

CHEMISTRY

Paper 9701/11
Multiple Choice

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

This examination paper provided a difficult but suitable challenge to the candidates. There were many pleasing performances, and some excellent ones.

Thirteen questions can be said to have been found to be easier. 60% or more of candidates chose the correct responses to each of **Questions 1, 8, 11, 15, 16, 18, 19, 22, 31, 32, 35, 37 and 38**.

Six questions can be said to have been found to be particularly difficult. Less than 30% of candidates chose the correct responses to each of **Questions 3, 6, 21, 24, 28 and 39**.

Question 3

29% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answers were **B**, chosen by 32% of candidates, and **C**, chosen by 28% of candidates. The original combustion reaction produces 0.50/12 moles of CO₂ (1 dm³), and 0.50/12 moles of CO (1 dm³). The NaOH will absorb the CO₂ leaving 1 dm³ of CO as the remaining gas.

Question 6

25% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 33% of candidates. Candidates might have imagined the equilibrium situation in the 1 dm³ flask, followed by a sudden doubling of volume, perhaps by the movement of a piston. The pressure in the flask has instantaneously halved, this favours the forward reaction since there are more gas molecules on the right hand side of the equation. This causes the equilibrium concentration of PCl₅ to decrease.

Question 21

28% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 30% of candidates. This suggests that a majority of the candidates realised that the cyclic compound would hydrolyse to HOCH₂CO₂H and H₂NCH₂CO₂H. Approximately half of those that got this far then realised that the amine produced would be protonated under acidic conditions, giving HOCH₂CO₂H and NH₃⁺CH₂CO₂H, hence the answer **B**.

Question 24

21% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 34% of candidates. This was a difficult question to visualise, it was hoped that candidates would draw the structures given on their papers. The compounds in **A** and **B** have cyclopentane rings; since a C–C bond will not be broken in a nucleophilic substitution reaction these choices are not possible answers. Since **C** has a butyl group, and **D** has the necessary propyl group, the answer is **D**.

Question 28

29% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 27% of candidates. This question again required careful visualisation by the candidates. All carbon atom positions in the Ladenburg structure are equivalent, so the first chlorine atom can be put on the carbon right at the top of the diagram. It can then be seen that there are only three other different positions for the second chlorine atom.

Question 39

20% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **B**, chosen by 33% of candidates. The majority of candidates therefore realised that compounds 1 and 2 would react with HBr to give R, but many of those did not realise why compound 3 would do so.

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Paper 9701/12
Multiple Choice

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

This examination paper provided a suitable challenge to the candidates. There were a large number of pleasing performances, and many excellent ones.

Eighteen questions can be said to have been found to be easier. 60% or more of candidates chose the correct responses to each of **Questions 1, 3, 4, 5, 8, 13, 14, 16, 20, 22, 24, 25, 27, 28, 31, 33, 35 and 39.**

Four questions can be said to have been found to be particularly difficult. 40% or less of candidates chose the correct responses to each of **Questions 2, 21, 32 and 37.**

Question 2

37% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **D**, chosen by 39% of candidates. The choice of **D** suggests some candidates successfully calculated that one egg shell contains 0.025 moles of calcium carbonate, and that the sample of acid contains 0.100 moles of ethanoic acid. The 1:4 ratio between these two amounts suggests an answer of **D**. However one formula unit of calcium carbonate neutralises two molecules of ethanoic acid, so two complete egg shells, containing 0.050 moles of calcium carbonate, neutralises 0.100 moles of ethanoic acid.

Question 21

33% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **D**, chosen by 33%. These figures suggest that the majority of candidates knew that, in an excess of HBr, both OH groups would be substituted by Br atoms. The decision between **C** and **D** is based on Markovnikov addition. The hydrogen atom adds to the CH group, where “most hydrogen atoms are already bonded”, and the bromine atom adds to the carbon atom originally bonded to no hydrogen atoms, hence the answer is **C**. There will certainly be some of **D** in the product mixture, but it should be noted that the question asks for the identity of the major product, which is **C**.

Question 32

35% of candidates chose the correct answer, **D**. The most commonly chosen incorrect answer was **B**, chosen by 34% of candidates. This shows that the majority of candidates knew that “The intermolecular forces between the Al_2Cl_6 molecules are weak”, but that approximately half of this majority also believed “The co-ordinate bonds between aluminium and chlorine are weak” was true. Co-ordinate bonds, being covalent bonds, should be described as strong, therefore statement 2 is false and the correct answer is **D**.

Alternatively some candidates may have approached this question in another way. It is possible that candidates who chose **D** knew that when aluminium chloride sublimes it forms $Al_2Cl_6(g)$, and not $AlCl_3(g)$. It is also possible that candidates who chose **B** believed that when aluminium chloride sublimes it forms $AlCl_3(g)$, however this is not the case.

Question 37

24% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **C**, chosen by 30% of candidates. The presence of π -bonding involving two of the labelled carbon atoms in structures 1 and 2 causes the planar configuration asked for in the question. In structure 3 the central labelled carbon atom is also bonded to a hydrogen atom, therefore the bond angles around it are less than 120° and the four labelled carbon atoms are not co-planar.

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Paper 9701/13
Multiple Choice

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

This examination paper proved to be very accessible to the candidates. There were many pleasing performances, and some excellent ones.

Eleven questions can be said to have been found to be easier. 70% or more of candidates chose the correct responses to each of **Questions 1, 2, 5, 8, 14, 16, 17, 24, 27, 31 and 32**.

Six questions can be said to have been found to be particularly difficult. Less than 40% of candidates chose the correct responses to each of **Questions 9, 15, 26, 28, 39 and 40**.

Question 9

29% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 31% of candidates. Option **A** might be true if H_2 and Cl_2 came in contact with each other in a diaphragm cell, but the H_2 bubbles out as soon as it is formed, so this is not true. Without the diaphragm the reaction $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaClO} + \text{H}_2\text{O} + \text{NaCl}$ would take place, so the answer is **C**.

Question 15

39% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answers were **A**, chosen by 27% and **D**, chosen by 24% of candidates. This question is based on factual recall; MgCl_2 does not hydrolyse to any significant degree to form HCl . It is possible that the significance of the word “not”, emboldened twice in the question, was missed by some candidates.

Question 26

27% of candidates chose the correct answer, **B**. The most commonly chosen incorrect answer was **A**, chosen by 40% of candidates. Alkane X can be either butane or methylpropane. If X is butane it will react with chlorine to produce 1-chlorobutane and 2-chlorobutane. 2-chlorobutane will react with hot ethanolic KOH to give more than one alkene product. X is therefore methylpropane and Y is methylpropene which reacts with hot concentrated acidified MnO_4^- to give CO_2 and CH_3COCH_3 .

Question 28

30% of candidates chose the correct answer, **C**. The most commonly chosen incorrect answer was **A**, chosen by 31% of candidates. These figures suggest that the majority of candidates understood the $\text{S}_{\text{N}}1$ mechanism and so identified **B** and **D** as incorrect. However the carbocation that is formed in the reaction is an intermediate and not a transition state, so the correct answer is **C**.

Question 39

31% of candidates chose the correct answer, **A**. The most commonly chosen incorrect answer was **D**, chosen by 34% of candidates. This suggests that the majority of candidates were sure that the reaction between an aldehyde and Fehling's reagent is a redox reaction, but were unsure when the reactants were a hydrocarbon and a halogen. In both the reactions $\text{C}_2\text{H}_4 + \text{Br}_2 \rightarrow \text{C}_2\text{H}_4\text{Br}_2$ and $\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$ the oxidation number of each halogen atom decreases from 0 to -1, so these are indeed redox reactions.

Question 40

33% of candidates chose the correct answer, **B**. The other three choices were chosen in approximately equal amounts. $\text{CH}_2\text{BrCHCH}_2$ is a bromoalkene. It will undergo hydrolysis since, if water is added, the Br will be substituted by an OH group. It will undergo free radical substitution if treated with chlorine in the presence of UV light. However the nucleophilic addition mechanism is followed by such reactions as the reaction between HCN and a carbonyl compound. There is no carbonyl group here, statement 3 is not correct, so the correct answer is **B**.

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Paper 9701/21
Structured Questions AS Core

Key Messages

Candidates are to be reminded to read questions carefully and check answers thoroughly, especially in the extended answers of **1(d)(ii)**, where candidates often contradicted themselves through the imprecise use of chemical terminology.

The calculation in **2(b)** was well attempted by some, though it is recommended that similar calculations be practised frequently in preparation for examination.

Candidates ought to be clear about the difference between intermolecular and intramolecular forces, and to know exactly the meaning of structure in the context of covalent/ionic/metallic bonding. Particular care in the use of chemical terminology is recommended: clear statement of fact is crucial in the presentation of argument.

Candidates are also reminded that their 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. The overall standard achieved by candidates was lower than in previous years, in reflection of apparent unfamiliarity with some areas of the syllabus that had not recently been assessed at this level. Scripts were generally clear and well presented; as a general point of presentation, it ought to be noted that it is difficult for Examiners to read scripts where answers written in pencil have been overlaid with ink and not rubbed out.

Comments on Specific Questions

Question 1

This question gave a comprehensive assessment of candidates' knowledge of both atomic structure and the structure and bonding present in molecules and compounds.

- (a) A surprising number of candidates offered incorrect answers to this straightforward question. It is noted that relative charge needed a magnitude (± 1) to be credited.
- (b)(i) Whilst it was clear from candidates' answers that they were aware of the two definitions being tested in this question, insufficient precision in many answers often meant that credit could not be awarded. For instance, each definition required reference to *atoms* (or *isotopes* for A_r), to make it clear what kind of particle was being referenced. Candidates are advised to learn simple definitions thoroughly, so as easily to be able to repeat them when in examination conditions.

Some candidates confused the definitions of *isotope* and *isomer*.

- (ii) There were many correct answers to this part, though many candidates did not respond to the requirement for the answer to be provided to two decimal places. Other frequent errors included simple miscalculations, and the misidentification of the element (using atomic number, giving Au, rather than atomic mass).

- (c) (i) Most candidates gained at least partial credit for this calculation; many did not use 270 as a guide to determining that the empirical and molecular formulae were the same. Other errors seen were inverted fractions, use of Z rather than A_r , flipped ratios and use of C_l rather than Cl .
- (ii) Many different answers were encountered in this question, with the whole range of different types of bonding and structure being offered.
- (iii) This question tested candidates' ability to transfer their knowledge to a new situation: those who spotted the analogue with $SiCl_4$'s chemistry were generally adept at constructing an equation, although there were evidently issues with balancing the species.
- (d) (i) There were many good answers to this question. Candidates are advised to include specific colours in their answers in order to gain full credit.
- (ii) The identification of structure and bonding types tended to be more accomplished than the reasoning thereafter, although many candidates incorrectly suggested that $SiCl_4$ was giant covalent. Others unfortunately gave contradiction, e.g. "Giant ionic lattice structure with metallic bonding."

Credit available for explanation required a reference to the *difference* in electronegativity of the elements (resulting in ionic bonding for $NaCl$) and, further, to relate this to the structure (simple vs giant) of the two compounds.

Question 2

Although many candidates answered this question well, it was clear that a good proportion was not sufficiently familiar with ideal gases and the gas laws and confused answers were offered as a result.

- (a) (i) There were many good answers to this question, though Examiners would like to stress the need for candidates to use a ruler to draw straight lines.
- (ii) Few candidates were able to identify T_1 as being the lowest temperature **and** give an acceptable reason for this, relating to the extent to which the line for T_1 deviates from the ideal gas line.
- (iii) The key to answering this question was to observe that intermolecular forces necessarily become *significant* at low temperature: many candidates correctly observed that the interactions increase as intermolecular distance falls, but did not make the link that this breaks the assumptions made by the ideal gas model.
- (iv) One of the more challenging questions on the paper, this tested candidates' recall of the loss of ideal conditions at high pressure. Some candidates were able to gain partial credit, identifying high pressure as giving the greatest deviation, but then many answered this in terms of intermolecular forces rather than in terms of non-negligible volume of particles.
- (b) An essentially straightforward calculation, this question nevertheless proved difficult for candidates.
- The most common error was for candidates to assume that the flask containing air was instead under vacuum: this meant that they then used an incorrect mass of 0.059 g of Y to find its M_r .
 - This error was compounded by some who used this mass to work out a volume for Y using the density of air, obtaining $0.059 \text{ g} \div 0.00118 \text{ g cm}^{-3} = 50.0 \text{ cm}^3$ (whereas the volume of the flask, 100 cm^3 should have been used throughout).
 - Other common mistakes were not to convert 26°C to 299 K, or to misuse 100 cm^3 in the final calculation.
- (c) (i) Although Examiners credited candidates with a wide variety of expressions, many candidates were awarded no credit in this question for want of a statement about the strength of the $N\equiv N$ triple bond.
- (ii) There were many correct answers to this part. No credit was given if candidates made reference to catalytic conversion: the question references the conditions within a car's engine.
- (iii) There were many correct answers given to this part.

- (iv) Few candidates could recall the correct equation, or the alternative involving the disproportionation of NO_2 into HNO_2 and HNO_3 . Many candidates treated the reaction like that of sulfur trioxide with water, leading to incorrect answers that were unbalanced, or that featured H_2NO_3 . Some candidates realised that the creation of HNO_3 required redox, but chose instead to produce H_2 , rather than add O_2 .
- (v) This question was not well answered: only a very few could give the correct two equations in the right order. Many wrong answers likened the process to that in (c)(iii), suggesting that N_2 would be formed.

Question 3

This question proved to be a significant discriminator of candidates, whose calculations contained many different errors, and whose knowledge of reactions and mechanism in organic chemistry was not as secure as might have been hoped.

- (a) This question saw many variations of approach and surprisingly few correct answers. Common incorrect answers included $+20 \text{ kJ mol}^{-1}$ (obtained by the 'reverse' subtraction) and other answers that had omitted one or more bond enthalpies in calculation. Some candidates also neglected to put a sign on their final numerical answer.

It is suggested that candidates look only to incorporate in their numerical answers the bonds that have "changed" — *i.e.* only those that are broken and not remade. This avoids the unnecessary use of the C—H bond enthalpy for example.

Candidates ought to be aware however that the replacement of C=O with C—O in the product is not the result of the breaking of a single carbon-to-oxygen bond: rather, the C=O is broken fully, and C—O formed in its place.

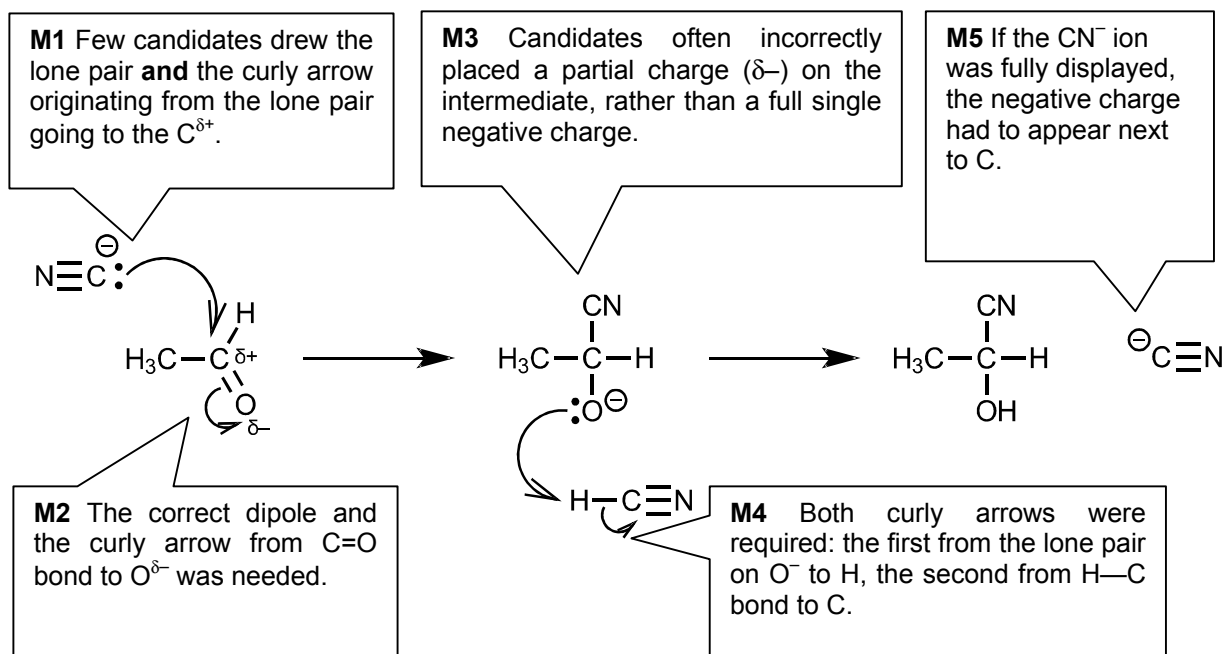
- (b)(i) Many definitions of stereoisomerism came close: the key points are that the molecules will have the same structural formula but different spatial arrangement of their atoms. It is not enough to say there is a different displayed formula, as this is only true of geometrical isomers. Any suggestion that the *molecules* are arranged differently in space was not accepted.

Candidates' knowledge of chiral centres seemed secure, although they are reminded of the need to be precise in their use of chemical terminology.

- (ii) This question attracted very few correct answers, perhaps for reasons linked to unfamiliarity with the mechanism. Many candidates fixed on the idea of chirality giving two enantiomers, and did not spot the real question: why are the optical isomers produced in **equal** amounts? Examiners were looking for answers detailing the planar carbonyl group, with non-selective attack of the nucleophile from above or below the plane of this group.

- (c) (i) Few candidates received full credit for this question. It is important to note the specific requirements of each of the marking points for this type of question.

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- (ii) There were many correct answers to this part. Some candidates were too imprecise in their answers; by suggesting that the NaCN as a whole is the nucleophile, for example.

Question 4

This question set in an organic context, tested candidates' knowledge of isomerism, arising from features and functional groups within molecules, and from particular chemical reactions. Candidates were also tested on their ability to represent molecules in different formats.

- (a) This question tested candidates' ability to use skeletal formulae to draw and identify different types of *structural* isomerism within the context of compounds' chemical reactions. Although some candidates scored very well here, many candidates' answers showed insufficient comprehension of positional, chain and functional group isomerism. Skeletal formulae were often misrepresented, mostly by a missing bond from carbon to oxygen, or by too short or long a carbon chain.

Candidates are reminded of the need to represent "connectivity" correctly: HO— is correct, whereas OH— is not creditable. (It is however permissible to represent a terminal methyl group as either H_3C- or CH_3- .)

- (b) (i) There were many good answers to this part. Candidates are reminded that butane alone does not fully and precisely identify the molecule but-1-ene.
- (ii) Candidates need to be careful with precision of language: cis/trans isomerism is possible because of the lack of free rotation about a $C=C$ bond where each carbon is bonded to two different groups.
- (iii) There were many good answers to this part, though candidates frequently did not show the fully displayed formulae of both molecules — it is necessary for all side groups to be expanded; CH_3- is not a fully displayed formula.

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Paper 9701/22
Structured Questions AS Core

Key Messages

- Candidates need to read through a question carefully before attempting to answer it and should also check their answers.
- Candidates need to know the precise wording of definitions, and should be particularly careful in their use of chemical terminology, e.g. references to ions as opposed to molecules.
- Careful attention is needed with respect to organic mechanisms in both the placing and direction of curly arrows.
- Candidates need to show their working in mathematical questions; where a final answer is incorrect often credit can be obtained from correct working.
- Candidates should also beware of offering multiple answers to questions as an incorrect second answer can invalidate an otherwise correct first answer.
- Candidates must avoid repeating the question when asked for an explanation.

General Comments

Careful reading of questions would have been of particular benefit in **Question 1(d)(i)** where specific references to bonding (and not just structure) were required and in **Question 2(a)(i)** where the oxidation state of lead in the product was given.

Candidates need to use the information in the question coupled with their knowledge to give concise and relevant responses.

Comments on Specific Questions

Question 1

- (a) This was generally well known but some candidates did not know the relative mass of an electron.
- (b)(i) Many candidates confused this definition with that of 'relative atomic mass' and referred to 'average mass' and some candidates defined isotopes. Many of those who had the correct idea often omitted 1/12 or carbon-12 or 12 units.
- (ii) Most candidates gained full credit.
- (c)(i) Candidates found the equations difficult. Some had the electrodes reversed and some had chloride ions being produced at the anode.
- (ii) Many candidates gained full credit.
- (d)(i) Many candidates could not identify the bonding in SO_3 or gave metallic as the bonding in Na_2O .
- (ii) Some equations were well known but the reaction between Al_2O_3 and NaOH wasn't. A common incorrect response had Al_2C_6 as a product of the reaction between Al_2O_3 and HCl .

Question 2

- (a)(i) Many candidates gave equations with an oxide of lead with a different oxidation number to that given in the question.

- (ii) Many candidates didn't appreciate that an oxidation number refers to a single atom and so gave the oxidation number of oxygen in SO_2 as -4 .
- (b) (i) Whilst many candidates gave the correct temperature many could not relate this to the position of equilibrium, some confused the sign of ΔH and rate was often omitted.
 - (ii) Most candidates gained partial credit for the economic argument with many also gaining credit for the effect on the equilibrium. Few candidates discussed rate and those who did rarely mentioned the effect on collision frequency.
- (c) (i) Generic references to explosions, danger and spray were seen frequently and were insufficient to be creditworthy.
 - (ii) Most candidates gained full credit but some included (aq) incorrectly in the first equation.
- (d) Most candidates knew the action of the SO_2 but few stated that it is a preservative.
- (e) Many candidates gained full credit, the calculations being carried out competently.

Question 3

- (a) (i) Many candidates didn't calculate the numbers of bonds broken and made correctly; for example incorrectly believing that a compound with three carbons has three C–C bonds. Sketching the compounds may help to overcome this difficulty.
 - (ii) The conditions were well known.
 - (iii) Many candidates gained full credit. However, some gave a fully correct response but also gave extra incorrect equations which contradicted the correct ones and so these candidates only gained partial credit.
- (b) Candidates generally answered this question well. However, a large minority of candidates gave ethanol incorrectly in part (i) which meant that there was no valid equation in (iii).

Question 4

- (a) (i) The structures of **A**, **B**, and **D** were generally correct, but for **C** many candidates redrew **B**.
 - (ii) Candidates found this quite difficult. Some candidates attempted to draw structures in which identical bonds were at 90° or 180° to each other which is not creditworthy.
- (b) (i) The reagents were well known but many candidates didn't include warm/heat with Fehling's or Tollens' and didn't include the precipitates formed.
 - (ii) The test was well known.

CHEMISTRY

Paper 9701/23
Structured Questions AS Core

Key Messages

- Candidates need to read through a question carefully before attempting to answer it and should also check their answers.
- Candidates need to know the precise wording of definitions, and should be particularly careful in their use of chemical terminology, e.g. references to ions as opposed to molecules.
- Careful attention is needed with respect to organic mechanisms in both the placing and direction of curly arrows.
- Candidates need to show their working in mathematical questions; where a final answer is incorrect often credit can be obtained from correct working.
- Candidates should also beware of offering multiple answers to questions as an incorrect second answer can invalidate an otherwise correct first answer.
- Candidates must avoid repeating the question when asked for an explanation.

General Comments

Candidates need to use the information in the question coupled with their knowledge to give concise and relevant responses.

Comments on Specific Questions

Question 1

- (a) Most candidates gained credit.
- (b) (i) Candidates found this definition difficult. Many confused the ideas of a single electron and a mole of atoms.
- (ii) Candidates often didn't mention that shielding is unchanged.
- (c) (i) Many candidates confused this definition with that of 'relative isotopic mass' and didn't refer to 'average mass'. Many of those who almost gained credit often omitted 1/12 or carbon-12 or 12 units.
- (ii) Many candidates gained full credit but some didn't round the answer to an integer value.
- (d) (i) Many candidates found this calculation difficult mainly due to the need for the conversion of both pressure and volume to the appropriate units.
- (ii) Many candidates found this difficult as they allotted Ne a value of x and Ar a value of y which meant that the ensuing equation contained two unknowns and therefore could not be solved.
- (e) (i) Many candidates appreciated that van der Waals' forces involve temporary dipoles but the original temporary dipole was not well explained.
- (ii) This was generally well answered.

Question 2

- (a) (i) Many candidates restated the question stem without explanation, for example 'reactivity increases down the group because the Group 2 elements get more reactive down the group'.
- (ii) Candidates often gave the equation for the reaction of hot magnesium with steam required in (a)(iv)
- (iii) Many candidates did not refer to the formation of a precipitate.
- (iv) Candidates often gave the equation for the reaction of magnesium with cold water required in (a)(ii).
- (b) (i) Many candidates incorrectly gave MgNO_3 as the formula of the product.
- (ii) This question was generally well answered.
- (iii) This equation was not well known by most candidates.
- (iv) A significant number of candidates didn't appreciate that an oxidation number refers to a single atom and so gave the oxidation number of oxygen in KNO_3 as -6 and in KNO_2 as -4 .
- (c) Many candidates didn't explain why the bonding is so strong in MgO . There were frequent incorrect references to metallic bonding and intermolecular forces alongside the ionic bonding.
- (d) (i)(ii) Both of these parts were generally well answered.
- (iii) Most candidates gained full credit but some didn't apply the correct ratio from the equation.

Question 3

- (a) (i) Most candidates appreciated that the unknowns were aldehydes or ketones but often didn't gain credit because the skeletal formulae drawn were incorrect.
- (ii) The distinctions between 'chain', 'positional' and 'functional group' isomerism as categories of structural isomerism was not well known.
- (iii) This was generally well answered
- (b) (i) Most candidates appreciated that there must be a $\text{C}=\text{C}$ in the structure but commonly drew an OH attached to one of the carbons in the double bond as they overlooked the information given in the question stem.
- (ii) This was generally well known.
- (c) Candidates found this question difficult with many trying to incorporate the reducing or oxidising agent into their equations.

Question 4

- (a) The reactions were generally well known but many candidates either incorrectly oxidised the primary $-\text{OH}$ in (i) or did not oxidise it in (ii).
- (b) (i) Candidates found this difficult. Candidates should ensure that curly arrow originate from a bond or a lone pair.
- (ii) Many candidates thought bromine was naturally polar and so didn't describe an induced dipole.
- (iii) This was generally well known.
- (iv) Candidates found drawing the enantiomers very difficult.

CHEMISTRY

<p>Paper 9701/31 Advanced Practical Skills 1</p>
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Key Messages

- Centres should be reminded of the importance of practical work and examination practice throughout the course in preparation for this examination.
- Candidates need to understand the correct use of significant figures and decimal places, especially giving thermometer readings to the nearest 0.5 °C and burette readings to 0.05 cm³.
- Candidates should be able to produce a graph with suitable scales and know how to construct appropriate lines of best fit.
- Candidates should understand the meaning of 'precipitate' and appreciate that 'precipitate insoluble' is not a valid comment on its solubility in excess reagent.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** and **Question 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.

It is imperative that every candidate is linked to a particular session/laboratory and to a corresponding set of Supervisor's results to enable them to have access to the full range of available credit.

This paper proved accessible to most candidates and differentiated well, there was no evidence of candidates being short of time to complete the paper.

Comments on Specific Questions

Question 1

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

- (a) Many candidates completed the titration accurately with all data clearly presented. Common incorrect and inaccurate responses included not recording the burette readings for the rough titration, not recording accurate burette readings to 0.05 cm³ or carrying out a third titration which was more than 0.10 cm³ from either of the two previous concordant titres.
- (b) The majority of candidates calculated a suitable value for the volume of **FA 1**. Some candidates did not indicate which titres they used in their calculation or did not record their volume correctly rounded to two decimal places.
- (c) Most candidates gained full credit. Often the calculation was incorrect by a factor of 10 or the calculation of the M_r was incorrect. Answers needed to be given to three or four significant figures.

Question 2

Most candidates were able to gain at least partial credit for accuracy and in the calculation. However candidates found considering errors and possible improvements difficult.

- (a) Many candidates gained full credit for accuracy. Some candidates either did not quote an initial temperature or did not quote their readings to the nearest 0.5 °C. A number of Centres gave a maximum temperature rise that was much lower than that expected, which may have been due to the solutions being prepared incorrectly, and candidates from these Centres sometimes found the graph more difficult to plot.
- (b) Candidates found drawing the graph difficult. Common incorrect responses included scales where the plotted points occupied less than half of the grid, not plotting the initial temperature, reversing the x and y axes, not allowing for a 5 °C extension and drawing lines which were not the lines of best fit. Many candidates did not extrapolate the lines to obtain the theoretical temperature change.
- (c) Part (i) was generally well answered. Some candidates did not convert J to kJ in part (ii). Answers needed to be given to 2, 3 or 4 significant figures.
- (d)(i) Since only one temperature was involved the percentage error should be based on 0.5 °C. A number of candidates doubled this in their calculation.
- (ii) A significant number of candidates gained credit.
- (iii) The strongest candidates gained credit. Many thought incorrectly that the temperature rise would be different.

Question 3

The original colour of solids or solutions undergoing changes due to heating or addition of a reagent needs to be given. In the investigation of cations, it is necessary to add excess reagent.

- (a)(i) Most candidates noted the correct observation but few could use this to identify that an acid had been added in the preparation of **FA 2**.
- (b)(i) Most candidates noted the change in colour when the solid was heated but few gave any other observation.
- (ii) Many candidates gave only one observation rather than both. Where a gas was observed many tested it correctly. When sodium hydroxide was added some candidates gave observations either when a few drops had been added or when excess had been added but both are required.
- (iv)(v) As in (ii), observations need to be given after the addition of a few drops and also after the addition of excess of the reagent.
- (vi) Many candidates gained credit.
- (vii) Many candidates correctly suggested the presence of Cu^{2+} and a smaller number also gave Mg^{2+} . Very few however recognised that, from the tests performed at this stage, the anion could be carbonate, sulfite or sulfate.
- (viii) Although a significant number of candidates used an acid to distinguish the possible anions, many did not make it clear what the acid was being added to.

CHEMISTRY

<p>Paper 9701/32 Advanced Practical Skills 2</p>
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Key Messages

- Centres should be reminded of the importance of practical work and examination practice throughout the course in preparation for this examination.
- Candidates need to understand the correct use of significant figures and decimal places, especially giving thermometer readings to the nearest 0.5 °C and burette readings to 0.05 cm³.
- In the Qualitative Analysis question, candidates should follow the instructions given and should not use additional reagents unless testing for a gas or told to do so.
- Candidates should understand the meaning of 'precipitate' and appreciate that 'precipitate insoluble' is not a valid comment on its solubility in excess reagent.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** and **Question 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.

It is imperative that every candidate is linked to a particular session/laboratory and to a corresponding set of Supervisor's results to enable them to have access to the full range of available credit.

This paper proved accessible to most candidates and differentiated well, there was no evidence of candidates being short of time to complete the paper.

Comments on Specific Questions

Question 1

The majority of candidates successfully completed the practical work and gained credit for accuracy and calculations.

- (a) Most candidates measured the volume of **FB 1** correctly and many completed the titration accurately with all data clearly presented. Common incorrect and inaccurate responses included not recording the burette readings for the rough titration, not recording accurate burette readings to 0.05 cm³ or carrying out a third titration which was more than 0.10 cm³ from either of the two previous concordant titres.
- (b) The majority of candidates calculated a suitable value for the volume of **FB 2**. Some candidates did not indicate which titres they used in their calculation or did not record their volume correctly rounded to two decimal places.
- (c) Most candidates gained credit in (i) and (ii); fewer calculated the concentration correctly in (iii). Candidates found (iv) difficult with few appreciating that the dilution factor involved 250 and the volume of **FB 1** from (a). In (v) a significant number of candidates used their answer from (iii) instead of their answer from (iv) and some calculated 106/125. Answers needed to be given to three or four significant figures.

Question 2

Most candidates were able to gain at least partial credit for accuracy and in the calculation. However candidates found considering errors and possible improvements difficult.

- (a) The majority of candidates gained at least partial credit for accuracy although many candidates recorded temperatures as integer values rather than to the nearest 0.5°C. Some candidates used the term *weight* instead of *mass*.
- (b)(i) Many candidates clearly understood the calculation but a significant number used the mass of metal added as *m* in the expression for the heat energy produced.
- (ii)(iii) Many candidates gained full credit but some gave answers which incorrect by a factor of 10.
- (iv) The majority of candidates gained credit here.
- (c)(i) A number of candidates used 0.5°C in their calculation rather than the 1.0°C needed due to the two temperature readings involved.
- (ii) Candidates found this very difficult. Many gave modifications that required altering the apparatus in some way and so didn't gain credit. Some candidates appreciated that greater amounts of reagents were needed but most of these did not specify that the increase should be in **FB 4**.

Question 3

Some candidates gave deductions with no appropriate observations recorded and some did not undertake tests to identify the gas produced. In the investigation of cations, it is necessary to add excess reagent.

- (a)(i) The vast majority of candidates recognised that aqueous sodium hydroxide and aqueous ammonia are used to identify cations and many correctly gave observations following the addition of a few drops and then excess of each reagent and so identified Zn^{2+} . Only the strongest candidates appreciated the need to warm the mixture with sodium hydroxide and test for the formation of ammonia in order to test for the presence of the other cation.
- (ii) Many candidates gave vague answers; it was unclear whether aluminium was being used or which ions were being identified.
- (b)(i) Many candidates observed the yellow precipitate but few noted the two layers. Some gave the halogen incorrectly as iodide rather than iodine.
- (ii) Many candidates gained credit but incorrect responses included redox and elimination.
- (c)(i) Almost all candidates noted the fizzing but few went on to use limewater to test for the formation of carbon dioxide. Most candidates also observed the formation of a white precipitate.
- (ii) Very few candidates identified the cation or the anion correctly.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key Messages

- Centres should be reminded of the importance of practical work and examination practice throughout the course in preparation for this examination.
- Candidates need to understand the correct use of significant figures and decimal places, especially giving thermometer readings to the nearest 0.5 °C and burette readings to 0.05 cm³.
- Candidates should be able to produce a graph with suitable scales and know how to construct appropriate lines of best fit. Anomalous points must be clearly indicated.
- Candidates should understand the meaning of 'precipitate' and appreciate that 'precipitate insoluble' is not a valid comment on its solubility in excess reagent.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** and **Question 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.

It is imperative that every candidate is linked to a particular session/laboratory and to a corresponding set of Supervisor's results to enable them to have access to the full range of available credit.

This paper proved accessible to most candidates and differentiated well, there was no evidence of candidates being short of time to complete the paper.

Comments on Specific Questions

Question 1

The majority of candidates successfully completed the practical work and gained credit for accuracy and calculations.

- (a) Many candidates completed the titration accurately with all data clearly presented. Common incorrect and inaccurate responses included not recording the burette readings for the rough titration, not recording accurate burette readings to 0.05 cm³ or carrying out a third titration which was more than 0.10 cm³ from either of the two previous concordant titres.
- (b) The majority of candidates calculated a suitable value for the volume of **FA 1**. Some candidates did not indicate which titres they used in their calculation or did not record their volume correctly rounded to two decimal places.
- (c) Many candidates gained full credit although some answers were not given to three or four significant figures.
- (d) Most candidates realised that the M_r would be greater but only a few candidates appreciated that this was due to a smaller concentration rather than just due to a smaller number of moles.

Question 2

Most candidates were able to gain at least partial credit for accuracy and in the calculation. However candidates found considering errors and possible improvements difficult.

- (a) Many candidates gained full credit for accuracy. Some candidates either did not quote an initial temperature or did not quote their readings to the nearest 0.5 °C. A number of Centres gave a maximum temperature rise that was about half of that expected, which may have been due to the solutions being prepared incorrectly. Some candidates did not follow the instructions and only added **FA 3** until a total volume of 45.00 cm³ was reached, others included columns of data that were not required.
- (b) Candidates found drawing the graph difficult. Common incorrect responses included the y-axis starting at 0 °C, not allowing for a 2 °C extension, not plotting the initial temperature, not indicating any anomalous points and drawing lines which were not the lines of best fit. Many candidates who drew curves showed a graph with a maximum rather than an intersection. Many gave the maximum temperature rather than the maximum temperature change.
- (c) Parts (i), (iii) and (iv) were generally well answered. In (ii) many candidates did not add the volume of **FA 3** to the 25 cm³ of **FA 4**.
- (d) A number of candidates used 0.5 °C in their calculation rather than the 1.0 °C needed due to the two temperature readings involved.
- (e) Most candidates answered in terms of heat loss but most were not detailed enough to be creditworthy. A minority answered in terms of stability and so gained credit.
- (f) Many candidates gained credit.

Question 3

The original colour of solids or solutions undergoing changes due to heating or addition of a reagent needs to be given. In the investigation of cations, it is necessary to add excess reagent.

- (a)(i) Most candidates observed the colour change but some omitted the starting colour.
 - (ii) Most candidates noted the expected change to the litmus but few gave any other observation.
 - (iv) The majority of candidates gained partial credit. A significant number described the precipitate as grey-green. It is wise to leave any green precipitate for a few minutes while continuing with other parts of the experiment to check for a colour change. Any green precipitate turning brown in air should not be described as grey-green.
 - (v) While most candidates reported a white precipitate forming not all indicated clearly that it was insoluble in acid.
 - (vi) Most candidates thought incorrectly that a yellow precipitate had been formed; few appreciated that any solid observed was **FA 5** that had not dissolved.
 - (vii) Many candidates gained at least partial credit, the ammonium ion was the one most likely to not be identified.
- (b)(i) Most candidates were able to suggest a suitable reagent, the most common being acidified potassium manganate(VII) or sodium hydroxide solutions.
 - (ii) The majority of candidates gained credit for the observation although some used a different reagent from that stated in (i). Candidates often did not refer back to (a)(vi) and so did not gain further credit.

CHEMISTRY

Paper 9701/34

Advanced Practical Skills 2

Key Messages

- Centres should be reminded of the importance of practical work and examination practice throughout the course in preparation for this examination.
- Candidates need to understand the correct use of significant figures and decimal places, especially giving thermometer readings to the nearest 0.5 °C and burette readings to 0.05 cm³.
- In the Qualitative Analysis question, candidates are advised to follow instructions given and not to choose to use additional reagents unless testing for a gas or when told to do so.
- Candidates should understand the meaning of 'precipitate' and appreciate that 'precipitate insoluble' is not a valid comment on its solubility in excess reagent.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** and **Question 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.

It is imperative that every candidate is linked to a particular session/laboratory and to a corresponding set of Supervisor's results to enable them to have access to the full range of available credit.

This paper proved accessible to most candidates and differentiated well, there was no evidence of candidates being short of time to complete the paper.

Comments on Specific Questions

Question 1

The majority of candidates successfully completed the practical work and gained credit for accuracy and in the calculation.

- (a) Many candidates completed the titration accurately with all data clearly presented. Common incorrect and inaccurate responses included not recording the burette readings for the rough titration, not recording accurate burette readings to 0.05 cm³ or carrying out a third titration which was more than 0.10 cm³ from either of the two previous concordant titres.
- (b) The majority of candidates calculated a suitable value for the volume of **FB 2**. Some candidates did not indicate which titres they used in their calculation or did not record their volume correctly rounded to two decimal places.
- (c) Most candidates gained credit in **(i)** and **(ii)**; fewer calculated the concentration correctly in **(iii)**. Candidates found **(iv)** difficult, often either multiplying by 5.91 or using the answer to **(ii)** instead of **(iii)** in the calculation. Answers needed to be given to three or four significant figures.
- (d) Many candidates gained full credit. Common incorrect responses included the use of the mean of 15 and **(c)(iv)** as the denominator and not calculating the difference in concentration as the numerator. Many successfully used the default values rather than their own.

Question 2

Most candidates were able to gain at least partial credit for accuracy and in the calculation. However candidates found considering errors and possible improvements difficult.

- (a) The majority of candidates gained at least partial credit for accuracy. A few candidates recorded thermometer readings as a tenth of the true value and many gave integer values for temperature rather than quoting readings to the nearest 0.5°C. Some candidates did not use the mass ranges specified.
- (b) Many candidates gained full credit. Some, however, didn't give their answer to the required number of decimal places or rounded the answer incorrectly.
- (c) Most candidates gained credit in (i) but found (ii) more difficult. Candidates often used the mass from (b)(i) rather than the volume of solution. Some candidates gave the enthalpy change an incorrect negative sign.
- (d) A number of candidates used 0.5°C in their calculation rather than the 1.0°C needed due to the two temperature readings involved. A small number used the answer to (b) instead of the smaller of the two experimental changes in temperature.
- (e) (i) Candidates found this very difficult.
(ii) Few candidates gained credit. Many discussed heat loss to the surroundings which is not creditworthy for an endothermic reaction.

Question 3

Some candidates gave deductions with no appropriate observations recorded. In the investigation of cations, it is necessary to add excess reagent.

- (a) (i) Most candidates gave an observation when a few drops of aqueous ammonia were added but few went on to add the reagent to excess. The colour of the precipitate with **FB 4** was sometimes incorrect.
(ii)(iii) Many candidates gained full credit. However, a significant number incorrectly added a second reagent when the precipitate was seen. Some candidates reported a white solution; this is not creditworthy as solutions must be clear and white suggests opacity in which case a precipitate or emulsion must have been formed.
(iv) Most candidates gained credit.
(v) Fewer candidates gained credit as sulfite was often omitted and aluminium was omitted by some.
(vi) Most candidates gained at least partial credit with many gaining full credit.
- (b) (i) A minority of candidates gained credit. Common incorrect responses included specific transition metals or their ions, potassium, ammonium or iodine.
(ii) Many candidates did not gain credit as they only gave one correct observation. Few tested for the gas.
(iii) Common incorrect responses included an incorrect colour of solution or a statement that a precipitate was formed when any solid observed was actually **FB 6** that had not dissolved.
(iv) Many candidates correctly reported the appearance of the red-brown precipitate but then did not specify that it was a gas which turned red litmus blue when the mixture was warmed.
(v) Most candidates gained credit.
(vi) There were many correct answers though credit was often not gained due to insufficient suitable observations.

- (vii) A large minority of candidates gained credit for redox. Common non-creditworthy responses included oxidation without stating what had been oxidised, substitution and displacement.

CHEMISTRY

Paper 9701/35

Advanced Practical Skills 1

Key Messages

- Centres should be reminded of the importance of practical work and examination practice throughout the course in preparation for this examination.
- Candidates need to understand the correct use of significant figures and decimal places, especially giving thermometer readings to the nearest 0.5 °C and burette readings to 0.05 cm³.
- Candidates should understand the meaning of 'precipitate' and appreciate that 'precipitate insoluble' is not a valid comment on its solubility in excess reagent.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper.

The Examiners thank Supervisors at Centres who supplied experimental data for **Question 1** and **Question 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.

It is imperative that every candidate is linked to a particular session/laboratory and to a corresponding set of Supervisor's results to enable them to have access to the full range of available credit.

This paper differentiated well and proved accessible to most candidates however, some gained little credit. There was no evidence of candidates being short of time to complete the paper.

Comments on Specific Questions

Question 1

The majority of candidates successfully completed the practical work and gained credit for accuracy and in the calculation.

- (a) Many candidates completed the titration accurately with all data clearly presented. Common incorrect and inaccurate responses included not recording the burette readings for the rough titration, not recording accurate burette readings to 0.05 cm³ or carrying out a third titration which was more than 0.10 cm³ from either of the two previous concordant titres. Candidates from some Centres filled in the marking boxes as though they had performed seven titrations although no burette readings were shown.
- (b) The majority of candidates calculated a suitable value for the volume of **FA 3**. Some candidates did not indicate which titres they used in their calculation or did not record their volume correctly rounded to two decimal places.
- (c) Most candidates gained credit for (i) to (v) with answers given to three or four significant figures. Candidates found (vi) more difficult.

Question 2

Most candidates were able to gain at least partial credit for accuracy and in the calculation. However candidates found considering errors and possible improvements difficult.

- (a) Many candidates gained full credit for accuracy and the majority displayed their results clearly with correct units.
- (b) Most candidates gained full credit for (i) and (ii) but some didn't convert J to kJ in (iii).
- (c) A number of candidates did not quote their thermometer readings in (a) and (c) to the nearest 0.5°C. However, many gained credit for the accuracy of the temperature change.
- (d) Those who gained credit in (b) also gained credit here. Most candidates gained credit for the negative signs and suitable significant figures in their two values of ΔH .
- (e) Some candidates drew excellent Hess' Law energy cycle diagrams and gave suitable equations which showed a good understanding of the chemistry involved. Many candidates had difficulty in drawing a suitable cycle but most were able to calculate the required enthalpy change correctly.
- (f) (i) A number of candidates used 0.5°C in their calculation rather than the 1.0°C needed due to the two temperature readings involved.
(ii) Use of a pipette or burette was the most common correct response.

Question 3

Some candidates gave deductions with no appropriate observations recorded. In the investigation of cations, it is necessary to add excess reagent.

- (a) (i) Many candidates gave only one correct observation and so gained partial credit.
(ii) Many candidates noted the precipitate forming and described the colour correctly. Few tested any gas evolved appropriately.
(iii) Many candidates gained credit for two correct observations.
(iv) A minority of candidates completed the equation successfully. The incorrect inclusion of O₂ was seen quite often.
- (b) (i) Some candidates reported a white solution; this is not creditworthy as solutions must be clear and white suggests opacity in which case a precipitate or emulsion must have been formed.
(ii) Some candidates who correctly recorded a white precipitate didn't go on to dissolve it in aqueous ammonia.
(iii) Some candidates omitted this part.
(iv) Many candidates gained credit.
(v) The 'no observation' given by some candidates should not be used to mean 'no change' and so is not creditworthy here.
(vi) Many candidates gained partial credit usually for Zn²⁺ in FA 8 and either Cl⁻ in FA 9 or unknown in FA 8.
(vii) Few candidates gained credit. Some tested for a cation contrary to their answer in (vi) and some tested for an anion eliminated by the tests already performed.

CHEMISTRY

Paper 9701/41
Structured Questions

Key Messages

- Candidates need to read through a question carefully before attempting to answer it.
- Candidates need to show their working in mathematical questions, where a final answer is incorrect often credit can be obtained from correct working.
- Candidates should write clearly in black or dark blue ink and should not overwrite any pencil working.

General Comments

This paper differentiated well with no evidence of candidates being short of time.

Comments on Specific Questions

Question 1

- (a) Most candidates gained full credit.
- (b) (i) This was well answered by most candidates. Common incorrect responses included FO_2 and using *F* as the symbol for fluorine.
- (ii) Many candidates gave a clear, correct 'dot-and-cross' diagram.
- (iii) Most candidates gained credit.
- (c) (i) Most candidates gained at least partial credit here. It was common for either the E^\ominus values not to be quoted or for the relationship between the oxidising ability and the E^\ominus values to be reversed.
- (ii) This was not well known and many candidates suggested substitution.
- (iii) Many candidates found this question difficult with a variety of incorrect equations being seen.

Question 2

- (a) (i) Most candidates correctly identified $\text{HC}\ddot{\text{L}}$.
- (ii) This proved difficult for many but stronger candidates appreciated the relative effect of the two electron withdrawing groups
- (b) (i) Many candidates correctly identified compound **P**, although the identity of compound **Q** proved to be more difficult. Candidates should be encouraged to use the information given; in this question, the formula of **Q** was provided.
- (ii) Most candidates gained at least partial credit here. Common errors included acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or the omission of heat in **step 1**, and the use of NaBH_4 or nickel catalyst with H_2 in **step 4**.

Question 3

- (a) (i) This was well answered, although for a number of candidates the total abundance was not 100%.
- (ii) Many correct calculations were seen, but a significant number of candidates did not quote their answer to two decimal places and so did not gain full credit.
- (b) (i) Both the trend and its explanation were well understood by candidates. Some answered incorrectly in terms of atomic size or van der Waals' forces and did not specify which ion was being polarised.
- (ii) Most candidates gave the correct products for this decomposition, although some did not balance the equation for the oxygen.
- (iii) Many discussed the ionic radii increasing down the group which was not a valid response.

Question 4

- (a) (i) Many candidates gained credit though common errors included incorrect ionic charges and incorrect units.
- (ii) Candidates answered reasonably well. A common error was 1.56×10^{-5} where candidates had not included 2^2 in their calculation.
- (b) This proved difficult for many candidates although most gained partial credit. Common errors included omitting state symbols, omitting the '2' with $\text{Ag}^+(\text{aq/g})$ and not completing the remaining two arrows showing the correct direction of each enthalpy change.
- (c) (i) Candidates usually performed the calculation correctly and identified Ag as the positive electrode. Pt was a common incorrect response.
- (ii) Candidates found it difficult to give an explanation for this.
- (iii) The common ion effect was not well known.
- (iv) Most candidates were unable to explain their answers in (iii).
- (d) Few candidates appreciated that the $[\text{Fe}^{3+}]$ would be 0.2 mol dm^{-3} but credit was available for an error carried forward.

Question 5

- (a) Many candidates gained full credit but a significant number gave 12 protons and 14 electrons.
- (b) Many candidates gained full credit though equations were often unbalanced.
- (c) Candidates found this difficult. Many wrote that carbon has no d orbitals, which needed more information in order for credit to be awarded.
- (d) Many candidates did not quote E^\ominus data for chlorine, or discussed Pb^{2+} being more oxidising than Sn^{2+} without any reference to the oxidising ability of chlorine, or didn't include an equation.
- (e) (i) Many candidates knew this relationship..
- (ii) Many candidates gained partial credit with a few gaining full credit. Common errors included use of 22.4 or 96 500. Some candidates gave 6.02×10^{23} with no correct calculation which could not be credited.

Question 6

- (a) (i) Candidates needed to look carefully at the reaction scheme to deduce the answer to this question.
- (ii) Most candidates answered this correctly.
- (iii) Many candidates correctly identified the reagents although some did not include 'concentrated'.
- (iv) Many candidates appreciated that CHI_3 was formed but few gave the correct carboxylic acid. Common incorrect responses included CH_3I or substituting hydrogen for iodine as a substituent on the ring or the side chain.
- (b) Parts (i), (ii) and (iii) were answered very well by most candidates.
- (iv) Many candidates correctly identified the reagents and conditions though 'heat' or 'concentrated' were commonly omitted.
- (v) Many candidates could not relate the structure of the polymer to its properties.

Question 7

- (a) (i) Most candidates recognised the need for 'heating' but fewer included the need for a catalyst.
- (ii) Many candidates gave the correct response.
- (iii) Most candidates gained full credit though **D** and **E** were often drawn with identical structures with no reference to their stereochemistry.
- (iv) This was marked according to the candidate's answers to (iii) but if structures **D** and **E** were identical then credit could not be given.
- (b)(i) This was generally well known.
- (ii) Many candidates gained credit.
- (iii) A significant number of candidates did not gain credit. Common incorrect responses included incorrect charges on $\text{Br}-\text{Br}$, partial charges shown on the intermediate carbocation or bromide ion and incorrect source or direction of the curly arrows.

Question 8

- (a) (i) Almost all candidates gained credit.
- (ii) Many candidates drew a dipeptide but did not give a skeletal structure, as requested by the question.
- (iii) Most candidates gained partial credit for naming two correct side-chain interactions but many did not link their interactions to an amino acid or side-chain group.
- (b)(i)(ii) Many candidates showed good knowledge. Diagrams sometimes needed more complete labelling particularly the active site. Some candidates suggested incorrectly that the inhibitor bonded to the substrate.

Question 9

- (a) (i) This was well known by many candidates.

- (ii) This was not as well answered as (ii).
 - (iii) Many candidates gave an imprecise generic answer outlining the basic principles of electrophoresis but relatively few addressed how the charges on the amino acids or on DNA explained these observations.
 - (iv) Many candidates correctly suggested the fragment of ancient pottery but then also went on to incorrectly include the piece of wood.
- (b) (i) This was answered well by most candidates.
- (ii) Most candidates gained credit. However some thought that the higher atomic mass or higher proton number of phosphorus was responsible.
- (c) (i) Definition of partition coefficient tended to be too imprecise to be creditworthy with the key terms ratio and concentration frequently missing.
- (ii) Solvent extraction was not well understood.

Question 10

- (a) (i) Most candidates gained at least partial credit here for two correct structures. A number of candidates repeated the structures of propane or propene drawn in such a way as to make them appear different.
- (ii) Many candidates gained credit. The most common incorrect response was source L due to it having the most CH₄.
 - (iii) Many candidates suggested one viable method but few gained full credit here.
- (b) (i) Many candidates found this very difficult with few gaining credit. The common response of 'shale gas contains less carbon atoms' was not creditworthy.
- (ii) This was generally answered well. 'Fuel oil' was a popular incorrect response.
 - (iii) Many answered incorrectly in terms of the composition of the reacting mixture suggesting that the coal and fuel oil have more N₂ in their mixtures.
 - (iv) Most candidates scored credit though some gave vague references to haemoglobin and greenhouse gas which were too insufficient to be creditworthy.

CHEMISTRY

Paper 9701/42
Structured Questions

Key Messages

The rubric requires answers to be written in ink, the use of pencils by candidates in writing formulae, structures and equations is to be strongly discouraged. Pencilled text is sometimes too faint to read and also some candidates write over the pencil in ink so that their answers become illegible.

General Comments

The paper differentiated well, with no evidence of candidates being short of time.

Candidates need to show their working in mathematical questions, where a final answer is incorrect often credit can be obtained from correct working.

There was evidence, even from some stronger candidates, of incorrect bond connectivity, 3- and 5-valent carbon atoms and formulae errors such as CO_3^- and PO_4^- .

Comments on Specific Questions

Question 1

- (a) This was well answered by most candidates. Incorrect responses for S included $3d^4$ and $3s^13p^5$.
- (b) (i) Most candidates gained credit. Some confused decomposition with ionisation so $\text{H}^+ + \text{Cl}^-$ was commonly seen. Some included O_2 as a reagent or produced H_2O or Cl_2O as a product.
- (ii) Most candidates quoted the bond energies but few related the higher bond energy to a stronger bond.
- (c) Candidates found this question challenging with few correct definitions and fewer explanations of bond polarity. Commonly candidates discussed high electronegativity as the cause of bond polarity rather than the difference in electronegativity.
- (d) (i) This was generally well known but candidates often didn't gain credit as they omitted the lone pairs on the sulfur and the four fluorine atoms. Some candidates incorrectly drew one or more dative bonds.
- (ii) This was marked consequentially on the candidate's answer to (i).
- (e) Many candidates claimed incorrectly that oxygen has no d-orbitals rather than the d-orbitals being inaccessible.
- (f) (i) Most candidates gained credit. Common incorrect responses included from car exhausts and from sulfide ores rather than from roasting sulfide ores.
- (ii) Almost all candidates gained credit. A few gave ozone breakdown or global warming.

Question 2

- (a) Many correct calculations were seen, but a significant number of candidates did not quote their answer to two decimal places and so did not gain full credit.

- (b)(i) Many candidates did not make a comparison so both being amphoteric or acidic or basic were common responses. Some candidates answered in terms of the relative stabilities or redox capabilities of Sn(II) and Sn(IV) which were not creditworthy.
- (ii) Some candidates showed incorrectly both oxides reacting as acids or bases. A number of candidates gave the products of SnO₂ reacting with HCl incorrectly as SnCl₂ + Cl₂.
- (iii) Most candidates gave correct equations but only the strongest candidates also gave the correct observation. Some candidates incorrectly included oxygen as a reagent.

Question 3

- (a) The majority of candidates correctly calculated the mass number and charge but a significant number did not give the correct symbol. S, Cl and As were commonly seen.
- (b) The majority of candidates gained full credit. Common incorrect responses included the solubility becoming more endothermic rather than $\Delta H_{\text{sol}}^{\circ}$ and that the enthalpy change of hydration decreased less rapidly.
- (c) Many candidates described seeing a white precipitate, but fewer identified it correctly. Common identities included CaO, Ca(OH)₂, Ca, Na₂O, Na. Most gained credit for the explanation.
- (d) Many candidates gained full credit and some gained partial credit for their working. However, some candidates who ended up with an incorrect answer did not show their working clearly enough to gain any credit.

Question 4

- (a)(i) Many candidates thought incorrectly that a buffer solution maintains pH or keeps pH constant. Some candidates didn't appreciate that only small amounts of acid or alkali are added.
- (ii) Most candidates gained credit for the reaction of the HCO₃⁻ with acid but fewer gave a correct equation with OH⁻.
- (iii) This buffer calculation proved difficult for some candidates. The most common incorrect responses included reversing the acid/base ratio or using the concentration of Na₂HPO₄ as 0.2 mol dm⁻³.
- (b)(i) Several candidates either omitted the charges on the ions or gave incorrect charges mainly Ag³⁺ and PO₄⁻, or omitted the cubic index. Some split the PO₄ into P and 4 × O. In general the units fitted the expressions.
- (ii) Many candidates answered very well here. Commonly candidates did not multiply the [PO₄³⁻] in their K_{sp} calculation by 3, in order to get the [Ag⁺]. Some expanded (3x)³ as 3x³ or 9x³, rather than = 27x³.
- (c) Several candidates either could not balance the equation, often including electrons on the left or the right hand side, or reversed the equation. Most calculated the correct E^o_{cell} although +0.49 V was a common incorrect response.

Question 5

- (a)(i) A significant number of candidates did not gain credit. Common incorrect responses included omission of H₂(g) reagent, omission of heat with Ni or used LiAlH₄.
- (ii) Most candidates circled the two correct atom centres, although some also circled the (CH₃)₂CH-group.
- (iii) Many candidates gained credit. Those that circled three centres in (ii) needed to give 8 here and a significant number thought the number to be 6.

- (iv) Many candidates did not appreciate that the hydrogens all add to the same side of the ring, or could not interpret the wedge-bonded partial structure. Some split the CH_3 groups from the side chain and drew the structure of 1,2-dimethylcyclohexanol, or 1,2,2-trimethylcyclohexanol.
- (b) (i) Many candidates correctly identified **C**.
- (ii) Although most candidates knew the reactions, credit was often not awarded because the conditions were not specified exactly enough. Common incorrect responses included aqueous rather than concentrated reagents or an incorrect temperature range in **step 1**, using LiAlH_4 for **step 2**, and an incorrect temperature range in **step 3**.
- (c) Common incorrect responses included NaOH also reacting with alcohol, HBr reacting with phenol, and HBr replacing some of the C-H bonds in the cyclohexanol.

Question 6

- (a) (i) The majority of candidates correctly chose the acyl chloride for **D**, and also correctly chose ammonia for **step 2**. **Step 3** was less well known with common incorrect responses including NaBH_4 , $\text{Sn} + \text{HCl}$ and $\text{Sn} + \text{H}_2$.
- (b) (i) Many candidates answered amide and a few phenol which were not creditworthy.
- (ii) Many candidates knew carboxylic acid but didn't mention phenol and so didn't gain credit. Common incorrect responses included ester and alcohol.
- (iii) Candidates found this difficult. Many of those who had correctly identified the groups in (i) and (ii) did not carry their knowledge through to correct deductions for compounds **E** to **H**. Confusion between amines and amides was common.
- (iv) This was marked according to the candidate's answers to (iii) and structures could gain credit provided they had an aromatic ring, were isomeric with $\text{C}_8\text{H}_9\text{NO}_2$ and contained just **two** functional groups. Structures that contained only 7 carbon atoms or which included ketone groups were quite common.

Question 7

- (a) Most candidates gained credit. Some candidates thought incorrectly that **L** contained an amide group rather than being able to form one.
- (b) Many candidates gained full credit. Omission of detail rather than incorrect statements was usually the cause of answers not being fully creditworthy such as no mention of DNA or ribosomes.
- (c) Candidates found this difficult. Many discussed blood cells and properties of the two free amino acids, neither of which earned credit.

Question 8

- (a) (i) Many candidates did not gain credit as reference to the nucleus of hydrogen was frequently omitted.
- (ii) Most candidates gained credit.
- (iii) Many candidates gained credit. Some thought incorrectly that oxygen or nitrogen would show the greatest absorption due to their greater electronegativity or chose sulfur due to its higher A_r or M_r value.
- (b) (i) Most candidates gained credit.

- (ii) Most candidates identified the group correctly although some gave CO_2H . The exchange of H by D was not well known, with D_2O reacting with OH being non-creditworthy.
 - (iii) Few candidates gained credit. Non-creditworthy responses often stated that it contained an OH group, or that it was bonded to three CH_3 groups.
 - (iv) Most candidates gained credit.
 - (v) A number of candidates did not piece together the answers from (i), (ii), (iii) and (iv) to arrive at a creditworthy response.
- (c) (i) Most candidates gained credit.
- (ii) Many candidates gained credit but some confused it with chlorine, and so suggested a 9:6:1 ratio.
 - (iii) Many gained credit. Some gave a structural formula, which did not gain credit.

Question 9

- (a) Many candidates correctly assigned the first and last monomers but thought incorrectly that the hydroxyalkene could undergo both types of polymerisation. Some candidates ticked almost every box.
- (b) Candidates found this difficult with few gaining credit.
- (c) (i) A significant number of candidates gained credit but there were many incorrect answers with $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$ and $\text{CH}_2=\text{CHCO}_2\text{H}$ being the most common.
 - (ii) It was common for candidates to mention hydrolysis but many omitted ester.
- (d) Most candidates gained some credit but it was common for the melting point to be related incorrectly to the strengths of bonds within the molecules, rather than to intermolecular forces.

CHEMISTRY

Paper 9701/43
Structured Questions

Key Messages

- Candidates need to read through a question carefully before attempting to answer it.
- Candidates need to show their working in mathematical questions, where a final answer is incorrect often credit can be obtained from correct working.
- Candidates should write clearly in black or dark blue ink and should not overwrite any pencil working.

General Comments

This paper differentiated well with no evidence of candidates being short of time.

Comments on Specific Questions

Question 1

- (a) Most candidates gained full credit.
- (b) (i) This was well answered by most candidates. Common incorrect responses included FO_2 and using *F* as the symbol for fluorine.
- (ii) Many candidates gave a clear, correct 'dot-and-cross' diagram.
- (iii) Most candidates gained credit.
- (c) (i) Most candidates gained at least partial credit here. It was common for either the E^\ominus values not to be quoted or for the relationship between the oxidising ability and the E^\ominus values to be reversed.
- (ii) This was not well known and many candidates suggested substitution.
- (iii) Many candidates found this question difficult with a variety of incorrect equations being seen.

Question 2

- (a) (i) Most candidates correctly identified $\text{HC}\ddot{\text{L}}$.
- (ii) This proved difficult for many but stronger candidates appreciated the relative effect of the two electron withdrawing groups
- (b) (i) Many candidates correctly identified compound **P**, although the identity of compound **Q** proved to be more difficult. Candidates should be encouraged to use the information given; in this question, the formula of **Q** was provided.
- (ii) Most candidates gained at least partial credit here. Common errors included acidified $\text{K}_2\text{Cr}_2\text{O}_7$ or the omission of heat in **step 1**, and the use of NaBH_4 or nickel catalyst with H_2 in **step 4**.

Question 3

- (a) (i) This was well answered, although for a number of candidates the total abundance was not 100%.
- (ii) Many correct calculations were seen, but a significant number of candidates did not quote their answer to two decimal places and so did not gain full credit.
- (b) (i) Both the trend and its explanation were well understood by candidates. Some answered incorrectly in terms of atomic size or van der Waals' forces and did not specify which ion was being polarised.
- (ii) Most candidates gave the correct products for this decomposition, although some did not balance the equation for the oxygen.
- (iii) Many discussed the ionic radii increasing down the group which was not a valid response.

Question 4

- (a) (i) Many candidates gained credit though common errors included incorrect ionic charges and incorrect units.
- (ii) Candidates answered reasonably well. A common error was 1.56×10^{-5} where candidates had not included 2^2 in their calculation.
- (b) This proved difficult for many candidates although most gained partial credit. Common errors included omitting state symbols, omitting the '2' with $\text{Ag}^+(\text{aq/g})$ and not completing the remaining two arrows showing the correct direction of each enthalpy change.
- (c) (i) Candidates usually performed the calculation correctly and identified Ag as the positive electrode. Pt was a common incorrect response.
- (ii) Candidates found it difficult to give an explanation for this.
- (iii) The common ion effect was not well known.
- (iv) Most candidates were unable to explain their answers in (iii).
- (d) Few candidates appreciated that the $[\text{Fe}^{3+}]$ would be 0.2 mol dm^{-3} but credit was available for an error carried forward.

Question 5

- (a) Many candidates gained full credit but a significant number gave 12 protons and 14 electrons.
- (b) Many candidates gained full credit though equations were often unbalanced.
- (c) Candidates found this difficult. Many wrote that carbon has no d orbitals, which needed more information in order for credit to be awarded.
- (d) Many candidates did not quote E^\ominus data for chlorine, or discussed Pb^{2+} being more oxidising than Sn^{2+} without any reference to the oxidising ability of chlorine, or didn't include an equation.
- (e) (i) Many candidates knew this relationship..
- (ii) Many candidates gained partial credit with a few gaining full credit. Common errors included use of 22.4 or 96 500. Some candidates gave 6.02×10^{23} with no correct calculation which could not be credited.

Question 6

- (a) (i) Candidates needed to look carefully at the reaction scheme to deduce the answer to this question.
- (ii) Most candidates answered this correctly.
- (iii) Many candidates correctly identified the reagents although some did not include 'concentrated'.
- (iv) Many candidates appreciated that CHI_3 was formed but few gave the correct carboxylic acid. Common incorrect responses included CH_3I or substituting hydrogen for iodine as a substituent on the ring or the side chain.
- (b) Parts (i), (ii) and (iii) were answered very well by most candidates.
- (iv) Many candidates correctly identified the reagents and conditions though 'heat' or 'concentrated' were commonly omitted.
- (v) Many candidates could not relate the structure of the polymer to its properties.

Question 7

- (a) (i) Most candidates recognised the need for 'heating' but fewer included the need for a catalyst.
- (ii) Many candidates gave the correct response.
- (iii) Most candidates gained full credit though **D** and **E** were often drawn with identical structures with no reference to their stereochemistry.
- (iv) This was marked according to the candidate's answers to (iii) but if structures **D** and **E** were identical then credit could not be given.
- (b)(i) This was generally well known.
- (ii) Many candidates gained credit.
- (iii) A significant number of candidates did not gain credit. Common incorrect responses included incorrect charges on $\text{Br}-\text{Br}$, partial charges shown on the intermediate carbocation or bromide ion and incorrect source or direction of the curly arrows.

Question 8

- (a) (i) Almost all candidates gained credit.
- (ii) Many candidates drew a dipeptide but did not give a skeletal structure, as requested by the question.
- (iii) Most candidates gained partial credit for naming two correct side-chain interactions but many did not link their interactions to an amino acid or side-chain group.
- (b)(i)(ii) Many candidates showed good knowledge. Diagrams sometimes needed more complete labelling particularly the active site. Some candidates suggested incorrectly that the inhibitor bonded to the substrate.

Question 9

- (a) (i) This was well known by many candidates.

- (ii) This was not as well answered as (ii).
 - (iii) Many candidates gave an imprecise generic answer outlining the basic principles of electrophoresis but relatively few addressed how the charges on the amino acids or on DNA explained these observations.
 - (iv) Many candidates correctly suggested the fragment of ancient pottery but then also went on to incorrectly include the piece of wood.
- (b) (i) This was answered well by most candidates.
- (ii) Most candidates gained credit. However some thought that the higher atomic mass or higher proton number of phosphorus was responsible.
- (c) (i) Definition of partition coefficient tended to be too imprecise to be creditworthy with the key terms ratio and concentration frequently missing.
- (ii) Solvent extraction was not well understood.

Question 10

- (a) (i) Most candidates gained at least partial credit here for two correct structures. A number of candidates repeated the structures of propane or propene drawn in such a way as to make them appear different.
- (ii) Many candidates gained credit. The most common incorrect response was source L due to it having the most CH₄.
 - (iii) Many candidates suggested one viable method but few gained full credit here.
- (b) (i) Many candidates found this very difficult with few gaining credit. The common response of 'shale gas contains less carbon atoms' was not creditworthy.
- (ii) This was generally answered well. 'Fuel oil' was a popular incorrect response.
 - (iii) Many answered incorrectly in terms of the composition of the reacting mixture suggesting that the coal and fuel oil have more N₂ in their mixtures.
 - (iv) Most candidates scored credit though some gave vague references to haemoglobin and greenhouse gas which were too insufficient to be creditworthy.

CHEMISTRY

Paper 9701/51

Planning, Analysis and Evaluation

Key Messages

Some candidates answer in pencil and then overwrite their answers in ink making the creditworthy responses difficult to identify. Any alterations need to be clear, overwriting text or especially numbers is not recommended. The original should be clearly crossed out and the new answer written close by. In graph plotting a simple clear cross is preferred to large dots.

Since the primary focus of this paper is practical work, the more practical chemistry that has been undertaken by the candidate the more likely they are to gain success. The introduction to a question contains useful information which needs to be considered when answering the question.

During a calculation early or over rounding should be avoided, the vulgar fractions given by some calculators are acceptable during the course of a calculation but are not acceptable as a final answer. The final answer should be rounded correctly, in decimal or standard form and to the required number of significant figures or decimal places.

General Comments

Command words such as "state" or "what" require less extensive answers than those such as "explain" or "describe". Candidates need to make sure not to include contradictory statements within their answers, this was evident particularly in questions **2(e)** and **2(f)(ii)**. The space given for an answer is ample and candidates should not feel under pressure to always completely fill it.

Comments on Specific Questions

Question 1

- (a) (i) The majority of candidates found these equations very difficult and few gained full credit. Most candidates who gained partial credit usually did so with the manganate(VII) half equation; the correct methanoate equation was very rarely seen. Equations were often missing electrons or showed charge imbalance. A few candidates gave a correct full equation which gained some credit.
- (ii) Most candidates calculated the concentration of magnesium methanoate correctly although a few used an incorrect M_r of 114. Many candidates did not appreciate that the concentration of $\text{HCOO}^-(\text{aq})$ was also required but those who did usually gained credit for it.
- (iii) Most candidates realised that 5 cm^3 of the saturated solution needed to be diluted to 250 cm^3 but could not describe how this could be achieved accurately. Incorrect responses included measuring cylinders, non-volumetric flasks such as conical flasks or beakers, 10 cm^3 non-graduated pipettes and not specifying that the solution needed to be diluted up to the mark on the volumetric flask. Many candidates incorrectly added 245 cm^3 of water to the saturated solution usually without specifying how to do this.
- (iv) The majority of candidates found this very challenging. Many candidates thought that the acid reacts with the methanoate instead of facilitating the reduction of manganate(VII) and so few gained credit. Few candidates appreciated that provided the acid is in excess; its volume doesn't change the reaction.
- (v) A significant number of candidates gave the end point colour as pink, which is past the end point, rather than pale pink. Purple and the reverse colour change were common incorrect responses.

- (vi) Candidates who used 25 instead of 25.5 did not gain credit. A small number of candidates correctly calculated 0.051 but gave a non-creditworthy final response of 0.05.
- (vii) Very few candidates managed to convert a concentration of methanoate ions into that of magnesium methanoate. Of those who did, many gave their answer to four, instead of the required three, significant figures.
- (b) The majority of candidates had a good understanding of independent and dependent variables. Common errors included solubility or titre values as the dependent variable..
- (c) The majority of candidates knew that the enthalpy of solution is endothermic or that ΔH is positive but some candidates gave contradictions in their answer such as 'endothermic so ΔH is negative'. Candidates found the explanation of promotion of the forward reaction more difficult. Many candidates only restated the question and a number confused solution with solubility.
- (d) Very few candidates appreciated that barium sulfate is insoluble. Some candidates knew that barium methanoate would react with sulfuric acid but could not link this to the insoluble product.

Question 2

- (a) (i) Most candidates gave a correct expression for K_c . Errors included inverted expressions, missing the squared term in $[HI]^2$, $[H]$ instead of $[H_2]$ and $[I]$ instead of $[I_2]$.
- (ii) Most candidates found substituting **a** and **y** into the expression from (a)(i) very difficult. Common errors included $2y^2$ for $[HI]^2$ and **a** or $(a-2y)$ for $[H_2]$ or $[I_2]$.
- (b) (i) Most candidates gained full credit by subtracting column 2 from column 1 correctly, and quoting the result to three decimal places. A few candidates calculated K_c and used this to calculate the remaining **y** values; this approach does not produce correct values due to the experimental variation in the concentration data.
- (ii) Candidates found the plotting of points quite difficult. There is no tolerance allowed for points which should be on the intersection of two grid lines, all other points have a tolerance of half a small square. Typically misplots tended to be inaccurate by two squares such as 1.135 being plotted at 1.035. Many candidates were either too inaccurate or used dots which were so large they filled a small square.
- (iii) Due to the variation in the experimental data, candidates needed to exercise judgement in drawing the line of best fit. A significant number of candidates did not appreciate that the line should go through the origin and either did not extend the line to an axis or did not give the line sufficiently close to the origin to be creditworthy. Some lines were excessively thick.

Candidates need to be equipped with a suitable pencil and ruler in order to plot points and draw lines with the necessary precision.

- (c) (i) A significant number of candidates gave coordinates as $(x_1, x_2) : (y_1, y_2)$ or gave just one x value and one y value rather than in the standard $(x_1, y_1) : (x_2, y_2)$ format. Many candidates chose table points for their co-ordinates which is only acceptable if the points are on their line or have not been mis-plotted. Candidates should ideally use points from their graph, preferably where the line passes through an x and a y grid line, with a reasonable separation of the points. The origin was acceptable as one of the co-ordinates provided the line went through the origin. The gradient was usually calculated correctly with very few candidates inverting the expression, however, many did not give their answer to the required three significant figures.
- (ii) Candidates who used the equation in (b) and the gradient in (c)(i) usually gained credit. Incorrect responses included using an (x, y) co-ordinate instead of the gradient and using the expression derived in (a), neither of which were creditworthy for the first point but which, if used correctly, could go on to gain credit for the second point. Those who used the expression from (a) often expanded $(a-y)^2$ incorrectly as $a^2 - y^2$ or $(2y)^2$ as $2y^2$. Candidates found difficulty manipulating the square root often giving K_c as 2.45 from $\sqrt{K_c} = 6$ rather than 36. Often the final answer did not quite

match the working as rounding had been undertaken mid calculation rather than only in the final step. A few candidates rounded their answer incorrectly.

- (d) Most candidates realised that there was a danger of explosion but many did not gain credit as the condition which would enable this to occur, such as the high temperature, was not included.
- (e) A small number of candidates appreciated that only two points were required, with many giving lengthy justifications that often included contradictory statements. The flask volume increasing was a common incorrect response.
- (f) (i) Most candidates drew a second line and many had a correct line of smaller gradient and below the original. A few drew a parallel line either above or below the original line but a larger number drew a line of greater gradient above the original. A small number drew a line with negative gradient.
- (ii) Although a higher temperature would reduce the value of K_c , there was an error carried forward from the line drawn in (f)(i) which enabled candidates to gain credit.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key Messages

Candidates should always explain all of the steps in a calculation. This helps the candidate to clarify their thoughts but also, where the candidate doesn't arrive at the correct final answer, allows them to gain credit for their method.

Where a question asks for state symbols to be provided for an equation it is important they should be included and that care is taken to decide whether a substance is present as a solid or as a solution.

If a graph has a curved line, candidates should provide a single continuous line and must avoid awkward joins between points and thick or double lines.

General Comments

Generally candidates answered the questions on this paper a little more successfully than has been the case in the recent past. With the exception of **2(d)(i)**, which was intended to challenge even the strongest candidates, the responses to the theoretical and numerical parts were frequently of a high standard. The answers to the more practical components, however, were usually of a lower standard.

Question 1(b)(i) showed that candidates often knew what they were trying to achieve when providing a circuit for the electrolysis but were frequently unable to draw a diagram which took account of the need to avoid the mixing of the gases produced and which successfully allowed the absorption of carbon dioxide. Centres should be reminded of the importance of practical work throughout the course in preparation for this examination.

Candidates could often provide balanced equations, though not always with correct state symbols.

Comments on Specific Questions

Question 1

- (a) (i) There were many good answers though many candidates thought that the sulfate ion was the source of the oxygen or that oxide ions were present in the solution. A few candidates reversed the electrode equations thus gaining no credit.
- (ii) Candidates found this very difficult, even those who had given the correct equations in part (i). Many drew lines which had no relationship to the line given in the question. Of the few candidates who appreciated that the same volume of hydrogen would be collected in half the time, most did not gain credit as the line was not drawn correctly.
- (iii) More candidates gained credit than in (ii) but there were still a number of carelessly drawn lines.

- (b)(i)** Candidates found this difficult. Some candidates drew good diagrams but did not use connecting tubes which would allow the carbon dioxide to be absorbed. If a solution of an alkali was used, credit was gained only if the tube from the electrolysis cell passed into the solution, and was then connected to the syringe by another tube which was not in the solution. Some forgot to label the alkali or left it open to the air so that the ethene would not be collected at all.
- Many candidates could have gained more credit by labelling the circuit and correctly including an ammeter rather than voltmeter. For many candidates, more practice is needed in how to set up an experiment, including the correct placing of delivery tubes and bungs.
- (ii)** Very few candidates gained full credit by appreciating that six measurements would be required to verify the equation: the size of the current, the time of the experiment, the volumes of hydrogen and ethene and the mass of the alkali before and after the absorption of carbon dioxide. Candidates who named three were awarded partial credit but a significant number did not receive any credit.
- (iii)** Most candidates understood what was required but incorrectly multiplied by 24 instead of 24000.
- (iv)** Candidates who knew that 2 Faradays would be needed to produce a mole of hydrogen gave this as the answer rather than an answer in terms of N.
- (v)** Many candidates either did not include state symbols or only gave them for some of the substances in the equation. Common errors included giving the carbonate as solid rather than aqueous or giving water as aqueous rather than liquid.
- (vi)** Some candidates were able to use the information about the production of ethene given at the start of the question in order to deduce that a butene would be produced. Only a small number gave the fully correct answer of but-2-ene but cyclobutene or any version of butene gained credit. Common incorrect answers included propene and hexane.

Question 2

- (a)(i)** The equation was well known although some candidates gave H_2CO_3 instead of $\text{CO}_2 + \text{H}_2\text{O}$, and since this isn't a major product it did not gain credit.
- (ii)** This was well answered and often carefully explained.
- (b)(i)** Many candidates were able to give the expression for K_a correctly. A few, however, included [X] in their answer and so didn't gain credit. Some of these candidates continued to give a correct answer to **(b)(ii)**, clearly demonstrating their understanding. It is important that candidates be encouraged to read a question carefully before answering it.
- (ii)** Many candidates gained credit here. However, answers were often very disordered which made finding the creditworthy responses difficult. Candidates should be encouraged to set out their responses to such questions in a logical manner.
- (c)(i)** Most candidates plotted the points correctly although a significant number plotted the last point at 4.01 rather than 4.11. Candidates found drawing a smooth curve more challenging and should ensure to not draw a double line or a line with kinks. Since candidates did not know which point was anomalous more than one path for the curve was possible.
- (ii)** The anomalous point was identified by almost all candidates and although the fourth point was the one expected, credit was awarded according to the line drawn by the candidate. A variety of reasons were accepted for the presence of the anomalous point but it was not correct to refer to a change in the reaction as a cause.
- (d)(i)** This proved to be the most difficult question on the paper and many candidates were unable to carry out the necessary calculation. Stronger candidates who appreciated what was required usually obtained the answer $\text{HX} = 90$ and gained full credit. There were a number of ways of solving the problem and if answers were clearly explained they gained credit. Many candidates did not explain their calculation despite being asked to in the question.

- (ii) Many candidates omitted this part of the question or gave the formula of a simple carboxylic acid instead of a hydroxycarboxylic acid.
- (e) Few candidates could suggest a valid reason for why it would be difficult to evaporate a solution to dryness. This highlights the importance of regular practical work as part of the A Level Chemistry course.

CHEMISTRY

Paper 9701/53

Planning, Analysis and Evaluation

Key Messages

Some candidates answer in pencil and then overwrite their answers in ink making the creditworthy responses difficult to identify. Any alterations need to be clear, overwriting text or especially numbers is not recommended. The original should be clearly crossed out and the new answer written close by. In graph plotting a simple clear cross is preferred to large dots.

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During a calculation early or over rounding should be avoided, the vulgar fractions given by some calculators are acceptable during the course of a calculation but are not acceptable as a final answer. The final answer should be rounded correctly, in decimal or standard form and to the required number of significant figures or decimal places.

General Comments

Command words such as "state" or "what" require less extensive answers than those such as "explain" or "describe". Candidates need to make sure not to include contradictory statements within their answers, this was evident particularly in questions **2(e)** and **2(f)(ii)**. The space given for an answer is ample and candidates should not feel under pressure to always completely fill it.

Comments on Specific Questions

Question 1

- (a) (i) The majority of candidates found these equations very difficult and few gained full credit. Most candidates who gained partial credit usually did so with the manganate(VII) half equation; the correct methanoate equation was very rarely seen. Equations were often missing electrons or showed charge imbalance. A few candidates gave a correct full equation which gained some credit.
- (ii) Most candidates calculated the concentration of magnesium methanoate correctly although a few used an incorrect M_r of 114. Many candidates did not appreciate that the concentration of $\text{HCOO}^-(\text{aq})$ was also required but those who did usually gained credit for it.
- (iii) Most candidates realised that 5 cm^3 of the saturated solution needed to be diluted to 250 cm^3 but could not describe how this could be achieved accurately. Incorrect responses included measuring cylinders, non-volumetric flasks such as conical flasks or beakers, 10 cm^3 non-graduated pipettes and not specifying that the solution needed to be diluted up to the mark on the volumetric flask. Many candidates incorrectly added 245 cm^3 of water to the saturated solution usually without specifying how to do this.
- (iv) The majority of candidates found this very challenging. Many candidates thought that the acid reacts with the methanoate instead of facilitating the reduction of manganate(VII) and so few gained credit. Few candidates appreciated that provided the acid is in excess; its volume doesn't change the reaction.
- (v) A significant number of candidates gave the end point colour as pink, which is past the end point, rather than pale pink. Purple and the reverse colour change were common incorrect responses.

- (vi) Candidates who used 25 instead of 25.5 did not gain credit. A small number of candidates correctly calculated 0.051 but gave a non-creditworthy final response of 0.05.
- (vii) Very few candidates managed to convert a concentration of methanoate ions into that of magnesium methanoate. Of those who did, many gave their answer to four, instead of the required three, significant figures.
- (b) The majority of candidates had a good understanding of independent and dependent variables. Common errors included solubility or titre values as the dependent variable..
- (c) The majority of candidates knew that the enthalpy of solution is endothermic or that ΔH is positive but some candidates gave contradictions in their answer such as 'endothermic so ΔH is negative'. Candidates found the explanation of promotion of the forward reaction more difficult. Many candidates only restated the question and a number confused solution with solubility.
- (d) Very few candidates appreciated that barium sulfate is insoluble. Some candidates knew that barium methanoate would react with sulfuric acid but could not link this to the insoluble product.

Question 2

- (a) (i) Most candidates gave a correct expression for K_c . Errors included inverted expressions, missing the squared term in $[HI]^2$, $[H]$ instead of $[H_2]$ and $[I]$ instead of $[I_2]$.
- (ii) Most candidates found substituting **a** and **y** into the expression from (a)(i) very difficult. Common errors included $2y^2$ for $[HI]^2$ and **a** or $(a-2y)$ for $[H_2]$ or $[I_2]$.
- (b) (i) Most candidates gained full credit by subtracting column 2 from column 1 correctly, and quoting the result to three decimal places. A few candidates calculated K_c and used this to calculate the remaining **y** values; this approach does not produce correct values due to the experimental variation in the concentration data.
- (ii) Candidates found the plotting of points quite difficult. There is no tolerance allowed for points which should be on the intersection of two grid lines, all other points have a tolerance of half a small square. Typically misplots tended to be inaccurate by two squares such as 1.135 being plotted at 1.035. Many candidates were either too inaccurate or used dots which were so large they filled a small square.
- (iii) Due to the variation in the experimental data, candidates needed to exercise judgement in drawing the line of best fit. A significant number of candidates did not appreciate that the line should go through the origin and either did not extend the line to an axis or did not give the line sufficiently close to the origin to be creditworthy. Some lines were excessively thick.

Candidates need to be equipped with a suitable pencil and ruler in order to plot points and draw lines with the necessary precision.

- (c) (i) A significant number of candidates gave coordinates as $(x_1, x_2) : (y_1, y_2)$ or gave just one x value and one y value rather than in the standard $(x_1, y_1) : (x_2, y_2)$ format. Many candidates chose table points for their co-ordinates which is only acceptable if the points are on their line or have not been mis-plotted. Candidates should ideally use points from their graph, preferably where the line passes through an x and a y grid line, with a reasonable separation of the points. The origin was acceptable as one of the co-ordinates provided the line went through the origin. The gradient was usually calculated correctly with very few candidates inverting the expression, however, many did not give their answer to the required three significant figures.
- (ii) Candidates who used the equation in (b) and the gradient in (c)(i) usually gained credit. Incorrect responses included using an (x, y) co-ordinate instead of the gradient and using the expression derived in (a), neither of which were creditworthy for the first point but which, if used correctly, could go on to gain credit for the second point. Those who used the expression from (a) often expanded $(a-y)^2$ incorrectly as $a^2 - y^2$ or $(2y)^2$ as $2y^2$. Candidates found difficulty manipulating the square root often giving K_c as 2.45 from $\sqrt{K_c} = 6$ rather than 36. Often the final answer did not quite

match the working as rounding had been undertaken mid calculation rather than only in the final step. A few candidates rounded their answer incorrectly.

- (d) Most candidates realised that there was a danger of explosion but many did not gain credit as the condition which would enable this to occur, such as the high temperature, was not included.
- (e) A small number of candidates appreciated that only two points were required, with many giving lengthy justifications that often included contradictory statements. The flask volume increasing was a common incorrect response.
- (f) (i) Most candidates drew a second line and many had a correct line of smaller gradient and below the original. A few drew a parallel line either above or below the original line but a larger number drew a line of greater gradient above the original. A small number drew a line with negative gradient.
- (ii) Although a higher temperature would reduce the value of K_c , there was an error carried forward from the line drawn in (f)(i) which enabled candidates to gain credit.