CHEMISTRY

Paper 9701/11
Multiple Choice

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

General Comments

This examination paper provided a difficult challenge to the candidates with many pleasing performances.

Sixteen questions can be said to have been found to be easier. 50% or more of candidates chose the correct responses to each of **Questions 4, 7, 10, 11, 12, 16, 17, 19, 20, 21, 22, 23, 24, 27, 28,** and **32**.

Six questions can be said to have been found to be particularly difficult. Fewer than 31% of candidates chose the correct responses to each of **Questions 2, 15, 29, 31, 33** and **40**.

Comments on Specific Questions

Question 2

26% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answers were **A**, chosen by 30% of candidates, and **C**, chosen by 33% of candidates. This question requires candidates to insert the data in the question into $pV=nRT$, and then to rearrange the expression to find T. Answer **A** arises if candidates do not appreciate that iodine vapour consists of I_2, with an M_r of 254. Answer **C** arises if candidates do not convert the volume 1.247 dm^3 into 1.247×10^{-3} m^3.

Question 15

30% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 39% of candidates. Although calcium is directly below magnesium in the Periodic Table it does not burn with a purely white flame. The flame seen when calcium burns is red.

Question 29

9% of candidates chose the correct answer, **C**. Choices **A**, **B** and **D** were each chosen by an approximately equal number of candidates. It was hoped that candidates would draw structures on their examination paper to help them and ideally these would have been skeletal formulae. This exercise probably produces four diagrams which can be called “cis-cis”, “cis-trans”, “trans-cis”, and “trans-trans”. However it can be seen that the “cis-trans” and “trans-cis” diagrams actually represent the same structure. Therefore, hex-2,4-diene has three geometrical isomers.

Question 31

28% of candidates chose the correct answer, **C**. Choices **A**, **B** and **D** were each chosen by an approximately equal number of candidates. The only reasonable structure for N_2F_4 is $F_2N\text{-}NF_2$. The reaction is therefore $N_2F_4 \rightarrow 2NF_2$ and it involves the breaking of the N-N bond. Statement 1 is therefore false. Statement 2 can be verified in the *Data Booklet*. Statement 3 can be verified with the help of a ‘dot-and-cross’ diagram.

Question 33

27% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **A**, chosen by 31% of candidates. Statement 1 is true; the activation energy of a chemical reaction has an effect on the reaction rate. Statement 2 is false; the size of the enthalpy change does not affect the reaction rate. Statement 3 is false; an equilibrium constant is a calculated value based on experimental observations made under certain conditions, it is not a “factor” that influences other properties.

Question 40

28% of candidates chose the correct answer, **A**. Choices **B**, **C** and **D** were each chosen by an approximately equal number of candidates. The three alcohols given are isomeric so 74.00 g is 1.00 mol in each case. The question therefore rests on whether the given mass represents 0.62 mol of the given product. Since this *is* true for choices 1, 2 and 3 the answer is **A**.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General Comments

This examination paper provided a suitable challenge to the candidates with many pleasing performances.

Thirteen questions can be said to have been found to be easier. 65% or more of candidates chose the correct responses to each of **Questions 2, 5, 6, 7, 8, 16, 17, 18, 22, 23, 26, 29** and **33**. Six questions can be said to have been found to be particularly difficult. Fewer than 36% of candidates chose the correct responses to each of **Questions 9, 11, 12, 25, 35** and **39**.

Comments on Specific Questions

Question 9

33% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 30% of candidates. After writing a balanced chemical equation candidates should have realised that 0.1 mol of propan-1-ol reacts with 0.45 mol of oxygen. The product mixture therefore includes 0.05 mol of unreacted oxygen and 0.3 mol of carbon dioxide, which occupies 8.4 dm^3 under room conditions. Candidates choosing **A** possibly did not consider the unreacted oxygen.

Question 11

32% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 45% of candidates. It was hoped that the candidates would sketch an appropriate Hess' law cycle on their examination paper. The answer **C** arises if the Hess' Law cycle is incorrectly labelled with the $\Delta H^{\ominus}_f$ of cyclopropane as -53.3 kJ mol^{-1}.

Question 12

35% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 37% of candidates. Although barium is in the same group as magnesium in the Periodic Table it does not burn with a purely white flame. The flame seen when barium burns is green.

Question 25

32% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 29% of candidates. Statement **C** is the only false statement – the burning of PVC will *not* produce a "significant amount" of ethene.

Question 35

34% of candidates chose the correct answer, **D**. Choices **A**, **B** and **C** were chosen in approximately equal amounts. The syllabus asks candidates to "explain the reactions of halide ions with aqueous silver ions followed by aqueous ammonia". In the reaction of $AgCl$ with aqueous ammonia a complex is formed, so statement 1 is correct. Ammonia molecules do not accept H^+ ions so statement 2 is incorrect. No redox reaction occurs so statement 3 is incorrect.

Question 39

27% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 45% of candidates. The majority of candidates therefore appreciated that statement 1 is correct, and statement 3 is incorrect. Therefore the question rested on the truth, or otherwise, of statement 2. Statement 2 refers to the reaction between hexane and bromine "under suitable conditions". In the presence of ultraviolet light or at high temperatures the reaction $C_6H_{12} + Br_2 \rightarrow C_6H_{11}Br + HBr$ will occur. Bromine is being reduced from 0 to -1, so this is a redox reaction, and statement 2 is correct.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General Comments

This examination paper provided a suitable challenge to the candidates with some pleasing performances.

Ten questions can be said to have been found to be easier. 70% or more of candidates chose the correct responses to each of questions **4**, **6**, **7**, **8**, **16**, **22**, **23**, **31**, **32** and **36**. Six questions can be said to have been found to be particularly difficult. Fewer than 43% of candidates chose the correct responses to each of questions **17**, **20**, **21**, **26**, **35** and **37**.

Comments on Specific Questions

Question 17

15% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 46% of candidates. Chlorine will react with an excess of hot NaOH(aq) to form $NaClO_3$. The equation is $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$. Therefore 0.6 moles of Cl_2 gives 0.2 moles of $NaClO_3$ which has a mass of 21.3 g. Candidates who chose **B** may have done so assuming the product was $NaClO$.

Question 20

42% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 34% of candidates. Candidates are encouraged to draw out the formula given on their question paper to enable them to see the residue of butane-1,4-dioic acid in the centre of the molecule.

Question 21

41% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 48% of candidates. In the free radical substitution reaction between ethane and chlorine a number of radicals are formed, including $C_2H_5\bullet$, ethyl radicals. Two ethyl radicals can join together to form a molecule of butane, hence the answer **C**. Answer **A**, CH_3Cl, would only be correct if C-C bonds were broken in the reaction which does not happen.

Question 26

33% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **C**, chosen by 54% of candidates. **A** is correct because H_2 + Ni will reduce an alkene to an alkane and will also reduce an aldehyde to a primary alcohol. **C** is incorrect because $NaBH_4$ will reduce an aldehyde to a primary alcohol, but it is not capable of the reduction of an alkene to an alkane.

Question 35

40% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 30% of candidates. It can be inferred from this that for many candidates the choice of answer rested on the truth, or otherwise, of statement 2. Statement 2 is correct. The conversion of alcohols to acids is an oxidation reaction, since SO_2 is a reducing agent and an anti-oxidant it will help to prevent these reactions. SO_2 also helps to inhibit microbial growth, this will also contribute to the prevention of the oxidation of alcohols to acids.

Question 37

40% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 30% of candidates. It can be inferred from this that for many candidates the choice of answer rested on the truth, or otherwise, of statement 1. Statement 1 is incorrect. If 2,4-dinitrophenylhydrazine is added to propanal, the familiar reaction, giving an orange crystalline product, takes place at room temperature and no heating is required.

CHEMISTRY

Paper 9701/21
AS Structured Questions

Key Messages

Candidates should be reminded to read questions carefully and check their answers thoroughly.

Candidates ought to be clear about the transition of physical and chemical properties of elements/compounds across Period 3, and should be particularly careful in their use of chemical terminology, e.g. ions as opposed to molecules. Careful attention is also required with respect to organic reactions and mechanisms, where small slips can often invalidate answers.

Candidates should also be reminded that all working in calculations should be shown to ensure that due credit can be awarded.

General Comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. Careful reading of questions would have been of particular benefit in **Question 3(a)**, where the identity of atoms and ions were tested, with accompanying balanced equations. **Question 4(b)** highlighted the same issue.

Comments on Specific Questions

Question 1

This question combined an assessment of candidates' knowledge of atomic structure with some Period 3 Chemistry. There were good answers to **(a)**, **(b)** and **(e)**, although **(c)** and **(d)** were less well answered; many candidates struggled with the calculation of A_r and with the identification of the differing behaviour of the chlorides of sodium and silicon.

(a) Most candidates were able to identify the loss of an electron as a process of ionisation, but references to a molar enthalpy and gas-phase species were less frequently given.

(b) (i) The group to which **A** belongs was frequently correctly identified, but the accompanying explanation sometimes lacked a clarity of expression that would have correctly highlighted the large difference between the fifth and sixth ionisation energies.

(ii) This part was generally well answered, although some candidates incorrectly gave electronic configurations for atoms in Period 3.

(c) (i) Candidates' recall of this definition was not particularly secure, and the choice of terminology undermined some answers. Many wrote correctly of an average mass, but then did not relate that either to atoms of an element, nor make mention of the carbon-12 scale.

(ii) A number of different methods were employed here to good effect. Common errors included omitting to count <u>two</u> chloride ions in the compound and not giving answers to three significant figures. A significant number of candidates incorrectly attempted the calculation by pre-determining the element they guessed Z to be.

(d) (i) Candidates were often able to correctly identify the reaction(s) between $SiCl_4$ and water, but many suggested that $NaCl$ is hydrolysed to give $NaOH$ and HCl.

(ii) Following from **(d)(i)**, some candidates were unable to score credit in this part. Reference was required both to the structure and bonding of the compounds; many answers referred to $SiCl_4$ as being giant covalent.

(e) This question was generally answered well.

Question 2

This question was generally answered well, although the latter parts of **(b)** elicited guesses about the value of *x*, which then led to circular calculations being performed.

(a) (i) Candidates' attention should be drawn to the wording of the question, which asks for the meaning of *oxidise* in the context of the statement, not for a definition of oxidation.

(ii) A large variety of answers were observed here.

(b) (i) There were many correct answers given to this part.

(ii) There were many correct answers given to this part.

(iii) Many candidates did not use their answer to **(ii)** in the calculation, opting instead to use a constructed answer from **(iv)**.

(iv) Where candidates had not managed to obtain a correct answer to **(iii)**, the value of *x* was guessed (often as 1), incorrectly to derive $M_r = 151.8$.

(v) Candidates who had followed **(i)** to **(iv)** correctly answered this well; others ended up performing circular calculations for which credit could not be awarded.

Question 3

Part **(b)** of this question was largely answered well, whereas very few candidates secured full credit in any of the three parts of **(a)**, perhaps revealing a lack of knowledge of the properties and reactions of group 7 elements and compounds.

(a) (i) **K** was rarely correctly identified as chloride, although many candidates were awarded credit for their equation (common errors included a lack of balancing and/or the use of $NaSO_4$ as a wrong formula) and explanation.

(ii) Neither Iodide, I^-, nor the colour of its precipitate with silver, were rarely correctly identified, but candidates tended to give the equations successfully.

(iii) This question was correctly answered by many candidates, although many also omitted to give reference to the number of electrons and the intermolecular forces involved.

(b) (i) Many candidates answered this question very well. There was some confusion observed between the products at the anode and cathode.

(ii) There were many correct answers seen for this part. Near-correct answers were often let down by the lack of balancing or the misplacement of electrons.

Question 4

This question tested a wide range of topics within organic chemistry. Candidates' recall of conditions and mechanism names was good, but answers often lacked further depth.

(a) Many answers contradicted the question stem by stating that alkanes do not react with bromine, and were unable, therefore, to gain credit for highlighting the (reasons for) different conditions required for reaction.

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

(ii) This question was answered well.

(iii) This question was not generally answered well. Many candidates omitted some/all of the three necessary pieces of information: that it was a termination step within the bromination of ethane, producing a hydrocarbon.

(iv) Again, candidates' knowledge of free-radical mechanisms was poor. Only the most able candidates scored credit here.

(c) (i) This question was answered well.

(ii) Most candidates scored some credit here. Common errors included an incorrectly displayed dipole on Br—Br and imprecisely drawn curly arrows, both in the reactants and from the lone pair of Br^- to the carbocation intermediate.

(d) This question was answered well, although some candidates drew too many chlorine substituents, or opted to draw a hexane derivative rather than a polymer.

(e) (i) The identification of NaOH (or KOH) as the reagent was generally given correctly. The need for alcoholic conditions for heat/reflux was often omitted as a second piece of information.

(ii) Although many candidates were awarded credit for this, the skeletal representation of ethanol was generally poor. Candidates should be reminded to draw full-length bonds at 120° where possible.

(iii) Only the most able candidates scored well here. The most common error with the displayed formula was to not show the cyanide/nitrile group fully (—C≡N). Contractions of the name propanenitrile, e.g. "propanitrile", often invalidated the answer.

CHEMISTRY

Paper 9701/22
AS Structured Questions

Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly. In this paper, candidates would have benefitted from this particularly in **Question 1(d)(i)**, where answers included unbalanced equations or, in some cases, no equations at all; **Question 4(c)(i)**, where there was often a propagation equation given involving methane, rather than ethane as asked; and in **Questions 5(a)(ii)** and **5(a)(iii)** where skeletal formulae were specifically required.

Candidates need to ensure that any equations given are balanced and are also reminded that their working in calculations should be shown to ensure that due credit can be awarded.

Candidates are recommended to make sure that keywords and definitions are learnt thoroughly; not only so that questions such as **1(b)(i)** can be answered correctly, but also so that the correct basic principles of chemistry can be applied. This is especially true when explaining ideas such as trends in ionisation energies and melting points.

General Comments

This paper tested a range of recall and application skills from across the AS syllabus and discriminated effectively between candidates from across the ability range. There were, however, some recurrent weaknesses which candidates would be well-advised to address. These include providing correctly linked explanations of phenomena, such as in **Question 3**, where candidates needed to link their explanations of melting point trends to the nature and size of the forces involved.

Comments on Specific Questions

Question 1

This question covered some basic recall questions on atomic structure and inorganic chemistry together with some calculations related to atomic mass and empirical formulae.

(a) Most candidates answered this question correctly and it serves as an early illustration of the importance of precisely learning keywords and definitions. In particular, it should be noted that the phrase “in an element” is incorrect in this context and does **not** mean the same thing as “in an atom”.

(b) (i) Very few candidates scored well in this question although most were able to earn some credit. There was confusion with the idea of *relative atomic mass*, which is an **average** of the isotopic masses, and *relative isotopic mass,* where there should be no mention of average.

(ii) Again, very few candidates received full credit. The most frequent error was for candidates to use 79 and 81 as the isotopic masses, which still allowed some credit to be awarded. This error follows from the common confusion between the concepts of mass / nucleon number and isotopic mass which are often, incorrectly, seen as the same thing.

(c) Often candidates are required to calculate empirical formulae from percentage composition data and atomic masses but, in this question, the inversion of the more familiar calculation seemed to cause difficulties for many candidates. Some candidates also did not give their answer to three significant figures.

(d) (i) Quite a number of candidates did not correctly balance their equations with $Mg + O_2 \rightarrow MgO$ seen quite frequently. In the descriptions, a common error was to refer to the white solid formed in the reaction between magnesium and oxygen as a "precipitate"; this is a term that should only be used to describe a solid formed on mixing two solutions, or when a gas is bubbled through a solution.

(ii) This proved to be one of the questions on the paper which candidates found particularly difficult. A frequent reason for candidates scoring poorly was not balancing the equations correctly or lack of knowledge of the aluminate ion (AlO_2^- or $[Al(OH)_4]^-$).

(e) Learning shapes and associated bond angles seems to be another area where more attention is needed by candidates. Only a minority of candidates gained full credit for this question.

Question 2

This question involved further equation balancing, this time in a redox context, and a calculation based on titration data. Overall, it proved to be the best attempted question on the paper with many candidates gaining full credit. However, a significant number of candidates failed to gain credit in **(a)(ii)**, again indicating issues with balancing of equations.

(a) (i) Most candidates were able to answer this question using a simple definition of oxidation. An ideal answer here, given the context of the question, would have referred to the role of the manganate(VII) as an oxidising agent.

(ii) This proved to be one of the hardest parts of a question for candidates. Specific recall of the use of manganate(VII) as an oxidising agent (and the formation of Mn^{2+} in the process) was not necessarily required as the product could have been worked out by balancing the electron transfer.

(b) This was well answered by many candidates although some candidates who began the question well assumed that they knew the molecular mass in **(b)(iii)**, instead of using their answer from **(b)(ii)**.

Question 3

This question involved producing explanations for melting points and for the relative magnitudes of ionisation energies. It proved to be a difficult question for many candidates and illustrated the importance of careful reading of the question in order to decide on the relevant factors to be described in each part.

(a) (i) It is important for candidates to take note of the number of marks available in a question of this nature as an aid to deciding how much detail is needed in the response. In general, any question involving a comparison of melting points involves: identifying the nature of the attractive force or forces involved, in this case metallic bonding as all three elements are metals; stating that the pattern of increasing melting points is due to the increasing strength of the attractive force; and finally, explaining the underlying reason, in this case either increasing charge density of the cation from Na^+ to Al^{3+} or increasing number of delocalised electrons. A significant number of answers showed confusion between different bond types with contradictory references to ionic bonding and/or intermolecular forces, while others failed to gain credit through vague explanations rather than specific, clear references.

(ii) A very similar approach was needed here to **(a)(i)** with the difference being that the forces involved in this case were van der Waals' forces.

(iii) This question was generally well answered by candidates.

(b) (i) This proved to be one of the most difficult parts of a question on the paper and candidates must remember that any question about relative ionisation energies across a period or down a group must refer to both relevant factors, namely nuclear charge **and** shielding. Across a period, the general increase is explained by the increasing nuclear charge with no increase in shielding, since successive electrons are added to the same shell; whereas down a group, despite the increasing nuclear charge, the ionisation energies decrease as a result of increasing shielding and/or distance from nucleus. It is never sufficient simply to state that an ionisation energy is greater in one case than another due to greater "stability" and there is a common misconception that a full or half-full shell is somehow "more stable" than other configurations. Such a statement does not constitute an explanation.

(ii) This question was much better answered than **(b)(i)** but care is needed not to refer incorrectly to a "p shell" rather than "p sub-shell".

(iii) It is recommended that candidates note down electronic configurations, even when they are not specifically asked for, as such a visual aid makes it much easier to produce a written description. In this case, what was needed was a clear statement of the existence of repulsion between a pair of electrons in the same orbital in sulfur.

Question 4

This question focused on hydrocarbons and included a mechanism section.

(a) Most candidates answered this question correctly some candidates got the ideas of physical and chemical processes the wrong way round.

(b) (i) Too many answers focused on what an alkane does **not** have (a double bond) rather than taking the required approach of describing the high bond energy and non-polarity of alkanes.

(b) (i)(ii) Fewer candidates than expected were able to recall or deduce these angles and names.

(iv) This proved to be a very challenging question for candidates with many answers lacking specific detail on the actual numbers of each type of bond, making it difficult to award credit.

(c) (i) This question is another example of the importance of thorough learning of key principles. Mechanisms and their associated conventions must be committed to memory in full detail. Candidates should be aware that written details are not required when a mechanism is asked for as, when correctly used, the conventional abbreviations and equations communicate all necessary information.

(ii) Many candidates did not read the question carefully and did not show the formation of butane.

Question 5

This question focused on organic reactions as an aid to compound identification and included the need to apply naming conventions and ideas related to isomerism.

(a) (i) Candidates must remember that when a question asks for an explanation of observations it is important that each stage in the sequence described is related to the specific conclusion that can be drawn from it. In this case, decolourisation of bromine revealed the presence of C=C; reaction with manganate(VII) to form a single organic product revealed symmetry around the C=C moiety or the presence of a terminal $=CH_2$; reaction with DNPH indicated a carbonyl group; and lack of reaction with Tollens' reagent confirmed a ketone. Many candidates incorrectly answered that carboxylic acids give a positive result with DNPH and / or thought that aldehydes show no reaction with Tollens' reagent.

(ii) A key aspect of a sequential question such as this is the need for candidates to show continuity in their responses; here many candidates had indicated in **(a)(i)** that **P** was an alkene but then ignored that fact in suggesting its structure and name. The skill of correctly naming organic compounds is also a key one and candidates must remember the need for a locant to indicate the position of a double bond in a chain.

(iii) Here again many candidates forgot the continuity of the question and, having identified **Q** as a ketone in **(a)(i)**, subsequently suggested structures that were not ketones.

(b) The majority of candidates received full credit in this question but the commonest mistake was to suggest the same structure more than once, or to suggest that two different stereoisomers were different structural isomers. For example, the cis- and trans-forms of hex-3-ene were drawn by many candidates who did not realise that they do not constitute two different structural formulae.

CHEMISTRY

Paper 9701/23
AS Structured Questions

Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly. In this paper, candidates would have benefitted from this particularly in **Question 1(c)**, where there was often a lack of continuity between the answers offered; **Question 3(a)(ii)**, where answers included unbalanced equations; and in **Question 4(e)(ii)**, where specific guidance was given as to the features to be included in the mechanism.

Candidates need to ensure that any equations given are balanced and are also reminded that their working in calculations should be shown to ensure that due credit can be awarded.

Candidates are recommended to make sure that keywords and definitions are learnt thoroughly; not only so that questions such as **1(a)** can be answered correctly but also so that the correct basic principles of chemistry can be applied. This is especially true when explaining ideas such as trends in physical and chemical properties.

General Comments

This paper tested a range of recall and application skills from across the AS syllabus and discriminated effectively between candidates from across the ability range. There were, however, some recurrent weaknesses which candidates would be well-advised to address. These include areas such as organic nomenclature, for example in **Question 1(c)**; and characteristic reactions of particular elements, for example in **Question 4**, where the recall of halogen / halide reactions was expected.

Comments on Specific Questions

Question 1

This question included a definition, a calculation sequence and some organic reactions.

(a) This was one of the most poorly answered questions on the paper and highlights the importance of candidates thoroughly learning keywords and definitions.

(b) (i) More than half of candidates gained full credit here.

(ii) Full credit was obtained by the majority of candidates. The nature of many of the incorrect responses, which did not fully take into account information provided by the question, reinforces the importance of reading all the information given before attempting an answer.

(iii)–(v) Calculating the volume of oxygen used up was not well attempted by many candidates but most were able to earn credit in **(b)(iv)** and **(b)(v)** as errors were carried forward ("ecf") from the earlier sections of the question.

(c) (i) It is recommended that candidates plan their answers to sequential questions such as this, perhaps using a rough flow diagram so that the relationships between the different compounds can be seen. This should reduce the lack of continuity in some candidates' answers. For example, in this case, a significant number of candidates offered a primary halogenoalkane as their answer for **X** and then a secondary or tertiary alcohol as their answer for **Z**.

(ii) A large number of candidates produced a response containing the mnemonic “the strong get stronger” but it should be remembered that this is only an aid to remembering the outcome of this reaction and does not actually constitute an explanation of why it happens. To gain full credit for this question, a clear reference to the greater stability of the tertiary carbocation or to the inductive effect of three (rather than one) alkyl groups was needed, but was not offered by many candidates.

Question 2

This proved to be by far the easiest question on this paper although there were again some problems with a lack of continuity between the answers offered by candidates. For example, in **(b)(ii)** candidates were told that the amount of NaOH calculated was equal to the amount of HC*l* left in excess, but many were unable to use this idea to calculate the answer to **(b)(iii)**.

Question 3

This question involved some introductory questions on atmospheric chemistry followed by calculations based on a gaseous equilibrium.

(a) (i) Very few candidates offered the expected answers of lightning, causing reaction between atmospheric nitrogen and oxygen, and car engines, where the high temperature causes some reaction between nitrogen and oxygen.

(ii) This equation was not well remembered by candidates and was poorly attempted. Many candidates offered $NO_2 + H_2O \rightarrow HNO_3$ despite this equation being unbalanced.

(iii) By contrast, this question was much better attempted and most candidates were able to earn credit for $SO_3 + H_2O \rightarrow H_2SO_4$. Fewer candidates were able to include both the other equations required.

(b) (i) Most candidates used the correct powers and terms in the relationship. However, many candidates did not finally gain credit as a result of including square brackets, which should only be used in an expression for K_c and never in an expression for K_p.

(ii) The key in questions of this type is to remember that there are potentially three quantitative pieces of information about each species in the equation: initial amounts, final amounts and the amounts reacting or being produced. Crucially, the stoichiometric ratio shown in the equation only applies to the last of these. In this case initial amount of N_2O_4 is 2.00 mol, initial amount of NO_2 is 0.00 mol, and final amount of N_2O_4 is 1.84 mol. From this it can be deduced that 0.16 mol of N_2O_4 has reacted during the reaction. As the ratio of NO_2:N_2O_4 is 2:1, the amount of NO_2 produced is twice this, i.e. 0.32 mol.

(iii) Candidates should remember that, despite being called a “mole fraction”, the conventional way of presenting this information is as a decimal, rounded to an appropriate number of significant figures; in this case the expected answers were therefore 0.852 (or 0.85) and 0.148 (or 0.15).

(iv)(v) Given the possibility of carrying errors forward, most candidates were able to earn credit in these sections. Candidates must be alert for any instruction to give an answer to a specific number of significant figures.

Question 4

This question focused on halogen chemistry both from the point of view of Group VII and halogenoalkanes.

(a) (i) There was evidence of confusion here with some candidates discussing the trend in reactivity of the hydrogen halides instead of the reactivity of the halogens themselves. Despite this, the majority of candidates was able to earn credit for stating that reactivity decreases down the group.

(ii) Most candidates earned some credit here for a correct reference either to the halogen-halogen bond strength **or** to the halogen-hydrogen bond strength, but very few were able to combine the two ideas into a coherent argument for full credit.

(b) (i) This was correctly answered by the vast majority of candidates.

(ii) Very few candidates were able to offer an adequate explanation for using a different preparation method.

(iii) Following on from **(b)(ii)**, this proved to be one of the most challenging questions on the paper for candidates as the oxidation of the halide ion by concentrated sulfuric acid was not well remembered.

(c) (i) It was pleasing to see that this question was one of the best answered on the paper. Most candidates avoided drawing the same structure twice.

(ii) Naming caused difficulties for many candidates. There was also a lot of variation in the manner of drawing three-dimensional structures. To be sure of communicating the correct idea, candidates should use the conventional approach illustrated in section 10.1 of the syllabus.

(d) This proved a difficult question for many candidates. Some candidates were able to earn credit for appreciating that the precipitate was due to halide ions liberated from the halogenoalkane, but very few were able to explain the order of appearance of the precipitates in terms of the trend in carbon-halogen bond strengths.

(e) (i) This question was mostly well answered by candidates.

(ii) The conventional representations of the principle organic reaction mechanisms must be learnt thoroughly and, unfortunately, few candidates seemed to have done so in the case of nucleophilic substitution. Candidates should remember that a curly arrow will always begin either at a lone pair or at a line representing a bond.

(f) (i)(ii) Recall of these ideas related to atmospheric chemistry was generally good.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key Messages

- Candidates should practise reading scales on apparatus to an appropriate level of precision. The data should then be recorded to reflect this precision.
- Candidates should practise recording errors and improvements in their quantitative lab work carried out over the whole course.
- Candidates should be careful to obey instructions given in the exam paper, to quote answers to an appropriate number of significant figures and to be careful to round these answers correctly.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General comments

The Examiners thank Supervisors at Centres who supplied experimental data for **Questions 1** and **2** for each Session/Laboratory. 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 examination paper with the Supervisor’s experimental results.

If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor’s results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

The majority of the candidates successfully completed the practical work and were able to gain credit both for accuracy and in the calculation.

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. A significant minority of candidates did not record accurate burette readings to 0.05 cm^3 and lost the credit available for concordant titres by carrying out further titrations that were more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3. Many candidates completed the titration well and so gained full credit for accuracy.

As in most titration questions set, the quantities given were intended to produce titre values that were in the mid-range of the burette. Some Centres recorded Supervisor values that were very small (less than a few cm^3) and others recorded values that meant that the burette would have had to be refilled. In either case the Centre should check the chemicals used, since very small or very large titres can make it difficult for candidates to access the credit available for accuracy.

(b) The majority of candidates calculated a suitable value for the volume of **FA 1** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to two decimal places.

(c) Most candidates correctly calculated the number of moles of potassium manganate(VII) in **(i)** and many then went on to use the stoichiometry of the equation to find the concentration of the hydrogen peroxide in **(iii)**. Even less able candidates could write an equation for the decomposition of hydrogen peroxide in **(iv)**, but only the most able could interpret the information on 'volume strength' to correctly complete **(v)**.

Question 2

(a) Most candidates drew a table and successfully carried out the practical to record reaction times. A small number, however, did not include all the required volumes of solutions used and a significant number did not, as given in the instructions, 'record this reaction time to **the nearest second**'. In this case rates quoted to two or three significant figures were accepted but a number who had clearly calculated the value could not be awarded credit when they rounded their answers incorrectly.

(b) It was not necessary to attempt to quote the exact mathematical relationship between 'rate of reaction' and concentration, but answers had to make it clear in which direction the effect of changing the concentration affected the rate.

(c) This part was not well answered with only the most able candidates gaining credit. Since the question asked for the effect of changing the concentration of potassium iodide it was the volume of **FA 4** that had to be altered. Many candidates recognised this but few also recognised that the total volume of solution must be kept constant so that the volume of **FA 4** used had to be less than $20\,cm^3$.

(d) Acceptable responses to questions asking about errors and improvements must be specific to the actual example. Some responses clearly recognised a problem, but the suggested solutions were too imprecise. Examples of this include the idea that changing the temperature would have an effect and then trying to correct this problem by keeping it constant without specifying a practical method, such as a water bath, for actually doing so.

(e) (i) Many candidates correctly calculated the percentage error using the expression 1/time from **Experiment 1**.

(ii) This was less well done since a number of candidates assumed that, as the concentration increased, the rate would be higher and the time less. However, since the colour change occurred when all the thiosulfate had been used up, a higher concentration actually meant that the reaction time was greater.

Question 3

Although many candidates gained the majority of the available credit, some ignored the instruction to give the full name or formula of any reagent selected for a test. Use of the Qualitative Analysis Notes helps with the descriptions of precipitates formed and should remind candidates that, in the investigation of cations, it is necessary to add excess reagent.

(a) (i) Most candidates recognised that it was necessary to use aqueous sodium hydroxide and aqueous ammonia, and a large number gave all observations correctly to identify the presence of Zn^{2+} and thus score full credit. A number, however, did not unambiguously give observations when first a small volume and then excess of these reagents were added.

(ii) Most candidates clearly recognised that the tests were designed to show the presence of a halide and then sulfate/sulfite. To conclude that the halide was bromide, the precipitate formed with silver nitrate must be described as being cream.

(b) In this part the descriptions of observations had to be precise to be awarded credit. In **(i)** the original precipitate had to be given as being green but, since the instruction stated that the test should be left for a few minutes, it was also necessary to state that it then went brown.

In **(ii)** no reaction was expected but answers that gave a yellow or green solution were accepted. In **(iii)** the formation of a precipitate of iron(III) hydroxide was recognised by many but few candidates noted the effervescence that also occurred, and even fewer identified the gas by use of a glowing splint.

Many candidates correctly recognised the reaction as being redox in **(iv)** but a small number suggested just oxidation, neutralisation or displacement.

Answers to **(v)** which focused either on the formation of oxygen from the hydrogen peroxide or oxidation of iron(II) to iron(III) were accepted and credit was often awarded.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key Messages

- Candidates should practise reading scales on apparatus to an appropriate level of precision. The data should then be recorded to reflect this precision.
- Candidates should practise recording errors and improvements in their quantitative lab work carried out over the whole course.
- Candidates should be careful to obey instructions given in the exam paper, to quote answers to an appropriate number of significant figures and to be careful to round these answers correctly.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General comments

The Examiners thank Supervisors at Centres who supplied experimental data for **Questions 1** and **2** for each Session/Laboratory. 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 examination paper with the Supervisor's experimental results.

If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. A significant minority of candidates did not record accurate burette readings to 0.05 cm^3 and lost the credit available for concordant titres by carrying out further titrations that were more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3. Many candidates completed the titration well and so gained credit for accuracy.

As in most titration questions set, the quantities given were intended to produce titre values that were in the mid-range of the burette. Some Centres recorded Supervisor values that were very small (less than a few cm^3) and others recorded values that meant that the burette would have had to be refilled. In either case the Centre should check the chemicals used since very small or very large titres can make it difficult for candidates to access the credit available for accuracy.

(b) The majority of candidates calculated a suitable value for the volume of **FB 1** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to two decimal places.

(c) Most candidates correctly calculated the number of moles of hydrochloric acid in **FB 1** in **(i)** and a significant number then multiplied this answer by 40 to find the concentration of hydrogen carbonate in **FB 2**. To score credit for this calculation it was necessary to give the final answer correct to three or four significant figures; for this reason a number of answers which were chemically logical could not be credited.

The ionic equation was only given by the most able. Candidates must recognise that 'spectator' ions should not be included in these equations.

Question 2

(a) Most candidates drew a table and successfully carried out the practical to record masses although some did not record all the masses specified in the instructions. Although most results were possible, some examples were seen that were clearly not and should have been recognised as such by candidates. Examples of this were when the mass of the crucible + final anhydrous solid was more than the initial mass of the crucible + hydrated solid, sometimes by a significant amount. Such results could have been due to the inclusion, or not, of a lid on the crucible.

It should be noted that 'weight' is not accepted when 'mass' is being measured.

How well the experiment had been carried out was assessed by comparison of the candidates' results with Supervisor's results. This then allowed for variations in the samples used by the Centre. Many candidates scored full credit.

(b) (i) Most candidates used the M_r of water to find the number of moles present, but a significant number did not divide by 10 to find the number of moles of salt.

(ii) The method to be used was recognised by nearly all candidates and credit was given for answers which used the mass, from **(a)**, and the number of moles, from **(b)(i)**, even if these values were incorrect.

(iii) Since the calculation of the A_r included the need to subtract 240 from the relative formula, mass this part was difficult for candidates whose answer to **(ii)** was less than 240. Credit was however given for the identification of any Group 1 element based on it being the one whose A_r was closest to the value calculated.

(c) The accuracy of the balance used had to be considered when awarding credit. Candidates were allowed to give the error based on one or two balance readings.

(d) Acceptable responses to questions asking about errors and improvements must be specific to the actual example. The most popular answer recognised that not all the water might have been removed after one heating so that heating to constant mass would be an improvement. Other answers that were based on the procedure of this particular experiment were credited.

Question 3

Although many candidates gained the majority of the available credit, some ignored the instruction to give the full name or formula of any reagent selected for a test. Use of the Qualitative Analysis Notes helps with the descriptions of precipitates formed and should remind candidates that, in the investigation of cations, it is necessary to add excess reagent. The use of the notes would also have helped a number of candidates who described tests for negative ions in **(a)(i)** and for positive ions in **(a)(ii)**.

(a) (i) Most candidates recognised that it was necessary to use aqueous sodium hydroxide and aqueous ammonia, and a large number gave all observations correctly to identify the presence of Mg^{2+} and thus score full credit. A number, however, did not unambiguously give observations when a small volume and then excess of these reagents were added.

(ii) Most candidates used solutions containing Ba^{2+} but, to gain full credit, it must be shown that the precipitate formed was insoluble in aqueous hydrochloric or nitric acid. A significant number of candidates used sulfuric acid which, in this case, was unsuitable. It was, however, acceptable to use tests based on sulfite decolourising acidified manganate(VII) or producing sulfur dioxide with a strong acid.

(b) Although many candidates were clearly aware of tests for organic compounds, a significant number were not apparently familiar with the expected observations and significance of the tests described.

(i) Since it was specified that Tollens' reagent was being used, only observations reporting a silver mirror or a dark precipitate were credited. If the test was carried out as instructed, i.e. only a few drops of manganate(VII) and a 1 cm depth of sulfuric acid were used, the purple colour should disappear with **FB 7**. A significant number of candidates recorded the formation of a brown precipitate which suggests that excess manganate(VII) ions were present.

(ii) Many candidates correctly identified ethanal, propanone and ethanol but credit was only available if the identification followed the observations in **(i)**.

(iii) The use of 2,4-dinitrophenylhydrazine was known by many candidates, but a significant minority suggested that a positive result was shown by a colour change to green or the formation of an orange solution.

(c) In this test, as in **(b)**, some candidates did not apparently use a large excess of sulfuric acid and only a few drops of manganate(VII) solution, shown by the formation of a brown colouration. Most candidates, however, correctly observed the effervescence formed when sodium hydrogen carbonate was added to **FB 8** and many went on to use limewater to identify the gas formed.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key Messages

- Candidates should practise reading scales on apparatus to an appropriate level of precision. The data should then be recorded to reflect this precision.
- Candidates should practise recording errors and improvements in their quantitative lab work carried out over the whole course.
- Candidates should be careful to obey instructions given in the exam paper, to quote answers to an appropriate number of significant figures and to be careful to round these answers correctly.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General comments

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If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and wide range of credit was awarded. Very few candidates were unable to complete the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Almost all candidates were able to complete the practical work, and were awarded credit both for accuracy and in the calculation. This question was answered well by a large majority of candidates.

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. A significant minority of candidates did not record accurate burette readings to 0.05 cm^3 and lost the credit available for concordant titres by carrying out further titrations that were more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3. The credit awarded for accuracy tended to be Centre-dependent with many candidates gaining the majority of the available credit.

(b) The majority of candidates calculated a suitable value for the volume of **FA 1** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to two decimal places.

(c) The initial sections of the calculation were straightforward with only a minority of candidates unable to round the answer correctly in **(iii)** or give final answers to fewer than three or four significant figures. A number of candidates were unable to give a clear explanation of which equation matched their answer in **(iii)** and needed to refer to mole ratios. Many correctly identified the new oxidation number of **M** from their answer in **(iv)**, although some gave the initial oxidation state instead.

Question 2

This question appeared to cause candidates the most difficulty with few attaining full credit, although the credit was awarded for all parts. The range of masses of the pieces of magnesium ribbon recorded by the candidates appeared Centre-dependent with some being very different from that recorded by the Supervisor. It is important that materials are prepared and supplied according to the Confidential Instructions.

(a) Almost all candidates tabulated their results clearly. The most common error was failing to record thermometer readings to the nearest 0.5 °C. A number of candidates confused mass and weight. A large majority of candidates gained at least partial credit for accuracy.

(b) This section was a good discriminator with the more able candidates gaining full credit. The majority were able to use the data correctly in **(i)**. Lack of precision in **(ii)** lost credit for some; 'All the Mg reacted' is a deduction and not an observation. The most common error in **(iii)** and **(v)** was to use the mass of magnesium rather than the volume of acid. Careful reading of the statement about the value of the specific heat capacity would have helped. Many candidates were awarded credit for the correct expressions in **(iv)** and **(vi)**, although a significant number lost credit for inappropriate rounding in their final answers.

(c) Few gained credit for the percentage error, although it was clear that a few Centres had worked on this. Candidates should be reminded that two thermometer readings are taken to find a temperature change so the maximum error given in **(i)** needed to be doubled. Most candidates were aware that the shorter piece of magnesium would generate the larger percentage error.

(d) Despite the introductory phrase to this part, a significant minority answered in terms of heat loss. As the occurrence of acid spray was given in the method only partial credit was available for those suggesting ways of reducing it. A significant number of candidates were awarded full credit, although this tended to be Centre-dependent. Candidates should be reminded that parallax error will not occur if the instrument is read correctly, so this point could not be credited.

Question 3

Careful reading of the introductory paragraphs would have helped some candidates. There were some excellent responses from candidates who carried out the instructions carefully and used the Qualitative Analysis Notes to good effect.

(a) Only a minority gained full credit here. The most common errors were incorrect reporting of colour changes and precipitates.

(b) As there were only five possible cations present apart from the ammonium ion, it was sufficient to react the unknowns with aqueous sodium hydroxide. A significant minority did not add their reagent(s) to excess, even though this is stipulated in the introductory paragraphs and in the Qualitative Analysis Notes. The most common error was reporting the precipitate formed with **FA 6** dissolved in excess to give a dark green solution which they would not have seen. Some reported a white precipitate with **FA 5** and concluded Mg^{2+} even though this is not a transition metal. Few candidates tested for the ammonium ion and fewer recorded their result successfully; a **gas** turns (damp) red litmus paper blue. Some candidates, however, gained full credit in this section.

(c) The majority of candidates gave the full name or correct formula of a suitable reagent. Those selecting only aqueous barium chloride or barium nitrate generally gained full credit. However, some of the observations with aqueous silver nitrate were incorrect. It is important to distinguish the colour of a precipitate from that of the solution it is in. Some precipitates were also reported when aqueous silver nitrate was added to **FA 6**. Although it is possible that a little silver is formed this would not constitute a white precipitate. Candidates should avoid using the words 'no observation' when they mean 'no (visible) reaction', as the former implies that no test has been carried out. However, more candidates gained full credit in this section than in either **(a)** or **(b)**.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key Messages

- Candidates should practise reading scales on apparatus to an appropriate level of precision. The data should then be recorded to reflect this precision.
- Candidates should practise recording errors and improvements in their quantitative lab work carried out over the whole course.
- The overwriting in pen of answers in pencil should be discouraged as the difficulty of reading may lead to the candidate being unnecessarily penalised. In the case of crossed out answers any subsequent work should be clearly set out for marking.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General comments

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** for each Session/Laboratory. Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

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If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Almost all candidates were able to complete the practical work, and were awarded credit both for accuracy and in the calculation. Part **(d)** discriminated between those aware of the procedure they had just carried out and the candidates who gave answers in line with questions from past papers.

(a) Candidates should be reminded to read the instructions carefully so that all data specified is recorded including burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres or for the volume of solution diluted. A significant minority of candidates did not record accurate burette readings to 0.05 cm^3 and lost the credit available for concordant titres by carrying out further titrations that were more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3. The credit awarded for accuracy tended to be Centre-dependent with many candidates from some Centres gaining the majority of the available credit.

(b) The majority of candidates calculated a suitable value for the volume of **FB 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to two decimal places.

(c) The calculation was straightforward and very many candidates gained full credit. A minority, however, did not use the mole ratio to obtain the correct answer in **(ii)** or used 25 cm^3 instead of their titre in **(iii)**. Most candidates were then able to progress correctly through the rest of the calculation. The more common errors in **(iv)** to **(vii)** were inverting the percentage calculation or using the mass of **FB 1** divided by 100.1. Another common error was to give some final answers to fewer than three significant figures.

(d) Many candidates found this section difficult and in **(i)** only a minority realised that measuring a volume of **FB 2** would involve two burette readings, or that the answers should be to two decimal places as given in the question. One common error in **(ii)** was to assume that **FB 4** had been in the burette so candidates answered in terms of volume of sodium hydroxide added. Another incorrect response was to answer the question in terms of percentage error.

Question 2

The standard of response tended to be Centre-dependent with many finding this the most difficult of the three questions overall. However, some very good responses were seen and credit was awarded for all parts.

(a) Candidates should ensure that they record all data stipulated in the instructions with full and unambiguous headings. Some candidates confused mass and weight. Most candidates recorded balance readings to a consistent number of decimal places and gave units in the accepted format. Candidates in some Centres did not find any loss in mass even on the second heating. The use of spirit burners in A Level practicals is usually inappropriate as the higher temperature of a Bunsen or gas burner is needed for many experiments. Some candidates lost time by reheating and cooling more times than specified in the question.

(b) The majority of candidates answered **(i)** correctly, with most of these showing the correct use of 44 and 100.1 in **(ii)**. Most candidates used the mass of **FB 5** (before heating) in **(iii)** but some lost credit by inappropriate rounding in **(ii)** or **(iii)**. Many of those who found no loss in mass went on to gain credit for calculation by showing the working needed and concluding zero percent of calcium carbonate, so were not greatly disadvantaged other than in terms of time taken.

(c) The more able candidates were able to suggest heating to constant mass to be an improvement but some did not appear to appreciate that **FB 5** was a second sample of the impure calcium carbonate used as **FB 1** in **Question 1** and so comments about the differences in percentage purity found in the two experiments were rare.

Question 3

Careful reading of the introductory paragraphs would have helped some candidates attain more credit. There were some excellent responses from candidates who carried out the instructions carefully and used the Qualitative Analysis Notes to good effect.

(a) Many candidates gained full credit. The most common errors were not adding the aqueous ammonia to excess in **(i)**, which affected the ions to include in **(iv)**, and either reporting a precipitate with aqueous silver nitrate in **(ii)** or by writing ‘no observation’ which is not synonymous with ‘no reaction’.

(b) Only a minority of candidates reported the expected colour change of the solid in **(i)**. The instruction to identify gases released by a test was ignored by most, even though a large minority of candidates correctly reported fizzing, bubbles or effervescence on adding nitric acid to **FB 7** in **(ii)**. However, the majority of candidates reported the expected results in **(iii)** and **(iv)**. Candidates needed to realise that a larger than normal volume of aqueous ammonia would be needed to test for cations in **FB 7** owing to the presence of excess nitric acid in the solution. Many candidates were able to gain partial credit for the conclusion by identifying iodide and either carbonate or zinc ions.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key Messages

- Candidates should practise reading scales on apparatus to an appropriate level of precision. The data should then be recorded to reflect this precision.
- Candidates should practise recording errors and improvements in their quantitative lab work carried out over the whole course.
- The overwriting in pen of answers in pencil should be discouraged as the difficulty of reading may lead to the candidate being unnecessarily penalised. In the case of crossed out answers any subsequent work should be clearly set out for marking.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

General comments

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If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results. Where this data is missing and unobtainable candidates may be disadvantaged as a consequence.

This paper proved accessible to most candidates and wide range of credit was awarded. Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Very few candidates were unable to complete the practical work, and most were able to gain credit both for accuracy and in the calculation. This question was answered well by a large majority of candidates.

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. A significant minority of candidates did not record accurate burette readings to 0.05 cm^3 and lost the credit available for concordant titres by carrying out further titrations that were more than 0.10 cm^3 from others. Candidates should be encouraged to continue with the rest of the paper once they have achieved two titres within 0.10 cm^3. The credit awarded for accuracy tended to be Centre-dependent with many candidates from some Centres gaining the majority of the available credit.

(b) The majority of candidates calculated a suitable value of the volume of **FA 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correct to two decimal places.

(c) The calculation was straightforward and many candidates gained full credit. The majority gave final answers correct to three or four significant figures.

(d) Many candidates found this section difficult and in **(i)** only a minority realised that a volume of **FA 2** would involve two burette readings, or that the answers should be to two decimal places as given in the question. Only a minority of candidates were able to link the lower volume of **FA 2** with a greater concentration of calcium hydroxide. Some candidates attempted to answer the question in terms of percentage error.

(e) The responses tended to be Centre-dependent. A number of candidates suggested that the calcium hydroxide would react with oxygen in the air.

Question 2

This question was generally answered well by a large majority of the candidates.

(a) Candidates should ensure they record all data stipulated in the instructions with full and unambiguous headings. Most candidates recorded balance readings to a consistent number of decimal places and gave units in the accepted format. However, many candidates ignored the instruction to record their observations on heating and cooling the solid. Many candidates gained credit for accuracy.

(b) A large majority of candidates answered **(i)** correctly with most of these showing the correct use of 44 and 125.4 in **(ii)**. Most candidates used the mass of **FA 4** (before heating) in **(iii)** and so gained most of the available credit.

(c) Many candidates specified heating to constant mass in part **(i)**, indicating that they were familiar with this type of procedure, although some did not explain the reason for this sufficiently clearly.

Question 3

Careful reading of the introductory paragraphs would have helped some candidates attain more marks. The marks ranged widely with some excellent responses from candidates who carried out the instructions carefully and used the Qualitative Analysis Notes to good effect.

(a) Most candidates gained some credit for **(i)**. Some needed to realise that larger than normal volumes of aqueous sodium hydroxide and ammonia would be needed to test for the second cation in **FA 5** owing to the presence of excess nitric acid in the solution. However, the majority of candidates achieved some credit for this section.

(b) The instruction in **(i)** to heat gently and then strongly implied that two observations were needed but not all candidates gave these. However, many tested successfully for ammonia. Many candidates recorded the expected results in test **(ii)**, but fewer completed **(iii)** as they did not test the gas evolved on adding nitric acid, contrary to the instructions at the start of the question. Again, many candidates gained at least partial credit for the identities of the ions present.

CHEMISTRY

Paper 9701/41
A2 Structured Questions

Key Messages

- Candidates would benefit from an increased familiarity with drawing structural formulae, especially three-dimensional diagrams for octahedral, square planar and tetrahedral structures.
- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.
- Candidates should set out calculations which clearly explain what the numbers refer to.

Candidates should also be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly in the key definitions as seen in **Questions 2(a)(i)** and **3(c)(i)**, and organic chemistry.

Candidates need to read the questions carefully before answering them; questions where this often appeared not to have been done were:

Question 2(a)(ii) – required a three-dimensional structure to be drawn,

Questions 7(b)(i)-(ii), 7(c) and **7(d)** – answers to this question tended to be very good from candidates who were familiar with NMR, or quite poor from candidates who resorted to an amount of guesswork.

General Comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who were well-prepared for the examination were able to tackle all of the questions. There was no evidence that candidates had insufficient time to complete the paper.

The questions in ***Section B*** were generally answered well, and the overall neatness and legibility of answers was good. This was not always the case however, and candidates are reminded to make sure that their desired final answers are legible and obvious to the Examiner.

The arithmetical working in calculation questions should be set out clearly, to allow Examiners to award ‘error-carried-forward’ marks wherever possible.

Candidates are also reminded of the importance of careful, thorough reading of the question before attempting to answer it, underlining key words or phrases on the question paper to ensure that it is answered in the correct manner.

This report should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

(a) (i) Most candidates answered this correctly.

(ii) Only a few candidates managed to explain these differences correctly. For high melting point, few candidates mentioned about more delocalised electrons. For density, many candidates referred to mass instead of atomic mass, and often the link to atomic/ionic radius was omitted.

(b) (i) This was generally answered well, although some candidates erroneously included a battery in their circuit. A number did not include or label a salt bridge.

(ii) Most candidates scored some credit here. Many mentioned 1 mol dm^{-3}, but some called the solutions "Cu(II)/Cu and Fe(II)/Fe". Another common error was to suggest platinum as one or both of the electrodes.

(iii) Most candidates carried out the calculation correctly.

(iv) This question was more challenging, with only the more able candidates giving a well argued answer. Some candidates gained partial credit for explaining their E_{cell} change in terms of the $Fe^{2+} + 2e^- \rightleftharpoons Fe$ (or $Cu^{2+} + 2e^- \rightleftharpoons Cu$) moving to the right hand side.

Candidates were expected to state how the $E_{electrode}$ changes and relate this to their E_{cell}.

(c) (i) Few candidates knew that the end point of the reaction is given by the first appearance of a pale pink colouration when one drop of $KMnO_4$ is added in excess. A common error was to give the colour change as from purple to colourless.

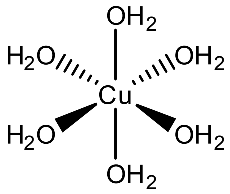
(ii) Most candidates scored some credit here. The final molar mass was found to be more challenging than the other two parts.

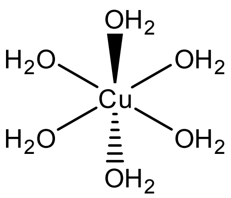
Question 2

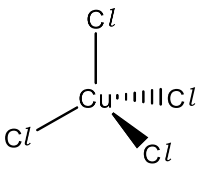
(a) (i) This was generally answered well, although a number of candidates did not specify (central) atom or ion in their definition of a complex.

(ii) This question was not answered well. Some poor three-dimensional diagrams were drawn as well, as there were many square planar instead of tetrahedral structures of $CuCl_4^{2-}$.

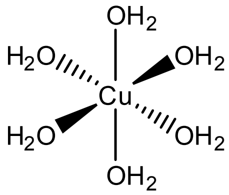
Some examples of correct three-dimensional diagrams of $(Cu(H_2O)_6)^{2+}$ and $(CuCl_4)^{2-}$ are shown below.

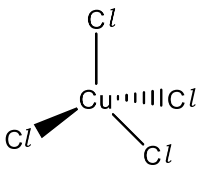




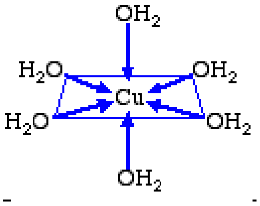


Common incorrect structures included:





A small number of octahedral structures were given that showed two vertical bonds and a perspectively-drawn square planar of 4 H_2Os. These structures did not normally include any out of plane bonds, so this structure gained no credit.



(iii) This was generally answered well. Geometrical was accepted as an alternative to cis-trans. Some candidates incorrectly suggested optical isomerism or stereoisomerism.

(b) (i) A significant number of candidates were not awarded credit here; a common error was filling the 4s orbital either fully or partially.

(ii) This seemed to be Centre-specific. The first part of the explanation was standard bookwork. Some very good answers were seen but equally quite a number of candidates did not mention the splitting of the d-orbitals by the ligand field or/and the promotion of an electron from a lower to a higher level by the absorption of visible light. For the second part, it was expected that the candidates would state that the d subshell is full or that there are no unpaired electrons in a d-orbital; common incorrect answers included statements that the energy gap between the d-orbitals is too large or that they have a full d-orbital.

(c) (i) This was answered well. Common incorrect answers included –212 (incorrect subtraction), +178.8 (omitting to multiply by 2), and –393.8 or +79.2 (one incorrect sign), all of which were partially credited.

(ii) Many candidates performed well here and the application of le Chatelier's principle in the second part was good.

Question 3

(a) Few candidates gave the correct reagents and conditions for this hydrolysis, with most omitting the water or heating.

(b) (i) A number of candidates failed to recognise that there were four isomers of piperic acid.

(ii) Fewer candidates were able to draw a *cis* isomer of piperic acid. Many candidates gave the same isomer of piperic acid as given in the question.

(iii) This proved to be a difficult question and was not answered well. Candidates needed to draw the two products from the oxidative cleavage of the two C=C bonds using hot concentrated acidified $KMnO_4$.

(c) (i) This was answered very well. The expression $K_w = K_a \times K_b$ was **not** accepted since the ionisation of water should be defined as $K_w = (H^+(aq))(OH^-(aq))$.

(ii) Many candidates carried out this calculation correctly.

(iii) This proved difficult for many candidates. Answers were often too vague such as stating that NaOH is more basic, and candidates did not mention that piperidine was a poorer proton acceptor or only partly ionised.

(iv) Many candidates also found this difficult. Only the more able recognised that the piperidine was more basic due to the presence of the electron donating alkyl groups.

(d) (i) Many candidates calculated the starting n(HC*l*) instead of the remaining n(HC*l*).

(ii) Only occasionally could error-carried-forward credit be awarded. Many candidates divided their answer to **(d)(i)** by 0.02 rather than 0.03, or just took the pH = –log(n(HC*l*)).

(iii) A reasonable number of candidates scored full credit for the graph, although many of these included an error-carried-forward for the pH at 20 cm^3. The most common error was suggesting that the end-point was 10 cm^3 instead of 15 cm^3.

(iv) A number of candidates correctly identified B as the most suitable indicator.

Question 4

(a) Most candidates correctly identified three functional groups here.

(b) (i) This proved difficult for many candidates with only the more able gaining full credit. For the first part, only a few recognised that **Z** was a cyanohydrin. The analogous benzyl alcohol and benzoic acid were common errors. In the second part, most omitted a base or NaCN with the HCN reagent, and Sn + HCl was a common error for the reductant.

(ii) Most candidates described the correct colour change or formation of a white precipitate, but far fewer managed to suitably brominate the ring, with the OHs often undergoing replacement.

(c) (i) This was generally answered well, although many candidates formed the sodium alkoxide as well as the two phenoxides.

(ii) Fewer candidates were able to draw the correct product of noradrenaline with HCl(aq). A common error was substitution of one or both OHs by Cl.

(iii) The reaction with CH_3COCl was much better known by candidates, and many gained some credit. However, only the more able realised that three ester and one amide groups would be formed with excess CH_3COCl.

(d) Only a minority of candidates scored full credit here, although most correctly identified the ester.

Question 5

(a) (i) This was correctly answered by most candidates.

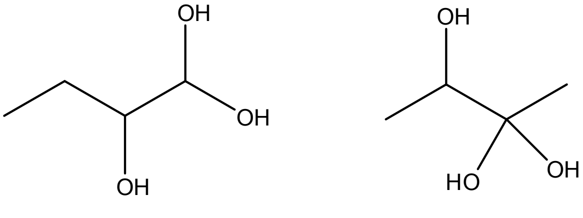
(ii) This too was mostly answered correctly.

(iii) This was less well known, with many candidates suggesting a secondary alcohol which was not sufficient.

(b) In this part, candidates were expected to use their answers from **(a)(i)-(iii)** to suggest structures for **V** and **W**. Often their answers did not tally with the groups suggested. A common error was drawing an enol for one or both structures.

(c) Most candidates scored full credit here, although many of these included error-carried-forward for cis-trans and corresponding isomers of their enol suggested in **(b)**.

(d) This proved difficult for many candidates, with only the more able gaining full credit. A number of gem-diols were incorrectly suggested.



Section B

Question 6

(a) This part was straightforward, and most candidates scored full credit.

(b) This question was answered well. Common errors seen were thyamine/thiamine (instead of thymine) and cysteine (instead of cytosine).

(c) (i) Most candidates gave the correct answer here.

(ii) This was generally answered well. It was expected that candidates would mention that hydrogen bonds are weak so are easy to break; a number did not give a full explanation.

(d) Many candidates gave the correct answer here.

Question 7

(a) Candidates showed a good understanding of how to calculate the number of carbon atoms from the mass spectrum peak height ratio.

(b) (i) This question required the use of the *Data Booklet* and the splitting pattern, which is so characteristic of the ethyl group. These seemed to be ignored by a lot of candidates. Common errors were (δ 2.2) RCH_2R and (δ 11.8) OH.

(ii) This proved a challenging question with only the more able candidates gaining full credit. Only about half of the candidates correctly identified the peak at δ 11.8. There seemed to be a poor understanding of hydrogen-deuterium exchange.

(iii) This question proved to be difficult with only the stronger candidates drawing the correct structural formula of **G**, CH_3CH_2COOH. A small number suggested the acceptable amide alternative, $CH_3CH_2CONH_2$. Many candidates did not suggest a viable structure that only had three different proton environments, or a structure that had a group that would undergo hydrogen-deuterium exchange.

(c) (i) Only a few candidates gave one of the acceptable structures, methyl ethanoate being the most common. Most incorrect answers suggested had three, instead of two, different proton environments.

(ii) This was marked conditionally of **(c)(i)**. Full credit was rarely awarded.

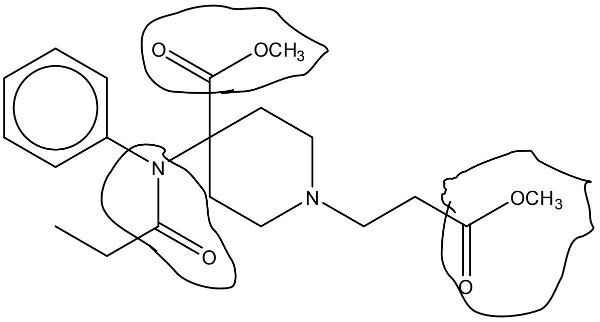
Question 8

(a) (i) This part was generally well answered. A common incorrect answer was amine.

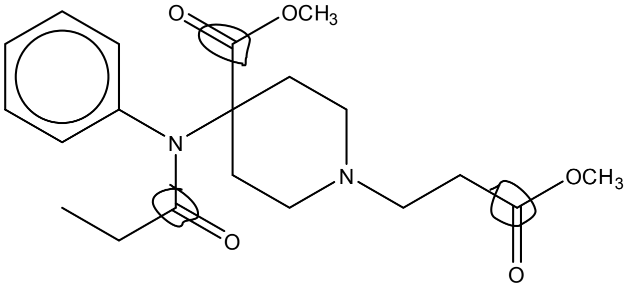
(ii) Fewer candidates managed to state that the type of reaction is hydrolysis. A variety of incorrect answers were seen including condensation, neutralisation and reduction.

(iii) This part was answered well.

(iv) This was marked conditionally of **(a)(iii)**. It was expected that candidates would circle three functional groups, two methyl esters and the amide.



Many circled two groups only and the amide was commonly forgotten. Many only circled the C of the C=O and did **not** include the singly-bonded heteroatom either. In this case partial credit was awarded.



(b) (i) Most candidates identified the correct location, **Q**, and gave a suitable explanation here.

(ii) There were many good answers to this part. Some candidates stopped short with only a reference to its hydrophilic nature.

(c) (i) Most candidates gave a correct response here.

(ii) Fewer candidates scored here and it usually depended on whether they mentioned 'cells' or 'tissues'. A number of vague references to causing harm and comparing the size of the nanocage to the wavelength of the radiation were seen.

CHEMISTRY

Paper 9701/42

A2 Structured Questions

Key Messages

It was noted that some candidates were still using an old edition of the *Data Booklet*, which quoted the Cl–Cl bond energy as $+244\,kJ\,mol^{-1}$ rather than $+242\,kJ\,mol^{-1}$. Although both values were accepted in the calculation in **Question 2(d)(ii)**, Centres should try to ensure that their candidates are given the up to date Booklet. (This will be especially important from 2016, when an entirely new *Data Booklet* will come into use).

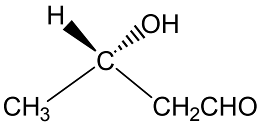
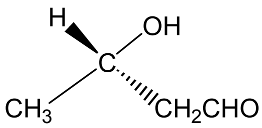
Candidates seem confused as to how to write the structural formulae of organic compounds, especially when they are drawing mirror image isomers. There are two things to point out:

1. The convention, followed by all chemists, is that the hydrogen atoms joined to a carbon atom are **always** written *to the right* of that particular carbon atom. The only exception is when the carbon atom is part of a methyl group at the very left hand end of a chain, in which case the methyl group can be written *either* as CH_3– *or* as H_3C–. Hydrogen atoms joined to oxygen or nitrogen atoms at the left hand end of a chain are conventionally written to the left of the hetero atom, e.g. HO– or H_2N–. The aldehyde group should be written as –CHO, and not –COH, and when at the left hand end of a chain it should be written as OHC– or OCH– and not HOC–, which implies that the hydrogen is bonded to the oxygen and not to the carbon.

   All other positions of hydrogen atoms lead to potential ambiguity, or an actual error.

   Question 5(e)(ii) in this paper brought these inaccuracies to the attention of Examiners. If candidates attempted to draw the mirror image of $CH_3CH(OH)CH_2CHO$ as $OCHCH_2CH(OH)CH_3$ (see below for the stereochemical formulae), they often felt they needed to reverse the Hs and the Cs. Some, therefore, drew the isomer as $OHCH_2CHC(OH)CH_3$ *or* $HOCH_2CH(OH)CCH_3$, whose left hand carbon looks very like a primary alcohol. Some even moved the subscripts over to the left, and wrote $HOC_2HCH(OH)CH_3$ which is a long way from the correct $OCHCH_2CH(OH)CH_3$.

2. The second point to mention is the convention for drawing the stereochemical formula of chiral centres. The solid wedge bond and the hatched wedge (or dashed line) bond should always be **adjacent**, not opposite to each other.

Thus  is correct, but  is incorrect.

Candidates should be reminded to read the questions carefully; the boxes in **Questions 2(b)(i)** and **3(d)(v)** required candidates to place **one tick only** in the last column. No credit was given if there was more than one tick. **Question 2(c)(ii)** asked for an equation showing the reduction of $PbCl_2$, not $PbCl_4$, and the oxidation **of** $SnCl_2$, not the oxidation of Sn **to** $SnCl_2$. **Question 8(a)** asked for the names of *synthetic* polymers, not natural ones.

General Comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates found the questions in ***section B*** particularly straightforward this year.

Candidates should be encouraged to show their method of working with arithmetical questions; credit may be awarded through consequential marking, but only if Examiners can see the working clearly. This was particularly relevant with the lattice energy calculation in **Question 2(d)(ii)**.

Candidates should be reminded that if they use the word ‘it’ in an answer, they must be sure that there is no ambiguity as to what ‘it’ refers to. This was apparent in **Question 2(d)(iii)**.

Candidates should also be reminded that any alterations to writing that has been crossed out should be clear.

There was no evidence that candidates had insufficient time to complete the paper.

This report should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

(a) (i) Only the most able candidates scored full credit for this part. Although most candidates gave the correct configuration of Fe, many showed the electron pair in the high-spin version of Fe^{2+} in one of the upper d-orbitals, rather than one of the lower ones. Several candidates showed electrons in the 4s orbital of Zn^{2+}.

(ii) Although many candidates scored well here, there were several misconceptions in candidates' answers, for example that it was the *orbitals* that were ‘promoted’ when light was absorbed, or it was the ligands that caused the electron (or orbital) to be promoted, or that it was a photon that caused the splitting of the d-orbitals. For zinc, several candidates did not make it clear that the d-orbitals were completely full, so there was no space for an excited electron to go.

(b) (i) The yellow species was often incorrectly thought to be $(CuCl_4(H_2O)_2)^{2-}$, $(CuCl_4)^{2+}$, $CuCl_4$, $CuCl_2$ or Cl^-. While the majority of candidates knew it was a ligand substitution reaction, others omitted the key word “ligand”. It was sometimes thought to be a redox or an acid/base reaction.

(ii) While stronger candidates tended to do well, very many candidates had little idea of the sequence of reactions when ammonia is added to the yellow solution. A wide range of incorrect chloro-aqua-amino complex ions were suggested. The initial formation of $(Cu(H_2O)_6)^{2+}$ was usually omitted; the blue precipitate was often mentioned but frequently not identified as $Cu(OH)_2$; among the incorrect formulae for the complex ion formed on adding excess ammonia were $(Cu(NH_3)_6)^{2+}$ and numerous permutations containing H_2O or Cl in varying proportions. It was not unusual to see ammonia written as NH_4. The copper(II) tetra ammine complex was often not recognised as being in *solution*. The charges on the various complexes were often incorrect, e.g. $(Cu(OH)_2(H_2O)_4)^{2-}$ or $(Cu(NH_3)_4)$ with no charge.

(c) (i) Most candidates were awarded credit here, although some wrote incorrect charges on the ions (SO_4^-, or $S_2O_8^-$). Others tried to incorporate Fe^{2+} or Fe^{3+} into their equation.

(ii) Despite the question asking for the *precise* role of the iron ions, the vast majority of candidates failed to mention that they were acting as a *homogeneous* catalyst. Occasionally the words ‘homolytic’ or ‘homozygous’ were seen.

(iii) Those candidates who went beyond the simple ‘lowers the activation energy’ usually appreciated that the reaction involved the attraction of the catalytic cations to the oppositely charged reactant ions.

Question 2

(a) Most candidates recognised that **A** was a voltmeter, although ‘ammeter’, ‘galvanometer’ or ‘voltage’ were also seen. Some suggested a battery or power pack. Most gave **B** as platinum, but many also gave **D** as platinum or graphite, rather than lead/Pb. A common error for **C** was to omit the 1.0 mol dm^{-3}. Where sulfuric acid was mentioned, the concentration needed to be 0.5 mol dm^{-3}.

(b) (i) This was not well answered by the majority of candidates, who thought the electrode potential was either 0.00 V (standard hydrogen electrode) or –0.13 V (standard Pb^{2+}/Pb electrode). Of those who identified the potential as -0.17 V, many did not mention that this was because (Pb^{2+}) was less than 1.0 mol dm^{-3} due to the low solubility of $PbCl_2$.

(ii) The solubility product was usually stated correctly, but common errors including omitting the charges on the ions, not squaring the (Cl^-) term or having (2 Cl^-), $(2Cl^-)^2$ or including ($PbCl_2$) in the expression.

(iii) With the aid of consequential marking most candidates gained some credit for their answers. The usual error was that candidates did not realise that (Cl^-) = 2 × 3.5 × 10^{-2}. Some candidates were unsure what to do with the dm^{-3} part of the units; instead of dm^{-9}, several gave dm^{-6} or dm^{-27}. The unit "mol^3/dm^9" gained credit but "mol^3/dm^{-9}" did not.

(c) (i) Many candidates focused only on M^{2+}/M or M^{4+}/M^{2+}. Electrode potentials for **both** oxidation number changes for **each** metal were expected. Some candidates did not mention electrode potentials at all. Whilst stronger candidates clearly stated that Sn^{2+} is more easily oxidised (to the +4 state) than is Pb^{2+}, some weaker candidates gave ambiguous responses such as 'lead oxidises more'. Some attempted to differentiate between the oxidising abilities by concentrating on the 0.01 V difference in M^{2+}/M potentials.

(ii) The most popular reductants were Zn or Mg. Those that react violently with water, such as Na or K, were not allowed. Some candidates attempted to reduce $PbCl_2$ with H_2 or H_2O or OH^- or H_3O^+. The oxidation of $SnCl_2$ was less straightforward for some. Successful oxidants included Cl_2, Br_2, Fe^{3+}, MnO_4^-, $Cr_2O_7^{2-}$ and even Pb^{4+}. For the oxyanion oxidants, some candidates found the balanced equation difficult.

(d) (i) Most candidates correctly wrote an equation to represent the lattice energy of $PbCl_2$. Incorrect responses included the use of incorrect state symbols (such as 'aq' with Pb^{2+} and Cl^-), omitting the state symbol with "Pb" (or suggesting it was gaseous) or giving the enthalpy change of formation of $PbCl_2$, ($Pb(s) + Cl_2(g) \rightarrow PbCl_2(s)$). The syllabus defines lattice energy as an exothermic quantity (the *formation* of the lattice). Those candidates who wrote $PbCl_2(s) \rightarrow Pb^{2+}(g) + 2Cl^-(g)$ did not score credit here, but were allowed full credit for +2264 kJ mol^{-1} in part **(ii)**.

(ii) It was encouraging that many candidates calculated a correct value for the lattice energy of $PbCl_2$. The main errors involved the omission of the $Cl-Cl$ bond energy (242) or the ionisation energies (716 and 1450), not doubling the electron affinity (using 349 instead of 698), halving the bond energy (using 121 instead of 242) or not having the correct sign for the relevant enthalpy change. Some candidates misread the electron affinity of chlorine, writing 394 rather than 349. A significant number of candidates did not use their calculators correctly; they had the right expression for LE, but their final answer was incorrect.

(iii) Although most candidates knew that the lattice energy of $PbCl_2$ was larger (more exothermic) than $PbBr_2$, many tried to explain their answer in terms of bond length, bond energy or ionisation energy / electron affinity. Many who had the right idea did not clearly state that the size / radius of Cl^- was smaller than Br^-; instead they compared atoms (rather than ions) or compared $PbCl_2$ and $PbBr_2$. Candidates should be discouraged from using formulae as abbreviations for names; the statement 'Cl_2 has a smaller ionic radius than Br_2' is incorrect, and was not credited.

Question 3

(a) (i) Apart from **B** and **D**, compound **C** was thought by several candidates to exist as optical isomers.

(ii) Several candidates thought that not only compound **D**, but also compounds **B** and/or **C** would produce a secondary alcohol on hydrolysis.

(b) Most appreciated that dilute aqueous acid or alkali were required here, but many did not state that the reaction needed to be heated. Those who employed $OH^-(aq)$ needed to acidify the solution subsequently, to afford the acid rather than its anion. Some incorrect reagents included concentrated H_2SO_4, water, $KMnO_4$ or $NaBH_4$.

(c) (i) A number of candidates concentrated on the electron-donating ability of the ethyl group in ethanol, without mentioning the anion stabilising ability of the CO_2^- group in ethanoic acid through charge delocalisation. Most, however, gained credit for relating the electron-withdrawing ability of the chlorine atom in $ClCH_2CO_2H$ to the easier ionisation of the O–H bond.

(ii) Many candidates scored well here. Common errors were not taking the square root, or not taking into account the 0.100 mol dm^{-3} concentration. Some found difficulty in converting (H^+) into pH.

(d) (i) Most calculated this correctly.

(ii) Many did not take account of the dilution factor, so that when 20 cm^3 has been added, the final total volume is 30 cm^3, not 10 cm^3 or 20 cm^3.

(iii) Many candidates used K_w correctly, and arrived at (H^+) = 3 × 10^{-13} mol dm^{-3}.

If the (OH^-) calculated in **(ii)** was incorrect, consequential error credit was still allowed here.

(iv) Likewise, credit for consequential errors was allowed for both the starting and the finishing pH values on the sketch graph. However, several candidates did not use the pH values they had calculated in **(c)(ii)** and **(d)(ii)**. Other errors included not showing a clear vertical portion (of at least two pH units) at the end point; showing the end point at a volume other than 10 cm^3; and drawing the whole curve reversed, i.e. starting at pH 12.5 and finishing at pH 2.9. Some candidates had little idea of what a titration curve should look like, and drew a straight line from 2.9 to 12.5.

(v) Most candidates appreciated that the indicator needed to change colour at pH > 7, so correctly chose thymolphthalein.

Question 4

(a) Although most candidates recognised **(i)** as an addition, and **(ii)** as a substitution, several incorrectly used the words ‘nucleophilic’ or ‘free radical’, for either or both reactions.

(b) Only a minority answered this correctly. Many wrote an equation showing the formation of the intermediate carbocation, or an equation that produced $AlBr_4^+ + Br^-$ rather than $AlBr_4^- + Br^+$.

(c) (i) Only the most able candidates scored full credit here. Common errors were to include two Br atoms instead of one in $CH_2Br–CH_2^+$; showing the carbocation as still containing a C=C double bond; giving it a partial δ+ charge rather than a full + charge. The Wheland intermediate from benzene sometimes showed charges on the Br and H atoms as well as, or instead of, the ring; or the + charge was not clearly associated with the delocalised ‘horseshoe’; or the open end of the ‘horseshoe’ was not pointing in the right direction - towards the sp^3 carbon atom of the ring.

(ii) The anticipated answer would have pointed out that the ring of π electrons in benzene is a stable configuration, so is reformed rather than atoms/groups added to it. Many candidates, however, interpreted the question as meaning ‘what is it about the product that makes it unsaturated’. Correct answers to this interpretation were therefore given credit, e.g. that it still contains π bonds, or that it can still undergo addition reactions.

(d) Despite the information given in the question, quite a number of candidates chlorinated methylbenzene first, giving **E** as 3-chloromethylbenzene, which they then oxidised to compound **F**. They still gained some credit, however.

Most candidates gave the correct reagent for the oxidation ($KMnO_4$), but several failed to heat the reaction. For the chlorination, those who correctly recognised it as an electrophilic substitution, rather than a free radical substitution, sometimes gave the reagent as $AlCl_3$, without adding the required Cl_2.

Both here and in part **(e)** some candidates lost credit through not showing clearly which atom in their side-group was joined to the benzene ring. In each case it is the *carbon* atom that should be joined to the ring by a bond, not the O, H or Cl atoms.

(e) Many candidates realised that **G** had to be the acyl chloride, although several incorrectly gave its formula as Ar–CO_2Cl. Some, however, felt they needed to introduce a nitrile group, so reacted **F** with KCN and suggested **G** as Ar–COCN. Those who gave **G** as the acyl chloride invariably also scored credit for the correct reagent ($SOCl_2$ or PCl_5). Various reducing agents were suggested for reaction 4: H_2 + Ni; $NaBH_4$; $LiAlH_4$, however, only the last in this list would be effective.

Question 5

(a) (i) Most candidates recognised that sodium tests for –OH groups, although some seemed to think that it was only –OH groups in –CO_2H acid groups that reacted.

(ii) Not so many appreciated that the Fehling's solution test is specific for aldehydes. Several suggested 'carbonyl compounds', whilst others suggested 'ketones'.

(b) Almost all candidates correctly explained that a negative test with Br_2(aq) showed the C=C double bond grouping (not just 'double bond') to be absent.

(c) Despite the question clearly stating that only **straight-chain** isomers were required, several candidates chose to include branched-chain isomers in the three they drew. Quite a number of 5-valent carbon atoms were seen. This was a good discriminating question; a significant number, but by no means the majority, recognised the three compounds were the three hydroxy-butanals.

(d) (i) Many candidates did not recall the groups identifiable by the iodoform reaction. 'Methyl ketone' or 'methyl secondary alcohol' were accepted; 'secondary alcohol', 'methyl alcohol', 'aldehyde'; 'ketone' were not.

(ii) Despite giving a correct answer to **(d)(i)**, several candidates chose not to identify **J** as the methyl secondary alcohol they had drawn in their answer to **(c)**, but instead chose one of the others. 2-hydroxybutanal was the most popular incorrect answer.

(e) (i) Most correctly gave 'optical isomerism' as their answer here, although geometrical, cis-trans and even structural isomerism were seen on a fair number of scripts.

(ii) As mentioned at the start of this report, candidates were generally not good at representing optical isomers. Each structure needed two solid bonds, one wedge bond, and one (adjacent) dashed or hatched bond. If the groups are written on the other side of the central atom, the correct atoms need to be shown as being joined to the central atom, but the hydrogen atoms should always stay to the right of the carbon atoms to which they are bonded.

Section B

Question 6

(a) (i) A number of candidates drew an ester, formed from the -OH group on serine condensing with the –CO_2H group on valine. Other incorrect answers included drawing a tripeptide; adding an extra –CH_2– group in either valine or serine; showing the peptide bond as –CO–O–NH–. Quite a number of candidates who drew structural or displayed formulae omitted the α-hydrogen atom from either or both the amino acids. A minority drew the structure of ser-val rather than val-ser.

(ii) This was a high-scoring part, with most candidates correctly stating 'condensation'.

(iii) Almost all candidates scored credit here for 'water'.

(b) The majority of candidates scored full credit here. Some lost credit by describing 'ribose' as 'oxyribose', by stating that RNA contained a single helix, or contained an α-helix. Other differences, such as DNA occurring in the nucleus, whereas RNA is predominantly found in the cytoplasm, were not accepted, as these are not differences in their *structures.*

(c) (i) Most candidates correctly identified the sequence as leu-thr-pro-glu.

(ii) 'Mutation' was the most popular correct answer, given by almost all candidates.

(iii) Most candidates recognised that an **A** needed to be changed to a **U**, but several did not explain their thoughts clearly, just giving '**GUG**' as the answer.

Question 7

(a) Most candidates recognised that charge was important in electrophoretic separation, but some thought that merely existing as zwitterions allowed amino acids to be separated. It is the overall *average* charge that is important. Other factors given credit were the size or shape or M_r of the species.

Candidates were less clear about the factors involved in paper chromatography. It is not just the solubility of the amino acid in the solvent, but the ratio of its solubilities in the moving and the stationary phases that determines its R_f value.

(b) Ninhydrin was the most popular correct answer here. Descriptions of techniques involving UV or tagging with ^{32}P were common, but were given no credit.

(c) Measuring just the distance moved by the amino acid was not sufficient. Candidates needed to state that it is the ratio between this distance and that travelled by the solvent front (the R_f value) that is important.

(d) Although all combinations of the three amino acids were seen as answers, the vast majority of candidates scored full credit here. The most common error was to swap glutamic acid and lysine.

(e) Most candidates scored well here. Almost all correctly identified **U** in **(i)**, very many correctly identified **W** in **(iii)**, and a similar number correctly picked out the two amino acids having the same R_f value in solvent 1, in **(ii)**.

Question 8

(a) (i) Whilst many candidates knew a polymer of each type, quite a number swapped them around, so gave Kevlar as an addition polymer, and PTFE as a condensation polymer. The question clearly asked for a synthetic polymer of each type, and so rubber, silk, wool, protein or polypeptides were not allowed any credit.

(b) (i) Most candidates correctly identified the reaction type as a hydrolysis.

(ii) Several candidates seemed to confuse the functional groups that would be hydrolysed, and those that would give condensation polymers when reacted together. Thus 'amine', alcohol' and 'carboxylic acid' were quite common answers here, rather than the correct 'ester' and 'amide'.

(c) Although the vast majority of candidates correctly joined the two monomers with an ester bond, several did not show the ester group in its displayed form. Many also included an extra oxygen atom in the repeat unit (including an oxygen at each end of the unit), or showed the 'dimer', with an –OH group at one end and a $-CO_2H$ group at the other, or attempted to join the two monomers through the CH_3 group.

(d) This part was well answered, although several candidates failed to state specifically that it is the absence of a C=C double bond, rather than just a 'double bond', that was the important feature of the plant-derived monomers. These monomers, being hydroxy- or amino-acids, contain the doubly-bonded C=O group.

(e) (i) Most candidates correctly identified the inter-chain forces as van der Waals' forces for **Y** and hydrogen bonding for **Z**. Incorrect answers included hydrogen bonding for **Y** and ionic bonding for **Z**.

(ii) Although some candidates suggested **Y** to be the most hydrophilic, possibly because they had not recalled the correct meaning of 'hydrophilic', most suggested **Z**. The reason looked for was not just that **Z** forms hydrogen bonds, but that it forms hydrogen bonds *to water molecules*, or that it contains polar NH and CO groups.

CHEMISTRY

Paper 9701/43
A2 Structured Questions

Key Messages

- Candidates would benefit from an increased familiarity with drawing structural formulae, especially three-dimensional diagrams for octahedral, square planar and tetrahedral structures.
- Many candidates should be reminded of the distinguishing tests for the different functional groups in organic chemistry.
- Candidates should set out calculations which clearly explain what the numbers refer to.

Candidates should also be reminded of the need to re-visit and revise AS material while preparing for the A Level examination, particularly in the key definitions as seen in **Questions 2(a)(i)** and **3(c)(i)**, and organic chemistry.

Candidates need to read the questions carefully before answering them; questions where this often appeared not to have been done were:

Question 2(a)(ii) – required a three-dimensional structure to be drawn,

Questions 7(b)(i)-(ii), 7(c) and **7(d)** – answers to this question tended to be very good from candidates who were familiar with NMR, or quite poor from candidates who resorted to an amount of guesswork.

General Comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who were well-prepared for the examination were able to tackle all of the questions. There was no evidence that candidates had insufficient time to complete the paper.

The questions in ***Section B*** were generally answered well, and the overall neatness and legibility of answers was good. This was not always the case however, and candidates are reminded to make sure that their desired final answers are legible and obvious to the Examiner.

The arithmetical working in calculation questions should be set out clearly, to allow Examiners to award ‘error-carried-forward’ marks wherever possible.

Candidates are also reminded of the importance of careful, thorough reading of the question before attempting to answer it, underlining key words or phrases on the question paper to ensure that it is answered in the correct manner.

This report should be read in conjunction with the published mark scheme for this paper.

Comments on Specific Questions

Section A

Question 1

(a) (i) Most candidates answered this correctly.

(ii) Only a few candidates managed to explain these differences correctly. For high melting point, few candidates mentioned about more delocalised electrons. For density, many candidates referred to mass instead of atomic mass, and often the link to atomic/ionic radius was omitted.

(b) (i) This was generally answered well, although some candidates erroneously included a battery in their circuit. A number did not include or label a salt bridge.

(ii) Most candidates scored some credit here. Many mentioned $1\,mol\,dm^{-3}$, but some called the solutions "Cu(II)/Cu and Fe(II)/Fe". Another common error was to suggest platinum as one or both of the electrodes.

(iii) Most candidates carried out the calculation correctly.

(iv) This question was more challenging, with only the more able candidates giving a well argued answer. Some candidates gained partial credit for explaining their E_{cell} change in terms of the $Fe^{2+} + 2e^- \rightleftharpoons Fe$ (or $Cu^{2+} + 2e^- \rightleftharpoons Cu$) moving to the right hand side.

Candidates were expected to state how the $E_{electrode}$ changes and relate this to their E_{cell}.

(c) (i) Few candidates knew that the end point of the reaction is given by the first appearance of a pale pink colouration when one drop of $KMnO_4$ is added in excess. A common error was to give the colour change as from purple to colourless.

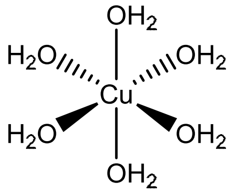
(ii) Most candidates scored some credit here. The final molar mass was found to be more challenging than the other two parts.

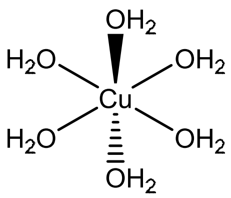
Question 2

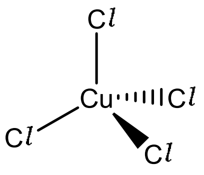
(a) (i) This was generally answered well, although a number of candidates did not specify (central) atom or ion in their definition of a complex.

(ii) This question was not answered well. Some poor three-dimensional diagrams were drawn as well, as there were many square planar instead of tetrahedral structures of $CuCl_4^{2-}$.

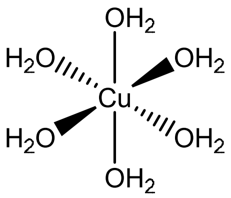
Some examples of correct three-dimensional diagrams of $(Cu(H_2O)_6)^{2+}$ and $(CuCl_4)^{2-}$ are shown below.

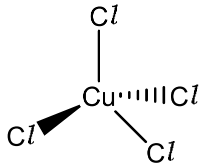




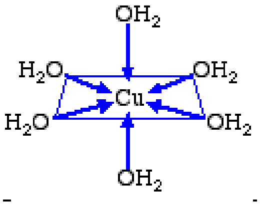


Common incorrect structures included:





A small number of octahedral structures were given that showed two vertical bonds and a perspectively-drawn square planar of 4 H_2Os. These structures did not normally include any out of plane bonds, so this structure gained no credit.



(iii) This was generally answered well. Geometrical was accepted as an alternative to cis-trans. Some candidates incorrectly suggested optical isomerism or stereoisomerism.

(b) (i) A significant number of candidates were not awarded credit here; a common error was filling the 4s orbital either fully or partially.

(ii) This seemed to be Centre-specific. The first part of the explanation was standard bookwork. Some very good answers were seen but equally quite a number of candidates did not mention the splitting of the d-orbitals by the ligand field or/and the promotion of an electron from a lower to a higher level by the absorption of visible light. For the second part, it was expected that the candidates would state that the d subshell is full or that there are no unpaired electrons in a d-orbital; common incorrect answers included statements that the energy gap between the d-orbitals is too large or that they have a full d-orbital.

(c) (i) This was answered well. Common incorrect answers included –212 (incorrect subtraction), +178.8 (omitting to multiply by 2), and –393.8 or +79.2 (one incorrect sign), all of which were partially credited.

(ii) Many candidates performed well here and the application of le Chatelier's principle in the second part was good.

Question 3

(a) Few candidates gave the correct reagents and conditions for this hydrolysis, with most omitting the water or heating.

(b) (i) A number of candidates failed to recognise that there were four isomers of piperic acid.

(ii) Fewer candidates were able to draw a *cis* isomer of piperic acid. Many candidates gave the same isomer of piperic acid as given in the question.

(iii) This proved to be a difficult question and was not answered well. Candidates needed to draw the two products from the oxidative cleavage of the two C=C bonds using hot concentrated acidified $KMnO_4$.

(c) (i) This was answered very well. The expression $K_w = K_a \times K_b$ was **not** accepted since the ionisation of water should be defined as $K_w = (H^+(aq))(OH^-(aq))$.

(ii) Many candidates carried out this calculation correctly.

(iii) This proved difficult for many candidates. Answers were often too vague such as stating that NaOH is more basic, and candidates did not mention that piperidine was a poorer proton acceptor or only partly ionised.

(iv) Many candidates also found this difficult. Only the more able recognised that the piperidine was more basic due to the presence of the electron donating alkyl groups.

(d) (i) Many candidates calculated the starting n(HC*l*) instead of the remaining n(HC*l*).

(ii) Only occasionally could error-carried-forward credit be awarded. Many candidates divided their answer to **(d)(i)** by 0.02 rather than 0.03, or just took the pH = –log(n(HC*l*)).

(iii) A reasonable number of candidates scored full credit for the graph, although many of these included an error-carried-forward for the pH at 20 cm^3. The most common error was suggesting that the end-point was 10 cm^3 instead of 15 cm^3.

(iv) A number of candidates correctly identified B as the most suitable indicator.

Question 4

(a) Most candidates correctly identified three functional groups here.

(b) (i) This proved difficult for many candidates with only the more able gaining full credit. For the first part, only a few recognised that **Z** was a cyanohydrin. The analogous benzyl alcohol and benzoic acid were common errors. In the second part, most omitted a base or NaCN with the HCN reagent, and Sn + HC*l* was a common error for the reductant.

(ii) Most candidates described the correct colour change or formation of a white precipitate, but far fewer managed to suitably brominate the ring, with the OHs often undergoing replacement.

(c) (i) This was generally answered well, although many candidates formed the sodium alkoxide as well as the two phenoxides.

(ii) Fewer candidates were able to draw the correct product of noradrenaline with HC*l*(aq). A common error was substitution of one or both OHs by C*l*.

(iii) The reaction with CH_3COCl was much better known by candidates, and many gained some credit. However, only the more able realised that three ester and one amide groups would be formed with excess CH_3COCl.

(d) Only a minority of candidates scored full credit here, although most correctly identified the ester.

Question 5

(a) (i) This was correctly answered by most candidates.

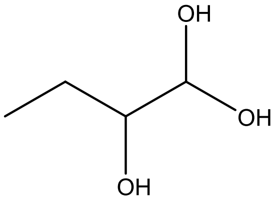
(ii) This too was mostly answered correctly.

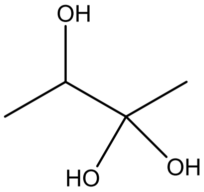
(iii) This was less well known, with many candidates suggesting a secondary alcohol which was not sufficient.

(b) In this part, candidates were expected to use their answers from **(a)(i)-(iii)** to suggest structures for **V** and **W**. Often their answers did not tally with the groups suggested. A common error was drawing an enol for one or both structures.

(c) Most candidates scored full credit here, although many of these included error-carried-forward for cis-trans and corresponding isomers of their enol suggested in **(b)**.

(d) This proved difficult for many candidates, with only the more able gaining full credit. A number of gem-diols were incorrectly suggested.





Section B

Question 6

(a) This part was straightforward, and most candidates scored full credit.

(b) This question was answered well. Common errors seen were thyamine/thiamine (instead of thymine) and cysteine (instead of cytosine).

(c) (i) Most candidates gave the correct answer here.

(ii) This was generally answered well. It was expected that candidates would mention that hydrogen bonds are weak so are easy to break; a number did not give a full explanation.

(d) Many candidates gave the correct answer here.

Question 7

(a) Candidates showed a good understanding of how to calculate the number of carbon atoms from the mass spectrum peak height ratio.

(b) (i) This question required the use of the *Data Booklet* and the splitting pattern, which is so characteristic of the ethyl group. These seemed to be ignored by a lot of candidates. Common errors were (δ 2.2) RCH_2R and (δ 11.8) OH.

(ii) This proved a challenging question with only the more able candidates gaining full credit. Only about half of the candidates correctly identified the peak at δ 11.8. There seemed to be a poor understanding of hydrogen-deuterium exchange.

(iii) This question proved to be difficult with only the stronger candidates drawing the correct structural formula of **G**, CH_3CH_2COOH. A small number suggested the acceptable amide alternative, $CH_3CH_2CONH_2$. Many candidates did not suggest a viable structure that only had three different proton environments, or a structure that had a group that would undergo hydrogen-deuterium exchange.

(c) (i) Only a few candidates gave one of the acceptable structures, methyl ethanoate being the most common. Most incorrect answers suggested had three, instead of two, different proton environments.

(ii) This was marked conditionally of **(c)(i)**. Full credit was rarely awarded.

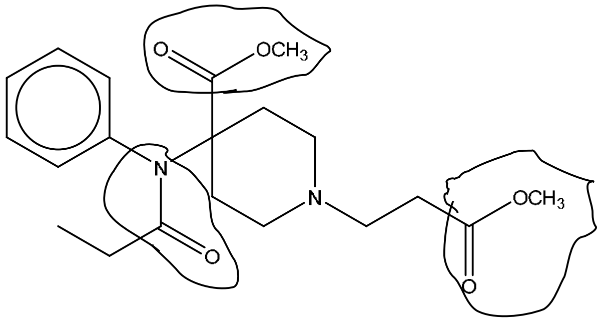
Question 8

(a) (i) This part was generally well answered. A common incorrect answer was amine.

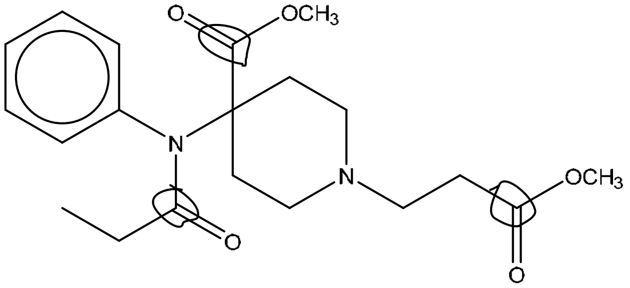
(ii) Fewer candidates managed to state that the type of reaction is hydrolysis. A variety of incorrect answers were seen including condensation, neutralisation and reduction.

(iii) This part was answered well.

(iv) This was marked conditionally of **(a)(iii)**. It was expected that candidates would circle three functional groups, two methyl esters and the amide.



Many circled two groups only and the amide was commonly forgotten. Many only circled the C of the C=O and did **not** include the singly-bonded heteroatom either. In this case partial credit was awarded.



(b) (i) Most candidates identified the correct location, **Q**, and gave a suitable explanation here.

(ii) There were many good answers to this part. Some candidates stopped short with only a reference to its hydrophilic nature.

(c) (i) Most candidates gave a correct response here.

(ii) Fewer candidates scored here and it usually depended on whether they mentioned ‘cells’ or ‘tissues’. A number of vague references to causing harm and comparing the size of the nanocage to the wavelength of the radiation were seen.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key Messages

- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.

- Candidates should be reminded that useful information is often given in the question introduction which needs to be considered before answering.

General Comments

The basis of **Question 1** was the determination of the stoichiometric relationship for the thermal decomposition of magnesium nitrate(V). Candidates struggled with formulae and with drawing suitable equipment for gas collection.

In **Question 2** candidates were required to handle electrode potential data and manipulate the Nernst equation, the latter proving difficult for some candidates. The drawing of the graph was much improved on previous years' performances, possibly because of the introduction of labelled axes on which candidates plotted their points.

Comments on Specific Questions

Question 1

(a) (i) Despite being given the reactants and products, many candidates were not able to state correct equations for the thermal decomposition of magnesium nitrate(V). The formulae of magnesium nitrate(V) and nitrogen(IV) oxide were common problems. It should be emphasised that the skills involved here are fundamental in chemistry and provide the basis for much subsequent understanding.

(ii) Most candidates calculated a correct relative molecular mass for magnesium oxide. Many candidates were successful in calculating molar volumes even if their equation in **(a)(i)** was incorrect, provided they correctly used the molar ratios given by their equation. Candidates should be reminded to make sure they have fully answered the question; in this case all values were required. Units should always be given.

(b) (i) Experience of practical experimental procedures was necessary to produce a diagrammatic representation of equipment that would carry out the required process. The question required that the nitrogen(IV) oxide absorbance and oxygen collection be done separately and sequentially. Many candidates had two output tubes from the reaction vessel leading to two syringes or one tube that split into two and onto two syringes. In both these cases the candidates assumed that each syringe would collect one of the gases alone. Some drawings of oxygen collection over water did not function. Various nitrogen(IV) oxide absorbers were proposed and although the question stated that the nitrogen(IV) oxide was acidic and reacts completely with alkalis, many did not include an alkali (or base) in their absorber. Many attempts were made which included an alkali but would not properly work. These included having cotton wool soaked in alkali in the upper part of the tube, having the magnesium nitrate(V) heated in an alkali solution, having various U tubes that would not allow the passage of gas and passing the gas stream over solid alkali in a tube. Often the diagrams were not sufficiently labelled or the apparatus was not drawn as airtight. Very few candidates received full credit on this question which is significant since confidence in experimental set up details of this nature are fundamental to practical chemistry.

(ii) In order to successfully state the volume of the gas collector, candidates needed to be familiar with the equipment available in a common school laboratory. Some candidates proposed very large (e.g. 50 dm^3) collectors which were impractical or sizes that lacked a unit.

In order to calculate an appropriate mass of magnesium nitrate(V) to be used, a number of operations were required. These included converting the proposed volume of the gas collector to moles of oxygen, then using their mole ratios from the answer to **(a)(i)** along with the relative molecular mass of magnesium nitrate(V). Many candidates made a good attempt at this calculation and most of those were successful. As a generality in a multistage calculation it is best not to round values during the calculation but to do so at the final answer (if necessary). On occasion the unit was missing or incorrect. Some candidates confused magnesium nitrate(V) and magnesium oxide.

(c) Most candidates had some idea of the measurements of the reactant and products required for the verification of the equation, but the answers were mostly incomplete. There was a requirement for the starting **and** finishing mass; this was often omitted.

(d) (i) There are many observations (e.g. no bubbles in the trough or syringe plunger stops moving) that could be used to indicate the end of the reaction; simply saying ‘no more gas is produced’ does not indicate how this would be observed. Some candidates who gave ‘until no more solid in the tube’ did not take account of the solid nature of the magnesium oxide product. Others incorrectly surmised there may be a colour change at the end.

(ii) In experiments involving measurement of gas volumes, the temperature and/or pressure conditions are crucial to having accurate results. Too many answers did not refer to this, instead referring to having a syringe set to zero, empty or in a vacuum.

(e) The majority of the candidates understood that a response in terms of mole ratios was required but often became confused. In order to maintain clarity in responses requiring more than one piece of information, candidates may find it helpful to use bullet points.

(f) The hazard data given in the question concerned the dangers of inhaling nitrogen(IV) oxide, thus ways of preventing that were required, such as masks or guards of various descriptions or fume cupboards that would prevent gas escape into the laboratory.

Question 2

There was a substantial amount of background information concerning the cell set up which needed to be considered before attempting answering the questions. A feature of the calculations in this question was the significance of the negative sign which was often ignored by candidates.

(a) The data calculation was very straightforward and the vast majority of the candidates gained full credit here. Most of the errors were in decimal place typically 1.00 and 2.00 being given as 1 and 2 respectively. Sometimes there was evidence of truncation rather than correct rounding, e.g. the last value of -3.699 given a -3.69 rather than -3.70.

(b) The candidates were not required, as in past years, to draw, label and scale the axes which made good graphical representation much more straightforward. All the candidates used the given axes without alteration and coped well with the negative log scale.

The nature of the values of the data and scaling of the axes meant that all of the points were on the intersection of two grid lines. As a consequence the plotting of the data was very well done. There were only a few mis-plots, notably the point (-0.30,0.94) which was often plotted at (-3.00,0.94). Some candidates’ plots were very faint and difficult to see, for example a dot plot often gets obscured by the drawn line. Some candidates with a dot or cross plot had a small circle around them making them more obvious (any anomaly would then have a double circle to identify it).

The line of best fit was mostly done very well with the best line going through five points and just missing points 3, 5 and 7. There was some evidence that a few candidates did not use a ruler or had a line composed of more than one line.

(c) It was apparent that most candidates were expecting there to be anomalous points and selected those that were just off the line as anomalous. However those points were well within the variation that could be expected in the data so were not anomalous. A minority of candidates correctly reported no anomalies. Even fewer gave a reason for that based on the rounding of the log values and the measurement of the cell potential to two decimal places leading to some variability in the data.

(d) (i) Most candidates drew satisfactory construction lines on their graphs. For the calculation of the slope most candidates correctly read the co-ordinate values typically using data points that were on the line and correctly calculated the slope. However, some candidates gave some inversion of co-ordinate values i.e. $(y_1 - y_2)/(x_2 - x_1)$ whist others did not give the slope as negative which should have been apparent to candidates by way of the negative slope of the line.

The calculation of a value for n proved difficult for many candidates, even though the equation given could be rearranged into the form $y = mx + c$. Some candidates with a good value for n did not round to the nearest whole number.

(ii) The simplest way of determining $E^\ominus$ is from the line equation $y = mx + c$ where the intercept on the y axis (at $x = 0$) is $E^\ominus$ and if the line was produced back to that axis it would give 0.931 V. As the data was given to two decimal places then 0.93 V was acceptable. Some candidates calculated $E^\ominus$ from the Nernst equation using the value of n from **(d)(i)** and one set of data. If a reasonable value of n was used this approach was usually successful.

(e) Only a minority of candidates used a correct calculation in this part. The most common deviations were the inversion of the calculation and the loss of the important negative sign. Also required was the identity of M from the $E^\ominus$ value which had to be a metal but was often given as an ion.

(f) The required equation was often given incorrectly here. Common errors were having the reverse reaction or not balancing the equation, particularly in the number of silver atoms in the products.

(g) (i) It was very pleasing to see that many candidates were aware that the salt bridge allows the movement of ions rather than electrons.

(ii) This question was not well answered; the solubility of potassium and nitrate compounds and the insolubility of lead and silver chlorides were not well known. Many candidates attempted explanations in terms of electrode potential.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key Messages

- Candidates should read the paper carefully to make sure that they have read all the information required in order to answer the questions.
- Numbers must be rounded correctly and units supplied for all numerical quantities.
- Points on graphs should be marked clearly and neatly. Large crosses or other styles of plots that do not indicate precisely where the candidate intends the point to lie may not receive credit.

General Comments

Question 1, which required an appreciation of practical procedures, was generally poorly answered. Many appeared to have little knowledge or experience of practical work and were unable to suggest how to dilute a solution to one of lower concentration or to provide details of how to make up a standard solution. Understanding how to carry out an experiment successfully is a vital skill in A Level Chemistry and, even if the equipment available is limited, care should be taken to either demonstrate or to explain to candidates what these procedures involve. There was evidence that a surprisingly large number of candidates were unaware of the precision that was achievable with various pieces of apparatus. Marks on conical flasks were often thought to give equivalent accuracy to the mark on a volumetric flask and the use of a measuring cylinder was considered an acceptable alternative to a pipette or a burette. Candidates need to have a thorough understanding of practical techniques. Handling calculations based on molar quantities is also an area that many find difficult.

Candidates were often good at handling the data in **Question 2** and many were able to convert between units reliably.

Comments on Specific Questions

Question 1

(a) Most candidates knew that the greater solubility of ammonia in water was the result of hydrogen bonding but further explanation was required in order for full credit to be awarded. Only a small number of candidates gave any comment that received further credit.

(b) Despite the explanation of partition coefficient in the stem of the question, intended to help those candidates who would not have carried out this type of experiment, very few were able to answer this question. The partition coefficient could be defined with either the concentration of ammonia in water or in trichloromethane as the numerator but it was then required that a statement was given as to whether the coefficient would be greater or less than 1. Not all remembered to do this.

(c) There seemed to be confusion between volume and concentration, leading many candidates to conclude that the volumes of water and trichloromethane had to be the same. This was the case even for those who had provided a correct definition for the partition coefficient. Where candidates did understand the difference they were usually able to provide a reason.

(d) It was very disappointing that this question led to so many incorrect answers. The formation of either ammonium hydrogen sulfate or ammonium sulfate received credit. There were, however, many who could not provide a correct formula for ammonia or who thought that sulfur dioxide, nitrogen monoxide, nitric acid or other substances would be formed by the reaction.

(e) (i) Credit was awarded for the calculation based on the reacting quantities that candidates had provided in their answer to **1(d)** but, as has been the case in the past, a significant number struggled to solve this type of problem. Even those who did succeed in providing a suitable concentration of ammonia for the titration were frequently unable to suggest what dilution was required.

(ii) The procedure for carrying out the dilution was often outlined but the necessary detail was missing. Although some were able to explain the procedure for using a volumetric flask many thought a conical flask was equally acceptable. Where a volumetric flask was chosen many measured out the volume of ammonia to be taken using a measuring cylinder and thereby negated the value of the greater precision of using volumetric equipment. Partial credit was gained by a reasonable number of candidates.

(f) The vast majority of candidates gained credit here, including those who had struggled with earlier parts.

(g) It was not well understood that as this was a titration between a weak alkali and a strong acid, phenolphthalein could not be used as the indicator. In order to obtain full credit, a reason for the choice needed to be stated.

(h) It was hoped that candidates would appreciate the greater reliability that the titration of the aqueous layer would allow, using larger volumes. However this proved a very difficult question for even the most able candidates.

(i) Candidates did not always appreciate that the experiment could have been carried out with different volumes of the two solvents. Therefore the correct procedure would be to use the result of the titration of the aqueous layer to determine the amount in moles of ammonia present. Since only this titration had been done the moles of ammonia in the trichloromethane layer could then be determined by subtracting the moles in the aqueous layer from the total number of moles used initially.

Question 2

(a) The plotting of the points on the graph was generally well done although as mentioned in the key messages it was sometimes impossible to decide where the candidate intended the point to be because of the size of the point that had been made. It was recognised that it was difficult to draw a convincingly smooth curve and some reasonable leeway was allowed in the award of credit. A few did not appreciate that the points represented a curve and drew a straight line instead.

(b) Most candidates identified the anomalous point correctly but then had difficulty giving a convincing reason as to how it might have occurred. Those who did provide a suitable answer usually correctly focused on the possibility that the time was read after the concentration was recorded. Credit was not awarded for answers of ‘careless experimenting’. Acceptable answers needed to focus on some aspect relevant to the procedure being carried out.

(c) It was expected that candidates would use the constancy of the half-life to establish that the reaction was first order. Most did this but an appreciable number drew tangents to the curve at the two points on the graph and measured the gradients to identify the order. Where this was done correctly, credit was awarded but using this method was much more difficult and many did not manage to handle the results satisfactorily, often leading them to the conclusion that the reaction was second order.

(d) (i) Candidates were expected to draw a tangent at time zero and determine its gradient to obtain the initial rate of reaction. It was recognised that this was difficult to do precisely so a wide range of gradients were accepted. A common error was to assume the *y*-axis started at zero instead of 3×10^8.

(ii) Error carried forward was applied here from the answers to **2(b)** and **2d(i)**. On this basis some candidates managed to provide a numerical answer for the rate constant. Very few however were able to provide the correct units.

(e) Generally candidates gave a correct answer to this part from their gradient calculated in **2(d)(i)**. A frequent error was made in converting the answer in cm^3 to one in dm^3.

(f) Answers to this question were often poor. Only a minority appreciated that the order with respect to nitrogen(II) oxide can only be determined if the concentration of ozone is effectively constant. A few gained credit for referring to the nitrogen(II) oxide being a ‘limiting reagent’ but often it was not clear that the candidate understood what they meant by this.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key Messages

- An increased familiarity with experimental techniques and experience of carrying out practical procedures would be of benefit to candidates.

- Candidates should be reminded that useful information is often given in the question introduction which needs to be considered before answering.

General Comments

The basis of **Question 1** was the determination of the stoichiometric relationship for the thermal decomposition of magnesium nitrate(V). Candidates struggled with formulae and with drawing suitable equipment for gas collection.

In **Question 2** candidates were required to handle electrode potential data and manipulate the Nernst equation, the latter proving difficult for some candidates. The drawing of the graph was much improved on previous years' performances, possibly because of the introduction of labelled axes on which candidates plotted their points.

Comments on Specific Questions

Question 1

(a) (i) Despite being given the reactants and products, many candidates were not able to state correct equations for the thermal decomposition of magnesium nitrate(V). The formulae of magnesium nitrate(V) and nitrogen(IV) oxide were common problems. It should be emphasised that the skills involved here are fundamental in chemistry and provide the basis for much subsequent understanding.

(ii) Most candidates calculated a correct relative molecular mass for magnesium oxide. Many candidates were successful in calculating molar volumes even if their equation in **(a)(i)** was incorrect, provided they correctly used the molar ratios given by their equation. Candidates should be reminded to make sure they have fully answered the question; in this case all values were required. Units should always be given.

(b) (i) Experience of practical experimental procedures was necessary to produce a diagrammatic representation of equipment that would carry out the required process. The question required that the nitrogen(IV) oxide absorbance and oxygen collection be done separately and sequentially. Many candidates had two output tubes from the reaction vessel leading to two syringes or one tube that split into two and onto two syringes. In both these cases the candidates assumed that each syringe would collect one of the gases alone. Some drawings of oxygen collection over water did not function. Various nitrogen(IV) oxide absorbers were proposed and although the question stated that the nitrogen(IV) oxide was acidic and reacts completely with alkalis, many did not include an alkali (or base) in their absorber. Many attempts were made which included an alkali but would not properly work. These included having cotton wool soaked in alkali in the upper part of the tube, having the magnesium nitrate(V) heated in an alkali solution, having various U tubes that would not allow the passage of gas and passing the gas stream over solid alkali in a tube. Often the diagrams were not sufficiently labelled or the apparatus was not drawn as airtight. Very few candidates received full credit on this question which is significant since confidence in experimental set up details of this nature are fundamental to practical chemistry.

(ii) In order to successfully state the volume of the gas collector, candidates needed to be familiar with the equipment available in a common school laboratory. Some candidates proposed very large (e.g. 50 dm^3) collectors which were impractical or sizes that lacked a unit.

In order to calculate an appropriate mass of magnesium nitrate(V) to be used, a number of operations were required. These included converting the proposed volume of the gas collector to moles of oxygen, then using their mole ratios from the answer to **(a)(i)** along with the relative molecular mass of magnesium nitrate(V). Many candidates made a good attempt at this calculation and most of those were successful. As a generality in a multistage calculation it is best not to round values during the calculation but to do so at the final answer (if necessary). On occasion the unit was missing or incorrect. Some candidates confused magnesium nitrate(V) and magnesium oxide.

(c) Most candidates had some idea of the measurements of the reactant and products required for the verification of the equation, but the answers were mostly incomplete. There was a requirement for the starting **and** finishing mass; this was often omitted.

(d) (i) There are many observations (e.g. no bubbles in the trough or syringe plunger stops moving) that could be used to indicate the end of the reaction; simply saying ‘no more gas is produced’ does not indicate how this would be observed. Some candidates who gave ‘until no more solid in the tube’ did not take account of the solid nature of the magnesium oxide product. Others incorrectly surmised there may be a colour change at the end.

(ii) In experiments involving measurement of gas volumes, the temperature and/or pressure conditions are crucial to having accurate results. Too many answers did not refer to this, instead referring to having a syringe set to zero, empty or in a vacuum.

(e) The majority of the candidates understood that a response in terms of mole ratios was required but often became confused. In order to maintain clarity in responses requiring more than one piece of information, candidates may find it helpful to use bullet points.

(f) The hazard data given in the question concerned the dangers of inhaling nitrogen(IV) oxide, thus ways of preventing that were required, such as masks or guards of various descriptions or fume cupboards that would prevent gas escape into the laboratory.

Question 2

There was a substantial amount of background information concerning the cell set up which needed to be considered before attempting answering the questions. A feature of the calculations in this question was the significance of the negative sign which was often ignored by candidates.

(a) The data calculation was very straightforward and the vast majority of the candidates gained full credit here. Most of the errors were in decimal place typically 1.00 and 2.00 being given as 1 and 2 respectively. Sometimes there was evidence of truncation rather than correct rounding, e.g. the last value of -3.699 given a -3.69 rather than -3.70.

(b) The candidates were not required, as in past years, to draw, label and scale the axes which made good graphical representation much more straightforward. All the candidates used the given axes without alteration and coped well with the negative log scale.

The nature of the values of the data and scaling of the axes meant that all of the points were on the intersection of two grid lines. As a consequence the plotting of the data was very well done. There were only a few mis-plots, notably the point (-0.30,0.94) which was often plotted at (-3.00,0.94). Some candidates’ plots were very faint and difficult to see, for example a dot plot often gets obscured by the drawn line. Some candidates with a dot or cross plot had a small circle around them making them more obvious (any anomaly would then have a double circle to identify it).

The line of best fit was mostly done very well with the best line going through five points and just missing points 3, 5 and 7. There was some evidence that a few candidates did not use a ruler or had a line composed of more than one line.

(c) It was apparent that most candidates were expecting there to be anomalous points and selected those that were just off the line as anomalous. However those points were well within the variation that could be expected in the data so were not anomalous. A minority of candidates correctly reported no anomalies. Even fewer gave a reason for that based on the rounding of the log values and the measurement of the cell potential to two decimal places leading to some variability in the data.

(d) (i) Most candidates drew satisfactory construction lines on their graphs. For the calculation of the slope most candidates correctly read the co-ordinate values typically using data points that were on the line and correctly calculated the slope. However, some candidates gave some inversion of co-ordinate values i.e. $(y_1 - y_2)/(x_2 - x_1)$ whist others did not give the slope as negative which should have been apparent to candidates by way of the negative slope of the line.

The calculation of a value for n proved difficult for many candidates, even though the equation given could be rearranged into the form $y = mx + c$. Some candidates with a good value for n did not round to the nearest whole number.

(ii) The simplest way of determining $E^\ominus$ is from the line equation $y = mx + c$ where the intercept on the y axis (at $x = 0$) is $E^\ominus$ and if the line was produced back to that axis it would give 0.931 V. As the data was given to two decimal places then 0.93 V was acceptable. Some candidates calculated $E^\ominus$ from the Nernst equation using the value of n from **(d)(i)** and one set of data. If a reasonable value of n was used this approach was usually successful.

(e) Only a minority of candidates used a correct calculation in this part. The most common deviations were the inversion of the calculation and the loss of the important negative sign. Also required was the identity of M from the $E^\ominus$ value which had to be a metal but was often given as an ion.

(f) The required equation was often given incorrectly here. Common errors were having the reverse reaction or not balancing the equation, particularly in the number of silver atoms in the products.

(g) (i) It was very pleasing to see that many candidates were aware that the salt bridge allows the movement of ions rather than electrons.

(ii) This question was not well answered; the solubility of potassium and nitrate compounds and the insolubility of lead and silver chlorides were not well known. Many candidates attempted explanations in terms of electrode potential.