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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

GCE Advanced Level and GCE Advanced Subsidiary Level

Paper 9701/01
Multiple Choice

Question Number	*Key*	*Question Number*	*Key*
1	**A**	21	**B**
2	**B**	22	**D**
3	**D**	23	**B**
4	**C**	24	**B**
5	**D**	25	**D**
6	**C**	26	**A**
7	**D**	27	**C**
8	**A**	28	**D**
9	**C**	29	**C**
10	**C**	30	**D**
11	**A**	31	**C**
12	**D**	32	**A**
13	**C**	33	**A**
14	**C**	34	**C**
15	**D**	35	**B**
16	**D**	36	**C**
17	**C**	37	**B**
18	**C**	38	**B**
19	**D**	39	**C**
20	**D**	40	**B**

General comments

For this Paper, the mean score was 22.5 (56.2%), just below the targeted value, and the standard deviation of the scores was 7.32 (18.3%), indicating that the Paper discriminated satisfactorily among candidates.

The first 30 questions were simple completion items: **Questions 31** to **40** were three-statement multiple completion items.

Comments on specific questions

Three questions had a facility above the design limit: **Question 3** on the calculation of the number of neutrons in a given isotope, **Question 9** on the commercial production of aluminium, and **Question 19** on the generation of acid rain from vehicle exhaust gases. These clearly represent areas of the syllabus that are well understood.

The results of two questions indicated that candidates found them very difficult at this stage of their experience, both showing much guessing among candidates. **Question 20** asked candidates to calculate the number of structural and *cis-trans* isomers for dichloropropene, $C_3H_4Cl_2$, the greater proportion of candidates failed to discover all the isomers and gave less than the correct answer of 7; this question did, however, discriminate well between the ability range of candidates. **Question 33** required clear thinking about the energy changes from the ground state of an element to its gaseous atomic state and its combustion products, in this case comparing these changes for graphite and diamond: because of its unsatisfactory statistics the Examiners have removed this question from the examination.

Two questions did not discriminate well within the ability range of candidates. **Question 23** gave suggested graphical displays of the ratio of the number of moles of oxygen required for the complete combustion of an alkane to the number of its carbon atoms: some of the more able candidates believed that this increased at a greater than linear rate. **Question 35** was concerned with the reasons for the use of sulphur dioxide as a food preservative: rather surprisingly 37% of candidates, while recognising that it is a reducing agent and therefore an anti-oxidant (option **1**), did not believe that it prevents alcohols forming acids (option **2**), a direct consequence of the first statement.

One other question requires comment. **Question 18** performed satisfactorily, but a higher proportion of candidates, 36%, opted for the distractor **B** believing that heating ammonium sulphate with dilute hydrochloric acid would liberate ammonia, rather than with limewater, only 35% choosing the key **C**.

Paper 9701/02

Theory 1

General comments

There has been a noticeable advance in the general standard of performance of the candidates.

There are seven questions in this Paper but only **Question 3** on the Haber Process and entrification contained questions largely based on knowledge. This question also contained a calculation, as did **Questions 1** and **2**. Higher skills requiring imagination were challenged by this Paper. Many scripts scored over 85% of the marks, and these candidates can be congratulated on a high achievement of knowledge and understanding of Chemistry.

Comments on specific questions

Question 1

(a) Some reference to atoms having the same number of protons but different numbers of neutrons was expected. Since the question asks for a definition of isotopes in terms of its sub-atomic particles, it was not considered adequate to say ‘same proton number, but different mass number’.

(b) The Examiners considered that any study of the atom would consider the question of chlorine having an atomic mass which was not near a whole number as is the case with so many elements. The introduction to **Question 1 (b)** contains all the necessary information for candidates who covered this. The lines at 35 and 37 are for ^{35}Cl and ^{37}Cl; those at 36 and 38 are for $^{1}_{1}H^{35}Cl$ and $^{1}_{1}H^{37}Cl$; these are each in the ration of 3:1.

A common error was to give the two isotopes of chlorine mass numbers of 35 and 38, but in this case the lines at 36 and 37 are impossible to explain, and no credit could be given.

Question 2

(a) A glance down the question would indicate to candidates that this question puts quantitative flesh on the kinetic theory assumption that the volume of the gas particles is negligible compared to the volume of the container. The other usual assumption was the absence of intermolecular forces, which could here be expressed (as several candidates did) that atoms of an inert gas do not have dipoles.

(b)(c) Only weak candidates or those who had not studied the nature of gas molecules found difficulty with this calculation. **(b)** is the Avogadro constant, 6×10^{23}.

The atomic radius of aragon is 0.192 nm. This is required for **(c)(i)**. The volume of one atom of argon is 0.0296 nm^3 or 2.96×10^{-26} dm^3 or 2.96×10^{-29} m^3. At some stage in the question the candidate has to adjust atomic dimensions to those of bulk gas volumes. The volume of 6×10^{23} atoms is 1.78×10^{-2} dm^3. This calculates to be 0.074% of 24dm^3, which should connect in **(c)(v)** to the negligible volume of the atoms themselves.

Question 3

In this question on the industrial manufacture of ammonia by the Haber Process, it is bookwork knowledge which is tested in parts **(a)**, **(b)**, **(c)** and **(e)**. The Haber Process is an important topic in the 9701 syllabus and involves so many applications and considerations of reaction rate, activation energy and equilibrium with reference to ΔH values and Le Chatelier's principle.

The hazard of eutrification, caused by the excessive use of soluble nitrogenous fertilisers, has been a major concern of the last twenty five years. Answers which involved acid rain or pH changes due to the acidity of nitric acid or the alkalinity of ammonia did not score marks for explanation.

The calculation in **(d)** is for K_p for a Haber Process equilibrium. In **(i)** pressure terms need to be used, so the use of square-bracket concentration terms lost a mark. The individual pressures of the three gases are given in the question, and it is a mistake to manipulate these (like partial pressures) for they can be inserted directly into the K_p expansion.

As always in this Paper, the Examiners used the method of error carried forward (or consequential error) so that each error was given one penalty only.

Question 4

(a) These sketches test knowledge and understanding of the periodicity of elements across the third period, and fundamental differences between metals and non-metals both in their physical properties and that metals form cations, non-metals anions.

(b) In this question, some candidates found difficulty with the oxides of Na and P.

The equations in **(b)(ii)** and **(iii)** could, of course, be given as ions. A few candidates gave acids as products of reaction with alkali, but this is impossible. The acid salts, $NaHSO_3$ or $NaHSO_4$, could be formed if the alkali was not in excess.

Question 5

(a) The Examiners were surprised that so many candidates gave incorrect structures for poly(propene). The two commonest errors were the inclusion of double bonds, or the structure of poly(ethene).

(b) Since the polymer only contains single bonds, it must be an alkane.

(c)(i) Since poly(propene) is an alkane, it is unreactive and not biodegradable. It does not absorb water as cotton does, and therefore becomes an inert insertion in the body. Some candidates answered in terms that the poly(propene) was involved in the healing of the wound only, but it becomes a permanent fixture.

(ii) This was marked as a consequence of the candidate's answer to **(b)**. Alkene reactions include those with oxygen and halogens with different products, but the conditions would not exist in body tissues.

Question 6

(a) This calculation giving C_4H_8O was usually correct.

(b) The answer in **(ii)** has to be *ketone*. **A** is butanone, $CH_3COCH_2CH_3$.

(c)(ii) This question asks for *two words* to the answer. The Examiners hoped this would produce *secondary alcohol*, as emphasised in the 9701 syllabus. The answer hydroxyl group was inadequate and could not be given a mark.

Answers to **(b)(iii)** which incorrectly gave butanal could score full marks in **(c)** with **(ii)** primary alcohol and **(iii)** $CH_3CH_2CH_2CH_2OH$.

Question 7

This question was well answered. Candidates whose study of Organic Chemistry had not included esters had to struggle with the structures in **(a)(i)**, but most scored good marks for the general physical properties and uses of esters.

Paper 9701/03

Practical Test

General comments

The Examiners thank Supervisors who provided results for the experiment in **Question 1**. On this occasion accuracy marks were not awarded for a comparison with the Supervisor's results but the latter were useful in giving the reaction times to be expected from each candidate.

Many Centres made use of the boxes, new to the Practical Paper this year, for recording the practical session and laboratory in which the candidate was examined. If the Examiners are to give maximum credit for the accuracy of experimental work it is necessary to be able to identify the session and laboratory for each candidate.

There was little evidence that candidates had insufficient time to complete the Paper.

Comments on specific questions

Question 1

(a) The practical task involved the familiar rate experiment involving hydrochloric acid and aqueous sodium thiosulphate. Candidates were asked to record the time for each experiment to the nearest second (rounding up or down as appropriate). As volumes of solutions were measured with measuring cylinders and timing started on mixing the solutions, the Examiners considered it inappropriate to measure times to 0.1 s or 0.01 s. Many candidates did, however, record the full display from their digital timers. They were not penalised at this stage. A few candidates recorded times greater than 60 seconds in the form seen on the digital display (1:10.67). Examiners converted such times to the correct time in seconds (70.67 s/71 s).

The calculation of $\frac{1000}{\text{time}}$ caused problems for many candidates. The instruction was to evaluate 1000 divided by time correct to one decimal place. The Examiners awarded one mark if all six ratios were quoted to one decimal place and the ratios for 50.0 cm^3, 30.0 cm^3 and 20.0 cm^3 of **FA 1** were correctly evaluated to one decimal place. Many candidates calculated ratios that were 1000 times too small. A time of 23 seconds should have given a ratio of 43.5. This was frequently recorded as 0.0435, 0.044 or 0.04.

In assigning accuracy marks, the Examiners calculated (volume of **FA 1** x candidate's time corrected to the nearest second) for Experiments 1, 3 and 5. These values should have been constant and maximum marks were awarded where all three Vt values were within 10% of the largest. By looking for consistency within each candidate's results – obtained over a short space of time – it was hoped to minimise any variation due to temperature change. It was not uncommon to see a very close pair of Vt values, the third being at some "distance" from the other two. A formula (explained in the mark scheme) was applied with accuracy marks diminishing as the Vt values moved further apart.

6 accuracy marks were available and the majority of candidates scored 6, 5 or 4 marks.

(b) Many candidates either did not see this section above the graph grid or were unable to supply a suitable answer. Candidates who appreciated that the units of rate are s^{-1} or that a short experimental time implied a fast rate were rewarded.

Many weaker candidates associated the 1000 in $\frac{1000}{\text{time}}$ with 1000 cm^3 in 1 dm^3.

(c) One mark was awarded for a suitable scale (not necessarily starting at zero) on the y axis. A few candidates made the plotting of the graph difficult by choosing a scale that necessitated the use of a calculator to work out the number of "small squares" to be counted for each plotted point. An example of such a scale would be 6 scale units covering 15 small squares.

The plotting of three representative points (experiments 1, 3 and 5, where plotted) was checked. As the scale had been given on the *x* axis the Examiners were looking for precise placement of the centre of a cross or dot on the vertical line. It was also necessary for the point to be positioned in the correct "small square" and within ½ small square of the correct position on the *y* axis.

Crosses were often drawn with blunt pencils – the thickness of the line being as much as one "small square". Large dots were often drawn – nearly filling a "small square". If the experiments had been carried out carefully the plotted points should have clearly lain close to a straight line. One mark was given for a ruler drawn straight line fitting the experimental evidence (not necessarily a line of best-fit). A very large number of candidates drew lines that were intended to be straight but were drawn in short sections with different gradients – seen when viewed along their length from the origin. One continuous straight line was needed to gain the mark.

A large number of candidates appreciated that the graph should pass through the origin (0,0). Unfortunately, many candidates achieved this by drawing a straight line of different gradient or a curve connected to their straight line. Other candidates drew lines that were clearly intended to pass through the origin but were drawn with a lack of precision that forfeited this mark. The Examiners were disappointed with the general standard of plotting and drawing on the graph. Many candidates lost up to 4 marks through a lack of care and precision.

(d) If a straight line had been plotted (not necessarily passing through the origin), one mark was available to candidates who stated that the rate of reaction was *directly* proportional to the concentration of the sodium thiosulphate solution or equivalent description words or in the form of a mathematical expression. It was not sufficient to just say the two were proportional – a common mistake. The few candidates who drew smooth curves were able to obtain this mark for (a proportional relationship that was) not directly proportional. No mark was available from a graph that joined point to point.

(e) The majority of candidates did not appreciate the reason(s) for keeping the total volume constant. The Examiners accepted any of the following reasons:

- To keep the depth of solution constant
- To ensure the same amount of sulphur was produced in each experiment at the time the cross was obscured
- Constant opacity of the solution
- So that the concentration of **FA 1** was the only variable

It was noted that candidates who scored this mark often gave two or more of the reasons above.

Question 2

(a) One mark was available for recording no reaction or no precipitate on adding sodium hydroxide to the filtrate containing **FA 4**. A large number of candidates observed a white precipitate at this stage which is difficult to explain, as the solution should have contained only ammonium, nitrate and iodide ions.

The second mark in **(a)** was obtained by the majority of candidates for the evolution of a gas turning red litmus blue (or other chemical test for ammonia) or for a gas stated to be ammonia. There were a number of candidates who simply recorded *"It turned red litmus blue"*. As sodium hydroxide was present in the tube the Examiners were uncertain as to the nature of *"It"*. In such cases further evidence was sought in the deduction section. Marks not awarded in the observation boxes were given retrospectively from the deduction section when the explanation unambiguously referred back to appropriate test.

(b) Most candidates obtained the yellow precipitate in this test.

(c) In this test iodide ions were oxidised to iodine. With the reagent concentration specified and the amount of **FA 3** provided, a solution with a distinct brown colouration should have been observed. The Examiners accepted yellow-brown, orange-brown, red-brown or brown for the solution colour or a grey or black precipitate. If iodine was stated as formed this was also accepted.

(d) This complete section was left blank by a small number of candidates.

The Examiners were looking for effervescence, a gas turning lime-water milky or carbon dioxide stated as being formed. This mark was gained by the majority of candidates.

A white precipitate insoluble in excess sodium hydroxide was needed to gain the mark. Many candidates still record the formation of the initial precipitate and make no comment regarding solubility or insolubility in excess.

A white precipitate insoluble in excess ammonia solution was needed to gain the mark. Many candidates failed to observe any precipitate in this test. The precipitate should have been clearly visible with the amounts specified – even where there was difficulty in dissolving the solid in acid.

Deductions

One mark was given for the correct ions in **FA 4** – ammonium and iodide. The addition of further ions negated this mark.

One mark was given for reference to a single correct piece of evidence that related to one of the ions stated as being present – e.g. ammonia gas produced in **(a)** for ammonium or yellow precipitate in **(b)** for iodide. Incorrect or incomplete explanations for other ions were ignored. Retrospective observation marks could be earned at this point.

Candidates should be encouraged at this stage of the question to clearly link the observation with the deduced ion – e.g. the formation of ammonia gas on heating with NaOH indicates the presence of NH_4^+. One mark was given for the correct ions in **FA 5** – magnesium and carbonate. The addition of further ions again negated this mark.

As for **FA 4**, one mark was given for reference to a single correct piece of evidence that related to one of the ions stated as being present – e.g. effervescence for carbonate or white precipitates insoluble in both NaOH and ammonia solution for magnesium. Many candidates scored a mark for calcium in this section where a white precipitate had been obtained with NaOH but no precipitate seen with aqueous ammonia. Incorrect or incomplete explanations for other ions were again ignored. Retrospective observation marks could be earned at this point.

Some candidates interchanged **FA 4** and **FA 5** in the deductions. No marks were scored for the stated ions but evidence marks could be obtained for both **FA 4** and **FA 5**.

Eleven marking points were available – a maximum of ten marks for the question. A small number of candidates obtained all 11 marks. Marks of 7 or more for the question were common.

Paper 9701/04

Paper 4

General comments

The Paper performed well, and several very high marks were gained by candidates. It was, perhaps, a little more difficult to gain really high marks this year, and allowance was made for this in the grading procedure. As has been observed over the last two sessions, however, there is a considerable number of candidates who score very low marks. Looking at their Papers it would seem that large portions of the syllabus have not been covered. This is often the Organic Chemistry sections, but this year gaps were also noticed in Electrochemistry and Inorganic Chemistry.

There was evidence that many candidates did not take enough time over reading the Question Paper carefully enough. Thus in **Question 1 (b)(iii)** molecular rather than ionic equations were often written; in **Question 1 (c)(i)** some candidates omitted to show the polarity of the power source (which would have given them a 50:50 chance of a mark!); in **Question 2 (a)(i)** the units were often omitted (although they *were* included in **Question 2 (b)(i)**, so this was not through lack of knowledge); in **Question 2 (b)(iii)** many calculated the percentage of magnesium *left* in the seawater, rather than the percentage *extracted*; in **Question 5 (b)(ii)** most candidates used the diacid **L** rather than its diacyl chloride. Lastly, and more seriously, several candidates seemed not to notice the *"Turn over"* statement at the bottom of page 11, and omitted to answer **Question 6**.

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

This question required an understanding of both cells and electrolysis. Candidates scored well on part **(c)**, but less well on part **(b)**.

(a) Several candidates did not score full marks for this standard definition, which should have been in terms of the EMF of a cell compared to the *standard hydrogen electrode*, measured under *standard conditions of concentration, temperature and pressure*. There was a vagueness about some of the ideas candidates expressed concerning electrode potentials, and even some confusion with *ionisation energy.*

(b) In **(i)** the most common errors were to omit the negative sign, or to add $E_{right} + E_{cell}$ rather than to subtract them. In **(ii)** the majority of candidates scored a mark for a left → right arrow, but several drew the arrow backwards, from the positive to the negative terminal. In part **(iii)** some candidates attempted to identify *M* (variously as Mn or Ni or Zn! – these symbols were ignored) but most scored a mark or two for the observations: in I the rod of *M* would dissolve, the blue solution would fade, and a red deposit of copper would be formed; in II the rod of *M* would dissolve and hydrogen gas would be evolved (in each case *one* of the various observations was all that was needed for the mark). Candidates were less good at constructing the ionic equations. Either the two half equations were written, but not combined, or molecular equations were given.

(c)(i) Although most candidates scored a mark for the polarity, a significant number showed the object connected to the positive electrode, and as mentioned above, some candidates failed to indicate any polarity. Any soluble copper salt was accepted as the electrolyte – some candidates did not appreciate what was involved in electroplating, and suggested H_2SO_4, $FeSO_4$, and even copper metal. The calculation in **(c)(ii)** was generally well done, the most common error being to forget that *two* moles of electrons are needed to deposit *one* mole of copper atoms.

Answers: **(b)(i)** -0.42V; **(c)(ii)** 3035 ± 5 seconds (50.7 min).

Question 2

A clear distinction was apparent between candidates who had covered Solubility Product in detail, and those who had not spent as much time on this part of the syllabus.

(a) In **(i)** most candidates scored a mark for $K_{sp} = [Ba^{2+}][SO_4^{2-}]$, but many forgot to include the units. The calculation in **(a)(ii)** caused no problems. Part **(a)(iii)** was a good discriminator for those who could apply their knowledge – candidates who appreciated that barium carbonate would react with the acid in the stomach to form soluble barium salts scored the mark.

(b) In **(i)** most candidates wrote a correct expression for the K_{sp} of $Mg(OH)_2$, although some confused it with the K_c for the reaction given. Units were often correct, and more commonly included here than in **(a)(i)**. The most common error in **(ii)** was to forget to divide by 4 before taking the cube root. In **(iii)** the vast majority of candidates did not read the question properly. They used their value for $[Mg^{2+}(aq)]$ to calculate the percentage of magnesium left in the seawater, but then failed to subtract this value from 100% to calculate the percentage *extracted*.

(c) The calculation in **(i)** was fairly well answered. Common errors were to reverse all the signs (giving +160 kJ mol^{-1}) or one of them. In **(ii)** the mark was for observing that a negative ΔH value implies that the reaction is likely to be favourable.

(d) There were some excellent answers to this part. Some, however, confused the explanation of this trend with that of the decomposition of nitrates and carbonates, and thus concentrated more on how the physical properties of the ions varied down the group (e.g. ionic size increasing, extent of polarisation decreasing) rather than the effects of ion size on *lattice energy* and *hydration energy*. Because of the large size of the sulphate ion, the latter decreases *more* than the former, and hence the enthalpy change of solution becomes more positive.

Answers: **(a)(ii)** 1.14×10^{-5} mol dm^{-3}; **(b)(ii)** 1.7×10^{-4} mol dm^{-3}, **(iii)** 99.7 %; **(c)(i)** -160 kJ mol^{-1}.

Question 3

This question revised the first year ideas of structure and bonding, combined with some specific Group IV chemistry. Many candidates showed a misunderstanding of the former, and a lack of detailed knowledge of the latter.

(a) The key phrases looked for were that CO_2 is a simple *or* discrete, covalent *or* molecular structure; SiO_2 is a giant *or* macro, covalent *or* molecular structure; and SnO_2 is a (giant) ionic structure (albeit with some covalent character). The explanation of the melting points should have been in terms of there being only weak van der Waals attractions between CO_2 molecules, in contrast to the strong covalent bonds between Si and O atoms in SiO_2, or the strong ionic attractions in SnO_2. Many candidates have an unclear idea as to why simple covalent compounds have low melting points, confusing the weak intermolecular bonds with weak covalent bonds within the molecules, and claiming that it was these weak covalent bonds that were broken on melting.

(b) The main problems in this part were that many candidates thought that SiO_2 reacted with NaOH(aq) and HCl(aq), whereas in fact silica is inert to both these reagents. The amphoteric nature of SnO_2 was fairly well known, however, as was the lack of reaction between CO_2 and HCl(aq). Candidates were less good at writing balanced equations: sodium carbonate was sometimes written as $NaCO_3$, and in some answers the oxidation state of tin miraculously changed from +4 in SnO_2 to +2 in Na_2SnO_2 or $Na_2Sn(OH)_4$. Oxygen gas was then invented as a product to make the equation balance.

(c) Once the correct $E^\ominus$ value for PbO_2/Pb^{2+} was extracted from the *Data Booklet*, most candidates correctly subtracted 1.36V to arrive at the answer of 0.11V. The alternative value of 1.69V for Pb^{4+}/Pb^{2+} was allowed, giving an answer of 0.33V, but several candidates incorrectly used the Pb^{2+}/Pb value. For the most part, candidates wrote a correctly balanced equation: *either* $PbO_2 + 4H^+ + 2Cl^- \rightarrow Pb^{2+} + 2H_2O + Cl_2$ *or* $Pb^{4+} + 2Cl^- \rightarrow Pb^{2+} + Cl_2$ *or* their molecular equivalents, depending on the $E^\ominus$ used.

Answer: **(c)** 0.11 V (*or* 0.33 V if Pb^{4+}/Pb^{2+} was used).

Question 4

This question, couched in terms of the tear gas *CN*, was mainly concerned with reactions of chloro compounds. A large number of candidates did not attempt, or made only a cursory attempt at this question, along with the other organic **Question 5**.

(a) Many candidates scored the mark here, although some omitted to include Cl_2 as a reagent, or incorrectly used Cl_2(aq).

(b) Most appreciated the need for a halogen carrier ($AlCl_3$ *or* Fe were the two most common ones), but again some omitted to include Cl_2 as a reagent, or incorrectly used Cl_2(aq).

(c) Although a good number of candidates correctly deduced that benzoic acid would be the product, several suggested $C_6H_5CH_2CO_2H$ *or* $Cl\text{-}C_6H_4CO_2H$.

(d) The iodoform reaction was the only one that candidates could use to distinguish these two compounds from each other. The majority of candidates who answered this question chose the correct reagents (NaOH(aq) + I_2) and gave the correct observations (yellow precipitate with **C**, and nothing with **F**). The description of an *orange* precipitate did not score the mark.

(e) Despite the name *chloroacetophenone* being included in the specific question in this part, several candidates thought "*CN*" stood for a cyanide radical, and used the M_r value of 26 in their calculation. However, most candidates who attempted this calculation scored full marks.

(f) Several candidates in **(i)** gave the wrong order, not reading the instruction *in order of increasing ease* carefully enough. It was often possible to give them the mark, however, if their answer to part **(ii)** demonstrated that they knew that **G** would be the quickest to hydrolyse (due to a highly $\delta+$ carbon atom joined to both oxygen and chlorine) and **H** the slowest (due to the strong $C\text{-}Cl$ bond because of overlap between the π orbitals on the ring with the lone pair on chlorine).

Answer: **(e)** 0.0117 mol.

Question 5

This question was specifically set on the organic part of the second year syllabus, involving the reactions of phenol, and condensation polymerisation.

(a)(i) Most candidates correctly suggested PCl_3, PCl_5 or $SOCl_2$. The most common incorrect answer was HCl (aq). Most candidates also wrote a correct equation in **(ii)** (either ionic or molecular). Candidates were less sure about the structures of **J** and **K**, however. For **J** they often thought that phenol + NaOH were the *reactants*, rather than additional *reagents*, so suggested that the product was sodium phenoxide, rather than phenyl ethanoate. The formula of ethanamide for **K** often included an extra hydrogen atom (i.e. CH_3CONH_3).

(b) Most candidates correctly identified *condensation polymerisation* in **(i)**, but did not read the question carefully enough in **(ii)**, either using $HO_2CCH_2CH_2CO_2H$ rather than $ClCOCH_2CH_2COCl$ as one of the reagents, of drawing the part structure of a *polymer* for the product, rather than the diester $HOCH_2CH_2OCOCH_2CH_2COOCH_2CH_2OH$.

(c) In **(i)** the answer expected was *polyamide*. *Nylon* was also accepted, as also was *condensation*, due to the nature of the question. *Polypeptide* or *protein* were *not* accepted. These terms specifically refer to polymers of α-aminoacids. Many candidates scored [2] marks in **(ii)** for the formulae $HO_2C\text{-}C_6H_4\text{-}CO_2H$ (*or* $ClCO\text{-}C_6H_4\text{-}COCl$) and $NH_2CH_2CH_2CH_2CH_2NH_2$, although some lost marks for not included all four CH_2 groups in the diamine, or omitting one or more hydrogen atoms.

Question 6

Apart from some candidates not seeming to realise this question existed, there were many who did not know of the chemistry described in **(b)**, or lacked precision in their answers. There were some candidates who seemed to have learnt their transition metal chemistry well, and scored full marks.

(a)(i) Most candidates correctly described the Ti atom as $[Ar]4s^2 3d^2$ (the order of 4s and 3d could be reversed). In **(ii)** any *two* of $TiCl_2$, $TiCl_3$ or $TiCl_4$ were accepted for the mark. The inclusion of others, such as $TiCl$ or $TiCl_6$, negated this mark.

(b) In **(i)** a blue *solution* would be formed, due to the formation of the complex ion $[Cu(H_2O)_6]^{2+}$ ($[Cu(H_2O)_4]^{2+}$ was also allowed for the mark). In **(ii)** the solution would turn *deep blue*, or *purple*, due to the H_2O ligand being *replaced* by NH_3 ligands, forming $[Cu(NH_3)_4]^{2+}$ *or* $[Cu(NH_3)_4(H_2O)_2]^{2+}$. The intermediate formation of the pale blue precipitate of $Cu(OH)_2$ was described by some, although it was not required as an answer to this particular question.

Paper 9701/05

Practical Test

General comments

The Examiners thank those Supervisors who provided all of the information necessary to assess the accuracy of the titration in **Question 1**. In working through scripts from a Centre they often note a difference in the "average titre of candidates" working in different examination sessions and/or laboratories, even when information from the Centre would suggest that identical solutions had been used by all of the candidates. The Examiners take action to maximise the accuracy marks where there is a significant difference in this "average titre" provided they are able to identify the groups of candidates in different laboratories. The Examiners require complete listings for each session and for each laboratory (seating plans should also be provided) and separate sets of Supervisor titration results for each such group. Some Centres made use of the Session/Laboratory boxes printed on the cover of the Paper this year and this assisted the Examiners in sorting the candidates into their correct groups. The Paper appeared to be of the correct length – there being little evidence of candidates failing to complete both questions. The titration calculation produced much more working than is usually seen – many of the spaces were filled with lines of very small writing.

Comments on specific questions

Question 1

(a) The standard of individual titration work continues to rise with the majority of candidates automatically recording burette readings to the second decimal place as required by the syllabus (a burette should be read to the nearest 0.05 cm^3). Fewer "silly" burette readings, e.g. 23.53 cm^3 were seen in this examination.

One mark was given if the initial and final burette readings in each table were in the correct place, all final burette readings were recorded to the second decimal place and the subtraction in Table 1.1 was correct. A further mark was given in Table 1.1 for a recorded volume of **FB 1** diluted between 45.0 cm^3 and 45.5 cm^3.

(b) It was pleasing to see the majority of candidates performing only two or three titrations in order to obtain two titres within 0.10 cm^3 – as required in the syllabus. Two uncorrected titres within 0.10 cm^3 gained one mark and the second mark in Table 1.2 was awarded for a correctly calculated average providing there was no subtraction error in the table. In calculating the average it was sufficient to tick the titres to be used. Candidates who did not tick the titres used but showed a calculation, e.g. $\frac{23.50 + 23.40}{2} = 23.45$, were not penalised. Where no values were ticked and no calculation shown the mark for the average was not awarded but Examiners accepted the candidate's average titration value (if suitable) in assessing accuracy. Where there was a subtraction error in the titration table it was corrected by the Examiner and a suitable average chosen from the corrected titres for assessing accuracy.

Accuracy (eight marks)

From the Supervisor's results and from the results of each candidate the value of $\frac{\text{volume of FB 1 diluted}}{45.00} \text{ x Titre}$ was calculated.

The value obtained for each candidate was compared to that for the Supervisor and eight marks awarded for a difference up to 0.10 cm^3. Marks awarded for accuracy decreased on a widening scale to 1 mark for a difference of (0.80+ to 1.00) cm^3.

The report has made reference to the improved quality of individual titration work but the Examiners noted a wider spread of titres than expected in this particular titration. Two factors may have contributed to this – the use of the diluted **FB 1** in the burette and the presence of a coloured ion at the end-point. Where a group of candidates scored poor accuracy marks when compared to the Supervisor's standard the Examiners carefully considered the spread of titres for the group to see if there was any consistent value that could be used as an alternative standard. In some cases this was possible but in some Centres titration results were spread over several cm^3 with no consistent values.

(c) One mark was given for $\frac{\mathbf{100}}{\mathbf{248.2}}$ or its evaluation. Where working was shown 32.1 had to be used – a number of candidates lost this mark by using 32 for the A_r value of sulphur. It was quite common to see candidates evaluating the concentration as 0.4029 or 0.403 mol dm^{-3} and then correcting to 1 significant figure, i.e. 0.4 mol dm^{-3}. This was not penalised but noted by the Examiners as bad practice.

(d) Most candidates were able to calculate the concentration of sodium thiosulphate in the diluted solution **FB 3**.

The Examiners expected to see answer to **(c)** x $\frac{\text{volume of FB 1 diluted}}{250}$

Very few candidates calculated this directly, most worked in 2 stages:

answer to **(c)** x $\frac{\text{volume of FB 1 diluted}}{1000}$ then multiplied by $\frac{1000}{250}$

A small number of candidates used the titre rather than the volume of **FB 1** diluted at this stage.

(e) Most candidates were able to calculate the moles of sodium thiosulphate run from the burette (answer to **(d)** x $\frac{\text{Titre}}{1000}$) and then to convert this into moles of iodine by multiplying by $\frac{\mathbf{1}}{\mathbf{2}}$.

A small number of candidates used the volume of **FB 1** diluted rather than the titre at this stage and an equally small number multiplied by 2 to convert to moles of iodine.

(f) Nearly all candidates correctly calculated the moles of chromate ion pipetted into the flask.

From this point forward many candidates resorted to theory. There was an impressive use of correctly balanced half equations but the practical work ceased to be used.

(g) The Examiners expected to see the answer to **(e)** divided by the answer to **(f)** in calculating the moles of I_2 produced by each mole of chromate ion.

(h) Very few candidates scored the two marks available in this section. They were asked to use oxidation numbers and the experimental results to show that the chromium had been reduced to a +3 oxidation state.

Very few candidates gave the three oxidation numbers required by the Examiners. The +6 value in chromate was common but –1 for iodide and 0 for elemental iodine were rare. One mark was given for these three oxidation numbers.

Working from the oxidation numbers for iodide and iodine and the moles of iodine produced per mole of chromate ion it was the intention that candidates should establish:

$CrO_4^{2-} \equiv$ 3 mole of electrons

and from this deduce that the +6 oxidation state for chromium must have been reduced to the +3 state.

The majority of candidates scored no marks in **(h)** as they resorted to theory and half equations. Those who did score the second mark often used half equations but used their practical results to establish that 3 moles of iodide ions were involved in the reaction.

Question 2

The ability to plan an experimental solution to a problem is a skill that needs careful development. In this particular exercise the Examiners observed that many candidates made use of both of the reactions shown in the equations. This resulted in a mixture of possible methods in the plan.

In marking the plan section (4 marks) the Examiners looked for the best general outline of a method. There was no penalty for using apparatus that would not actually work if the experiment had been attempted (e.g. running acid through a thistle funnel into a conical flask connected to a gas syringe). 3 or 4 marks were often awarded in this section.

In the recording of results section (3 marks) it was stated that “all necessary measurements” should be shown and this was the approach taken by the Examiners in marking the section. Were any other practical measurements necessary in order to produce a % of copper carbonate in the malachite? Very few candidates showed an appreciation of the measurements that would need to be recorded while conducting the experiment. Mass of malachite was often recorded. The Examiners expected to see (i) mass of a container, (ii) mass of container + malachite, and if the solid was transferred to another vessel during the experiment (iii) mass of container + residue. Volume of gas collected was often recorded. The Examiners expected to see (i) initial volume reading on a syringe and (ii) final volume reading on a syringe. Appropriate units were expected at least once for each unit.

Each experiment was assessed for the necessary readings (e.g. heating to constant mass would need at least two weighings after heating; a titration would need the standard titration table in addition to initial weighings).

Most candidates scored zero for this section, a number 1 mark and a small number 2 or 3 marks.

The processing section (3 marks) was generally well presented and many candidates scored all three marks. Weaker candidates often generalised – “calculate the moles of carbon dioxide given off and convert this to a mass of calcium carbonate” – for which no marks were awarded. These candidates were able to score point **(g)** for dividing the mass of pure calcium carbonate by the mass of malachite and multiplying by 100.

Many candidates were able to show how the experimental results would be processed using the atomic masses and/or molar volume data given. For experiments involving the collection of gas, 24 dm^3 or 24000 cm^3 had to be used. In calculating the mass of pure copper carbonate 123.5 had to be used.

The Examiners initially identified 7 ways in which they expected the experiment to be conducted. A further, less common, method was identified in some scripts and added to the list. Some candidates considered it possible to directly titrate copper carbonate or copper oxide with an acid. An approach that enabled them to obtain 3 of the 4 marks available was added to the mark scheme (i.e. they were penalised once for the basic mistake that neither solid is soluble in water).

During marking a few further and inventive methods were seen and marked appropriately using the general principles applied to the other methods.

The methods most commonly seen were:

Heating – change in mass
Heating – gas collected
Addition of acid – gas collected
Addition of acid – change in total mass
Back titration involving copper carbonate
Back titration involving copper oxide
Addition of acid – mass of residue left
(Direct titration of copper carbonate or copper oxide)

Many candidates scored 7 marks for this question and some were able to score 8 or 9 marks.

Paper 9701/06
Options

Comments on specific questions

Biochemistry

As in previous years this was a popular option and candidates were, on the whole, well prepared.

Question 1

Most candidates were able to describe the action of enzymes and scored reasonable marks in part **(a)**. Part **(b)** was, on the whole, less well done with marks being lost through a lack of thought. The most common errors included incorrectly spacing the V_{max} lines, and having values of K_m which wandered along the *x*-axis.

Question 2

Candidates scored reasonably on this question too, but it was interesting to see which species they did not recognise. In most cases, candidates who could identify the species shown could also describe its importance. The species were; ATP; glutamic acid (an amino acid was acceptable); a phospholipid; deoxyribose and glucose-6-phosphate. The last two of these caused the most difficulty with both being described as either 'sugars' or carbohydrates.

Environmental Chemistry

This option proved more popular this year, and many of the answers were of a much higher standard than previously.

Question 3

Teachers seemed to have taken note of comments in previous reports, and many of the candidates obviously read the question thoroughly before committing their answers to paper. Part **(a)** was generally well answered by most candidates, but part **(b)** produced more problems. It was expected that candidates should recognise that wetlands would produce anaerobic conditions, and that under these the reduction of sulphate to sulphate ions would use hydrogen ions. As the aluminium ions are precipitated as the hydroxide, the pH would be lowered. In part **(c)**, only the best candidates scored both marks, and this seemed to be an area of the syllabus that was less well understood.

Question 4

Part **(a)** was a standard question and, pleasingly, few candidates had trouble with it. It was expected that part **(b)** would be fairly routine, but some candidates did not seem to appreciate that $Cl\bullet$ is a catalyst in the reaction. Part **(c)** should have been straightforward, as the $ClO\bullet\ NO_2$ adduct had been given in the stem and candidates only had to recognise that if $ClO\bullet$ was removed no $Cl\bullet$ would be generated.

Phase Equilibria

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

Question 5

In part **(a)** of this question candidates were required to plot data for the tin/bismuth eutectic system, and whilst many scored good marks, a significant number failed to appreciate the need to extrapolate the lines to give the eutectic composition and melting point. Part **(b)** was marked consequently from candidates' graphs, but again a significant number dropped marks, failing to identify what happened at each stage of the cooling curve. Examples of eutectic systems were generally known in part **(c)**.

Question 6

Candidates in general found this question more taxing than **Question 5**. Only around half the candidates could describe the technique of gas/liquid chromatography with or without a labelled sketch. Most, however, knew that the process involved adsorption/partition. The interpretation of the chromatogram was generally well done, and most candidates suggested a suitable temperature range for the analysis. Few candidates successfully explained the chemical nature of the stationary phase, ignoring the increased retention times of the alcohols over the longer chain ketones.

Spectroscopy

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

Question 7

Parts **(a)** should have been relatively straightforward for those candidates prepared for this option, and there were some good answers. Weaker candidates merely referred to the number of electrons in the *d*-orbitals, and made no mention of the fact that these were split into two energy levels in the presence of ligands. In part **(b)** it was expected that candidates would recognise the presence of both π bonds and non-bonding electrons in (i), non-bonding electrons in (ii) and π bonds in (iii), and indicate the appropriate transitions.

Question 8

The interpretation of spectra always proves to be a good discriminator and this question proved to be no exception with only the best candidates scoring full marks. At least 9 marking points were available in part **(a)** for a maximum of 8 marks, but candidates did need to use the data from the spectra. The mass spectrum allowed candidates to show that 8 carbons were present, and this together with the 9 protons shown in the n.m.r. spectrum showed that only 1 oxygen and 1 nitrogen atom could be present. The n.m.r. spectrum also showed 5 aromatic protons together with 3 identical protons (a methyl group) and a labile proton. The infrared spectrum shows one clear peak at around 3300 cm^{-1}, this is not broad enough to be –OH, and is hence –NH. Putting this evidence together gives an aromatic secondary amide.

Transition Elements

This remains a very popular option, although this year there seemed to be fewer high scoring answers.

Question 9

It was expected that part **(a)** would prove relatively straightforward, but a surprising number of candidates gave incomplete answers, either not referring to the fact that the carbonyl was distilled off, or that the carbon monoxide is recycled. Most candidates could describe a use of nickel, although some candidates could not explain why the metal is used. The drawing of the structural formulae was usually well done, although a worrying number of candidates did not recognise *cis-trans* isomerism.

Question 10

Part **(a)** of this question proved reasonably straightforward for most candidates. In part **(b)** although most candidates could describe disproportionation, a significant number failed to correctly calculate $E^{\ominus}_{\text{cell}}$. The hardest part for all candidates was part **(c)**, where many candidates lost marks by failing to think about the reactions described. Part **(c)(i)** should have been routine, and although **(c)(ii)** required a little more thought, the colour changes should have given sufficient clues.