CHEMISTRY

> **Paper 9701/12**
> **Multiple Choice**

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

Key messages

- This examination paper provided a suitable challenge to the majority of the candidates.
- Most candidates had sufficient time to finish the Question Paper.

General comments

Candidates found **Questions 1**, **2**, **4**, **6**, **8**, **11**, **14**, **15**, **16**, **19**, **23**, **30** and **40** most accessible.

Questions 17, **27**, **32**, **36**, **37** and **39** were more challenging for candidates. Since four of these more challenging questions are from **Section B**, this suggests that more practice on this type of question would benefit many candidates.

Comments on specific questions

Question 17

The most commonly chosen incorrect answer was **C**. Since $NaClO_3$ is one of the products, the NaOH must be hot and the equation is $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$. Therefore, 0.600 mol of Cl_2 gives 0.200 mol of $NaClO_3$, which has a mass of 21.3 g. Choice **C**, 63.9 g, does not take into account the stoichiometry of the reaction.

Question 27

The most commonly chosen incorrect answer was **A**. The five possible products are HO_2CCO_2H, HO_2CCHO, HO_2CCH_2OH, OHCCHO, $OHCCH_2OH$. The answer is therefore four $-CO_2H$ groups and four $-CHO$ groups. Candidates who chose **A** may not have realised that HO_2CCH_2OH and $OHCCH_2OH$ are also oxidation products of CH_2OHCH_2OH.

Question 32

The most commonly chosen incorrect answer was **B**. This indicates that for many candidates the question rested on the veracity of statement **2**. Statement **2** says "The gas partially liquefies". If this occurred, the volume of the gas would drop by a greater amount than that predicted by the ideal gas equation. In fact, the volume of the gas has dropped by a smaller amount, so statement **2** is incorrect.

Question 36

The most commonly chosen incorrect answer was **C**. This indicates that for many candidates the question rested on the veracity of statement **1**. Statement **1** says that "Sodium chloride is not oxidised by concentrated sulfuric acid". This statement is correct; a reaction does occur but the reaction is not a redox reaction.

Question 37

The most commonly chosen incorrect answer was **B**. This indicates that for many candidates the question rested on the veracity of statement **3**. Statement **3** is true since ethanoic acid, CH_3CO_2H, can be obtained from but-2-ene in a single reaction by treating but-2-ene with a hot, concentrated solution of manganate(VII) ions.

Question 39

Approximately equal numbers of candidates chose each of the incorrect three options. All three of the compounds will react with alkaline aqueous iodine to give a pale yellow precipitate of tri-iodomethane because compounds **1** and **2** contain the CH_3CO- group, while compound **3** contains the CH_3CHOH- group.

CHEMISTRY

> **Paper 9701/22**
> **AS Level Structured Questions**

Key messages

Candidates are to be reminded to read questions carefully and check answers thoroughly. In extended answers, where more writing is required, the accurate use of chemical terminology is welcomed, as it removes ambiguity from responses.

Candidates should look to practise applying their knowledge of organic chemistry.

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

General comments

Good recall of material was seen on most topics; candidates are advised to heed advice on how to answer questions on particular topics, especially infra-red spectroscopy. Responses were generally clear and well presented. As a general point of presentation, it is often difficult to read responses where answers have been written in pencil and then overlaid with ink and not rubbed out.

Comments on specific questions

Question 1

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

(ii)   There were many complete answers. The point most frequently missed was that of the relatively constant shielding from left to right across the third period. Some candidates chose to try to explain a trend from Na to Cl other than atomic radius.

(iii)   Many candidates were able to identify the ions correctly; although a large number of candidates neglected to answer this part. Some responses did not include a sufficient explanation that stated, explicitly or otherwise, that Mg^{2+} has one fewer shell than S^{2-}. Answers referring to relative numbers of subshells or orbitals were not sufficiently precise to gain credit. A significant minority of candidates wrote about increased electron–electron repulsion or increased shielding in S^{2-} compared to S, which was credited.

(b)(i)   The question stated that there was excess oxygen, meaning the product was phosphorus(V) oxide, written as P_4O_{10} or P_2O_5. A large number of candidates incorrectly offered $P \; + \; O_2 \; \rightarrow \; PO_2$ as an answer.

(ii)   Candidates are reminded that observations should be limited to what can be seen, felt or heard. Thus, statements such as "an exothermic reaction" were not credited, as these constituted an inference or conclusion based on observation.

(iii)   Few candidates were able to answer this question correctly. Attention is drawn to the wording of the question in the first instance; candidates were asked to <u>name</u> the compound formed. Many candidates incorrectly stated that phosphorus hydroxide was formed.

(c) (i)   Many answers were not awarded full credit due to a lack of clarity.

Care should be taken in the choice of terminology. The lattice comprises regularly arranged cations, not atoms, and the electrons are delocalised throughout this structure. The size of the charge of the cations was not important in this case. Answers that bore too similar an appearance to an ionic structure were not credited.

(ii) Credit was given to stated physical properties typical of a ceramic; candidates did not need to know anything about CeO_2 specifically to gain marks. Many answers referred incorrectly to typical metal, or gave chemical properties, which were not credited.

(iii) This question was answered well by many candidates. Good responses included clear working and intermediate stages of working.

Question 2

(a) (i) Some candidates showed a reasonable understanding of the concept of bond polarity, though this question was generally answered rather poorly. A common error was simply to restate the term in a different form and many candidates sought to define *electronegativity* instead. Precise use of vocabulary was necessary.

(ii) There were few good answers to this question. Candidates often confused intermolecular forces with covalent bonds and therefore wrote about breaking internal (intramolecular) bonds, rather than overcoming intermolecular forces. Much of the confusion came from a loose understanding or explanation of hydrogen bonding; candidates often suggested that these were the H–F bonds themselves. An explicit statement about a greater energy requirement to overcome the forces between HF molecules compared to the other hydrogen halides was expected in this case.

(iii) The majority of candidates correctly identified the trend in the thermal stabilities going down the group and many candidates could write about the decreasing H–X bond strength. Few candidates were able to relate this to the increasing size of the halogen atom. A common confusion was to relate thermal stability to boiling point.

(b) (i) Candidates found this question challenging. Some candidates were able to define a Brønsted–Lowry acid or base correctly.

(ii) Few candidates were able to identify iodine (I_2) as the salient product. Candidates who wrote correct chemical equations showing the oxidation of I^- to I_2 were awarded both marks.

(c) (i) There were many correct answers to this question, although common incorrect answers included the use of bond enthalpies. Many candidates did not notice the stoichiometry of the chemical equation, or reversed the thermodynamic data to give a positive final answer.

(ii) Candidates should be encouraged to learn a full definition for a catalyst, allowing them to supply a sufficiently detailed answer appropriate to the number of marks available. Answers here often approached what was necessary but did not include enough detail. The mechanism of a catalyst's action, provision of an alternative reaction pathway (of lower E_a), was required. The type of catalyst was often miswritten as "heterolytic".

(iii) Good responses stated whether the (forward) reaction was endothermic or exothermic, which way the equilibrium position would shift and the effect on the composition of the equilibrium mixture. A mere statement of Le Chatelier's Principle was not sufficient.

(iv) Many candidates were able to answer this question correctly, showing the correct method. However, numerous arithmetical errors were seen. Credit was awarded to candidates who could produce an answer for the mole fraction and / or the partial pressure of Cl_2, even if this was based on an incorrect calculation of the numbers of moles of HCl and O_2.

(v) This question was answered well by the majority of candidates.

(vi) This question was answered well by the majority of candidates.

Question 3

(a) (i) Although many candidates could identify pentanenitrile as the product, fewer candidates were able to draw a fully displayed formula, with $-C\equiv N$ and all C–H bonds shown. One common incorrect answer was to draw butanenitrile rather than pentanenitrile; candidates who mistakenly drew the terminal group as $-N\equiv C$ were not credited.

(ii) This question was answered well by many candidates. Attention is drawn to the need for reagents to be specifically identified; $H^+(aq)$, for example, is not a reagent. Candidates are reminded to give details of state and concentration, for example, HC*l* was not accepted, as HC*l*(aq) was needed, and H_2SO_4 needed to be dilute, if used.

(iii) Many candidates made the error of trying to form a polymer using the entire carbon backbone but only the two alkenyl carbons take part in the addition reaction.

(b) Good responses included an accurate representation of the mechanism, showing the correct location of lone pairs and dipoles. Curly arrows should have clearly started at the lone pair or the C–Br bond. The structure of the high-energy intermediate was not required. Many candidates incorrectly presented an S_N1 mechanism.

(c) (i) There were many good answers to this question; some candidates incorrectly wrote nucleophilic addition instead of *electrophilic* addition. Another common incorrect answer was *hydrolysis*.

(ii) Whilst it is true that the iodoform test gives a positive result (yellow precipitate) for a methyl ketone, candidates were directed to comment on the structural feature of **S**, which is not a ketone. Furthermore, it was insufficient to state that **S** is a secondary alcohol as some secondary alcohols such as pentan-3-ol would not give a positive result. A specific comment about **S** being a methyl secondary alcohol, or containing CH_3CHOH- was required.

(iii) Candidates are reminded that Markovnikov's rule does not itself give an answer to a question about the major / minor products of an electrophilic addition reaction to C=C. Good responses included statements on the relative stability of a secondary carbocation (compared to a primary one) and on the increased positive inductive effect of a greater number of vicinal alkyl groups in the secondary carbocation compared to in the primary.

(iv) There were many good answers to this question.

(v) Few candidates gained credit for this question. Many candidates correctly (re)identified compounds **S** and **U** and incorporated [O] into the equation, but the majority of equations were left unbalanced. The most common errors were the omission of H_2O or including incorrect species such as O_2 or H_2.

(d) (i) There were many good answers to this question. Some answers confused propanoate for pentanoate. Candidates are reminded of the need for legible handwriting and unambiguously spelled systematic names.

(ii) Many candidates were able to identify X correctly as being the spectrum corresponding to structure **V**. Few candidates were then able to relate their answer to features on all three spectra; many candidates did not heed the instructions to look only at absorptions at frequencies higher than $1500\,cm^{-1}$.

Candidates are reminded that all infra-red spectral identification needs to be made with reference both to the frequency of absorption and to the resonant bond, e.g. "Spectra X and Z showed absorptions between $1640\,cm^{-1}$ and $1750\,cm^{-1}$, which is indicative of a C=O stretch."

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> **Paper 9701/33**
> **Advanced Practical Skills**

Key messages

Candidates should be given the opportunity to discuss errors in and possible improvements for different procedures during their class practical sessions.

Candidates should note the degree of precision of the apparatus used so that they are able to provide answers correct to an appropriate number of significant figures.

Candidates should be encouraged to read through the tests to be carried out in Question 3 before starting any practical work so that they have some idea of what to look for and what further tests may be necessary.

Candidates should be encouraged to read through their observations for Question 3 to ensure that they are not ambiguous.

General comments

Almost all candidates completed the Question Paper, indicating that a shortage of time was not a factor which significantly affected performance.

Comments on specific questions

Question 1

(a) Almost all candidates recorded a volume of gas; a minority of candidates did not do so in the **Results** section in **(a)**. A substantial majority of candidates gained the accuracy mark for the volume of oxygen collected.

(b) Part **(i)** was the least well answered, which indicated that some candidates either did not read or did not understand the information given on page 2.

Parts **(ii)**, **(iii)** and **(iv)** were answered well by most candidates.

The errors seen tended to be either confusion between cm^3 and dm^3 in **(ii)**, rounding errors, or giving the answer to only one significant figure in **(iv)**.

(c) Candidates should be encouraged to think carefully about any improvements they suggest to a procedure. It is not possible to use a syringe to deliver the $MnO_2(s)$ and, if a syringe or tap funnel is used to deliver the $H_2O_2(aq)$, then the volume of air displaced must be subtracted from the volume of gas collected. Some candidates suggested using a syringe to collect the gas, which did not answer the question asked in **(i)**.

Only a minority of candidates gained full credit in **(ii)** as many candidates either did not multiply by three for the three additions or used the total volume of $H_2O_2(aq)$ added rather than $50\,cm^3$.

Only some candidates gave appropriate answers to **(iii)**. Incorrect comments included that the oxygen would react with the air; the oxygen already present in the air increased the error; or that the gases dissolving in water increased the error.

(d) There were some excellent answers to this question. Some candidates did not explain why the volume of gas collected would be the same. Those candidates who suggested that half the volume of gas would be evolved had not realised the significance of MnO_2 being a catalyst for the reaction.

Question 2

(a)   Many candidates ignored the instruction to record burette readings for the rough titration. Better responses included the correct headings for the accurate table of results. Some candidates did not record their accurate burette readings to $0.05\,cm^3$ and some candidates gave integer values. Candidates should be instructed to continue with the rest of the question once they have obtained two concordant titres; a few candidates recorded as many as seven accurate titres, which would have had implications for the time available for the third question. A large majority of candidates gained at least one mark for accuracy and many gained full credit.

(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 correct to two decimal places.

(c)   Many candidates answered this correctly. The most common error was to give answers to an inappropriate number of significant figures. Confusion between cm^3 and dm^3 was also seen occasionally.

Question 3

(a)   In **(i)**, the observation of the solubility of the precipitate in excess aqueous sodium hydroxide was expected. Candidates should take care that they test the gas evolved, for example by using litmus paper to identify the presence of ammonia.

   When testing with acidified aqueous potassium manganate(VII) in **(ii)**, candidates were expected to look for a change in colour; the response of "colourless" was insufficient.

   Many candidates reported effervescence with **FA 6** in test **(iii)**; few candidates went on to test the gas evolved, contrary to the general instructions at the start of the question.

   The majority of candidates reported obtaining a white precipitate on adding the solution containing barium ions to acidified **FA 6** in **(iv)**. However, no further change was expected on adding barium ions to acidified **FA 7** as the reaction occurred on adding the acid.

(b)   In **(i)**, the most commonly correctly identified ions were Fe^{2+}, SO_4^{2-} and NO_2^-.

   In **(ii)**, a few candidates identified the cation in **FA 7** as Na^+. These candidates need reminding that no additional tests for ions present should have been carried out. A large majority of candidates chose to confirm the identity of Fe^{2+} (or Cr^{3+} if given in **(i)**) and to use aqueous ammonia; the use of aqueous potassium hexacyanoferrate(III) was also seen in **(ii)**. Those candidates who suggested using aqueous sodium hydroxide did not answer the question as this reagent had already been used in **(a)**

   Only a minority of candidates gained credit in **(iii)**. Common errors seen were the inclusion of ammonia or the half-equation for the oxidation of Fe^{2+}.

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Key messages

- The overall standard of answers seemed better than last year.
- Candidates should write clearly in dark blue or black pen.

General comments

A number of candidates did not take enough time to read questions thoroughly. For example, **Question 1(a)(i)** asked for the answer to *two decimal places*; **Question 1(b)(ii)** asked about the structure and bonding in the *oxide* of **A**, not **A** itself; **Question 9(a)(ii)** asked for the identity of the fragment *lost* from **T**, not the daughter ion with m/e 119.

Comments on specific questions

Question 1

(a) (i) Most candidates managed the calculation; some candidates did give their answer to two decimal places, as the question asked.

(ii) Several candidates thought the formula of silicon chloride was $SiCl_2$. Other candidates did not balance their equation. Acceptable answers included SiO_2, $Si(OH)_4$ and H_2SiO_3.

(iii) Some candidates need practice in drawing three-dimensional diagrams. For a tetrahedral structure, two of the bonds should be represented by straight lines within the plane of the paper; one bond should be represented by a solid wedge (pointing out of the plane of the paper); and the fourth bond should be represented by a hatched wedge (pointing into the plane of the paper). The two wedge bonds must be adjacent to each other, not on opposite sides of the two in-plane bonds.
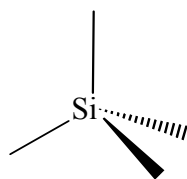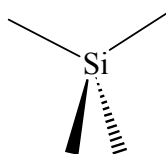
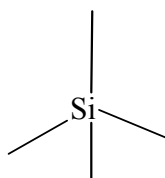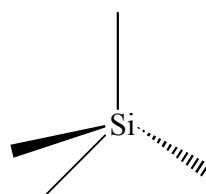Bond angles between 108° and 110° were accepted. Many candidates knew that the tetrahedral angle is 109.5°; some candidates suggested 120° or 104°.

(iv) Most candidates gave the correct formula although several candidates suggested Si_2O_4 or SiO. Most candidates correctly described SiO_2 as a giant covalent compound; fewer candidates also pointed out that $SiCl_4$ is a simple molecular compound. Some candidates answered in terms of the relative strengths of the Si–O and Si–Cl bonds. This was not awarded credit.

(b)(i) Many candidates were able to write a correct equation; some candidates confused "period" with "group" and suggested an equation for the decomposition of $A(NO_3)_4$, rather than $A(NO_3)_2$.

(ii) Most candidates described the bonding as "ionic" but some candidates omitted to state that the structure of the oxide of **A** was "giant", or that the ions were in a lattice. Some candidates misread the question and described the metallic bonding in the element **A**, rather than the bonding in its oxide.

Question 2

(a) Many candidates answered this question well although some candidates thought that electron affinity was only negative (this is not true for the O^- ion, for example), or that enthalpy change of atomisation or lattice energy could be either positive or negative.

(b)(i) Several candidates offered the statement that "the second ionisation energy is always greater than the first", without explaining why this is the case. Arguments in terms of the (electrostatic) difficulty of removing an electron from an already positive ion, or the fact that the Mg^+ ion has one more proton than electron, were accepted. Many candidates incorrectly thought that the second electron was being removed from an inner shell, closer to the nucleus.

(ii) Most candidates correctly identified ΔH_6 as the lattice energy, and ΔH_7 as the enthalpy change of formation. Several candidates confused these two terms.

(c) Most candidates appreciated that electron affinity decreases (i.e. became less negative) down Group 17. Many candidates attempted to explain this by referring to the decrease in electronegativity. Answers in terms of the greater distance of the incoming electron from the nucleus (and hence smaller electron-nuclear attraction) were sought.

(d) Many candidates answered this question well although some candidates gave confused answers. The main problem seemed to be when a candidate approached the calculation by first calculating the *total* entropy, through converting ΔH_r into $\Delta S_{surroundings}$. They were then confused as to which ΔS to use in the equation $\Delta G = \Delta H - T\Delta S$, or how to convert ΔS_{total} into ΔG. Other common errors were using 25 K instead of 298 K for the temperature; not converting ΔS into kJ; or forgetting a minus sign. A significant number of candidates thought that the units of ΔG included K^{-1} or dm^{-3}.

Question 3

(a)(i) Most candidates answered this question well although there was some confusion over the contents of the right-hand electrode system. Some responses included an iron electrode, with either Fe^{2+} or Fe^{3+} as one of the ions in the electrolyte. Other candidates described a cell in which the left-hand electrolyte contained Fe^{2+} ions, whilst the right-hand electrolyte contained Fe^{3+} ions. Some candidates described the gas **A** as either oxygen or chlorine, and a number of candidates did not point out that to measure the *standard* electrode potential, gases need to be at 1 atm, and solutions need to be at $1\,mol\,dm^{-3}$.

(ii) A majority of candidates did not score credit here. Most described the direction of electron flow as going through the voltmeter *from* the positive electrode, rather than *towards* it. Some candidates thought that the hydrogen electrode was the positive one and some candidates suggested that the electrons flow through the salt bridge, rather than through the wires.

(b) This question was answered well. A few candidates incorrectly used the $E^\ominus\,(Cu^+/Cu) = +0.52V$, or $E^\ominus\,(Fe^{2+}/Fe) = -0.44V$.

(c) (i) For numbers that can have positive or negative values, candidates need to make their answers very clear. Phrases such as "more negative" or "less positive" are more exact, and less ambiguous, than "larger" or "smaller", or "increases" or "decreases". Explanations in terms of Le Chatelier's principle or the use of the Nernst equation were expected.

(ii) A significant number of candidates used the Nernst equation correctly. The most common error was to invert the [oxidised species] / [reduced species] ratio. Some candidates did not appreciate that $z = 1$ for this equilibrium (values of z used by candidates included 2, 3, 24 and 52). Some candidates used 0.59 as the multiplier rather than 0.059.

Question 4

(a) (i) Many candidates performed well on this rates analysis question and explained their reasoning clearly. There were a few candidates who had little or no idea as to how to use the data to work out reaction orders.

(ii) Many responses were correct here, showing competence in working out the units for this third-order reaction.

(b) (i) Almost all candidates correctly described the difference between heterogeneous and homogeneous catalysts.

(ii) Most candidates knew the types of catalysis in each of these processes.

(c) (i) Correctly balanced equations were seldom seen. Candidates who calculated and then made use of oxidation number changes tended to be more successful.

(ii) Most candidates did not appreciate that the rate of reaction would be quite slow to begin with (and hence that the curve would be almost horizontal), before speeding up, and then levelling off as $[MnO_4^-]$ approached zero.

(d) (i) Many candidates drew the correct reaction pathway diagram, showing the decreased activation energy in the presence of a catalyst. Fewer candidates explained that catalysts affect the rates of both the forward and backward reactions equally, or that using them in industrial processes results in lower energy requirements.

(ii) Some candidates wrote a K_c rather than a K_p expression. There were many instances of square brackets being used along with p, such as $[p_{NH_3}]^2$, or $p[NH_3]^2$. This confusion should be avoided. Most candidates used the data correctly to calculate a figure for p_{NH_3}.

Question 5

(a) (i) The use of a Lewis acid catalyst (such as $AlCl_3$ or $FeCl_3$) for this Friedel-Crafts alkylation was well known. Some candidates did not specify the isomer of C_4H_9Cl to use; $(CH_3)_3CCl$ was required.

(ii) The need for UV light was known by most candidates; some candidates thought that the reaction required heating as well.

(iii) A significant number of candidates thought the intermediate **G** was $C_6H_5–C(CH_3)_2Cl$ rather than $C_6H_5–C(CH_3)_2CH_2Cl$.

(iv) Most candidates knew that the reagent required was ammonia. Only a few candidates correctly described the need to heat *under pressure*, as otherwise gaseous $NH_3(g)$ would escape before it could react.

(b) This question was well answered, with equations ranging from the simplest, using H^+ as the acid, to more complicated equations involving HCl or H_2O. Several candidates showed the amine behaving as an acid in a reaction with OH^- ions, giving $C_{10}H_{13}NH^-$.

(c) Most candidates correctly described the relative basicities of the three compounds and many candidates explained the trend in terms of electron donation from the alkyl chain of compound **H** and delocalisation of the lone pair over the benzene ring in phenylamine.

Question 6

(a) (i) Almost all candidates answered this question correctly. The most popular answer was the 4-lobed d_{xy} orbital; d_{z^2} was also seen fairly often.

(ii) Most candidates performed well here with the most common error being to suggest that Ni has the configuration $3d^{10}$, or that Ni^{3+} has the configuration $3d^5\ 4s^2$.

(b) (i) There were many good answers here as well as quite a number of incomplete or incorrect ones. The incomplete answers tended to show the splitting in *either* the octahedral *or* the tetrahedral complex but not in both. The incorrect answers tended to show the same splitting pattern for both the octahedral and tetrahedral cases.

(ii) This question was generally well answered. The idea of an electron in the lower d orbital being promoted to an upper d orbital by absorbing energy (or a photon) from visible light was known by most candidates. There were some candidates who thought that the colour was due to certain wavelengths being *emitted* as the electron fell back to the lower level, rather than being the complement of the colour absorbed.

(iii) Candidates who performed well explained that the difference in colour was due to the different energy gap, ΔE, between the two sets of d orbitals in the aquo and amino complexes.

(c) Several candidates suggested that the solution would be blue because blue light is absorbed the most. The majority of candidates correctly predicted green, due to the minimum absorption being in the green region of the spectrum.

(d) (i) Many responses were correct here. The common errors included writing the ligand as Cl_2 rather than Cl, or drawing two structures that were in fact identical (either two cis or two trans isomers). Some candidates used HO_2 or O_2H as a ligand, thinking that if they reversed 'H_2O' the subscript would also change its position. This is **never** the case; subscripts are always written *after* the element symbols that they multiply, never before.

(ii) This question was well answered.

(e) (i) Most candidates drew clear diagrams, showing the three *en* or $H_2NCH_2CH_2NH_2$ ligands around the central vanadium. Some candidates' answers showed two identical structures, rather than mirror images.

(ii) Optical isomerism was known by most candidates.

(f) (i) Most candidates performed well on this question; some candidates included $[H_2O]^6$ in their K_{stab} expression, or showed the charges of complexes *outside* the brackets representing concentration. Candidates need to be careful when describing the concentrations of complexes; often *two* sets of square brackets are needed, e.g. $[[Ni(NH_3)_6]^{2+}]$.

(ii) A large number of candidates suggested that $[Ni(en)_3]^{2+}$ (or $[Ni(NH_3)_6]^{2+}$) would be produced in the larger amount because it was the *less* stable complex, rather than because it was the *more* stable.

(iii) A minority of candidates were awarded full credit here. Most candidates appreciated there would be cis and trans isomers but few candidates understood that there are also non-superimposable mirror image isomers of the cis isomer, making three isomers in total. Many candidates did not appreciate the bidentate nature of *en*, and so suggested square planar rather than octahedral complexes.

Question 7

(a) Most candidates recognised the two chiral carbon atoms in the structure of *Advantame*; several candidates also circled other non-chiral carbon atoms.

(b) (i) Many candidates answered this question correctly but some candidates omitted to state that the acid (HCl, H_2SO_4 or H^+) needed to be aqueous and that the reaction mixture required heating.

(ii)   The term *hydrolysis* was known by most candidates; a few candidates thought that this was a reduction reaction.

(iii)   A common incorrect suggestion was methane, CH_4.

(c) (i)   Many candidates correctly deduced that a white precipitate would be observed (in an orange-brown solution, as the aqueous bromine was in excess).

(ii)   Many candidates only reacted one of the –OH groups of **J** with aqueous sodium hydroxide. Other candidates recognised that its structure contained two $-CO_2H$ groups and a few candidates correctly reacted the phenolic –OH as well, forming the tri-sodium salt. Equations were often left unbalanced, with too few moles of NaOH or H_2O.

(d) (i)   Most candidates appreciated that no change would be observed when aqueous bromine is added to **K**, as it contains no phenol or alkene group.

(ii)   Many candidates realised that **K** would form a polypeptide on polymerisation. Some candidates did not draw the –CONH– linkage in a fully displayed form, or drew the structure of a dipeptide (with –NH_2 and $-CO_2H$ as terminal groups), rather than two repeat units of the polypeptide chain. Some candidates drew only one repeat unit.

(e) (i)   Apart from the three distinct carbons in the side chain, there would be four different carbon environments in the phenyl ring, making a total of seven carbon environments. The most common responses were four or seven.

(ii)   Almost all candidates correctly identified x as an aryl carbon and y as the sp^2 carbon in the $-CO_2H$ group.

Question 8

(a)   Many candidates correctly described this as an oxidation (or dehydrogenation) reaction; some candidates then went on to reverse the functional groups and state that a carbonyl group was changed to an alcohol. A few candidates suggested that the product was a carboxylic acid.

(b) (i)   Dehydration or elimination were accepted answers. Several candidates suggested reduction or hydration.

(ii)   Al_2O_3 with heating was the most popular answer. Some candidates used hot H_2SO_4 or H_3PO_4 and gained credit for this.

(iii)   Candidates found this question challenging. Several candidates did not split the molecule at the double bond. Some of those candidates who did split the C=C bond produced two aldehydes rather than two carboxylic acids, or omitted the ketone group at the position two of the aryl acid, or included an extra CH_2 in the chain of the alkanoic acid.

(c)   Most candidates recognised that the last two tests indicated that zingerone contains a ketonic carbonyl; fewer candidates related the red precipitate in the first test to the presence of a phenol (or phenylamine).

Question 9

(a) (i)   This calculation was competently done by most candidates.

(ii)   Once nine carbon atoms had been accounted for (= 108 amu), the mass of the rest of the molecule could be calculated as $150 - 108 = 42$. This could be either $H_{10}O_2$ or $H_{26}O$. A chain of nine carbon atoms and one oxygen atom does not have enough spare valencies to accommodate 26 hydrogen atoms, so the formula must be $C_9H_{10}O_2$. Although many candidates performed well here, other candidates did not relate the M_r of their formula to the mass spectrum and suggested $C_9H_{10}O$, $C_9H_{18}O$ or $C_9H_{20}O$.

(iii)   Many candidates misread the question and worked out an identity for the actual peak at m/e = 119, rather than the fragment *lost* from **T**, which was CH_3O.

(b)   Almost all candidates correctly identified **V** as being produced by the C=O bond and **W** by the C–O bond.

(c) (i)   The expected answer was given by many candidates.

(ii)   Candidates performed well here. A few candidates suggested that the peak could be due to an alkyne proton, despite the question stating that the proton was attached to a *saturated* carbon.

(iii)   Most candidates knew the H–D exchange reaction; several candidates then stated that **T** contains an –OH or –NH group, rather than the reverse.

(d)   Candidates found this question challenging. Many candidates did not attempt it. Many candidates did not refer back to the NMR spectrum to realise that **T** contained only four aryl protons, so must contain a disubstituted ring. Two 3H singlet peaks indicated two –CH$_3$ groups, one of which had to be bonded directly to an oxygen atom.

CHEMISTRY

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Paper 9701/52
Planning, Analysis and Evaluation

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Key messages

- Candidates should read the introduction to each question to make sure that they understand what is happening in the experiment.

- Centres should include as much practical work as possible in their chemistry courses, so that candidates are familiar with common experimental techniques and apparatus. It was apparent that many candidates did not recognise the techniques involved in **Question 1**, which was based upon a very common A Level practical.

- If one answer is required, then candidates should only give one answer, to avoid confusion.

- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers.

General comments

In **Question 1**, many candidates were unaware that, to calculate the enthalpy change using this technique, the exact initial temperature of the solution is required. Furthermore, some candidates seemed unaware of the need to insulate the reaction vessel.

In **Question 2**, drawing graphs is a skill in which candidates should be proficient. Many candidates clearly had good graph drawing skills but other candidates' skills were poor. Candidates are advised to show their points clearly by using a cross, "×", with the intersect of the cross' lines being the exact coordinates on the grid. Alternatively, a point within a circle, "⊙", would be suitable, with the point being the exact coordinates on the grid. Candidates should be aware that a single point (with no circle) may no longer be visible if a line of best fit is drawn over it.

Comments on specific questions

Question 1

(a) Very few candidates appreciated that this decomposition needs heating, so it is therefore very difficult to measure a temperature change. Many candidates incorrectly assumed that this decomposition was an exothermic process.

(b) Many candidates seemed completely unfamiliar with this experiment. A significant number of candidates did not appear to refer to the data provided in the table. Very few candidates realised that the sodium carbonate was added at four minutes. The most common errors in candidates' diagrams were showing no insulation of the reaction vessel and suggesting that the mixture would be heated with a Bunsen burner.

(c) Many candidates were unable to answer this question, indicating a lack of familiarity with the experiment.

(d) The equation of $\Delta H = -mc\Delta T$ was seldom applied correctly. The mass of solvent, m, was frequently given as 3.18 g or 53.18 g instead of the correct 50.0 g. Many candidates erroneously added ΔT (5.3 °C) to 273 K to give a value of 278.3 K as ΔT.

Having obtained a figure for ΔH, many candidates were unable to convert the energy change produced by 3.18 g of sodium carbonate to molar proportions. Some candidates did not record their final answer to three significant figures.

(e) (i) A relatively large number of candidates realised that the hydrochloric acid was allowed to equilibrate to room temperature before the solid was added. Many other candidates gave vague answers relating to measuring the initial temperature.

(ii) Many candidates realised that the reaction had not finished at five minutes. The most common errors were that the temperature was measured at the wrong time or to suggest heat loss.

(f) Many candidates realised that residual solid could be left in the weighing boat, making weighing by difference the more accurate method.

(g) (i) As only one reading is taken when using a measuring cylinder, the expected error would be half a graduation (0.5 cm^3) divided by the volume measured, expressed as a percentage. The majority of candidates were unaware of this and 2% was a very common answer.

(ii) Most candidates realised that the concentration of the hydrochloric acid did not need to be measured accurately because the hydrochloric acid was in excess.

(iii) Relatively few candidates realised that using a larger mass of sodium carbonate (or a smaller volume of excess hydrochloric acid) would create a greater temperature increase, therefore reducing the percentage error. Many candidates suggested a change to the apparatus, despite the fact that they had been told not to do so.

(h) This question was rarely answered correctly. The information given indicated that the reaction was *endothermic*. Very few candidates drew an initial horizontal line from $x = 0$ to $x = 4$ minutes and a second line starting at $x = 4$ minutes from a lower temperature and gradually rising towards the temperature of the first line.

Some candidates drew the first line correctly but made errors with the second line. Many candidates simply redrew the original graph shown **1(b)** and some candidates drew single curve.

(i) The Hess cycle was provided and many candidates were able to obtain the correct answer. A frequent error was to omit the doubling of ΔH_2.

Question 2

(a) (i) This question was answered correctly by the majority of candidates. Some candidates worked out the correct answer (2.019 g) but did not record their final answer to an appropriate number of significant figures.

(ii) It was clear that many candidates did not know how to prepare a standard solution from a solid. The key points are:

- using a relatively small volume of distilled water to dissolve the solid in a beaker
- transferring this solution (with "washings") into a volumetric flask and topping up the volumetric flask to the (100.0 cm^3) mark with distilled water, followed by (several) inversions to ensure a homogenous solution.

Some candidates were unaware of the need for a volumetric flask. Other candidates showed poor experimental technique by adding the solid iron(III) nitrate directly into the volumetric flask. Some candidates decided to dissolve the solid in 100.0 cm^3 of (distilled) water before transferring this solution to the volumetric flask. Many of the candidates who knew the correct technique failed to state that distilled (or deionised) water should be used in both steps.

(b) (i) Plotting of the graph was generally very good although a few candidates missed out the points on both origins. Most candidates used rulers to draw the straight lines of best fit, but many candidates failed to extrapolate them to their cross-over point.

(ii) Most candidates were able to read the volumes required correctly from the graph but a significant number of candidates gave answers which added a total volume other than $10\,cm^3$.

(iii) This was a calculation that proved challenging for candidates. Most candidates did not realise that, as a mole ratio within a formula, the final answer needed to be a whole number.

(iv) The determination of the correct formula proved particularly challenging. Many combinations of ions were offered for the formula of the complex, often adding 2-hydroxybenzoate ions to the original complex ion without substituting for the water. The number of 2-hydroxybenzoate ions used in the complex did not always relate to the answer determined in **2(b)(iii)**. Many candidates were unaware that it is convention to show the overall charge outside the square brackets, rather than the charges on the individual ligands within the brackets.

(v) Most candidates knew that in order to measure small, variable volumes of solutions accurately, a burette (or *graduated* pipette) should be used.

(c) Many candidates did not realise that doubling the volumes would have no effect on the concentration of the solutions and consequently gave an absorbance double that expected.

(d) Most candidates were able to give the correct units of the constant.