

CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

This examination paper provided a difficult challenge to the candidates. The majority of candidates were able to finish the paper within the hour allowed.

Questions 7, 8, 18 and 23 were found to be easy. Questions 14, 20, 25, 31, 38 and 39 were found to be particularly difficult.

Comments on specific questions

Question 14

The most commonly chosen incorrect answer was **C**.

The solid residue does not react with $\text{HCl}(\text{aq})$ therefore no MgO is present, ruling out **C** and **D**. A mixture of BaO (which reacts with water to give $\text{Ba}(\text{OH})_2$ which is soluble) and MgSO_4 would not give a solid residue, ruling out **B**. The answer is **A** because the original solid residue is the BaSO_4 , and the filtrate contains $\text{Ba}(\text{OH})_2$ which gives a white precipitate with $\text{H}_2\text{SO}_4(\text{aq})$.

Question 20

The most commonly chosen incorrect answer was **B**.

The product nitrile has the carbon atom of the nitrile group, not the nitrogen atom, joined to the C_2H_5 group, so the answer is **A** or **B**. The $\text{S}_{\text{N}}2$ mechanism involves attack by a lone pair on a positively charged carbon atom, and does not involve the formation of a carbocation, so the answer is **A**.

Question 25

The most commonly chosen incorrect answer was **B**.

This was a difficult question. Since one mole of $\text{Cr}_2\text{O}_7^{2-}$ oxidises three moles of X, it gains two moles of electrons from the oxidation of each mole of X. From the information in the question this means that one atom of X either gains one atom of oxygen or loses two atoms of hydrogen. The only possible answer is propanal, since one molecule of propanal gains one atom of oxygen when it is oxidised to one molecule of propanoic acid. It may have helped candidates to construct half equations:

- A** $\text{C}_2\text{H}_5\text{CHO} + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{COOH} + 2\text{H}^+ + 2\text{e}^-$
B $\text{C}_2\text{H}_5\text{CH}_2\text{OH} + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{COOH} + 4\text{H}^+ + 4\text{e}^-$
C $\text{CH}_3\text{CHOHCH}_2\text{OH} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{COCOCH}_2\text{OH} + 6\text{H}^+ + 6\text{e}^-$
D $\text{CH}_2\text{OHCH}_2\text{CH}_2\text{OH} + 2\text{H}_2\text{O} \rightarrow \text{HOOCCH}_2\text{COOH} + 8\text{H}^+ + 8\text{e}^-$

Question 31

The most commonly chosen incorrect answer was **C**.

To correctly answer this question, the following considerations were necessary:

- The original mixture is 0.2 mol ethanol, 0.2 mol ethanoic acid, 0.1 mol ethyl ethanoate.
- At equilibrium there is 0.08 mol ethanoic acid.
- At equilibrium there must also be 0.08 mol ethanol, 0.22 mol ethyl ethanoate and 0.12 mol water.

These deductions can then be made:

- Statement 1 is true.
- A higher temperature of 323 K favours the endothermic back reaction, so more reactants are present at equilibrium, so statement 2 is true.
- K_c is not affected by the addition of water or any other substance, so statement 3 is true.

Question 38

The most commonly chosen incorrect answer was **C**. Of the six compounds listed butanone, pentan-2-one, propanone, and propan-2-ol will give a positive iodoform test. Therefore pair 1 and pair 2 can be distinguished with alkaline aqueous iodine, pair 3 cannot.

Question 39

The most commonly chosen incorrect answer was **B**.

Reaction 1 does give a coloured organic product – the orange crystals produced by the condensation reaction between ethanal and 2,4-DNPH reagent.

Reaction 2 also gives a coloured product, but it is an inorganic product containing Cr^{3+} , hence its green colour. The correct answer is therefore **D**, as statement 1 only is correct.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

This examination paper provided a suitable challenge to the candidates. The majority of candidates were able to finish the paper within the hour allowed.

Questions 4, 9, 11, 12, 17, 31 and 37 were found to be easy. **Questions 3, 7, 21, 30, 33, 34 and 40** were found to be particularly difficult.

Comments on specific questions

Question 3

The most commonly chosen incorrect answer was **D**.

Z does indeed have the highest boiling point as its interionic attractions are stronger than the hydrogen bonding in X, which is in turn stronger than the polar forces in Y.

Question 7

The most commonly chosen incorrect answer was **B**.

Since the reaction described is the decomposition of ammonia, not its synthesis, the activation energy of the first step is **D** not **B**.

Question 21

The most commonly chosen incorrect answer was **B**.

Steps 1 and 2 can be described as oxidations because hydrogen atoms are removed from the reactant in each case. Step 3 can be described as a reduction because hydrogen atoms are added to, and an oxygen atom is removed from, the reactant.

Question 30

The most commonly chosen incorrect answer was **C**.

The answer cannot be **C** as butanoic acid does not fit the stated molecular formula. The O-H absorption present on the left of the spectrum rules out **A**. The C=C absorption between 1600 and 1700 means that this is the spectrum of **D** and not **B**.

Question 33

The most commonly chosen incorrect answer was **A**.

For many candidates the key to this question was the correctness or incorrectness of statement 1. Statement 1 is not true. Reaction 1 is not taking place in a closed system.

Question 34

The most commonly chosen incorrect answer was **D**.

For many candidates the key to this question was the correctness or incorrectness of statement 2. Statement 2 is correct, as cooling the mixture will change the average kinetic energy of the gas particles. Adding a catalyst will not affect the average kinetic energy of the gas particles, so the combined effect of these changes is to lower the average kinetic energy of the gas particles.

Question 40

The most commonly chosen incorrect answer was **D**.

For many candidates the key to this question was the correctness or incorrectness of statement 2. Statement 2 is correct. If butanoate ions are treated with $\text{H}_2\text{SO}_4(\text{aq})$ the products are butanoic acid molecules and HSO_4^- ions.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General comments

This examination paper provided a suitable but slightly difficult, challenge to the candidates. The majority of candidates were able to finish the paper within the hour allowed.

Questions 1, 5, 8, 19, 22, 23, 29, 31, 33 and 35 were found to be easy. **Questions 4, 7, 9, 14 and 24** were found to be particularly difficult

Comments on specific questions

Question 4

The most commonly chosen incorrect answer was **C**.

The angles are approximately: $x = 109.5^\circ$, $y = 120^\circ$ and $z = 104.5^\circ$, so the order is z, x, y .

Question 7

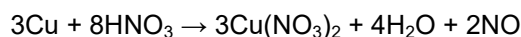
The most commonly chosen incorrect answer was **B**.

The sum which gives the correct answer is: $-276 + (-335) - (+25.9) = -636.9$.

The error that gives answer **B** is $-276 + (-335) + (+25.9) = -585.1$. This is an error in the application of Hess's law.

Question 9

The most commonly chosen incorrect answer was **C**. This is a difficult equation to balance. Since Cu is oxidised from 0 to +2 and N is reduced from +5 to +2 it can be deduced that three moles of copper are oxidised by two moles of nitric acid. Since all copper in the products is in the form of $\text{Cu}(\text{NO}_3)_2$ a further six moles of acid are required to provide the six nitrate ions, giving a total of eight moles of nitric acid.



Question 14

Each option was chosen with approximate equal frequency, which suggest candidates were guessing. It was hoped that candidates would be able to recognise **C** as a factually correct statement. **A** is incorrect because ammonium ions are weakly acidic, not alkaline. **B** is incorrect because ammonium nitrate is soluble in water. **D** is incorrect because if ammonia were to be produced it would raise the pH of the soil not lower it.

Question 24

The most commonly chosen incorrect answers were **B** and **C**.

One possible correct approach to this question is:

35 cm^3 of CO_2 and 55 cm^3 of water is a 7:11 ratio.

- A** 1 molecule of $\text{C}_2\text{H}_5\text{OH}$ and 3 molecules of CH_3OH give 5CO_2 and $9\text{H}_2\text{O}$. ratio 5:9. **Incorrect.**
- B** 2 molecules of $\text{C}_2\text{H}_5\text{OH}$ and 3 molecules of CH_3OH give 7CO_2 and $12\text{H}_2\text{O}$. ratio 7:12. **Incorrect.**
- C** 3 molecules of $\text{C}_2\text{H}_5\text{OH}$ and 2 molecules of CH_3OH give 8CO_2 and $13\text{H}_2\text{O}$. ratio 8:13. **Incorrect.**
- D** 3 molecules of $\text{C}_2\text{H}_5\text{OH}$ and 1 molecule of CH_3OH give 7CO_2 and $11\text{H}_2\text{O}$. ratio 7:11. **Correct.**

CHEMISTRY

Paper 9701/21
AS Level Structured Questions

Key messages

Candidates are reminded to read questions carefully and check answers thoroughly, especially in extended answers where more writing is required. The accurate use of chemical terminology is welcomed, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument, and it is advised that a concise range of vocabulary is incorporated into responses that demonstrate candidate understanding.

Candidates are reminded to address 'explain' questions fully — not merely to state facts or rules of thumb, but show how these combine to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules.

Candidates are also reminded that their working in calculations should be shown to ensure that due credit can be awarded. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

General comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. The large majority of questions were single-mark or two-mark items, allowing marks to be awarded across the entire range of questions; candidates were able to score well on both AO1 and AO2 items, though some recurring AO2 themes continue to be answered vaguely.

Candidates showed good knowledge of many topics, though a wide range of marks was scored across all centres. Good recall of essential material was sound, though candidates are advised to write carefully and precisely worded definitions, using standard chemical vocabulary.

There were several numerical answers required in this paper, but the best answers involved clearly laid out working (which also enables Examiners to give partial credit for ultimately incorrect answers). Candidates are also asked to ensure their drawings are clear and unambiguous.

Comments on specific questions

Question 1

This question was based around a dicarboxylic acid and tested straightforward physical and inorganic chemistry. The initial definition proved the most taxing, though dealing with the Avogadro constant also required some skill.

- (a) (i) Candidates mostly scored the first mark but errors then seen in answers included no mention of *atoms* of carbon-12, no mention of the reference unit, and an in specific reference to the 'mass of a compound'.
- (ii) It appeared many candidates were unfamiliar with the term *empirical* formula, as many gave the molecular or structural formula instead
- (iii) The major omission here was the factor of 2. Most candidates used the Avogadro number as a coefficient, but the value multiplied was not always a molar quantity.

- (b)(i) This was well answered, although recurring errors were the inclusion of O_2 as a reactant and use of the incorrect state symbols for CaO or CaC_2O_4 .
- (ii) This was answered well.
- (iii) This was straightforward for many candidates, although $CaCO_2$ was very often given as the (assumed) formula for calcium carbonate.

Question 2

Intermolecular forces, bonding and ideal gases were tested here: the question produced some surprising inaccuracies from candidates, with particular attention drawn to ideal gas conditions, which many seemed uncertain over.

- (a)(i) A large number of answers focused on the number of lone pairs on each atom in the respective molecules; similarly, most answers focused on the relative electron contribution of each atom to the triple bond, though fewer answers were developed enough to mention the co-ordinate or dative bond.
- (ii) Surprisingly, the number of electrons per molecule was often incorrect and Van der Waals' forces or covalent/dative bonds were frequent responses, for CO and N_2 .
- (b) Some incorrect bond energy statements were given: few candidates appreciated the difference in polarity even though a table of electronegativity values was provided.
- (c)(i) In asking for conditions, Examiners were looking for general statements about temperature and pressure, rather than the assumptions of the ideal gas model.
- (ii) Reactivity statements appeared regularly and were not well answered: candidates appeared unfamiliar with ideal gas behaviour.
- (d) Predictable errors were seen here, mainly in the conversion of physical quantities to SI units and incorrect rearrangement of the ideal gas equation.

Question 3

This short question on halogens distinguished candidates on their ability to deal with halogen oxidation compared to acid/base reactions: the trend and chemical properties of elements down Group 17 were brought into focus.

- (a)(i) Surprisingly few candidates were able to give the Brønsted–Lowry acid–base reaction of $NaCl$ with H_2SO_4 , trying instead to show a redox process.
- (ii) Candidates' responses to this question were largely dependent on their answers to (a)(i).
- (b)(i) Candidates appeared to be very uncertain about which species could be responsible for the fumes.
- (ii) This was poorly answered. Many candidates struggled to identify iodine from the information given about a dark grey solid.
- (c) This question was misunderstood by many candidates. Many answers included a description of the products from the reaction between $NaCl$ and NaI with H_2SO_4 .
- (d) Very few candidates were able to give a correctly balanced equation, with many answers incorrectly showing HBr as a product.

Question 4

Responses showed a surprising lack of precision in their answers, particular to **part (c)** which tested kinetics. Most candidates missed the factor of 10^5 on the graph and relatively few were able to present units correctly, or to sketch the outcome of **(ii)**.

- (a) This was answered well by most candidates: a variety of approaches were acceptable.
- (b) This was answered well.
- (c) (i) Many candidates appeared confused by the factor of 10^5 on the vertical axis, leading to some implausible values for the rate. The units of rate were often wrong: some candidates might have been trying erroneously to give the units of the rate constant, or simply could not deal with inverse indices. Candidates are advised to show units unambiguously, as described in the syllabus document.
- (ii) Very few candidates could address both criteria correctly: the most common mistake was to have the curve finishing at a different final (Br_2).
- (iii) The first mark was frequently awarded regularly but few candidates mentioned the change in proportion of particles' exceeding the activation energy.
- (d) This proved to be a surprisingly difficult question for candidates. A large proportion attempted to show hypervalent carbons or did not recall the difference in bond order between C and the two O atoms.

Question 5

This short question based on organic chemistry was well answered by many, but **(d)** proved to be quite challenging for many candidates, and **(e)** required much more concisely worded answers than were generally given.

- (a) (i) This was answered well.
- (ii) Many candidates' responses showed a lack of understanding of the term *raw material*.
- (b) (i) This was answered well.
- (ii) Fewer candidates than expected were able to identify pentane as the product.
- (c) (i) There was a very wide range of answers given. Candidates are advised to be quite explicit with identification of the carboxylic acid group, viz. $\text{CO}_2\text{H}/\text{COOH}$ or explicit naming of the acid, rather than just 'carboxyl'.
- (ii) Many candidates found this lower demand question difficult to answer.
- (d) Candidates found the skeletal representation of the polymer difficult to interpret and therefore could not accurately determine the structure of the monomer.
- (e) (i) CO_2 or CO was given as the most common answer.
- (ii) A surprising number of answers to the consequences of CO included 'acid rain' and 'depletion of ozone layer'.

Question 6

The context of this organic chemistry question was not unfamiliar, but **(d)** in particular—a substitute for a mechanism—proved challenging to candidates who were perhaps not so practised at looking at the regiochemistry of reactions in quite so much detail.

- (a)** Many answers incorrectly gave hydrolysis as the type of reaction.
- (b)** Candidates are reminded that reagents should be identified as fully named compounds, rather than *e.g.* $\text{H}^+(\text{aq})$.
- (c)** Very few candidates were able to identify the number of σ bonds in each molecule; identification of π bonds was more accurate.
- (d) (i)** Both carbocations often correct, though some incorrect structures contained double bonds. The use of the phrase 'greater inductive effect' was often not present and Markovnikoff's rule was often quoted but not substantiated.
- (ii)** Propan-1-ol and propanol most frequent errors.
- (e) (i)** Dehydration and substitution regularly appeared as answers.
- (ii)** If NaOH was given as an answer, then the second mark was often scored, though there were very many nil responses to this question. A whole range of reagents was offered, perhaps haphazardly – amongst which concentrated and dilute H_2SO_4 , Al_2O_3 , H_2O and H^+ , H_2 , LiAlH_4 and ethanoic NaOH **(g)** with heat/reflux appeared.

CHEMISTRY

Paper 9701/22
AS Level Structured Questions

Key messages

Candidates should ensure they can demonstrate knowledge of facts, definitions and theories with accuracy. Candidate answers should apply relevant knowledge to the specific details given in questions.

General comments

Candidates should be encouraged to use appropriate terms in their answers. Inappropriate use of vocabulary could introduce ambiguity into answers.

Lengthier responses or the inclusion of more details than required by a question sometimes led to contradictions in candidate answers.

Comments on specific questions

Question 1

- (a) The formula and colour of the precipitate made on addition of silver nitrate to the solid bromide was well known.
- (b) Correct balanced equations for the reaction were common. Weaker responses gave equations with an incorrect formula for the metal nitrate product.
- (c) Clear and logical workings were shown in many excellent responses. Some confusion was seen in the use of the terms *relative formula mass* and *relative atomic mass*.
- (d) (i) Formation of a precipitate, production of white fumes and effervescence were the most common incorrect answers.
- (ii) Many answers stated the reaction was an example of a displacement reaction. Incorrect answers often referred to neutralisation, hydrolysis or disproportionation.
- (e) Relatively few candidates identified concentrated sulfuric acid as the reagent. Key information provided in the question was ignored by many and the addition of silver nitrate followed by ammonia was a common response, even though the question asked for the addition of a single reagent.
- (f) (i) The action of heat on magnesium carbonate, oxide and nitrate was well known and many clear explanations were given. Some answers did not focus on change in mass but rather gave responses which identified the gaseous products of the reactions. Incorrect details included descriptions of a white flame or production of oxygen gas when magnesium oxide is heated or that magnesium oxide is a black solid.
- (ii) Understanding of the term cation was well known. The majority of candidates gave the correct electron configuration of the magnesium cation.

- (g) Good responses stated clearly one similarity and one difference which would arise when acid is added to the two samples. Incorrect ideas included the production of hydrogen gas on addition of acid to magnesium hydroxide. Some answers incorrectly stated that the hydroxide salt produced water and the carbonate produced carbon dioxide as the difference between the two reactions. The incorrect formula of magnesium chloride was also seen.

Question 2

- (a) (i) The majority of candidates correctly deduced that the particles present in solid lithium sulfide are ions, not all deduced the correct charge on the ions.
- (ii) Good answers explained the high melting point in terms of the large amount of energy required to break the many strong ionic bonds present in the giant lattice structure. Weaker answers identified the incorrect type of bond.
- (b) (i) Some excellent explanations of a coordinate bond were seen. Ambiguity occurred in answers which were given in terms of the transfer of electrons from one species to another.
- (ii) Some excellent 'dot-and-cross' diagrams were shown by those who used the information given in the question and applied knowledge of electronic structure and bonding between atoms. Partially correct answers were seen by those who represented a coordinate bond between the two atoms whilst not showing each atom in the molecule with a full outer shell of electrons.
- (c) (i) Clear statements using appropriate vocabulary were seen in the best responses. Weaker answers stated that particles had 'no mass' or that the volume of the 'gas' was negligible rather than the volume of the 'gas particles'.
- (ii) Excellent responses were seen which gave concise details that described the effect of high pressure on the forces of attraction or repulsion between the nitrogen molecules and compared the relative volume of the gas particles to the volume of the container. There was confusion by some who considered the presence of the strong triple bond was key to the non-ideal behaviour of nitrogen gas at high pressure.
- (iii) Many candidates did not consider all the types of intermolecular forces (van der Waals' forces) which exist in samples of carbon monoxide and described only the strongest force.
- (iv) The best responses described the difference in electronegativity of the two atoms in carbon monoxide. Some answers described a carbon monoxide molecule as polar but did not describe the difference between the two atoms in the molecule responsible for this polarity.

Question 3

- (a) Correct explanations of the term 'rate of reaction' were uncommon. Answers tended to be vague or incomplete.
- (b) (i) Most candidates correctly identified the area of the graph which represents the proportion of molecules with sufficient energy to react.
- (ii) The general shape of the curve was well known. Weaker responses were not drawn with enough precision to demonstrate clear understanding of the effect of different temperatures; for example, some curves started close to the origin rather than at the origin, others represented the new curve with little variation from the original so that it was difficult to determine if the curve drawn had shifted right of the original or produced a lower energy peak. Some curves showed the final part of the curve increase at the highest energies represented.

- (iii) Many answers mistakenly described why there would be an increase in rate of reaction at higher temperatures rather than state the effect of an increase in temperature on the activation energy.
- (c) (i) Excellent details for this mechanism were seen. Some answers gave a bimolecular rather than unimolecular sequence. Weaker responses did not draw curly arrows with enough precision to demonstrate clear understanding of what this symbol represents. Movement of a pair of electrons should always be represented by a double headed arrow.
- (ii) The name for this reaction mechanism was well known.
- (d) Detailed explanations that related the difference in strength of the carbon-halogen bond to the effect on the time taken for the reaction to occur were seen. Weaker responses answered in general terms of 'bond length' rather than describe the relative strength of the relevant bonds involved in this reaction.

Question 4

- (a) (i) The majority of candidates recognised the *cis-trans* pair of geometric isomers in **B** and **C**. 1,2-dimethyl ethene was a common incorrect answer for **D**.
- (ii) Candidates struggled to give complete explanations for the term stereoisomerism. Omission of key details produced ambiguity in responses. The use of molecular formula instead of structural formula also presented problems.
- (b) (i) The majority of candidates correctly identified alkene **W** as compound **A**.
- (ii) The skeletal formula of the major organic product was shown in many responses. Very good answers applied their knowledge of the stability of carbocations to the actual structure of the two possible carbocations involved in this reaction. Weaker explanations were given in general terms and were not specific to the actual reaction given in the question.
- (c) A small number of answers correctly described the concentrated sulfuric acid as a dehydrating agent, many identified it as a catalyst. Incorrect reference to oxidising or reducing agents was common.
- (d) (i) The correct name for the reaction was given in many responses.
- (ii) Many candidates used all the information provided in the details to correctly deduce that **Z** contained an aldehyde functional group.

Question 5

- (a) A significant proportion of answers represented the correct secondary alcohol. It was common to see the hydroxide group as -OH rather than all the bonds between the atoms shown, which is required when a displayed formula is represented.
- (b) (i) Some answers correctly named the specific bromoalkane produced in reaction 1. Incorrect answers included those that gave an incorrect alkyl group name. On occasions, inclusion of the appropriate prefix, which indicates the carbon atom that the bromine is bonded to, was omitted.
- (ii) The name of the type of reaction involved in step 1 was well known.

- (iii) Confusion of the reagent and conditions for substitution reactions of haloalkanes and addition reactions of carbonyl compounds, to form nitriles, was seen in many responses. Hydrogen cyanide or the presence of acid with potassium cyanide was frequently described. Few answers included the use of ethanol as the solvent.
- (iv) This question proved challenging. Identification of the formula of the carboxylic acid produced when dilute acid reacted with the nitrile molecule was seen in many answers. Few equations were given which also correctly identified ammonium ions as one of the products. Not all equations were correctly balanced.
- (v) Good answers identified the appropriate absorption and the bond that corresponds to the absorption which is unique to **U**. Weaker responses also identified the absorption which corresponded to C-H bonds that were present in **U** but were also present in the other samples.

CHEMISTRY

Paper 9701/23
AS Level Structured Questions

General comments

The incorrect use of the term *electronegativity* appears to be widespread and features in answers for many topics not related to electronegativity.

Questions involving intermolecular forces of attraction, featured only hydrogen bonding in this exam paper. Candidates should take care when identifying and explain clearly how hydrogen bonds are formed.

The definition of geometric isomerism requires some improvement. Candidates are still using expressions like 'end of' or 'either side of' the C=C double bond. Each C in the C=C has two different groups/atoms is an unambiguous description which should be encouraged.

Comments on specific questions

Section A

Question 1

- (a) (i) The trend of an **increase** in the relative strength of the van der Waals forces of attraction between the molecules down Group 17, was generally well recognised.
- (ii) The physical state of the elements, chlorine, bromine and iodine as gas, liquid and solid was less well known by many candidates; the most frequent error being iodine referred to as a liquid.
- (b) The behaviour of both $\text{Cl}_2(\text{aq})$ and $\text{I}_2(\text{aq})$ as oxidising agents of differing strengths did appear to cause some confusion.
- As $\text{Cl}_2(\text{aq})$ behaves as a stronger oxidising agent than $\text{I}_2(\text{aq})$, the observations would be the formation of an orange/brown solution when $\text{Br}^-(\text{aq})$ is added to $\text{Cl}_2(\text{aq})$ but no reaction when $\text{Br}^-(\text{aq})$ and $\text{I}_2(\text{aq})$ are mixed.
- (c) The equation for the reaction between Cl_2 and $\text{NaOH}(\text{aq})$ to form bleach, NaClO , NaCl and H_2O was quite well answered. The most common error was the omission of NaCl when only one NaOH appeared in the equation as a reactant.
- (d) (i) The definition of the term *Bronsted-Lowry base* as a proton acceptor, was well answered.
- (ii) ClO^- behaves as a *Bronsted-Lowry base* when added to water, to remove a proton to form HClO and OH^- . This question was generally poorly answered with the most frequent error being the formation of O_2 and Cl^- as products.
- (e) Candidates who recognised that the volume of gas, at room conditions, could be converted to moles by dividing by 24 dm^3 or $24 \times 10^3 \text{ cm}^3$ tended to give creditworthy answers. Common errors included using the 5 cm^3 sample of S to determine the number of moles of gas and/or omitting the step of converting the moles of NaClO into a concentration by dividing by $5 \times 10^{-3} \text{ dm}^3$.

- (f) The redox reaction between ClO^- and HCl to form Cl_2 , Cl^- and H_2O proved challenging for many candidates. Although the oxidation numbers of the chlorine containing products were given as 0 and -1 , many candidates managed to deduce that Cl_2 was one of the products but were unable to formulate the other species. Common errors included species such as HClO and ClO_3 as the chlorine containing species having an oxidation number of -1 .

Question 2

- (a) Recognising the requirements for hydrogen bonding, between molecules, still appears to create problems with many candidates.

Many answers contained polar O–H bonds, in either water or methanol, but then proceeded to show a hydrogen bond between an O atom, in water, and an H atom in the CH_3 group, of methanol.

The correct diagrams contained a lone pair on an O atom, in the H-bond, a polar O–H group and an annotated intermolecular hydrogen bond.

- (b)(i) Many candidates appreciated that it was the gaseous particles that are responsible for the vapour pressure but failed to realise, from the stem of the question, that the methanol was contained in a sealed flask. The gaseous particles are thus in equilibrium with the liquid methanol, which is one of the criteria for existence of a vapour pressure.

- (ii) There were many candidates who clearly understood that particles require a certain amount of energy to overcome any intermolecular attractive forces and escape into the vapour phase.

- (iii) Only a relatively few candidates mentioned that both methanol and water contain intermolecular hydrogen bonding and water has stronger hydrogen bonding because it can form two H-bonds.

Fewer water molecules escape into the vapour phase, thus leading to water having a lower vapour pressure.

- (c)(i) A *dynamic equilibrium* occurs in a closed system, when the rate of the forward reaction is equal to the rate of the backward reaction, and the concentrations of both the reactants and products remain at specific values and do not change.

Many answers included the statement re: rate of forward and backward reaction but failed to mention the requirement for a closed system or that the macroscopic properties do not change.

- (ii) The partial pressure of methanol vapour, at equilibrium, may be calculated by multiplying the mole fraction of methanol in the equilibrium mixture by the total pressure, 1×10^7 .

A large proportion of the answers did multiply by 1×10^7 Pa, but the calculation of the mole fraction of methanol was often incorrect.

- (iii) The expression for the equilibrium constant, $K_p = p_{\text{CH}_3\text{OH}}/p_{\text{CO}} \times p_{\text{H}_2}^2$ with units of Pa^{-1} .

Question 3

- (a)(i) This question involved the behaviour of samples of $\text{Ba}(\text{OH})_2$, NaCl , P_4O_{10} and SiCl_4 with Water and was generally poorly answered.

Both NaCl and SiCl_4 were commonly misidentified in the table with NaCl frequently identified as being acidic in solution, in a vigorous reaction.

- (ii) Consequently, the formula of the white solid formed when SiCl_4 reacts with water should have been SiO_2 .

- (iii) The question required the **name**, phosphoric (v) acid, for the solution formed when P_4O_{10} reacts with water; many candidates elected to write formulae for the answer.

- (b) (i) One of the properties of ceramic materials, which include high melting points, non-conductors of electricity and strong but brittle, frequently appeared as answers.
- (ii) The formula of a Period 3 oxide, other than MgO and Al₂O₃, which behaves as a ceramic material, is SiO₂.
- (c) Candidates who realised that, in a tungsten oxide, W_xO_y, if 79.29 per cent of it was tungsten by mass, then the remaining 20.71 per cent must be oxygen and gave creditworthy answers.

The calculation then involved dividing by the respective A_r's of tungsten and oxygen, followed by dividing by the lowest number to give the empirical formula of WO₃.

Question 4

- (a) (i) Many answers correctly named **M** as 1,3-dichloropropanone and in (a)(ii) recognised that it is a ketone functional group that changes during the reaction.
- (iii) A suitable reagent for the reduction of the ketone group, in **M**, to an alcohol can include either NaBH₄ or LiAlH₄.
- (b) When 1, 3-dichloropropan-2-ol and 3-chloropropane-1, 2-diol are oxidised, using acidified Cr₂O₇²⁻ the secondary alcohol group, in the propan-2-ol derivative, is oxidised to a ketone group, **Q**, whilst the primary and secondary alcohol groups in the propane-1, 2-diol analogue are oxidised to a carboxylic acid and a ketone respectively, **R**.

Hence **Q** and **R** both give red/orange precipitates with 2, 4-DNPH, but only **R** fizzes with Na₂CO₃(aq).

Candidates who were familiar with this chemistry tended to get credit for their answers.

- (c) Step 1, in this sequence of reactions required HCN (with KCN) as a reagent, in a nucleophilic addition reaction with a carbonyl group, to form a hydroxynitrile derivative.

Step 3, however, is a nucleophilic substitution reaction requiring KCN (or NaCN) in ethanol solution.

Many candidates confused the reagents and conditions for these two steps involving a cyanide (CN) moiety.

Steps 2 and 4 both involved hydrolysis reactions of the nitrile group, CN, to a carboxylic acid.

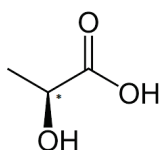
Question 5

- (a) Citric acid contains both an alcohol group and two carboxylic acid groups, all of which react with Na, to form the sodium derivatives and hydrogen gas.

The most common omission was the hydrogen gas, followed by the alcohol group not being involved in the reaction with the Na.

- (b) (i) X, C₃H₆O₃, contains an alcohol and carboxylic acid functional groups together with a chiral centre.

The skeletal formula of **2-hydroxypropanoic acid** with the chiral centre annotated with an asterisk meets the criteria in the table of reactions.



- (ii) Citric acid contains a tertiary alcohol functional group that is not oxidised by acidified Cr₂O₇²⁻, whereas X contains a secondary alcohol group that is readily oxidised (to a ketone).

- (c) The two key features that give rise to stereoisomerism are the requirement for a chiral centre, for optical isomerism, and a C=C double bond, for geometric isomerism, in which each C has two different groups.

Many candidates gained credit for the requirement of a chiral centre, for optical isomerism, but did not accurately describe the features for geometric isomerism.

- (d) The definition of *structural isomer* was quite well answered by many candidates although there is still some confusion with stereoisomerism with some answers referring to different spatial arrangements.

CHEMISTRY

<p>Paper 9701/31 Advanced Practical Skills 1</p>
--

Key messages

- It is essential that candidates and supervisors enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with the relevant supervisor values.
- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data in a suitable manner.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

General comments

This paper tested all of the practical assessment objectives listed in the syllabus. There appeared to be no time constraints with almost all candidates completing the paper. The marks given for presentation of results tended to be centre-dependent: teachers should encourage candidates to read the instructions given in a question, to complete all parts and to check their headings and units are correct.

Comments on specific questions

Question 1

A majority of candidate performed the experiment to a high degree of accuracy. However, only the strongest responses gained all the marks for the calculation. Some candidates ignored the information and/or instructions given in the question.

- (a) Most candidates presented their accurate titration data correctly. However, a significant number omitted the burette readings for the rough titration. Most candidates appeared aware of the need to achieve concordant titres. Most candidates gained at least 1 of the 3 accuracy marks.
- (b) This part was answered correctly by almost all candidates. The usual errors of no working shown or selecting a range of accurate titres with a spread greater than 0.20 cm^3 were seen only occasionally.
- (c) (i) Most candidates gave their answers to the expected 3 or 4 significant figures. However, some candidates did not provide sufficient answers to gain the mark.
- (ii) Nearly all candidates correctly calculated the number of moles of KMnO_4 .
- (iii) Whilst most candidates correctly used the stoichiometry of the equation to multiply by 5, a large number did not take into account that a factor of 40, to scale from 25 to 1000, was also necessary.
- (iv) Since the relative atomic masses are given to one decimal place in the Periodic Table provided, this is the accuracy expected in the calculation of the mass of FeSO_4 . Most candidates used the figure of 151.9 that was appropriate.
- (v) Most candidates were clearly aware of the need to find the ratio of the number of moles of water to iron (II) sulfate. A variety of acceptable approaches to this calculation was seen but a number of numerically correct answers could not be credited if the final answer was not given as an integer.

- (d) A number of candidates recognised that the oxidation of iron (II) ions meant that the volume of potassium manganate (VII) needed was less, but many responses did not go on to explain the effect that this had on the calculated value of x .

Question 2

It was evident that most candidates were familiar with the practical techniques involved in this question so that most scored well in recording results in a suitable format and in the space provided.

- (a) The description of the appearance of and observations on heating **FA 4** was often lacking, with few candidates describing the appearance before and during the heating process.

Although most candidates recorded their numerical results with suitable headings and correct units some used weight, instead of mass. Others gave the mass of **FA 4** after heating – this was not accepted since the residue at that stage is no longer **FA 4**.

Many candidates showed by their results that their technique was good others had apparently not heated strongly enough to remove all the water of crystallisation.

- (b) (i) Apart from a small number of candidates, who confused the mass of water and the mass of residue, most gained the mark.
- (ii) As in the similar calculation from **Question 1**, several correct methods are possible. Since it was stated in the introduction that y was an integer, the mark was lost if non-integral values were given as the final answer.
- (iii) Few candidates stated the assumption to be that all the water was lost or that **MZ** did not decompose in the heating.
- (c) Many candidates struggled with this question. The most common incorrect answer was that the lid would prevent the water escaping.

Question 3

It was clear that many candidates were accustomed to using the data in the Qualitative analysis notes and therefore correctly interpreted the observations with the more 'standard' reagents. Less familiar reagents were, unsurprisingly, more problematic.

Candidates should be encouraged to consider and prepare for possible outcomes on adding a reagent to or heating an 'unknown'. Candidates should be informed that indication of a change requires both the appearance before and after the test is carried out.

- (a) (i) **Test 1** As reactions with thiocyanate would generally be unfamiliar to candidates a range of colours was accepted but the suggestion of the formation of a precipitate was rejected.

Test 2 Whilst the reactions of iron (II) and iron (III) ions with sodium hydroxide should be recognised by candidates, the other reactions were less familiar. Many candidates reported seeing a darker coloured solution with thiocyanate at this stage.

- (ii) A significant number of candidates related the colour difference in the two tests to the oxidation of iron (II).
- (iii) A pleasing number also worked out the formula of ammonium thiocyanate.
- (iv) Very few realised that it was OH^- rather than NH_3 that should be in the ionic equation.

- (b)(i)** Marks were available for dissolving **FA 4** before carrying out any tests and for using an acceptable table to show reagents chosen and observations made. Most candidates scored the latter but very few made an aqueous solution.

All candidates scored some marks for the reagents and observations with a significant number scoring 4 or 5 of the 5 marks available.

- (ii)** Correct identifications of the ions present generally followed correct observations.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key messages

- It is essential that candidates and supervisors enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with the relevant supervisor values.
- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data in a suitable manner.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

General comments

This paper tested all the practical assessment objectives listed in the syllabus; it generated a wide spread of marks. There appeared no time constraints with almost all candidates completing the paper. The marks given for presentation of results tended to be centre-dependent: teachers should encourage candidates to read the instructions given in a question, to complete all parts and to check their headings and units are correct.

Comments on specific questions

Question 1

A majority of candidates performed the experiment to a high degree of accuracy. However, only the strongest responses gained all the marks for the calculation. Some candidates ignored the information and/or instructions given in the question.

- (a) Most candidates presented their accurate titration data correctly. However, a significant number omitted the burette readings for the rough titration. Most candidates appeared aware of the need to achieve concordant titres. Most candidates gained at least 1 of the 3 accuracy marks.
- (b) This part was answered correctly by almost all candidates. Some uncommon errors that were seen were omitting to show working or selecting a range of accurate titres with a spread greater than 0.20 cm^3 .
- (c) (i) Most candidates gave their answers to the expected 3 or 4 significant figures. However, some candidates did not provide sufficient answers to gain the mark.
- (ii) Nearly all candidates correctly calculated the number of moles of hydrochloric acid.
- (iii) Whilst most candidates correctly used the stoichiometry of the equation to divide by 2, a large number did not take into account that a factor of 40, to scale from 25 to 1000, was also necessary.
- (iv) Most candidates were clearly aware of the need to find the ratio of the number of moles of water to anhydrous sodium carbonate. A variety of acceptable approaches to this calculation were seen but a number of numerically correct final answers could not be credited if the final answer was given as an integer. The fact that x was not an integer was given in the information at the start of the question.

Question 2

It was evident that most candidates were familiar with the practical techniques involved in this question.

- (a) Most candidates recorded their numerical results with suitable headings and correct units with only a few using weight instead of mass. It should be noted that, with the accuracy of the thermometer provided, temperatures should be quoted to the nearest half a degree, i.e. should end with .0 or .5.
- Many candidates showed by their results that their experimental technique was good.
- (b)(i) Nearly all candidates clearly showed that they were familiar with the expression heat energy = $mc\Delta T$. The most commonly seen error was to use the mass of solid as m .
- (ii) In this part, it was necessary to use the information about enthalpy changes at the start of the question. Most candidates recognised this, but a few tried to calculate the relative formula mass of the sodium carbonate by adding the relative atomic masses of its constituents.
- (iii) This was the stage at which it was necessary to use the relative formula mass of the anhydrous sodium carbonate. Candidates who failed to score in (ii) could still access this mark as an error carried forward.
- (iv) A significant number of candidates struggled to find the value of the percentage impurity. Many attempted to use the relative formula mass in some way.
- (d) A large number ignored the instruction in the question 'not to make reference to...different masses'.

Question 3

It was clear that many candidates were accustomed to using the data in the Qualitative analysis notes and therefore correctly interpreted the observations with the more 'standard' reagents. However, candidates should be advised that observations should include the start and the final appearance and precise descriptions of, for example, the colour of a solution or precipitate. If this solution or precipitate is one included in the Qualitative analysis notes the description should match that colour.

(a) Test 1

Most candidates described the appearance of the solid when it was heated but few described it before heating. Since no solution was involved in the reaction, precipitate was not accepted as a synonym for solid. Few candidates noted the formation of condensation.

Test 2

Most candidates correctly observed bubbling but few identified the gas as being carbon dioxide. It should be noted that in a positive limewater test the observation should be 'white precipitate formed'.

- (b) With edta the original aqua complex and final edta complex are both blue and therefore to gain credit it was necessary to compare the darkness / intensity of the blue.

The other tests, on both **FB 6** and **FB 7**, should have been familiar to candidates and many acceptable descriptions of observations were seen

All candidates scored some marks for observations with a significant number scoring 4 or 5 of the 7 marks available.

- (c) Correct identifications of the ions present generally followed correct observations.
- (d) Few correct equations were seen: missing state symbols or additional spectator ions being included were common errors.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

- It is essential that candidates and supervisors enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with the relevant supervisor values.
- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data in a suitable manner.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

General comments

This paper tested all of the practical assessment objectives listed in the syllabus. There appeared to be no time constraints with almost all candidates completing the paper. However, a significant minority omitted part of **Question 3** indicating that some candidates did not read the information given with sufficient care.

Comments on specific questions

Question 1

Candidates are generally well-prepared for questions involving titrations. However, there were centres which experienced difficulties in obtaining household bleach containing sodium chlorate(I) of the expected concentration: some centres were unable to access any sodium chlorate(I) solution. Candidates were not disadvantaged provided this problem was reported by supervisors. The calculations arising from the method caused problems for some – candidates should be encouraged to look back at the information given in the question.

- (a) Most candidates gained the marks for the display of their titration results. The most common error was ignoring the instruction to record burette readings for the rough titration. Some candidates did not record all their burette readings for the accurate titrations to the nearest 0.00 or 0.05. As the procedure involved a dilution the tolerances for the difference between the results of candidate and supervisor were eased slightly and many gained at least 1 mark for accuracy.
- (b) This part was answered correctly by almost all candidates. Common errors, such as, no working shown or selecting a range of accurate titres with a spread greater than 0.20 cm³ were seen only occasionally.
- (c) (i) While some candidates wrote a note to themselves to give answers to the expected 3 or 4 significant figures, not all followed their own advice. However, a large majority of candidates gained this mark.
- (ii) Most candidates gained this mark. The most common errors were to use 25 cm³ instead of the mean titre or to omit the stoichiometric factor of 2 indicating a confusion between iodide and iodine.
- (iii) The most common error in this part was to omit the dilution factor. However, candidates showing clear working were generally able to gain 1 of the 2 marks available.

- (d)(i) A comparison of the amount (moles) of potassium iodide added and the number of moles of iodide required was expected. However, correct chemistry that answers the question is always credited and those comparing the volume of KI added with that required could access the mark. Some candidates ignored that a comparison of values was needed having calculated the quantities successfully.
- (ii) This question proved challenging to most candidates, but a range of good answers was seen. Even so it was rare for both marks to be awarded. Answers tended to lack detail such as at which stage of the method to add the chemical selected. Teachers need to ensure their learners understand the reasons for adding excess reagent or for adding solutions in a particular order: this can most easily be achieved when carrying out a variety of practical exercises in the laboratory.

Question 2

Many candidates were clearly confident in performing this procedure and with the subsequent calculations. Part (c) was the least well answered: it required a clear understanding of the chemistry underlying the procedure.

- (a) The majority of candidates provided their data clearly in a table with unambiguous headings and correct units though 'weight' was written by a few. Balance readings were almost all given to the same level of precision. However, candidates should be reminded that the thermometers calibrated as specified in the syllabus should be read and recorded to the nearest 0.0 or 0.5°C. A large majority of candidates gained at least 1 mark for accuracy with many achieving both those available.
- (b)(i) The equation to find the energy absorbed was well known and most candidates gained this mark. Candidates should note that the value for the specific heat capacity given in the paper involves the **volume** of solution and not the mass as in the usual $4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ($\text{J g}^{-1} \text{ K}^{-1}$) for water. A common error was to use either the mass of **FA 6** or this mass added to the volume of water.
- (ii) Most candidates gained at least 1 of the 2 marks available in this part. Errors arose from giving the final answer to more than 4 sf or omitting the conversion of J to kJ.
- (iii) Many candidates gained this mark. However, some failed to use the information provided. The periodic table gives relative atomic masses to 1 decimal place so the M_r of $\text{Na}_2\text{S}_2\text{O}_3$ had to be 158.2. The information at the start of the question stated **x** was an integer so answers of 5.0 or similar could not be credited.
- (c) Many candidates gained 1 mark for this section, but few achieved both. A common error of those correctly stating the temperature fall would be smaller or the heat energy change less than omitted a statement regarding the amount (moles) of sodium thiosulfate. Those incorrectly stating that the temperature fall would be greater were still able to gain the second mark (as error carried forward) by stating that the amount of sodium thiosulfate would be greater and so M_r would be smaller.

Question 3

Candidates should be informed that indication of a change requires both the appearance before and after the test is carried out. At this level candidates should be able to record fine distinctions in colour changes or in rates of evolution of gaseous products.

- (a)(i) Very few candidates gained both marks: most recorded 1 or 2 correct observations. The most common errors were to omit the initial appearance of **FA 7**, the state change on heating or to test for any gas evolved. Some candidates referred to the white solid formed on strong heating as 'ppt' thus showing a lack of understanding of the term.
- (ii) Many of those attempting this part achieved all 3 marks and almost all gained at least 1. Candidates should be aware that every part question will have an associated mark. The instruction was to record 'tests and observations in the space below' and this culminated in [3] as the mark available.

- (iii) Candidates generally reported the expected white precipitate though a cream ppt was given by a sizeable minority. Those subsequently adding aqueous ammonia could not access the mark as they were ignoring the instruction that no additional tests for ions present should be attempted.
- (iv) This mark was not available to candidates who failed to record a white ppt in (a)(ii) with at least one of the aqueous alkalis provided. However, most of those recording results in (a)(ii) gained the mark.
- (b) Many candidates observed the colour of the contents of the test-tube changed to brown (or other allowed colours) in **Test 1**, but fewer noted that the initial colour was yellow. However, most candidates correctly reported the blue-black or black colour on adding starch indicator. The most common error in **Test 2** was to omit that the colour faded on standing.
- (c) (i) Candidates should consider the purpose and potential results of each test. Candidates were told that two of the 'unknowns' were acids. As one was an organic acid it was likely to be a weak acid so having fewer $\text{H}^+(\text{aq})$ ions for the same concentration. Candidates should have looked for a difference in rate of bubbling with the magnesium ribbon in **Test 1**. Many candidates ignored the instruction given at the start of the qualitative analysis question to identify any gas produced by a suitable test. Candidates should be instructed to report the change of colour of a reagent such as aqueous acidified potassium manganate (VII) or aqueous bromine. A number of candidates wrote 'no change' on adding the acidified $\text{KMnO}_4(\text{aq})$ to **FA 10** instead of 'purple to colourless'. It is possible that the reagent was insufficiently acidified or that the mixture was not heated enough in **Test 2** with **FA 9** as a significant number of candidates reported yellow instead of a final colourless solution.
- (ii) Most candidates gained at least 1 mark in this part. A common error was in confusing the identities of the organic and mineral acids.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

- It is essential that candidates and supervisors enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with the relevant supervisor values.
- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data in a suitable manner.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

General comments

This paper tested all the practical assessment objectives listed in the syllabus and generated a wide spread of marks. There appeared no time constraints with almost all candidates completing the paper. The marks given for presentation of results tended to be centre-dependent: teachers should encourage candidates to read the instructions given in a question, to complete all parts and to check their headings and units are correct.

Comments on specific questions

Question 1

A majority of candidates performed the experiment to a high degree of accuracy. However, only the strongest responses gained all the marks for the calculation. Some candidates ignored the information and/or instructions given in the question.

- (a) Most candidates presented their accurate titration data correctly. However, some wrote the weighings and mass of **FB 1** in the method instead of in the allocated space: many more omitted the burette readings for the rough titration. Most candidates appeared aware of the need to achieve concordant titres. Most candidates gained at least 1 of the 3 accuracy marks.
- (b) This part was answered correctly by almost all candidates. The usual errors of no working shown or selecting a range of accurate titres with a spread greater than 0.20 cm^3 were seen only occasionally.
- (c) (i) Most candidates gave their answers to the expected 3 or 4 significant figures. However, some candidates did not provide sufficient answers to gain the mark.
- (ii) The periodic table gives relative atomic masses to 1 decimal place so the M_r of $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$ had to be 248.2. This value was used by the majority of candidates and the mark awarded.
- (iii) A common mistake was to divide by 1000 instead of by 250 or to confuse their mean titre with the volume they pipetted.
- (iv) This part discriminated well: Better responses recognised how to use the mole ratios in the equations and the scaling up from 25 cm^3 . Most candidates gained only 1 of the marks.

- (v) This part was well answered by many. However, some candidates appeared to alter previous answers in light of (correctly) calculating a large mass of KMnO_4 . Candidates should be reassured that correct working using previous (incorrect) answers is awarded marks as 'error carried forward'.
- (d)(i) Candidates arriving at a large mass in (c)(v) tended to use this as the denominator, showing a lack of understanding of this part. However, some calculated the high percentage accruing correctly so gained the mark. A substantial number of candidates correctly found the percentage error to be less than 1.0%, indicating commendable accuracy in their practical work.
- (ii) A large majority of candidates ignored the information given in the question that excess potassium iodide was added. This meant that the difference in precision of measurement of a pipette or a measuring cylinder was immaterial.

Question 2

Many responses showed candidates had a good understanding of the practical exercise and the resulting calculations. However, common errors involved lack of precision and insufficient working shown, both of which have been highlighted in the Reports for earlier series of examinations.

- (a)(i) Many candidates gained both marks in this part. However, it appeared from the ΔT values of supervisors and candidates in some centres that the concentrations of solutions were not those specified in the Confidential Instructions. The tolerance for the accuracy mark was changed to compensate for this as necessary.
- (ii) The equation to find the energy released was well known and most candidates gained this mark. A common error was to give the answer to 5 sf which was inappropriate given the calibration of both the thermometers and the measuring cylinders.
- (iii) Most candidates were able to gain 1 of the 2 marks available. The most common error was to omit the calculation of the amount (moles) of HCl(aq) to confirm that $\text{NH}_3(\text{aq})$ was the limiting reagent.
- (b)(i) Candidates should be encouraged to read the method carefully to ensure they record all the data required. Such data must reflect the precision of the apparatus used. A common error was to omit the .0 or .5 in a thermometer reading. Most candidates gained the mark for accuracy in this part.
- (ii) Candidates' responses here were varied with some appearing to find the calculation more straightforward than that in (a). However, a common error was to use the mass of **FB 8** instead of the volume of water when calculating the heat energy change. Candidates should note that the value for the specific heat capacity given in the paper involves the **volume** of solution and not the mass as in the usual $4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ($\text{J g}^{-1} \text{ K}^{-1}$) for water. Some candidates gave an incorrect sign in their final answer. A majority of candidates gained at least 1 of the 2 marks.
- (c) A common error was to ignore the prompt in the question to use their answer to (a)(iii) as well as that for (b)(ii). Those who drew out a Hess' diagram were more likely to complete the task successfully.

Question 3

It was evident that candidates were less practised in qualitative than in quantitative analysis questions. Candidates should be encouraged to consider and prepare for possible outcomes on adding a reagent to or heating an 'unknown'. Candidates should be informed that indication of a change requires both the appearance before and after the test is carried out.

- (a)(i) As **FB 9** was a basic carbonate candidates should have observed condensation on the upper part of the hard-glass test-tube on gentle heating; few reported this. Many candidates did not record that there was no change of state for most of the contents of the tube. Some omitted the change in the powder (back to white) on cooling though prompted to do so in the instructions.
- (ii) Most candidates reported effervescence on adding sulfuric acid. Far fewer gave a second observation or commented on the rate of bubbling. Those carrying out a test with limewater should ensure they use the correct terminology for a positive result: 'gives a white ppt.' is the optimal response.

- (iii) This part proved challenging for many candidates as they had to compensate for excess acid yet add sufficient alkali to test conclusively whether the precipitate formed was soluble in excess. However, many candidates gained at least 1 of the 2 marks.
- (iv) Candidates reporting correct observations made the correct deduction so gained the mark. Many of those with incorrect observations made a correct inference: almost all concluded **FB 9** contained carbonate ions.
- (b)(i) Few candidates gained 4 or 5 marks in this part. **Test 1** involved commonly encountered tests but with the 'unknown' and reagent exchanged in the first part. While many candidates correctly reported a blue ppt fewer noted bubbling on adding aluminium foil to the warmed mixture. Few tested the gas evolved on adding aluminium foil to the warmed **FB 10** in **Test 2** with a lighted splint. Many claimed incorrectly that the gas turned damp red litmus paper blue indicating poor practical technique. More candidates correctly noted the formation of a white ppt in the second part of the test. **Test 3** again reversed the usual mixing of a reagent containing hydroxide ions and an 'unknown' containing metal ions that would give a precipitate. Hence greater allowance was given to the reported colour of the precipitate and many candidates gave a 'correct' observation. Fewer candidates added sufficient **FB 10** to observe the precipitate dissolving in excess.
- (ii) Candidates might have benefited from using the Qualitative Analysis Notes as the precipitates listed could have been a prompt to deducing that the unknown contained hydroxide ions. Those claiming **FB 10** contained sodium ions could not access the mark as no tests were performed to identify this ion. Few candidates gained this mark.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

- It is essential that candidates and supervisors enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with the relevant supervisor values.
- Candidates should be reminded to read the full method before starting an experiment so that they record all the required data in a suitable manner.
- Candidates should ensure their observations are recorded in detail.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.

General comments

This paper tested all the practical assessment objectives listed in the syllabus. There appeared no time constraints as candidates completed the paper leaving very few unanswered parts. The marks given for presentation of results varied: teachers should encourage candidates to read the instructions given in a question, to complete all parts, check their headings and units are correct and give fine distinctions in qualitative observations.

Comments on specific questions

Question 1

A majority of candidate performed the experiment to a high degree of accuracy. However, many candidates struggled with the calculation. Candidates should be encouraged to think about any tests they are to devise to ensure they write all necessary information.

- (a) Most candidates presented their accurate titration data correctly. However, while few wrote the weighings and mass of **FA 1** in the method instead of in the allocated space, more omitted the burette readings for the rough titration. Almost all candidates appeared aware of the need to achieve concordant titres. Most candidates gained at least 1 of the 3 accuracy marks.
- (b) This part was answered correctly by almost all candidates. The usual errors of no working shown or selecting a range of accurate titres with a spread greater than 0.20 cm^3 were rarely seen.
- (c) (i) This part was answered correctly by most candidates. Only a few used their mean titre value instead of 25 cm^3 .
- (ii) Almost all candidates completed the equation correctly and used the mole ratio to calculate the expected answer to this part.
- (iii) Fewer candidates gained both marks in this part. A common error was to use 1000 instead of 250 in scaling up or by using 25 instead of the mean titre value. More candidates were able to use their answer and the mass of **FA 1** correctly and so access the second mark.
- (iv) The majority of candidates were successful in calculating the relative atomic mass of **E** and to use their answer to identify the element.

- (d) Candidates from some centres struggled with this question. The error in a single reading must be doubled when calculating the mass of **FA 1** as 2 balance readings were required to obtain this mass. Only very few candidates omitted $\times 100$ in the calculation.
- (e) It was important that a **solution** was tested with the aqueous silver nitrate and many candidates did not specify this: one of HX(aq), a solution of **FA 1** or **FA 3** was needed. More candidates gained the mark for the observation and conclusion than for the method.
- (f) Many candidates commented correctly about the difficulty in discerning the end-point of the titration.

Question 2

Candidates appeared familiar with this type of practical procedure and the related calculation. However, they should be encouraged to think carefully about appropriate headings for their data: use of the wording given in the method should act as a prompt.

- (a) The mark most frequently lost in this part was for the headings: 'mass of crucible, lid and **FA 4** after 1st heating' is incorrect as the solid is now anhydrous (or almost so). The method uses the word 'contents' for the solid remaining: 'residue' is also accepted here. Some candidates omitted the second heating so could not access the first or second mark. However, many candidates gained the marks for using the stipulated mass of **FA 4**, showing the precision of the balance used, and calculating the masses of **FA 4** and water lost correctly. Most candidates gained at least 1 of the 2 marks for accuracy.
- (b)(i) This part was answered correctly by most candidates.
- (ii) Few candidates gained this mark as the common response was to suggest that all water had been removed. However, this was covered by the 'anhydrous **FA 4**' given in the question so a further assumption needed to be suggested. Of the candidates who gained the mark the more popular answer was that the mass loss was **only** due to water.

Question 3

Candidates tended to score less well in this question. Although many of the tests were similar to those set in previous papers, the format differed for some parts: a calculation here is unusual. Candidates should be informed that indication of a change requires both the appearance before and after a test is carried out.

- (a)(i) Most candidates correctly selected the use of (aqueous) silver nitrate and (aqueous) ammonia. Some of the candidates then appeared to describe what they expected to see so may not have carried out the test. Better candidates noted the discrepancy in the result: the white ppt did not fully dissolve in aqueous ammonia.
- (ii) The white ppt on adding dilute sulfuric acid was noted by most candidates though not all identified the cation as Ba^{2+} . While a majority of candidates wrote a correct equation fewer wrote an ionic equation or included correct state symbols.
- (b) The majority of candidates gained the mark for calculating the M_r of their metal chloride. The second part of the question discriminated well between candidates: with many candidates struggling to calculate the moles of water of crystallisation successfully. There were several valid ways of calculating the value of x in $\cdot x\text{H}_2\text{O}$ and all were seen.
- (c)(i) Only a minority of candidates described the colour and state of **FA 5** before they started heating. Some appeared to heat the solid too strongly initially so did not record the condensation in the cooler part of the hard-glass test-tube. However, most candidates gained at least 1 of the 2 marks available.

- (ii) Almost all candidates noted the effervescence on reacting **FA 5** with dilute sulfuric acid but fewer commented on the rate of bubbling. Some candidates ignored the instruction at the start of the question to record 'the formation of any gas and its identification by a suitable test'. A few claimed the gas turned red litmus blue which is an impossibility. Those carrying out a test with limewater should ensure they use the correct terminology for a positive result: 'gives a white ppt.' is the optimal response. While some candidates noted a colourless solution was formed, very few noted the decrease in temperature of the mixture.
- (iii) Candidates had little problem with this test and almost all gained the mark.
- (iv) The majority of candidates successfully identified **FA 5**.

CHEMISTRY

<p>Paper 9701/41 A Level Structured Questions</p>

Key messages

- For a significant number of scripts, candidates were unable to attempt parts of some of the questions, possibly due to the current pandemic situation. Those candidates whose papers were particularly good deserve to be highly commended.
- Where a question asks for a comparison, candidates should always make it very clear which of the two substances they are describing in each part of their answer. An example of such a question on this paper is **3(a)(ii)**. The use of the word 'it' should be strongly discouraged in such answers.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- Candidates should never cross out an answer and attempt to overwrite with a new answer. This introduces doubt as to whether a correct answer is being presented or not. If a candidate has to cross out an answer and has no space to continue, they can use a blank page in the exam paper.

General comments

Candidates had the opportunity to show the facts that they have learnt and the skills that they are able to perform. There were many good scripts and a significant number of excellent ones.

Most candidates were able to work through to the end of the paper, suggesting that they had sufficient time.

Candidates should be discouraged from using non-standard abbreviations as without explanation these cannot be awarded credit.

Comments on specific questions

Question 1

- (a) This was answered well. Some candidates mistakenly discussed the solubility, instead of the thermal stability, of the Group 2 hydroxides.
- (b)(i) This was often answered well, however, many candidates omitted state symbols.
- (ii) Two marks were often scored; it is pleasing to see how answers to such calculations have improved over recent years.
- (iii) Correct answers were rare. Some candidates misunderstood the question and compared the solubility of $\text{Ca}(\text{OH})_2$ in water with the solubility of NaOH in water.

Question 2

- (a) This was answered very well. The splitting of d-orbitals, the absorption of photons of visible light, the excitation of electrons and the observed colour being complementary to the colour absorbed were all described more clearly than in previous years.
- (b) (i) The award of four marks was rare. Many answers were seen that scored three marks – for 3D shape, for all formulae correct and for correct *cis* and *trans* in R and S. The need to give correct charges on the complexes was seldom recognised.
- (ii) This mark was rarely awarded. Most answers included a statement about symmetry. The *cis* isomer also has a plane of symmetry. The key idea is that the dipoles cancel out in the *trans* complex.
- (c) (i) Generally answered well but many candidates lost marks here. It was not always stated clearly that two dative bonds are formed.
- (ii) Many candidates found this surprisingly difficult. Many different incorrect answers were seen, including those in which the N atom was protonated, giving the conjugate *acid* of picolinic acid.
- (iii) Some answers showed a lack of understanding of ‘geometry’.
- (d) (i) The mark was usually scored. An often-seen wrong answer for chromium in ammonium dichromate was +7.
- (ii) This mark was scored by a minority of candidates. Since chromium is reduced another element is oxidised. This must be nitrogen so the ‘inert colourless gas’ is N₂. After making this deduction the equation is easier to balance. Many equations were seen containing ammonia, however, this would involve no change in the oxidation number of nitrogen.

Question 3

- (a) (i) Many candidates answered this well.
- (ii) This was found to be straightforward by the majority of candidates.
- (b) (i) A significant number of candidates referred to the standard hydrogen electrode and therefore gave the definition for standard electrode potential, not standard cell potential.
- (ii) Many candidates answered this well. Some candidates are still including a cell symbol in their diagram. This cannot work unless a potentiometer circuit is also drawn. Common errors were electrodes or salt bridges that did not reach the solutions and iron electrodes.
- (c) (i) Candidates who understood the reaction could usually write the two equations and score two marks. Some unbalanced equations and equations with wrong ionic charges were seen.
- (ii) Some excellent answers were seen. Marks were lost by candidates who did not either:
- comment on the relative sizes of these E^\ominus values or
 - calculate the E^\ominus_{cell} values, with correct signs.
- (d) (i) The importance of the repulsion between two negatively charged reactant ions was appreciated by less than half of candidates.
- (ii) Correctly balanced equations were rare. The six electrons on the right were often missing.
- (e) (i) Marks were low here. For the upper product CH(OH)₂CH(OH)₂ was a common wrong answer as was ‘electrophilic substitution’ for the lower type of reaction. For the lower product many esters were seen that were ambiguous – they could have been methyl esters, therefore incorrect, or ethanoate esters, therefore correct. In such cases it is very helpful to see the ester linkage fully displayed.

- (ii) Very few correct answers were seen here. A lot of candidates submitted a single covalently bonded molecule or ion rather than an ion pair.

Question 4

- (a) (i) and (a) (ii) Candidates who had prepared well scored highly on these two questions. Special care was required when completing the ionic equations, ensuring that the formulae and charges of the copper-containing products was correct. Some candidates interpreted 'state' in the questions as 'oxidation state', which was incorrect.
- (b) The award of two marks was very rare.

Question 5

- (a) Many very imprecise answers were seen. Some answers stated making a single time measurement e.g. the time to collect 100 cm^3 of gas. To 'follow' a rate, a sequence of measurements at different times must be taken.
- (b) (i) This mark was often scored. Some candidates lost the mark because they did not specify what was halving.
- (ii) This discriminated well. All possible answers (increase, decrease and no change) were seen in approximately equal numbers.
- (iii) This discriminated well.
- (c) (i) It was common to see a candidate had calculated the average rate 'over' the first 200 secs. The question asks for the rate 'at' 200 secs, so a tangent to the graph should be drawn. The units were usually given correctly.
- (ii) Most candidates used their answers to (c)(i) to score this mark.
- (d) This discriminated well. The need for the first step to involve one O_3 and only one NO_2 was not always appreciated. Many excellent answers were seen.

Question 6

- (a) This was a difficult question. The importance of electron donating groups, such as C_2H_5 in ethanol, and electron withdrawing groups, such as the $\text{C}=\text{O}$ group in the two acids, to the strength of the $\text{O}-\text{H}$ bond was not appreciated by all candidates. Reference to 'the electronegative oxygen atom' did not score as all four compounds contain at least one oxygen atom. Many candidates thought ethanol to be more acidic than water.
- (b) (i) The award of three marks was very rare. Many reagents were seen that would not react with any of three acids in the question.
- (ii) This discriminated well.
- (iii) This discriminated well. The clearest way to show the effect of adding D_2O is the equation $\text{HCO}_2\text{H} + \text{D}_2\text{O} \rightarrow \text{HCO}_2\text{D} + \text{HDO}$. It was also necessary to specify that the peak for the OH proton disappears.
- (c) (i) This was answered well. Some candidates gave a nitrated product for compound H. This would not work.
- (ii) Answers here were disappointing. The reagents were not well done, the conditions even less so. Some candidates confused step 2 with step 3. Some excellent answers were seen however.
- (d) This was answered well.

Question 7

- (a) (i) This was answered well. Some candidates nitrated the benzene ring before oxidising the side chain. This would not work as methyl benzene nitrates to form 2- or 4-nitromethylbenzene, not 3-nitromethylbenzene.
- (ii) Although most candidates knew the reagents needed once again the necessary conditions were less well known.
- (b) (i) This question was found to be very difficult. It was hoped that candidates would use the molecular formula to deduce that the two isomers are the condensation products of reactions between two serine molecules. Many answers were seen that did not match the molecular formula in the question.
- (ii) This mark was rarely awarded.
- (c) (i) This was answered well.
- (ii) This discriminated well. A comparatively small number of candidates did not appreciate the importance of the hydrolysis of the amide bonds. Full credit was given for neutral species, but it was good to see that some candidates appreciated that the -NH_2 groups are protonated under acidic conditions.
- (iii) This discriminated well. Some answers stated that glutathione will hydrogen bond 'in water'. This is not the same as hydrogen bonding 'with water', so 'in water' did not score.

Question 8

- (a) (i) This was found to be very difficult. The mark for the identity of the two organic species was very rarely awarded. Very few candidates could explain why the pH changes slowly when OH^- ions are being added.
- (ii) The mark was awarded to a minority of candidates. Very few candidates stated that the salt being formed, sodium ethanoate, is basic.
- (b) Most candidates could calculate the number of moles of MnO_4^- in the titration. Far fewer candidates were able to use the 5:3 ratio correctly.

Question 9

- (a) This discriminated well. It was found to be very difficult by many candidates. Only a minority of candidates used the formulae of A and B to deduce that the reaction of A with $\text{Br}_2(\text{aq})$ is an electrophilic substitution reaction and then went on to conclude correctly that A must be a phenol. A surprisingly large number of candidates gave the structure of F as an ester formed by propan-1-ol, not propan-2-ol as in the question.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

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

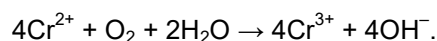
General comments

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

Comments on specific questions

Question 1

- (a) (i) Many candidates answered this well. Common errors were $3d^14s^2$ and $3d^54s^1$.
- (ii) Most candidates gave a correct definition for a complex ion.
- (b) This question was highly discriminating. The formula of the chromium species formed with NaOH(aq) and with an excess of $\text{NH}_3\text{(aq)}$ were well known. Many candidates gained at least one mark for the type of reaction. Only a few candidates gave correct species for $(\text{Cr}(\text{H}_2\text{O})_6)^{3+}\text{(aq)}$ and $\text{H}_2\text{O}_2\text{(aq)}$ reaction and identification of redox was quite rare. Common errors were
- $\text{Cr}(\text{OH})_2$ for the NaOH(aq) reaction
 - Cr_2O_3 and ligand substitution for H_2O_2 reaction,
 - $(\text{Cr}(\text{NH}_3)_4(\text{H}_2\text{O})_2)^{3+}$ for the $\text{NH}_3\text{(aq)}$ reaction.
- (c) This was generally well answered. Many candidates stated that ΔE would change, however often omitted that a different wavelength would be absorbed. Some also omitted 'd orbital' when describing different energy gaps.
- (d) (i) Many good answers were seen. Some candidates considered only one of the ligands.
- (ii) Candidates often gave the correct answer here.
- (iii) This question discriminated well. Many correct answers were seen. Metallic and ionic were common errors.
- (e) (i) This was generally well answered. Over half of the candidates gave a suitable equation. Common errors were incorrect balancing the equation or use of OH^- in an equation, for example



- (ii) This answer was usually correct.

Question 2

- (a) Most candidates had prepared well for this question. Many gave a correct statement regarding increasing stability and increasing cation radius down Group 2. Decreasing polarisation of the nitrate anion, was less frequently seen. Some candidates suggested there was polarisation of the cation, or that polarisation was caused by the anion.
- (b) (i) This was generally answered well. A common error was the equation $\text{Pb}(\text{NO}_3)_2 \rightarrow \text{Pb} + 2\text{NO}_2 + \text{O}_2$.
- (ii) This question was often found difficult, some candidates did not state clearly that Pb^{2+} has a smaller ionic radius than Ba^{2+} . Use of atomic radii was a common error.
- (c) (i) This proved difficult for some candidates. Answers with CO and O₂ were often not balanced, and a common error was answers with CO₂ and O₂ for example $\text{BaC}_2\text{O}_4 \longrightarrow \text{BaO} + \text{CO}_2 + \frac{1}{2}\text{O}_2$.
- (ii) This question discriminated well. Weaker responses omitted to calculate the initial moles of KMnO₄. Some others omitted or used incorrect ratios for M2 and M3. The marking point M4 was frequently awarded for error carried forward. Some common errors were:
- 12.5 (incorrect ratio for M3: 2/5 used not 5/2) for 3 marks
 - 31.4 (M3 being omitted) for 3 marks
 - 34.2 (initial moles of KMnO₄ and M3 being omitted) for 2 marks.
- (d) Candidates performed well on this question. A common error was 13.1 (no × 2).

Question 3

- (a) (i) This was generally well known. Some candidates gave the definition of the standard cell potential or did not quote the standard conditions.
- (ii) This was generally well answered. CBA was the most common error seen.
- (iii) This was answered well. It is recommended that candidates use the form of three dimensional (3D) bonds shown in the syllabus – wedged and dashed bonds. The errors most commonly seen were:
- diagrams without any 3-D bonds.
 - diagrams in which 3-D bonds were drawn but where the complex could not be octahedral.
- (b) (i) This answer was usually correct.
- (ii) Candidates found this difficult. Explanations frequently omitted (Ag^+) falls or do not relate to the equilibrium $\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}/E$ for (Ag^+/Ag) .
- (c) (i) This was generally well known. Omission of the lone pair was a common error.
- (ii) This proved difficult for many candidates. Common errors included the inclusion of (AgBr) in their expression and putting ionic charges outside the final set of square brackets.
- (iii) Candidates found this difficult. Common incorrect answers seen were calculations of $K_{\text{stab}}/K_{\text{sp}}$ and of $K_{\text{sp}}/K_{\text{stab}}$.
- (d) This was often answered well.

Question 4

- (a) (i) This was generally well answered. Common errors were
- omitting 1 mole with ionic compound formed, and
 - starting from 1 mole of gaseous ions.
- (ii) This question discriminated well. Many correct answers were seen. Common errors were the omission of the multiplier ($\times 2$) and incorrect signs in their calculation.
- (iii) Candidates found this difficult. Many identified this was due to the difference in the cationic radii. Only more able candidates linked this to the attraction of the water molecules.
- (b) (i) Candidates did not perform well on this question. Oxygen and calcium were the common errors.
- (ii) This question was usually fully credited. The omission of $\times 2$ was a common error.
- (c) (i) Many candidates gave the correct answer.
- (ii) Candidates performed well on this question.
- (iii) This was found to be difficult. The best answers related the Gibbs equation to the mathematical expression $y = mx + c$ and drew a straight line with a negative gradient passing through the x-axis at $T = 100^\circ\text{C}$. Most candidates started their sketch on the y-axis in the positive region (bullet 1).
- Common errors were
- a line passing through the x-axis around 50 or 75°C
 - a line with a positive gradient.
- (d) Many candidates found this question challenging. M2 was conditional on M1.

Question 5

- (a) Many candidates found this challenging and discriminated well. Answers were often not sufficiently detailed. For each substance a clear statement linked to the ability of the lone pair of electrons on the N to accept a proton was required. Most candidates recognised that the alkyl group is an electron donating group and the lone pair on the N of NH_2 is delocalised into the benzene ring.
- Common errors included:
- omitting the 'lone pair' in their explanation
 - 4-nitrophenylamine was more basic than phenylamine
 - The NO_2 group was an electron donating group.
- (b) (i) Many diagrams were well drawn. The most common error was the positive charge on the terminal nitrogen for the diazonium salt $\text{R-N}\equiv\text{N}^+$.
- (ii) This was found to be difficult. It was common to see the correct answer for step 1, however only the more able candidates identified 1-naphthol or omitted alkaline conditions for step 2. Many candidates suggested phenol or gave the molecular formulae for 1-naphthol.
- (c) (i) Many candidates gave an unambiguous name for **G**.
- (ii) Candidates performed well on this question. A common error was the initial oxidation of CH_3 to COOH .
- (iii) This was answered well. The most common errors were
- use of HNO_2 instead of HNO_3 or omission of 'concentrated' for the nitration
 - use of $\text{Br}_2(\text{aq})$ for the bromination
 - omission of heat for the oxidation.

Question 6

- (a) This question discriminated well. Many candidates were able to identify the four structural isomers of C_8H_{10} that contain a benzene ring. Some were unable to correctly assign their structure to the number of peaks observed in the carbon-13 NMR spectrum. Other common errors were drawing non-skeletal formulae for the isomers or omitting a benzene ring in their structures.
- (b) (i) This was generally well answered.
- (ii) Most candidates correctly identified **W**, however structure **X** was often incorrect.
- (iii) This was well known. Common errors were $HCl(aq)$ and $Cl_2 + AlCl_3$.
- (iv) Many good answers were seen; however, some errors frequently seen were:
- drawing of the partly delocalised ring which should **not** include the sp^3 carbon
 - position of the positive charge on the intermediate – this should be inside the partially delocalised ring system rather than on the sp^3 carbon
 - drawing of the curly arrow as the C–H bond breaks – this should start on or near the C–H bond, not on the hydrogen atom.
 - omission of H^+ at the end of the mechanism.

Question 7

- (a) (i) This definition was not well known. Some candidates omitted ‘concentration’ or did not link to the rate equation.
- (ii) Many candidates were able to provide concise and correct answer. Some excellent mathematically based answers were seen.
- (iii) This was usually answered well. Some candidates did not include k .
- (iv) The majority of candidates were able to calculate k . Stating the units are $dm^6 mol^{-2} s^{-1}$ was a common error.
- (b) (i) This question was found to be difficult by most candidates. Phenylamine was a common incorrect answer.
- (ii) This question discriminated well. Many candidates correctly calculated the gradient of the tangent at 100 s. A common error was 1.15×10^{-4} (no tangent and simply dividing ($C_6H_5N_2^+$) by 100 s).
- (c) Many candidates found this question challenging. Some made errors in one or both of the elements of this question.

Question 8

- (a) This question discriminated well. Many candidates gave the correct order for the relative rate of hydrolysis. Some gave well-reasoned explanations often based on acyl chlorides and aryl chlorides. Other answers lacked sufficient detail in their explanation.
- (b) This question was generally answered well. Methanol and propanoic acid were commonly identified. The other fragment was found more difficult.
- (c) (i) This was found to be difficult. Common incorrect errors were pentanoic acid, 2-methylbutanoic acid and 2,2-dimethylpropanoic acid.
- (ii) Many candidates found this question challenging. The environment of the proton and splitting pattern for each peak were often correctly assigned. The number of 1H atoms responsible for each peak was found more difficult and normally did not equal nine in total. Another common error was the use of ‘duplet’ instead of ‘doublet’.

CHEMISTRY

<p>Paper 9701/43 A Level Structured Questions</p>

Key messages

- For a significant number of scripts, candidates were unable to attempt parts of some of the questions, possibly due to the current pandemic situation. Those candidates whose papers were particularly good deserve to be highly commended.
- Where a question asks for a comparison, candidates should always make it very clear which of the two substances they are describing in each part of their answer. An example of such a question on this paper is **3(a)(ii)**. The use of the word 'it' should be strongly discouraged in such answers.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- Candidates should never cross out an answer and attempt to overwrite with a new answer. This introduces doubt as to whether a correct answer is being presented or not. If a candidate has to cross out an answer and has no space to continue, they can use a blank page in the exam paper.

General comments

Candidates had the opportunity to show the facts that they have learnt and the skills that they are able to perform. There were many good scripts and a significant number of excellent ones.

Most candidates were able to work through to the end of the paper, suggesting that they had sufficient time.

Candidates should be discouraged from using non-standard abbreviations as without explanation these cannot be awarded credit.

Comments on specific questions

Question 1

- (a) This was answered well. Some candidates mistakenly discussed the solubility, instead of the thermal stability, of the Group 2 hydroxides.
- (b)(i) This was often answered well, however, many candidates omitted state symbols.
- (ii) Two marks were often scored; it is pleasing to see how answers to such calculations have improved over recent years.
- (iii) Correct answers were rare. Some candidates misunderstood the question and compared the solubility of Ca(OH)_2 in water with the solubility of NaOH in water.

Question 2

- (a) This was answered very well. The splitting of d-orbitals, the absorption of photons of visible light, the excitation of electrons and the observed colour being complementary to the colour absorbed were all described more clearly than in previous years.
- (b) (i) The award of four marks was rare. Many answers were seen that scored three marks – for 3D shape, for all formulae correct and for correct *cis* and *trans* in R and S. The need to give correct charges on the complexes was seldom recognised.
- (ii) This mark was rarely awarded. Most answers included a statement about symmetry. The *cis* isomer also has a plane of symmetry. The key idea is that the dipoles cancel out in the *trans* complex.
- (c) (i) Generally answered well but many candidates lost marks here. It was not always stated clearly that two dative bonds are formed.
- (ii) Many candidates found this surprisingly difficult. Many different incorrect answers were seen, including those in which the N atom was protonated, giving the conjugate *acid* of picolinic acid.
- (iii) Some answers showed a lack of understanding of ‘geometry’.
- (d) (i) The mark was usually scored. An often-seen wrong answer for chromium in ammonium dichromate was +7.
- (ii) This mark was scored by a minority of candidates. Since chromium is reduced another element is oxidised. This must be nitrogen so the ‘inert colourless gas’ is N₂. After making this deduction the equation is easier to balance. Many equations were seen containing ammonia, however, this would involve no change in the oxidation number of nitrogen.

Question 3

- (a) (i) Many candidates answered this well.
- (ii) This was found to be straightforward by the majority of candidates.
- (b) (i) A significant number of candidates referred to the standard hydrogen electrode and therefore gave the definition for standard electrode potential, not standard cell potential.
- (ii) Many candidates answered this well. Some candidates are still including a cell symbol in their diagram. This cannot work unless a potentiometer circuit is also drawn. Common errors were electrodes or salt bridges that did not reach the solutions and iron electrodes.
- (c) (i) Candidates who understood the reaction could usually write the two equations and score two marks. Some unbalanced equations and equations with wrong ionic charges were seen.
- (ii) Some excellent answers were seen. Marks were lost by candidates who did not either:
- comment on the relative sizes of these E^\ominus values or
 - calculate the E^\ominus_{cell} values, with correct signs.
- (d) (i) The importance of the repulsion between two negatively charged reactant ions was appreciated by less than half of candidates.
- (ii) Correctly balanced equations were rare. The six electrons on the right were often missing.
- (e) (i) Marks were low here. For the upper product CH(OH)₂CH(OH)₂ was a common wrong answer as was ‘electrophilic substitution’ for the lower type of reaction. For the lower product many esters were seen that were ambiguous – they could have been methyl esters, therefore incorrect, or ethanoate esters, therefore correct. In such cases it is very helpful to see the ester linkage fully displayed.

- (ii) Very few correct answers were seen here. A lot of candidates submitted a single covalently bonded molecule or ion rather than an ion pair.

Question 4

- (a) (i) and (a) (ii) Candidates who had prepared well scored highly on these two questions. Special care was required when completing the ionic equations, ensuring that the formulae and charges of the copper-containing products was correct. Some candidates interpreted 'state' in the questions as 'oxidation state', which was incorrect.
- (b) The award of two marks was very rare.

Question 5

- (a) Many very imprecise answers were seen. Some answers stated making a single time measurement e.g. the time to collect 100 cm^3 of gas. To 'follow' a rate, a sequence of measurements at different times must be taken.
- (b) (i) This mark was often scored. Some candidates lost the mark because they did not specify what was halving.
- (ii) This discriminated well. All possible answers (increase, decrease and no change) were seen in approximately equal numbers.
- (iii) This discriminated well.
- (c) (i) It was common to see a candidate had calculated the average rate 'over' the first 200 secs. The question asks for the rate 'at' 200 secs, so a tangent to the graph should be drawn. The units were usually given correctly.
- (ii) Most candidates used their answers to (c)(i) to score this mark.
- (d) This discriminated well. The need for the first step to involve one O_3 and only one NO_2 was not always appreciated. Many excellent answers were seen.

Question 6

- (a) This was a difficult question. The importance of electron donating groups, such as C_2H_5 in ethanol, and electron withdrawing groups, such as the $\text{C}=\text{O}$ group in the two acids, to the strength of the $\text{O}-\text{H}$ bond was not appreciated by all candidates. Reference to 'the electronegative oxygen atom' did not score as all four compounds contain at least one oxygen atom. Many candidates thought ethanol to be more acidic than water.
- (b) (i) The award of three marks was very rare. Many reagents were seen that would not react with any of three acids in the question.
- (ii) This discriminated well.
- (iii) This discriminated well. The clearest way to show the effect of adding D_2O is the equation $\text{HCO}_2\text{H} + \text{D}_2\text{O} \rightarrow \text{HCO}_2\text{D} + \text{HDO}$. It was also necessary to specify that the peak for the OH proton disappears.
- (c) (i) This was answered well. Some candidates gave a nitrated product for compound H. This would not work.
- (ii) Answers here were disappointing. The reagents were not well done, the conditions even less so. Some candidates confused step 2 with step 3. Some excellent answers were seen however.
- (d) This was answered well.

Question 7

- (a) (i) This was answered well. Some candidates nitrated the benzene ring before oxidising the side chain. This would not work as methyl benzene nitrates to form 2- or 4-nitromethylbenzene, not 3-nitromethylbenzene.
- (ii) Although most candidates knew the reagents needed once again the necessary conditions were less well known.
- (b) (i) This question was found to be very difficult. It was hoped that candidates would use the molecular formula to deduce that the two isomers are the condensation products of reactions between two serine molecules. Many answers were seen that did not match the molecular formula in the question.
- (ii) This mark was rarely awarded.
- (c) (i) This was answered well.
- (ii) This discriminated well. A comparatively small number of candidates did not appreciate the importance of the hydrolysis of the amide bonds. Full credit was given for neutral species, but it was good to see that some candidates appreciated that the -NH_2 groups are protonated under acidic conditions.
- (iii) This discriminated well. Some answers stated that glutathione will hydrogen bond 'in water'. This is not the same as hydrogen bonding 'with water', so 'in water' did not score.

Question 8

- (a) (i) This was found to be very difficult. The mark for the identity of the two organic species was very rarely awarded. Very few candidates could explain why the pH changes slowly when OH^- ions are being added.
- (ii) The mark was awarded to a minority of candidates. Very few candidates stated that the salt being formed, sodium ethanoate, is basic.
- (b) Most candidates could calculate the number of moles of MnO_4^- in the titration. Far fewer candidates were able to use the 5:3 ratio correctly.

Question 9

- (a) This discriminated well. It was found to be very difficult by many candidates. Only a minority of candidates used the formulae of A and B to deduce that the reaction of A with $\text{Br}_2(\text{aq})$ is an electrophilic substitution reaction and then went on to conclude correctly that A must be a phenol. A surprisingly large number of candidates gave the structure of F as an ester formed by propan-1-ol, not propan-2-ol as in the question.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

General comments

The majority of scripts were complete. The number of 'no response' answers were few.

Some candidates need to improve the legibility of their answers.

The tendency to 'over-answer' in the form of lists remains popular and often distracts from an otherwise reasonable answer. For example, **Question 1(b)** asked for two answers and gave two lines, numbered 1 and 2. A significant number of candidates provided more, even labelling them 3 etc. Such over-answering can often provide responses that negate prior correct ones.

Candidates should be encouraged to look for command words (explain, state, describe etc.) and to properly respond to them. For example, **Question 1(g)** 'The metal oxide should remain the same mass with no chemical changes' is true but failed to 'demonstrate' that the metal oxide has not been affected by the reaction, which would involve weighing.

Comments on specific questions

Question 1

- (a) (i) A very straightforward question that was mostly answered well. An answer of 'rate' was not uncommon which revealed a lack of understanding of variables.
- (ii) The dependent variable is that which varies according to change in the independent variable so that means a measurable quantity. Common responses based on some sort of rate/rate expression are derived from measuring a dependent variable such as gas volume.
- (b) As is usual, there are a number of variables that need controlling so as not to interfere with the variables being changed. Some of the variables given, such as pH, nature of the catalyst or time, were not factors in this experiment.
- (c) Diagrams are often difficult, especially if the candidates' practical experience is minimal. Whilst there is no specific credit for 'neat' diagrams, poorly drawn diagrams may detract from the whole, although considerable latitude in drawing was allowed. Most candidates had a reaction vessel connected to a gas collection device. The element missing was a device keeping the two reagents apart prior to mixing and reaction, the most suitable being a small tube containing the catalyst. A number of candidates included direct Bunsen heating, this would interfere with the experiment. A (unnecessary) thermostatically controlled water bath was credited.
- (d) (i) This question proved more difficult than expected, probably due to candidates not recognising the question was about **initial** rate. Instead of measuring increasing gas volumes with time (which could be plotted), the majority of answers were about a volume at a time (an average rate situation) or time when gas evolution ceased (overall rate).
- (ii) The popular incorrect response was a division of gas volume by the time taken, which, unfortunately, does not give an initial rate. Looser answers such as 'The more oxygen the higher the rate' were also seen, as was just an oxygen volume. The key point here was the initial rate. Unfortunately, a number who correctly answered that a volume/time plot was required with a gradient calculation did not specify that the tangent/gradient had to be at time = 0.

- (e) Most candidates scored here with a simple 'Repeat the experiments', some incorrect responses centred around controlling variables.
- (f) Following the mass of the reaction in its container along with time was not the most popular response. However, most suggestions were impractical such as measuring the volume of water produced or 'waiting until the solution is entirely water with no oxygen in it'. Many candidates seemed unaware that gases have a mass. Most responses did not take a critical view of what is or is not practically possible.
- (g) A number of candidates responded by essentially restating the question with responses like 'look at the catalyst to see if it had changed'. The essence of a heterogeneous catalyst is that it is unchanged by the reaction which can be shown by no difference in mass after the experiment. Many candidates recognised this but referred to mass after without isolating or drying it, or stated 'compare the masses' without specifying what that comparison should be. Also, after isolation, candidates who suggested an alternative method which involved reusing the catalyst in the same reaction, frequently struggled to gain 2 marks. This was due to: M1 not using new hydrogen peroxide solution; M2 not mentioning that the resulting gas volumes/rate would be the same.
- (h) Most candidates realised that hydrogen peroxide decomposes slowly at room temperature, so oxygen (and pressure) must be released to prevent damage. Some candidates stated the hole was to let oxygen enter or had a role in an equilibrium situation.

Question 2

- (a) (i) Virtually all candidates were successful here.
- (ii) Many candidates struggled with this question. A two decimal place balance will have divisions of 0.01 which means the mass could be read to ± 0.005 . As weighing by difference features two mass readings then the error would be 2×0.005 . This calculation had to be shown as the question specified 'show your working'. Many candidates had an error of 0.01 without showing from where it had come, and some had an error of 0.02.
- (iii) One of the features of this exam is to highlight experience gained from practical work. This question requires a practical solution to a problem that arises during the making of a standard solution. This proved surprisingly difficult for candidates. Reweighing the weighing boat after addition of KMnO_4 to the beaker or rinsing off the residue into the beaker is sufficient. Extended, complex answers frequently contained contradictions for this response. Correct responses needed to maintain a quantitative transference, 'scrapping off with a spatula' is not a creditable response. Better answers involved using the beaker directly.
- (iv) Candidates needed to address the two significant features involved in making a volumetric solution, namely the quantitative transfer of the solute into the solution and ensuring solution and homogeneity. Popular responses which were not mark worthy were suggestions about using a funnel for the transfer and using a burette or measuring cylinder for the 50 cm^3 water. Some candidates confused weighing boat and beaker in **parts (a)(iii) and (iv)**.
- (b) (i) The preparation of a burette for use is a standard procedure for which all practical candidates should score. Many merely rinsed the burette with water followed sometimes by propanone. It was encouraging to see some candidates referred to filling the burette tip before titrating.
- (ii) The procedural use of a burette in a titration is a well-known practical technique with which the candidates should be familiar. Many, not realising that titrations need to be performed dropwise at the end, suggested doing the whole titration slowly, waiting for a colour change, repeating the titration or even adding an indicator.
- (c) (i) This question caused problems for many candidates. Most candidates recognised that using a measuring cylinder in step 2 is inappropriate as it cannot measure 25.00 cm^3 to two decimal places. However, the consequences of that were not well stated. This does not necessarily lead to an inaccurate titre. The effect of using a measuring cylinder is that the volume of the solution measured by the measuring cylinder is subject to such variation that a 25.00 cm^3 sample cannot be consistently reproduced leading to inconsistencies in titre values – not inaccurate titre values.

- (ii) The substitution of a pipette for a measuring cylinder was recognised by most candidates.
- (d)(i) These tables of titration results should be very familiar to candidates where the expectation is for the burette to be read to two decimal places and so reported as in the tables. Many values were erroneously quoted to only one decimal place e.g. 17.1 instead of 17.10. As there was no titration 3 in set B some candidates provided one. Normally, only titres within 0.1 cm^3 would be combined to produce an average titre as was the case in set A (17.10 and 17.05). This was not the case in set B where the candidates were obliged to average the two closest titres since that was all that was available. In set A some candidates included 17.30 in the average and in set B some candidates included the rough. The question specifically required the averages to be quoted to one decimal place which most did although there were a significant number to two or more decimal places.
- (ii) This question and the next two are complex multistage calculations. The four stages in this calculation were:
1. from the titre to moles of manganate(VII);
 2. moles Fe^{2+} from the stoichiometric ratio;
 3. mass from the M_r of 55.8 then
 4. scaling up from 25 to 100 cm^3 .
- Most candidates struggled with this although missing just one stage could gain one mark. The most common omission was stage 4 which led to an answer of 0.243 g. A few candidates used the wrong titre (17.1). Few candidates gained full marks here.
- (iii) This required the same four stages as the previous question with a different fourth stage requiring scaling up from 25 to 250 cm^3 which gave 0.0954 g. Again, few candidates were successful here.
- (iv) This final calculation required clear thinking on the part of the candidate. Firstly, the candidate had to appreciate that 2(d)(ii) determines the Fe^{2+} and Fe^{3+} together. 2(d)(iii) determines the Fe^{2+} alone. The difference between these can then be determined. However, the values in 2(d)(ii) and 2(d)(iii) were in different volumes so could not be directly subtracted. These masses needed scaling to be within the same volume. Most candidates did not do that and instead incorrectly used the masses directly.
- (v) The reason titration 3 could not be carried out was due to a lack of reduced solution, so the simple answer is 'reduce more than 100 cm^3 of the $\text{Fe}^{2+}/\text{Fe}^{3+}$ solution in step 6'. Popular responses included 'Making more of the $\text{Fe}^{2+}/\text{Fe}^{3+}$ solution' which is not necessary as there is just enough and 'More Fe^{2+} & Fe^{3+} solution' was insufficient as this could be the original solution not the 100 cm^3 in Step 6. In the same way having more manganate(VII) solution is not necessary. There were often uninvited list answers in Question 2(d)(v), which often contained contradictions.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus.

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

Candidates need to be aware that volumetric apparatus (burettes, pipettes, volumetric flasks) should be used to maintain the degree of accuracy required

General comments

In general, candidates seemed well-prepared for this exam.

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

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

Good answers are characterised by succinct answers. Often, the more a candidate wrote, the more likely they were to negate a correct response.

Comments on specific questions

Question 1

- (a) The candidates were asked initially for a prediction and the choice was positive or negative so any response other than 'positive' or 'negative' on the prediction line would not gain credit.

The explanation was generally well-answered as most candidates appreciated that bonds are formed between MgSO_4 and H_2O in the hydration process.

Responses, particularly weaker answers, correctly predicted 'negative' but simply stated, without explanation, that this was 'because the process was exothermic'.

- (b)(i) Many candidates were unfamiliar with this typical A level thermochemistry technique and the idea of extrapolating cooling curves to determine a theoretical temperature change at the point of reaction was not universally known.
- (ii) The majority of candidates correctly suggested that the water needed to be left to equilibrate with room temperature.

(iii) Candidates were asked to outline the procedure used for experiment 1. It was expected that candidates would use 4 key steps:

- Measuring of 50 cm³ of water into a suitable container.
- Measuring the temperature of this volume of water for 150 seconds at 30 second intervals.
- Addition of the MgSO₄ at 180 seconds
- Stirring and continuation of measurement of temperature at 30 second intervals

Point 1 was well scored but many descriptions lacked sufficient detail, and many made no mention of timing.

Weaker responses assumed the requirement of the question was to make up a standard volumetric solution.

(c) (i) Most candidates knew the basis of this calculation and were able to determine the mass and therefore the volume of water in 0.0250 mol of MgSO₄•7H₂O was 3.15 cm³.

Unfortunately, some left their answer at just that and failed to appreciate that the volume of distilled water needed to make the total volume up to 50.00 cm³ was 46.85 cm³. Others rounded 46.85 to 46.9 despite the question asking for a value to the nearest 0.05 cm³.

(ii) Having been told the volume of distilled water in (c)(i) was to the nearest 0.05 cm³, the piece of apparatus had to be a volumetric one and the reasons accepted were based either upon the fact the graduations are 0.1 cm³ or that readings could be made to the nearest 0.05 cm³.

Weaker responses failed to appreciate the need for volumetric apparatus and suggested a measuring cylinder would be appropriate.

A significant number of candidates wrote 'burette or measuring cylinder' – once again a case of giving two answers where one was required and the incorrect answer nullifying the correct one.

(d) The technique of scaling up the mass of solid to increase the temperature change during dissolving was known. The other acceptable response of reducing the volume of water used to dissolve the solid was frequently seen.

(e) (i) Candidates were required to scale both energy changes from the number of moles used to 1 and to convert these values from J to kJ.

The other requirement was to apply the energy changes into a Hess's cycle.

Most candidates achieved one of these requirements.

Application of the Hess's cycle proved the more difficult of the two marking points.

(ii) Most candidates could explain that if some of the solid was undissolved then less took part in the dissolving leading to a decrease in the magnitude of the enthalpy change. Candidates were told the reaction in Experiment 1 released energy (i.e. was exothermic) so the expected correct response was 'less exothermic'. Candidates should avoid general phrases such as 'lower' as a lower value than -50 kJ mol⁻¹ would be -60 kJ mol⁻¹, rather than a less exothermic value of -40 kJ mol⁻¹.

Question 2

- (a) Most candidates knew that butanoic acid needed to be kept away from naked flames due to it being flammable.
- (b) (i) This calculation was well done with almost all candidates scoring the mark.
- (ii) The three key points of making up a standard solution from a solid was known by most candidates. These points were:
- Dissolving the solid in a suitably low volume of distilled water in a suitable container e.g. a beaker.
 - Transfer of this solution, including rinsing the beaker of distilled water into a volumetric flask.
 - Topping the solution up to the 250 cm³ mark with distilled water.
- Common errors included:
- Dissolving the solid into unsuitable containers such as a measuring cylinder or a volumetric flask.
 - Omission of rinsing (the most common error).
 - Transferring into a volumetric flask using volumetric apparatus (e.g. pipette/burette) which meant some of the solution remained within the transfer apparatus rather than ending up in the volumetric flask.
- (iii) Most candidates were able to successfully complete the table. Weaker candidates sometimes struggled to obtain a correct volume of distilled water needed.
- (c) (i) This was another table that presented little in the way of challenges.
- (ii) The plotting of the points and drawing of the line of best fit were both done very well.
- (iii) The anomalous point was identified correctly almost universally. The explanation proved more difficult. Vague responses such as 'the concentrations were incorrect' or 'there is too much base' will never gain credit. Candidates need to be specific and state 'the moles (or concentration) of base is higher than the value given in the table'
- (iv) Most candidates correctly read the pH value from the line of best fit when $y = 0.0$
- (v) This question was usually answered well. A few candidates assumed there were no units. Candidates should state the units of concentration as 'mol dm⁻³', unless otherwise advised.
- (d) This question discriminated well. stronger answers knew that a lower pK_a resulted from a higher K_a and therefore the degree of dissociation was higher so the enthalpy of dissociation is endothermic.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

General comments

The majority of scripts were complete. The number of 'no response' answers were few.

Some candidates need to improve the legibility of their answers.

The tendency to 'over-answer' in the form of lists remains popular and often distracts from an otherwise reasonable answer. For example, **Question 1(b)** asked for two answers and gave two lines, numbered 1 and 2. A significant number of candidates provided more, even labelling them 3 etc. Such over-answering can often provide responses that negate prior correct ones.

Candidates should be encouraged to look for command words (explain, state, describe etc.) and to properly respond to them. For example, **Question 1(g)** 'The metal oxide should remain the same mass with no chemical changes' is true but failed to 'demonstrate' that the metal oxide has not been affected by the reaction, which would involve weighing.

Comments on specific questions

Question 1

- (a) (i) A very straightforward question that was mostly answered well. An answer of 'rate' was not uncommon which revealed a lack of understanding of variables.
- (ii) The dependent variable is that which varies according to change in the independent variable so that means a measurable quantity. Common responses based on some sort of rate/rate expression are derived from measuring a dependent variable such as gas volume.
- (b) As is usual, there are a number of variables that need controlling so as not to interfere with the variables being changed. Some of the variables given, such as pH, nature of the catalyst or time, were not factors in this experiment.
- (c) Diagrams are often difficult, especially if the candidates' practical experience is minimal. Whilst there is no specific credit for 'neat' diagrams, poorly drawn diagrams may detract from the whole, although considerable latitude in drawing was allowed. Most candidates had a reaction vessel connected to a gas collection device. The element missing was a device keeping the two reagents apart prior to mixing and reaction, the most suitable being a small tube containing the catalyst. A number of candidates included direct Bunsen heating, this would interfere with the experiment. A (unnecessary) thermostatically controlled water bath was credited.
- (d) (i) This question proved more difficult than expected, probably due to candidates not recognising the question was about **initial** rate. Instead of measuring increasing gas volumes with time (which could be plotted), the majority of answers were about a volume at a time (an average rate situation) or time when gas evolution ceased (overall rate).
- (ii) The popular incorrect response was a division of gas volume by the time taken, which, unfortunately, does not give an initial rate. Looser answers such as 'The more oxygen the higher the rate' were also seen, as was just an oxygen volume. The key point here was the initial rate. Unfortunately, a number who correctly answered that a volume/time plot was required with a gradient calculation did not specify that the tangent/gradient had to be at time = 0.

- (e) Most candidates scored here with a simple 'Repeat the experiments', some incorrect responses centred around controlling variables.
- (f) Following the mass of the reaction in its container along with time was not the most popular response. However, most suggestions were impractical such as measuring the volume of water produced or 'waiting until the solution is entirely water with no oxygen in it'. Many candidates seemed unaware that gases have a mass. Most responses did not take a critical view of what is or is not practically possible.
- (g) A number of candidates responded by essentially restating the question with responses like 'look at the catalyst to see if it had changed'. The essence of a heterogeneous catalyst is that it is unchanged by the reaction which can be shown by no difference in mass after the experiment. Many candidates recognised this but referred to mass after without isolating or drying it, or stated 'compare the masses' without specifying what that comparison should be. Also, after isolation, candidates who suggested an alternative method which involved reusing the catalyst in the same reaction, frequently struggled to gain 2 marks. This was due to: M1 not using new hydrogen peroxide solution; M2 not mentioning that the resulting gas volumes/rate would be the same.
- (h) Most candidates realised that hydrogen peroxide decomposes slowly at room temperature, so oxygen (and pressure) must be released to prevent damage. Some candidates stated the hole was to let oxygen enter or had a role in an equilibrium situation.

Question 2

- (a) (i) Virtually all candidates were successful here.
- (ii) Many candidates struggled with this question. A two decimal place balance will have divisions of 0.01 which means the mass could be read to ± 0.005 . As weighing by difference features two mass readings then the error would be 2×0.005 . This calculation had to be shown as the question specified 'show your working'. Many candidates had an error of 0.01 without showing from where it had come, and some had an error of 0.02.
- (iii) One of the features of this exam is to highlight experience gained from practical work. This question requires a practical solution to a problem that arises during the making of a standard solution. This proved surprisingly difficult for candidates. Reweighing the weighing boat after addition of KMnO_4 to the beaker or rinsing off the residue into the beaker is sufficient. Extended, complex answers frequently contained contradictions for this response. Correct responses needed to maintain a quantitative transference, 'scrapping off with a spatula' is not a creditable response. Better answers involved using the beaker directly.
- (iv) Candidates needed to address the two significant features involved in making a volumetric solution, namely the quantitative transfer of the solute into the solution and ensuring solution and homogeneity. Popular responses which were not mark worthy were suggestions about using a funnel for the transfer and using a burette or measuring cylinder for the 50 cm^3 water. Some candidates confused weighing boat and beaker in **parts (a)(iii) and (iv)**.
- (b) (i) The preparation of a burette for use is a standard procedure for which all practical candidates should score. Many merely rinsed the burette with water followed sometimes by propanone. It was encouraging to see some candidates referred to filling the burette tip before titrating.
- (ii) The procedural use of a burette in a titration is a well-known practical technique with which the candidates should be familiar. Many, not realising that titrations need to be performed dropwise at the end, suggested doing the whole titration slowly, waiting for a colour change, repeating the titration or even adding an indicator.
- (c) (i) This question caused problems for many candidates. Most candidates recognised that using a measuring cylinder in step 2 is inappropriate as it cannot measure 25.00 cm^3 to two decimal places. However, the consequences of that were not well stated. This does not necessarily lead to an inaccurate titre. The effect of using a measuring cylinder is that the volume of the solution measured by the measuring cylinder is subject to such variation that a 25.00 cm^3 sample cannot be consistently reproduced leading to inconsistencies in titre values – not inaccurate titre values.

- (ii) The substitution of a pipette for a measuring cylinder was recognised by most candidates.
- (d)(i) These tables of titration results should be very familiar to candidates where the expectation is for the burette to be read to two decimal places and so reported as in the tables. Many values were erroneously quoted to only one decimal place e.g. 17.1 instead of 17.10. As there was no titration 3 in set B some candidates provided one. Normally, only titres within 0.1 cm^3 would be combined to produce an average titre as was the case in set A (17.10 and 17.05). This was not the case in set B where the candidates were obliged to average the two closest titres since that was all that was available. In set A some candidates included 17.30 in the average and in set B some candidates included the rough. The question specifically required the averages to be quoted to one decimal place which most did although there were a significant number to two or more decimal places.
- (ii) This question and the next two are complex multistage calculations. The four stages in this calculation were:
1. from the titre to moles of manganate(VII);
 2. moles Fe^{2+} from the stoichiometric ratio;
 3. mass from the M_r of 55.8 then
 4. scaling up from 25 to 100 cm^3 .
- Most candidates struggled with this although missing just one stage could gain one mark. The most common omission was stage 4 which led to an answer of 0.243 g. A few candidates used the wrong titre (17.1). Few candidates gained full marks here.
- (iii) This required the same four stages as the previous question with a different fourth stage requiring scaling up from 25 to 250 cm^3 which gave 0.0954 g. Again, few candidates were successful here.
- (iv) This final calculation required clear thinking on the part of the candidate. Firstly, the candidate had to appreciate that 2(d)(ii) determines the Fe^{2+} and Fe^{3+} together. 2(d)(iii) determines the Fe^{2+} alone. The difference between these can then be determined. However, the values in 2(d)(ii) and 2(d)(iii) were in different volumes so could not be directly subtracted. These masses needed scaling to be within the same volume. Most candidates did not do that and instead incorrectly used the masses directly.
- (v) The reason titration 3 could not be carried out was due to a lack of reduced solution, so the simple answer is 'reduce more than 100 cm^3 of the $\text{Fe}^{2+}/\text{Fe}^{3+}$ solution in step 6'. Popular responses included 'Making more of the $\text{Fe}^{2+}/\text{Fe}^{3+}$ solution' which is not necessary as there is just enough and 'More Fe^{2+} & Fe^{3+} solution' was insufficient as this could be the original solution not the 100 cm^3 in Step 6. In the same way having more manganate(VII) solution is not necessary. There were often uninvited list answers in Question 2(d)(v), which often contained contradictions.