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Paper 9701/12
Multiple Choice

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

General comments

The majority of candidates were able to finish the paper within the hour allowed; some may have been hurrying towards the end.

Questions 1, **2**, **8**, **9**, **18** and **29** were found to be easy. Candidates found **Questions 3**, **27**, **32**, **34** and **35**. to be particularly difficult.

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Comments on specific questions

Question 3

The most commonly chosen incorrect answer was **C**. 3.22 g of carbon dioxide contains 3.22 × 12/44 = 0.878 g of carbon. The sample therefore contained 0.122 g of hydrogen. 3.22/12 = 0.0732. 0.122/1 = 0.0122. The ratio 0.0732:0.122 is 3:5 and so the empirical formula is C_3H_5. The only compound in options **A** to **D** with this empirical formula is cyclohexene, C_6H_{10}.

Question 27

Each option was chosen with approximate equal frequency, which suggests candidates were guessing. A small number of candidates did not submit an answer. When ethanal is reduced by $NaBH_4$ the product is ethanol, CH_3CH_2OH. The $–CH_2OH$ group will contain one ^1H atom and two ^3H atoms. When this group is oxidised back to –CHO a water molecule is produced, as described in the equation. This water molecule must contain at least one of the two ^3H atoms from the $–CH_2OH$ group. The ethanal molecule produced may have the ^1H atom from the $–CH_2OH$ group, or it may have one of the two ^3H atoms from the $–CH_2OH$ group. Therefore, both water and ethanal contain ^3H atoms.

Candidates found this question challenging but would have found it easier if the displayed formula of the ethanol product was drawn out, labelling the three hydrogen atoms in the $–CH_2OH$ group as ^1H or ^3H.

Question 32

The most commonly chosen incorrect answer was **D**. This means that most candidates knew that statement **1** is correct, however statement **2** gave more difficulty. Since $\Delta H^{\ominus}_z$ is the standard enthalpy change of combustion of one mole of carbon plus two moles of hydrogen, statement **2** is correct.

Question 34

The most commonly chosen incorrect answers was **C**. This means that most candidates knew that species **2** and **3** can form dative covalent bonds. Species **1** gave more difficulty. A BF_3 molecule has a boron atom with only six electrons in its valence shell, therefore a BF_3 molecule can also form a dative covalent bond.

Question 35

Each option was chosen with approximate equal frequency, which suggests candidates were guessing. A small number of candidates did not submit an answer.

As one possible approach to this question, *x* may be assumed to be 1. The equation for the precipitation is therefore $Al_2Cl_6 + 6NaOH \rightarrow 2Al(OH)_3 + 6NaCl$, so *y* is 6. After the addition of more NaOH solution Z contains two moles of $NaAl(OH)_4$. Therefore, it can be deduced that:

1 statement **1** is correct; this is required factual knowledge for the reaction of aluminium chloride with water
2 statement **2** is incorrect, since *y* is 6*x*
3 statement **3** is incorrect, since Z contains 2 × moles of aluminium.

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Paper 9701/22
AS Level Structured Questions

Key messages

- Candidates are reminded to read questions carefully and check answers thoroughly, especially in extended answers where more writing is required: the accurate use of chemical terminology is encouraged, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument.
- Candidates are reminded to address 'explain' questions fully — not merely to state facts or rules of thumb, but to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules.
- Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

General comments

Good recall of material was seen on most topics. Candidates are advised to write carefully and precisely worded definitions, using standard chemical vocabulary.

There were several numerical answers required in this paper, but the best answers involved clearly laid out working, which enables partial credit to be awarded for ultimately incorrect answers. Candidates should be encouraged to ensure their drawings are clear and unambiguous.

Comments on specific questions

Question 1

This question was predominantly based on physical chemistry. Candidates showed reasonable aptitude with calculations and a good basic understanding of kinetic theory of gases but were unable to secure the higher-ability marks for a want of detail or accurate working.

(a) (i) Many candidates were not able to label the axes correctly, or had the axes reversed. The first line (**T1**) was often correct, although a significant number did not start at the origin, instead taking the form more of an enthalpy profile diagram. The distribution is asymptotic at high energies.

(ii) Better responses showed that the mode was lower and shifted to the right.

(b) (i) Candidates who answered in terms of the negligible volume needed to give clear reference to the particles, rather than a general statement about volume of gases, which was not credited.

(ii) Candidates showed familiarity with the ideal gas equation, although some could not convert the quantities to consistent units (e.g. m^3, K). Candidates should avoid early rounding of numbers, in this case the number of moles of gas, as this led to significantly divergent answers.

(iii) Candidates often confused the conditions required for krypton to behave most like an ideal gas.

(c) (i) Many exothermic diagrams were seen. ΔH_f and E_a were often incorrectly labelled.

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(ii) This question revealed some significant confusions of theory. Few comprehensive answers were seen. 'More successful collisions' was often seen, without indication of time or frequency. Many candidates incorrectly asserted that the value of E_a either increased or decreased.

Question 2

There were several inaccuracies from candidates for this question. However, it was clear that many understood the broad theme of the topics. Answers requiring explanation needed precise reasoning and correct vocabulary: many responses could not be credited owing to the use of contradictory phrases.

(a) This was answered well by most candidates.

(b) (i) Many answers lacked critical detail or did not represent the correct process: for instance, absent state symbols, the formation of Cl^- or the ionisation of Cl_2.

(ii) Candidates were mostly able to identify the structure as simple but could not sufficiently link its covalency with the *hydrolysis* of the molecule.

(c) (i) There were some good answers, although many stated the trend correctly before focusing on the electronegativity of the halogen atoms, missing a reference to bond energy. Some candidates seemed confused about the meaning of *thermal stability*.

(ii) This was answered well by most candidates, although common mistakes were seen with the oxidation number of S in HSO_4^- ($+7$ or $+8$ being the most frequent).

(iii) This was not very well answered: many candidates referred to the oxidising power of the halides down the group.

(d) (i) This was answered well by many.

(ii) This was answered well by many.

(e) (i) Few entirely correct diagrams were seen: a large number portrayed a bond between the two aluminium atoms; others had reversed the dative bond. Many candidates neglected to show the lone pairs on the chlorine atoms.

(ii) Candidates are reminded to avoid contradictory statements, such as 'solid dissolves to form a white precipitate'.

(f) (i) A wide range of different answers was seen.

(ii) Candidates were often able to calculate the number of moles of $AgCl$ but then were unable to link this to the number of moles of **Z** and derive the value of *n*.

(g) (i) This was answered well by most candidates.

(ii) This was answered well by most candidates.

(iii) Some candidates seemed confused by the sight of the unpaired electron in $Cl^\bullet$, thinking this represented chloride rather than a chlorine atom.

(iv) Although many candidates were able to identify the correct formulae, answers were contradicted by the addition of stray charges or electrons.

(v) This was answered well by many candidates.

(vi) This was answered well by many candidates. $C_2H_4Cl_2$ was not credited as its formula is ambiguous.

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Question 3

This question covered a mixture of the strands of chemistry from the syllabus. The more technical parts of the question required a solid grasp of concepts. Some candidates' would have benefitted from a better understanding of molecular orbital formation.

(a) (i) All necessary data was presented in the question: candidates did not need to include the bond energies of e.g. O_2 or N_2. Some candidates neglected the stoichiometry of the reaction.

(ii) There were many good answers. A common error was not to mention that the triple bond was strong.

(b) (i) This was answered well by many candidates. Some showed confusion between the nature of acids and bases.

(ii) This question was answered well by only very few. All that was necessary was a diagram showing adjacent p-orbitals, which then overlap to form a new pattern (the π bond). Candidates seemed to have a poor understanding of the geometry of the orbital and of the location of the atomic nuclei relative to the bond.

(c) This was well answered by many candidates. Common errors were to refer to functional groups rather than individual bonds.

(d) (i) This was well answered by most candidates.

(ii) Common errors included drawing monomers or products containing the CN functional group rather than COOH.

(iii) Candidates are advised to be careful with names: for example, propamine was not accepted. A common error was to name an amide.

(iv) Both necessary conditions were rarely seen in answers. Many candidates incorrectly suggested heating under reflux.

Question 4

This short question based on organic chemistry was well answered by many, but **(c)(ii)** proved difficult for candidates to address the question thoroughly.

(a) There were many correct answers, although it was clear that many candidates were answering the question visually, rather than referring to VSEPR theory.

(b) There were many good answers here.

(c) (i) The most common error was 'reducing agent'.

(ii) Many candidates stated 'heat under reflux' but answers commonly referred to CHO being completely oxidised, with little appreciation that there were two functional groups that undergo oxidation.

(d) (i) Balancing what appeared to be a simple equation proved challenging for many, with 2[H] often missing.

(ii) There were many good answers here, although the formula of $LiAlH_4$ was not always correct.

(iii) This was very well answered.

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Paper 9701/33
Advanced Practical Skills

Key messages

- Candidates should be reminded to read the information and instructions given in the paper. Using a highlighter or underlining important points could help them produce relevant answers.
- Candidates should be encouraged to check through their working in calculations when an answer appears inappropriate so that errors can be corrected.
- Candidates should be given the opportunity to discuss the validity of experimental procedures, the errors arising in the different methods and possible improvements to ameliorate these.
- Candidates should practise writing ionic equations including state symbols.

Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:
- a list of the candidates present and a seating plan for the laboratory
- a copy of the question paper with the Supervisor's experimental results, including those for the question on qualitative analysis
- a Supervisor's report relevant to each session/laboratory using different batches of chemicals.

Invigilators/supervisors at centres running more than one session, and/or using more than one laboratory, should instruct their candidates to complete the Session/Laboratory boxes on the front of the question paper.

General comments

This paper proved accessible to most candidates and it generated a wide range of marks. A significant minority performed well, with good responses seen in all three questions. However, there were also candidates who did not achieve double figures. Almost all candidates completed the paper indicating that there were no time constraints. Candidates should ensure they read and follow the general instructions given at the start of both the **Quantitative** and **Qualitative Analysis** sections.

Comments on specific questions

Question 1

Candidates should be reminded to display data and answers to questions that reflect the precision of the apparatus and concentrations of solutions used. When an answer appears unrealistic, for example the answer for **(c)(iv)**, candidates should check through information given in the question and earlier stages in the calculation to correct possible errors. No credit is awarded to candidates who try to work backwards from an arbitrary final answer.

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(a) The most frequent errors evident were:

- burette readings not recorded for the rough titre
- incomplete or incorrect headings for the table of results
- burette readings recorded to one decimal place for the accurate titres
- performing a third accurate titration when the first two titres were within 0.10 cm^3.

Often in the last case, the third titre value was outside the range allowed from either of the previous titres so credit could not be awarded.

Most candidates gained some credit for accuracy.

(b) Most candidates gained credit for the mean with very few rounding errors or incorrect selection of titres seen. A small number of candidates did not show either which titres they had chosen or how they had obtained their answer.

(c) (i) Most candidates provided answers to the expected three or four significant figures in **(ii)** and **(iii)**; fewer were consistent in their display of final answers in **(iv)** and **(v)**.

(ii) Almost all candidates calculated the number of moles.

(iii) Most candidates completed the equation successfully and used the stoichiometry to deduce the amount, in mol, of **M**HCO_3. A minority of candidates calculated the number of moles in 250 cm^3 rather than 25 cm^3.

(iv) Most candidates used the mass of **FA 2** and the answer to **(c)(iii)** correctly; fewer remembered that only 25 cm^3 of the 250 cm^3 of solution prepared was titrated.

(v) The ignoring of the factor of 10 led to values of the A_r of **M** in the hundreds. Some candidates assumed the identity of **M** was sodium and changed their values in **(iv)** and **(v)** to reflect this. However, other candidates successfully identified the appropriate Group 1 element from their titration data and calculations. A small minority of candidates did not identify a Group 1 element, instead choosing whichever element on the Periodic table had the closest A_r to the value calculated.

(d) (i) Most candidates calculated the maximum percentage error.

(ii) Fewer candidates were successful here. The main errors were disregarding the need for two burette readings and not providing a comparison with the error in the pipette.

Question 2

A large majority of candidates gained credit for accuracy and for parts of the calculation. However, candidates should be encouraged to use the results of chemical tests to help them identify products when writing a balanced equation.

(a) Candidates were expected to tabulate four balance readings and two calculated masses with correct headings. Once **M**HCO_3 had been heated, it was no longer **FA 4** so 'mass of crucible, lid and **FA 4** after heating / g' was not credited. Some candidates either did not heat the crucible and contents a second time or omitted one of their balance readings. Some candidates confused the mass of residue with the mass lost. Only a few candidates reported impossible readings. Many of those completing the heating as instructed gained credit for accuracy.

(b) (i) There were many good responses, but few candidates noted that all the solid reacted or that a colourless solution was formed. Most candidates noted effervescence and tested for carbon dioxide successfully.

(ii) Many candidates correctly identified carbonate. However, there were some unexpected conclusions seen, such as ammonium and oxide. A few candidates concluded CO_2 instead of giving the ion from which the gas was formed.

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(iii) A large majority identified carbonate; fewer gave a correct equation. Many candidates denoted the solid product as **M**O, **M**O_2 or $\mathbf{M}_2O$ instead of $\mathbf{M}_2CO_3$. Some ignored the instruction to include state symbols in their balanced equation.

(iv) A few transcription or rounding errors were seen.

(v) Many candidates were successful in using their data from **(a)** and the stoichiometry from their equation to calculate the M_r of **M**HCO_3.

(vi) Better performing candidates compared the likely accuracy of the two procedures. Many answers were vague, e.g. 'titrations are more accurate', without an explanation of why this may be the case.

Question 3

Candidates should be reminded that the general instructions at the start of the section are there to help them provide full and accurate observations. Care is needed in clearly showing at what stage an observation is made.

(a) (i) Few candidates reported sufficient accurate observations. Many reported that the solid sublimed or described the process sufficiently well. Blue litmus will turn red when a gas is tested; this will not occur until after the red litmus has turned blue. This needed to be described clearly in the observations. A number of candidates reported effervescence or formation of a precipitate, neither of which were possible as no liquid was present.

(ii) The majority of candidates successfully concluded the ion present was NH_4^+, often from its odour rather than a successful litmus test. Some candidates were unable to gain credit as they included another ion, usually Cl^-, and a few candidates identified the ion as NH^{4+}.

(b) (i) Common errors included:

- incorrect colour of the precipitate on adding aqueous silver nitrate to **FA 7** and then giving the observation with aqueous ammonia that fitted the supposed halide
- reporting 'white solution formed' instead of a white precipitate
- not adding aqueous sodium hydroxide to excess after a precipitate was formed with **FA 8**
- reporting 'clear solution' in place of 'no visible reaction'
- not reporting bubbling on adding aluminium in **Test 3**
- reporting that a gas was given off upon heating the **FA 7** mixture in **Test 3** but not testing for it
- reporting the gas turned red litmus blue with **FA 8** in **Test 3**.

However, some candidates correctly noted the gas popped with a lighted splint in this last-mentioned test.

(ii) Many candidates correctly deduced the identities of **FA 7** and **FA 8**. Some candidates gave the names of the compounds instead of the <u>formulae</u> as instructed so could not access both marks.

(iii) Most candidates need to practise writing ionic equations. Many included spectator ions or ignored the instruction to include state symbols.

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Paper 9701/42
A Level Structured Questions

Key messages

- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be clearly crossed out and never overwritten with the new answer.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge. Cancellable species should be removed.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms.

General comments

Candidates who had prepared well for the examination were able to attempt all questions. Many candidates were able to work through to the end of the paper.

Comments on specific questions

Question 1

(a) Many candidates answered this well. Common errors were $3d^5 4s^2$ and $3d^4 4s^2$.

(b) This proved difficult for some candidates. Many did not use the $E^\ominus$ values and half-equations to make an accurate prediction. They needed to reverse the half-equation where oxidation occurs.

(c) This was generally well answered. Some observations suggested were too vague, for example 'a gas being formed' and 'water evaporating'.

(d) Candidates performed well on this question. Some did not state clearly that it is the increasing radius of the Group 2 metal **ion** leading to less polarisation of the nitrate **ion**. Some others suggested there was polarisation of the cation, or that polarisation was caused 'by the anion'.

Question 2

(a) (i) Many candidates completed this calculation successfully. Common errors involved omitting the multiplier with '496', use of the O–O bond energy instead of O=O and using the ionisation energy of oxygen.

(ii) Many correct answers were seen.

(iii) This was found to be difficult. It was common to see answers referring to 'greater lattice energy' rather than 'more exothermic lattice energy'. Many suggested that the ionic radii of Fe^{2+} was larger than Ca^{2+}.

(b) (i) Many candidates gave a correct definition of disproportionation but did not show how this reaction can be described as such.

(ii) Candidates did not perform well on this question. Most did not realise that the only ions present in this electrolysis are Fe^{2+}, Fe^{3+} and O^{2-}. Many other species were seen in the suggested equations.

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(iii) This was generally well answered. Some candidates found it difficult to derive and use the 3/8 ratio (as three moles of iron are produced when eight moles of electrons are passed). The M_r of Fe_3O_4 was used by some candidates instead of the A_r of Fe.

(c) (i) Many candidates gained credit; some just re-stated information given in the stem.

(ii) Many correct answers were seen.

(iii) Candidates often gave the correct answer here.

Question 3

(a) Most candidates found this question difficult. They did not appreciate that they needed to explain in terms of the three bonding regions and one lone pair around the iodine atom. Many focused on the oxygens and some gave an explanation leading to trigonal planar geometry.

(b) This was not well known. Common errors were NaIO or H_2 as products and giving an unbalanced equation.

(c) (i) Many candidates did not clearly link the $E^{\ominus}$ values to the separate reactions of H_2O_2 with IO_3^- and of H_2O_2 with I_2. Some candidates incorrectly included cancellable species in their equation.

(ii) This mark was rarely awarded. Many other incorrect species were seen such as IO_3^- and I_2.

(d) (i) Many candidates performed well on this question, clearly linking their reasoning to the chosen experiments to deduce the order. However, some did not choose suitable experiments in their reasoning to calculate the order.

(ii) Many candidates gave the correct answer. Some candidates omitted the rate constant.

(iii) Most candidates were able to do this correctly. Some ignored the instruction to use the results of experiment 4. Nearly all candidates used the correct representation for units.

(e) (i) This was generally well answered. A common error was to write an expression like an equilibrium constant with the concentration of the solid as the denominator.

(ii) Many correct answers were seen. Common errors included 7.17×10^{-5} [no $\div 4$] and 5.69×10^{-5} [$\div 2$].

(f) (i) Most candidates calculated the correct entropy change of reaction.

(ii) This proved difficult for many candidates. Some gave a clear explanation why the reaction is spontaneous. A common error was to omit ΔG in their explanation.

Question 4

(a) Many candidates understood the idea of a transition element, but some definitions lacked precision. A common example of imprecision in candidate's definitions was stating that a transition element 'is an element with an incomplete d sub-shell and forms one or more ions'.

(b) (i) Most candidates were able to give a suitable representation and gave two 3-2 splits. A common error was the same representation for both octahedral and tetrahedral complexes.

(ii) The majority of candidates were able to draw one suitable orbital. Some drawings of the higher-level orbital were the correct shape but along the wrong axis or axes.

(c) (i) This was found to be difficult. Many candidates did not choose suitable atoms that could form a dative covalent bond.

(ii) This was generally well answered. However, many explanations of colour were seen, rather than of colour difference. Most candidates stated that ΔE would change, however, often omitted that a different wavelength would be absorbed.

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(iii) This question was usually answered correctly.

(iv) This was often answered well. Common errors included putting ionic charges outside the final set of square brackets, e.g. $[Fe(H_2O)_6]^{3+}$ or $K_{stab} = [[Fe(edds)]^{-} / [Fe(H_2O)_6]^{3+}[edds]^{4-}$.

(v) Candidates performed well on this question. A number of candidates stated that 3.98×10^{20} was larger than 1.26×10^{25}.

(vi) Many candidates were able to evaluate this. Common errors were 3.16×10^{-5} and incorrect rounding of the final answer.

Question 5

(a) (i) This was generally well known. The best answers made it clear that the cisplatin binds to the DNA in the cells and that the consequence is that the cells involved are unable to undergo cell division. Some answers referred to preventing the spread of cancer, or the killing of tumour cells, which did not go far enough to gain credit.

(ii) Most candidates recognised square planar. Tetrahedral and octahedral were common incorrect answers.

(iii) This was rarely awarded. Candidates were unable to suggest a suitable explanation in terms of distance of the bonding oxygen atoms or resultant bond/angle strain.

(iv) Most candidates gave the correct answer. A common error was +2.

(b) (i) This answer was usually correct.

(ii) Common errors included:
- missing out one component in step 1, such as acidic or alkaline, or heat
- suggesting HCl or Cl_2 + AlCl_3 for step 2.

(iii) This was found to be very difficult by many candidates. Equations often had incorrect products or the need for two molecules of PCl_5 or SOCl_2 was often not appreciated.

(iv) Those who had learned the electrophilic substitution mechanism found this to be an accessible question. Common errors included:
- the curly arrow from the benzene ring did not go to the C atom
- the intermediate was drawn with a + charge within the ring and a + charge on the –COCl group
- the curly arrow in the intermediate started on the H not on the C–H bond
- H^+ ion was omitted with the product at the end of the mechanism.

Question 6

(a) Many candidates knew of the oxidative cleavage to ethanedioic acid but did not further oxidise this compound to CO_2 and water.

(b) (i) This was generally well answered.

(ii) Most candidates were able to draw the ester group from one of the monomers. Common errors included:
- omitting the C=C bond or displaying as a C-C bond
- omitting hydrogen atoms on the C=C bond
- omitting a carbon atom from the ethane-1,2-diol monomer.

(iii) This was well known.

(c) Most candidates were able to complete one correct stereoisomer. Common errors were placing two of the same group on one carbon or giving two identical stereoisomers.

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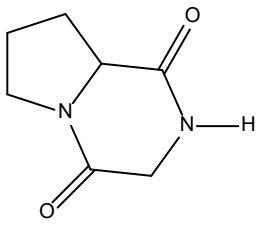
(d) Many good answers were seen. Some candidates showed no diagram or did not mention the active site of the enzyme.

Question 7

(a) (i) This was usually answered well. Some drew a cyclic compound rather than a dipeptide.

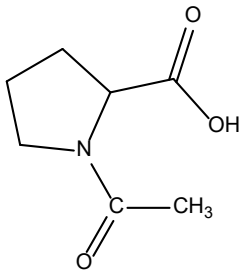


(ii) Most candidates answered this correctly.

(iii) This question discriminated well. Many candidates recognised that the poly(proline) structure had no H bonded to the N atom.

(b) (i) This question was generally answered well. The most common omission was H_2O.

(ii) This was found to be difficult. The most common mistake being a non-skeletal structure like the one shown.



(iii) This was well known.

(c) (i) Most candidates performed well here. Common errors were carboxylic acid and ketone. The use of 'cyano' alone was not sufficient.

(ii) Common errors included reduction and substitution.

(iii) Most candidates performed well here, normally with the off-specification $LiAlH_4$ rather than hydrogen and a catalyst. Some weaker responses gave ammonia.

(iv) This was found to be difficult. Common incorrect answers were hydrolysis and oxidation.

(v) This question discriminated well. The most common error was H_2O.

(vi) Many candidates found this question challenging. Common errors included:

- omitting the dipole for the C-Cl bond on **Z**
- not forming a bond between N and the correct C atom
- an incorrect intermediate structure
- omitting the lone pair on the N.

(vii) Most candidates answered this correctly.

(d) This was generally well answered. The most common error was five amino acids.

(e) (i) Candidates found it easier to draw the zwitterion than they did to explain how a zwitterion formed.

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(ii) Many candidates found this question challenging. There were some good answers. However, others did not use the information to deduce the resultant charge on the amino acids and thus did not relate this to the direction of movement.

(f) The best answers navigated through this calculation. Most responses gave initial amounts of the **ACES** salt and HC*l*. Only a few managed to then give the equilibrium amounts of **ACES** formed and the remaining **ACES** salt. A number of candidates correctly recalled the Henderson-Hasselbalch equation or used a correct K_a expression to $[H^+]$ then calculate the pH. A common error was reversing the [acid] and [salt] values in the final calculation.

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Paper 9701/52
Planning, Analysis and Evaluation

Key messages

- Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus. Many candidates appeared to be unfamiliar with simple A level and AS level techniques seen in the thermochemistry experiment in **Question 1**, the manganate(VII) titration in **Question 2** and weighing techniques seen in **Question 2(d)**.

- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures. One significant figure will usually be insufficient at A level.

- Diagrams should be labelled and should be simple 2D ones rather than 3D 'pictures'.

General comments

In general, many candidates were under-prepared for this exam.

In calculation work, candidates should be encouraged to show full working and in multi-step calculations, they should avoid early rounding as this invariably produces an incorrect final answer.

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

Comments on specific questions

Question 1

(a) Very few candidates were able to pick up that as the values in the table were given as either a whole number or to 0.5 °C then the graduations must be 1 °C to allow for ½ grades (i.e. 0.5 °C) to be used.

A significant number misunderstood this question and wrote answers such as 0 to 100 °C or irrelevant comments such as '*stop stirring the mixture*'.

(b) This question asked for a labelled diagram. It was expected that a (labelled) thermometer, free to use as a stirrer, was drawn with its bulb clearly immersed into the solution below. Clamped thermometers were allowed as the mixture could still be stirred but apparatus which included a bung (with the thermometer set within the bung) were not given credit as the thermometer could not be used as a stirrer.

The solution should be **labelled** as aqueous copper(II) sulfate and a suitable **labelled** container should be used. Ideally, the container should be insulated. For common A level experiments such as this, it was expected that candidates would not use test-tubes as the container.

Many candidates included zinc within the solution. This was incorrect as zinc was not added until four minutes.

Some candidates were completely unfamiliar with this type of experiment and thought the apparatus should be heated.

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(c) Nearly all candidates plotted the points correctly; relatively few followed the instructions and drew a cooling curve back to four minutes. This suggested the idea of using cooling curves to determine the theoretical maximum temperature change was not well known.

Most answers incorrectly included a line which went through the point at 4½ minutes.

Of those candidates who drew a line of best fit which crossed the four-minute line at a suitable temperature (42.0 °C to 44.0 °C) many erroneously subtracted the final temperature reading (31 °C) from the temperature value at four minutes and consequently many answers in the range 11 °C to 13 °C were seen.

(d) This straightforward AS-style calculation involved two steps. Firstly, an application of $mc\Delta T$ to determine the energy output of this particular reaction. Then, scaling up from the number of moles of $CuSO_4$ used to give a molar enthalpy change in kJ mol^{-1}.

The first part was frequently incorrectly done. Common errors were: 'converting' ΔT values from °C to K by adding 273 to ΔT, using a value of 1 g for mass, using a different ΔT to that determined in **(c)**.

Most candidates neglected to attempt the second part having satisfied themselves that conversion of $mc\Delta T$ from J to kJ was sufficient.

(e) (i) Most candidates were aware that doubling the mass of zinc would have no effect as zinc would still be in excess.

(ii) Many candidates realised that more heat would be lost but did not explain that this would be as a result of increased energy generated by more moles of $CuSO_4$ reacting. Many simply stated 'it was because the $CuSO_4$ is more concentrated'.

Many candidates opted to give an increased rate of reaction making the mixture become hotter thus losing more heat but in doing so they did not realise that the reason a quick reaction gets hotter is that it has less time to lose heat.

(iii) Very few candidates gave the expected answer. Most were oblivious to the idea that although double the energy would be generated, twice the mass of water would absorb this doubled energy, keeping the overall temperature increase, and therefore heat loss, constant.

Question 2

(a) Most candidates performed well on this question. The common omission was rinsing of the beaker and adding the washings to the volumetric flask. Many weaker responses chose the wrong container to make up a standard solution. Round-bottomed flasks, conical flasks and even beakers were offered as suitable vessels.

(b) (i) This finer point of titration was not known. Hardly any candidates knew that a pipette is designed so a small volume of solution should remain in the tip. This volume equates to the volume above the meniscus when at the 25 cm^3 mark and by remaining in the pipette, ensures that exactly 25.0 cm^3 of solution is transferred.

(ii) The idea that a measuring cylinder was the most appropriate apparatus to measure an excess volume was known by most candidates. Many jeopardised their answer by giving two answers. Burette or pipette were not uncommon responses.

(iii) It was apparent that manganate(VII) titrations were unfamiliar to candidates and few realised that the meniscus of dark solutions such as manganate(VII) are difficult to read and it is easier if a mark other than 0.00 cm^3 is used as a starting value.

(iv) Better responses knew that concordant readings are those within 0.10 cm^3 of each other. They do not need to be identical.

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(v) The lack of familiarity with manganate(VII) titrations meant many candidates were unable to give the colour change at the end-point.

(vi) Many candidates performed well in this typical titration calculation.

Weaker responses assumed it was an acid–base reaction and used 24.40 cm^3 as a volume of acid and went on to determine the number of moles of H^+ ions in solution **A**, a calculation which involved a reaction ratio of 5:16.

(c) (i) Many candidates gave an acid such as HC*l* or H_2SO_4 to titrate against the acid salt. Better responses realised an alkali was needed.

(ii) This calculation was challenging. It was expected that given the concentration of the H^+ ions in mol dm^{-3}, the candidates would determine the number of moles of H^+ ions in 250 cm^3 of solution by simply dividing by 4. Thus, the ratio of H^+ to $C_2O_4^{2-}$ in the solution could then be determined. This leads to a simple sum to determine the relative number of K^+ ions present.

A common error was to determine the inverse ratio of H^+ to $C_2O_4^{2-}$ in the solution. Many candidates did not give the answer to two decimal places. And many others rounded too early in the calculation and 0.01525 appeared as 0.015.

(iii) Most candidates were unable to determine a molar mass from the mass of crystals as they did not realise that the mass used (1.89 g) equated to the number of moles used (0.0122 – the answer to **(b)(vi)**).

Some candidates determined the molar mass of the anhydrous salt using values of a and b from **(c)(ii)**.

Some candidates did not read the instructions and the number of waters of crystallisations was not given to the nearest whole number.

(d) Inexperience of taking weighing measurements was evident here. A large majority of the candidates omitted to include the mass of the empty crucible as a reading. Only the very best responses indicated a second heating would be needed to ensure constant mass had been achieved.