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## FOREWORD

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

### General comments

For this paper, the mean score was 23.9 (59.7%), which was the targeted value, and the standard deviation of the scores was 7.41 (18.5%), indicating that the paper discriminated very well among candidates.

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

**Comments on specific questions**

Four questions had a facility above the design limit: **Question 2** on balancing an equation, **Question 6** on the type of bonding within magnesium oxide, **Question 25** on the action of a catalytic converter on car exhaust gases, and **Question 31** on the pattern of nucleons in  ${}_{27}^{60}\text{Co}$ . These clearly represent areas of the syllabus that are well understood.

Only one other question fell outside of the design limits: in **Question 4** some of the more able candidates, when asked about the order of increasing energy in the atomic orbitals of a transition metal, gave 3s 3p 3d 4s as the answer, which teachers will recognise as a common misunderstanding.

Three other questions, while performing satisfactorily, produced a pattern of answers that deserve comment. In **Question 21** 51% of candidates believed that a nucleophile is always negatively charged (option **D**) whereas only 38% recognised that its significant feature is that it has a lone pair of electrons (key **B**).

Within the context of desulphurising coal-burning power station emissions, candidates were asked how calcium oxide reacted with  $\text{SO}_2$  and  $\text{CO}$  (**Question 35**). The answers were a little surprising: 60% of candidates thought that  $\text{CaO}$  reacts with  $\text{CO}$  to form  $\text{CaCO}_3$ , and 27% of candidates thought that  $\text{CaO}$  does *not* react with  $\text{SO}_2$  to form  $\text{CaSO}_3$ . It may be that candidates are unsure about the chemistry of  $\text{SO}_2$ , because the results of **Question 13**, a very straightforward question on the reaction of  $\text{SO}_2$  with aqueous sodium hydroxide, would indicate that a significant number of candidates were guessing.

In **Question 39** more candidates chose the distractor **B** (48%) than the key **D** (42%): the results could be interpreted as indicating that up to 52% of candidates considered that benzoic acid is readily soluble in water.

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| <p><b>Paper 9701/02</b></p> |
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| <p><b>Theory 1</b></p> |
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**General comments**

Most candidates collected marks from the more straightforward sections of the paper; these were **Question 1 (b)**, **Question 2 (a)**, **(b)** and **(c)**, **Question 3 (b)** and **Question 5 (a)** and **(b)**.

The general impression was that the overall performance of the candidates was higher this year. Tribute can be made to the dedication of the teachers and the hard working candidates.

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

- (a) The chief assumptions of ideal gas behaviour are that intermolecular forces are negligible and that the volume occupied by the gas molecules is insignificant compared with the volume of the container. Answers such as *the volume of the gas is small* cannot score any credit.
- (b) The meaning of the terms needed to be explained. In (i) the pressure of the gas was the minimum response allowed. In (ii) it was the volume occupied by the gas.
- (c)(i) When the values given are inserted into the equation  $pV = \frac{W}{M_r}RT$ . The value for  $M_r$  is 40, which makes the gas argon. A few candidates failed to use the value of  $T$  as 297 K, and others were  $10^3$  out by not using  $\text{m}^3$ .
- (ii) Ammonia has a lone pair of electrons and forms hydrogen bonds with other ammonia molecules. The stronger intermolecular forces were not appreciated by all candidates.

**Question 2**

Most candidates scored the first five marks of this question. In **(d)** the expected combustion products are those mentioned in the syllabus i.e.  $P_4O_{10}$  and  $SO_2$ . The equations in **(d)(ii)** are of the pattern acidic oxide + water  $\rightarrow$  acid.

**Question 3**

- (a)** The colourless gas is  $CO_2$ . A not uncommon error was to offer  $CO$ , which is highly unlikely since the gas is not poisonous, and urea is a waste product of the animal kingdom.
- (b)** The Haber Process is central to the syllabus and was known by most candidates. Values were expected for the pressure and the Temperature. The catalyst is iron.
- (c)** There are 0.05 moles of ammonia, and this will be neutralised by  $50\text{ cm}^3$  of  $0.50\text{ mol dm}^{-3}$  of sulphuric acid. Most candidates knew the correct formula of ammonium sulphate,  $(NH_4)_2SO_4$ .
- (d)** The diagrams needed to show the three-dimensional shapes of ammonia and ammonium ions; the bond angles are  $107^\circ$  and  $109.5^\circ$ .
- (e)(i)** Nitrogen is converted from oxidation number -3 to zero and is oxidised, whereas oxygen is reduced as its oxidation number goes from zero to -2.

**Question 4**

This was probably the most challenging question on the paper.

- (a)** Heat and either an aqueous acid or base are required. In **(ii)** the equation must include the water molecule.
- (b)(i)** The trans stereo-isomer is the answer here.
- (c)(i)**  $M_r$  is 100.
- (ii)** Water is eliminated and the product is a diene.
- (d)** A test for alcohol is required. There are several to choose from e.g.  $Na$ ,  $PCl_5$ ,  $H^+/Cr_2O_7^{2-}$ . However, reagents which would prove positive with an alkene are excluded.

**Question 5**

Environmental Organisations have criticised the widespread use of halogen organic materials used currently in society. Other plastics e.g. poly(propene) can replace pvc; esters can replace solvents such as  $CH_3CCl_3$ ; butane or pentane can be used in aerosols.

- (b)** The salient points of good answers are that UV radiation causes chlorine radicals to be formed as the  $C-Cl$  has low bond energy, and these radicals destroy the ozone layer by a series of chain reactions.

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| <b>Paper 9701/03</b> |
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| <b>Practical Test</b> |
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**General comments**

When script packets are received, Examiners group the candidate scripts by session and by each laboratory within that session. The Supervisor's results are used for each session/laboratory to ensure that candidates are not disadvantaged by any variation etc. provided to a particular laboratory.

It is very helpful to the Examiner when the sessions and laboratories have the candidates arranged sequentially by candidate number, but if this is not possible then it is *essential* that an Examiner can correctly place any candidate in a specific session and laboratory.

The Examiners thank Centres and Supervisors who provided accurate distribution lists (*including seating plans as requested on the report form*) and experimental results for each laboratory.

There was little evidence to suggest a lack of time to finish the paper although a few candidates did not attempt the tests on the residue in **Question 2** – had they discarded the residue after filtering?

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

- (a) The candidates were expected to weigh the stoppered tube provided, empty the contents into a beaker then reweigh the empty tube and stopper. The majority of candidates correctly recorded the masses to at least 2 decimal places and performed a correct subtraction to find the mass of **FA 1** to be used in the question.

A small number of candidates recorded masses that were much greater than the 1.70 g to 2.00 g to be placed in the tube during the examination preparation. This suggests that these candidates forgot to reweigh the stopper with the empty tube.

- (b) Titrations were generally performed well. Burette readings for “accurate” titrations were recorded to 2 decimal places (nearest 0.05 cm<sup>3</sup> as required by the syllabus). The Examiners were pleased to see that few candidates recorded “impossible” burette readings such as 27.43 cm<sup>3</sup>.

The majority of candidates produced consistent titres as described in the syllabus (2 titres within 0.10 cm<sup>3</sup>). Many candidates, having obtained two titres within 0.10 cm<sup>3</sup> wasted time by performing further titrations: 3, or even 4, identical titres or titres within 0.10 cm<sup>3</sup> was not unusual

The selection of titres for calculation of the “average” was less successfully performed. Many candidates ticked only one titre. In this case Examiners accepted the candidate’s chosen value when assessing accuracy. The difference between the chosen value and the next nearest was used to calculate spread, and a penalty applied if necessary.

A large number of candidates ticked 3 titres but did not then calculate the “average” of the three titres (correct to 2 decimal places or rounded to the nearest 0.05 cm<sup>3</sup>)

e.g.

|  |       |       |       |
|--|-------|-------|-------|
| <i>Final burette reading/m<sup>3</sup></i>       | 23.40 | 46.80 | 24.50 |
| <i>Initial burette reading/cm<sup>3</sup></i>    | 0.00  | 23.40 | 1.00  |
| <i>Volume of <b>FA 2</b> used/cm<sup>3</sup></i> | 23.40 | 23.40 | 23.50 |

✓                      ✓                      ✓

**Summary**

25.0 cm<sup>3</sup> of **FA 3** reacted with 23.40 cm<sup>3</sup> of **FA 2**

This “average” would have been correct if the first two titres only had been ticked. As all three had been ticked the Examiners were expecting to see 23.43 cm<sup>3</sup> (correct to 2 decimal places) or 23.45 cm<sup>3</sup> (correct to the nearest 0.05 cm<sup>3</sup>) in the Summary.

**Accuracy Marks** were assessed by evaluating the expression:

Candidate’s titre x  $\frac{\text{Supervisor's mass of FA1}}{\text{Candidate's Mass of FA1}}$  and comparing this scaled titre with the Supervisor’s titre.

6 marks were awarded for a difference  $\leq 0.20$  cm<sup>3</sup>, 5 marks for a difference  $> 0.20$  cm<sup>3</sup> but  $\leq 0.40$  cm<sup>3</sup>. Marks continued to be awarded on a widening scale with 1 mark being awarded for a difference  $> 1.00$  cm<sup>3</sup> but  $\leq 2.00$  cm<sup>3</sup>.

A spread penalty was applied to accuracy marks where titres differing by more than 0.20 cm<sup>3</sup> had been used when determining the “average” value in the Summary. Comparatively few candidates had a spread penalty applied.

In many Centres, candidates scored high accuracy marks when compared to the Supervisor but in some Centres, candidates who were very consistent within their own set of titres showed great variation with the Supervisor and other candidates in the same Centre (i.e. the scaled candidate titres showed a wide spread of values). This suggests that the technique of weighing a solid, dissolving in water, transferring the solution to a volumetric flask, making up to 250 cm<sup>3</sup> and titrating the resultant solution was not familiar to the candidates.

- (c) The majority of candidates obtained the first mark for using calculating  $M_r$  of Na<sub>2</sub>CO<sub>3</sub> as 106.

Most candidates divided their mass of **FA 2** by the calculated  $M_r$  but some forgot to then multiply by 4 to obtain the concentration in mol dm<sup>-3</sup>.

- (d) Most candidates earned the mark in this section for  $\frac{25}{1000}$  x concentration from (c) in mol dm<sup>-3</sup> or for  $\frac{25}{250}$  x concentration from (c) in mol/250 cm<sup>3</sup>.
- (e) Nearly all candidates gained the mark for multiplying the answer to (d) by 2. A few candidates inverted the mole ratio and divided by 2.
- (f) Most candidates obtained the first mark for answer to (e) x  $\frac{1000}{\text{average titre}}$ .

A further mark was awarded if the calculated answer (with no chemical errors in parts (c) to (f)) was within 1% of the "correct" value, calculated by the Examiner from the candidate's value.

$$\left(1.887 \times \frac{\text{candidate's mass of FA 1}}{\text{candidate's titre}}\right).$$

Many candidates failed to gain the second mark as: their calculated value in (f) was only expressed to 2 significant figures or rounding at each stage of the calculation introduced substantial errors.

Candidates should be encouraged to "carry", in their calculators, values from one step of the calculation to the next and to give careful consideration as to the appropriate significant figures for each answer.

A few candidates did not gain the marks in (d) as the titre had been used or in (f) as the 25.0 cm<sup>3</sup> volume of the pipette was used.

## Question 2

Candidate's were provided with solid **FA 4** which was a mixture of sodium sulphite and calcium carbonate. On shaking with water the sodium sulphite (**FA 5**) dissolved to give the filtrate for the first set of tests and the calcium carbonate (**FB 6**) remained as a residue in the filter paper and was used in the second set of tests.

### Tests on the Filtrate - FA 5

- (a) Most candidates recorded a white precipitate with barium chloride and observed that the precipitate dissolved on adding hydrochloric acid. Any haziness in the acidic solution was ignored as some of the sulphite would inevitably have been oxidised to sulphate.
- (b) Nearly all candidates observed the solution turning green on adding acidified potassium dichromate(VI). Any references to a green precipitate were ignored. Some candidates failed to observe the colour change to green, ending with a yellow or orange solution. A minority of candidates recorded that the solution turned to a blue/green solution – this was not accepted by the Examiners.
- (c) Candidates were asked to identify the gas given off in the reaction of **FA 5** with dilute hydrochloric acid. The gas was sulphur dioxide. Examiners accepted any appropriate test for an acidic gas such as blue litmus paper turning red or for a reducing agent such as dichromate(VI) turning green. A blue-green colour with paper soaked in dichromate(VI) was accepted in this test.

- (d) The Examiners had hoped and expected to see complete observations in this test – the brown colour of the iodine disappearing, or becoming yellow, as it was poured into the **FA 5**. The Examiners were therefore disappointed when many candidates simply recorded a colourless solution in (d).

As the coloured iodine solution had been poured into the colourless solution of **FA 5** the Examiners decided to accept colourless solution or colourless solution remains as an appropriate answer. However, an answer that implied there was no change or no reaction was not accepted.

In recent examinations the column for a deduction after each test has been replaced by the identification of the ion present together with supporting evidence for each ion or pair of ions. Most candidates correctly identified the anion in **FA 5** as sulphite but a large number failed to give sufficient to support their conclusion.

The question asked “Which observations support your choice of this anion?” Many candidates simply referred to test (a) – the white precipitate with barium chloride, soluble in hydrochloric acid. The Examiners treated this as one piece of evidence and were also looking for some further evidence such as reducing properties in (b), (c), (d) or acidity of gas in (c).

Reference to reducing properties in two of (b), (c), (d) or reference to reducing properties in one of (b), (d) and acidic properties in (c) would have also gained the mark.

The mark for supporting observations was given if the correct observations were detailed or there was unambiguous reference evidence back to a specific test.

Some candidates, who had given insufficient detail in the individual tests (a) to (d) completed the observations in this final section and were awarded retrospective marks for the individual section as well as the evidence support mark. 3 or 4 marks from the maximum of 5 available for **FA 5** were frequently given, a smaller number of candidates scoring all 5 marks.

A number of candidates missed the question at the top of page 5 concerning the chemical nature of **FA 5** in tests (b) and (d).

Where an answer had been attempted, it was clear that many candidates did not understand the question and answers such as: sulphate, acid, base, sulphite were frequently seen.

The correct response of reductant or reducing agent was seen regularly; however, so was “oxidising agent” after a correct set of observations for a reductant in (b) and (d).

- (e) Most candidates observed effervescence in this test but many failed to test the gas to find its identity. The mark in (e) was for a chemical test for carbon dioxide.

To obtain the mark for (f) and the mark for (g) the candidates had to give the correct colour of the precipitate (if any) and the solubility of the precipitate in excess of the reagent added.

- (f) One mark was given for a white precipitate, soluble in excess NaOH.

A significant number of candidates recorded a white precipitate but made no reference to its solubility in excess NaOH.

A small number of candidates recorded no precipitate with sodium hydroxide.

- (g) The Examiners expected there to be no precipitate when aqueous ammonia was added to the dissolved residue. Many candidates scored this mark. Even in Centres where Supervisors reported the formation of a precipitate, a significant number of candidates recorded no precipitate and gained the mark.

The cation to be identified was marked consequentially for the observations in (f) and (g). A white precipitate with NaOH and no precipitate with  $\text{NH}_3(\text{aq})$  was sufficient evidence for the cation. Where white precipitates were observed with each reagent, the solubility of the precipitate in an excess of the reagent had to be clear to earn credit. The correct cation, calcium, was allowed providing a white precipitate had been seen with NaOH and no precipitate was formed with  $\text{NH}_3(\text{aq})$ .

Most candidates identified the anion as a carbonate. Effervescence or rapid bubbling had not gained the observation mark in (e) but was accepted as sufficient evidence for choosing a carbonate as the anion present. Many candidates made reference to lime water turning milky at this stage and gained a retrospective mark for (e).

Many candidates failed to score marks for the tests on **FA 6** because of the imprecision of their answers – failing to identify the gas in (e) and making no comment on the solubility of precipitates in (f) and (g).

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| <p><b>Paper 9701/04</b><br/><b>Structured Questions</b></p> |
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### General comments

The paper performed well this year, with a good spread of marks. Although full marks were a rarity, there were several candidates scoring in the upper fifties, and a pleasingly large number scoring 50+. Once again, however, the Examiners saw many low-scoring scripts, often due to a lack of knowledge of some parts of the syllabus. Answers to **Question 3** in particular were somewhat patchy, with many candidates clearly not having studied this topic.

The mark schemes for each of the three calculation questions allowed some credit to be given for partially correct answers. This can only occur, however, if the candidates show their working for each stage. Some of those who did not were unfortunately not able to be awarded any marks at all.

Candidates are once again reminded of the need to include *all* atoms in an organic structural formula, as mentioned in the syllabus - carbon atoms with “bonds” sticking out of them are *not* taken to imply hydrogen atoms.

### Comments on specific questions

#### **Question 1**

Most candidates scored fairly well on this question, which combined elements from several physical chemistry topics.

- (a) Virtually all candidates scored this mark, although some incorrectly showed the production of  $\text{Mg}^{2+}$  from Mg, rather than vice versa.
- (b) Fewer scored this mark, common errors being either to give an equation showing the production of  $\text{Cl}^-$  from  $\text{Cl}_2$  (the equation showing the production of  $\text{Cl}_2$  from  $\text{Cl}^-$  was accepted) or to suggest that the product was oxygen.
- (c) Many candidates found this tricky. The question merely expected them to realise that density = mass/volume, and to use the *Data Booklet* to determine that the mass of a magnesium atom is considerably less than the mass of an iron atom, and that the volume of the Mg atom, as indicated by both the atomic and ionic radii, is larger than that of iron. Many candidates thought the Mg atom was *smaller* than the Fe atom, or that the number of electrons within each atom had an effect, or that the packing of the atoms within the metallic lattice was important. (No doubt it is, to a certain extent, but this has nothing to do with the properties of the *atoms*, as indicated by the question.)
- (d)(i) The two key elements of this definition were that the lattice energy represents the energy change when *1 mole of solid* is formed from its *ions in the gas phase*. Candidates lost marks by suggesting that the 1 mole referred to the gaseous ions; that the gas phase particles were atoms, not ions; that the formation was from the elements in their standard states; and that the energy change was from solid-to-gas, and not vice versa.
- (ii) Despite the wrong definition in part (i), most candidates scored something here. The most common error was to indicate the state symbols for aqueous solution, rather than the gas phase.



- (e)(i)(ii) This part expected answers couched in terms of ionic size and charge – the lattice energy increasing with smaller *ionic* (not atomic) size and larger *ionic* charge. Several candidates based their answers on the energy changes in the Born-Haber cycle (e.g. ionisation energies), not appreciating that this cycle is only used as an aid to *calculating* the experimental lattice energy, rather than as an explanation of what determines its magnitude. Some candidates could not be awarded marks here because their answers were ambiguous – references to “its lattice energy is greater”, for example, did not make clear whether the LE of  $\text{MgCl}_2$  or that of  $\text{NaCl}$  was the greater.
- (f) A pleasingly large number of candidates scored full marks for this calculation. Common errors were to reverse all the signs; to mis-read 349 as 394 in the question; or to reverse the sign of  $\Delta H_f$ . Each of these was awarded 2 marks. Other incorrect answers were credited on the each-error-loses-one-mark principle.

Answer: (f)  $-785 \text{ kJ mol}^{-1}$ .

### Question 2

- (a) Most candidates scored a mark for *tetrahedral*, but several forfeited the mark for *covalent* by indicating that there was a trend to ionic or even metallic (!) bonding down the group, or for suggesting that the bonding was *giant* covalent.
- (b)(i) The plotting was performed with a reasonable degree of accuracy, although several candidates plotted  $114^\circ$  as  $104^\circ$ . Estimates of the boiling point of  $\text{PbCl}_4$  generously ranging from  $138^\circ$  to  $151^\circ$  were accepted by the Examiners.
- (ii) Candidates showed considerable confusion here, many relating the boiling points to the X-Cl bond strengths, rather than the strengths of the intermolecular (van der Waals) forces. Only a few gave a satisfactory explanation of the origin of these forces, in terms of the number of electrons within each molecule. Incorrect explanations included relating the increased van der Waals force to the increased molecular size, mass, electron cloud, bond length.
- (c)(i) The presence of *empty low-lying d-orbitals* in silicon, but not in carbon, was correctly suggested by many. Incorrect answers included suggesting that  $\text{SiCl}_4$  had a dipole, whereas  $\text{CCl}_4$  did not; and that the Si-Cl bonds were polar, whereas the C-Cl bonds were not.
- (ii) Most wrote the correct products ( $\text{HCl} + \text{SiO}_2$  or  $\text{Si(OH)}_4$ ) but quite a number omitted to balance the equation, thus forfeiting the mark.
- (iii) Candidates were expected to argue by analogy with Si that Ge would also hydrolyse readily due to the availability of low-lying d-orbitals.
- (d)(i) Although a significant number of candidates scored this relatively easy mark, there were many who did not. Errors included thinking zinc chloride had the formula  $\text{ZnCl}$ , or  $\text{ZnCl}_4$ ; or thinking that  $\text{Cl}_2$  was a product. Inevitably, some candidates forfeited the mark, despite having the correct formulae, by not balancing the equation.
- (ii) Examiners once again applied the error-carried-forward principle here, and the maximum marks could be gained from an incorrect equation in part (i), as long as the stoichiometry was consistent. Marks were lost by inconsistent stoichiometry; using atomic numbers instead of atomic masses; or mis-reading the question as referring to 250g of  $\text{SiCl}_4$  rather than pure Si.

Answer: (d)(ii) 1164 g.

### Question 3

There were some excellent full-mark answers to this question, but equally the Examiners found many blank scripts, indicating a total lack of knowledge of this part of the syllabus. The most common examples chosen were iron in the Haber process, and  $\text{FeCl}_3$  in the chlorination of aromatic rings, the former being a heterogeneous process and the latter homogeneous. The homogeneous example given in the syllabus is the role of  $\text{Fe}^{2+}$  in the reaction between  $\text{S}_2\text{O}_8^{2-}$  and  $\text{I}^-$ . Many candidates chose this example, but unfortunately the majority confused the persulphate and thiosulphate ions, and thought that the iron ions were catalysing the reaction  $\text{S}_2\text{O}_3^{2-} + \text{I}_2 \rightarrow \text{S}_4\text{O}_6^{2-} + 2\text{I}^-$ . Apart from the general definitions of homogeneous and heterogeneous, and the correct assignments of these terms to relevant reactions, marks were also awarded for brief outlines of how the two types of catalysis work (e.g. heterogeneous by *adsorption*, and homogeneous by forming an *intermediate species*). Several candidates did not restrict themselves to *iron*, as stated in the question, and included the Contact process (using  $\text{V}_2\text{O}_5$ ), or the hydrogenation of alkenes (using nickel). These did not attract any marks.

**Question 4**

- (a)(i) Although there were many correct answers here (ranging from  $C_3H_7CONH_2$  to  $HCONHC_3H_7$ ) a surprisingly large number of candidates confused *amides* with *amines*.
- (ii) Three aspects needed to be stated to obtain this mark: *aqueous*, *acid* (or *base*, or a *suitable formula*) and *heat*.
- (iii) Candidates should be reminded that the formulae of substances that take part in a reaction (e.g.  $H_2O$  in this instance) should be included on the left hand side of the balanced equation, and not just over the arrow.
- (b)(i) Once again, candidates confused acyl chlorides with alkyl or aryl chlorides.
- (ii) Many mentioned  $SOCl_2$  or  $PCl_5$ , but did not specify the starting material as *propanoic acid*.
- (iii) The most common error here was to omit the  $HCl$  on the right hand side, or to replace it with  $H_2O$ .

**Question 5**

- (a) Candidates were generally not good at stating correct reagents and conditions here: in (i) and (ii) UV light was often suggested as being necessary, or  $AlCl_3$  was given in the absence of  $Cl_2$ . In (iii) most scored a mark for nitric + sulphuric acids (although there were a few *nitrous acids*), but fewer scored the *conditions* mark ( $55^\circ C$  and concentrated acids).
- (b)(i) Most candidates correctly identified  $A^+$  as  $NO_2^+$ .
- (ii) The drawing of the Wheland intermediates needs to be done with care: There is no "+" charge on either the H or the  $NO_2$  group joined to the ring, or even on the  $sp^3$  carbon atom. Rather, the "+" charge is spread over the remaining 5 carbon atoms in the ring, and this should be indicated by the "+" symbol being drawn in the middle of the "horseshoe". The "horseshoe" should have its open end pointing towards the  $sp^3$  carbon atom, rather than to any other atom in the ring.
- (c)(i)(ii) Candidates who had understood the principle of the question had no problems here, suggesting 3-bromonitrobenzene (or 3,5-dibromonitrobenzene) in (i) and 3-chloro,4-aminobenzoic acid (or 3,5-dichloro,4-aminobenzoic acid) in (ii). Common errors were to draw a structure with bromine rather than chlorine in (ii), or to form the acyl chloride in (ii).

**Question 6**

- (a) This proved more difficult than imagined. Many cations, or anions, were seen.
- (b)(i) The most common error here was to form the acyl chloride from alanine.
- (ii) Many candidates lost a mark here, either through not including  $H_2O$  as a product, or by forming the di-sodium salt (from the OH in the side chain as well as the  $CO_2H$  group).
- (c) Some candidates did not show clearly the peptide bond in their structure (this could have been either the C-N bond or the whole CONH group). Others lost marks for not showing the structure of the peptide bond (including the C=O), or for drawing a tripeptide (with terminal groups of  $NH_2$  and  $CO_2H$ ), rather than a mid-chain residue i.e.  $[-NH-----CO-]$ .
- (d) Although *condensation* was expected, credit was also given to *polypeptide* or *polyamide*.
- (e) Totally correct answers were very rare indeed. There were three steps to the calculation: to add together the three  $M_r$  values, and then to deduct  $3 \times 18$ , giving an  $M_r$  of 215 (one molecule of water is lost when each amino acid joins the chain); to divide 600,000 by 215, giving the number of 3-aminoacid units; and finally to multiply that number by 3. The most common answer was 2230, involving the second step but not the first or the third. This attracted a mark of 1 out of 3.

Answer: (e) 8490.

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

When script packets are received, Examiners group the candidate scripts by session and by each laboratory within that session. The Supervisor's results are used for each session/laboratory to ensure that candidates are not disadvantaged by any variation in solutions etc. provided to a particular laboratory.

It is very helpful to the Examiner when the sessions and laboratories have the candidates arranged sequentially by candidate number, but if this is not possible then it is *essential* that an Examiner can correctly place any candidate in a specific session and laboratory.

The Examiners thank Centres and Supervisors who provided accurate distribution lists (*including seating plans as requested on the report form*) and experimental results for each laboratory.

There was no evidence from the scripts that candidates were unable to complete the paper in the time allowed.

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

- (a) Most candidates recorded all masses to 2 decimal places or better and performed the correct subtraction to find the mass of **FB 1** used in the experiment.

A small number of candidates recorded a mass of weighing bottle + residual zinc that was less than the mass of the empty weighing bottle, suggesting that the balance was not set to 0.00(0)g before each weighing. This reduced the mark available in (a) by 1.

Candidates had been asked to weigh between 2.90 g and 3.00 g of **FB 1**. 1 mark was awarded if the recorded mass of **FB 1** used was between 2.80 g and 3.00 g (allowing for some zinc powder to remain in the weighing bottle).

- (b) The majority of candidates followed the instructions to pipette 25.0 cm<sup>3</sup> of **FB 2** into the foamed plastic cup and to record the temperature of the solution every ½ minute for 2½ minutes. The zinc powder was added at 3 minutes and the temperatures recorded every ½ minute from 3½ minutes to 15 minutes.

Very few candidates failed to gain the mark for recording *all* thermometer readings to 1 decimal place.

Following the instruction in the practical section of the syllabus, Examiners expected to see temperatures recorded to the nearest 0.5°C:

e.g. 30.0°C, 30.5°C, 31.0°C.

Examiners did not penalise candidates who recorded temperatures such as:

30.2°C, 30.4°C, 30.9°C.

A small number of candidates indicated from their recorded temperatures that they were able to read a thermometer graduated by 1°C to 2 decimal places. They were not penalised on this occasion.

In the preparation instructions for the examination, it was stated "When 3 g of **FB 1** is added to 25 cm<sup>3</sup> of **FB 2** in a foamed plastic cup with constant stirring, the maximum temperature should be reached within 6 minutes of adding the **FB 1**." The Examiners were, therefore, disappointed to see many candidates' results where the maximum temperature rise was obtained after 6 minutes, often at 12 to 14 minutes. There were variations within a session/laboratory, some candidates reaching the maximum within 1 minute of mixing and others achieving the maximum after 10 minutes or more.

Candidates were instructed to stir constantly – if this was not done a slower increase in temperature and a later maximum would be expected as the zinc became coated with copper and settled in a layer at the bottom of the plastic cup.

Another possibility is that candidates within the same laboratory were given different samples of zinc powder.

Examiners calculated the difference between the temperature at 2½ minutes and the highest temperature recorded in Table 1.2. The difference was compared to that obtained from the Supervisor's results and 8 Accuracy marks were awarded if the differences were within 1.0°C, 7 marks for differences within 1.5°C decreasing on a widening scale to 1 mark for differences within 10.0°C.

The majority of Centres recorded temperature rises of about 30°C. At a few Centres the maximum temperature rise for Supervisor and candidates was about 15°C. In these cases the differences in the Accuracy table were halved so that candidates were not unduly advantaged.

The majority of candidates scored highly for accuracy in this experiment.

**(d)** Three marks were awarded for the plotting of the graph.

In awarding the first mark, Examiners checked the plotting of three points on the graph. The three points selected to be checked were:

- (i) the maximum temperature (as used in assessing accuracy)
- (ii) the first temperature on the cooling curve, lower than the maximum
- (iii) the next lower temperature that enabled two temperatures at whole minutes and one at a half minute to be plotted.

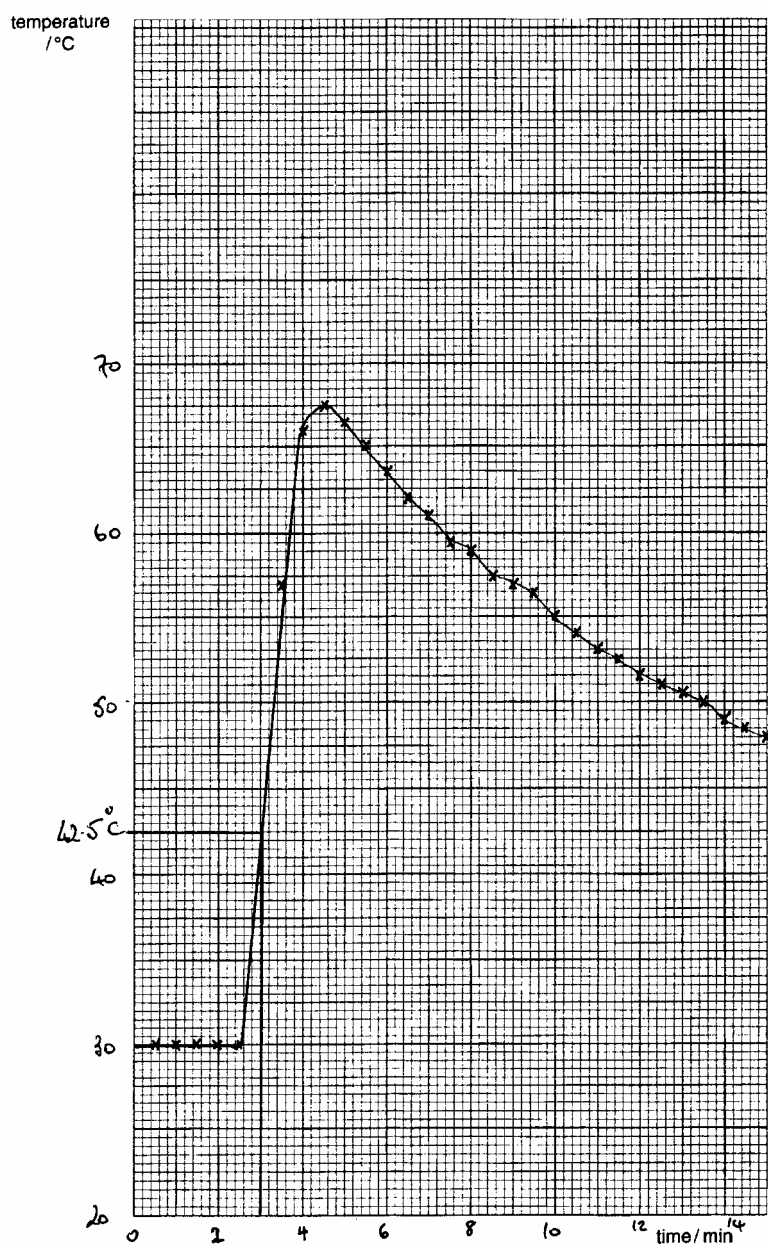
The second mark was awarded for drawing appropriate lines for the first 2½ minutes and from 3½ minutes to 15 minutes. The Examiners were looking for something close to a best fit line. Marks were not awarded for curves that joined or tended towards every point that had been plotted. It was expected that candidates would draw a smooth curve or straight line (if appropriate) for the cooling section of the graph.

This mark was not awarded very often – the Examiners were surprised by the vast majority of A2 candidates who joined every point on the cooling curve.

In section **(e)** the candidates were instructed to “extrapolate the cooling section of the graph back to time = 3 minutes and read the corresponding temperature.” Very few candidates understood what was meant by extrapolating the cooling curve back to time = 3 minutes. Those who did project a line back from the cooling curve often had a significant change in gradient or drew a separate straight line that did not match their cooling curve. As extrapolation was seldom seen, the Examiners gave the mark for any line projected back from the plotted points – however poorly drawn.

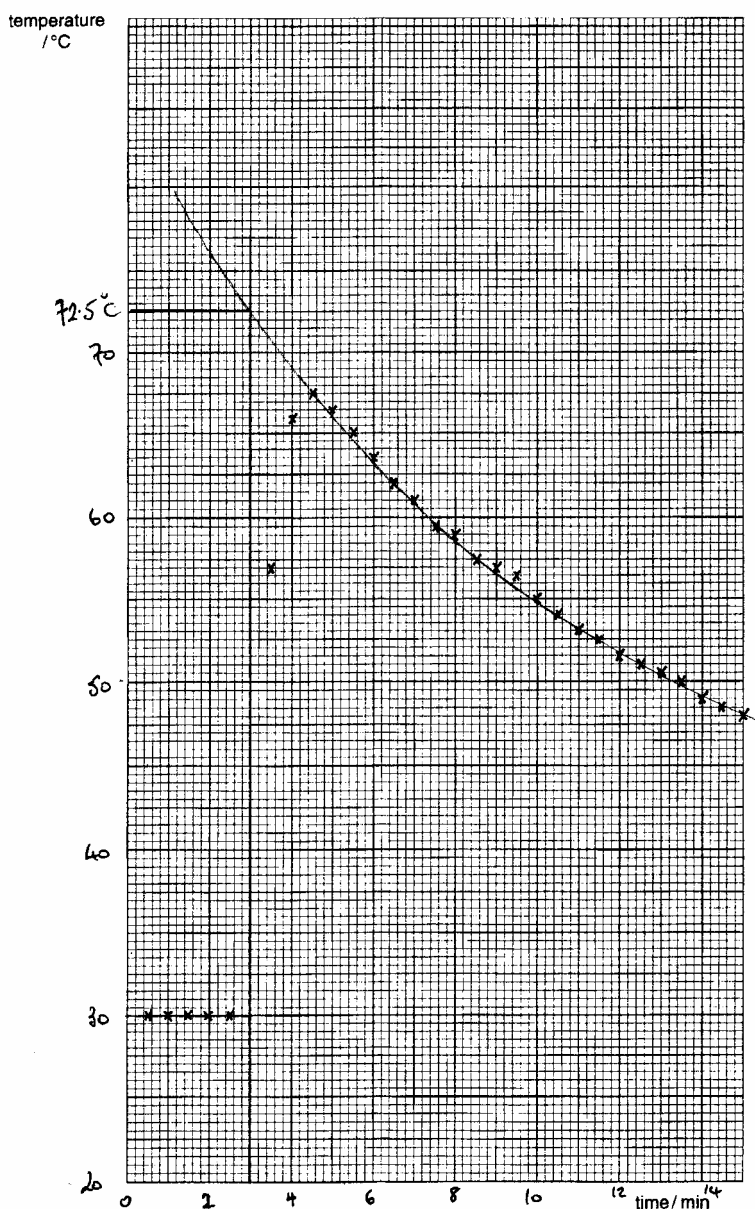
**(e)** One mark was given if a correct temperature at 3 minutes was read from an extrapolated cooling curve.

An example of a graph which would score the mark for plotting of points but *not* for the line drawn or for extrapolation is shown below:



The estimated temperature on this graph was read from the graph where the line rising from 2½ minutes to the maximum temperature cut the 3 minute vertical. This was a common error on many graphs.

The following graph illustrates what the Examiners had hoped to see.



- (f) The majority of candidates correctly calculated the moles of zinc that were placed in the cup.
- (g) The majority of candidates correctly calculated the moles of copper sulphate solution added to the cup. A minority stated that as there was a 1:1 mole ratio in the equation, moles of  $\text{CuSO}_4 \equiv$  moles Zn.
- (h) The heat energy produced in the cup during the reaction was correctly calculated by most of the candidates. (Examiners accepted the temperature change at the bottom of page 4 as the value to be used in this calculation, however it was derived).

A minority of candidates used the mass of zinc or  $(25.0 + \text{mass of zinc})$  in the calculation.

Examiners were looking for correct units (J or kJ) as part of the correct answer. Very few candidates showed incorrect units but a small number incorrectly included a second unit at this stage (J/g, kJ/mole etc.).

- (i) One mark was given for dividing the answer to (h) by the smaller of (f) or (g), having a correct sign and giving the enthalpy correctly in Joules or kilojoules, (moles or/mole were ignored).

**Question 2**

This question produced some excellent answers where candidates had carefully considered the “problem” posed, but also produced answers where candidates had little idea of what was being asked.

- (a) The quality of drawing was not a consideration when marks were awarded for this section. The first mark was given if the apparatus could be used to produce and collect hydrogen. It was expected that candidates would draw common laboratory apparatus and that the various sections of the apparatus could be assembled as shown in the diagram. The mark was not awarded where delivery tubes went through the sides of water troughs or inverted measuring cylinders. Marks were not deducted for apparatus in which water was run into a sealed system from a tap-funnel or from a burette whose jet passed through the stopper of a flask. Thistle funnels were allowed for the addition of water providing the first addition of water would seal the funnel, i.e. they were not allowed if ending just below the stopper of a flask.

The second mark was for measuring the volume of gas collected. To gain this mark it was necessary for graduations to be shown on the apparatus or for the apparatus to be labelled as a piece of apparatus that is graduated, e.g. syringe, burette, measuring cylinder.

- (b) Many candidates gained this mark for realising that the oil coating had to be removed from the lithium before it was weighed. Unfortunately some, who may have had this idea in mind, stated that the lithium had to be removed from the oil. Some candidates realised that despite storage under oil there is still oxidation of the metal surface and gained the mark for cutting off the oxide layer.
- (c) Candidates who did not gain the mark in this section often identified a reason but failed to give the appropriate practical safety measure. For example they stated that hydrogen was flammable or explosive in air but failed to state the safety measure of keeping a flame away from the apparatus. Other acceptable answers were handling lithium with gloves or tongs as it would react with moisture on the skin (reaction with the skin was insufficient) or wearing gloves as lithium hydroxide was corrosive.

A large number of candidates gave answers in this section that related to the conduct of the experiment rather than to a safety measure.

- (d) There were several ways of using the data to show that  $A_r$  for lithium was approximately 7. 3 marks were awarded for calculations which made use of the volume of gas given, the mass of lithium that reacted, the molar gas constant and the mole ratio of hydrogen to lithium from the equation.

Some candidates were not clear in their calculations about the mole ratio from the equation and arrived at answer of 13.922 which was conveniently divided by 2, with no justification, to obtain an answer of approximately 7. These answers were awarded 2 marks only.

Candidates who rounded to 1 or 2 decimal places at each stage of the calculation arrived an answer substantially greater than 7 and were again awarded a maximum of 2 marks.

- (e) 1 mark was given for a reason involving  $V_m$  or room conditions. An answer that stated that gas volume varies with changes in pressure or temperature, room conditions are variable or that  $V_m$  is approximate scored this 1st mark.

The second mark was for a practical reason such as loss of hydrogen, before sealing the apparatus, on adding the lithium/water, but not for hydrogen leaking from the apparatus. The second mark could also be gained for residual oil on the lithium; insufficient water/excess lithium (but not some lithium did not react) or for lithium having an oxide coating/reacting with oxygen or moisture in the air after weighing or during transfer.

- (f) Most candidates gained this mark for stating that a titration would be used. A minority suggested evaporating the water but failed to state the necessity of weighing the solid remaining. Some of the minority thought that lithium metal would be left after evaporating the water.

- (g) The Examiners were looking for the positive and practical aspects of a titration. The use of standardised acid; obtaining concordant titres; small % error in pipette and burette; sharp end-point would all have obtained the mark.

If the evaporation route had been suggested the candidate would need to state that balances can read to 3 decimal places or better to ensure sufficient accuracy.

Comparatively few candidates were awarded this mark as the majority concentrated on the problems of gas collection which they stated would not be there in the other methods.

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| <p><b>Paper 9701/06</b><br/><b>Options</b></p> |
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### Comments on specific questions

#### ***Biochemistry***

This continues to be a popular option and candidates were, on the whole, well prepared with no obvious gaps in their knowledge.

#### **Question 1**

Most candidates were able to describe the  $\alpha$ -helix and  $\beta$ -pleated sheet structures of proteins, in part (a), although some of the diagrams were far from accurate. Part (b) was less well done, with many candidates confusing high acidity and high pH. The action of heavy metal ions often referred to the change in properties of the protein, rather than the bonds affected. Almost all candidates could correctly give an everyday example of denaturing of a protein.

#### **Question 2**

In part (a), although many candidates were able to draw the displayed formula of a phosphoglyceride, a large number made basic errors in the structure, usually in representing the phosphate residue. The explanation of why the hydrophilic (phosphate) part was a zwitterion was generally poorly answered. There were some excellent diagrams showing the fluid mosaic structure of a membrane, but this often lost marks through being badly labelled. Explanations of the function of each part of the mosaic were variable, with some very good answers from a number of candidates.

#### ***Environmental Chemistry***

This option continues to grow in popularity, and many of the answers were of a good standard. There remain, however, a significant number of candidates who try to answer these questions from general knowledge, and who therefore score low marks.

#### **Question 3**

Candidates who thought about part (a), usually scored full marks, although there were a number who confused photosynthesis and respiration. Part (b) was generally less well answered, with some imprecise descriptions of how gases produce the 'greenhouse effect'. Candidates often referred to these gases 'trapping heat' without explaining that this occurred by energy causing increased bond vibration and being re-emitted to Earth. In part (c) candidates often knew about the formation of hydrogencarbonate and carbonate ions, but failed to go any further.

#### **Question 4**

This question was answered rather poorly by many candidates, their answers lacking chemical detail. In part (a) the Examiners were looking for answers involving either capillary action or water binding to the minerals present in clay soil. In part (b) the fact that both gases contained carbon should have prompted candidates to think about the decay of organic material - aerobically in sandy soils and anaerobically in waterlogged clay soils. Part (c) was generally better answered, although a significant number of candidates confused high acidity with high pH.



**Phase Equilibria**

This remains a very popular option and once again produced some very good answers.

**Question 5**

Most candidates were able to explain 'molar enthalpy change of vaporisation'. It was pleasing to see that a large number of candidates were also able to use the data to explain the different intermolecular forces in cyclohexane and ethanol in part (b). On the whole, the graph was well drawn in part (c), and many candidates used it to successfully determine the temperature and composition of the mixture at the azeotropic point. Part (d) proved more difficult for candidates, with only the best scoring more than 2 marks.

**Question 6**

Part (a)(i) was surprisingly poorly answered. The Examiners were looking for answers referring to heat for a long period with moderately concentrated (~6M) hydrochloric acid, or specified enzymes. In part (b), most candidates could draw the diagram of electrophoresis, although almost all forgot to mention that a buffered medium was required. The identification of peptides and/or amino acids was also rather sketchy with few full answers. The application of knowledge in part (c) proved beyond many candidates as they failed to relate the structures of the three amino acids to their likely speed and direction of movement.

**Spectroscopy**

Although one of the less popular options, there were some very well prepared candidates who scored good marks.

**Question 7**

Part (a) of this question was generally well answered, with most candidates recognising that the colour of the flower was due to yellow light being reflected, whilst the other colours were absorbed, and that in the street light yellow was being emitted from the sodium vapour. In part (b), good candidates had little trouble in identifying which protons produced the four peaks or groups of peaks in the spectrum, although weaker candidates often confused peaks A and D. Similarly, most candidates knew that D<sub>2</sub>O showed the presence of the labile-OH proton.

**Question 8**

Part (a) was generally well answered and caused few problems. Although many candidates clearly knew that carbon monoxide absorbed in the infra-region whereas hydrogen does not, few were able to give an explanation of this in terms of changing dipole in the molecule. In part (c)(i) some candidates correctly identified the strong C=O absorption at 1740 cm<sup>-1</sup> and looked no further, omitting the C-O absorption at either 1050 cm<sup>-1</sup> or at 1240 cm<sup>-1</sup>. As a result they had some difficulty in suggesting a structure which should have been an ester. Error carried forward marks were allowed here.

**Transition Metals**

This is also a very popular option, although again this year there seemed to be fewer high scoring answers. Many candidates continue to find the use of half-equations difficult when predicting chemical reactions and balancing equations.

**Question 9**

Almost all candidates knew that a ligand has a lone pair of electrons, although some did not state that such species formed dative (or coordinate) bonds with a transition metal ion. Most candidates were able to give correct examples of ligand species in part (b). Many candidates correctly circled the two nitrogen atoms and four oxygens in EDTA in part (c)(i). It was part (c)(ii) that caused the most difficulty, for although many candidates clearly understood the process, relatively few were able to give full explanations of the use of EDTA, and any associated problems with calcium or zinc ions. Correct use of the  $K_c$  values was relatively rare, and often resulted in the loss of at least 2 marks.

**Question 10**

This proved to be one of the more difficult questions on the paper, with many candidates failing to correctly interpret the data provided. Parts **(a)(i)** and **(ii)** were usually correct, but the construction of equations was generally poor, with the majority of candidates failing to score any further marks in part **(a)**. In part **(b)**, a significant number of candidates did not seem to understand the meaning of disproportionation, and as a result could not score either of the marks. In part **(c)**, although candidates could often work out the oxidation state of manganese in the final solution, they seemed unable to write a balanced equation for the reaction, despite being given the sulphite half-equation.