

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

Six questions were found to be more difficult, **Questions 2, 9, 25, 35, 38 and 39**. These questions will be looked at in greater detail.

Comments on specific questions

Question 2

The most commonly chosen incorrect answer was **A**. One mole of malachite reacts with four moles of nitric acid. 30.0 cm³ of 1.50 mol dm⁻³ nitric acid contains 0.045 mol. This will react with 0.01125 mol of malachite which has a mass of 2.49 g. This means 12.0–2.49 g is left unreacted, so the answer is 9.51 g.

Question 9

The most commonly chosen incorrect answer was **B**. 180 cm³ of oxygen contains 7.5×10^{-3} moles. The stoichiometry in the equation shows that 0.015 mol of hydrogen peroxide decomposes to produce this amount of oxygen. The time taken, 90 seconds, is 1.50 minutes. The rate of the reaction is therefore 0.015 mol of hydrogen peroxide divided by 1.50 minutes. This gives 0.010 mol min⁻¹.

Question 25

The most commonly chosen incorrect answer was **B**. One mole of lead(II) nitrate has a mass of 331.2 g. On decomposing, it leaves a residue of one mole of PbO which has a mass of 223.2 g. The percentage loss in mass is therefore 32.6 %. One mole of ammonium nitrate has a mass of 80 g. On decomposing it leaves a residue of two moles of water which has a mass of 36 g. The percentage loss in mass is therefore 55.0 %, so the answer is **A** or **B**.

The NO₂ gas produced from lead(II) nitrate is acidic and so will react with NaOH(aq), leaving one mole of oxygen to be collected. Two moles of nitrogen and one mole of oxygen are produced from ammonium nitrate, neither gas is acidic so a total of three moles of gas is collected. The answer is **A**.

Question 35

The most commonly chosen incorrect answer was **C**. 1-chloro-2-methylpropane is a primary halogenoalkane so the mechanism of hydrolysis is S_N2. 2-bromo-2-methylbutane is a tertiary halogenoalkane so the mechanism of hydrolysis is S_N1. The bromide will hydrolyse more quickly than the chloride, so time T₂ is less than time T₁.

Question 38

The most commonly chosen incorrect answer was **B**. Both compounds must be reduced to CH₂(OH)CH₂CH₂CH₂OH, butan-1,2-diol. This is the only possible reduction product with empirical formula C₂H₅O. Since the double bond in each of X and Y has been reduced to a C–C single bond, compound P and compound Q do not show geometrical isomerism. Therefore, they are identical. Since X is a cis isomer the answer is **A**.

Question 39

The most commonly chosen incorrect answer was **A**. The structural formula of but-2-ene is CH₃CHCHCH₃. Each hydrogen atom has one occupied s orbital only. The hydrogen atoms therefore do not need to be considered. The two middle carbon atoms are sp² hybridised, so they have no sp³ hybrid orbitals. The end carbons are sp³ hybridised, they each have four sp³ hybrid orbitals. There are therefore eight sp³ hybridised orbitals used in the bonding of but-2-ene.

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Paper 9701/22 AS Level Structured Questions
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Key messages

Structured questions give candidates the opportunity to show their knowledge and understanding over a wide range of syllabus topics. The best answers are concise and precise: there is often little need for fully developed sentences, providing that the sense and balance of answers are clear. The accurate use of chemical terminology remains crucial to remove ambiguity from responses.

Candidates are reminded to address 'explain' questions fully — not merely to state facts, but then to show how these combine to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules, in particular for organic species, linking structural feature to mechanistic probabilities.

Working in calculations should be shown to ensure that due credit can be awarded, especially where a numerical answer might be obtained by different methods, correctly or incorrectly. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

General comments

Where candidates find it necessary to write at greater length than the space provides, they are requested to give a clear indication of where their continued writing can be found. Diagrams should be labelled as fully as possible, to avoid ambiguity or conflict with more extended writing.

Candidates are asked not to use non-standard abbreviations in answer to questions: apart from a very few (e.g., ppt and, although these are deprecated, VdW and IMFs), these are not commonly understood and are not credited.

Comments on specific questions

Question 1

Poor reading of the question hindered some candidates in their approach to the items tested here. Many candidates did not show their working or tried to gain credit by restating information in a question. Some candidates struggled with the concept of an observation. Care must be taken with handwriting when subtle variations in words (e.g., ethanoic compared with ethanolic) lead to significant differences of understanding.

- (a) (i) This was generally well answered. The most common errors were -3 and -5 for the oxidation state of chlorine.
- (ii) There were many good answers here. Many candidates wrote about increasing the concentration of reactants, ignoring the state of PCl_3 . Answers giving general definitions of equilibrium were ignored.
- (iii) Many candidates gave the answer of PCl_3 without any working shown. Some attempted trial and error; many had not appreciated that the M_r was between that of PCl_3 and PCl_5 .
- (iv) Many candidates stated it was simple molecular without any attempt at explanation of the information given in the question.
- (b) (i) A common incorrect answer was to reference misty fumes.

- (ii) There were many good answers here although many incorrect answers were also provided. Many candidates omitted the *bi-* prefix from bipyramidal.
- (iii) This was often correctly answered.
- (iv) Many candidates did not answer the question by giving a name to the compound.
- (v) Only relatively few candidates were able to give the diol as the answer.
- (c) (i) This was answered very well.
- (ii) Candidates were able to identify the solvent but many omitted heat as a condition.
- (d) (i) The best answers were able to reference the isotopic abundance of chlorine and link this to the relative peak height shown in the mass spectrum. There was a high occurrence of referencing the $[M + 1]^+$ peak, erroneously.
- (ii) Many candidates did not note that **D** has an M_r of 60, hence several structures were given that exceeded 60. Substituted alkenes were often given as an answer.

Question 2

Lengthy and wordy answers did not help candidates to score in places here: it is often better to write itemised or bulleted responses to set out one's thinking clearly.

- (a) Many candidates omitted 'electrostatic attraction' in their answers. 'Sea of electrons' appeared frequently on its own.
- (b) (i) Most candidates were able to identify the increase in ionic radius. The reasoning for this was varied, and imprecise vocabulary was used often (e.g., orbitals, subshells).
- (ii) The explanations given here were quite often too vague or incorrectly worded, such as talking about an increase in overall nuclear charge. In explaining the large difference between the 2nd and 3rd ionisation energies, comments regarding the third electron's being removed from a shell closer to the nucleus were often absent.
- (c) (i) Many answers did not address the question, with little mention of the massive nucleus, or the relative position and mass of the electrons.
- (ii) This was well answered, though some confused proton and neutron number, while others gave nucleon number.
- (iii) The general direction of travel of the two particle beams was nearly always correct. The extent of the deflection of the electron beam was not always very clear.
- (d) (i) Many candidates gave the idea of a white precipitate being formed, and/or effervescence as an answer in both cases. This often had the effect of negating some correct answers
- (ii) This was quite often answered correctly, although many candidates chose to show a type of reaction similar to that of magnesium oxide with steam.
- (iii) This was very often correctly answered. Incorrect answers tended to be the opposite trend.

Question 3

Some answers showed similar traits to those seen in **Question 2**. Stronger candidates were able to set out their answers concisely or use higher-level approaches to avoid ambiguity.

- (a) (i) Candidates often confused liquid bromine and bromine water, and even more common was the suggestion of iodine as a purple substance in various different states. Many candidates omitted the state of matter.
- (ii) Very many answers confused bond energy and ionisation energy when trying to explain the pattern of data.
- (b) There were many correct answers here. Candidates should be careful to reference the relevant active species.
- (c) (i) NaCl and NaBr were often seen here.
- (ii) NaBr and NaI were often seen here.
- (iii) This was very often correct. 'White precipitate' was the most common error.
- (d) (i) Reference to instantaneous dipole—induced dipole / id—id / London / dispersion (forces) was nearly always seen; much less common was a reference to permanent dipole—permanent dipole interactions.
- (ii) Many varied answers were given and all common types of mechanism were named.
- (iii) This was quite well answered, although the positional isomers were often given incorrectly with iodine and bromine on the same carbon atom, or with only bromine substituted, or with substituted ethane structures shown. The use of skeletal formulae often avoided errors of representation.
- (iv) This was nearly always correctly answered, with or without reference to the structures given in **3(d)(iii)**.
- (v) Many extended answers were given here referencing the positive inductive effect of the alkyl groups but not related to a more stable secondary carbocation/intermediate. It was often suggested that the secondary halogenoalkane itself was more stable. Answers discussing the relative electronegativity of the halogens, or that the electrophile approaches with $\text{I}^{(\delta+)}$ nearest were rarely seen.

Question 4

- (a) This was answered well. Candidates were able to identify 2,4-DNPH and effervescence with Na(s) easily. Common errors were mainly to do with the observation of the reaction with acidified $\text{K}_2\text{Cr}_2\text{O}_7$, answers to which incorrectly referenced precipitates or the reverse colour change.
- (b) (i) Candidates' mechanistic drawings were often poorly set out. Curly arrows need to start from lone pairs or from the centre of covalent bonds. Many candidates showed the cyanide ion attacking an implausible intermediate. A large minority of candidates attempted to show the movement of an electron pair from an H^+ ion.
- (ii) Many variations of answer were seen
- (iii) This was often well answered. The phrase 'surrounded by' is not a legitimate substitute for 'attached to' or 'bonded to'. Some candidates described the substituents on a chiral carbon as *molecules* or *compounds*: this was not credited.

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Paper 9701/33 Advanced Practical Skills
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Key messages

Candidates are encouraged to:

- read the introductions to the questions carefully as the information given will be needed to answer the questions fully
- ensure they follow the instructions in the method
- show the precision of the apparatus used in their recorded data
- use precise language when reporting chemical changes in qualitative tests and note the examples of observations given in the guidance.

General comments

Supervisor results for both the quantitative and qualitative tasks are used in awarding accuracy marks in **Questions 1 and 2** and as a check on the 'unknowns' and reagents in **Question 3**. Supervisors should carry out experiments using the same solutions, solid samples and equipment as candidates so that supervisor/candidate results and observations can be compared and the quality of candidates' practical work assessed fairly. It is advisable that the best practical chemist in the centre carries out the experiments.

Any issues with supply or preparation of chemicals or apparatus that would affect the results obtained by candidates should be communicated on the Supervisor's report form. This information should be provided even if the issue has already been communicated to Cambridge prior to the examination period.

Comments on specific questions

Question 1

Some candidates appeared well prepared in carrying out the procedure and subsequent calculation; others struggled to attain over half marks. Candidates with lower scores tended to find recording their results in **(a)** more challenging than the calculation.

- (a)** Candidates are expected to give precise labels to their experimental data. Common errors were to describe mass as weight, the contents of the crucible after heating as **FA 1**, i.e., hydrated potassium alum, or to not distinguish between the two masses after heating. A few candidates were inconsistent with the inclusion of the lid. However, almost all candidates included correct units with every label. Given the time the crucible and contents were heated, all or almost all the water of crystallisation should have been removed after the first heating. Consequently, the masses recorded after first and second heating should be very similar. It was evident from some candidates' results that this had not been achieved. Almost all candidates consistently recorded their balance readings to the expected two decimal places. A very common error was to confuse the mass of water lost and the mass of residue. A large majority of candidates gained at least one of the two marks for accuracy with many gaining both marks.
- (b)(i)** Most candidates were awarded this mark. The most common error was to give the answer to one significant figure, e.g., 0.05 moles.
- (ii)** Most candidates successfully divided their answer by 12.

- (iii) Slightly fewer candidates answered this correctly as some used the mass of **FA 1** instead of the mass of the residue in their calculation. It is important to read each question carefully.
 - (iv) Only a minority of candidates answered this correctly. Working must be shown and the formula proposed must be neutral when charges of ions are considered. Many candidates ignored the instruction to use their M_r from **(b)(iii)** and/or the information given that one mole of potassium alum contains one mole of potassium ions. Some candidates used the M_r and component A_r s successfully but then gave a formula such as $\text{KA/}\text{SO}_4$ which does not have balanced charges.
- (c) (i) Many candidates did not gain credit for this. Reading the question carefully was necessary. Two balance readings were required to calculate the mass of anhydrous potassium alum. Hence, the uncertainty must be multiplied by two. The other (less common) error was to use the mass of hydrated potassium alum as the denominator.
- (ii) Very few candidates were successful in this part. Some correctly linked the increased mass loss with a decrease in the M_r of the residue but few incorporated the amount (moles) of residue in their answer.

Question 2

Most candidates were well prepared to carry out the titration experiment and successfully work through the associated calculations.

- (a) A large proportion of candidates gained full credit. Marks were lost most often for omitting the burette readings for the rough titre (candidates are instructed to do this in the method) or for not recording accurate burette readings to either $\text{#.}\text{#}0$ or $\text{#.}\text{#}5\text{ cm}^3$. Some candidates did not label their results table accurately or omitted the titre values. A small number of candidates recorded the volume at which starch was added for each titration. This is not needed. Many candidates appeared to refill their burettes to 0.00 cm^3 for each accurate titration. Whilst credit is not lost for doing this, provided there is sufficient solution present to complete the titration, filling to 0.00 cm^3 is an unnecessary use of valuable time. A few candidates were not awarded credit for concordant titres as their final accurate titre was more than 0.10 cm^3 from any previous value. Once concordance in the accurate titrations has been achieved there is no reason to continue with further titrations. A large majority of candidates gained at least one of the three marks available for accuracy.
- (b) Most candidates answered this correctly. The errors seen were too wide a spread of accurate titres used for the mean and giving the answer to one decimal place. A few candidates inappropriately rounded their mean titre to the nearest $\text{#.}\text{#}0$ or $\text{#.}\text{#}5\text{ cm}^3$, e.g., 25.53 was rounded to 25.55 cm^3 .
- (c) (i) Many candidates gave at least one of their answers in **(c)(ii)**, **(c)(iii)** and **(c)(iv)** to two significant figures so were not awarded credit. Given the precision of the apparatus and concentrations of the solutions used, answers to three or four significant figures were appropriate. The concentration of **FA 4** was only given to two significant figures as it was an excess so its concentration is immaterial. A small number of candidates appeared to confuse decimal places with significant figures.
- (ii) Most candidates used the correct figures in their calculations. However, some rounded the value of $22 \div 248.2$ inappropriately before multiplying by their titre in dm^3 . Some candidates omitted one of the steps so could not access the mark.
- (iii) Almost all candidates answered this correctly.
- (iv) A large majority of candidates answered this correctly. A few rounded their answer incorrectly: 4.375 should round to 4.38 .

- (v) Fewer candidates answered this correctly. The most common error was to ignore the instruction to give the answer to one decimal place. Some candidates did not understand that their answers to (c)(iii) and (c)(iv) needed to be used. A small number of candidates worked backwards from their answer to (c)(vi). This was not awarded credit.
- (vi) Many candidates recognised potassium manganate(VII) from its colour. They then used the information given in the question to show an oxidation state change of $+7 \rightarrow +2$. Only the better performing candidates were able to gain full credit by using their answer to (c)(v) and multiplying it by 2 ($2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^-$).
- (d) Candidates were told in the method that the amount of **FA 5**, sulfuric acid, was an excess. However, many candidates answered in terms of the uncertainty in measurement associated with pipettes and measuring cylinders or unavailability of pipettes able to measure 20 cm^3 . Candidates should be aware that pipettes are available in sizes other than 25.0 cm^3 .

Question 3

Candidates should be encouraged to read and make use of the guidance given at the start of the qualitative analysis section. Use of the qualitative analysis notes (on pages 10 and 11 in this paper) would have helped some with describing some of their observations. Some candidates had considerable difficulties in describing the changes they saw; others performed well. Candidates are reminded to add reagents carefully, noting changes as they occur; sometimes reactions may not be immediate or there may be a series of changes. Candidates should also be reminded that dark, clear and foggy are not colours. 'Gas released' is not credited in place of effervescence/fizzing/bubbling. 'No observation' is not the same as 'no (visible) change.'

- (a) Most candidates gained one or two marks in this part. The most common correct observations were 'no change' in Test 1 box 1 and 'effervescence' in Test 3.

Test 1: It is important to describe the state as well as the colour of substances. In box 2, **FA 3** changed first to green solution and then formed a brown precipitate. On adding sulfuric acid (in box 3) the solution turned colourless. Candidates should be aware that 'clear' is not a colour; aqueous solutions are usually clear but they may vary in colour.

Test 2: Very few candidates noted any bubbling.

Test 3: Most candidates noted effervescence; only a small minority tested the gas produced. Candidates should be reminded to record any positive gas test. A (dark) brown precipitate forms but this was generally described as black or as solution.

Few candidates were credited for identifying the gas. A large number suggested 'oxygen', however, they could not be credited as the question asked for the formula to be given.

- (b)(i) Many candidates gained credit for this part; only those using the information given in the question paper gained over 3 of the 6 marks available.

Test 1, box 1: Many candidates described the precipitate as orange or red and only a few candidates noted the result on adding excess NaOH(aq) . If the instructions do not state how much sodium hydroxide (or ammonia) to add, candidates should add until in excess. Box 2: Warming the alkaline mixture is a test for the ammonium ion so any gas evolved should have been tested with (damp) red litmus paper. Some recorded this as 'litmus turns blue' without stating the gas was being tested. Many candidates noted the litmus changing colour in Box 3, which was too late. Not all candidates noted the fizzing as the aluminium started reacting. This suggests either insufficient warming or a lack of practice. Some confused effervescence with boiling.

Test 2: 'Red' and 'orange' are not suitable descriptions of the colour of aqueous iodine. However, many candidates were credited for blue-black on adding starch solution.

Test 3: Almost all candidates correctly noted effervescence; very few tested the gas (as stipulated in the initial information).

Test 4, box 1: Many were credited for noting a white precipitate was formed on adding the $\text{Ba}^{2+}(\text{aq})$ salt. However, 'milky white' was not credited as it does not describe the formation of a precipitate. Some candidates wrote the precipitate was cream or off-white: candidates should observe the colour of the ppt at the bottom of the test-tube if its colour is being disguised by the colour of the solution. Box 2: The change of colour of the solution as well as the solubility of the precipitate should have been noted on addition of dilute hydrochloric acid. Many candidates incorrectly suggested that the precipitate had changed colour, rather than the solution, suggesting they were not aware of the significance of the addition of acid to barium sulfate/sulfite precipitate.

Test 5, box 1: 'No observation' is not synonymous with 'no change' so should be avoided. Box 2: It was evident that some candidates did not add sufficient aqueous ammonia as they did not note the brown precipitate. However, some candidates described the precipitate in the accepted range of colours and noted that it was insoluble in excess ammonia.

- (ii) A large majority gained one of the two marks available. H^+ was often not identified and sometimes NH_4^+ . Incorrect ions given included NO_3^- , SO_3^{2-} , I^- , Fe^{2+} , Cr^{3+} , and 'unknown'. Very few candidates gained both marks.
- (iii) Few candidates gave a correctly balanced equation with correct state symbols. The equation for the formation of iron(III) hydroxide was the most common answer but was sometimes not balanced or missing one or more state symbols. Some candidates gave equations for reactions other than those seen in Test 1 or Test 3 so could not be credited.

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Paper 9701/42
A Level Structured Questions

Key messages

- Candidates must ensure their presentation is clear.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows are a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.

General comments

The correct convention is needed when writing the formulae of substances. For example, potassium manganate(VII) should be written KMnO_4 and not KmNO_4 or KMNO_4 .

Comments on specific questions

Question 1

- (a) This was not well known. Candidates were required to state that silver can form stable ions with incomplete d orbitals. A common error was stating silver has partially filled d-orbitals and forms stable ions.
- (b)(i) Most candidates gave the correct equation for the standard enthalpy change of atomisation of silver, including the correct state symbols. However, the enthalpy change of formation of silver fluoride was less well known and many candidates did not realise that one mole of silver fluoride was required as the product. Some candidates thought that silver fluoride was formed from its ions.
- (ii) This was generally well answered. Common errors were:
- omitting '1 mole' with 'ionic compound formed'
 - starting from 1 mole of gaseous ions.
- (iii) Candidates performed well on this question. Common errors included -308.5 (use of $79 \div 2$), -269 (omission of 79) and -696 (use of 2 moles).
- (c)(i) Most candidates correctly calculated the enthalpy change of solution of AgF(s) . A common error was -1925 .
- (ii) Most candidates explained correctly that the negative ΔH_{sol} would make AgF soluble in water. Some candidates gained credit by error carried forward being applied to their answer from (c)(i).
- (d)(i) Many candidates could successfully explain the trend in electron affinities down Group 7. Some candidates referred to an increase in size of the ion rather than the atom. Many did not mention that the attraction of the nucleus for the incoming electron decreased as the size of the atom increased.
- (ii) Many gave an incomplete explanation for the decrease of the lattice energies from AgCl to AgI and did not mention that the attraction between ions become less when the halide ions become larger.

- (e) (i) The E°_{cell} value was calculated correctly by most candidates but the equation for the overall cell reaction was often constructed incorrectly.
- (ii) Of the three values to be inserted into the Nernst equation, most candidates were able to calculate the concentration of chloride ions in mol dm^{-3} (4.83). However, the E° value for the silver electrode was often taken to be 0.12 V, which was the value for the E°_{cell} and the number of electrons transferred, which should have been 1, was often given as 2.

Question 2

- (a) (i) Many candidates did not understand that a large concentration of CH_3COCH_3 was used to keep its concentration constant so that it did not affect the rate. A common error was 'to allow the reaction to go to completion'.
- (ii) Some very good answers were seen. On questions of this type candidates must ensure:
- they identify the order with respect to the reactant that must be addressed first - in this case it was $[\text{H}^+]$
 - they clearly identify which experiments each part of their explanation refers to
 - answers rely on explanation, not on annotations on the table.
- (iii) Some answers referred to constant half-life without presenting supporting evidence. It should be noted that '170 s and 330 s' is not supporting evidence. 'The time taken to halve from 100% to 50% is 170 s, the time taken to halve from 50% to 25% is 160 s' is supporting evidence.
- (b) Many candidates identified mechanism 4 but found the explanation very difficult. Candidates were expected to explain that the rate equation given contained the species in the slow step of mechanism 4 in the correct stoichiometric amounts.
- (c) (i) This answer was usually correct.
- (ii) Most candidates were able to calculate the correct pH of solution. A common error was $\text{pH} = 1.98$ (error carried forward from $[\text{H}^+] = 0.010592$)
- (d) (i) Most candidates knew the definition in the syllabus. Some did not give a precise definition, stating that the pH would remain unchanged or omitted 'small' amounts of acid and base should be added.
- (ii) This proved difficult for many candidates. In particular, the number of moles of acid **C** left. Common errors included 3.55 (0.05 used instead of 0.03) and 4.13 (reverse ratio used $0.03 \div 0.02$).

Question 3

- (a) (i) Most candidates gave the correct answer.
- (ii) Many successfully completed all the boxes in Table 3.1 with information about the different Fe^{2+} and Fe^{3+} complexes. Two common errors were writing Cl or Cl_2 as the ligand in $[\text{FeCl}_4]^{2-}$ and giving the coordination number of 3 for $[\text{Fe}(\text{en})_3]^{3+}$.
- (iii) Most candidates correctly drew three higher and two lower energy levels for the splitting of the d-orbitals in a tetrahedral complex.
- (b) (i) Most candidates gave good explanations of the differences in colour.
- (ii) This proved challenging to most candidates. Many gave an expression with charges outside the last set of brackets. Some others were written the wrong way up, or with $[\text{H}_2\text{O}]$ included in the expression.
- (iii) Most calculated K_c correctly.
- (iv) Many candidates were able to state that the solution turned from purple to colourless, but some candidates thought the solution would then turn red on addition of the KSCN. Some unusual answers were seen, for example precipitates being formed and the use of 'common ion effect', in the explanation.

- (c) (i) Better performing candidates were able to write balanced half-equations for both the oxidation of $\text{C}_2\text{O}_4^{2-}$ and the reduction of MnO_4^- . However, many found working out the half-equations challenging and H^+ was often seen as a reactant in the oxidation of $\text{C}_2\text{O}_4^{2-}$. Candidates need to be reminded that they should balance the charges as well as the species in the half-equations.
- (ii) Many completely correct calculations were seen, but others found the calculation very difficult, only gaining one or two marks. Nearly all candidates were able to work out the amount of the manganate(VII) ion and but did not always multiply this by the correct ratio of 5:2 to obtain the moles of ethanedioate ion.

Question 4

- (a) Most candidates gave the correct order of basicity. The positive inductive effect of the propyl group was well known for propylamine being the strongest base. However, many did not link basicity to the availability of the lone pair on the nitrogen atom to accept a proton. The ability of the lone pair on the nitrogen to attract a proton is not sufficient. Only higher performing candidates were able to explain the delocalisation of the lone pair on nitrogen into the $\text{C}=\text{O}$ group in propanamide.
- (b) This was answered well by many candidates. **L** and **M** were more well known than **K**. Common errors included:
- for **K**: $\text{CH}_3\text{CH}_2\text{COOH}$
 - for **M**: Sn and conc. HCl or NaBH_4 .
- (c) Many candidates were able to draw the hydrolysis products benzylamine and ethanoic acid but did not realise that benzylamine would be protonated in excess concentrated hydrochloric acid. The third hydrolysis product proved much more challenging. A common error were structures containing an acyl chloride instead of a carboxylic acid group.
- (d) (i) This question discriminated well. Some unbalanced equations were seen without H_2O in the products. Other common errors were use of $[\text{H}^+]$ (instead of $[\text{H}]$) or forming O_2 as a by-product.
- (ii) Many incorrect reagents and conditions were seen. The types of reaction were well known, although oxidation was a common error for step 2. Some candidates who chose to name the reagent in step 4 (instead of the formula $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}$) often gave the incorrect name, 3-methylbutanol, instead of 3-methylbutan-1-ol.

Question 5

- (a) Most candidates gave the correct answer.
- (b) (i) This was usually answered correctly.
- (ii) This was usually correct.
- (iii) Those who had learnt the electrophilic substitution mechanism found this to be accessible.
- Common errors included:
- the curly arrow in step 1 going to the CH_3 carbon instead of the CH^+ carbon in the electrophile
 - an incorrect structure of the intermediate – the partly delocalised ring should not include the sp^3 carbon and the positive charge should not be on the sp^3 carbon or the hydrogen atom
 - the curly arrow in the intermediate starting on the H not on the C-H .
- (iv) This question was found to be difficult by many candidates. The greater stability of a secondary carbocation over a primary carbocation was known but the idea due to the greater inductive effect of the alkyl group was often omitted.
- (c) (i) The standard entropy change of reaction 1 was correctly calculated by the majority of candidates.
- (ii) The correct use of the Gibbs free energy equation was required to show that reaction 1 was feasible. Some candidates did not correctly convert 25°C to 298 K .

- (d)(i) The condition required for the reaction of bromine with phenol was for the bromine to be aqueous. Some candidates just described the condition as room temperature which was insufficient. Many correctly stated that the lone pair on oxygen was delocalised into the ring, although omitted to explain that this increased its electron density. The final part of the explanation was omitted by many candidates, that the increased electron density in the ring polarised the bromine molecule more.
- (ii) Most candidates drew 2,4,6-tribromophenol. Some incorrectly gave the mono-brominated phenol.
- (iii) Many candidates knew the structure for the benzene diazonium ion, however placed the positive charge on the wrong nitrogen.
- (iv) This was answered well by many candidates. Diazo and diazonium group were common incorrect answers.
- (v) The two isomers of dinitrophenol were usually drawn correctly. The explanation for the nitro groups being in the 2, 4 positions was less well known. Most stated that the —OH group was electron donating but did not state that it was 2, 4-directing.

Question 6

- (a)(i) The ester group was usually drawn correctly but the rest of the molecule was found to be more challenging.

Common errors included:

- drawing more than one repeat unit and
- omitting some hydrogen atoms in their structure.

- (ii) Although KMnO_4 was usually identified as the suitable reagent, sometimes one of the three conditions of cold, acidified and dilute was omitted in their answer.

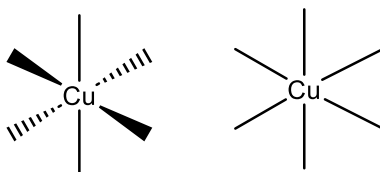
- (b)(i) Most candidates gave the correct answer.

- (ii) This was answered correctly by the majority of candidates.

- (iii) Many accurately-drawn correct answers were seen, using correct conventions for the three-dimensional bonds (wedged and dashed bonds).

The most common errors were:

- diagrams without any 3-D bonds
- diagrams in which 3-D bonds were drawn but where the complex could not be octahedral as shown.



- (c)(i) Many candidates gave the correct number of eight carbon environments but four and six were common incorrect answers.

- (ii) Many candidates understood that dissolving **X** in D_2O would remove OH peaks.

- (iii) There were some very good answers seen. Candidates needed to carefully consider all the information given in **6(c)** to draw a correct structure of **X**. They were told **X** was an aromatic compound and there was a positive triiodomethane test. This suggested $\text{CH}_3\text{CO}-$ bonded to the benzene ring. The loss of the two NMR signals in D_2O solvent suggested there were also two $-\text{OH}$ groups attached to the ring. These were in unsymmetrical positions around the benzene ring because this was the only way to produce eight different carbon environments. Some of the carbon-13 spectrum signals confirmed these conclusions, for example the peak at $\delta 205$ for a carbonyl carbon and at $\delta 62$ for a carbon next to a $\text{C}=\text{O}$.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

The accuracy of numerical values of mass and volume should reflect the apparatus used. For example, in **1(f)** where a two decimal place balance was used for weighing, the resultant mass should be given to two decimal places.

General comments

If a single answer is asked for, two (or three) answers should not be given as incorrect statements may contradict correct answers.

Candidates should ensure that at A level, numerical answers reflect the appropriate number of significant figures. Usually, most numerical answers, if not indicated otherwise, should be to three significant figures.

Comments on specific questions

Question 1

- (a) Most candidates secured this mark, but candidates should be advised to identify the toxic gas as NO_2 rather than state the generic 'toxic gas formed', for example.
- (b) Most candidates are familiar with the reasoning behind weighing by difference and correct responses based upon the idea of needing to know the exact **mass** of brass transferred into flask **A** were frequently seen.

Many candidates gave responses such as 'so we know the mass of brass left in the beaker' without going on to state the relevance of this mass.

Weaker candidates assumed weighing by difference was done to ensure all the brass was transferred.

- (c) Nearly all candidates identified the apparatus needed as a volumetric pipette. The volume was not required for this particular question although there may be times when it will be.

Candidates should be advised that burettes are not suitable for **transfer** of known volumes of solutions.

- (d) Nearly all candidates knew that the burette should be rinsed with the $(0.0600 \text{ mol dm}^{-3})$ aqueous sodium thiosulfate.

- (e) Despite this type of question frequently appearing in papers, many candidates struggled to describe the preparation of a standard solution from an aqueous solution.

Most candidates correctly calculated the volume of $0.200 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3(\text{aq})$ as 30 cm^3 but omitted to give this as an accurate volumetric quantity of 30.00 cm^3 .

A sizeable number of candidates did not appreciate that 30.00 cm^3 of $0.200 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3(\text{aq})$ can be placed directly into a 100 cm^3 volumetric flask from a burette and opted to use a beaker as an intermediary vessel. This was accepted as long as the beaker was rinsed.

Many candidates insisted on rinsing the burette after addition of 30.00 cm^3 of 0.200 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ and adding the rinsings to the volumetric flask. This would have placed a greater volume of 0.200 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ into the volumetric flask.

Candidates should be advised that once the volumetric flask has been topped up to the 100 cm^3 mark with distilled water, the flask should be stoppered and inverted several times.

- (f) Whilst the majority of candidates correctly gave the mass of brass added (1.00 g) using a two decimal place balance to two decimal places, some gave this mass to only one decimal place and others to a whole number of grams. Weaker candidates got this simple calculation wrong.
- (g)(i)/(ii)/(iii) The first two parts were very well answered although some candidates included non-concordant titres when calculating the mean titre in **1(g)(ii)**.

Although percentage error calculation in **1(g)(iii)** was better answered than in previous series, many candidates did not secure this mark.

Half a burette graduation is 0.05 cm^3 and two burette readings had to be made to produce a titre value of 22.40 cm^3 . This should have been taken into consideration for the percentage error calculation.

- (h)(i)-(v) This 5-part question was done very well by most candidates. Parts **(i)** to **(iii)** proved no problem but many did not scale up by a factor of 10 in part **(iv)**. Even so, with an error carried forward mark, most provided a creditworthy answer to part **(v)**, though many did not give their answer to three significant figures.

Question 2

- (a)(i) It is concerning that candidates are not familiar with typical A level practical techniques such as refluxing. Many candidates could not draw a reflux condenser and label the flow of cold water correctly. Although detailed technical aspects of apparatus are not required, the diagrams should be good enough to show that the apparatus works.
- (ii) Although many candidates did gain credit here, a significant minority were unable to give the required answer of anti-bumping granules.
- (b) Most candidates realised that the suitable indicator was thymolphthalein, but very few could satisfactorily explain why.

Very few candidates realised that potassium hydroxide is a strong alkali and, as it is used up in the reaction, the pH would fall from about 14 to 7 as equimolar amounts were used in the reaction and thymolphthalein was the only one of the three indicators which would change colour over this range.

- (c) The question asked candidates to 'State what feature of the chromatogram ...'. Many candidates did not refer to the chromatogram at all.

There needed to be some reference to the spots or their R_f values. For example, 'one of the spots in the reaction mixture had the same R_f value as the ester spot'.

The common error was referring to the 'extra' spot for the reaction mixture.

- (d) This question was answered correctly by the majority of candidates as fractional distillation was known to most candidates.
- (e) The analysis of the infrared spectrum of ROH was done well by the majority of the candidates and a considerable number correctly identified the lack of a peak between $1710\text{--}1750\text{ cm}^{-1}$.
- (f) Very few candidates scored all 3 marks for this question. More could explain the singlet as coming from the proton in an --OH group in an alcohol than could explain the multiplet, which was from the $>\text{CH--O}$ -proton (next to two CH_3 groups to explain the splitting into a heptet).

However, even without scoring the first two marks for analysis of the (^1H) spectrum, many candidates were able to identify the alcohol as propan-2-ol.

- (g) Most candidates could draw the ester group correctly and a pleasing number drew the complete displayed formula correctly.

Candidates should be advised that a methyl group drawn as $-\text{CH}_3$ is **not** a displayed formula.

A significant minority misread the question and drew the displayed structure of the alcohol identified in **2(f)**.

- (h) Very few candidates noticed the fact that concentrated sulfuric acid was a catalyst and therefore the pH of the mixture would not (significantly) change. Thus, none of the indicators would change colour.