# CHEMISTRY

## Overall grade boundaries

## Higher level

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-18 | 19-35 | 36-50 | 51-60 | 61-69 | 70-79 | 80-100 |

## Standard level

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-17 | 18-33 | 34-47 | 48-59 | 60-70 | 71-81 | 82-100 |

# Higher and standard level internal assessment

## Component grade boundaries

### Higher level

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

### Standard level

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

## General comments

The moderators expressed the opinion that there was a considerable variation between schools in the standard of internal assessment (IA) received this examination session. There were a good number of schools who submitted challenging work which reinforced learning and provided a suitable opportunity for assessment. However other schools were still not undertaking a suitable practical scheme of work and were failing to appropriately address the assessment criteria. It is disappointing that some of these schools were not implementing recommendations given on the previous years 4/IAF feedback form.

Overall most schools are following instructions provided in the *Vade Mecum* when compiling samples for submission to the moderator with a minority of schools incorrectly completing the form 4/PSOW or not submitting the correct pieces of candidate work. An area of particular weakness is the lack 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. Often the similarity of response from all the candidates in the sample indicated that further instructions had been given but not evidenced for the moderator.

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 were lacking in others – these concerns should be universal.

## The range and suitability of the work submitted

Some schools supplied evidence that a range of experimental techniques were used but in a significant number of cases there was an over-reliance on investigations that are too trivial or simplistic for IB Diploma candidates, such as the tasks 'Separating Mixtures' or 'Determining Density'. 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. However these tasks should not predominate the 4PSOW nor should they form the basis for assessment.

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

There was very little evidence of the use of data-logging techniques in the samples sent for assessment. The fact that very few students refer to data-logging in planning activities indicates that they are not yet familiar with the technology concerned. There is no reason why data-logging cannot be incorporated into successful planning or CE tasks.

Most investigations used for assessment were appropriate for that purpose. However, a significant number 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.

There were two common reasons for investigations being deemed unsuitable. The first is the issue of simplicity as cited above especially if only a minimum of data is generated. The second reason 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 supplied data tables (happily a less common occurrence this session).
DPP: candidates instructed on which data to graphically plot or given step-by-step guide to calculations.
CE: students being instructed to respond to a series of set questions.

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)

In many schools the students displayed a suitable understanding of the terms *control*, *dependent* and *independent* in relation to variables. Where candidates seemed unaware or confused as to their meaning it was often reflected throughout a school's sample, indicating that these terms have not been appropriately defined for the students.

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 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 (e.g., 'Determine concentration of ethanoic acid in vinegar').

### Planning (b)

This standard of this criterion was similar to previous years. Candidates generally selected suitable equipment and devised appropriate strategies for carrying out investigations. An investigation that requires the teacher to specify the equipment or methodology 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, web-based sources or possibly the teacher.

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 most common example of this 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 of the independent variable upon the dependent variable.

### Data Collection

Most candidates had been presented with suitable data collection tasks and their performance was generally good with candidates independently able to present data in suitably constructed tables with appropriate column headings and units. The most common failings still related to the first aspect with 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 full marks 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 of uncertainty in a derived result and appreciation of significant figures was also often lacking. The TSM 1 should be referred to for guidance in this area.

A major disappointment was the relatively small number of graphs presented for moderation and their poor quality overall. 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.

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 as a result improve.

### Conclusion and Evaluation

This is still an area where candidates do not score particularly well. For example, it is 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.

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. Some candidates were able to make appropriate suggestions to improve the investigation following the identification of weaknesses, although many were only able to suggest simplistic or completely unrealistic improvements.

### Manipulative skills

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

### The Group 4 Project

Nearly all schools provided evidence for participation in the Group 4 Project for each of the candidates in the sample. This is an essential requirement of the IB programme. When submitting samples for moderation, teachers should provide evidence of participation in the group 4 project for each candidate in the sample. This 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.

# Higher level paper one

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-10 | 11-19 | 20-28 | 29-31 | 32-34 | 35-37 | 38-40 |

## General comments

This paper consisted of 40 questions on the Subject Specific Core (SSC) and Additional Higher Level (AHL) material and was to be completed without a calculator or Data Booklet. Each question had four possible responses with credit awarded for correct answers and no credit deducted for incorrect answers.

Teachers' impressions of this paper were conveyed by the 19 G2 forms that were returned. In comparison with last year's paper, nearly half felt that it was of a similar standard, with most of the remainder considering it a little easier rather than a little more difficult. The level of difficulty was considered appropriate by almost all. Syllabus coverage and clarity of wording was considered good by nearly two-thirds and satisfactory by the remainder. The presentation of the paper was considered good by almost all.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 96% to 25% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.57 to 0.03 (The higher the value, the better the discrimination).

The following comments were made on individual questions.

### Question 6

Some respondents suggested that the correct response was D but that A could also be correct. Although response A (electrons absorb energy as they move from low to high energy levels) is a correct description of a process that occurs, this process does not directly lead to the formation of an emission spectrum, which was clearly stated in the question. It was not a problem for candidates, with 88% choosing the correct response (D) and 8% choosing response A.

### Question 18

One respondent suggested that the correct response was A (always) but that for the example used in this question response B was also correct. Candidates should realise that the decomposition of the oxide of a reactive metal is a very endothermic reaction, and that in comparison the entropy change is a minor factor. The rubric states that candidates should choose the answer they consider to be the best, and in this question it is considered that candidates should choose response A because it is certainly (and always) correct. 82% of candidates chose the correct response, with only 8% choosing response B.

**Question 33**

One respondent suggested that this question was difficult without access to $E°$ data. Had the example used been an unfamiliar one, the comment would have been valid. However, it is considered that the electrolysis of aqueous copper(II) sulfate should be familiar to candidates (it is also mentioned in the teacher's note to A.S. 19.3.1). 57% of candidates chose the correct response (D), although a substantial number (23%) chose response A, perhaps in the belief that hydrogen gas, rather than copper, would be formed at the negative electrode.

**Question 39**

One respondent stated that electrophilic substitution (response B) is covered in the Options rather than in the Core or AHL material. This is true, but candidates did not need knowledge of this reaction type to choose response A as the obvious answer. It was not a problem for candidates, with 88% choosing the correct response.

# Higher level paper two

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-14 | 15-29 | 30-41 | 42-50 | 51-59 | 60-68 | 69-90 |

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

- Calculation of rate constant units
- Definition of $M_r$
- Explanations of bonding
- Use of concentrated phosphoric acid as a dehydrating agent
- Calculation of buffer pH
- Significance of values of lattice enthalpies
- Thermochemical calculations
- Interpreting mass spectra

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

- The operation of the mass spectrometer
- Le Chatelier’s principle
- NMR spectra

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

### Section A

### Question 1

a) Half-life was generally well defined.

b) Many students had problems measuring half-life and often students gave concentration values rather than time intervals.

c) A number of students correctly identified the reaction as first order and gave the correct equation whereas fewer mentioned the fact that there was a constant half-life.

d) This calculation was generally well done although the calculation of units was more challenging and many students failed to notice the reaction was in minutes and not seconds.

### Question 2

a) i) Most students correctly identified the three processes in the mass spectrometer and the order they occurred in.

ii)If students had correctly identified the processes they usually were able to explain how they worked, although marks were lost for lack of precision. For example ionisation caused by firing electrons at the sample was not specific enough - students had to state that the electrons had high energy or high velocity.

b) i) Surprisingly few students were able to define $M_r$

ii) The $M_r$ of germanium was well calculated however several students lost the mark by having an incorrect number of decimal places.

c) Most students were able to correctly write the electronic configuration of germanium - either the full form or from the nearest noble gas.

d) i) Most students correctly identified a p orbital.

ii) The equation for the ionisation of germanium was generally done poorly as many students did not use the correct gas state symbols.

iii) Explaining the difference in the ionisation energies was done poorly; students failed to specify that the change was due to the different energy level that the electron is removed from and the subsequent greater attraction for the nucleus.

### Question 3

a) Many students lacked detail in their answers when answering this question about structure and bonding - often talking about metallic bonding without describing the lattice of positive ions surrounded by mobile delocalised electrons.

b) Many students were able to state that silicon dioxide had a macromolecular structure, but unfortunately many students linked this to double bonds between silicon and oxygen. Few specified the high melting point was due to the energy needed to break the covalent bonds between the atoms.

c) i) Few students identified the easily overcome van der Waals' forces as the reason for the low melting point of $SiCl_4$

ii) Very few students wrote the correct equation for the reaction of $SiCl_4$ with water.

## Question 4

a) Many students did not correctly draw the butan-2-ol isomer and those that did failed to name it correctly. The concept of chirality was well known, but many students did not clearly explain that the isomers would rotate the plane of polarised light in opposite directions.

b) Students who recognised phosphoric acid as a dehydrating agent had few problems and correctly drew but-1-ene or but-2-ene, not all of these then correctly named the alkene. However a number of students tried to make an ester with phosphoric acid or thought it was an oxidising agent. Those students who recognised the product would be an alkene usually suggested the decolourization of bromine as a test for the alkene functional group.

## Section B

## Question 5

a) A complete definition was rarely given - the most common omission being mole or elements, although most students did mention standard states. The formation of one mole of nitric acid was poorly done - those that managed it rarely identified the correct state symbols, often not realising that nitric acid was a liquid.

b) The combustion of propyne proved a difficult calculation for many as they rarely set out the calculation correctly, and many students attempted to find a solution using bond enthalpies, even though enthalpies of formation were given.

c) Predicting the value of the entropy change was done fairly well - although explaining why in terms of the reduction of gas particles was poorly done.

d) Calculating the value for the entropy change caused some problems, as students set out the calculation wrongly or forgot to multiply by the number of moles present.

e) Calculating the free energy was attempted by most and pleasingly many were able to convert the units correctly, and/or use temperature in Kelvin.

f) The Born–Haber cycle was drawn particularly poorly, and very few students were able to get more than half of the marks available. Electrons were omitted, equations were unbalanced and there was little awareness that some values were endothermic and some exothermic.

g) This question was done very poorly; few students compared the theoretical and experimental values and those that did talked about silver fluoride having stronger bonds - hardly anyone identified the greater difference in values as due to the greater degree of covalent character.

## Question 6

a) This question was well answered, if marks were lost it was because students did not mention moles of gas in part i) or the fact that rates are affected equally in part ii).

b) Very few students were unable to write the expression for $K_c$.

c) The calculation of concentrations was generally well done, although there were errors made, particularly when reducing the concentration of HI - a common mistake was to give a value of 0.05 instead of 0.04. Most students were then able to correctly answer the question about temperature and $K_c$.

d) Bronsted-Lowry acids were well known but Lewis bases proved more difficult and few students correctly stated electron pair donor.

e) Many students were able to correctly predict and explain the colours of the indicators.

f) The calculation of pH was either done very well or very poorly - the most common error was to assume that the concentrations of hydrogen ions and base were equal, or to incorrectly use the logarithmic version of the equation.

**Question 7**

a) Many of the students that answered this were unable to correctly write the equations - often making errors. Also few correctly explained how electricity was conducted.

b) About half the students correctly stated that there would be twice as much sodium formed and explained it by reference to the stoichiometry of the equation.

c) Most students were able to perform this calculation to see how much chlorine would be produced.

d) A few students correctly wrote the equations and identified the products but the majority had problems and made mistakes with their equations and also the products formed.

e) Part i) was poorly answered as students failed to refer to the equation of to loss or gain of electrons. Part ii) was answered more successfully, and many students correctly calculated the oxidation numbers.

f) The definition of standard electrode potential was not well known. Most students could correctly choose the reaction and from that calculate the potential of the cell, but they found the balanced equation difficult.

**Question 8**

a) The definition of nucleophilic substitution was often vague and it was rare for both marks to be awarded.

b) The $S_N1$ mechanism was quite well known, but the exact placing of the curly arrows was poorly carried out.

c) The $S_N2$ mechanism was again well known, but the curly arrows and the transition state were quite haphazard.

d) The isomers were usually identified but the naming was often incorrect.

e) Most candidates correctly stated the alcohol had a higher boiling point and why but they failed to mention why bromobutane's boiling point was lower.

f) The mass spectrum data were not well understood; very few students correctly identified the two isomers of bromine, those that identified the hydrocarbon fragments often omitted the + charge. Very few students worked out that it was a tertiary isomer.

g) Most students worked out it was a secondary isomer from the NMR data.

h) Although NMR data was well understood, many students misread the question and drew a halogenoalkane instead of an alkane.

i) Homolytic fission was understood but often poorly explained; few students wrote a simple equation and instead wrote a mechanism. Most students could correctly identify the radical.

## Recommendations and guidance for the teaching of future candidates

- Use past examination papers and their markschemes to prepare for examinations.
- Read the questions carefully in the examination.
- Read through the optional questions and look at the mark allocation for the different sections before deciding which question to do.
- Learn precise definitions.
- Set answers out clearly - especially calculations, as marks can be obtained for the method.

# Higher level paper three

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-7 | 8-15 | 16-22 | 23-27 | 28-32 | 33-37 | 38-50 |

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

Most students seemed very well prepared, although a small but significant number gave the impression that they had not encountered much of the information or concepts before and performed very badly. No one option proved easier to score marks on than any of the others and many candidates gained very similar marks for each of the two options they attempted. The paper proved to be a good discriminator, with the best students scoring high marks particularly on those areas testing objective three. Precise details are given under the individual options in part C, but areas where considerable difficulty was encountered included:

- stoichiometric calculations.
- understanding how an intoximeter works
- the use of chiral auxiliaries.
- hydrogen bonding between bases in DNA.
- the role of $NO_x$ in ozone depletion
- identification of amino acids formed by the hydrolysis of proteins
- *cis*- and *trans*- isomerism applied to cyclic compounds
- the acidity of 2,4,6-trinitrophenol compared to phenol itself

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

Clearly the majority of students were very familiar with the subject material. However there are a few centres where students gave the impression that they had not been taught much of the material on the options they answered. Often this correlates with the choice of options. As in previous years, centres where all the candidates answer the same two options tend to do considerably better than when a range of options is chosen. There is also a strong correlation between candidates' abilities to express clearly and concisely their ideas with their overall scores. Generally most students demonstrated a good knowledge of the factual content of the options chosen. Areas which seemed particularly well-known and understood included:

- side effects associated with particular drugs
- correct identification of functional groups within drug structures
- the differences between fats and oils
- diseases associated with particular vitamin deficiencies
- conversion of sea water to drinking water
- electrolytic extraction of aluminium from alumina
- calculations involving the energy produced by fossils fuels

- interpreting simple mass spectra

Although there were exceptions many students were able to write chemical equations correctly. Some students gave excellent answers to the questions on modern analytical chemistry but others found it difficult to describe chromatographic techniques correctly. On the further organic chemistry option some students gave excellent answers but there were many who were unable to recognise and describe the relevant structures and isomers asked for.

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

### Option B – Medicines and drugs

Surprisingly the first question on antacids produced some problems. Most students were able to write a correct equation for the reaction of either magnesium hydroxide or aluminium hydroxide with hydrochloric acid although some forgot water as a product and others clearly did not know the correct formula for the salt formed. Those that did give a correct equation generally realised from the stoichiometry that 0.1 mol of aluminium hydroxide has the potential to neutralise more acid than 0.1 mol of magnesium hydroxide. However for part B1(c) only relatively few candidates stated that sodium hydroxide is too strong a base to be used as an antacid as it is corrosive to body tissue.

In B2 most students were familiar with the redox reaction between alcohol and acidified potassium dichromate(VI) and the use of an intoximeter (which can work either using a fuel cell or by infrared spectroscopy) to detect alcohol in the breath and almost every student knew that taking aspirin with ethanol increases the likelihood of stomach bleeding.

Question B3 on analgesics was generally answered well except that relatively few students knew that the main side effect of morphine is that it causes constipation. Many students wrote that it is addictive which is a property associated with morphine but not a side effect.

For question B4 Most students gave *cis*-platin as an example of an anticancer drug which shows geometrical isomerism but relatively few knew that taxol is an example of an anticancer drug that shows optical isomerism. Even without the example it was still possible to score both marks in B4(a)(ii) by explaining the structural features of the two different types of isomerism. Many students did not realise that a chiral auxiliary is itself an enantiomer and that it must be removed after the desired stereospecific product is obtained.

Question B5 on anesthetics was generally answered well although some students did not state that a general anesthetic works on the brain and that the patient is unconscious.

### Option C – Human biochemistry

Most students were able to identify the $\alpha$ and $\beta$ forms of glucose but were less certain about whether they were enantiomers or not even though they are clearly not mirror images of each other. The remaining parts of C1 generally presented few problems.

Most candidates were able to calculate correctly the number of carbon to carbon double bonds in linoleic acid in C2(a)(i) but many made the mistake of taking iodine as monomolecular and so ended up with half the correct value in part (ii). The differences in the structures of fats and oils in C2(b) and how this affects their melting points was generally answered well. Similarly C3 on vitamins presented few problems. Many students were thrown by the structures of the bases in C4 being drawn differently to that shown in many books and were unable to show correctly where the hydrogen bonding occurs. A surprising number also tried to pair adenine with thymine rather than with uracil in part (b). The remainder of C4 tended to distinguish well between candidates, as only those who understood about charge density were able to explain why potassium ions pass more easily through the cell membrane. Students needed to give $Fe^{2+}$ and $Fe^{3+}$ together with $Cu^{+}$ and $Cu^{2+}$ to gain full marks for C4(e).

## Option D – Environmental chemistry

Like Options B and C this was another popular option answered by many candidates. Although there may be a perception that this is one of the easier options the answers given do not always bear this out. Question D1 is an example of this as very few students correctly identified **three** correct primary pollutants, with oxides of sulfur often given as a wrong answer. Similarly only about half of the students gave the correct equation for a reaction between two primary pollutants in a catalytic converter.

Good candidates were able to list the properties required for HFCs in D1(b) but many others only referred to the lack of a C–Cl bond rather than the low flammability, low toxicity and low reactivity which are all required. A sizeable proportion of candidates did not read question D2 carefully and went into detail about all three methods they had listed, although generally this was well-known, as were the similarities and differences of treating drinking water with chlorine or with ozone.

The question that was less well answered was D3. Many confused reducing smog with photochemical smog and were unable to show the mechanisms whereby secondary pollutants are formed from primary pollutants. Answers which included references to ultraviolet light causing free radicals and particulates acting as heterogeneous catalysts were few and far between. Similarly the role of nitrogen oxides in ozone depletion was not well known and where steps were given they often did not add up to an overall catalytic process.

## Option E – Chemical industries

The extraction of aluminium from its ores is a key part of this option and many students answered question E1 well. Some gave rather vague answers to part (a) whereas some reference to the electrochemical series or the relative reactivities of the two metals should have been included in the answer. Most students know why molten cryolite is used during the process but some failed to score the mark by stating that it lowers the melting point of aluminium rather than alumina, although it is probably more correct to say that it acts as a solvent for the alumina.

The function of coke in the blast furnace was well known, but fewer students were able to write correct equations for the reaction of calcium oxide with silica or explain in E2(b) that the reaction occurs because calcium oxide is basic whereas silica is acidic. Some confused the addition of oxygen and limestone to the basic oxygen converter with other metals e.g. nickel or chromium. Both oxygen and limestone are necessary additions to make steel – the addition of other metals depends on the type of steel required. In E3 part (a) many students were able to give good answers but not so many knew why sulfur must be removed from crude oil. To prevent the formation of sulfur dioxide during combustion was accepted as was the fact that it acts as a poison to catalysts during the refining processes. The details of cracking in E4 also caused some problems. The majority were able to distinguish between steam and catalytic cracking in terms of temperature but were less clear about the mechanisms involved. The questions on the electrolysis of brine in E5 proved straightforward for those that knew their chemistry.

## Option F – Fuels and energy

Most students were able to calculate correctly the energy produced by completely burning 1.00g of natural gas and 1.00g of petroleum from the given data in F1(a). However many were less clear with their answers to part (b). This may have been due to not reading the question carefully. Answers often just referred to the formation of the pollutant after combustion rather than the fact that it is difficult to remove sulfur from coal or that it is the high temperature in the internal combustion engine which leads to oxides of nitrogen being formed. Many students gave a correct equation for the formation of carbon monoxide from the combustion of natural gas in part (c), but some then failed to realise that in part (d) complete combustion was involved.

Those students that understood and knew how a lead-acid storage battery worked had little difficulty with question F2, although a surprising number seemed to have no real knowledge about this straightforward part of the topic.

Question F3(a) discriminated well between students. Good students gave answers which included references to localised or delocalised electrons. Many were able to discuss well the doping of silicon in F3(b) and many also gave good answers for the advantages and disadvantages of using hydrogen as an energy source in F4.

### Option G – Modern analytical chemistry

This option produced some good answers. Most students were able to interpret the mass spectra correctly and it was pleasing to see that almost all answers given for the fragments in G1(a)(ii) included the fact that they are positive ions. Question G1 part (b) concerned $^1H$ NMR spectroscopy. Many students in their answers to (i) and (ii) showed that they understood the general information given by this type of spectroscopy but then had more difficulty in assigning the correct ratios of peak areas in parts (iii) and (iv).

Question G2 which was concerned with chromatography was less well answered and suggests that students would benefit either from hands-on practical experience with one or more chromatographic techniques or seeing them demonstrated in a research laboratory or on film or video. In part (a) very few mentioned that after the elution has taken place the chromatogram has to be developed (usually with ninhydrin) to enable the spots to be seen. For G2(b) GLC or HPLC can be used to detect alcohol in the blood. Students should be encouraged to state the nature of the mobile phase and the stationary phase and mention how the retention times vary and how the components are detected. In both techniques it is also important to include a reference sample of alcohol to ensure correct calibration.

### Option H – Further organic chemistry

Most candidates realised that the statement in H1(a) referred to different compounds with the formula $C_4H_7Cl$ as no one compound with that formula can exhibit both geometrical and optical isomerism. Most had little difficulty with giving possible *cis*- and *trans*- isomers but surprisingly many were less clear with the optical isomers. Part (b) was generally not well explained and suggests that some students had not come across geometrical isomerism in ring compounds before. In alkenes geometrical isomerism exists because the $\pi$ bond prevents rotation. In cyclic compounds rotation is hindered as the carbon atoms are held in a ring even though there are no $\pi$ bonds present.

Question H2 involved an understanding of Markovnikov addition. A few students still try to explain this simply by stating the rule rather than by considering the stability of the intermediate carbocations formed. Good students knew the example of nucleophilic addition asked for in H3(a) and also knew that the resulting nitrile can be hydrolysed to give a carboxylic acid in part (b). H4 proved an excellent discriminator. Many were able to mention the inductive effect in part (a) to explain the basicity of ethylamine compared to ammonia, but fewer students also mentioned that the basic property depends on the lone pair of electrons on the nitrogen atom attracting a proton. Part (b) was less well answered. The ability of the electron-withdrawing $-NO_2$ groups to stabilise the resulting substituted phenoxide ion was rarely mentioned.

## Recommendations and guidance for the teaching of future candidates

- The options form an important part of the overall syllabus. Many teachers leave the teaching of the options until last. If possible, refer to the options when covering the core part of the course and ensure that the recommended time is given to covering two options thoroughly. Students who are left to teach themselves the options material generally do not perform well in the exam. Use examples from the options to cover the stoichiometry part of the core programme to get students used to this type of question.
- Relate part of the practical programme to the options so that students have first-hand experience of many of the techniques (e.g. chromatography) or materials (e.g. lead-acid battery) used.
- Give students guidance as to the level of answer expected. Journalistic answers to questions at this level will not suffice. Chemical equations should be given wherever possible. Organic mechanisms should be clearly described and definitions given precisely and accurately.

- Provide students with adequate resources to complement the teaching of the options. Many chemistry books do not contain much of the option material and students often seem unfamiliar with some of the basic information.
- Make sure every part of the syllabus has been covered. Give a copy of the syllabus to students so that they can run their own checklist.
- Strongly encourage students to answer questions **only** on the options they have studied. Ensure that students are aware of the importance of "action verbs" and that their answers address the question that has actually been asked.
- Give students practice with past papers. Train them to pay attention to the number of marks allocated to each sub-question to ensure that they cover a sufficient number of different points to score the full range of marks assigned.

# Standard level paper one

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-7 | 8-13 | 14-19 | 20-22 | 23-25 | 26-28 | 29-30 |

## General comments

This paper consisted of 30 questions on the Subject Specific Core (SSC) and was to be completed without a calculator or Data Booklet. Each question had four possible responses, with credit awarded for correct answers and no credit deducted for incorrect answers.

Teachers' impressions of this paper were conveyed by the 21 G2 forms that were returned. In comparison with last year's paper, over half of respondents felt it was of a similar standard, with most of the remainder considering it a little easier. Nearly all thought the level of difficulty was appropriate. Both syllabus coverage and clarity of wording were considered good by nearly two-thirds and satisfactory by the remainder. The presentation of the paper was considered good by over three-quarters and satisfactory by the remainder.

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

The difficulty index (the percentage of candidates achieving each correct answer) ranged from 90% to 37% and the discrimination index, an indication of the extent to which questions discriminated between high- and low-scoring candidates, ranged from 0.68 to 0.16. (The higher the value, the better the discrimination).

Comments were made on only two individual questions.

### Question 6

Some respondents suggested that the correct response was D but that A could also be correct. Although response A (electrons absorb energy as they move from low to high energy levels) is a correct description of a process that occurs, this process does not directly lead to the formation of an <u>emission</u> spectrum, which was clearly stated in the question. It was not a problem for candidates, with 73% choosing the correct response (D) and 10% choosing response A.

**Question 9**

One respondent suggested that a comparison of bond types and intermolecular forces might be confusing for candidates. It is accepted that the phrase 'hydrogen bond' describes one type of intermolecular force rather than a bond (covalent, ionic or metallic); however, the syllabus (A.S. 4.3.1) makes it clear that hydrogen bonding is the strongest type of intermolecular force and that these forces are weaker than covalent bonds. 52% of candidates chose the correct response (A), although 39% chose response C (in the belief that hydrogen bonds were stronger than covalent bonds). The question discriminated well, with a value of 0.51.

# Standard level paper two

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-7 | 8-15 | 16-21 | 22-28 | 29-34 | 35-41 | 42-50 |

## 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 standard-level course. It produced a range of responses from full marks to zero. In general, answers lacked precision in terms of wording used and explanation were often vague and repetitive. There were some schools where candidates seemed unfamiliar with most of the subject material and left many areas of the question paper blank.

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

The 20 G2 forms that were returned conveyed teachers' impressions of this paper. In comparison with last year's paper, 79% felt that it was of a similar standard, 14% thought it a little easier, 7% considered it a little more difficult. All respondents thought the level of difficulty was appropriate. Syllabus coverage was considered satisfactory by 45% and good by 55% of the respondents. Clarity of wording was considered good by 65% and satisfactory by 35% of the respondents. The presentation of the paper was considered good by 80% and satisfactory by 20% of the respondents.

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

- Definition of the rate of reaction
- Definition of ionization energy and an equation for the first ionization energy of aluminium
- Reaction of lithium with water and stating two observations
- Buffer solution
- Oxidation of ethanol to ethanal and ethanoic acids.

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

- Empirical formula

- Two ways of increasing the rate of reaction
- Number of sub-atomic particles in different species
- Position of equilibrium and Le Chatelier's principle
- Energetics
- Homologous series

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

### Section A

**Question 1**

a) Most candidates managed the correct empirical formula although some overlooked the oxygen in the organic compound.

b) A number of candidates found this challenging. Common errors were not converting degrees Celsius to Kelvin and not using the correct value of the gas constant R.

c) This part was done well by candidates who got the correct molar mass.

d) This part was also done well although some candidates gave the name as 3-methybutanoic acid, which was incorrect.

**Question 2**

a) Most candidates could not define the rate of reaction correctly. Some common errors were *'the time it takes for the reaction to reach completion'* or '*the time it takes for the reactants to form products'*.

b) (i) There were some good answers here but many candidates gave vague answers such as *'there were fewer collisions or particles didn't have* $E_a$*'*.

(ii) Good reasons were given to explain the relatively large increase in the rate because of a small increase in temperature. Again, some candidates wrote *'more collisions'* instead of *'more frequent collisions'* or '*more collisions per unit time'*.

(iii) Most candidates were successful in this part with a minority referring to surface area, even though the reaction involved two gases.

**Question 3**

a) Many candidates demonstrated a good knowledge of the number of protons, electrons and neutrons in the species shown.

b) Most candidates gave the correct answer.

c) The majority of candidates wrote the correct electron arrangement but some candidates had difficulty in stating the correct formula of calcium bromide.

**Question 4**

a) Only a minority of candidates were able to give the correct definition of ionization energy and the relevant equation. In many cases, they failed to indicate that all the species had to be in the gaseous state.

b) Most candidates gave the correct answer.

c) The equation stated by the candidates to represent the reaction of lithium with water was correct in only some cases. The common mistakes were writing an unbalanced equation, showing the formation of the oxide instead of the hydroxide and formation of $H^+(aq)$ instead of $H_2$ gas. A Substantial number of candidates were not clear about the term observations and wrote changes that could not be observed. For example, *lithium becomes oxidised, a base is formed, it is a redox reaction, pH is increased etc.*

### Section B

### Question 5

a) (i) Many candidates missed the word ‘standard’ when naming the term $\Delta H^{\ominus}$. The majority of candidates stated correctly the temperature would increase because it is an exothermic reaction.

(ii) This part was relatively well answered and most candidates stated that the $\Delta H^{\ominus}$ value would be more negative if solid $SO_3$ was formed instead of gaseous $SO_3$.

(iii) Most candidates calculated the correct answer as –389 kJ.

(iv) Many candidates realised that disorder was less in the products and the sign of $\Delta S^{\ominus}$ for the reaction was negative.

b) (i) Only a minority of candidates were able to give the correct definition of average bond enthalpy. In many cases, they failed to indicate that all the species had to be in the gaseous state.

(ii) Most of the candidates could not give a satisfactory answer to this part and wrote vague or incorrect answers.

(iii) This calculation showed very good results giving a final answer of –37 kJ. Some candidates were confused with the sign while other candidates used wrong values from the Data Booklet.

(iv) In general the enthalpy level diagram was drawn correctly, although a few candidates did not label the axes.

(v) Many candidates correctly stated that the enthalpy change for the reaction would be nearly the same because the same number and type of bonds were broken and formed.

### Question 6

a) (i) Most candidates wrote the correct expression for the equilibrium constant, ($K_c$) for the given reaction. The explanation of the significance of the horizontal parts of the lines on the graph was good and the correct value of $K_c$ was deduced.

(ii) The majority of candidates predicted and explained correctly the effect of increasing temperature on the position of the equilibrium.

(iii) The Majority of candidates predicted and explained correctly the effect of increasing pressure on the position of the equilibrium.

(iv) Only a few candidates answered this question stating all six points whereas many candidates did not receive full credit because they missed some of the effects of a catalyst on the position of equilibrium and on $K_c$.

b) (i) The majority of candidates stated that acid X was the least acidic organic acid.

(ii) Many candidates wrote correct answers but some candidates failed to state that acid Y was more acidic than acid Z by a factor of 10.

(iii) Many candidates were able to correctly arrange the three acids in decreasing order of electrical conductivity with appropriate reasoning. A few candidates wrote electrons instead of ions.

(iv) Only some candidates stated correctly that NaOH or a sodium salt of the acid would be added to solution of acid X to form a buffer solution.

**Question 7**

a) The three features of members of the alkene homologous series were well answered by the majority of candidates.

b) Many candidates correctly identified but-2-ene as the alkene with the highest boiling point but their explanations lacked proper reasoning. Some candidates stated that '*but-2-ene has a higher boiling point because it has the greatest number of bonds to break'*.

c) Most of the candidates correctly wrote the structural formula of the alkene containing five carbon atoms.

d) Many candidates recognised this reaction as addition and generally wrote the correct equation and the structure of the organic product.

e) This part proved to be difficult for many candidates. The answers were vague and only a few candidates interpreted the question correctly.

f) Some candidates stated that the strongest intermolecular force present in propan-1-ol, propanal and propanoic acid is hydrogen bonding instead of identifying the strongest intermolecular force in the compounds separately.

## Recommendations and guidance for the teaching of future candidates

- 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.
- Candidates must write the answers in Section A in the question paper and not on separate sheets. In addition, answers should not be written in pencil, and underlining with red pen should be avoided.

# Standard level paper three

## Component grade boundaries

| **Grade**: | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Mark range**: | 0-6 | 7-12 | 13-18 | 19-22 | 23-26 | 27-30 | 31-40 |

## General comments

In general the range of marks awarded to this Paper 3 was very wide. Some candidates tried to answer some of the Options which were clearly very demanding for them and which they weren't really prepared for. They scored poorly. Also there were very good answers in some of the Options chosen, thus gaining very high marks. Everybody attempted just the two Options.

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

The majority of candidates seemed very well prepared to answer the Options they chose, but a minority chose Option E (Chemical Industries) giving very poor answers or not answering all the questions asked, and in this way losing many marks. Also Option F was not that popular with the candidates, but the answers given were better and obviously they received higher marks. Some candidates still lose marks by giving answers that are too superficial or contain very little chemistry. There are still some candidates that do not comprehend the processes of melting and boiling of substances. The areas where it seemed that the candidates had considerable difficulty were:

- Reaction Mechanisms
- Rate constant and its units
- pH of buffers
- Methods for alcohol detection
- Main and side effects of some drugs
- Calculation of Iodine number
- Differences between fats and oils, mainly about their structures
- Extraction of aluminium
- Batteries

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

This was in general a straightforward paper. Most candidates showed that they were familiar with the subject material in the Options chosen. Candidates from some centres chose different Options, but it seemed that where all the candidates chose the same Option they performed much better. The paper discriminated well between candidates, and the better candidates gave some very good answers showing that they were well prepared. In general candidates limited their answers well to the space given.

The areas which seemed well known and understood were:

- Order of reactions
- Weak acids and $K_w$ and $K_a$.
- Neutralization, antacids
- Analgesics
- Vitamins
- Primary pollutants
- Water treatment

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

## Option A – Higher physical organic chemistry

### Question 1

a) Nearly everybody deduced the correct order of reaction with respect to $O_2$. Some of the wrong answers gave the order as zero or ½.

b) Deducing the order of reaction with respect to NO was a bit more difficult. A few candidates said it was order 1 or order 3, but the majority correctly said it was second order.

c) Stating the rate expression for the reaction given didn't present any difficulty.

d) Substituting the values of rate and concentrations from the table was fine and produced the correct value for the rate constant : $1.75 \times 10^2$, but getting the correct units proved to be more challenging. The units were $dm^6 mol^{-2} s^{-1}$.

e) In this section many candidates lost a few marks. The possible mechanisms given didn't always agree with the rate expression, or they said it was a $S_N1$ or $S_N2$ reaction. In general the candidates could identify the rate determining step as the one where the $NO_2$ was formed.

### Question 2

a) This was another question where the candidates had problems, but a great number of them gave the correct equations illustrating the $S_N1$ mechanism. The carbocation was shown correctly in the ionisation equation of the organic compound and then the equation showing the bond formation.

b) Many candidates correctly identified the rate determining step and gave the correct reason as saying that it was the slow step or it was the step where a bond breaking took place.

c) (i) Here there were very good answers saying that the rate of the reaction between 2-chloro-2-methylpropane and KOH would be less than the rate of the 2-iodo-2-methyl propane and KOH because the C-Cl bond was stronger than C-I bond and so it would be more difficult to ionise or break.

(ii) In a similar way many candidates correctly said that the rate with 2-iodo-2-methyl propane with KOH would not be affected by a higher concentration of KOH because the kinetics for these reactions was first order and so the KOH (the nucleophile) was not involved in the rate determining step, therefore its concentration did not influence the rate.

### Question 3

a) (i) Nearly all the candidates gave the correct expression for the ionic product constant of water, $K_w$. Writing $[H_2O]$ in the denominator was a common error.

(ii) Most candidates answered this correctly giving a value of $1.5 \times 10^{-7}$ mol $dm^{-3}$ as the $H^+$ concentration at 310 K.

b) (i) Writing the equation to show the reaction of the lactic acid with water did not present a real problem to candidates. One of the main mistakes was not to use the double arrow to show that the acid was not completely ionised in water or that it was a weak acid.

(ii) Most candidates gave the correct ionisation constant expression for lactic acid.

(iii) The pH was correctly calculated as 2.3 by most candidates.

(iv) The pH of the solution containing the acid and the sodium salt in equal amounts was correctly given as 3.85, either determined or calculated using the ionisation constant expression, by some candidates.

## Option B – Medicines and Drugs

### Question 1

a) Most candidates correctly wrote the balanced equation for the reaction of HCl with magnesium hydroxide and a few wrote the equation for HCl with Aluminium hydroxide instead. The main loss of marks was due to the wrong formula for the $Mg(OH)_2$, $MgCl_2$, $Al(OH)_3$ or $AlCl_3$ or for not balancing the equation given.

b) $Al(OH)_3$ was correctly identified as the antacid that would neutralize the greater amount of HCl present in the stomach.

c) Only a few candidates realised that using NaOH to neutralize the acid in the stomach would be wrong because NaOH would corrode the tissue in the stomach because it is a strong alkali.

### Question 2

a) Not many candidates knew that the function or role of potassium dichromate(VI) was to be an oxidising agent and would accept electrons. Most candidates gave one colour, yellow, orange or green, but did not give the colour change asked for.

b) The answers to this question were rather poor. Not many candidates gave the correct answers which were gas-liquid chromatography and infra-red spectroscopy.

c) The harmful effect of aspirin missed by the candidates was stomach bleeding especially if it was taken with alcohol.

d) The two functional groups that were present in the two depressants were ketone or carbonyl and amine. Not many candidates gave both correctly.

### Question 3

a) (i) The majority of candidates gave the correct effect of aspirin, other than reducing pain, which was common to paracetamol (acetaminophen) which was to be antipyretic or that reduced the fever.

(ii) One advantage of aspirin which was not common to paracetamol was that aspirin was anti-inflammatory or had anti-clotting properties or was used in the treatment of and to prevent heart attacks.

b) (i)Functional groups that were common to morphine, codeine and heroin were ether, alkene or carbon to carbon double bond or amine.

(ii) The main effect of morphine was correctly given by most candidates as pain relief, but the side effect, constipation, was missed by most candidates.

c) (i) The meaning of the term $LD_{50}$ was well explained by the majority of candidates. Some of the wrong answers were: it is the amount of drug that is given to a patient depending on the size of the person, the % of substance in the body found after ingestion.

(ii) Also, a great number of candidates realised that the heroin was more toxic because its $LD_{50}$ was 4 and for morphine was 20.

## Option C – Human Biochemistry

### Question 1

a) (i) Most candidates identified correctly alpha and beta glucose as the diagrams A and C respectively.

(ii) Many candidates responded “yes” to this question, that the two ring forms of glucose would be enantiomers. Only a few gave the correct answer saying that they would not be because they were not mirror images, or that they were both D isomers or because the OH group at C1 was below the plane in one form and above the plane in the other form.

(iii)Most candidates correctly said that carbons 1 and 6 in structure B were not chiral, but a few candidates said that

carbon 4 was also not chiral.

b) The ring structure of galactose was well drawn in most cases and given the correct form, this was beta isomer. A few candidates showed the OH group in C4 below the plane.

c) All candidates correctly stated that one of the major functions of polysaccharides in the body was as energy storage or energy reserve.

**Question 2**

a) (i) Some candidates could not determine the correct number of carbon to carbon double bonds in linoleic acid from the molecular formulas given.

(ii) The calculation of the iodine number seemed more difficult for the candidates. Knowing that linoleic acid had two double bonds it was found that 280.5 g of linoleic acid would add to (react with) 507.6 g of Iodine, so 181 g of Iodine would add to100 g of linoleic acid.

b) (i) This question was not properly answered. Not many candidates said that fats and oils are tri-glycerides or tri-esters or made up from glycerol and fatty acids. Most candidates just quoted “ester”.

(ii) This question was in general only partially well answered. Most candidates mentioned the presence of the carbon to carbon double bonds in oils, and not in fats, but not all of them mentioned the weaker van der Waal’s forces present due to the fact that oil unsaturated chains will pack less closely. Some candidates were very confused saying that fats were saturated so they had double bonds or that fats were unsaturated with double bonds. Some also said that oils were liquids because the bonds between Carbon and Carbon were easily broken, and didn’t talk about intermolecular forces. A few candidates said that oils had double bonds and because these bonds were weaker the oils had lower melting points.

c) (i) High temperature was needed for the reaction between fat and NaOH solution. Some of the wrong answers were water or a catalyst.

(ii)The other product formed besides soap was glycerol. A few candidates said it was water, others $H_2$. The structural formula of 1,2,3-propantriol was not always given.

**Question 3**

a) Most candidates gave the three correct names of the diseases which resulted from the deficiencies of Vitamins A, C and D. Some candidates gave the symptoms of diseases instead of naming them as asked.

b) A large majority of candidates knew that vitamin C was water soluble so it would be excreted from the body and vitamin D would be stored because it is fat soluble.

## Option D – Environmental chemistry

**Question 1**

a) (i) Most candidates identified correctly the main two primary pollutants, CO and NOx, but they missed others such as hydrocarbons. Everybody correctly said that CO is produced by the incomplete combustion of hydrocarbons, but not everybody said that the NOx are produced by the high temperatures in an internal combustion engine.

(ii) The equation to show the reaction between two primary pollutants in a catalytic converter was sometimes not balanced or had $O_2$ as a reactive or sometimes as a product.

(iii)Most candidates stated correctly the natural and the man made source of sulphur dioxide in the atmosphere.

b) This question was rather difficult for most candidates. Some of them stated some of the HFC's uses or how good or bad a solution to the problem they were or that they should have a low melting point.

**Question 2**

a) There were very good answers about the three different methods by which sea water can be converted into fresh water. In particular, many candidates gave good features of reverse osmosis, indicating its main points in a concise way. A few candidates did not give the proper names for the 3 methods, but they explained some of the features, thus losing a few marks.

b) The majority of candidates stated the two differences between drinking water treatment with chlorine and ozone, but some of the candidates did not give the correct similarity, that chlorine and ozone are both oxidizing agents so they kill microorganisms such as bacteria. A few candidates just said that both chlorine and ozone purify the water or clean the water or that both give good results in purifying water.

## Option E – Chemical industries

**Question 1**

a) Not all the candidates who tried this question gave full answers, the comparison in reactivity between Al and C was missing. It was not enough to say that aluminium was very reactive.

b) The strong attraction between ions of high charge density was the reason that alumina had such a high melting point.

c) Many candidates knew that molten cryolite was used because cryolite lowered the melting point of alumina. One of the wrong responses was : it was used to remove impurities.

d) Good attempts at answering this part with the ionic equations. Some candidates missed the charges or they were wrong.

e) Positive electrodes had to be replaced because they react with the oxygen (they are made of graphite). Again this question was not clearly answered by a few candidates who said that they had to be replaced because impurities accumulated on the surface of the electrodes.

**Question 2**

a) The other function of coke was to act as a reducing agent, by reducing iron oxide to iron.

b) The impurity removed by calcium oxide was $SiO_2$ or sand and this was possible because CaO was basic and $SiO_2$ acidic.

c) (i) Many candidates didn't know the other two substances added to the basic oxygen converter. They were oxygen and calcium carbonate or limestone and not just carbon.

(ii) The function of these two substances were: oxygen to oxidise impurities and then the oxidised impurities reacted with limestone.

d) Some good answers here but a few candidates gave wrong answers such as: Al resists corrosion because it does not bond with oxygen; or Al resists corrosion because it is amphoteric.

**Question 3**

a) Most candidates gave the correct names and formulas for the products formed in the three types of reforming processes.

b) Many candidates explained very well the reasons behind the removal of sulfur compounds from crude oil.

c) The by-product of both cracking and reforming processes was Hydrogen ($H_2$).

**Option F – Fuels and energy**

**Question 1**

a) The calculation of the amount of energy produced proved to be difficult for the great majority, but those who did it correctly in general showed the working out and obtained the correct values of 55.6 kJ and 48.4 kJ for natural gas and petroleum respectively. A few candidates did not even try to answer this question, others made a mistake in calculating the mass of $C_8H_{18}$.

b) (i) Only very few candidates said that the removal of sulfur compounds from coal was difficult.

(ii) Most candidates correctly said that most oxides of nitrogen are produced by the high temperature in internal combustion engines.

(iii) Nearly all candidates knew that CO is produced from all three fossils by their incomplete combustion.

c) The equation showing the formation of CO by the combustion of methane was very well done in general, but sometimes it was not correctly balanced.

d) This calculation was done well by some candidates. A few candidates used the equation for the incomplete combustion of methane instead of using the equation for the complete combustion of methane as asked. Assuming that air contains about 20% oxygen by volume the complete combustion of 100 $dm^3$ of pure methane needed 1000 $dm^3$ of air.

e) Not many candidates answered this question correctly. Two of the properties that make the components present in gasoline suitable for use in internal combustion engines are the fact that gasoline is a liquid at room temperature and that it readily transforms into vapour.

f) A few candidates gave the formula of octane instead of the formula of heptane. The structural formula of 2,2,4-trimethyl pentane was correctly given most of the time.

g) The fraction of crude oil that was used as jet fuel was kerosene (paraffin).

**Question 2**

a) Not many candidates could write the correct half-equations to show the reactions taking place during the discharge. Sometimes the electrons or the hydrogen ions were missing or the equations had $PbSO_4$ as a reactant.

b) Many candidates correctly identified the reducing agent as Pb, but finding the oxidizing agent was a bit more difficult. Some of the following were given as such: $PbSO_4$, Pb, S.

c) Only very few candidates gave a possible change in the electrolyte. These possible changes were a decrease in concentration, density or acidity or an increase in pH.

d) The majority of candidates gave good answers to this question.

## Recommendations and guidance for the teaching of future candidates

- Candidates should be prepared all year round with questions from past examinations and markschemes.
- Candidates should pay attention to the number of marks allocated to each sub-question and to the space given for the required answer.
- Candidates should focus on understanding the chemistry involved in the two Options rather than memorizing it.

- Candidates should read questions carefully and answer the question that is being asked, rather than making general comments.
- Candidates should become familiar with the different types of reaction mechanisms by doing many examples.