Group 4 Project as an ideal opportunity to stimulate group collaboration within an interdisciplinary framework and assess the Personal Skills criteria, but do not award grades for the written criteria. This is in harmony with the aims of the Group 4 Project.

Recommendations for the teaching of future candidates

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

- candidates should be made aware of the different aspects of the 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 students 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 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.
- teachers should consult TSM 1 on the Online Curriculum Centre regarding the consideration 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.
- encourage candidates to form a hypothesis that is directly related to the research question and is explained in terms of chemistry concepts, often at the molecular level.
- candidates should be encouraged to consider repeat trials, calibration or generation of sufficient data to undertake graphical analysis, when designing procedures for Pl (b).

- candidates must record qualitative as well as quantitative raw data, where appropriate, including units and uncertainties where necessary.
- 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.
- 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.