CHEMISTRY

Paper 9701/01
Multiple Choice

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

General comments

For this paper, the mean score was 22.1 (55.2%), a little below the targeted value, and the standard deviation of the scores was 6.72 (16.8%), indicating that overall the paper performed satisfactorily.

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

Comments on Individual Questions

Two questions – **Question 3** on the electronic structures of elements, and **Question 7** on the properties of MgO that make it a good insulator – had a high facility, representing areas of the syllabus that are widely understood.

Four questions had a low discrimination in distinguishing between more able and less able candidates. In **Question 18** this may have been because of a high facility: 75% of candidates were aware of the reducing properties of sulphur dioxide which make it useful as a food preservative.

The response to **Question 5** would indicate that many candidates are not familiar with the way that a π-bond is formed by the overlap of orbitals: only 37% chose the key **B,** but 46% chose distractor **D** which used the overlap of four orbitals in a square planar arrangement.

A question on the reaction conditions of the Contact process has not previously been asked, and **Question 19** was set to test this. The reason why a temperature as high as 450 ^{o}C is used was only properly understood by 39% of candidates (the key **B**): at lower temperatures the V_2O_5 catalyst is ineffective. Curiously, given that the reaction is an exothermic one such that lower temperatures could be expected to move the equilibrium in the direction of the SO_3 product, 32% chose distractor **A** believing that this would not be the case.

Question 39 turned on the ability of concentrated sulphuric acid to carry out a dehydration. 52% of candidates appreciated that this can be done with both secondary and tertiary alcohols (key **B**), but 25% of candidates, including some of the more able ones, thought that it would react both with a secondary alcohol and with ethanoic acid (distractor **C**): not only was the inclusion of the acid a surprise, but this neglected the tertiary alcohol, when tertiary alcohols dehydrate far more readily than secondary and primary alcohols.

In four questions there appears to have been an element of guessing, where candidates were uncertain of the chemistry involved.

Question 4 involved a graphical display of the quantitative results of burning the first four members of the homologous series of alkanes in an excess of oxygen: there was an almost even distribution among the four options.

Although **Question 11** performed satisfactorily, only 36% of candidates chose the correct answer **B**. Examiners have noted in the past that candidates have difficulty in determining the proportions of reactants and products from a given value of K_c.

When potassium bromide is heated with concentrated sulphuric acid (**Question 17**), 41% of candidates believed that only potassium hydrogensulphate and hydrogen bromide are produced (distractor **A**): only 22% were aware of the oxidising properties of sulphuric acid in knowing that bromine, water and sulphur dioxide are also produced (key **D**).

The structure of a cyclic ester was given in **Question 40**. 67% of candidates thought this to be a ketone, and 37%, in not recognising it as an ester, did not identify the carbon-oxygen bond that is broken on hydrolysis.

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Paper 9701/02

Theory 1

General comments

The paper tested candidates' knowledge and understanding of the required subject matter and the majority of candidates made good attempts to complete all of the questions. There were many good answers to this paper and most candidates were able to demonstrate some positive achievement. Candidates' knowledge of organic chemistry was better in this examination than in previous ones

However, a number of candidates clearly had not prepared thoroughly for the examination by learning important factual chemistry, while a significant number of candidates gave some answers that were muddled with the result that Examiners were unable to give them credit.

Comments on specific questions

Question 1

This question tested candidates' knowledge of the structure of the atom. While there were many good attempts, some candidates gave responses which were ambiguous and were penalised as a result.

(a) There were many good answers to this part with the majority of candidates scoring high marks. One common error was to fail to explain why the electron, because of its very small mass, shows the greatest deviation.

(b) Most candidates were able to answer this part correctly. The most common mistake was to define proton number in terms of the number of protons in an element rather than in the nucleus of an atom.

(c) This part was less well answered with many candidates failing to keep their answers to a simple explanation of the lack of forces of repulsion between the protons in the nucleus and a neutral neutron moving towards it.

(d) While many candidates clearly understood that an isotope of the same element would be formed, they failed to explain clearly that there would be no change in the chemical properties because these are determined by the electronic configuration of the atom. When a new isotope is formed, the electronic configuration is unaffected.

Question 2

This question required candidates to explain simply and clearly the nature of the particles in the two structures and what forces exist between them. While many did this well, there was a significant number who made contradictory statements and were penalised as a result.

(a) Examiners expected candidates to state that iodine molecules, formula I_2, are present in solid iodine.

(b) Many candidates knew that the bonding in copper is metallic but fewer were able to explain clearly the nature of this bonding in terms of cations and delocalised electrons. Those who referred to atoms rather than cations were penalised. A larger number of candidates correctly explained the forces present in solid iodine. One common mistake was to discuss the covalent bonding within the iodine molecules rather than the weak van der Waals' forces between them.

(c) The majority of candidates knew that chlorine oxidises heated copper but relatively few explained correctly that iodine will not react with copper because it is a weaker oxidising agent than chlorine.

Question 3

This question simply tested candidates' knowledge of the properties of the elements concerned. While there were very many good answers, only a very small number of candidates scored full marks on this question.

(a) Examiners expected candidates to know that noble gas molecules only contain one atom and that the only element that has a molecule which contains only four atoms is phosphorus.

Atomic radii increase down a Group and generally decrease across a period. Candidates were therefore expected to deduce that the atom that has the largest radius is potassium.

Most candidates knew that the only element from the part of the Period Table that was given in the question which is liquid at room temperature and pressure is bromine. Fewer knew that the element with the highest melting point in Period 3 is silicon.

The largest anion from the same Period will be the P^{3-} ion formed by phosphorus.

(b) Answers to this part were generally less good than those to part **(a)**. A number of elements, such as sulphur or phosphorus form two acidic oxides but carbon is not one of them. Aluminium oxide is the most common amphoteric oxide. Only the oxides of Group I will dissolve in water to give a strongly alkaline solution.

A significant number of candidates struggled to identify sodium or magnesium chlorides as the only ones which dissolve in water to give a neutral solution.

Answers to the last section were very poor with manganese, a metal that does not dissolve in water, a popular wrong answer. Examiners expected candidates to give chlorine or bromine as their answer.

Question 4

An early part of this question was concerned with a reaction mechanism from organic chemistry which was well answered by many candidates. Fewer were able to carry out correctly the calculation in the latter part of the question.

(a) The majority of candidates knew that 'cracking' of large organic molecules is carried out by using high temperatures (thermal cracking) or by using catalysts (catalytic cracking). Some candidates, however, used enzymes as their catalysts and were penalised.

(b) This was generally well answered with equations such as the following.

$$C_{18}H_{38} \rightarrow C_6H_{14} + C_{12}H_{24}$$

Alternative answers, such as replacing $C_{12}H_{24}$ by $4C_3H_6$ or by $6C_2H_4$ were accepted.

(c) There were many fully correct answers to this part showing that candidates had learned and understood the mechanism of electrophilic addition. Examiners expected to see a dipole on the Br_2 molecule clearly shown by $\delta+$ and $\delta-$ with the $\delta+$ nearest the π bond of $CH_2 = CH_2$. From this bond, Examiners wished to see a curly arrow to $Br^{\delta+}$. They then looked for the formation of a carbocation and Br^- ion, followed by attack on the carbocation by a lone pair of electrons on the Br^- ion.

A very clear explanation of this mechanism may be found on page 303 of AS Level and A Level Chemistry by Ratcliff et al, published by Cambridge University Press.

(d) Most definitions of the term *standard enthalpy change of combustion* were correct. The most common mistakes were to fail to refer to one mole of an element or compound, or to omit any reference to the use of an excess of oxygen or air.

(e) While there was a pleasing number of candidates who were able to show that hydrocarbon **Z** was propene, C_3H_6, there was also a large number who either made mistakes or who were unable to answer this part at all. Full working is shown below.

(i) heat released = m c δT = 200 × 4.18 × 27.5 = 22990 J = 23.0 kJ

(ii) 23.0 kJ are produced from 0.47 g of **Z**

2059 kJ are produced from $\frac{0.47 \times 2059}{23.0}$ g = 42.08 g of **Z**

M_r of **Z** = 42

Candidates who used 4.2 J g^{-1}°C^{-1} for the specific heat capacity of water were not penalised in any way.

The most common error was to convert the change in temperature from 27.5°C into 300.5 K. It must be stressed that this is a *change* in temperature and will have the same numerical value if the original temperature were measured in degrees Celsius or in Kelvin.

The other common error was to use a mass of 0.47 g rather than 200 g. In addition, some candidates struggled with units.

(f), (g) Those candidates who had correctly calculated ***M*r of** Z were able to identify it as propene but fewer were able to draw a correct structure showing **two** repeat units. The minimum that was accepted as a correct answer was as follows.

$$-CH(CH_3)CH_2CH(CH_3)CH_2-$$

This question did not require a displayed formula although many candidates drew one; this was, of course, accepted by Examiners.

Question 5

This question tested candidates' knowledge of important organic chemistry and their ability to apply it in an unusual context. It is pleasing to be able to report that there were many good answers. It should be noted that in questions of this type, the condition mark is only awarded if the reagent is correctly stated.

(a) Many candidates knew that a cold dilute acidic or alkaline solution containing manganate(VII) ions would carry out this oxidation. The most common error was to use heat which would cause further oxidation.

(b)(i) Fewer candidates recognised this reaction as a free radical substitution of the $-CH_3$ group of ethanoic acid. Chlorine would be used in the presence of ultra violet light.

(ii) More candidates were able to state the correct reagent and conditions for the subsequent hydrolysis, although significant numbers failed to state that the NaOH must be in aqueous – rather than alcoholic – solution.

(c) Many candidates struggled with this part. On oxidation,

lactic acid gives CH_3COCO_2H,

glycollic acid gives HO_2CCO_2H.

(d) There were many very good attempts at these two structures with the chiral carbon atom clearly marked and the mirror object/mirror image nature of the two three-dimensional isomers clearly represented. However, many candidates did not give fully displayed structures, presenting the carboxylic acid group as COOH or CO_2H, or showing an –OH group bonded to C through the H atom. For details of how structures should be presented, candidates should refer to ***Section 10.1*** of the Syllabus.

(e) A pleasing number of candidates were able to draw two correct structures. As in **Question 4(g)**, displayed formulae were not required but many candidates sensibly used them in their working. The two structures are

$CH_3CH(OH)CO_2CH_2CO_2H$ and $HOCH_2CO_2CH(CH_3)CO_2H$.

(f) Many candidates were able to deduce that the reaction referred to in the question would be hydrolysis of the esters and that the products would be soluble because the products would be able to form hydrogen bonds with water molecules. They are to be congratulated for doing so well at the end of the paper.

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Paper 9701/03

Practical Test

General comments

When a script packet is received and opened, Examiners check for the presence of the following documentation:

- a completed report form showing the candidates present in each session;
- seating plans for each session;
- a Supervisor's script giving experimental results **for each session and each laboratory within a session**.

If candidates are not to be disadvantaged Examiners must be able to relate each candidate to a specific set of experimental results provided by the Supervisor.

In the October/November 2006 examination Examiners noted that many Centres failed to provide the Supervisor's results and CIE were asked to contact the Centres concerned to obtain these results. These results were often unobtainable.

When sorting candidates into correct sessions and laboratories it is very helpful if candidates are arranged or listed in sequential candidate order. Boxes are provided on page 1 of the examination paper for candidates to enter the session and the laboratory in which they took the examination. Unfortunately these boxes are left blank by many Centres.

The Examiners thank those Centres where all the required information was provided.

The quality of titration work, which has shown a steady improvement in recent years, now appears to be in decline. Many Centres do have a majority of candidates who do produce consistent burette readings, show appropriate precision for the apparatus used and obtain titre volumes close to the Supervisor. An increasing number of Centres however, had candidates unable to reproduce individual titre readings and who incurred one or more penalty marks for imprecision in carrying out the titration. A significant number of candidates were unable to attempt more than the first section of the titration calculation.

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

Comments on specific questions

Question 1

Titration

In assessing the accuracy of working in **Question 1** the candidate's titre was scaled as if the candidate had diluted the same volume of **FA 1** as the Supervisor. Comparison was then made to the titration value obtained by the Supervisor. 8 marks were awarded for a difference within 0.20 cm^3, decreasing on a sliding scale to 1 mark for a difference between 1.00+ cm^3 and 1.50 cm^3.

A deduction was made from the accuracy mark for each of the following errors seen in the titration information. There was a maximum deduction of 2 marks.

- No data recorded in Table 1.1 **or** the recorded (uncorrected) volume of **FA 1** diluted outside the range on the question paper.

- Any final burette readings in Table 1.1 or Table 1.2 not recorded to the nearest 0.05 cm^3 (Examiners expect to see a second decimal place ending with a 0 or a 5), **or** "impossible" burette readings (e.g. 22.73 cm^3) recorded at any point in either of the tables, **or**
- all final burette readings given as 50(.00) cm^3.
- No two recorded (uncorrected) titres within 0.1 cm^3 in Table 1.2.
- An incorrect average calculated **or**
- no selection of at least two titres for the calculation of an average indicated (selected titres may be ticked or shown in a calculation), **or**
- an error in subtraction for any accurate titre in Table 1.2 or the volume diluted in Table 1.1.

Examiners noted that "penalties" were commonly applied within particular Centres. Candidates in Centres where notice has been taken of previous reports and mark schemes were seldom penalised.

In determining the accuracy mark to be awarded, Examiners corrected any errors in subtraction and assessed the quality of the practical work performed.

It was also noted that **spread penalties** for the titres selected for the "average" titre were common in the same Centres that incurred the earlier penalties. Candidates are expected to use titre values no more than 0.20 cm^3 apart in calculating the "average". Candidates should be taught to use judgement on the titres obtained, rather than apply a rigid rule such as the average of three titrations. The syllabus requirement for this examination is any two titres within 0.10 cm^3.

Calculations

Marks were awarded for mathematical expressions which displayed correct chemistry. Any arithmetic error in an individual step was penalised only in **(f)** where 1 mark was given for a final answer evaluated to within 1% of that determined by the examiner from the candidates uncorrected values.

(c) The majority of candidates were able to produce the correct expression in this section. One of the two marks in this section was frequently lost for using 214 instead of 214.1 for M_r of KIO_3, the individual relative atomic masses having been given in the question.

(d) Use of the correct ratio, 1:6, was very common, but 1:5 and 6:5 were also seen.

(e) Most candidates who attempted this part of the calculation were able to multiply their answer to **(d)** by $\frac{1000}{titre}$.

(f) The mark for converting mol dm^{-3} to g dm^{-3} was common but many candidates missed the dilution factor in this final section and failed to multiply by $\frac{250}{volume\ diluted}$.

Many candidates did not make use of the answer to **(e)** in this section. They multiplied an earlier answer by 36.5.

Question 2

The mixture **FA 6** contained ammonium chloride (**FA 7**), soluble in water and manganese(II) carbonate (**FA 8**), insoluble in water. As description of the colour of manganese(II) hydroxide precipitates is often poor, there were 12 scoring points in **Question 2**. Marks in excess of 10 were cancelled.

It was noted that many candidates confused cations and anions when drawing conclusions from the tests.

(a) No observation was expected in this section. Shaking **FA 6** with water and filtering was intended to dissolve **FA 7** into the filtrate and leave **FA 8** as a residue on the filter paper.

(b) No precipitate and a colourless solution should have been observed on adding aqueous sodium hydroxide to the filtrate from **(a)**. The Examiners allowed a slight brown colouration in the solution but no precipitate or yellow/orange solutions.

Precipitates and highly coloured solutions were both commonly observed.

Most candidates recorded red litmus turning blue on warming the solution. Many candidates, however, were not awarded the observation mark because they did not make it clear that the **gas evolved** was tested and turned the litmus paper blue. The solution contained sodium hydroxide, which would also have turned red litmus blue.

(c) This was a test rewarded by careful observation. Insoluble lead(II) chloride was formed as a white precipitate on adding aqueous lead(II) nitrate.

The precipitate was soluble on heating to the boiling point of the solution.

On cooling the lead(II) chloride should have reappeared as white crystals.

One mark was awarded for the white precipitate soluble or partially soluble on heating. The second mark was given for observing crystals or the precipitate reforming on cooling. No mark was given for the formation of a precipitate on cooling. It was important that observations were recorded in the appropriate section of the test, indicated by the dotted horizontal lines.

(d) The standard test for chloride ions is routine and most candidates observed the white precipitate on adding silver nitrate and that the precipitate dissolved on adding aqueous ammonia.

As well as identifying the cation and anion present, candidates needed to supply the appropriate evidence from their observations. It was sufficient to refer to a test by letter, e.g. test **(d)** for chloride – providing the mark had already been awarded in that section. Where evidence was presented in words it needed to be complete.

The cation NH_4^+ was allowed from reference to a correct test **(b)** or reference to ammonia gas having been evolved on heating with aqueous sodium hydroxide.

The anion, $C\ell$, was allowed from reference to a correct test **(d)** or white precipitates in tests **(c)** and **(d)**.

(e) Many candidates recorded effervescence in this test but failed to perform any test to identify the gas given off. Some candidates tested for carbon dioxide with a burning splint. This is not an acceptable test for carbon dioxide.

(f) Recording the colour of manganese(II) hydroxide always presents problems. The precipitate is never white it starts as off-white and rapidly darkens to a light brown – especially at the surface where aerial oxidation takes place. The Examiners accepted off-white/buff/pale(light) brown as acceptable colours.

(g) As **(f)**.

Many candidates reported one or other of the precipitates in **(f)** and **(g)** as soluble in excess of the reagent. Both precipitates needed to be insoluble in the excess reagents.

Brown precipitates, insoluble in excess were commonly observed in both tests.

Conclusions

The cation present was marked consequentially to the observations obtained in **(f)** and **(g)** so that candidates were not penalised a second time, e.g. Fe^{3+} was allowed from brown precipitates insoluble in excess NaOH(aq) and excess NH_3(aq).

The carbonate cation was allowed from a reference to test **(e)** providing a test for carbon dioxide had been performed in that test or there was reference in the evidence to effervescence with hydrochloric acid.

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Paper 9701/04
Structured Questions

General comments

The general standard of answers was about the same as last year's. It was noted once again, however, that some candidates lost marks through thoughtlessness or carelessness. In addition, there was evidence of an incomplete or rushed reading of the question paper by a significant number of candidates. Thus in **Question 1** there were many answers describing the variation in the boiling points of the *elements*, rather than the chlorides; in **Question 2(b)** it was sometimes assumed that ibuprofen was dibasic, because the acid produced in part **(a)(iv)** was dibasic; in **2 (c)(iii)** the K_a of ibuprofen, given in part **(b)**, was used instead of the "pK_a" figure for hydrogenphosphate of 7.20, given in the relevant part. Furthermore, in the organic questions, more than one repeat unit was often given in **9 (a)(iii)**, whereas in **(a)(iv)** the formula of the repeat unit rather than that of the monomer was often given.

All examiners reported their disappointment at how poorly the Organic Chemistry questions had been answered by the majority of candidates. Yet the vast majority of the 22 marks allocated to the last two questions were very much "on-syllabus", and should have bean easily answerable by those candidate who knew their facts. Candidates are strongly encouraged to spend more time on the Organic sections of the syllabus, and to get more practice in applying their knowledge of Organic reactions to novel situations.

Answers to numerical calculations

1. (e)	569 g of sodium
2. (a) (iii)	$M_r = 206$ mass = 3.1 g
(a) (iv)	$M_r = 167$
(b) (ii)	pH = 3.0
(c) (iii)	pH = 6.8
3. (b)	volume = 3.88 dm^3

Comments on specific questions

Question 1

(a) A significant number of candidates thought that whilst CCl_4 was molecular, the rest were either giant covalent or giant ionic or even metallic. They might have scored the first mark, for describing the trend, but not the other two. Nevertheless, most candidates did realise that it was the increasing strength of the van der Waals forces, due to an increase in the total number of electrons within each molecule, that was responsible for the increase in boiling points. Teachers might be aware, however, that although this trend is clearly in the syllabus, it is not a regular one: the boiling points of $SiCl_4$ and $PbCl_4$ are lower than expected. Well-taught candidates knew this, and mentioned it in their answers, but this subtlety was not needed to obtain full marks.

(b) Most candidates knew that the molecule of $SiCl_4$ was tetrahedral, but only a minority gave the correct bond angle (109-110°). The most common incorrect answers were 107°, 104°, 120° and 90°.

(c) (i) Few candidates scored both marks here: many forgot to include the two lone pairs remaining on Xe, or forgot to include the three lone pairs on each of the fluorine atoms.

(ii) The most common incorrect description of shape was tetrahedral or octahedral. The term "planar" was not accepted unless qualified by "square". Although many candidates correctly stated 90° as the bond angle, there were some who thought that the two lone pairs would be on adjacent vertices of the "octahedron" of electron pairs around Xe, and suggested angles of 80-89°.

(d) Although some candidates thought CCl_4 reacted with water but $SiCl_4$ did not, most candidates did score the mark for stating that it was $SiCl_4$ that reacted. Many also wrote a correctly balanced equation (accepted products included SiO_2, $SiO_2.2H_2O$, $Si(OH)_4$ and partially hydrolysed $SiOCl_2$ or even $SiCl_3(OH)$). Most candidate also scored a mark for recognising the reason for the lack of reactivity of CCl_4 – that carbon does not contain empty orbitals that are *available* or *low-lying*, unlike silicon that contains available 3d orbitals. Some candidates' descriptions were somewhat inaccurate, confusing reactivity-with-water and solubility-in-water.

(e) Most candidates correctly balanced the equation, the most common error being not realising that 8 moles of Na (rather than 4) were needed, since 8 moles of chlorine atoms have been converted into $NaCl$. The calculation was also performed fairly well, the most common error being to use the M_r of $PbCl_4$ rather than that of $Pb(C_2H_5)_4$.

Question 2

(a) (i) This had been considered an "easy starter", but a surprisingly large number of candidates failed to score this mark. Either they circled more than the one correct atom (the "CH" in the 2-methylprop-1-yl group or the carbonyl carbon were the favourite extra ones, but also atoms in the ring were sometimes circled), or their circles were so large as to cover more than one carbon atom. Several did not even have an attempt at this part.

(ii) Many candidates also failed to score this seemingly straightforward mark. The most common errors were to include an extra 1 or 2 H atoms in the formula (by assuming that the benzene ring contributed 5 or 6 hydrogens, rather than 4), or to write a *partial* molecular formula, for example $C_{12}H_{17}CO_2H$.

(iii) Credit was given for an incorrect M_r value as long as it was consistent with the candidate's molecular formula as given in part **(ii)**. The "error carried forward" rule was also applied to the calculation, which was carried out correctly by the majority of candidates.

(iv) Most candidates could correctly calculate the number of moles of NaOH used, for [1] mark, but many then failed to take account of the fact that the acid was dibasic. The correct answer (benzene-1,4-dicarboxylic acid) was guessed at by some, by deduction from the formula of ibuprofen, using their knowledge of Organic Chemistry. For this they gained the last mark.

(b) (i) Several candidates gave the expression $K_a = [H^+]^2/[HA]$, which, whilst useful for calculating the value of K_a, is not correct. The full formula of ibuprofen was not required – the expression $K_a = [H^+][A^-]/[HA]$ would have sufficed.

(ii) Whilst there were many candidates who correctly calculated the pH, the usual errors crept in here. Either the square root was not taken, or the expression was reversed, or $[H^+]^2$ was multiplied by 0.15 rather than divided, or the natural logarithn was taken rather than $\log_{10}$. Some candidates were convinced that ibuprofen was dibasic (like the acid **A** in part **(a) (iv)**), and so ended up with a cubic equation.

(c) (i) This was answered fairly well by the majority of candidates. The most common errors were stating that there was *no change* in the pH (rather than a change being *resisted*, or *controlled*, or *minimised*), and not stating that buffers only work when *small quantities* of acid or base are added.

(ii) Examiners were surprised at how few candidates scored the full [2] marks for this part. Whilst some managed the equation for the reaction between HPO_4^{2-} and H^+ (to produce $H_2PO_4^-$), very few realised that the added OH^- ions needed to react with $H_2PO_4^-$ ions (to produce $HPO_4^{2-} + H_2O$).

(iii) This proved the most low-scoring part of the question. The calculation was easy as long as candidates knew the Henderson-Hasselbach equation ($pH = -pK_a + \log([base]/[acid])$), but few did. Partial credit was given to those candidates who had reversed the [base]/[acid] ratio, and ended up with pH = 7.6.

Question 3

(a) (i) Many candidates scored well here, although a considerable number lost the mark through incorrect balancing (½ O_2 was needed per mole of $Ca(NO_3)_2$). Equations starting with 1 or 2 moles of $Ca(NO_3)_2$ (or even more!) were all acceptable, as long as they included the correct products and were balanced. To avoid the use of ½ O_2 some candidates produced Ca metal rather than CaO as the solid product.

(ii) Most candidates knew that the nitrates became more stable down the group, and some also knew that size and polarisation came into the explanation. Many lost marks, however, by not being clear enough in their explanations: It is the size (or radius) of the *cations* that is important (not the atoms), and the smaller cations are more effective at polarising the *nitrate anion*. A stated decrease in charge density was accepted instead of an increase in ion size, as long as it was clear that it was the *cation's* charge density that was being considered. Some candidates argued the case the wrong way round, stating that the nitrates became *less* stable down the group as the ionic bond became less strong due to the larger cation. They scored only the "larger cation" mark of the three available.

(b) The M_r of $Sr(NO_3)_2$ was given in the question paper to save candidates having to perform the trivial calculation of its value. Unfortunately this well-intentioned help seemed to have been a hindrance for most! It diverted many candidates from looking at the *whole* of the left hand side of the equation, and they used the value of 211.6 rather than the correct value of 247.6 (=211.6 + 3 x 12) for the total molar mass of the reactants. However, because of a generous marking allowance for the question they were not penalised unduly.

(c) This was well answered by most candidates, who would have known about the toxicity of CO from their O Level/IGCSE courses. Examiners were, however, looking for a little more detail, in accord with the question being of A level standard. One mark was allocated to a description of the complexing of CO with the Fe of the haem group in haemoglobin (or ligand exchange), and the other for the consequent inability of the haemoglobin to transport oxygen in the blood from the lungs to the tissues. There were a few fanciful alternatives: "CO causes suffocation by using up the oxygen in the body through its oxidation to CO_2", "CO is a reducing agent so it reduces the amount of O_2 in the body", "CO in the atmosphere causes acid rain which is poisonous".

Question 4

(a) (i) Light is needed for this reaction (or in this case heat would also effect the change). Nothing else. Weaker candidates often forfeited this mark by also mentioning $AlCl_3$, or the presence of water.

(ii) There was confusion in some candidates' minds between the elimination of HC*l* from a halogenoalkane and that of water from an alcohol. Thus heating with concentrated H_2SO_4 or Al_2O_3 was a not uncommon answer. Heating with an alkali (e.g. KOH) in ethanol (NOT water) was the correct response.

(iii) Candidates were surprisingly poor at answering this part. Even if they did read the question carefully, and draw *one* repeat unit rather than several, they often included the benzene ring in the polymer chain.

(iv) Although the better candidates scored well here, there were many who lost the mark through not including the C=C double bond in their formula, or showing the repeat unit rather than the monomer, or drawing the isocyanide (i.e. $CN\text{-}CH{=}CH_2$) rather than the cyanide.

(b) (i) Heating with aqueous alkali/NaOH was known by many. Although alkali in ethanol is incorrect (cf. part **(a) (ii)**), the use of *aqueous* alcohol was allowed.

(ii) Many candidates knew the production of a yellow precipitate (or crystals). Any mention of orange in the colour forfeited the mark.

(iii) The usual mistakes occurred during the drawing of the structure of tri-iodomethane: CH_3I was seen quite often. Candidates were much less sure of the structure of the other product (sodium benzoate, NOT benzoic acid), and less than 1 in 20 candidates scored both marks here.

(c) (i) A surprisingly large number of candidates drew the structure of (2-chloro)-ethylbenzene rather than the 4-isomer. Some even suggested a side-chain chloro compound.

(ii) Any "halogen carrier" or Friedel-Crafts catalyst was acceptable ($AlCl_3$, Fe, I_2 etc), but the mention of light, or the presences of water, forfeited the mark.

(iii) The oxidation of side chains on benzene rings needs a strong oxidising agent such as $KMnO_4$ in acidic or (preferably) alkaline conditions. $K_2Cr_2O_7$ only works when the ring is substituted with an NO_2 group.

Question 5

(a) (i) Candidates were expected to recognise that compound **F** was a substituted phenylamine, and so would react readily with bromine *water* (NOT $Br_2(l)$) in the absence of a Lewis acid such as $AlCl_3$. It was surprising how many candidates were not aware of these conditions.

(ii) Good candidates drew two correct structural formulae for **G** (the phenylamide) and **H** (the phenylammonium chloride). Some failed to score a mark or two either by carelessly drawing the amide showing a *carbon atom* attached to the ring (e.g. $NHCOCH_3$-aryl) or not including the charges in the phenylammonium salt ($ArNH_3^+ Cl^-$).

(iii) All manner of functional group names occurred here (e.g. ester, ketone, amine), but the majority of candidates gave the correct name of amide (NOT peptide).

(b) (i) This part was not well answered by the majority. Many candidates clearly had not come across diazonium salts before, and those that had could not remember the correct reagents for their production. The usual errors of HNO_3 instead of HNO_2, or $NaNO_3$ instead of $NaNO_2$ (with HCl) were seen. Some even used the nitrating mixture of concentrated HNO_3 + H_2SO_4. Several had remembered that the solution needs to be cooled ($T < 10°C$ was expected), but some then forfeited the mark by stated that the solution was "refluxed at a temperature of <10°C". Examiners interpret the term "reflux" entirely and solely as an alternative to "heat", and so it was inappropriate in this context.

(ii) The reagent for reaction **V** was 2,5-dimethylphenol, and the conditions were aqueous alkali. Common errors were not to include the alkali, or to leave out the water (or (aq)), or to include an $-NH_2$ group on the dimethylphenol ring.

(c) This part was aimed at testing candidates' ability to apply their knowledge of the properties of ionic compounds (e.g. syllabus section 3k) to a novel situation. The better candidates scored well, recognising that the inclusion of ionic groups would increase the compound's solubility in water through ion-dipole interactions, or its attraction to food components by hydrogen bonding with the oxygen atoms of the $-SO_3Na$ groups. Weaker candidates either left this part blank, or suggested that it was the sulphur in the $-SO_3Na$ groups that conferred the yellow colour, or that it acted as a preservative (cf. SO_2).

CHEMISTRY

Paper 9701/05
Practical Test

General comments

When a script packet is received and opened, Examiners check for the presence of the following documentation:

- a completed report form showing the candidates present in each session;
- seating plans for each session;
- a Supervisor's script giving experimental results **for each session and each laboratory within a session**.

If candidates are not to be disadvantaged Examiners must be able to relate each candidate to a specific set of experimental results provided by the Supervisor.

In the October/November 2006 examination Examiners noted that many Centres failed to provide the Supervisor's results and CIE were asked to contact the Centres concerned to obtain these results. These results were often unobtainable.

When sorting candidates into correct sessions and laboratories it is very helpful if candidates are arranged or listed in sequential candidate order. Boxes are provided on page 1 of the examination paper for candidates to enter the session and the laboratory in which they took the examination. Unfortunately these boxes are left blank by many Centres.

The Examiners thank those Centres where all the required information was provided.

Supervisors are reminded that they should provide full experimental details – all readings of mass and temperature, not just mass used and temperature rise.

Supervisors at some Centres provided experimental details for the first experiment (thermometric titration) but not for the second experiment (determination of an enthalpy change) in **Question 1**. A default value of 11.5 ^{o}C g^{-1} was used where no experimental data was provided.

Comments on specific questions

Question 1

Thermometric titration

The majority of candidates recorded temperatures to 1 decimal place. The preparation instructions called for –10 ^{o}C to 110 ^{o}C thermometers calibrated at 1 ^{o}C intervals. Candidates were expected to read such thermometers to the nearest 0.5 ^{o}C. Many candidates recorded all temperatures to **XX.0** ^{o}C, suggesting that they were in fact reading thermometers to the nearest whole degree.

One mark was awarded if all temperatures were recorded to 1 decimal place.

One mark was awarded if a correct average temperature was calculated in Table 1.1 and a correct temperature rise calculated for experiment 2 in Table 1.2.

If solutions had been prepared as per the instructions the "end-point" of the titration should have been 0.05 and 0.06 moles of sodium hydroxide, with three plotted points on either side of the end-point.

Accuracy marks were assessed on the temperature rise for experiment 2 (corrected where necessary). 4 marks were awarded for a difference within 0.5 °C of the temperature rise obtained by the Supervisor, decreasing on a sliding scale to 1 mark for a difference of 2.0 to 3.0 °C.

Graph

(a) Two marks were awarded for the correct plotting of the temperature rise for experiments 1, 2, 5 and 6. One of these marks was withheld for any point incorrectly plotted.

Examiners paid particular attention to the placement of points on the vertical lines – most candidates having chosen scales where the moles of NaOH to be plotted were on vertical lines of the grid provided. Many candidates were penalised one plotting point for imprecise placement of the centre of the cross or dot for a point in the correct place on the graph. (This error was penalised once only.)

The Examiners recommend the plotting of small crosses (x) or small dots using a sharp, HB or harder pencil. Some “dots” seen were drawn with a blunt, B or 2B pencil and covered nearly 1 small square in area.

A penalty (maximum 1 mark) was also applied to the plotting marks for any of the following: inverting the axes, plotting measured temperature rather that temperature rise, plotting points in less than 4 large squares on either axis.

Most candidates chose correct axes and scales but many lost one of the plotting points for the imprecision in plotting otherwise correct points.

(b) Most candidates drew two straight lines through the plotted points and extended these lines to the point where they intersected. Examiners were not looking for lines of “best-fit” but expected the lines to relate closely to the points for each line. Some candidates correctly realised that the origin of the graph (0,0) was a point on the graph. The Examiners accepted a line drawn through the origin and two of the points before the end-point. Some candidates forced one of the lines to intersect with the other at one of the plotted points and were not awarded the point for appropriate straight lines.

(c) One mark was given for reading, correct to ½ of a small square, the moles of NaOH represented by the intersection of the two lines or the maximum of any graph involving a “rounding” at the end-point.

(d) This mark was the most difficult mark to obtain unless the intersection of the two lines was at a value given in Table 1.2.

Many candidates calculated the volume of 2 mol dm^3 NaOH that contained the moles of NaOH obtained from the graph and gave this as the volume of H_2SO_4 reacting at the end-point. More able candidates correctly subtracted the volume of NaOH from 50 cm^3 to give the volume of acid.

(e) Most candidates correctly halved the moles of NaOH obtained from the graph.

(f) Most candidates were able to combine ***Sections (d)*** and ***(e)*** to calculate a concentration for the sulphuric acid. Any error in **(d)** was carried forward and this section marked consequentially.

A small number of candidates made no attempt at ***Sections (d)*** to ***(f)***.

Determining an enthalpy change

Supervisors report

The Examiners checked and corrected (where necessary) all subtractions in Table 1.3. The temperature rise per gram of **FB 3** was calculated, correct to 1 decimal place.

Candidate scripts

Subtractions in Table 1.3 were similarly checked and corrected. The temperature rise per gram of **FB 3** obtained from the candidate's results was compared to the value from the Supervisor. 4 marks were awarded for a value within 0.2 $^{o}C\ g^{-1}$ decreasing on a sliding scale to 1 mark for a difference of 0.6+ to 1.0 $^{o}C\ g^{-1}$.

One mark was withheld from this accuracy mark if any mass had been recorded to less than 2 decimal places or if there was an error in subtraction in the table.

(g) Most candidates used the correct expression for the heat generated in the cup: (50 x 4.3 x temperature rise). A small number of candidates used the mass of **FB 3** or (50 + mass of **FB 3**) instead of 50 in the expression. Incorrect units were ignored at this stage.

(h) One mark was awarded if $\frac{50}{1000}\ x\ [H_2SO_4]$ or $\frac{mass\ of\ FB\ 3}{40}$ was calculated.

Candidates were able to use the concentration of sulphuric acid calculated in **(f)** or the default value of 1.5 mol dm^{-3} given in the section.

A **second** mark was given for calculating the second molar quantity and correctly stating which reagent was in excess from the figures calculated.

Most of the candidates who attempted this section gained both of the marks.

(i) One mark was given for correctly calculating the ΔH value for the limiting reagent in **(h)** – the reagent not stated as being in excess. To gain this mark the value had to be correctly expressed in kJ mol^{-1}.

A **second** mark was awarded for a –ve sign.

Most candidates were able to show in **(h)** that sulphuric acid was in excess and sodium hydroxide was the limiting reagent. They then divided **(g)** by the moles of NaOH calculated in **(h)** to gain the mark in **(i)**.

Those who gave NaOH in excess (sulphuric acid as the limiting reagent) usually divided **(g)** by the moles of sulphuric acid but omitted the additional x2 from the denominator.

A small number of candidates divided their answer to **(g)** by the moles of reagent stated as being in excess.

Many candidates forgot the –ve sign for an exothermic reaction.

Question 2

(a) Many candidates will have encountered a formula such as $CuSO_4.5H_2O$ but clearly did not understand the formula $2CuCO_3.Cu(OH)_2$, treating it as 2 moles of $CuCO_3$ and 2 moles of $Cu(OH)_2$. Candidates should appreciate the significance of a dot between the different parts of a formula.

One mark was given for a fully correct equation, including the state symbols for the decomposition of malachite.

$$CuCO_3.Cu(OH)_2(s) \rightarrow 2CuO(s) + CO_2(g) + H_2O\mathbf{(g)}$$

Many candidates gave the state symbol (l) for the H_2O when produced by heating malachite. A second mark was given for a correctly balanced equation for the decomposition of azurite.

$$2CuCO_3.Cu(OH)_2 \rightarrow 3CuO + 2CO_2 + H_2O$$

(b) Most candidates were able to produce a plan scoring at least 2 or 3 marks for the decomposition of the minerals.

The Examiners were looking for the following points in a correct sequence:

- weighing the empty boiling tube (not crucible or other container);
- weighing the tube + mineral;
- heating the sample (with a Bunsen burner – water bath was seen but not acceptable);
- **cooling** the hot tube and reweighing the sample;
- continuing the heating, cooling, weighing to constant mass.

Common errors included the following:

- failing to weigh the empty tube or weighing it as an afterthought, incurring a penalty for an incorrect sequence of steps;
- failing to cool the tube after heating and before weighing;
- not continuing the heating to constant mass. (some candidates repeated the experiment or all of the steps to obtain constant mass – which is not the same as continuing the heating to completion.)

A small number of candidates introduced unnecessary steps or equipment (e.g. to test the gas to show that carbon dioxide was evolved).

(c) Many candidates made no attempt or were unable to show any logical approach to this section. The question had asked candidates to show by calculation how they would show if the mineral was azurite or malachite.

One mark was awarded to candidates who showed an expression for $\frac{\textit{mass of CuO}}{79.5}$ and $\frac{\textit{mass of mineral}}{221}$ or $\frac{\textit{mass of mineral}}{344.5}$.

Many candidates gained this first mark.

To gain the second mark the candidate had to show the second of the moles of mineral expressions above and relate the mole ratios of mineral and copper oxide to the ratios from the equation.

Unfortunately no error could be carried forward from the equations for this second mark. The misinterpretation of the formula for azurite, already referred to, gave an M_r of 442 (2 x M_r of malachite) and an identical mole ratio of mineral to copper oxide.

(d) Many candidates gained this mark for collecting and measuring the volume of carbon dioxide given off on heating the malachite or azurite.

The mark was not given for collecting unspecified gas or including water vapour in the volume, as the water would condense.

Other appropriate methods for condensing or absorbing the water and measuring its mass were accepted but seldom seen.

CHEMISTRY

Paper 9701/06

Options

Biochemistry

This remains a popular option, and candidates often produced good answers.

Question 1

In part **(a)** candidates generally scored well with many candidates picking up 4 or more marks. The weakest area seemed to be in explaining the two roles of mRNA. In part **(b)(i)** there was some confusion over what constituted the tertiary structure of the protein, and in part **(ii)** some answers lacked detail, losing candidates marks.

Question 2

This question was slightly less well-answered than **Question 1**. In part **(a)(i)**, few students remembered the charges on oxygen in the triphosphate, and few explained the energy release correctly in terms of the high concentration of negative charge causing repulsion. Many talked (incorrectly) about the energy released when the bonds were broken. In part **(iii)** water was often missing from the equation. Parts **(iv)** and **(v)** were generally answered better. Most students gave good answers to part **(b)**.

Environmental Chemistry

As in the past years, some candidates found this option difficult generally due to a lack of knowledge of the chemistry involved. It seems that far too many candidates' try to answer these questions from general knowledge without showing any A Level chemistry.

Question 3

This question tackled an area of the syllabus which should have been familiar territory, yet only a few candidates scored more than 6 marks. In part **(a)(i)**, the calculation simply required students to multiply three numbers together. In part **(a)(ii)** candidates needed to show that they understood photochemical reactions in the atmosphere. Parts **(b)** and **(c)** dealt with the role of CFCs in ozone destruction, and of other molecules in breaking down ozone. Part **(b)** was generally well understood, but part **(c)** proved more difficult.

Question 4

Many candidates seemed not to know how to tackle this question, and some ignored the data provided. Not everyone gave a plausible answer to part **(a)**. In part **(b)**, more candidates suggested advantages and disadvantages of recycling, but in some cases lack of detail restricted the marks scored. In part **(c)** it was clear that a number of candidates had not studied or learned about incineration as a disposal method, and answers to the question about land-fill often showed little idea of the chemistry involved.

Phase Equilibria

This option remains very popular, although candidates seemed to find it harder to score high marks on this paper.

Question 5

Part **(a)** was the reverse of a question that has been set several times before, yet in this form candidates found it much harder to score high marks. The main problem was their inability to explain how the apparatus works, rather than identifying the different parts. Most candidates gave two correct materials in part **(b)**. Part **(c)** proved rather more tricky with few candidates correctly identifying **A** and **B** as water and ethanol, and a number of candidates failing to realise that the peak furthest right was the first to be eluted.

Question 6

The less familiar diagram in part **(a)** seemed to confuse a number of candidates with marks testing this area of the syllabus somewhat lower than on previous occasions. In part **(b)**, most candidates could explain the term *azeotrope* and the features of a mixture which produces one. Part **(c)** proved to be a good discriminator, with good candidates scoring 4 or 5 marks, and weak candidates struggling to score 2.

Spectroscopy

Whilst this remains the least popular option, on average it was not the lowest scoring option, suggesting that candidates had been well prepared.

Question 7

In part **(a)** lots of candidates quickly realised that **A** contained two chlorine atoms and used this to gain 4 marks. Answers to part **(b)** required a little thought and not all candidates spotted that this was about ^{13}C. Surprisingly, few candidates suggested that nitrogen from the air might cause the peak at *m/e* 28. Good candidates scored all 3 marks in part **(d)**, but a number of candidates confused chlorine with bromine here.

Question 8

Despite being printed in bold type, not all candidates used uv/visible spectroscopy to distinguish between the two compounds in part **(a)**, and were duly penalised. Answers to part **(b)** were often very good, but some candidates lost marks by failing to give sufficient detail. As a result they picked up perhaps 4 or 5 of the 7 marks available, despite working out the correct structure of **E**.

Transition Metals

A significant number of candidates are prepared for this option, but on this occasion candidates found **Question 9** particularly demanding, scoring on average about 2 marks less on this question than on **Question 10**.

Question 9

Most candidates correctly answered part **(a)(i)**, but a significant number gave at least one incorrect oxidation state in part **(ii)**. Rather less than half the candidates knew a method for preparing the MnO_4^{2-} ion. Part **(b)** showed yet again that candidates do not really understand how to use $E^{\ominus}$ values to explain reactions. The calculation in part **(c)** proved to be a good discriminator, with good candidates scoring all 3 marks and weak candidates struggling to score 1 mark.

Question 10

Part **(a)** was well answered, with many candidates scoring both marks. In part **(b)**, despite the rather unfamiliar ligands, candidates thought carefully about the question and scored good marks, with many scoring at least 4 marks. Finally, part **(c)** caught a few weaker candidates out, some drew correct structures but failed to identify the type of isomerism.