CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

There were many good performances, and some really outstanding ones, seen on this paper.

Candidates found **Questions 2**, **3**, **4**, **7**, **10**, **11**, **14**, **16**, **19**, **24**, **25**, **31** and **33** to be the most accessible. Overall, ***Section B*** was answered almost as well as ***Section A***, suggesting candidates had sufficient time. Candidates found **Questions 9**, **20**, **22**, **23**, **37** and **39** to be the most challenging. The questions that were found to be particularly difficult will now be looked at in greater detail.

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Comments on specific questions

Question 9

The most commonly chosen incorrect answer was **C**. The answer **C** arises if the concentration of Ag(s) is calculated to be 0.56 mol dm^{-3}. However, silver is a solid; it does not have a concentration and should therefore be ignored when calculating the value of K_c.

Question 20

Each of the four responses were chosen by an approximately equal number of candidates. In compound 1, five of the carbon atoms in the six-membered ring are bonded to at least one hydrogen atom. A second methyl group could therefore be added at those five positions. There are two double bonds, each of which has two π electrons, making a total of four; hence the answer is **D**.

Question 22

Each of the four responses was chosen by an approximately equal number of candidates. Careful analysis will show that none of the reactions in choices **B**, **C** or **D** involve redox. The reaction that occurs in **A** is electrophilic addition, in which bromine is reduced from oxidation state zero to oxidation state -1. This is therefore a redox reaction.

Question 23

The most commonly chosen incorrect answer was **A**. Candidates choosing answer **A** may have thought that there are two different first propagation steps because the C*l*• could remove a hydrogen atom from either a CH_3 group or a CH_2 group. However, this does not take into account the two different CH_2 group environments in a pentane molecule, so there are three different first propagation steps.

Question 37

The most commonly chosen incorrect answers were **A** and **D**. This suggests most candidates knew that graph 1 is correct. Graph 2 is also correct because the Boltzmann distribution is not affected by pressure. Graph 3 is not correct as at a higher temperature, T', the peak should be at a lower proportion of molecules, not at a higher proportion of molecules.

Question 39

The most commonly chosen incorrect answer was **A**. This suggests most candidates knew that statements 1 and 2 are correct, but many also believed that statement 3 is correct. The first step in the synthesis should involve $H^+/Cr_2O_7^{2-}$ with immediate distillation, to give ethanal. Statement 3 describes the conditions as "heating under reflux", which will give ethanoic acid, not ethanal.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

There were a large number of good performances, and many truly outstanding ones, seen on this paper. Candidates' performances on ***Sections A*** and ***B*** were similar, suggesting that most candidates had sufficient time to complete the paper.

Candidates found **Questions 1**, **2**, **6**, **8**, **9**, **11**, **20**, **21**, **27**, **28**, **34**, **36** and **37** to be the most accessible. **Questions 10**, **14**, **16, 18**, **22** and **29** were more challenging for candidates.

Comments on specific questions

Question 10

The most commonly chosen incorrect answer was **B**. Answer **B** arises from (0.7 × 0.7)/0.3, but this has not converted the numbers of moles into concentration by dividing by 0.500 and it also includes the moles of ammonium chloride. Since this substance is a pure solid it does not have a concentration and so should be omitted from a K_c calculation. Since $K_c = [NH_3][HCl]$ the correct sum is (0.7/0.5) × (0.7/0.5), giving **C**.

Question 14

The most commonly chosen incorrect answers were **B** and **C**. Better performing candidates would have written out the balanced chemical equations and seen that the decomposition of 0.005 moles of calcium nitrate produces 2.5 times the volume of gas compared with 0.005 moles of calcium carbonate, under the same conditions.

Question 16

The most commonly chosen incorrect answers were **C** and **D**. **B** is correct because hydrogen is given off and a precipitate of calcium sulfate is seen. **C** is not correct because, although hydrogen is given off, magnesium sulfate is soluble. **D** is not correct because, although carbon dioxide is given off, strontium chloride is soluble.

Question 18

The most commonly chosen incorrect answer was **B**. In each case, 6×10^{-3} moles of NaOH are reacting. When the NaOH is cold, 3×10^{-3} moles of NaCl are formed. When the NaOH is hot, 5×10^{-3} moles of NaCl are formed. The difference is therefore 2×10^{-3} moles, which is 0.002 moles.

Question 22

The most commonly chosen incorrect answer was **B**. For many candidates this question rested on whether or not but-1,3-diene can be formed from the cracking of oct-1-ene. But-1,3-diene can form along with butane, when the carbon chain breaks between the fourth and fifth carbon atoms. It is possible that candidates who chose **B** were thinking about “what can be obtained by cracking a single oct-1-ene molecule”, rather than “what can be obtained by cracking oct-1-ene”.

Question 29

The most commonly chosen incorrect answer was **C**. The five isomeric esters are:
- $HCO_2(CH_2)_3CH_3$
- $HCO_2CH_2CH(CH_3)_2$
- $HCO_2CH(CH_3)CH_2CH_3$ - this compound exists as two optical isomers
- $HCO_2C(CH_3)_3$.

CHEMISTRY

Paper 9701/13
Multiple Choice

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

General comments

There were many good performances, and some really outstanding ones, seen on this paper. On average, candidates' performances on ***Section B*** were only slightly below their performances on ***Section A***, suggesting they had sufficient time to complete the paper.

Candidates found **Questions 2**, **6**, **9**, **13**, **19**, **20** and **40** to be particularly accessible. **Questions 1**, **12**, **18**, **25** and **27** were more challenging for candidates.

Comments on specific questions

Question 1

The most commonly chosen incorrect answer was **C**. Candidates had to remember that bond making is exothermic and bond breaking is endothermic and that neutralisation and combustion are exothermic.

Question 12

The most commonly chosen incorrect answers were **A** and **B**. The answer cannot be **A**, as aluminium oxide has no effect on litmus, while aluminium chloride turns litmus red. The answer cannot be **B**, as calcium oxide turns litmus blue, while calcium chloride has no effect on litmus. The answer is **D** because both phosphorous oxide and phosphorous chloride turn litmus red.

Question 18

The most commonly chosen incorrect answer was **C**. At the end of the experiments iodine will be present in experiments 3 and 6, because it has formed in redox reactions. Iodine is also present in experiments 7, 8 and 9 as it remains unreacted. Therefore, five test-tubes contain iodine and will give a purple upper layer when hexane is added.

Question 25

The most commonly chosen incorrect answer was **C**. The reaction pathway diagram describes a reaction that has a two-step mechanism. Candidates had to choose a reaction that does not have this pathway diagram.

- **B** has a two-step mechanism; the first step is heterolytic bond fission forming Br^- and a carbocation. **B** cannot be the correct answer.

- **C** has a two-step mechanism; the first step is electrophilic attack by H^+ (or $H^{\delta+}$) forming Br^- and a carbocation. **C** cannot be the correct answer.

- **D** has a two-step mechanism; the first step is electrophilic attack by H^+ forming HSO_4^- and a carbocation. **D** cannot be the correct answer.

The answer is **A**, which proceeds by an S_N2 mechanism, which only involves one step. Reaction **A** is therefore the only reaction that would not have the reaction pathway shown.

Question 27

The most commonly chosen incorrect answers were **C** and **D**.
- Propan-2-ol will react with sodium to form hydrogen but it will form iodoform with alkaline aqueous iodine, so **C** is incorrect.
- Propanone will not react with sodium to form hydrogen but it will form iodoform with alkaline aqueous iodine, so **D** is incorrect.
- Propan-1-ol will react with sodium to form hydrogen and it will not form iodoform with alkaline aqueous iodine, so **B** is correct.

CHEMISTRY

Paper 9701/21
AS Level Structured Questions

Key messages

- Candidates should be reminded to read the questions carefully and to check their answers thoroughly, especially in extended answers where more writing is required.
- They should be encouraged to use chemical terminology accurately as this ensures responses are clear.
- All working should be shown in questions where calculations are included as credit may be available for correct working even if the final answer is not correct.

General comments

Overall there was a strong performance on this paper with good recall of material shown across all questions. However, candidates should practise applying their knowledge of organic chemistry, as these questions were not always answered as well as others.

Responses were generally clear and well presented.

Comments on specific questions

Question 1

(a) Many candidates were able to answer this question well. However it was quite common for answers to be based on data found in the Periodic Table, for example giving A_r 35.5 for chlorine rather than the correct atomic number, or A_r 16 for oxygen. Some candidates confused atomic number and atomic mass. Some candidates also missed the idea of particle charge.

(b) The vast majority of candidates understood that the neutron beam would show no deviation and that the proton beam would deviate in the opposite direction to the electron beam.

(c) (i) Many good answers were seen here. Candidates were expected to account for the large jump between the sixth and seventh ionisation energy values. Contradictions between this and the identified group number could not be credited.

(ii) Stronger answers gave an explanation of the general trend here, with reference to increased nuclear charge, similar shielding, and therefore a greater attraction of the nucleus for the outer electrons.

(iii) Most candidates understood that X was in group 5 (or 15) and Y was in group 6 (or 16). Many appreciated that there was electron-pair repulsion, but were rarely able to express the location of this pair clearly to be in a p-orbital. Confusion over the terms *subshell* and *orbital* was quite common.

(iv) Although told the table showed elements in the third period, there were quite a few answers which gave the electron configuration of this group 7 element in the second period. Similarly, some candidates seemed to be using the mass number of the element to incorrectly calculate the number of electrons and hence their configuration.

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

(ii) Candidates' approach to this question was on the whole very good. Weaker candidates calculated incorrectly or did not understand that mass number should be an integer (and/or that 84.0 is not an integer).

Question 2

(a) This question was only answered well by stronger candidates. Common wrong answers included aluminium, sulfur and germanium.

(b) (i) The equation for the reaction of the oxide with HCl was quite well answered, although there was some difficulty balancing the equation. Some responses showed the chloride made as a dimer, which would not exist in aqueous solution and could not gain full credit.

(ii) This proved challenging for many candidates. Even those candidates who identified the correct metal product found it difficult to balance the equation correctly.

(c) Reference to the type of bonding with no comment about the structure was commonly seen.

(d) This question was answered well by many candidates who correctly gave $H_2\mathbf{G}O_3$ or H_2SeO_3 as their answer. However a large number of candidates incorrectly gave $H_2\mathbf{G}O_4$ or equivalent, hydroxides, H_2 and O_2 gas.

Question 3

(a) (i) Only stronger candidates answered this question well. The statement that a gas or hydrogen was produced was a common error. Many candidates thought calcium floated or caught fire, confusing their observations with group 1 metals.

(ii) A number of candidates omitted the H_2, writing an incorrect formula for calcium hydroxide, or suggesting that CaO was formed instead. Some candidates omitted the 2 to balance H_2O.

(iii) Very few candidates gave an observation, instead simply stating that the reaction would be faster.

(b) (i) Most candidates gained partial credit for giving a correctly labelled exothermic reaction profile (including the activation energy "hump"). However, candidates often incorrectly labelled the activation energy or the enthalpy change. Some candidates drew a Boltzmann distribution.

(ii) The idea that heat was needed for the reaction to occur was well known. It was common to read that heat was needed so particles have the activation energy but few answers mentioned the idea that the activation energy was high.

(iii) This question was well answered by many candidates. There was however, some confusion regarding the type of bonding within magnesium oxide.

(iv) This question was well answered by most candidates. The idea of a neutralisation reaction appeared frequently in answers; more descriptive answers however sometimes suffered from a confusion over the chemistry (e.g. production of carbon dioxide, or magnesium hydroxide).

(c) (i) The description of the change in temperature down the group was key to this question but many answers just referred to the trend in thermal stability/decomposition and therefore could not be credited.

(ii) This question was well answered by many. It was not uncommon to see $Mg(CO_3)_2$ as the formula of magnesium carbonate.

(iii) Candidates seemed confused here about the formula of calcium nitrate, or the products of decomposition of group 2 nitrates. Even when these were correct, many candidates were not able to balance the equation.

Question 4

(a) Candidates knew and understood the term *positional isomer* well.

(b) The term *chain isomer* seemed less well understood by candidates. It was common to see but-2-ene with methylpropene, or rotations or mirror images of methylpropene.

(c) Many candidates were unable to name geometrical isomers correctly. This type of question is frequently asked and it is recommended that students practise these questions more.

(d) While most candidates gained full credit for this question, some candidates gave a structure that did not match the formula. Some candidates did not draw an isomer, introducing O or other atoms, and then struggled to find a distinguishing test.

Question 5

(a) Details of the mechanism were only described accurately by a small number of candidates. Very few candidates correctly placed a lone pair on the C of the CN^- group, and curly arrows were often poorly placed. Br^- was also often not given as the answer.

(b) (i) This question was well answered by many candidates.

(ii) Knowledge that different functional groups produce different absorptions ("peaks") was common. However identification of which bond (stretch) was responsible, or the details in terms of wavenumbers describing where these differences occurred were rarely described.

(c) (i) This question was well answered by many candidates.

(ii) This question was generally well answered but candidates often focused on a change in temperature rather than solvent.

(d) (i) This was another question well answered by many candidates. However some candidates stated "heat/reflux" without specifying the acid.

(ii) Only the stronger candidates were able to correctly represent the structure skeletally. Oxygen atoms were often incorrectly placed in particular.

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

(e) (i) Only a few candidates were able to correctly identify hex-3-ene as **V**. Candidates are advised to read the question stem carefully. In this case they should have noted that the action of concentrated hot acidified $KMnO_4$ on **V** gave a single product.

(ii) Many candidates answered well here, but it was common for *cis* and *trans* to be offered as separated points and this could not be credited.

CHEMISTRY

Paper 9701/22
AS Level Structured Questions

Key messages

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

Clear distinctions are needed when using subject-specific terms, especially with regard to the key distinctions between different types of bonding and intermolecular forces.

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

General comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. In **Question 2** many candidates confused the various types of bonding and intermolecular forces; covalent bond strength was often thought to be related to melting and boiling points of molecular substances.

Calculations were generally well done. More rigorous learning of organic reactions would have helped many candidates.

This was the first time that an infra-red spectra question was included in the June series and many candidates need to improve their familiarity with this content.

Comments on specific questions

Question 1

(a) Please note that due to an issue with the data in row 1 of the table, 1 mark was awarded to all candidates for this part of the question. The published question paper has had the data corrected. The published mark scheme reflects this change.

The table of data relating to some isotopes was generally well completed but there was some confusion with some candidates using relative atomic mass data from their Periodic Table instead of the mass (nucleon) number data given in the table.

It is vital for candidates to remember the distinction between the mass (nucleon) number, which is always an integer and identifies the total number of nucleons in a specific atom, and the relative atomic/isotopic mass, which is a value representing the mass of an atom relative to 1/12th the mass of an atom of ^{12}C; and is usually written to several decimal places.

(b) (i) This was generally answered well although some explanations were confused. Very few candidates chose the wrong Group number.

(ii) This definition needs two key ideas, reflected by the mark allocation for this part question. Firstly, that the increasing ionisation energy across the period is due to increasing strength of electrostatic attraction between the nucleus and the outer electrons. Secondly, that this is due to the increasing nuclear charge **AND** similar shielding. A significant number of candidates made this second point 'correctly' but then negated it by also stating that the 'distance' was the same/similar across the period. This cannot be accepted as atomic radius decreases across the period.

(iii) This was an example of a question where many candidates did not read the stem of the question. The elements were described as being in the third period, which means that their outermost electrons must be in shell 3.

(c)(i)(ii) These calculations were generally done well. Some candidates did not recognise that as a 'mass number' was asked for here, the answer must be a whole number as it refers to the number of protons and neutrons in the nucleus of an atom.

Question 2

(a) (i) This definition did not seem to be well known by candidates, many omitting to mention that the element (from which the mole of gaseous atoms forms) must be in its standard state. Most candidates gained credit for referring to 'standard conditions' but, for many, this was the only credit awarded.

(ii) This was answered better than expected with many candidates appreciating that the difference was due to the need for bromine and iodine to change state during the atomisation process while fluorine and chlorine are already gaseous.

(iii) Conversely, this was less well answered than expected. Many candidates chose to write the equation as

$$I_2 + Cl_2 \rightarrow 2ICl$$

but then did not double the enthalpy of formation value given (which refers to forming *one* mole of ICl). Alternatively, candidates who showed the formation of one mole of ICl in their equation often did not divide the bond energies by 2. Candidates are strongly advised to draw out the cycle as the basis for answering such questions.

Candidates who based their answers on the enthalpies of atomisation given in the table of data were also able to earn full credit for this question.

(b) (i) The key here is for candidates to recognise that, although these molecules do have permanent dipoles, these are not responsible for the significant intermolecular forces operating. The answer needs to explain the increasing boiling point down the group in terms of the increasing strength of id-id (VdW) forces due to increasing numbers of electrons in the molecules. It must be clear that the forces referred to are *between* molecules and not *in* molecules.

(ii) Most candidates recognised that HF forms intermolecular hydrogen bonds. For further credit to be awarded, there needed to be an explanation that these are stronger than the intermolecular forces present in the other hydrogen halides.

(c) (i) The most significant clue to the identities of $\mathbf{P}_2$ and $\mathbf{Q}_2$ should have been the colours of the precipitates formed on addition of silver nitrate to solutions of the hydrogen halides in water. Most candidates were able correctly to identify iodine and chlorine from these clues.

(ii) Most candidates correctly stated that the bond in H**P** must be weaker than that in H**Q** but far fewer candidates went on to explain this in terms of bond length (or shielding or orbital overlap). Where there are two marks available for a question, two different marking points are required.

(iii) Most candidates were able to give the appropriate equation for the decomposition. Some candidates incorrectly wrote an equation for a reaction between H**P** and oxygen.

(d) (i) Most candidates gained at least partial credit here by referring to the increasing number of valence electrons across the period. However, many candidates were not specific enough for the award of full credit; this required a precise reference to the fact that the number of chlorines increased by one each time.

(ii) It was clear in this question that the reactions of the chlorides with water are not as well remembered as the reactions of the oxides. A large number of candidates treated all three chlorides in the same way and attempted to write equations showing all three forming oxides or hydroxides. The selection was chosen to allow candidates to demonstrate their knowledge of the differing behaviours of chlorides with ionic bonding ($MgCl_2$ simply dissolves – although credit was also available for those candidates who were aware of the slight partial hydrolysis that occurs), covalent bonding ($SiCl_4$ is fully hydrolysed to the oxide and HCl) and intermediate bonding ($AlCl_3$ is partially hydrolysed).

Question 3

(a) Many candidates were not confident with creating the overall equation from two half-equations.

(b) (i) The first part of the calculation was correctly answered by the vast majority of candidates with only a few not converting cm^3 to dm^3.

(ii) Some candidates took an incorrect approach by inventing a value for the M_r of the hydrated acid (which is not possible without knowing the value of x).

(iii) In this question the need for an appropriate number of significant figures in answers was applied in the mark scheme; as described in the syllabus on page 11 and in ***section 1.5b***. Either 3 or 4 significant figures was allowed here in line with the guidance on page 52.

(iv) The final part of the calculation was also usually correct although some candidates did not recognise that the answer should be an integer and that decimal places are inappropriate when referring to the number of water molecules.

Question 4

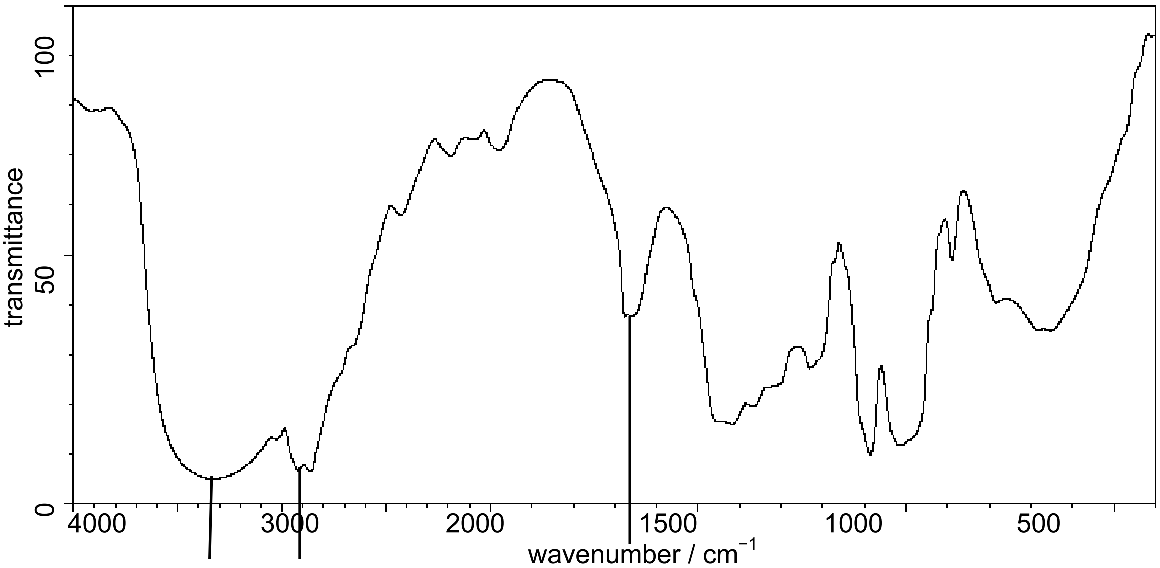
(a) In line with the guidance on page 71 of the syllabus the style of answer expected here, for a **structural** formula, was $CH_3CH_2CH_2COOH$. However, answers given as displayed or semi-displayed formulae were also credited. Most candidates answered correctly although some drew the same structure twice.

(b) (i) The structure of esters was less well known than that of carboxylic acids in the previous question and some candidates drew very confused attempts at representing the structures. Candidates should be reminded that, if rough work is done in the answer space it must be crossed out or it can appear that there are two answers and an incorrect one may contradict one that would otherwise be correct.

(ii) Most candidates gained credit for describing the need for sulfuric acid and heat, but many did not identify the carboxylic acid and alcohol needed to produce one of their esters in **(i)**.

(c) This was the least well answered question on the paper and there seems to be some confusion amongst candidates as to the meaning of the ranges of wavenumbers quoted in the Data Booklet.

Some candidates gave answers implying that the range refers to the width of an absorption curve as seen on a spectrum, but this is not the case. When an absorption curve is seen on a specific spectrum its wavenumber should be read off the horizontal scale from the lowest point of the curve. The range given in the table in the Data Booklet refers to the fact that the wavenumber of a particular bond will not always be exactly the same as it also depends on the environment of the bond in a particular compound.



e.g. In the spectrum above the three significant absorptions with wavenumbers above 1500 cm^{-1} (indicated by vertical lines) are at:

just above 3300 cm^{-1} (which falls within the range of 3200–3600 given in the data table for H-Bonded alcohol, RO–H);

2900 cm^{-1} (which falls within the range of 2850–2950 given in the data table for alkanes CH_2–H, although this absorption is of little value in compound identification as it is present is any organic compound containing a hydrogen atom attached to a saturated carbon atom);

about 1670 cm^{-1} (which falls within the range of 1500–1680 given in the data table for alkenes C=C).

Any reference to an absorption when answering a question must make specific reference to both the wavenumber and to the specific bond responsible. So, a reference to wavenumber 3300 cm^{-1} being due to an alcohol is not sufficient as it is not clear whether the candidate is referring to the C–O bond or to the O–H bond.

Question 5

(a) (i) This was generally well answered although candidates should be aware that a request in a question for 'reagents' means that the precise chemical compound should be stated e.g. potassium dichromate(VI) or potassium manganate(VII). However, some leeway was allowed when marking and the minimum required here was $H^+/Cr_2O_7^{2-}$ or H^+/MnO_4^-. Most candidates were able to answer this correctly although the need for acidification of the oxidising agent was sometimes overlooked.

(ii) Once again the need to 'explain' the answer was sometimes overlooked by candidates and many made a single statement without developing it further. Most candidates were aware that distillation was needed for reaction 2 although some candidates also incorrectly referred to reflux as well e.g. the phrase 'heated under reflux and distilled' was seen quite often. The second marking point was for the explanation in terms of the fact that those conditions were to avoid further oxidation of the aldehyde produced.

(b) In describing the conditions needed for reaction 3 some candidates seemed to be confused with the conversion of a halogenoalkane to an alkene and suggested heating with ethanolic NaOH. Most candidates were able to suggest using concentrated H_2SO_4, however heat was required to be mentioned for credit to be awarded.The use of HBr was less well known for reaction 4 and again, heat was required for the award of credit. Alternative answers were allowed in both cases if correct.

(c) (i) This question proved to be quite challenging for many candidates; more precision is required in positioning curly arrows, there were incorrect or missing dipoles, there was confusion between partial and full charges and there were many missing lone pairs. Some candidates misinterpreted the layout of the question and tried to fit the whole mechanism into the box drawn; it was intended that the candidates complete the mechanism by adding lone pair(s), dipole and curly arrows to the structures of propanone and the cyanide ion, with the intermediate being drawn in the box. In many cases the lone pair on the cyanide ion was incorrectly placed on the N (there is one there but it is not involved in this reaction) instead of on the C. Candidates are also reminded that a curly arrow should always start from either a bond or from a lone pair.

(ii) Drawing a pair of stereoisomers is also a tricky skill for candidates and, although a range of alternatives is allowed, the safest approach for candidates is to copy the style shown on page 72 of the syllabus. In particular, examples of what is not acceptable include; 2 bonds in the plane of the page drawn at 90° or 180° to each other, 4 different ‘types’ of bond – as bonds can only be in the plane of the page, behind the plane or in front of the plane. Another common mistake in this question was due to incorrect connectivity when candidates show CN bonded to C through the N, or OH bonded through the H or CH_3CH_2 bonded through the CH_3.

(iii) Most candidates gained at least partial credit here. The most common error was simply to repeat the question and state that two stereoisomers were formed, when the key was to indicate that the presence of the chiral carbon created the ability for two different isomers to be formed. Candidates must be careful not to contradict a reference to a chiral carbon by going on to describe 4 different *molecules* or *compounds* being attached to the same carbon atom.
A more advanced answer based on the planar carbonyl and thus an equal chance of attack from either side was also credited.

CHEMISTRY

Paper 9701/23
AS Level Structured Questions

Key messages

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

Clear distinctions are needed when using subject-specific terms, especially with regard to the key distinctions between different types of bonding and intermolecular forces.

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

General comments

This paper tested candidates' knowledge and understanding of important aspects of AS Level Chemistry. In **Question 2** many candidates were confused with rate and equilibria.

Calculations were generally well done. More rigorous learning of organic reactions would have helped many candidates.

This was the first time that an infra-red spectra question was included in the June series and many candidates needed to improve their familiarity with this content.

Comments on specific questions

Question 1

(a) (i) Many candidates did not notice the information in the question which stated that the iron was converted to the +2 oxidation state. Others did not know that hydrogen would be a product and some were not able to write the correct formula for sulfuric acid.

(ii) Many candidates were not confident with creating the overall equation from two half-equations.

(iii) This calculation was done well by most candidates although some did not convert cm^3 to dm^3

(iv) The expected answer was 6 x the answer to **(a)(iii)** but answers were allowed based on alternative ratios from the candidate's equation.

(v)–(vii) Some candidates did not appreciate that the context of the question was to find the percentage of iron in the wire (implying that it was not pure iron) and chose to work 'backwards' through this part of the question by starting with the assumption that all 3.35 g was iron. Some credit was still possible in **(vi)** and **(vii)** as long as the working was clearly shown.

(b) (i) This question required candidates to combine their knowledge that aluminium chloride is covalent (unlike most metal chlorides) with their awareness that bonding type depends on the difference in electronegativity between atoms. The values in the table show that the difference between Fe and C*l* is less than that between A*l* and C*l* so this should have led candidates to state that the bonding in iron(III) chloride is covalent too.

(ii) Even the candidates who recognised that iron(III) chloride is covalent were generally not able to produce the correct equation with most showing formation of the hydroxide. Candidates who had stated, in **(i)**, that the chloride was ionic could gain credit here for an equation showing simple dissolving of the chloride. In general, it seems that ideas related to the comparisons between covalent and ionic chlorides are less well known than similar comparisons for ionic and covalent oxides.

Question 2

(a) This was another equation that was expected to be straightforward for most candidates but a surprising number could not correctly produce a formula for nitric acid.

(b) (i) Very few candidates were able to draw the correct representation of the distribution for a higher temperature.

(ii) This explanation proved tricky for even the highest achieving candidates. Most recognised that at higher temperature more molecules will have $E > E_a$ but few went on to state that this means there will be more *frequent successful* collisions. Many answers simply referred to the number of collisions and many implied that it is the overall number of collisions that is important, rather than referring to the successful ones.

(iii) Most candidates were able to draw the line representing the catalysed E_a correctly but some went on to state that the catalyst increases the energy of the molecules.

(iv) When explaining the effect of temperature on equilibria it is important for candidates to realise that they should not imply that only the rate of one reaction increases with increasing temperature. Increasing temperature increases the rate of both the forward and reverse reactions but the effect on the endothermic reaction is greater, which leads to the idea that an equilibrium will shift in the endothermic direction when temperature is increased.

(c) Many candidates were able to identify some oxidation numbers correctly but few referred correctly to the changes for both oxygen and nitrogen. As all species in the equation were referred to in the stem of the question they were often correct in the answer, but balancing was not always correct.

(d) (i) Many candidates drew the ammonia molecule instead of an ammonium ion here.

(ii) Shapes and angles were not as well-known as expected given the specific examples in ***section 3.2*** of the syllabus.

(e) Eutrophication is now fairly well-known and described by candidates, but they must be clear that the oxygen depletion is due to the process of decay that follows algal bloom and not due to the growth process.

Question 3

(a) (i) Surprisingly few candidates recognised that the crude oil enters the column as a vapour and that therefore the initial process must involve converting the liquid crude oil to vapour.

(ii)–(iii) Some candidates seem to be confused by the distinction between *structure* and *properties* so that properties were often referred to in **(ii)** and structure in **(iii)**.

(b) (i) The cracking equation was generally correct but some candidates could not write the correct formula for ethene or overlooked the stated 2:1 ratio of products.

(ii) The uses of the products and the reasons for them were not generally well known.

(c) (i) Most candidates recognised that the origin of oxides of nitrogen is the reaction between atmospheric nitrogen and oxygen but fewer stated that it was possible due to the high temperatures in an engine.

(ii) Candidates found problems with balancing this equation or showed nitrogen as being monatomic.

(iii) Some candidates did not realise that this question was about the formation of acid rain from SO_2 and so offered equations for the formation of HNO_3 or HNO_2 instead of showing the catalytic involvement of NO.

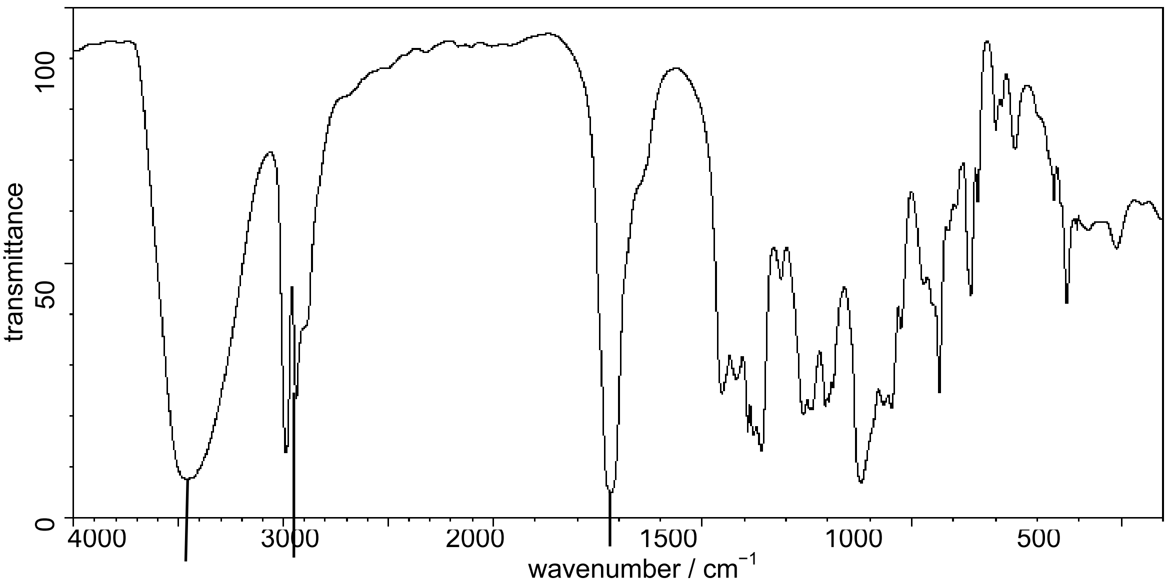
(iv) Most candidates could suggest one problem associated with acid rain but few could make two different suggestions and many repeated the first idea in slightly different words. For example, causing damage to statues and to buildings would not count as two separate ideas.

Question 4

(a) Several alternatives for the systematic name of acetoin were credited as, in some parts of the world, there is a convention to place numbers before names (e.g. 2-butanol instead of butan-2-ol) despite this not being the IUPAC convention. Candidates are not expected to have a detailed knowledge of the order of priority of functional groups when naming compounds but, as here, they should be aware that a group that includes a carbon in a chain will take priority over a group that is a side-chain – hence this is a ketone with an –OH (hydroxy) side chain.

(b) Candidates needed to recognise that this was oxidation of a (secondary) alcohol and so choose the correct combination of reagents and the appropriate conditions (heat). Candidates should be aware that a request, in a question, for 'reagents' means that the precise chemical compound should be stated e.g. potassium dichromate(VI) or potassium manganate(VII). However, some leeway was allowed when marking and the minimum required here was $H^+/Cr_2O_7^{2-}$ or H^+/MnO_4^-. Most candidates were able to answer this correctly although the need for acidification of the oxidising agent was sometimes overlooked and mention of heating was also sometimes missed.

(c) (i) This was the least well answered question on the paper and there seems to be some confusion amongst candidates as to the meaning of the ranges of wavenumbers quoted in the Data Booklet. Some candidates gave answers implying that the range refers to the width of an absorption curve as seen on a spectrum, but this is not the case. When an absorption curve is seen on a specific spectrum its wavenumber should be read off the horizontal scale from the lowest point of the curve. The range given in the table in the Data Booklet refers to the fact that the wavenumber of a particular bond will not always be exactly the same as it also depends on the environment of the bond in a particular compound.



e.g. In the spectrum above the three significant absorptions with wavenumbers above 1500 cm^{-1} (indicated by vertical lines) are at:

3450 cm^{-1} (which falls within the range of 3200–3600 given in the data table for H-Bonded alcohol, RO–H);

2950 cm^{-1} (which falls within the range of 2850–2950 given in the data table for alkanes CH_2–H);

about 1720 cm^{-1} (which falls within the range of 1670–1740 given in the data table for aldehydes/ketones C=O).

In this case the fact that the structure responsible for the spectrum was known should have avoided any confusion with ranges in the data table that overlap with those required such as the range for N–H in amides or amines, which cannot be relevant here.

Any reference to an absorption when answering a question must make specific reference to both the wavenumber and to the specific bond responsible. So, a reference to wavenumber 3300 cm^{-1} being due to an alcohol is not sufficient as it is not clear whether the candidate is referring to the C–O bond or to the O–H bond.

(ii) As in **(c)(i)** a clear reference to bond and wavenumber is needed. Some candidates showed confusion here by mistakenly thinking that the presence of two C=O bonds in diacetyl would mean there would be two separate absorptions around 1700 cm^{-1} when in fact both bonds will contribute to the same absorption. In general, use of the word ‘peak’ when referring to absorptions, should be discouraged as some candidates clearly think that the regions of low transmittance are the ‘peaks’ when they should actually be describing the regions of low transmittance.

(d) (i) Most candidates who could attempt this question recognised that a double bond would form but some did not realise it was due to dehydration so left the OH group in place in the final product.

(ii) There is still a minority of candidates who do not realise that stereoisomerism collectively refers to both optical and geometric isomerism which restricted their opportunities for credit here. This question could actually be answered either with reference to why no geometrical isomerism, or with reference to why no optical isomerism. Both marking points chould also be awarded as ecf to those candidates who had given a structure in **(d)(i)** that did not contain C=C.

(iii) Candidates must be careful not to contradict a reference to a chiral carbon by going on to describe 4 different *molecules* or *compounds* being attached to the same carbon atom.

(iv) Drawing a pair of stereoisomers is a tricky skill for candidates and, although a range of alternatives is allowed, the safest approach for candidates is to copy the style shown on page 72 of the syllabus. In particular, examples of what is not acceptable include; 2 bonds in the plane of the page drawn at 90° or 180° to each other, 4 different 'types' of bond – as bonds can only be in the plane of the page, behind the plane or in front of the plane. Another common mistake in this question was due to incorrect connectivity when candidates showed CH_3CO bonded to the chiral carbon through the CH_3.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

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- Candidates should be given the opportunity to practise key techniques including those for qualitative analysis and should be given appropriate feedback with the help of past papers, mark schemes and Examiner reports.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper. This is particularly important where Centres are sharing a venue.

General comments

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If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

Most candidates completed the paper so there was no indication that a shortage of time was a factor that significantly affected performance.

Comments on specific questions

Question 1

(a) Most candidates recorded six masses although the calculation of the mass of carbon dioxide given off during the heating was often incorrect. A significant number merely subtracted the mass of beaker and acid from the mass of the final beaker and contents after the reaction. This did not take into account the mass of **FA 1** added. Candidates are advised to pay attention to headings in tables of results. In this case it was necessary to indicate clearly which reading was the mass of beaker + acid before the reaction and which was the mass of beaker + contents after the reaction.

(b) (i) Nearly all candidates knew how to calculate the number of moles of carbon dioxide but the answer needed to be given to an appropriate number of significant figures. If a balance reading to at least 2 decimal places was used, the minimum expected was 3 significant figures and 2 was accepted if a 1 decimal place balance had been used.

(ii) Many correct equations were seen but a number of candidates omitted or gave incorrect state symbols.

(iii) and **(iv)** The relationship between number of moles, mass and M_r was well known by most candidates. However some candidates did not subtract the 60 from this value to calculate the A_r of **X**. Credit was given for correctly identifying the Group 2 element whose A_r most closely corresponded to this value. A number of candidates chose elements not in Group 2 or apparently confused the atomic number and the relative atomic mass from the Periodic Table of Elements.

(c) (i) Only the most able candidates explained the effect of acid spray on the calculated A_r. Many started with the idea that more carbon dioxide would be given off while in fact the same mass of carbon dioxide would actually be released. It would just appear that more had been given off.

(ii) The stronger candidates gave good answers here. Weaker answers just stated that the change in loss of mass would be small. It was necessary to mention the effect of this on the calculated A_r for credit.

(iii) This was the best answered part of **(c)** with a variety of answers accepted. Using a lid or bung was however not accepted, unless a hole of some sort was described.

Question 2

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to 0.05 cm^3 and a few candidates showed an initial burette reading of 50.00 cm^3. Candidates gaining two titres within 0.10 cm^3 should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

(b) The majority of candidates calculated a suitable value for the volume of **FA 4** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) (i) Nearly all candidates answered this correctly.

(ii) This part however was less well answered and a large number of candidates did not use 250 and/or the volume of **FA 4** from **(b)**.

(iii) The stoichiometry of the equation was correctly interpreted in most responses.

(iv) Only the most able candidates understood that the number of moles of hydrochloric acid from **(ii)** and **(iii)** had to be added together.

(d) (i) Most candidates recognised that volumes measured using measuring cylinders are less accurate than those using pipettes or burettes.

(ii) Few candidates were able to explain that a greater volume of acid would be necessary since less acid would remain if more $\mathbf{X}CO_3$ were used.

Question 3

(a)(i)(ii) Most candidates tested the gas produced to observe that litmus turned blue and hence identified the cation as ammonium. Very few noticed condensation or sublimation.

(b) (i) Selection of the correct reagents to test for cations was generally known and most candidates then used the correct description of the appearance of the precipitate. This led to the identification of manganese(II). A small minority of candidates omitted the II (or 2+) in this identification however.

(ii) Correct observations led many to identify the presence of sulfate.

(iii) Although many candidates correctly used the correct reagents, few realised that although a white precipitate was formed when silver nitrate was added, the presence of manganese(II) meant that this precipitate did not dissolve in aqueous ammonia. This led to the inconclusive nature of the test for halides in this case.

(c) Some candidates who knew the ions present, could not be given credit because they named possible compounds rather than, as the question required, giving formulae.

(d) This part was only well answered by stronger candidates. A number of candidates described the formation of brown precipitates in the tests. This would happen if too much manganate(VII) was added. This result caused confusion about the identity. Sometimes correct observations were given but there was no explanation for the choice of identity was given.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key messages

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- Candidates should be given the opportunity to practise key techniques including those for qualitative analysis and should be given appropriate feedback with the help of past papers, mark schemes and Examiner reports.
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If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

Most candidates completed the paper so there was no indication that a shortage of time was a factor that significantly affected performance.

Comments on specific questions

Question 1

(a) Nearly all candidates gained credit for clearly recording the results and many also recorded the volume within an acceptable range. The low volumes recorded by some however, indicated that a significant volume of gas was allowed to escape.

(b) Most candidates were clearly familiar with the relationship of number of moles, volume of gas, mass and A_r so credit was generally given for these calculations.

Question 2

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to 0.05 cm^3 and a few candidates showed an initial burette reading of 50.00 cm^3. Candidates gaining two titres within 0.10 cm^3 should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

(b) The majority of candidates calculated a suitable value for the volume of **FB 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) Some candidates were competent in the use of the basic formulae connected with this type of calculation but many found it difficult when the calculation needed real understanding of the significance of some of the values produced. This led to some being unable to answer a part of the calculation and then not attempting the rest of the question. Candidates should be advised to attempt later parts of a question if possible. This may involve the stated assumption of an answer to a particular part and then demonstration of how this value is used in later parts.

(i) Most candidates correctly calculated the number of moles of sodium hydroxide.

(ii) and **(iii)** Most candidates also used the stoichiometry of the equation correctly in **(ii)** but a significant number apparently did not realise that **(iii)** involved multiplying this answer by 10.

(iv) Most candidates correctly calculated the number of moles of sulfuric acid.

(v) A number of candidates found this part of the question challenging. Correct subtraction of **(iii)** from **(iv)** was accepted, even if the values were actually incorrect.

(vi) Most candidates who had been able to calculate an answer to **(v)** were able then to calculate an A_r for magnesium.

(d) (i) Although a variety of answers were acceptable, most candidates chose to consider the possible loss of gas before the bung was inserted. A practical method of improvement was needed. This meant some way in which the acid and magnesium could be kept apart until after the bung had been inserted. Since hydrogen is almost insoluble in water, answers based on collecting the gas in a gas syringe, rather than over water, were not accepted.

(ii) Many candidates recognised the need to use 24.3 and 20.8 but a number of candidates used them inappropriately.

Question 3

(a) (i) The majority of candidates gained at least partial credit in this section but very few gained full credit. Common errors included “gas evolved” (a deduction) instead of “effervescence/bubbling” (an observation). Weaker answers did not test or gave incorrect test results for the gases produced in the first two tests in the table.

(ii) The observation that hydrogen was produced with hydrochloric acid provided the information that **FB 5** was a metal. Although some candidates realised that aluminium was the most likely (in view of the reaction with **FB 6** and sodium hydroxide to produce ammonia), a number suggested that **FB 5** was Al^{3+}.

While a few candidates suggested one of the several possible identities of the cation in **FB 5**, based on the solubility of its hydroxide, a very small number were able to identify the anion. To positively conclude that it contained NO_3^- it was necessary both to recognise its reduction to ammonia and also that NO_2^- was not present since this would have produced a brown gas with hydrochloric acid.

(b) (i)(ii) Although most candidates realised that the main reagents needed were mineral acid, silver nitrate and barium nitrate/chloride, a significant number did not produce an acceptable layout to show how the tests were to be carried out, the observations that were made or the relevant conclusions. In the tests for sulfate the addition of a suitable named acid i.e. nitric or hydrochloric acid, is essential while the use of sulfuric acid is clearly unsuitable. In the test for halide it was expected that the addition of aqueous silver nitrate would be followed by the addition of aqueous ammonia.

Since the question stated that two anions were present in **FB 7** and **FB 8** and that a different anion was present in each solution, candidates were expected to give conclusions that fitted with this information. It could not therefore be, as suggested by a number of candidates, that one of the solutions contained both chloride and sulfate whilst the other also contained one of these ions.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

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(b) The majority of candidates calculated a suitable value for the volume of **FA 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) There were some excellent answers to this question showing that some Centres had prepared their candidates well. Some candidates used 25 cm^3 instead of their titre in **(iv)** and few remembered to use the dilution factor of 10. However, many candidates gave their answers to the expected 3 or 4 significant figures.

Question 2

(a) Many candidates gained credit for clearly recording the results. However, a number of candidates (and Supervisors) recorded low volumes of gas evolved. There were other Centres where many of the candidates gained credit for accuracy.

(b) In general the calculation was carried out well. A large majority of candidates calculated the moles of gas correctly in **(i)**, noted the 1:1 mole ratio in **(ii)**, and most of these correctly calculated the M_r in **(iii)**. Again, many candidates correctly calculated the A_r in **(iv)** with only a few omitting the division by 2. However, the identification of the metal in **(iv)** was less commonly seen as only a minority suggested a group 1 metal and of those who did, some did not explain their choice. Other candidates simply selected the element with the closest A_r regardless of group.

(c) A large majority of candidates correctly selected an appropriate volume error for their data in **(i)** but some then used $250\,cm^3$ as the denominator instead of the volume of gas collected. Many gained partial credit in **(ii)**. This was mainly due to the inaccuracies, especially regarding the solubility of CO_2. However, some candidates gave examples of their own poor technique rather than making a relevant comment about the procedure given. Some of the modifications did not match the reason for the inaccuracy such as “use a gas syringe” for gas escaping before the bung could be inserted.

Question 3

(a) The majority of candidates gained at least partial credit in this section but very few gained full credit. Common errors in **(i)** included “gas evolved” (a deduction) instead of “effervescence” (an observation) with **FA 5** and **FA 6** reacting with Na_2CO_3 with no test for the gas, incorrect positive and negative outcomes with Tollens’ reagent, and incorrect colour changes with acidified $KMnO_4$(aq). However, most candidates correctly identified the presence of carboxylic acids. Many candidates correctly identified aldehyde in **(iii)** which was allowed from an incomplete reaction with Tollens’ reagent. Fewer candidates gained credit for **(iv)** with many writing “oxidation” without specifying the species oxidised. Many candidates were able to give sensible suggestions for the identity of **FA 7** in **(v)** but fewer gave sufficiently detailed tests to confirm this identity in **(vi)**. Common errors were to omit “heating” if carrying out a test with Fehling’s solution, to omit “precipitate” if suggesting the use of 2, 4–DNPH or to omit adding H_2SO_4 when preparing an ester.

(b) This section was only well answered by stronger candidates. In **(i)** poor technique meant that some candidates wrongly identified an alkaline gas on adding NaOH and warming the contents of the boiling tube. Many candidates did not report effervescence on adding A*l* although many candidates realised that they were testing for NO_2 and NO_3 and gained credit in **(ii)**. A significant number of candidates did not specify that it was the gas they were testing with litmus paper. Very few candidates reported two observations on heating **FA 9** in **(i)**. Candidates should realise that gases are frequently evolved, water may be driven off, changes in state may occur and the colour of the residue should be reported. Some candidates reported “no reaction” on heating **FA 10** and few heated **FA 9** long enough to see the brown gas. Although in **(iii)** many candidates realised that NO_2, and NO_3, can be distinguished by adding acid they did not specify the acid to be used and some did not state the expected observations. Many candidates appeared to assume that **FA 9** and **FA 10** would contain different anions.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 2

Key messages

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(b) The majority of candidates calculated a suitable value for the volume of **FB 3** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) There were some excellent answers to this section showing that some Centres had prepared their candidates well. Although many candidates ignored the dilution factor of 25 in **(i)**, the majority went on to gain credit in **(ii)**, **(iii)** and **(iv)**. However, a significant number of those gaining a M_r for borax of around 15 did not go on to calculate the value of **x** correctly as they probably realised this would have an impossible negative value. A few candidates ignored their calculation and worked out the value of **x** by using oxidation numbers. Candidates should note that the number of significant figures to be used reflects the accuracy with which the solutions have been prepared and the accuracy of the apparatus used. The first four answers in this section should have been displayed to 3 or 4 significant figures and the fifth needed to be an integer.

Question 2

(a) A large majority of candidates gained partial credit though some did not distinguish sufficiently between “crucible, (lid) + **FB 4**” and “crucible, (lid) + residue or **FB 4** after heating” or wrote “crucible and lid after heating” without mentioning the contents. Only a small minority ignored the instruction concerning the mass of **FB 4** to use. However, this mass and the mass of residue were not always listed on page 4 as instructed.

(b) In general the calculation was carried out well. A large majority of candidates used the correct value of 24.3 for the A_r of Mg in **(i)** and applied the mole ratio factor correctly in **(ii)**. Almost all candidates gained credit for calculating the M_r in **(iii)**. Performance in **(iv)** varied considerably with many candidates not making an appropriate calculation nor giving an adequate explanation. However, there were some excellent answers where candidates had calculated the range of M_r values within 2.5% of **(iii)** and then commented on whether the value in **(ii)** fell within this range. There were several other valid approaches seen and credited.

(c) Many candidates answered **(i)** well and realised the need to heat to constant mass. A common incorrect response was to repeat the experiment and take an average of the results. Fewer candidates answered **(ii)** as well rarely going further than suggesting the values could be compared or that it would make the experiment “more accurate”. As in a titration exercise they should be seeing whether the results were concordant. Most candidates stated the error in one balance reading correctly but far fewer remembered to multiply this by 2 or used an incorrect mass when calculating the percentage error in the mass of **FB 4**.

Question 3

(a) The majority of candidates gained at least partial credit in this section though few gained full credit. Common errors included not noting the reaction of Mg with **FB 6**, not testing the gas, varying colours of precipitate with **FB 6** and NaOH(aq) and incorrect observations when a reagent was added in excess. Despite clear instructions to the contrary, a significant number of candidates used additional reagents and so could not be credited for otherwise correct observations. Some candidates incorrectly gave “white solution” or similar incorrect terminology.

(b) The majority of candidates gained credit in **(i)** correctly noting the yellow precipitate with KI(aq). However, some linked Fe^{2+}, Fe^{3+}, Cr^{3+} or Mn^{2+} with their incorrect observations of the precipitate colour with NaOH(aq) in **(a)**. There were many correct answers in **(ii)** though there were some surprising combinations of ions suggested for the solution **FB 5** such as Ba^{2+} and SO_4^{2-}. Far fewer candidates identified **FB 7** as H_2SO_4(aq) in **(iii)** though many realised it was an acid. The ionic equation was not well answered as spectator ions were frequently included or the equation involved the SO_4^{2} ion, had Mg^{2+} as a reactant or omitted Mg altogether.

(c) Very few candidates reported two observations on heating **FB 8** in **(i)**. Candidates should realise that gases are frequently evolved, water may be driven off and the colour of the residue should be reported. Of those testing the gases with litmus papers, most incorrectly stated the red litmus turned blue. This indicated some solid was reaching the test paper showing greater care was needed. A greater number of candidates gained credit in **(ii)** with some recording three correct observations. Candidates should be reminded that “gas evolved” is not an observation. However, many candidates successfully tested the gas with limewater. Although most candidates realised the anion was CO_3^{2} or HCO_3 in **(iii)** many incorrectly included cations for which there had been no tests. Candidates should realise that it is not always possible to come to a definite conclusion especially if the evidence is lacking.

CHEMISTRY

Paper 9701/35
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to evaluate the practical procedures they practise during the course so that they become accustomed to discussing errors and relevant improvements.
- Candidates should be instructed to supply a key if they are using non-standard abbreviations.
- Candidates should be given the opportunity to practise key techniques including those for qualitative analysis and should be given appropriate feedback with the help of past papers, mark schemes and Examiner reports.
- Candidates should be reminded to complete the Session and Laboratory boxes on the front of the paper. This is particularly important where Centres are sharing a venue.

The Examiners thank Supervisors at Centres who supplied experimental data for **Questions 1** and **Question 2** for each Session/Laboratory. Centres are reminded that the following documentation for each session and for each laboratory within a session should be included in the script packet:

- a list of the candidates present and a seating plan for the laboratory
- a copy of the examination paper with the Supervisor's experimental results.

If candidates are not to be disadvantaged it is important that every candidate can be linked to a particular session/laboratory and to a corresponding set of Supervisor's results.

Most candidates completed the paper so there was no indication that a shortage of time was a factor that significantly affected performance.

Comments on specific questions

Question 1

(a) Candidates should be reminded to record burette readings for the rough titration even though these do not need to be to the same level of precision as those generating values for the accurate titres. Some candidates did not record accurate burette readings to 0.05 cm^3 and a few candidates showed an initial burette reading of 50.00 cm^3. Candidates gaining two titres within 0.10 cm^3 should be encouraged to continue with the rest of the paper rather than perform a subsequent titration. Many candidates completed the titration well with correctly headed data tables and clearly presented readings and titres.

(b) The majority of candidates calculated a suitable value for the volume of **FA 2** to be used in the calculation. Candidates should be reminded that they must indicate which titres they are using in their calculation and record their answers correctly rounded to 2 decimal places.

(c) There were some excellent answers to this section showing that some Centres had prepared their candidates well. Most candidates correctly calculated the number of moles of NaOH used in **(i)** and the majority used the mole ratio correctly in **(iii)**. However, many candidates ignored the instruction to include state symbols when completing the equation in **(ii)**. Other errors included incorrect state symbols and incorrect balancing of the equation. Candidates were more successful in **(iv)** and **(v)** but some used an incorrect dilution factor in **(v)**. Candidates should note that the number of significant figures to be used reflects the accuracy with which the solutions have been prepared and the accuracy of the apparatus used. The answers in this section should have been displayed to 3 or 4 significant figures.

Question 2

(a) A large majority of candidates gained credit for the headings and units of the tables in **(a)(i)** and **(b)(i)** but a few omitted the temperature changes. However a number of candidates then wrote thermometer readings as integers rather than to .0 or .5, and a few did not calculate the temperature change correctly. Most candidates carried out correct calculations in **(ii), (iii)** and **(iv)** though a few appeared unsure of the steps. Some, with otherwise correct answers, gave the enthalpy change a positive sign.

(b) In this question there was a similar split in the standard of answers in **(ii)** and **(iii)** to that in **(a)**. However, some candidates mistakenly used $40\,cm^3$ in **(ii)** which was the volume of solution heated rather than the volume used in the experiment.

(c) The standard of answer in **(i)** tended to be Centre dependent with some very clear Hess' Law cycles. Candidates often omitted values on the arrows, mistakenly show Mg, C and O_2 instead of $MgSO_4$ or had some non-existent products of the reactions. However, more candidates were able to calculate the enthalpy change correctly in **(ii)** either with their own values of the values given in the paper.

(d) Many candidates carried out a correct calculation in **(i)** for the error. However, far fewer took into consideration that the MgO was in excess so the exact mass would not matter.

Question 3

(a) The majority of candidates gained some credit in **(i)** but few gained full credit for the observations and decisions expected for heating **FA 6**. Candidates should realise that gases are frequently evolved and should be tested for, water may be driven off, the state may change and the colour of the residue should be reported. Many candidates answered **(ii)** well but some did not add excess reagent. However, poor technique meant that some candidates wrongly identified an alkaline gas on adding NaOH(aq) and warming the contents of the boiling tube instead of only when the A*l* was added. Some candidates incorrectly recorded "white solution" or used similar incorrect terminology. The majority of candidates identified $Mg(NO_3)_2$ correctly in **(iii)** but only a few candidates were able to write a correct ionic equation with appropriate state symbols for the reaction between $Mg^{2+}(aq)$ and $OH^-(aq)$.

(b) The majority of candidates gained partial credit in **(i)** and many answered the whole question very well. Common errors were not reporting the effect of using excess alkali and unusual colours reported with the acidified $KMnO_4(aq)$ test followed by aqueous starch. It is possible that candidates did not follow the instruction to add only a few drops of the oxidising agent. Many candidates correctly concluded **FA 7** to be ZnI_2 in **(ii)** and went on to carry out a successful test with $AgNO_3(aq)$ (and $NH_3(aq)$) in **(iv)**.

CHEMISTRY

Paper 9701/41
A Level Structured Questions

Comments on specific questions

Question 1

(a) (i) This question provided an accessible beginning to the paper for many candidates.

(ii) and **(iii)**
Many candidates did not appreciate that in order to work, the hydroxide compound must be capable of forming a solution, and a visible white precipitate must form when carbon dioxide is added. Barium hydroxide satisfies both of these requirements, magnesium hydroxide does not. Many incorrect answers were seen that focused on the stability of the hydroxide compounds.

(b) This was well known to many candidates. Common mistakes included reference to atomic radii not ionic radii and describing a decrease in polarising ability without identifying the species that is polarised; the carbonate ion.

(c) Many answers were seen that referred incorrectly to the $E^\ominus$ values for the reduction of Ni^{2+} and Ca^{2+}. Better performing candidates realised the importance of ionic radii and quoted the relevant data.

Question 2

(a) (i) This question was usually correctly answered.

(ii) This question was highly discriminating. Some excellent answers were seen, that described all or some of the colours, formulae and geometry correctly; many incorrect responses were also seen.

(b) Many candidates worked out that the nickel complexes are square planar and the cobalt complex is tetrahedral. Some of the diagrams drawn did not show these shapes correctly.

Question 3

(a) Many candidates gave a K_c expression not a K_p expression.

(b) (i) and **(ii)**
This calculation discriminated well; many fully correct answers were seen.

(c) (i) Many candidates knew the link between more gas molecules and positive $\Delta S^\ominus$; others incorrectly referred to the $\Delta H^\ominus$ value.

(ii) Those who knew the Gibbs equation usually answered this question correctly.

(d) Many incorrect answers were given. Some good answers were seen that started with the increase in $T\Delta S^\ominus$ as T increases and went on to deduce that $\Delta G^\ominus$ will become smaller (or less positive, or more negative) and therefore the reaction becomes more feasible. It should be noted that if a candidate did not write about the $T\Delta S^\ominus$ term and instead wrote about the $-T\Delta S^\ominus$ term, they should have stated that this term became more negative, not smaller.

Question 4

(a) (i) Many correct definitions of standard electrode potential were seen.

(ii) This question was usually answered correctly. Some candidates incorrectly included the symbol for a cell.

(iii) Common incorrect answers to this question included:

- the use of an iron rod instead of platinum for the Fe^{3+}/Fe^{2+} half-cell
- specifying an insoluble compound such as $AgCl$ for the Ag/Ag^+ half-cell.

(b) (i) Many candidates calculated $E^\ominus$cell correctly but did not go on to write an equation for the cell reaction.

(ii) Many candidates had correctly learnt this new material. It was hoped that the method used would be to calculate the new E value for the Ag/Ag^+ half-cell, 0.77 V, and then to subtract this from the $E^\ominus$ value for the Fe^{3+}/Fe^{2+} half-cell, 0.77 V, to get the correct answer, 0.0 V.

Question 5

(a) (i) This question was usually correctly answered.

(ii) Many candidates realised that the first bullet point meant that the dicarboxylic acids are stronger acids, but did not explain how the second $–CO_2H$ group influences this. The electron donating effect of alkyl groups was known by many.

(iii) Few correct answers were seen.

(b) (i) This was usually well known; some candidates did not specify that a buffer resists change in pH (it does not maintain pH, or keep pH constant) or that this is only when small amounts of acid or alkali are added.

(ii) This was a very discriminating question. Many candidates did not follow the instruction and gave equations that began with butanedioic acid or disodium butanedioate.

Question 6

(a) (i) and **(ii)**
Although the equation in **(i)** was often correct, its importance for the equation in **(ii)** was seldom appreciated.

(b) (c)(i) and **(ii)**
This was a very discriminating question, with some excellent answers but there were also many completed incorrect responses. Common incorrect answers included:

- giving 4.2/5.0 = 84% as the answer in **(b)** rather than calculating the numbers of moles first
- not realising how to find the mass dissolved in the aqueous layer in **(c)(ii)**.

(d) It was well known that ethylamine is the stronger base. Many candidates did not go on to explain in clear terms:

- that the lone pair in phenylamine is delocalised over the benzene ring
- that this makes the lone pair less available to accept an H^+.

(e) (i) and **(ii)**
Step 1 was often well answered but step 2 was not. To synthesise phenol, the aqueous solution should be boiled, not just allowed to warm up above 10 °C. Many incorrect answers had nitrobenzene as **E**.

Question 7

(a) (i) This question was usually correctly answered.

(ii) Many incorrect answers were seen here, for example omitting the oxygen in the serine side-chain and getting an answer of 217.

(b) (i) Repsonses were usually correct for this part. The commonest mistake was to draw a 2– ion with a $–CO_2–$ group and a $–CH_2O–$ group.

(ii) Common incorrect answers to this question included:
- not specifying that the power supply must be DC
- getting the anode and cathode the wrong way round
- not stating that **I** is buffered.

(iii) Candidates found this to be a challenging question. Many candidates had not noted the presence of Ala-Ser-Gly in the mixture, as given in the question.

(c) (i) Many answers were seen that did not include water, e.g. HCl/heat or H_2SO_4/heat.

(ii) This was answered well by most candidates.

Question 8

(a) This was answered well.

(b) (i) Many candidates gave the correct answer. “Stereoisomerism” was seen on many scripts; this was not sufficiently precise.

(ii) This was often answered well though some candidates did not focus on the variation in the ΔE values.

Question 9

(a) **T** and **U** were only identified correctly by a minority of candidates. Common incorrect answers included:
- substituting in a propyl group instead of an ethyl group to form **T**
- substituting an in an –OH group instead of a –CN group to form **U**.

(b) This was found to be a very challenging question by many candidates. Common incorrect answers included:
- not using C_6H_5COCl in step 1
- omitting $AlCl_3$ in steps 1 and 2
- using $Br_2(aq)$ in step 3
- using an oxidation reaction in step 5 instead of hydrolysis.

(c) Many candidates answered this incorrectly.

Question 10

(a) This calculation was often done well. A significant number of candidates gave 0.171 as their answer; with the only error being to not appreciate that only one quarter of the resulting solution was titrated.

Many candidates, here and elsewhere on the question paper, used a correct method but arrived at an answer significantly different from the correct answer. This arose because the intermediate answers were rounded off after each step. It would have been better to leave all the figures from each step on the calculator, rounding to two or three significant figures when the final answer was reached.

(b) (i) Many candidates gave a suitable reagent.

(ii) The properties of acyl chlorides were not well known. Many answers for **K** did not fit the formula given.

(c) (i) Many candidates read the spectrum correctly.

(ii) Better performing candidates saw that when the two peaks from the solvent had been accounted for there was only one other, hence one carbon environment but this was rare. Some candidates stated that there is a carboxyl group present. References in candidates' answers to C=C bonds were ignored, references to arenes were incorrect, as there can be no arene with the given formula.

(d) (i) **M** was often correct but **N** and **O** were usually incorrect. The answers seen for **N** and **O** were often $HO_2CCH_2CO_2H$ and $HO_2CCH_2CH_2CO_2H$. This suggests comparatively few candidates realised the importance of the sentence "**M** is formed as one of the products when either **N** or **O** is heated with aqueous acid."

(ii) This was often left blank.

CHEMISTRY

Paper 9701/42
A Level Structured Questions

Key messages

Candidates need to show clear working in mathematical questions as when a final answer is incorrect often credit can be obtained from correct working.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) This was well answered by most candidates. Common errors for H_2O and Mg^{2+} were covalent and ionic.

(ii) This was generally well known.

(iii) Most candidates gained partial credit here. Common errors were omitting sufficient detail in the expected observations or giving two balanced equations. The observations, water vapour and brown gas, were normally stated. Some thought that magnesium hydroxide was the decomposition product.

(iv) Some candidates struggled with this calculation. Common errors were 15.7 % (% of mass remaining), 42.1 % (some candidates thought that the final solid was $Mg(NO_3)_2$ and 72.8 (M_r of 148.3 for $Mg(NO_3)_2$ used instead of 256.3).

(b) The trend and its explanation in terms of cation size and polarisation of the anion was well understood by candidates, Some, however wrote in terms of atomic, rather than cationic, size and did not clearly specify that the anion was undergoing polarisation.

(c) Many candidates found this challenging. A number of candidates did not read the question carefully and gave Ag_2O as the product.

Question 2

(a) This was well answered. A few candidates incorrectly gave a description in terms of dissolving, for example, a substance that was partially dissolved.

(b) (i) This was well answered by most candidates. A common error was stating that pK_a had an inverse proportional to K_a.

(ii) This proved difficult for many candidates. Most candidates were able to correctly compare acidity of the acids and received credit for this, although answers often lacked clarity in the explanation. Many candidates did not compare the electron donating ability of alkyl groups. However more candidates were able to identify C*l* as an electron withdrawing group and that the effect of C*l* decreases the further from the CO_2H. Only the more able candidates linked these to the effect on the stability of the anion or the strength of the O-H bond.

(c) (i) This was well answered. Many diagrams were well drawn and labelled.

(ii) Most candidates gave the correct answer here.

(d) (i) Many candidates gained full credit here. A common error was 5.91 (no square root taken).

(ii) This proved a challenging question. Only a few candidates used the Nernst equation correctly. Mostly the electrode potential and the cell potential were confused. Partial credit was awarded for answers of 0.40, 0.17 and –0.17.

Question 3

(a) (i) Most candidates gave a correct structure for **X**. Occasionally an additional CH_2 group or NO_2 group instead of CN group were seen.

(ii) Most candidates gained some credit here. Reagents and conditions were not often given, omitting the need for high pressure as a condition in reaction 1. Use of HCN in reaction 2 was a common error. Reaction 3 was usually correct.

(b) (i) This proved challenging for many candidates. The key point here was the formation OH^- ions. A common error was the equation $CH_3CH_2NH_2 + H^+ \rightarrow CH_3CH_2NH_3^+$.

(ii) Most candidates gained some credit here. Some omitted sufficient detail about the lone pair on the nitrogen being more available to protonation or donation.

(c) (i) This was well answered. A common error was stating that a buffer solution "maintains constant pH".

(ii) Many candidates gained some credit here. The equation, $CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$.was seen more often than the other equation, $CH_3NH_3^+ + OH^- \rightarrow$. $CH_3NH_2 + H_2O$. A common error was forming CH_3NH_2Cl as a product in the second equation.

Question 4

(a) (i) Most candidates identified the structure as square planar. The quality of diagrams was mixed.

(ii) Only the stronger candidates answered this question well. There were many poor explanations with no comment about dipoles. Some candidates discussed the Pt^{2+} and $2Cl^-$ charges cancelling so no overall charge or polarity.

(iii) Many candidates gave answers which were vague and not related to the structure of the complex. Only the more able candidates applied their knowledge of stereoisomerism to this question.

(b) (i) Most candidates did not refer to any stereochemistry. A common error was *cis*-*trans* or optical isomerism.

(ii) This question was generally not well answered. Many candidates gave a square planar structure. Only the strongest gave a correct three-dimensional tetrahedral diagram.

Question 5

(a) (i) Most candidates gained partial credit here for the correct units. However candidates often put charges outside the bracket.

(ii) This question was not well answered. Only a few candidates scored full credit here. Many did not calculate the new (Cd^{2+}) correctly and used 1×10^{-4} instead 1×10^{-7} in their expression.

(b) (i) Most candidates found this difficult. The key point here was recognising that the same number and type of bonds were being broken and made here. Many candidates omitted any reference to bond making/breaking.

(ii) Most candidates gave the correct answer here. A common error was –14.1.

(iii) Only a few candidates gave a valid answer with most answering in terms of increased disorder of the product or increased entropy.

(iv) Many candidates identified the correct complex, although they gave a reason based on ΔS rather than larger K_{stab} or more negative ΔG.

Question 6

(a) This question proved challenging for most candidates. Many candidates gained credit for clear, labelled diagrams. Common errors were omitting any reference to “active site” in their explanation and unlabelled diagrams with little explanation.

(b) (i) Many candidates identified the isomers and assigned their δ values correctly.

(ii) Most candidates recognised the need to hydrolyse the esters in step 1 but some omitted dilute/aq with acid and heat. Many used Br_2(aq) to distinguish between the isomers. Use of iron(III) chloride solution was a valid alternative here. Common errors were use of the iodoform reaction or aqueous sodium carbonate.

Question 7

(a) Most candidates gained partial credit here. Common errors included an incomplete circuit and omitting the filter paper/gel.

(ii) Most candidates gained credit for linking charge on the amino acid to the direction of movement. However many omitted any reference of size/M_r/magnitude of charge to the speed of movement/distance travelled. Mass was often stated instead of M_r which was insufficient.

(b) This proved difficult for many candidates. Some candidates were able to correctly identify a pH that could be used. However, many had difficulty identifying the charge on the amino acid at a particular pH. Other candidates often referred only to the R group in their explanation and omitted the effect of pH on the COOH and NH_2 groups. Only a few candidates scored full credit here.

(c) (i) This was well answered. Common errors were connectivity errors linked to the CH_2OH and COOH groups.

(ii) Many candidates gained some credit here. Common errors included giving the structure or naming the functional group without highlighting the specific bond responsible for the peak.

Question 8

(a) Many candidates were able to clearly describe this explanation. A common error was omitting any reference to the enthalpy of solution, ΔH_{sol}.

(b) (i) This was less well answered. Many candidates did not appreciate that both acids would be fully ionised.

(ii) This proved difficult for many candidates. Most did not draw a complete Hess cycle here. A wide range of answers was seen for the calculation with only the more able candidates gaining full credit. Common errors included missing out necessary values and incorrect signs.

(c) This was less well known. Many candidates recognised that ethanoic acid was a weak acid but did not explain the difference in standard enthalpy change.

Question 9

(a) This was generally well answered. However a significant number of candidates did not identify the chiral centre in the carboxylic acid.

(b) Structures **H** and **J** were deduced correctly by many. A common error was identifying **H** as an alcohol.

(c) This was usually well answered. Common errors were incorrect structures for the halogenoalkane and acyl chlorides or omitting $AlCl_3$ in steps 1 and 2, omitting 'concentrated' with H_2SO_4/H_3PO_4 and use of $LiAlH_4$ in step 6.

(d) Candidates generally knew the names of the mechanism and reaction.

Question 10

(a) (i) This was well answered. Occasionally d^8 was seen.

(ii) This was less well answered. Many candidates had more than one unpaired electron.

(b) This was generally well answered by candidates.

(c) Candidates found it difficult to apply the information given in the question here. A number of candidates did not provide an explanation.

(d) The majority of candidates gave a correct answer here.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Comments on specific questions

Question 1

(a) (i) This question provided an accessible beginning to the paper for many candidates.

(ii) and **(iii)**
Many candidates did not appreciate that in order to work, the hydroxide compound must be capable of forming a solution, and a visible white precipitate must form when carbon dioxide is added. Barium hydroxide satisfies both of these requirements, magnesium hydroxide does not. Many incorrect answers were seen that focused on the stability of the hydroxide compounds.

(b) This was well known to many candidates. Common mistakes included reference to atomic radii not ionic radii and describing a decrease in polarising ability without identifying the species that is polarised; the carbonate ion.

(c) Many answers were seen that referred incorrectly to the $E^{\ominus}$ values for the reduction of Ni^{2+} and Ca^{2+}. Better performing candidates realised the importance of ionic radii and quoted the relevant data.

Question 2

(a) (i) This question was usually correctly answered.

(ii) This question was highly discriminating. Some excellent answers were seen, that described all or some of the colours, formulae and geometry correctly; many incorrect responses were also seen.

(b) Many candidates worked out that the nickel complexes are square planar and the cobalt complex is tetrahedral. Some of the diagrams drawn did not show these shapes correctly.

Question 3

(a) Many candidates gave a K_c expression not a K_p expression.

(b) (i) and **(ii)**
This calculation discriminated well; many fully correct answers were seen.

(c) (i) Many candidates knew the link between more gas molecules and positive $\Delta S^{\ominus}$; others incorrectly referred to the $\Delta H^{\ominus}$ value.

(ii) Those who knew the Gibbs equation usually answered this question correctly.

(d) Many incorrect answers were given. Some good answers were seen that started with the increase in $T\Delta S^{\ominus}$ as T increases and went on to deduce that $\Delta G^{\ominus}$ will become smaller (or less positive, or more negative) and therefore the reaction becomes more feasible. It should be noted that if a candidate did not write about the $T\Delta S^{\ominus}$ term and instead wrote about the $-T\Delta S^{\ominus}$ term, they should have stated that this term became more negative, not smaller.

Question 4

(a) (i) Many correct definitions of standard electrode potential were seen.

(ii) This question was usually answered correctly. Some candidates incorrectly included the symbol for a cell.

(iii) Common incorrect answers to this question included:

- the use of an iron rod instead of platinum for the Fe^{3+}/Fe^{2+} half-cell
- specifying an insoluble compound such as $AgCl$ for the Ag/Ag^+ half-cell.

(b) (i) Many candidates calculated $E^{\ominus}$cell correctly but did not go on to write an equation for the cell reaction.

(ii) Many candidates had correctly learnt this new material. It was hoped that the method used would be to calculate the new E value for the Ag/Ag^+ half-cell, 0.77 V, and then to subtract this from the $E^{\ominus}$ value for the Fe^{3+}/Fe^{2+} half-cell, 0.77 V, to get the correct answer, 0.0 V.

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(a) (i) This question was usually correctly answered.

(ii) Many candidates realised that the first bullet point meant that the dicarboxylic acids are stronger acids, but did not explain how the second $–CO_2H$ group influences this. The electron donating effect of alkyl groups was known by many.

(iii) Few correct answers were seen.

(b) (i) This was usually well known; some candidates did not specify that a buffer resists change in pH (it does not maintain pH, or keep pH constant) or that this is only when small amounts of acid or alkali are added.

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(a) (i) and **(ii)**
Although the equation in **(i)** was often correct, its importance for the equation in **(ii)** was seldom appreciated.

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- that the lone pair in phenylamine is delocalised over the benzene ring
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(e) (i) and **(ii)**
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Question 7

(a) (i) This question was usually correctly answered.

(ii) Many incorrect answers were seen here, for example omitting the oxygen in the serine side-chain and getting an answer of 217.

(b) (i) Repsonses were usually correct for this part. The commonest mistake was to draw a 2– ion with a $–CO_2–$ group and a $–CH_2O–$ group.

(ii) Common incorrect answers to this question included:

- not specifying that the power supply must be DC
- getting the anode and cathode the wrong way round
- not stating that **I** is buffered.

(iii) Candidates found this to be a challenging question. Many candidates had not noted the presence of Ala-Ser-Gly in the mixture, as given in the question.

(c) (i) Many answers were seen that did not include water, e.g. HCl/heat or H_2SO_4/heat.

(ii) This was answered well by most candidates.

Question 8

(a) This was answered well.

(b) (i) Many candidates gave the correct answer. “Stereoisomerism” was seen on many scripts; this was not sufficiently precise.

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Question 9

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Question 10

(a) This calculation was often done well. A significant number of candidates gave 0.171 as their answer; with the only error being to not appreciate that only one quarter of the resulting solution was titrated.

Many candidates, here and elsewhere on the question paper, used a correct method but arrived at an answer significantly different from the correct answer. This arose because the intermediate answers were rounded off after each step. It would have been better to leave all the figures from each step on the calculator, rounding to two or three significant figures when the final answer was reached.

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(ii) The properties of acyl chlorides were not well known. Many answers for **K** did not fit the formula given.

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(ii) This was often left blank.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

General comments

Candidates should read the questions carefully before starting their answer. It was apparent that in some cases candidates did not recognise where a new experiment started and so based their answers to some questions on the previous experiment.

Candidates should be encouraged to write precise and concise answers in order to avoid possible confusion. There were a number of instances of candidates providing multiple responses to a simple question which sometimes led to contradictions.

Generally answers were given to an appropriate number of significant figures.

Candidates should be given more practice in answering evaluative type questions such as those required to answer **1(d)** and **2(c)**.

As preparation for this paper, candidates would benefit from performing or observing more chemistry practical work. This would also enhance the drawing of apparatus diagrams that represent a particular procedure.

Candidates should avoid writing responses in pencil and then overwriting in ink with the pencil erased. This sometimes produces an answer which is difficult to read.

Comments on specific questions

Question 1

(a) Frequently candidates found difficulty in drawing apparatus. Candidates should aim to keep any drawings simple and clear. The requirements in this case were for labelled reagents showing them coming together at some time in a gastight apparatus that has a gas collecting device. Most candidates had the two reagents together in a gas tight connection to a gas syringe which was a good attempt but lacked the separation of the two reagents within one apparatus. Many candidates had the lithium outside the apparatus and the water within where the only way of uniting them was in opening the stopper leading to some gas loss, this did not fulfil the criteria for credit. Acceptable separation techniques include divided bottom flasks, small inserted test tubes containing a reagent or even water being added from a burette or similar device. Unfortunately a number of potentially excellent diagrams lacked detail, for example stems of thistle funnels not long enough to reach a liquid surface, gas delivery tubes under a liquid surface and lack of a gastight stopper.

(b) (i) Most candidates found this question challenging. Whilst many candidates cut the lithium with a knife the majority did not attempt to clean off the oil. Some unsuitable cleansing techniques such as using solvents or sandpaper were seen.

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CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

Candidates should make sure that they have understood the purpose of an experiment that is described in a question. Their answers should relate directly to the procedures and problems relevant to this experiment.

Diagrams used to describe practical activity, should be clearly drawn with essential components labelled.

Candidates should be reminded to read questions carefully and to answer them as set. For example, it is important that if one example is required in an answer, then only one example is given. Giving more than the required number of points or examples means there is a risk of contradiction.

General comments

There were some very good performances on the paper this year. Many candidates answered the questions well with strong responses seen to many theoretical and numerical parts, particularly those seen in **Question 2**. Some responses to the questions which looked at practical applications in **Question 1** were less strong however.

The more practical work that a candidate has carried out during their studies the more prepared and confident they will be in answering the questions on this paper.

Comments upon specific questions

Question 1

(a) Although nearly all candidates were able to predict the relationship between the two factors, most candidates did not appreciate that both $E^\ominus_{cell}$ and ΔH_r were dependent upon the relative reactivity of the metals. Many focused solely upon the feasibility of the reaction or attempted to explain their prediction in terms of rate of reaction.

(b) The dependent variable here was the type of metal used in the displacement experiment. Many incorrectly stated the number of moles of the metal (which was stated as being constant in the question).

Most candidates realised that the independent variable was the outcome of changing the metal used and gave the correct response of temperature *change* (or *increase*). As the temperature increase led on to calculating ΔH_r, this was also accepted as the independent variable.

A significant proportion of candidates suggested that $E^\ominus_{cell}$ was either the dependent or independent variable suggesting they had not appreciated the simple experiment being carried out.

(c) (i) Any experiment which measures a temperature change needs some form of insulation and the minimum insulation expected was a plastic/polystyrene/Styrofoam cup. The question asked for apparatus which could be used to determine the increase in temperature of a solution of copper(II) sulfate so it was expected that the diagram would include a labelled thermometer clearly inserted into the solution. Weaker candidates thought that heat, in the form of a Bunsen burner, was required.

(ii) Most candidates knew that the temperature increase needed to be determined and that the measurements needed to obtain this were the initial temperature and final (or highest) temperature achieved. Temperature change or increase is not a measurement which can be directly made. The other expected direct measurement was the mass of the sample of metal provided.

(iii) The corrosive nature of zinc sulfate meant that gloves were the one essential safety precaution needed.

(iv) Please not that due to an issue with the data for this question, all candidates were awarded 2 marks for this question part. The published question paper has had the data corrected. The published mark scheme reflects this change.

(v) Candidates usually realised that a quicker reaction would mean less time for heat loss to occur and that smaller particles, with their higher surface area, would bring about an increased rate of reaction.

(vi) Few candidates realised that stirring would mean that all parts of the solution would be of equivalent temperature. One very common error seen was to state “So all the metal would react”. This suggests that candidates had not understood that in each case, the metal was in excess so could not fully react.

(d) This calculation of an enthalpy change of a reaction from experimental data was only performed well by the stronger candidates. There are two steps in such calculations. The first step is using the experimental data and the equation $E = mc\Delta T$ to determine how much energy went into the solution during the reaction. Step 2 involved scaling up to molar quantities. As an indication of the exothermic nature of the question candidates were asked to include a sign in their answer.

Having been told to assume 1 cm^3 of solution weighed 1 g, candidates were expected to determine m to be 50 g. Many candidates thought that m was equal to 1 g. Similarly, many candidates took the value of ΔT given (58.5 °C) and added this to 273 K. One common error made by many was to round off after step 1. Rounding should take place at the end of a calculation and not part way through as this involves introducing rounding errors.

(e) Candidates were generally aware of the apparatus required and followed the instructions to state the concentrations of the solutions used. Poorly drawn diagrams often had an incomplete circuit due to the absence of a salt bridge or due to the salt bridge not being in contact with both solutions.

(f) Only stronger candidates answered this well. The question tested candidates’ understanding of the need to only have two variables and that introducing a non-constant temperature would affect $E^{\ominus}_{cell}$. However, relatively few candidates were aware of this.

(g) This involved candidates using their prediction from **(a)** and their numerical answer to **(d)** to show a trend in ΔH_r values in the table. Most were able to complete this task.

Question 2

(a) Most candidates were able to complete the table without errors in subtraction. A few incorrectly gave answers to three decimal places for the mass values or one decimal place for the volume values.

(b) There were many good plots and lines of best fit seen. Most candidates realised that 2 points were clearly anomalous and consequently drew very good lines. However, the first point from the table (0.15, 48) was often misplotted as (0.11, 48).

(c) There were two syringes present in the procedure; the hypodermic syringe which carried liquid **Y** and from which vapour may have escaped due to evaporation, and the sealed gas syringe. Lack of precision shown by many candidates in their responses often made it difficult to award credit to some answers. It was not easy, at times, to tell which syringe the candidates were discussing.

(i) Candidates needed to realise that if some of liquid **Y** evaporated from the hypodermic syringe between the first weighing and the final weighing then the apparent mass of **Y** used would be higher than the actual amount injected into the gas syringe.

(ii) Most candidates who correctly answered this part chose to keep the syringe as cool as possible although credit was also awarded to those who suggested undertaking the process as quickly as possible. A number of candidates thought that they needed to make the result more reliable by repeating the experiment rather than by modifying the procedure.

(d) (i) The co-ordinates were accurately read by most. Candidates should remember that it is co-ordinates from the line which should be used and not co-ordinates of any points plotted. Also, when choosing the co-ordinates, the range should show the co-ordinates to be wide enough apart to produce an accurately calculated gradient.

(ii) Most candidates produced a correct answer. Some made an incorrect calculation and ended up with an M_r far higher than 1000 g mol^{-1}. A substance with such a high M_r would not be volatile and where such inconsistencies appear in answers candidates are advised to check their working.

(e) The information about **Y** was given in the form of a mass spectrum (enabling candidates to spot that the molecular ion peak showed the M_r to be 84 g mol^{-1}) and percentage composition by mass. It was expected that the empirical formula of CH_2 would be determined followed by realising that 6 units of this added up to 84 g mol^{-1} and consequently the formula of the hydrocarbon was C_6H_{12}.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

General comments

Candidates should read the questions carefully before starting their answer. It was apparent that in some cases candidates did not recognise where a new experiment started and so based their answers to some questions on the previous experiment.

Candidates should be encouraged to write precise and concise answers in order to avoid possible confusion. There were a number of instances of candidates providing multiple responses to a simple question which sometimes led to contradictions.

Generally answers were given to an appropriate number of significant figures.

Candidates should be given more practice in answering evaluative type questions such as those required to answer **1(d)** and **2(c)**.

As preparation for this paper, candidates would benefit from performing or observing more chemistry practical work. This would also enhance the drawing of apparatus diagrams that represent a particular procedure.

Candidates should avoid writing responses in pencil and then overwriting in ink with the pencil erased. This sometimes produces an answer which is difficult to read.

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