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## FOREWORD

This booklet contains reports written by Examiners on the work of candidates in certain papers. **Its contents are primarily for the information of the subject teachers concerned.**



# CHEMISTRY

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## GCE Advanced Level and GCE Advanced Subsidiary Level

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| <p>Paper 9701/01<br/>Multiple Choice</p> |
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| <i>Question Number</i> | <i>Key</i> | <i>Question Number</i> | <i>Key</i> |
|------------------------|------------|------------------------|------------|
| 1                      | C          | 21                     | B          |
| 2                      | D          | 22                     | C          |
| 3                      | B          | 23                     | D          |
| 4                      | C          | 24                     | A          |
| 5                      | A          | 25                     | D          |
| 6                      | A          | 26                     | C          |
| 7                      | A          | 27                     | C          |
| 8                      | C          | 28                     | B          |
| 9                      | B          | 29                     | D          |
| 10                     | C          | 30                     | B          |
| 11                     | C          | 31                     | D          |
| 12                     | D          | 32                     | D          |
| 13                     | D          | 33                     | A          |
| 14                     | D          | 34                     | B          |
| 15                     | C          | 35                     | A          |
| 16                     | C          | 36                     | B          |
| 17                     | B          | 37                     | D          |
| 18                     | C          | 38                     | A          |
| 19                     | B          | 39                     | B          |
| 20                     | B          | 40                     | B          |

### General comments

For this paper, the mean score was 23.0 (57.4%), very near the targeted value of 60%, and the standard deviation of the scores was 7.34 (18.4%), indicating that overall the paper performed satisfactorily.

The first thirty questions were simple completion items: **Questions 31-40** were three-statement multiple completion items.

### Comments on specific questions

Three questions – **Questions 9, 22** and **28** – had a high facility, representing areas of the syllabus that were widely understood.

Two questions did not adequately distinguish between the more able and less able candidates. The

relatively high facility of **Question 10** indicated that the acid catalysis of esterification is widely understood, and this led to a low discrimination. **Question 34** was concerned with the dissolution of hydroxyapatite within tooth enamel under acidic conditions, and gave two successive equilibria. There was an indication that some candidates did not appreciate that the reaction of the  $\text{PO}_4^{3-}$  ion with a proton (in the second equilibrium) would reduce its concentration in the first equilibrium, causing this equilibrium to move to the right with the consequent increase in solubility of the hydroxyapatite.

**Question 24** had both a low facility and a low discrimination among candidates: this question tested candidates' understanding of how an alcohol could be dehydrated by concentrated sulphuric acid to give alkenes, and the possible *cis-trans* isomerism of these products. 2-Methylbutan-2-ol gives both  $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)=\text{CH}_2$  and  $\text{CH}_3\text{CH}=\text{C}(\text{CH}_3)_2$ , and neither of these possess *cis-trans* isomerism, yet no less than 58% of candidates believed that there were three possible products.

**Question 12** although a valid question this did not perform as well as expected, and was withdrawn from the examination.

All other questions performed satisfactorily but two deserve comment. **Question 16** tested knowledge of the relative ease of thermal decomposition of Group II carbonates by asking candidates to consider the effect of heat on some double salts: the result shows that this novel approach led to many candidates guessing the answer. **Question 18** asked why a mixture of CaO and  $(\text{NH}_4)_2\text{SO}_4$  would not be effective in acting both to reduce soil acidity and to be a fertiliser. Whereas 33% of candidates correctly realised that under damp conditions ammonia would be lost, some 46% thought that the significant factor would be that the consequent  $\text{CaSO}_4$  would cause hard water.

Paper 9701/02

Theory 1

### General comments

Many candidates made good attempts to answer all of the questions, demonstrating sound knowledge and a good understanding of the Chemistry examined in this paper. However, there are still a significant number of candidates whose knowledge, particularly of Organic Chemistry, is poor.

Overall, however, the answers given maintained the improvement in the quality of candidates' performance which has been evident in recent examinations. Most candidates were able to demonstrate some positive achievement.

### Comments on specific questions

#### Question 1

This question tested candidates' understanding of important evidence used in the determination of the electronic configuration of elements. There were a good number of high scoring answers.

- (a) While there were some very clear and accurate answers to this part, there were also many answers that were incomplete or contradictory. Typical of these were answers such as 'It is the energy required to remove one mole of electrons from one atom of an element in the gas phase'.

It is important that definitions of energy changes are unambiguous. In their answers to this question candidates were expected to refer to the energy required for the removal of one mole of electrons from one mole of gaseous atoms.

- (b) This was generally well answered although a significant number of candidates either omitted the state symbols asked for in the question or gave an equation for *first* ionisation energy.
- (c) Most candidates deduced that element **X** would be in Group V because of the large jump in ionisation energies between the fifth and sixth values. Fewer were able to relate this observation to the sixth electron of element **X** being removed from an inner shell.
- (d) The question asked for an explanation of the data 'in terms of the atomic structure of the elements'. A significant number of candidates chose to discuss the nature of the bonding within a sample of the element and were penalised as a result. Examiners expected a discussion of the changes in atomic radius, numbers of shells and shielding on going down Group IV and how they influence the ionisation energies. Many candidates referred to at least two of these points but few considered the effect of the increase in nuclear charge which takes place from carbon to tin.

**Question 2**

A good understanding of bonding and energetics is important and many candidates answered this question well.

- (a) Most candidates drew clear diagrams showing the correct numbers of electrons associated with each atom and the double bond that exists between each of the S atoms and the central C atom.
- (b) The majority of candidates correctly stated that the CS<sub>2</sub> molecule is linear with a S-C-S bond angle of 180°.

Examiners did not accept 'planar' as a correct description of the shape of the CS<sub>2</sub> molecule.

- (c) There were many answers that contained very loosely worded definitions of the term *standard enthalpy change of formation*. Examiners expected candidates to refer to the energy change that occurs when one mole of a compound is formed, under standard conditions, from its elements in their standard states. Examiners did not allow the use of the word 'substance' instead of the word 'compound'.
- (d) There were many correct answers of +119 kJ mol<sup>-1</sup>. The most common error was to omit to double the value for  $\Delta H_f^\ominus$  for SO<sub>2</sub>.
- (e) A surprising number of candidates struggled with this part. The yellow solid can only be sulphur and this leads to the following equation: CS<sub>2</sub> + 2NO → 2S + CO<sub>2</sub> + N<sub>2</sub>. In this equation, the molar ratio of the gases is in the ratio 1:1, as stated in the question.

**Question 3**

The chemistry of nitrogen is important and there were many good answers to this question.

- (a)(i) Most candidates related the unreactivity of nitrogen to the presence of the N:N triple bond. Unfortunately a significant number made no specific comment about the *strength* of this bond or that a large amount of energy is required to break it, and these candidates were not given full credit for their answers.
- (ii) Most candidates gave a suitable equation although some were penalised for giving unbalanced equations. Conditions were generally clearly and correctly stated.
- (iii) This part was not as well answered. Many candidates did not explain clearly how the conditions they gave would provide enough energy to break the N:N bond or overcome the activation energy.
- (b)(i) Most candidates correctly gave 'fertiliser' as their answer.
- (ii) There were many clear accounts of how eutrophication occurs and what happens as a result. There was, however, a significant number of candidates who either talked about acid rain or who made general comments about pollution and were given no credit for their answers.
- (c) Most candidates correctly identified gas Y as ammonia and were able to give the correct equation for its formation. Even though state symbols were given in the question, a small number of candidates omitted them or gave incorrect ones, and were penalised as a result.
- (d) While many candidates knew that ammonia would react with concentrated sulphuric acid in an acid-base reaction, there were some who thought, wrongly, that ammonia would be oxidised by concentrated sulphuric acid.

### Question 4

Understanding the structures of molecules is an important part of AS Chemistry but many candidates continue to be confused when representing the structural formulae of organic molecules.

- (a) Many candidates struggled to explain the term *primary alcohol* in a clear and unambiguous way. The simplest statement Examiners accepted was that a primary alcohol 'is a compound which contains the  $-\text{CH}_2\text{OH}$  group'. An alternative definition describes a primary alcohol as having the  $-\text{OH}$  group on a carbon atom which is bonded to only *one* other carbon atom – see for example the endorsed text book "AS Level and A Level Chemistry" by Ratcliff et al, published by Cambridge University Press, page 338.
- (b) While there were many candidates who drew three different structures which were correctly labelled, there were also many who confused themselves by drawing the same structure in a slightly different format. A typical wrong answer using, butan-1-ol, the structure of which was given in the question, is shown below:



- (c) The majority of candidates correctly described the colour change as being from orange to green. Examiners did not accept 'yellow' as correctly describing acidified potassium dichromate(VI). There was a significant number of candidates who gave the colour change as being purple to colourless, clearly having acidified potassium manganate(VII) in mind.

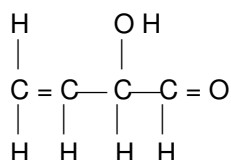
### Question 5

This question assessed candidates' ability to interpret the results of specific reactions and gradually deduce the structure of compound **Z**. Examiners were impressed by many of the answers given.

- (a)-(c) While many candidates made sensible deductions, there were also some who did not make their functional group unambiguous.

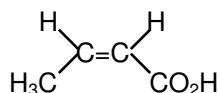
For example, Examiners expected the following answers: (a) alkene *not* double bond; (b) alcohol *not* hydroxyl; (c) aldehyde *not* carbonyl.

- (d) Relatively few candidates were able to give a correct structure involving all of the groups given above *and* including a  $\text{H}_2\text{C}=\text{C}$  group so that the compound would *not* show *cis-trans* isomerism. There are three possible correct answers, one of which is given below:



- (e) There were many good attempts at drawing the required structures. Both reactions involved the alcohol group with the formation of an alkoxide with sodium and a methyl ester with ethanoic acid.
- (f) Fewer candidates were able to identify the organic products of the two reactions involving the aldehyde group. With Tollens' reagent, the corresponding carboxylic acid would be formed while with 2,4-dinitrophenylhydrazine, an addition-elimination reaction would take place with the formation of the corresponding 2,4- dinitrophenylhydrazone.

- (g) Many candidates found this part difficult. The structural formula (not displayed) of *cis*-but-2-enoic acid is shown below:



A significant number of candidates failed to draw the *cis* isomer and were penalised. Another common error was for candidates to give a structure containing two carboxyl groups. Such a compound would be called butanedioic acid.

**Paper 9701/03**

**Practical Test**

### General comments

The Examiners reiterate the general comments made after the June 2005 examination session.

Upon receipt of a packet of scripts, Examiners used the information supplied in the Report on the Examination, the seating plans and the Supervisor's Results to sort candidates into appropriate groups for the award of accuracy marks. Accuracy marks were awarded from a comparison of (Volume of **FA 2** diluted x Titre) for candidate and Supervisor.

The Examiners again thank those Centres where all of the information above was provided and they were able to place each candidate in the correct session and laboratory within that session. *A number of Centres failed to provide sufficient (or any) information.*

- Such Centres are again reminded of the wording in the Confidential Instructions.
- Large volumes of solutions should not be bulked (30 candidates maximum for any one solution).
- Separate Supervisor results should be provided for *each Session and for each laboratory within that Session.*
- *Seating plans* should be provided. (It is often possible to spot and resolve solution/titre problems for a small group of candidates in one part of a laboratory where the seating plan has been provided.)

*Where inadequate information was supplied there was the risk that candidates were disadvantaged.*

The Examiners noted that the range of ability to perform a titration was considerable. In many cases the candidates were well prepared and performed the titrations efficiently and with considerable accuracy. At the other extreme, some candidates appeared to have little experience of the apparatus used in performing a titration.

The changes taking place during the tests in **Question 2** required close and careful observation. Many observations were consequently missed.

**Comments on specific questions****Question 1***Titration*

The Examiners checked the subtraction in **Table 1.1** and the volume of **FA 2** run into the graduated flask. The subtraction for all titres in **Table 1.2** was also checked as was the selection, by the candidate, of an appropriate “average” to use in the calculation.

Candidates are reminded of the guidance given in the syllabus:

- Burettes should be read to the nearest  $\frac{1}{2}$  graduation – i.e. to the nearest  $0.05 \text{ cm}^3$ .
- Two titres within  $0.10 \text{ cm}^3$  are sufficient.

The Examiner calculated the difference between the Supervisor’s (volume of **FA 2** diluted x titre) and the same product for the candidate (volumes used corrected where necessary). A maximum of six accuracy marks were awarded for a difference up to eight. Accuracy marks decreased on a sliding scale, four marks being awarded for a difference of 12+ to 20 and one mark for a difference of 40+ to 70.

A deduction was made from the accuracy total for each of the following errors in recording the titration information, (there was a maximum deduction of two marks):

- No data recorded in **Table 1.1** or the recorded (uncorrected) volume of **FA 2** diluted outside the range on the question paper.
- Final burette readings in **Tables 1.1** or **1.2** not recorded to two decimal places or “impossible” burette readings (e.g.  $23.47 \text{ cm}^3$ ) recorded at any point in the table or initial and final burette readings transposed or 50 used as initial burette reading.
- No two titres, as recorded by the candidate, within  $0.1 \text{ cm}^3$ .
- An incorrect “average” calculated or no selection of at least two titres for the calculation of the “average” (*The candidate was allowed to tick the chosen titres or to show a calculation using two or more titres*) or an error in subtraction in any accurate titration (or the titre labelled rough if it was ticked and used in calculating the average).

Failure to indicate the titre used in calculating the “average” titre was a common error.

Candidates are expected to use titre values no more than  $0.20 \text{ cm}^3$  apart in calculating the “average”. In some cases the practice appears to be to perform and average two, three or more titres, regardless of the values obtained.

*Calculations*

- (c) This proved to be a difficult calculation for many candidates. The correct answer was given by dividing the volume of **FA 2** diluted by 250.

A number of candidates calculated the moles of hydrochloric acid in  $250 \text{ cm}^3$  of solution. (These often corrected themselves in the next section).

$\frac{250}{1000}$  or  $\frac{\text{titre}}{1000}$  were other commonly seen ratios.

- (d) Most candidates correctly use  $\frac{\text{titre}}{1000}$  x answer to (c) in this section.

$\frac{\text{titre}}{1000}$  x 1.00 was a common error.



- (e) Most candidates were able to divide their answer to (d) by two, correctly applying the mole ratio for the reaction.

Many candidates omitted to multiply by  $\frac{1000}{25}$  to find the concentration of the disodium tetraborate in **FA 1**.

- (f) A commonly gained mark: the candidate's answer to (e) x an attempted molecular mass for anhydrous borax.

The second mark in this section was for a fully correct evaluation that was within 1% of the value calculated, by the Examiner, from the candidate's results.

Candidates who rounded answers in previous sections to insufficient significant figures were unlikely to obtain this mark.

Sections (g) and (h) were left blank by many candidates.

- (g) Where candidates calculated a mass in (f) that was less than 38.10 the mark was generally gained here for (38.10 – answer to (f)).

Candidates who obtained an answer to (f) that was greater than 38.1 should have been alerted to an error in steps (c) to (e).

Most of these candidates did not look for the error and subtracted 38.10 from their answer to (f).

- (h) The second part of this section, the calculation of a value for **x**, was left blank by the majority of candidates. More able candidates arrived at a correct value by a variety of methods.

Most candidates who gave an answer in (f) were able to divide by 18 to obtain the moles of water present but  $\frac{38.10}{18}$  was a common incorrect answer.

## Question 2

There were fourteen marking points with a maximum of ten marks for the question. Few candidates scored in excess of ten marks for their observations and deductions.

- (a) The Examiners were expecting to see a colourless filtrate and a brown residue.

The colourless filtrate was rarely recorded. Candidates continue to describe a solution as clear when they presumably mean colourless.

More candidates recorded a black mixture or residue than a brown residue.

This observation scored one mark, a brown residue gaining two marks.

- (b) The instruction for the test was to identify the gas evolved. A considerable number of candidates however reported that no gas was given off.

More than half of the candidates failed to identify oxygen as the gas given off in this test – did they follow the instruction to heat strongly?

Carbon dioxide or sulphur dioxide were other gases identified.

- (c) Most candidates recorded a white precipitate, soluble in (excess) sodium hydroxide.

- (d) Most candidates recorded a white precipitate that did not dissolve in (excess) aqueous ammonia.

In tests (c) and (d), the inclusion of the word excess was not necessary as candidates were instructed to add the reagent until there was no further change.

- (e) Almost 100% of candidates recorded a yellow precipitate on adding potassium iodide.
- (f) Most candidates failed to record the solution colour (yellow or yellow/green) after warming the residue from (a) with 50% hydrochloric acid.

Many candidates failed to identify chlorine as the gas given off.

The bleaching effect of the gas on litmus paper was missed. Some observations left the Examiner uncertain as to whether the solution or the gas had bleached litmus paper.

Some Centres had provided starch-iodide paper for the identification of chlorine – not a test included in the printed notes. Correct observations in this test (and deductions from the test) scored marks as correct Chemistry is always rewarded. Some candidates, however, recorded their observation with this test paper as white litmus paper turning blue.

A number of candidates reported carbon dioxide, sulphur dioxide or ammonia.

### Deductions

Most candidates correctly identified the cation present in **FB 4** as  $Pb^{2+}$  and gave at least one piece of supporting evidence.

Evidence accepted by the Examiners was:

- The yellow precipitate with potassium iodide.
- White precipitate with sodium hydroxide dissolving in (excess) reagent *and* the white precipitate with aqueous ammonia, insoluble in (excess) reagent.

Many candidates did not appreciate that the evidence from sodium hydroxide and aqueous ammonia had to be taken together to support a conclusion of  $Pb^{2+}$  (or  $Al^{3+}$ ). The test with potassium iodide identifies the cation as  $Pb^{2+}$  and not  $Al^{3+}$ .

Better candidates gave a full and logical identification of  $Pb^{2+}$  and elimination of  $Al^{3+}$ .

Many candidates stated that **FA 4** acted as an oxidising agent but were unable to support this conclusion.

Some candidates justified their conclusion of an oxidising reagent from the yellow precipitate with potassium iodide, having detected chlorine in test (f).

A significant number of candidates stated that **FA 4** acted as an *oxidising agent* because it *reduced* chloride to chlorine gas, or that it was a *reducing agent* as it *oxidised* the chloride to chlorine.

Paper 9701/04

Structured Questions

### General comments

The general standard of answers was about the same as last year's. It was noted, however, that some candidates lost marks through thoughtlessness or carelessness. Since the time allowed for this examination is now quite generous, candidates are strongly advised to check their work before handing in their papers. Examples included the unreadable alteration or writing-over of crossed-out formulae and charges, rather than writing the whole formula again; the incorrect transcription of numbers from calculators (e.g.  $10^{-13}$  being transcribed as  $10^{-3}$  or  $10^{-31}$ ); the omission of, or the use of the incorrect, state symbols; and the reversal of the positions of atoms in organic groups (e.g.  $CN-CH_2^-$  rather than  $NC-CH_2^-$ ).

The organic chemistry questions still show up an enormous difference between some candidates in the effectiveness with which they learn the reagents, and the reactions of functional groups.

**Comments on specific questions****Question 1**

- (a) Many candidates scored two marks here, but a common error was to use the  $A_r$  of Ag instead of the  $M_r$  of AgBr to calculate the number of moles in a grain of AgBr. Some candidates attempted to use the (approximate) figure given for the diameter of the grain in their calculation, with predictable results.
- (b)(i) The structure of the question helped most candidates to score at least one mark here. Common errors were to refer to **A** as an inert electrode (or graphite) rather than platinum; to suggest that **B** was a solution of a silver salt; to identify **C** as an ammeter, a galvanometer or a voltmeter; or to suggest **D** was made of platinum (or copper, or steel) rather than silver.
- (ii) Most candidates scored this mark, for predicting a decrease in electrode potential.
- (iii) Some candidates included  $[AgBr(s)]$  in their  $K_{sp}$  expressions. Candidates seem to be more familiar with using solubility products to calculate solubilities, rather than the other way round. Thus several took the square root of  $7.1 \times 10^{-7}$ , rather than squaring it.
- (c)(i) The lattice energy should have been defined in the exothermic direction, as mentioned in the syllabus. Many candidates scored a mark here, but a few wrote the equation defining enthalpy change of formation, or started with the gas phase atoms rather than the ions. More lost the mark through not including the correct state symbols for the three species involved.
- (ii) The usual range of values was seen for the final answer, although it was heartening to see how many candidates' calculations were totally correct. The most common error, apart from omitting the negative sign, was to divide the  $\Delta H_{at}$  of bromine by two (possibly thinking it was the Br-Br bond energy that had been given in the question).
- (iii) Candidates were less successful in scoring marks for this part. Although many correctly suggested that the lattice energy of AgCl should be higher than that for AgBr, their explanations were not convincing. Answers that did *not* score the mark included references to electron affinity, electronegativity, bond strength (or length) of the Ag-X bond, charge density, and the size or radius of the Cl or Br **atoms** (rather than the **ions**).
- (d) For this explanation candidates were expected to consider the differences between the (isolated)  $Cl^-$  and  $Br^-$  ions. Correct answers included references to the differences in one or more of the following: ionic or atomic radius or size, shielding of outer electrons, electron affinity, ionisation energy.

Answers: (a)  $8.0 \times 10^9$  ions; (b)(ii)  $5.0 \times 10^{-13} \text{ mol}^2 \text{ dm}^{-6}$ ; (c)(ii)  $-903 \text{ kJ mol}^{-1}$ .

**Question 2**

- (a) Many candidates scored well on this part. The answer should have included reference to the standard hydrogen electrode, and to the standard conditions needed (temperature of  $25^\circ\text{C}$  and concentrations of  $1.0 \text{ mol dm}^{-3}$ ).
- (b) Candidates were expected to show evidence of having extracted the correct  $E^\ominus$  values from the Data Booklet, and to have stated that the stronger the halogen is as an oxidising agent, the more positive is its  $E^\ominus$  value. This was generally well answered.

- (c) This type of question is always a good discriminator between the better candidates, who grasp the chemistry of redox reactions, and the less able candidates, who pick the first pair of electrode potentials that they come across, and often end up with “reactions” between two oxidised forms, or reactions including reagents not mentioned in the question.
- (i) This proved to be the more difficult of the two parts, with a significant number of candidates coming into the “less able” category mentioned above. Playing with figures, and getting the signs of  $E^\ominus$  values wrong, allowed a considerable number of candidates to predict a “reaction” in which  $\text{H}_2\text{O}_2$  was able to reduce  $\text{K}^+$  to  $\text{K}$  (in aqueous medium!), in the process being oxidised to  $\text{O}_2(\text{g})$ . No thought was given to the oxidation of  $\text{I}^-$  to  $\text{I}_2$ .
- (ii) The more straightforward oxidation of  $\text{SO}_2$  to  $\text{H}_2\text{SO}_4$  by  $\text{Cl}_2$  was recognised by many, who also wrote the correct (easily) balanced equation.
- (d) This was another question that separated candidates who had just taken a cursory look at the Data Booklet from those better candidates who had looked in greater detail. The  $E^\ominus$  value of  $\text{I}_2/\text{I}^-$  is high enough not only to oxidise  $\text{Sn}$  to  $\text{Sn}^{2+}$ , but also  $\text{Sn}^{2+}$  to  $\text{Sn}^{4+}$ . Thus the final product would be  $\text{SnI}_4$ .

Answers: (c)(i)  $E^\ominus = 1.23 \text{ V}$ , (ii)  $E^\ominus = 1.19 \text{ V}$ .

### Question 3

- (a)(i) Many graphs were drawn very poorly, with no indication of where on the curves the individual elements occurred. Candidates were expected to know that the melting point of either of the carbon allotropes is high ( $\approx 3500^\circ\text{C}$ ); those of silicon and germanium are medium ( $\approx 1000^\circ\text{C}$ ); whereas those of tin and lead are low ( $\approx 300^\circ\text{C}$ ), but with lead having a slightly *higher* melting point than tin.

As far as the conductivity graph was concerned, either graphite (high conductivity) or diamond (low conductivity) could have been used for carbon. Both silicon and germanium have medium conductivities, whereas those of tin and lead are high.

Candidates were not expected to know actual values, but for the reference of teachers, the following table lists values as given in various Data Books.

| element  | m.pt./ $^\circ\text{C}$ | conductivity        |
|----------|-------------------------|---------------------|
| C(graph) | 3652                    | $2 \times 10^3$     |
| C(dia)   | 3550                    | $1 \times 10^{-15}$ |
| Si       | 1410                    | $2 \times 10^{-2}$  |
| Ge       | 937                     | $2 \times 10^{-2}$  |
| Sn       | 232                     | $9 \times 10^4$     |
| Pb       | 328                     | $5 \times 10^4$     |

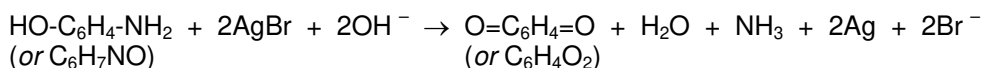
- (ii) Candidates were expected to describe the bonding in diamond, silicon and germanium as *giant covalent*, with localised electrons, whereas that in tin and lead is *metallic*, with delocalised electrons. Mention of the causes of the intermediate conductivities of silicon and germanium due to the low-lying (potentially delocalised) conduction band was not required. Many candidates described silicon and germanium as *metalloids*. This may well be true, but the term was not accepted as a description of the structure and bonding within these two elements.
- (b)(i) Candidates were better at illustrating this comparison between the oxides of carbon than the one between the lead oxides in (ii). Suitable reactions quoted included the burning of  $\text{CO}$  in air to produce  $\text{CO}_2$ , or the use of  $\text{CO}$  to reduce  $\text{Fe}_2\text{O}_3$  in the blast furnace.
- (ii) The most suitable reaction here was the thermal decomposition of  $\text{PbO}_2$  to  $\text{PbO}$  and  $\text{O}_2$ .
- (c) One of the learning outcomes in the syllabus states that “candidates should be able to recognise the properties and uses of ceramics based on silicon(IV) oxide”. Few candidates had any idea as to what a ceramic is. Most suggested, incorrectly, that glass is a ceramic. Some suggested silicon chips or quartz. Answers describing tiles, bricks, pottery, china, porcelain, ceramic hobs etc. were expected, but rarely seen. Suitable properties (depending on their use) included hardness, strength, high melting point, insulator, unreactivity.

- (d) Most candidates knew the term *amphoteric* in (i), and many were able to write an equation for the reaction between tin oxide and an acid in (ii). Very few, however, successfully composed an equation for the reaction between tin oxide and an alkali. There was a considerable number of candidates who lost a mark in one of the following ways: using SnO<sub>2</sub> instead of SnO as the formula for tin(II) oxide; using PbO instead of SnO; or writing the symbol for tin as Tn or (most commonly) Ti, instead of Sn. Accepted formulae for the stannate salt formed by reaction with NaOH included Na<sub>2</sub>SnO<sub>2</sub>, Na<sub>4</sub>SnO<sub>3</sub>, NaSn(OH)<sub>3</sub>, Na<sub>2</sub>Sn(OH)<sub>4</sub> etc.

#### Question 4

This question continued the photography theme of **Question 1**, by looking at the role of the organic reducing agent used as the “developer”.

- (a) This was quite a difficult equation to construct, and thus it proved a good discriminator. The more able candidates produced the correct equation, as follows.



- (b) Most candidates correctly predicted that rodinol would be less basic than ammonia, but fewer were able to explain this in terms of the delocalisation of the nitrogen's lone pair of electrons over the ring, which makes it less available for reaction with a proton. Some suggested that the presence of the (weakly acidic) phenolic group in rodinol was responsible for the lack of basicity. Unfortunately, a few candidates misread the question, and thought it asked how the basicity of rodinol might be compared to that of ammonia, and thus attempted to describe an experiment to determine this.
- (c) Candidates' recall of aromatic chemistry was patchy. Most correctly suggested the sodium phenoxide for **E**, but often incorporated a chlorine atom into the ring in their structure for **F** (which was the hydrogen chloride salt of rodinol). Another error was to incorporate an extra hydrogen atom into the formula (ArNH<sub>4</sub>Cl instead of ArNH<sub>3</sub>Cl). Although many drew a brominated ring for **G**, a mark was only gained if *more than one* bromine atom had been incorporated (the orientation was not assessed).
- (d)(i) Gaps in knowledge of aromatic chemistry were again shown by candidates in their answers here. Most incorrectly suggested the usual nitrating mixture, whereas *dilute* nitric acid (without any sulphuric acid) was the correct answer, rodinol containing a highly activated ring, like phenol.
- (ii) Many candidates correctly suggested that step **II** was a reduction reaction.
- (iii) Even candidates whose answer to (ii) was correct often failed to identify the one reducing agent in the list, Sn + HCl(aq).
- (e)(i) Surprisingly, it was the phenol rather than the amide that proved difficult for candidates to identify. Many suggested hydroxy (too vague) or alcohol (incorrect). Some attempted to split the amide group into an amine and a ketone.
- (ii) Either ethanoyl chloride or ethanoic anhydride (or their formulae) was accepted. Common incorrect answers included ethanoic acid and ethyl or ethanyl chloride.

#### Question 5

- (a) Many candidates correctly identified **H** as an addition polymer and **J** a condensation polymer.
- (b) Most candidates recognised that *hydrogen bonding* would be important here.
- (c)(i) Having identified the “side-chain” functional group in **J** as an alcohol, the more able candidates were able to choose the diacid HO<sub>2</sub>CCH<sub>2</sub>CH<sub>2</sub>CO<sub>2</sub>H as the most likely candidate for the cross-linking molecule. Less able candidates seemed to choose a compound at random, the most popular being the diamine.
- (ii) The expected answer was ester, and many candidates gave this. However, due to a slight ambiguity in the wording of the questions, the word “covalent” was also accepted!

- (d) This was well answered on the whole. Most candidates realised that suitable hydrolysis conditions would be to heat in aqueous acid or alkali, and many drew the correct structures in (ii). A bonus mark was available for candidates who appreciated that one or other of the products would be in its ionic form after treating with an acid or a base. Thus acidic hydrolysis would produce the dication of the diamine, whereas alkaline hydrolysis would produce the dianion of the dicarboxylic acid.
- (e)(i) A number of candidates had little idea of the structure of the intermediate, whereas many of those who did, failed to score the mark due to their drawing the structure as  $\text{CNCH}_2\text{CO}_2\text{K}$  (i.e. the isocyanide) rather than as  $\text{NCCH}_2\text{CO}_2\text{K}$ .
- (ii) Many suggested  $\text{LiAlH}_4$  for stage II ( $\text{H}_2 + \text{Ni}$  or  $\text{Na} + \text{ethanol}$  were also accepted, but  $\text{NaBH}_4$  is not strong enough to reduce nitriles). The reagent for stage III stumped many, which was a great surprise. This simple acid-base reaction could be effected by dilute  $\text{H}^+(\text{aq})$  (at room temperature). Some suggested that  $\text{NaOH}$  was the ideal reagent to form an acid from its salt!

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| <p><b>Paper 9701/05</b></p> |
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| <p><b>Practical Test</b></p> |
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### General comments

The practical exercise set in **Question 1** was probably unfamiliar to the majority of candidates although similar exercises have been set in the past. The practical work appears to have been conducted without difficulty but the calculations that followed and the answers to questions about the method, revealed many misconceptions about equilibrium.

Some Centres experienced difficulty in providing the specified chemicals. The Centres that had brought this problem directly to the attention of CIE had alternatives suggested. One or two Centres provided their own alternatives, some of which did not work effectively. Guidance from CIE should always be sought where there is any difficulty in providing materials or apparatus for an examination.

In the Planning Exercise (**Question 2**), a small number of candidates ignored the rubric, which was in bold type and enclosed in a box, stating that only the listed solutions and apparatus should be used. Examiners saw the use of indicators in the first section to identify the acids and the alkali, followed by a titration to determine acid concentration.

Candidates were instructed to prepare Flasks **A** and **B** for **Question 1** and to proceed to **Question 2** while the contents of the two flasks came to equilibrium. There is some evidence from the titration results to suggest that flasks were not left for sufficient time or shaken sufficiently.

### Comments on specific questions

#### **Question 1**

Candidates were instructed to titrate three  $10 \text{ cm}^3$  portions of the lower aqueous layer from each flask against aqueous sodium hydroxide using phenolphthalein as indicator.

One mark was awarded if the burette readings were in the correct places, the final burette reading to the nearest  $0.05 \text{ cm}^3$  and the subtraction correct for each titration performed.

For each flask, three consistency marks were awarded, comparing the closer pair of titres in each of tables **1.1** and **1.2**. Most candidates scored well for consistency.

For Flask **A**, three accuracy marks were also awarded, comparing the mean of the Supervisor's closest pair with the closest individual titre in the candidate's table.

Considerable variation was found.

## Calculations

Marks were available in each section for carrying forward and processing a previous answer. In marking this question, Examiners carried errors forward in all steps, a single error in the calculation being penalised only once.

(d) Most candidates correctly calculated the moles of propanoic acid contained in the 50 cm<sup>3</sup> of **FB 1** placed in each flask at the start of the experiment.

(e) It was comparatively rare to see a fully correct answer in this section.

Most candidates calculated the moles of propanoic acid remaining in 10 cm<sup>3</sup> of the aqueous layer, i.e. the moles of propanoic acid in the volume pipetted from the flask. A factor of x5 was missing from their answers. Many of these candidates corrected the error in **Section (g)**.

A small number of candidates calculated an amount of propanoic acid transferred, performing a subtraction from the answer to (d) as part of this section.

(f) The majority of candidates correctly subtracted their answer to **Section (e)** from their answer to **Section (d)**.

(g) Candidates were expected to multiply their answers in (f) by  $\frac{1000}{50}$ . The use of 70 and 90 (total volume of liquid in the flasks) instead of 50 was common.

(h) This was the most difficult section, as two different volumes of liquid were involved,  $\frac{1000}{20}$  for Flask **A** and  $\frac{1000}{40}$  for Flask **B**. Only the more able candidates were able to score 1 or 2 marks here.

(i) The expressions for the possible equilibrium constants were given and the majority of candidates did have values for Flask **A** and Flask **B** in **Sections (g)** and **(h)**. It was therefore disappointing that the four possible  $K_c$  expressions were not evaluated.

One mark was given for evaluating the equilibrium expressions in both horizontal or both vertical columns:

| Mark   | Flask A  | Flask B  |
|--------|--|--|
| 1      | $K_c = \frac{[\text{C}_2\text{H}_5\text{COOH}(\text{organic layer})]}{[\text{C}_2\text{H}_5\text{COOH}(\text{aqueous layer})]}$        | $K_c = \frac{[\text{C}_2\text{H}_5\text{COOH}(\text{organic layer})]}{[\text{C}_2\text{H}_5\text{COOH}(\text{aqueous layer})]}$        |
| 1      | $K_c = \frac{\sqrt{[\text{C}_2\text{H}_5\text{COOH}(\text{organic layer})]}}{[\text{C}_2\text{H}_5\text{COOH}(\text{aqueous layer})]}$ | $K_c = \frac{\sqrt{[\text{C}_2\text{H}_5\text{COOH}(\text{organic layer})]}}{[\text{C}_2\text{H}_5\text{COOH}(\text{aqueous layer})]}$ |
| (Mark) | 1  | 1  |

No marks were given for a single "diagonal" pair.

An additional mark was given for deciding which of the  $K_c$  values was "correct". Because of errors in the calculations many candidates calculated values with similar differences, neither expression exhibited constancy. Because of the wording of the question, the mark was given for selecting the closer pair of values. Where there was no obvious choice, the differences were calculated as a percentage of the larger value.

A considerable number of candidates selected the "correct" expression having only evaluated one pair.

- (j) Many candidates were unable to suggest two or even one reason why there might be variation in the calculated value of  $K_c$ . The most common scoring points were the mixture not reaching equilibrium, variation of  $K_c$  with temperature.
- The most common misconceptions included; changes in the equilibrium when a sample is withdrawn, equilibrium affected by temperature change and equilibrium affected by change in concentration.
- (k) The Examiners were looking for the transfer of organic acid into the aqueous layer or the presence of water being necessary to dissociate the organic acid. Few candidates scored marks in this section. Many candidates thought it made the test fair or maintained a constant volume.

Concepts relating to rates of reaction were frequently seen in **Sections (j)** and **(k)**.

## Question 2

- (a) The majority of candidates missed or ignored the instruction to plan the *minimum number of practical steps* to identify the alkali.

It was common to see the three possible mixtures made and the temperature changes noted. The Examiners expected candidates to realise that the sodium hydroxide could be identified after mixing just one pair, if that produced no temperature change (two acids mixed) or from two pairs if the first produced a temperature change and the second either a temperature change or no change.

Where all three mixtures were made in the plan or in the result, the first plan mark was not awarded.

A plan with explanation of how the results would show which was the sodium hydroxide was expected. In some cases, candidates had obviously mixed pairs of solutions and then written the plan as results; no credit was possible in such a case.

Most candidates obtained at least one of the two marks for the plan for explaining how the expected results would identify the solution containing the sodium hydroxide.

To gain the first of the results marks, the temperature change had to be indicated or stated for at least two mixtures or the lack of a temperature change for the mixture of acids. For the second mark, the Examiners expected the identity of the solutions to be given in the results and not just inferred. Many candidates missed this mark.

Candidates who used indicators or known acids/alkalis to identify which of **FB 3**, **FB 4** or **FB 5** contained acids or alkali scored no marks in this section but could score all marks in subsequent sections if the specified apparatus was used.

- (b) One mark was given to a plan where a volume of each acid was mixed with a *greater volume* of the alkali. The majority of candidates planned to mix equal volumes of acid and alkali.

The second planning mark was for stating that more concentrated acid would give a greater temperature rise. This mark was awarded regardless of the volumes of acid and alkali mixed.

In recording the results, one mark was given for the tabulation of volumes of solutions used (if not given in the plan), initial and final temperatures, and the temperature change for two pairs of solutions. Correct units were required throughout the table.

The second mark was given if  $\Delta T$  was recorded for each mixture.

The third mark was given if one pair had a greater temperature rise than the other pair. This mark was not awarded where equal volumes of acid/alkali were mixed or volumes mixed had not been specified.

### Identity

This was a freestanding mark and was awarded for the correct identification of the solutions. Where equal volumes of acid and alkali had been mixed in the second section, it was not uncommon to see the identities of the two acids reversed.



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| <p><b>Paper 9701/06</b><br/><b>Options</b></p> |
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**General comments***Biochemistry*

As in previous sessions, this proved to be a popular option. The candidates did not seem to score such high marks in this option as in recent examinations.

*Environmental Chemistry*

Answers to this option were again disappointing. It appeared to the Examiners that a number of candidates appeared not to have learnt the contents of the specification.

*Phase Equilibria*

This option remains very popular, although candidates seemed to find it harder to score high marks on this paper. In particular, candidates found **Question 5** hard, often confusing HPLC with GLC.

*Spectroscopy*

Although the least popular of the options, candidates who had studied spectroscopy once again appeared to be well prepared and scored good marks.

*Transition Metals*

This remains a very popular option, although answers in this session did not score particularly well.

**Comments on specific questions****Question 1**

Most candidates were able to draw a reasonable structure for glucose, and most could write an equation for its hydrolysis. A number of candidates omitted acid when giving conditions for hydrolysis, or failed to give a reasonable temperature when using enzymes. In part **(c)**, answers were often vague and lacked the detail needed to score more than a couple of marks.

**Question 2**

Good candidates seemed to find this question straightforward, but less strong candidates often struggled both with the calculation in part **(b)** and with information on the vitamins in part **(c)**. As a result, this question scored rather lower marks than **Question 1**.

**Question 3**

Although many candidates knew the geometries of the silicate and aluminate structures, and could draw a reasonable diagram of the structure of the clay, few could explain cracking using the idea of hydrogen bonds. In parts **(b)** and **(c)**, answers often lacked sufficient detail to score more than one or two marks.

**Question 4**

Parts **(a)** and **(b)** were generally well-answered, but part **(c)** answers rarely went beyond trivial explanations. There was very little mention of carbonate and hydrogencarbonate ions, or the role of oceans as a 'heat store' that affected weather patterns.

**Question 5**

This question was one of the most poorly answered questions in recent years on this option, and it appeared that candidates had not sufficiently prepared to answer questions about HPLC. In part **(a)**, many gave the carrier as gas, rather than liquid or solvent. In part **(b)**, only very good candidates scored high marks, with few able to calculate the area under the peaks to determine the ratio of the components.

**Question 6**

This was a more familiar question and candidates found it much easier to score reasonable marks. Few had difficulty in sketching the phase diagram, although some still confuse the terms 'liquid' and 'solution'. In part **(b)**, answers sometimes lacked the detail needed to score full marks.

**Question 7**

Although a few candidates misread the bromine for chlorine, many scored good marks in parts **(a)** and **(b)** of this question. Part **(c)**, whilst a familiar task, proved more taxing with some candidates failing to think through their suggested approach and consequently losing marks.

**Question 8**

Part **(a)** of this question was surprisingly poorly answered, with few candidates mentioning bending as well as stretching of bonds. In parts **(b)** and **(c)**, although many candidates knew what was required, and in many cases could identify the characteristic absorptions, few were able to relate these to types of plastics/polymers.

**Question 9**

Variations on this question have been set a number of times in the past but this year the question scored rather lower marks. Candidates often missed a key point in part **(a)(i)** and failed to give full details in **(a)(ii)**. Part **(b)** was usually understood, but candidates did not always draw the correct structures.

**Question 10**

Most candidates knew what paramagnetism was, and could say which ion was the more highly paramagnetic. Unfortunately, not all candidates could deduce the electronic configuration of the ions. In part **(b)**, reagents which gave distinct colours for the two species were required, and too many described reactions that would only work with pure samples of each of the ions. In part **(c)**, most candidates were familiar with the reaction, but very few stated that it was an example of homogeneous catalysis, and a significant number failed to use  $E^{\ominus}$  values in explaining the reaction.