

CHEMISTRY

Paper 9701/01
Multiple Choice

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

General comments

For this paper, the mean score was 23.1 (57.8%), slightly below the targeted value, and the standard deviation of the scores was 7.77 (19.4%), indicating that the paper discriminated very satisfactorily among candidates.

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

Comments on individual questions

Five questions had a very high facility, **Question 4** on counting electrons and neutrons within an atom, **Question 7** on the recognition of the type of bonding within a crystal lattice, **Question 9** an exercise in calculating oxidation numbers, **Question 13** on trends in atomic radius within groups of the Periodic Table, and **Question 22** on the recognition of *cis-trans* isomers. These clearly represent areas of the syllabus that are well understood.

Question 38 was essentially a test of knowledge of which compounds undergo addition with hydrogen bromide, but given a twist by replacing it with deuterium bromide. This proved challenging: there were clear signs of candidates guessing the answer, and the question failed to distinguish satisfactorily between the more and less able candidates.

Two other questions, while performing satisfactorily, deserve comment. In **Question 10** candidates were asked to construct the equilibrium constant, K_p , for the equilibrium between N_2O_4 and NO_2 , and then calculate its value. More candidates chose distractor **D** (44%) than the key **C** (31%): it is not unusual to find that candidates have difficulty in calculating partial pressures.

Question 33 explored the fact that hydrazine does not burn spontaneously in oxygen. 28% of candidates correctly appreciated that this is a mark of high activation energy and gave the key **D**, but 40% gave **B** as the key, incorporating the high strength of the $N\equiv N$ triple bond as being a factor. This would be relevant to a calculation of the overall change in enthalpy, but not to the rate of the reaction.

CHEMISTRY

Paper 9701/02
Structured questions as Core

General comments

There were many good answers to this paper and most candidates were able to demonstrate some positive achievement. The paper must include harder parts to each question but the majority of candidates made good attempts to answer all of the questions.

However, a number of candidates clearly had not prepared thoroughly for the examination by learning important factual chemistry. In particular, many answers to **Question 3** did not state clearly what would be seen when the reactions described were carried out. Clear observations and deductions are essential components of the study of chemistry. There still remains a significant number of candidates whose knowledge of organic chemistry is poor. Examiners do, however, give credit for the correct use of less familiar reagents that could be used to carry out the reaction under consideration.

Comments on specific questions

Question 1

This question tested candidates' basic knowledge of simple inorganic reactions and their ability to carry out stoichiometric calculations. There were many very good answers but a significant number of candidates struggled with the calculations.

- (a) Most candidates correctly identified the alkaline gas as ammonia and the cation as NH_4^+ . Fewer were able to deduce that the grey/green residue would be iron(II) hydroxide, $\text{Fe}(\text{OH})_2$.
- (b) Most candidates correctly deduced the white precipitate to be barium sulphate, BaSO_4 .
- (c) (i) While there were many correct answers to this part, there were also many which showed that candidates had not read the question carefully. Mohr's salt is a double sulphate so the two salts from which it is made must each be a sulphate. However, a significant number of candidates gave chlorides, hydroxides or oxides as their answer and were penalised. A small number of candidates gave names and not formulae of their salts, as the question required, and lost marks.
- (ii) The two salts that are used to make Mohr's salt are ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$, and iron(II) sulphate, FeSO_4 . The majority of candidates calculated the relative formula masses of these salts correctly as 132.1 and 151.9 respectively.
- (iii) Fewer candidates were able to calculate the number of moles of water, $x\text{H}_2\text{O}$, which is given by the following expression.

$$x\text{H}_2\text{O} = 392 - (132.1 + 151.9) = 108$$

$$x = \frac{108}{18} = 6$$

Examiners expected the answer to be expressed as a whole number.

Question 2

This question also tested candidates' ability to do routine calculations correctly when applied to an unfamiliar compound. While there were many very good answers, a significant number of candidates struggled with part **(b)** and/or part **(d)**.

- (a)** Most candidates gave a correct 'dot-and-cross' diagram.
- (b)** In order to use $pV = nRT$ correctly in this question, it was necessary to convert the pressure of the gas into Nm^{-2} (Pa) and the volume of the gas into m^3 . Thus n is given by the following expression.

$$n = \frac{PV}{RT} = \frac{(1515 \times 10^3) \times (76 \times 10^{-3})}{8.31 \times 298} = 46.5$$

Candidates who failed to change their values of pressure and volume were penalised.

- (c) (i)** This was correctly answered by the vast majority of candidates.
- (ii)** While most candidates used their answers to part **(b)** correctly, there was a significant number who used M_r of C_2H_2 rather than M_r of CaC_2 , or who forgot to multiply their answer by 100. The correct calculation is given below.

$$n(\text{C}_2\text{H}_2) = n(\text{CaC}_2) = 100 \times 46.5$$

$$\text{mass of CaC}_2 = 100 \times 46.5 \times 64 = 297570 \text{ g} = 297.6 \text{ kg}$$

Either answer was accepted providing it had the correct units.

- (d)** This part was answered poorly by many candidates. Common errors included using wrong values from the *Data Booklet* – such as the value for C-O rather than for C=O – and ignoring the stoichiometry of the equation – $\frac{5}{2}\text{O}_2$ and 2CO_2 . The correct answer is -980 kJ mol^{-1} and is obtained as follows.

bonds broken:	2(H-C)	2 × 410	=	820
	C≡C	840	=	840
	$\frac{5}{2}(\text{O}=\text{O})$	$\frac{5}{2} \times 496$	=	<u>1240</u>
				2900 kJ mol^{-1}

bonds made:	4(C=O)	4 × 740	=	2960
	2(O-H)	2 × 460	=	<u>920</u>
				3880 kJ mol^{-1}

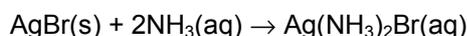
$$\Delta H_{\text{comb}} = -3880 + 2900 = -980 \text{ kJ mol}^{-1}$$

- (e) (i)** Most candidates were able to define ΔH_{comb} correctly but a surprising number began their answer by referring to '... the energy required to ...' and were penalised because combustion is always exothermic.
- (ii)** There were few correct answers to this part. Candidates were expected to mention either that average bond energy terms are used in the *Data Booklet* or that the calculation in **(d)** includes $\text{H}_2\text{O}(\text{g})$ whereas ΔH_{comb} involves $\text{H}_2\text{O}(\text{l})$.

Question 3

This question assessed candidates' factual knowledge of the chemistry of the halogens. While there were many good answers, there were also responses from candidates who had not learnt the relevant material. Descriptions of observations that could be made were often poor.

- (a) This was quite well answered; the most common error was to describe solid iodine as purple.
- (b) (i) Relatively few candidates correctly described what would be seen in these three reactions. In each case, the hydrogen halide is first formed but the concentrated sulphuric acid has a different effect on each of them and candidates answers were expected to reflect this.
- (ii) Most candidates gave the correct equation but there were instances of unbalanced equations suggesting that the answer had not been checked.
- (c) (i) This was poorly answered. The need for candidates to study the reactions of aqueous halide ions with aqueous silver ions followed by aqueous ammonia is clearly stated in syllabus **section 9.4(f)(i)**. The information given in the question confirms that the precipitate is AgBr.
- (ii) The equation for the dissolving of AgBr(s) in NH₃(aq) is given below.



State symbols were often omitted and some candidates wrote otherwise correct equations that were unbalanced, again suggesting a lack of checking of the answer.

- (d) (i) There were many good answers to this part although a surprising number wrongly thought that HCl would decompose and HI would not.
- (ii) Many candidates answered this well and some backed up their answers by quoting bond energy values from the *Data Booklet*.
- (iii) This part was less well answered. The hot glass rod simply provides heat energy, which, in the case of HI, enables some gas molecules to acquire energy greater than the activation energy, leading to decomposition.

Question 4

This question tested candidates' ability to apply their knowledge of organic chemistry to an unfamiliar compound. While there were many good answers, there was also a significant number whose knowledge was poor.

- (a) This part of the question was concerned with a familiar reaction of the C=C bond and another of the -CH₂OH group. The compounds formed would be as follows.
- (i) BrCH₂CHBrCH₂OH
- (ii) CH₂=CHCO₂H
- (b) Most candidates recognised this reaction as an oxidation.
- (c) The two compounds show structural or functional group isomerism. A significant number of candidates believed that the presence of the C=C bond meant cis-trans isomerism would be shown while a few thought chirality to be present.
- (d) There were many good answers to this part although relatively few candidates scored all four marks. Both reagents – H₂ in step I and acidified Cr₂O₇²⁻ in step II – were well known. However, many forgot the catalyst in step I or refluxed the reagents in step II. The latter would give rise to propanoic acid rather than propanal. The same acid would also be formed if acidified MnO₄⁻ were used as the oxidising agent in step II.
- (e) Relatively few candidates deduced that the reaction in (c) involved both oxidation and reduction.

- (f) Those candidates who really knew their organic chemistry were able to deduce that the following compounds would be formed.
- (i) $\text{CH}_2\text{OHCHOHCH}_2\text{OH}$
- (ii) $\text{HO}_2\text{CCO}_2\text{H}$

Question 5

This question asked candidates to consider some routine organic chemistry. There were many good answers although part (d) was usually answered less well.

- (a) Many candidates clearly knew what a substitution reaction was but often struggled to express themselves clearly. Examiners looked for a simple statement such as '... a reaction in which one atom or group of atoms replaces another atom or group of atoms.'
- (b) This was generally well answered although not all candidates made it clear that aqueous NaOH must be used.
- (c) This too was quite well answered although a significant number of candidates believed HCN rather than NaCN or KCN to be the reagent.
- (d) Many candidates struggled with this part although part (c) was intended to give candidates some help by referring to $\text{C}_2\text{H}_5\text{Br}$ and a compound with 'one more carbon atom than the starting material'.

Compound **K** must be $\text{C}_2\text{H}_5\text{Cl}$, $\text{C}_2\text{H}_5\text{Br}$, or $\text{C}_2\text{H}_5\text{I}$.

Compound **L** must have an extra carbon atom in its molecule and is $\text{C}_2\text{H}_5\text{CN}$.

Where candidates correctly identified **K** and **L** they were usually able to give the correct reagents and conditions. One common mistake among these candidates was to describe, in step III, the reagents for the formation of $\text{C}_2\text{H}_5\text{CN}$ rather than for its conversion into $\text{C}_2\text{H}_5\text{CO}_2\text{H}$. The former reaction occurs in step II. It was also asked for in part (c) so candidates should have been wary about giving it again.

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Paper 9701/03

Practical Test

General comments

The Examiners thank Supervisors who did provide titration information and seating plans for each Session and each Laboratory within a Session. Where some or all of this information was not provided, Examiners attempted to allocate candidates to the correct Session/Laboratory and to use an appropriate titre value in assessing accuracy. This was not always possible. Centres are reminded of the statement on p6 of the Confidential Instructions that “**Failure to provide appropriate documentation in each envelope may cause candidates to be penalised**”.

The titration exercise set in this examination involved oxidation of potassium iodide using a primary standard (potassium iodate(V)) and titration of the liberated iodine with sodium thiosulphate. This is a straightforward titration capable of producing very precise and reproducible results. The Examiners were therefore very surprised to see the wide variation in individual titration results between candidates in a Centre and often within the results of an individual candidate.

The calculation section of the titration appeared to present more problems than in previous years although the **Sections (a) to (f)** in the calculation involved identical steps to those used in previous papers. **Section (g)** did require some original thought.

The inclusion of an Organic observation and deduction question was less usual and many candidates did not perform as well as expected in this question.

Question 1

(b) Titration

Most candidates recorded their burette readings to the nearest 0.05 cm^3 , obtained two titres within 0.10 cm^3 and indicated clearly which titres have been used in calculating the “average” to be used in the calculation. Many candidates did however overlook one of these points and had one mark deducted from the accuracy marks awarded.

Few candidates selected values more than 0.20 cm^3 apart when calculating the “average” titre and spread penalties were not often applied.

The titre was expected to be around 24 cm^3 . As has already been reported there was a wide, inexplicable, variation within many Centres where the Supervisor had recorded consistent titrations giving a value close to 24 cm^3 . Some individual candidates also had a wide spread of titres. The iodine liberated should have dissolved readily in the excess potassium iodide forming a red-brown solution containing the KI_3 complex. As each titration proceeded the colour should have diminished through orange to yellow. Candidates were instructed to add starch indicator when the solution was pale yellow in colour and to continue the titration until the blue colour of the starch indicator disappeared, leaving a colourless solution. The blue colour should have finally cleared on addition of 1 drop of **FA 2**.

Some Centres used solutions with incorrect concentrations – titre averages were far too low or too high. In the latter case the potassium iodate(V) was probably too concentrated and solid iodine was precipitated in the titration flask, there being insufficient excess iodide to dissolve all of the iodine formed. It was still possible to titrate this mixture accurately.

Calculations

- (c) Most candidates earned the two marks for this section. Some however performed only half of the calculation, working out the molar concentration of the sodium thiosulphate or the mass of sodium thiosulphate run from the burette.

Some candidates lost one of the two marks by using 32 as A_r of sulphur instead of the 32.1 given in the question.

- (d) Nearly all candidates correctly divided the answer to (c) by 2.
- (e) This section followed the form that has been common in titration questions for some years. Candidates had to calculate the concentration of the diluted solution **and** allow for the dilution in determining the concentration of **FA 1**.

Some candidates left this section blank. The majority who did make an attempt at an answer only multiplied the answer to (d) by 1000/25 or by 250/25 and scored one of the two marks available. Multiplying by 1000/250 was a common error that scored no marks.

The third mark was given for a fully correct answer, evaluated to within 1% of the value obtained by the Examiner from the candidate's titre. (candidate titre \times 0.02501).

- (f) This section was often left blank.

Comparatively few candidates used the correct ratio in calculating the chlorine concentration in 'Germfree'.

The Examiners expected to see: $0.082 \times 250/50 = 0.41 \text{ mol dm}^{-3}$.

Common errors were to multiply 0.082 by 1000/50, by 50/1000 or by 50/250.

- (g) This section was often left blank.

Many candidates came to a conclusion based solely on $\text{\$/dm}^{-3}$ given on the paper or their calculated concentrations.

The Examiners were expecting to see a calculation of $(\text{mol } \text{\$/}^{-1})$ or $(\text{\$/ mol}^{-1})$ and the appropriate conclusion drawn from the calculation.

A few candidates performed correct calculations and then selected the wrong bleach.

A common error was to multiply the concentration by the cost for each bleach.

Question 2

Candidates were told that each solution contained one of four unknowns (a carboxylic acid, an alcohol, an aldehyde, a ketone).

The reagents provided were those stated in the syllabus, giving a reaction with at least one of the unknowns.

The carboxylic acid was expected to react **vigorously** with magnesium powder and with sodium carbonate, giving hydrogen and carbon dioxide gases respectively. Tests for gases (printed on page 8) were to be described and the gas identified.

The alcohol was expected to be oxidised by acidified potassium dichromate(VI), the solution turning from orange to green. Observation of a "brown" solution was allowed as a mixture of orange/green.

The aldehyde was expected to give a yellow/orange precipitate with 2,4-dinitrophenylhydrazine; a brown/black precipitate or silver mirror in test (d) and a green solution with potassium dichromate(VI).

The ketone was expected to give a yellow/orange precipitate with 2,4-dinitrophenylhydrazine.

Although the table of results may have looked daunting a candidate who was organised and followed the instructions in each test should have been able to perform all of the practical work in a relatively short space of time.

One mark was given if candidates observed a gas under **FA 5** in both tests **(a)** and **(b)**. Any gas recorded under **FA 6** for these two tests was ignored (as ethanal may have contained some ethanoic acid).

This mark was not awarded if gases were recorded in tests **(a)** and **(b)** for **FA 4** or **FA 5**.

- (a)** Candidates were asked to put the unknowns into four separate test-tubes and then to add powdered magnesium to each. Candidates should have been looking for effervescence between magnesium and the carboxylic acid – recognising that the gas would be hydrogen.

Observation of a gas evolved, which burnt or popped with a lighted splint or if brought near a flame and therefore identified as hydrogen earned a mark.

Common errors were not to record the identity of the gas or to state that the gas popped with a glowing splint. A glowing splint ceases to glow if put into hydrogen.

- (b)** Candidates were asked to put the unknowns into four separate test-tubes and then to add powdered sodium carbonate to each. Candidates should have been looking for effervescence between sodium carbonate and the carboxylic acid – recognising that the gas would be carbon dioxide.

Observation of a gas evolved, which turned limewater milky earned a mark.

Common errors were not to record the identity of the gas or to state that the gas put out a burning splint. A glowing splint ceases to glow if put into hydrogen.

A candidate who correctly described the tests on the gases in **(a)** and **(b)** but failed to record the identity of the gas earned one of the two marks available.

- (c)** When 2,4-dinitrophenylhydrazine was added to the four unknowns in separate test-tubes an immediate yellow/orange precipitate should have been seen with **FA 4** and **FA 6**.

Common errors, where precipitates were seen, was to fail to record the colour of the precipitate or to describe the contents of the test-tube as a cloudy solution.

- (d)** Failure to follow the instructions for the preparation of Tollen's Reagent often led to too many precipitates or formation of no precipitate with **FA 6**.

Many candidates successfully recorded a black precipitate or even a silver mirror with **FA 6**.

- (e)** Addition of too much potassium dichromate(VI) masked any colour change. If carried out carefully this test did give colour changes with **FA 6** and **FA 7**.

Many candidates missed the colour change with one or both of these unknowns.

Some Centres had difficulty in obtaining one or more of the Unknowns or Reagents. Modified mark schemes were applied in such cases so that no candidate was disadvantaged.

Because of potential missing reagents only the identity of **FA 5** and **FA 7** were awarded marks.

Identification of **FA 5** as the carboxylic acid was allowed provided the tests for gases had been correctly described or a minimum of effervescence (or bubbles of gas) recorded for tests **(a)** and **(b)**.

Correct identities were often given but without the supporting evidence.

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Paper 9701/04

Theory 2

General comments

The paper contained a range of questions which enabled most candidates to score highly in some parts. A whole range of marks was scored, from the significant number of candidates scoring zero (often as a result of writing very little – these candidates would be well advised to delay their sitting of the paper until they had prepared themselves adequately) right up to several hundred who scored either in the high fifties or even full marks. There were at least three places (mentioned below) where a significant number of candidates lost marks through not reading the questions carefully enough.

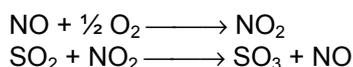
Answers to numerical calculations

1. (a) (i) NO: 2
O₂: 1
(ii) rate = $k[\text{NO}]^2[\text{O}_2]$
 $k = 1.6 \times 10^5 \text{ mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$
(iii) rate = $2.5 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$
2. (a) (ii) $5.5 \times 10^{-3} \text{ mol dm}^{-3}$
(iii) 55 g
- (b) (ii) $8.1 \times 10^{-11} (\text{mol}^2 \text{ dm}^{-6})$
3. (b) (ii) 15.6%

Comments on specific questions

Question 1

- (a) Many candidates scored well in this part. Even those who deduced the wrong orders in (i) were able to score the rest of the marks by the “error-carried-forward” procedure used by examiners. The *rate equation* asked for in (ii) had to be a full equation. Thus the expression $k[\text{NO}]^2[\text{O}_2]$ (without the “rate =”) did not score. Several candidates incorrectly wrote the equilibrium constant expression, or included $[\frac{1}{2} \text{O}_2]$ in their rate equation, based on the stoichiometric equation given in the question. The units of k ($\text{mol}^{-2} \text{ dm}^6 \text{ s}^{-1}$) stumped several candidates, the most common errors being to omit s^{-1} or to quote dm^{-6} rather than dm^6 .
- (b) This part was much less well answered. There were many alternatives offered for “homogeneous” in (i): apart from the expected confusion producing *heterogeneous*, the words *homologous*, *homozygous*, and (especially) *homolytic* were common. A great surprise to examiners was the very poor knowledge shown in (ii). There seemed to be many candidates who had not covered this process in detail at all, despite it having specific mentions in **Sections 8** and **9.6** of the syllabus. The most common mechanism that was suggested involved the oxidation of SO_2 to SO_3 by NO, which was reduced to N_2 or N_2O . The following were the correct equations that scored the marks:



Question 2

- (a) Most candidates scored a mark in (i) for $K_{sp} = [Ca^{2+}][SO_4^{2-}]$, but a surprisingly large number failed to state the units for K_{sp} . They seemed not to have read the question. The calculation in (ii) caused few problems, but many candidates failed to score full marks in (iii). Common errors were misreading 100 dm^3 as 100 cm^3 ; assuming the loss in mass was due entirely to the loss of CO_2 ; and calculating the mass of $CaSO_4$ dissolved, rather than the mass of $CaCO_3$ lost.
- (b) Several “explanations” in (i) were based on the generalisation that the sulphates become less soluble as one goes down the Group. Those who attempted a proper explanation often lost marks by using trends in **atomic** radius, rather than **ionic** radius of the cation, or mentioning hydration energy but omitting reference to lattice energy. There were, however, many correct and well-expressed explanations, referring to the large decrease in cationic hydration energy contrasting with the smaller decrease in lattice energy, thus causing the $\Delta H_{(solution)}$ to become more endothermic as one goes down the Group.

In (ii) several candidates incorrectly multiplied the value of K_{sp} by 2, rather than squaring it.

- (c) The definition required in (i) (for two marks) was: *the energy change when 1 mole of (ionic) solid/crystals is formed from its gaseous ions*. Many candidates lost a mark in one of the following ways: not stating that a **solid** was formed; specifying gaseous **atoms** (or even “elements” or “molecules”) rather than ions; not mentioning that **1 mole** of solid is formed. The explanation in (ii) relied on a comparison of cationic sizes (as in b(i)). Some candidates wrote about the charge densities of the ions, which are not at all relevant to a discussion of lattice energy.

Question 3

- (a) This straightforward “deduction” part was surprisingly poorly answered by many candidates. It was expected that candidates could have predicted that the likely oxidation states would be (+1), +2, +3, +4 and +5; and that the electronic configuration would be $[Ar]3d^2$. Apart from the common error of $[Ar]4s^2$, examiners also saw $[Ar]3d^1$, $[Ar]3d^14s^1$, and even $[Ar]4s^23d^6$ (i.e. the electronic configuration of X^{3-}).
- (b) Redox titrations involving $KMnO_4$ are described in **Section 9.6** of the syllabus, but many candidates seemed not to have carried out such a titration themselves in the laboratory. Several added an indicator (phenolphthalein was the most common) to provide an end-point colour change of pink-to-colourless (or vice versa). Answers describing either the conventional $KMnO_4$ -in-the-burette or the reverse case, with the Fe^{2+} solution in the burette, were capable of scoring full marks. The end point in each case is different, however: If the Fe^{2+} solution is in the conical flask, the end point is the first **permanent** pink colour from an (almost) colourless solution, whereas if the $KMnO_4$ is in the conical flask, the end point is when a colourless solution is first produced from the (by now) pink solution just before the end point. Many candidates failed to score the end-point mark either by confusing the two cases described above, or by describing changes in colour associated with the Fe^{2+}/Fe^{3+} system. Had they carried out the titration themselves, they would have been aware that these colours are insignificant compared to the purple/pink of the $KMnO_4$. A mark could also be gained for mentioning that in order to increase the accuracy and reliability of the results, the titration should be repeated until two titres were within 0.1 cm^3 , and the average taken. The calculation in (ii) was marked in the light of the equation stated in (i). Using the 5:1 ratio of $Fe^{2+}:MnO_4^-$ produces an answer of 15.6%. Candidates sometimes forgot to multiply the number of moles of Fe^{2+} by 4 ($= 100/25$) or used the M_r of $FeSO_4$ instead of the A_r of Fe.
- (c) The mark in (i) was for stating $Cu^{2+}(aq)$ or $[Cu(H_2O)_6]^{2+}$. Cu^{2+} on its own was inadequate (viz. white anhydrous $CuSO_4$), and even more so was the word “copper”. In (ii) most candidates scored a mark for *deep blue solution*, but very few also mentioned that a pale blue precipitate (of $Cu(OH)_2(s)$) would first be formed. The explanation expected was in terms of the production of the complex ion $[Cu(NH_3)_4]^{2+}$ by ligand exchange of H_2O molecules with NH_3 .

Question 4

- (a) Three methods were acceptable for the hydrolysis of proteins: aqueous acid (but not nitric acid) + heat; aqueous alkali + heat; or an aqueous proteolytic enzyme (e.g. protease, peptidase, pepsin, trypsin etc) at a warm temperature ($< 50^\circ C$). Candidates tended to lose marks by not specifying the solvent (water) or the temperature.

- (b) Many candidates lost this mark if they ringed the α -carbon in glycine as well as those in tyrosine and lysine. Some were even less aware of the meaning of “chiral”, and ringed the C=O carbon too.
- (c) Most candidates correctly drew the zwitterion, although some lost a mark by showing the (+) charge on a specific hydrogen atom in the NH_3 group rather than on the nitrogen atom, or on the whole group.
- (d) Most scored the mark in (i) (either the anion, or the (ionic) sodium salt, or the formula $\text{NH}_2\text{CH}_2\text{CO}_2\text{Na}$ were acceptable, but **not** the covalent $\text{NH}_2\text{CH}_2\text{C}(\text{O})\text{O}-\text{Na}$) but fewer recognised that tyrosine would form the dianion in (ii). In (iii), [2] marks were available for the dication, or for the di-ammonium salt. Examiners required candidates to show the charge on the NH_3^+ group, so $\text{R}-\text{NH}_3\text{Cl}$ was not accepted. In (iv) a mark was awarded for the dibromide (2,6 to the OH group preferred, but any orientation was accepted). Mono, tri or tetra-bromides were not accepted. Several candidates incorrectly thought that HCl would produce the acid chloride in (iii), and that $\text{Br}_2(\text{aq})$ would produce the acid bromide, or even the α -bromo compound, in (iv).
- (e) Some confusion arose in several candidates minds as to whether a tripeptide contains three amino acids or three peptide bonds. Also, some candidates did not show a complete tripeptide, but a tripeptide **fragment** of a polypeptide. A mark was lost in each case. A few candidates cleverly drew a cyclic tripeptide, which does contain three peptide bonds. These answers were given full credit. Many candidates did not show clearly which were the peptide bonds – either the C-N bond or the whole C(O)-NH group was accepted for this mark.
- (f) Most candidates correctly identified a repeat unit in (i) (any combination of ring + 6 chain atoms was accepted), although some thought a repeat unit was a monomer unit. Some of those who chose “unconventional” repeat units (e.g. from one CH_2 to another CH_2) attempted to produce monomers that would join at the position they had arbitrarily chosen as the end of their repeat unit, and hence scored no marks in (ii). Many candidates, however, correctly identified 1,2-diaminoethane and 1,4-benzenedicarboxylic acid (or its acyl dichloride) as the monomers.

Question 5

- (a) Many candidates scored well on this part, showing a competent knowledge of the reagents used for each step. Several lost marks by not being specific enough with their conditions, however. For reaction **I** the mixed acids $\text{HNO}_3 + \text{H}_2\text{SO}_4$ should have been **concentrated**, and at a temperature somewhere between **30°C and 60°C** (benzene needs $> 50^\circ\text{C}$, but methylbenzene is more reactive); for reaction **II** an oxidising agent such as KMnO_4 ($\text{K}_2\text{Cr}_2\text{O}_7$ also works with nitromethylbenzene, although it is not strong enough to oxidise methylbenzene itself) needs to be **heated** in order to work; for reaction **III** Sn (or Fe) + HCl is the preferred reagent, although $\text{H}_2 + \text{Ni}$ (**not** Pt or Pd , which would cause reduction of the ring too) was also acceptable. LiAlH_4 reduces aryl nitro compounds to azo compounds, so is not suitable in this case. Neither is NaBH_4 . For the esterification in reaction **IV** ethanol was needed, being **heated** in the presence of **concentrated** H_2SO_4 (or dry HCl). A surprisingly large number of candidates wrote the formula of ethanol as $\text{CH}_2\text{CH}_3\text{OH}$ rather than $\text{CH}_3\text{CH}_2\text{OH}$.
- (b) Candidates’ answers to this part were disappointingly poor. There were two main points examiners were looking for: the statement that NO_2^+ was the electrophile, and that H^+ was formed in the last step; and the structure of the intermediate. This had to include both H and NO_2 joined to the sp^3 carbon atom; a “horseshoe” showing the delocalised electrons around the other 5 carbon atoms of the ring; and a (+) charge inside the horseshoe (a classical structure, with two ring double bonds and a (+) charge of the 5th ring carbon, would have been equally acceptable). Candidates lost a mark through one of the following ways: not showing a complete horseshoe (e.g. one covering only 3 carbons); drawing the horseshoe the wrong way up (i.e. facing the CH_3 group rather than the sp^3 carbon); drawing the (+) charge on the sp^3 carbon rather than within the horseshoe; including (+) charges on the H or the NO_2 , or both. Generally, many candidates showed that they did not really understand what the drawing of the intermediate represented. Rather, they had attempted to reproduce a structure incompletely learnt from a book.

- (c) It was important for candidates to **name** the two functional groups in (i), rather than just to draw their structures (these could have merely been copied from the formula given in the question). Many correctly identified an ester and an amine, although common errors were carbonyl, carboxylic acid or amide. The explanation in (ii) for the greater basicity of **X** compared to benzocaine could have been stated in terms of either the greater electron-donation by the alkyl groups in **X** or the delocalisation of the lone pair of nitrogen over the ring in benzocaine.

CHEMISTRY

Paper 9701/05

Practical Test

General comments

The Examiners thank Supervisors who provided results for **Question 1**. These were checked to ensure that the experiment had performed as expected but were not used in assessing accuracy marks for the candidates. As rate experiments are susceptible to temperature change, each candidate was self-assessed for accuracy using the times for the first three experiments. It was assumed that these three experiments would have been conducted in a relatively short space of time with minimal variation in temperature.

Candidate answers to **Question 2**, the planning exercise, continue to display a lower standard than the practical experiment.

Question 1

Candidates were instructed to record the time for each reaction to the nearest second. Many candidates recorded times to 1 or even 2 decimal places. It should be appreciated that 20.0 or 20.00 is not recording a time to the nearest second.

Most candidates correctly calculated $(1000/\text{time})$ and $\lg(1000/\text{time})$. The units of $\text{s}^{-1} \times 10^3$ confused some candidates who gave $(1/\text{time})$ as their answer. Most of these did, however, get the correct value for $\lg(1000/\text{time})$. A small number of candidates incorrectly multiplied $(1000/\text{time})$ by the value for $\lg(\text{vol } \mathbf{FB } 1)$ to obtain their value of $\lg(1000/\text{time})$.

- (a) The reaction of sodium thiosulphate with hydrochloric acid is a first order reaction with respect to sodium thiosulphate. As the concentration of sodium thiosulphate was directly proportional to the volume of the reagent used, $(\text{volume of } \mathbf{FB } 1 \times \text{reaction time})$ should have remained constant for each experiment. Accuracy marks were awarded on the difference in Vt values for experiments 1, 2 and 3. Most candidates scored 4 or more from a maximum of 6 marks for accuracy.
- (b) The standard of selecting appropriate scales for the graph and the plotting of points was generally good.

A small number of candidates did not gain the first mark in this section as:

- they reversed the axes
- plotted $\lg(1000/\text{time})$ against volume of **FB 1** rather than $\lg(\text{volume of } \mathbf{FB } 1)$
- started scales at zero which compressed the plotted points into a few small squares in the centre of the page
- selected scales that were very difficult to use when plotting points or checking the plotting of the points

Two marks were awarded for the correct plotting of all five points. One mark was deducted for one point incorrectly plotted and two marks deducted for two plotting errors. Most candidates who chose “difficult” scales still earned these marks.

The final mark in this section was for a “best-fit” straight line. Very few candidates showed an even distribution of points on either side of the line. In the rubric to the section candidates were asked to indicate clearly any point that they considered represented an experimental error. Many candidates, with four points close to or on the line, would have gained the “best-fit” mark if they had identified the fifth point as showing experimental error.

- (c) Most candidates correctly stated that the depth was kept constant by having a constant (total) volume of solution in each experiment.
- (d) Very few candidates gained either mark in this section. Answers were generally vague and restated the question asked. Many candidates related concentration of sodium thiosulphate to the rate of reaction.

Any reference to proportionality of volume of sodium thiosulphate and its concentration earned one mark. An answer that described different amounts of reagent from the different volumes of **FB 1** but contained in a constant total volume of solution would have gained this mark.

A statement that the volume of **FB 1** was directly proportional to the concentration of the sodium thiosulphate gained both marks.

- (e) Most candidates drew construction lines on the graph, as instructed. These could be in the form of a constructed triangle or a horizontal and vertical line to two points on the graph.

Candidates who did not gain this mark had generally constructed too small a triangle on the plotted line – the smaller the triangle the greater the % error in the length of each side of the triangle.

The construction coordinates were generally read correctly from the graph and the gradient calculated. Some candidates use coordinates of experimental points which they have placed on the line of “best-fit”. Candidates should be encouraged to take new, non-experimental, points from the line when constructing their triangles.

Candidates were allowed to leave a fractional order or round the calculated value to the nearest whole number.

Where incorrect axes were used marks in this section were allowed (error carried forward).

No marks were earned in (e) where a curve had been drawn.

A small number of candidates drew no construction lines (first mark not awarded) but attempted to use the equation of a straight line to find the value of x the gradient. The second and third marks were awarded where $\lg k$ was read from the graph and substituted in the equation or eliminated in simultaneous equations for two points on the graph.

- (f) Some candidates did not realise that in experiments 6 and 7:

- the volume of **FB 1** had to remain constant at 40 cm^3
- the total volume in each experiment had to remain constant at 55 cm^3
- the volume of **FB 2** had to be different in each experiment.

Most candidates used appropriate volumes of **FB 2**, e.g. 2.5 cm^3 , 10 cm^3 , 15 cm^3 .

The third mark was for calculating $(1000/\text{time})$ correctly, with significant figures correct for the decimal places displayed.

- (g) No mark was awarded in (g) if the volumes were incorrect in (f).

Many of the better candidates noted that the rate of reaction increased slightly when the concentration of hydrochloric acid increased (but that it was not first order with respect to hydrochloric acid). This observation gained the mark.

Other candidates saw the slight increase in rate (some even calculated concentration and rate ratios) and then leapt to the false conclusion that it was directly proportional or 1st order.

For an acceptable conclusion of zero order or rate independent of the concentration of the acid all three times had to be within 10% of the largest value or all within 2 seconds. Many candidates concluded zero order with results that did not fit the conclusion.

Question 2

- (a) Many weird pieces of apparatus were drawn that bore no relationship to any apparatus that would be found in a school laboratory.

The first mark was simply awarded for any apparatus that showed the oxide being heated in a vessel with an inlet and outlet for hydrogen gas. Most candidates gained this mark although some did not show heating of the oxide.

The second mark was for recognisable laboratory apparatus that would condense and collect the water formed and could be dismantled to enable the mass of oxide/copper and mass of water to be measured. Many candidates lost this mark as they included no joints in their apparatus to enable it to be dismantled for weighing.

The third mark was for burning hydrogen at the end of the apparatus. Many candidates failed to show the gas being burned or had hydrogen leaving the apparatus before passing through a condenser. Where hydrogen left the apparatus 'early', only the third mark was penalised.

- (b) Most candidates failed to realise that the mixture of hydrogen and air inside the apparatus would be explosive. Some thought that lighting small amounts of gas coming out of a small hole would prevent explosion. Many candidates wanted to conduct the experiment in a sealed environment or in a vacuum.

A minority of candidates flushed the apparatus with hydrogen before lighting the excess, or flushed the apparatus with an inert gas before passing hydrogen. The Examiners did accept answers that evacuated the apparatus before introducing hydrogen.

- (c) Many candidates correctly stated that hydrogen was passed until the copper was cool to prevent re-oxidation of the copper; many other candidates thought it was passed to ensure complete reduction or to prevent copper from reacting with the steam produced.

- (d) The majority of candidates depended on visual observations such as 'copper finishes glowing', 'colour changes from black to orange/brown', 'no more water drips out of the condenser'.

The Examiners only rewarded answers that stated or implied constant mass (copper or water) after repeated heating.

- (e) Some very good and some nonsensical answers were seen in this section. One mark was given for processing of practical results (mass to moles) and the second mark for relating experimental data to equation ratios.

The most successful methods involved:

- masses of copper and water converted to moles and compared to the ratios from the equations
- the mass of copper formed converted to moles and the mass of each oxide required to produce that much copper calculated and compared to the starting mass of the oxide.

Some very elegant algebraic solutions were seen.

Some candidates lost marks by only processing data for one oxide.

CHEMISTRY

Paper 9701/06

Options

General comments

The paper proved accessible with no obvious 'dead' marks. The different options did not appear to show any significant differences in mark spread

Comments on specific questions

Biochemistry

As in previous years, this proved to be a popular option, and candidates often produced good answers. In particular they seemed to find the chemical aspects of the option more difficult.

Question 1

In part **(a)** most candidates were able to correctly draw the tripeptide showing the peptide linkages, and most knew that a condensation reaction occurred in its formation. Part **(b)** proved less straightforward, and it seemed that a significant number of candidates had not considered why a particular amino acid might produce a given physical property in the protein. Few candidates had any difficulty with part **(c)**, if they knew sufficient to score good marks on parts **(a)** and **(b)**.

Question 2

This question proved to be a good discriminator between those candidates who fully understood phospholipid bilayers, and those who only knew about them. Although most candidates drew a reasonable sketch of a bilayer in part **(a)**, a disappointing number bothered to label or state which side was the aqueous interface. In part **(b)**, good candidates correctly stated that the interaction would be *via* van der Waals' forces, but only the best candidates could suggest the effect of a high nitrogen concentration. Most candidates scored 3 of the 4 marks available in part **(c)**, the most common mistake being the direction of movement of the K^+ and Na^+ ions.

Environmental Chemistry

As in past years, some candidates found this option difficult, scoring fewer than 6 marks on either question. This was generally due to a lack of knowledge of the chemistry involved. There were, however, some good answers scoring 8 marks or more.

Question 3

The majority of this question should have been simple recall, yet it was clear that many candidates found it difficult to score high marks on this area. In part **(a)** good candidates correctly explained that chlorine formed the OCl^- ion in water, and that this acted as an oxidising agent. In part **(b)** most candidates dropped a mark for failing to state the origin of the organic material (from pollution). For good candidates part **(c)** proved straightforward, with marks of 5 or 6 out of 7 common. Weaker candidates lost marks by failing to explain the effects of phosphates on algae and how this would lead to a drop in photosynthesis of other water plants. They also struggled with what was expected to be a simple calculation.

Question 4

Very few candidates were able to correctly replace the central silicon atom with an aluminium atom and correctly show the formula and overall charge of the aluminosilicate. A greater proportion was, however, able to explain how electrical neutrality is achieved. In part **(b)** most candidates were able to score at least 2 marks in explaining how soil acidity is maintained in clays, and how humus aids this. In part **(c)** although most (but not all) candidates knew what lime was, and how it could reduce soil acidity, few gave adequate explanations of the limitations or disadvantages of the process.

Phase Equilibria

This option remains very popular, although once again candidates seemed to find it harder to score high marks on this paper. In some cases this seemed to be due to a lack of practice in answering numerical questions.

Question 5

Although most candidates could state a correct version of Raoult's Law, there are still some candidates unable to do this. As a result a number of candidates were unable to calculate the vapour pressure of the mixture in part **(a)(ii)**, and a disturbing number failed to state the assumption they had made. Good candidates found part **(b)** straightforward, although having correctly explained negative deviation here, then went on to get the sequence of distillates incorrect in part **(c)**.

Question 6

Most candidates showed good knowledge of the phase diagram of carbon dioxide in part **(a)**, and also knew how it differed from that of water in part **(c)**. It was the explanations in part **(b)** that proved tricky for all but the best candidates. All that was required was that the candidates should sketch the 298K and 60 atm lines on their phase diagrams and then explain the cause of the physical observation.

Spectroscopy

Although the least popular of the options, there seemed to be rather more candidates offering this option this year. Candidates who had studied spectroscopy appeared to be well prepared and scored better than average marks.

Question 7

Almost all candidates correctly identified the two absorptions of carbon dioxide in part **(a)**. In part **(b)** most candidates correctly identified the bonds responsible for the absorptions, and arrived at a plausible structure for the compound. A minority ignored the statement that it only contained two functional groups. In part **(c)**, although most candidates correctly suggested n.m.r. spectroscopy or mass spectrometry, only the best candidates were able to suggest key evidence to look for in their chosen technique.

Question 8

Part **(a)** was straightforward, although some candidates did not look closely enough at their data sheets to see the clue of the ester given by the absorption at 1200 cm^{-1} . An acceptable alternative was to point out the absence of an absorption due to $-\text{OH}$. In part **(b)(i)** few candidates scored full marks because although they knew what the triplet/quartet sequence meant, few gave an adequate explanation of how these splitting patterns arise. The remainder of the question was answered much better.

Transition Metals

This remains a very popular option, and answers in this session scored rather higher than in last June's session. It was, however, disappointing to see the lack of knowledge displayed by many candidates in those parts of the questions that should have been part of their practical experience.

Question 9

Many candidates correctly gave a suitable percentage of chromium in stainless steel, and most knew the reason why the chromium reduced corrosion in part **(a)**. Although most candidates could calculate the empirical formula and correctly state the oxidation number of chromium in **A**, a worrying number gave poor explanations of the observations in part **(b)**.

Question 10

Answers to part **(a)** were mixed, although good candidates found it easy and scored all 3 marks available. Answers to part **(b)** seemed to indicate a lack of practical knowledge for many candidates. In **(b)(i)**, most could guess that the colour change was brought about by ligand replacement, but few could say any more or write balanced equations. In **(b)(ii)**, most recognised that redox reactions were involved and identified the blue and green vanadium ions, but again were unable to write balanced equations.