CHEMISTRY

Paper 9701/11
Multiple Choice

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

General comments

Thirteen questions were found to be more straightforward. **Questions 1**, **2**, **7**, **8**, **10**, **11**, **12**, **25**, **26**, **28**, **29**, **31** and **36**.
Six questions can be said to have been found to be more difficult. **Questions 3**, **13**, **16**, **30**, **32** and **34**.
These questions will now be looked at in greater detail.

Comments on specific questions

Question 3

The most commonly chosen incorrect answer was **C**. The question hinges on the ability to construct the balanced chemical equation for the reaction from the information given in the question.
A possible sequence of decisions is as follows:

1. $Al_4C_3 + NaOH \rightarrow NaAlO_2$ this is the information in the question
2. $Al_4C_3 + NaOH \rightarrow 4NaAlO_2$ balancing for aluminium
3. $Al_4C_3 + 4NaOH \rightarrow 4NaAlO_2$ balancing for sodium
4. $Al_4C_3 + 4NaOH + 4H_2O \rightarrow 4NaAlO_2$ balancing for oxygen – water must be involved
5. $Al_4C_3 + 4NaOH + 4H_2O \rightarrow 4NaAlO_2 + 3CH_4$ balancing for carbon and hydrogen gives CH_4

Question 13

The most commonly chosen incorrect answer was **A**. If we assume that the initial number of moles of H_2 is 1 and the initial number of moles of I_2 is 1 then the equilibrium amounts can be given as $H_2 = 1-y$, $I_2 = 1-y$, and

HI = 2y, where y is the number of moles of H_2 that reacted. The mole fraction of HI at equilibrium, x, is therefore 2y/2, which simplifies to y, so $x = y$. This means that $K_p = 4x^2/(1-x)^2$.

Question 16

The most commonly chosen incorrect answer was **D**. Since X and Y are in the same group of the Periodic Table, and the first ionisation energy of X is greater than the first ionisation energy of Y, X is above Y in its group. The answer therefore cannot be **B** or **C**. If the answer is **D** and Y is phosphorus, Z would have to be aluminium or silicon, but neither element has a lower melting point than phosphorus. If X = boron, Y = aluminium and Z = phosphorus all the information in the question is correct, so the answer is **A**.

Question 30

The most commonly chosen incorrect answer was **C**. When one b-carotene molecule is treated with hot, concentrated acidified $KMnO_4$ the six membered rings on each end of the molecule will each produce a molecule with a ketone functional group. In addition the four $-CH-C(CH_3)=$ sections of the chain will each produce CH_3COCO_2H. This makes a total of six product molecules that contain a ketone functional group.

Question 32

Answers **A**, **B** and **C** were each similarly incorrectly chosen by candidates. The answer is **D** because KCN will react with bromoethane to form propanenitrile which is hydrolysed by dilute HCl to give propanoic acid.

Question 34

The most commonly chosen incorrect answer was **C**. 21% of candidates chose this answer. **C** is incorrect because the ethyl group is electron-donating, this will tend to concentrate negative charge on the oxygen, not to delocalise it. This has the effect of making the oxygen in $CH_3CH_2O^-$ more negative, so $CH_3CH_2O^-$ is a stronger base, the answer is therefore **B**.

CHEMISTRY

Paper 9701/12
Multiple Choice

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

General comments

Questions 1, **6**, **9**, **12**, **13**, **18**, **24**, **28** and **31** were found to be the most straightforward.

Many candidates found **Questions 17**, **26**, **29**, **35**, **38** and **40** to be more challenging. It should be noted that four of these six questions are from the organic section of the syllabus. The questions that were found to be particularly difficult will now be looked at in greater detail.

Comments on specific questions

Question 17

The most commonly chosen incorrect answer was **C**. Statement 1 is untrue as adding an inert gas at constant volume does not affect the concentrations of the other gases and so has no effect on the rate of the forward or backward reactions. Statement 2 is true. If hydrogen iodide is added at constant volume equilibrium is re-established with higher concentrations of all three gases. This means that the rate of the forward reaction is increased at equilibrium. Statement 3 is true. Decreasing the volume causes a higher concentration of all three gases.

Question 26

The most commonly chosen incorrect answer was **A**. The ammonium ion is indeed an acid, as it donates a H^+ ion to the OH^- present. Water also behaves as an acid, as it donates a H^+ ion to the ammonia gas that is formed. Candidates may have been unwilling to describe **both** the ammonium ions and the water molecules

as acids, but it should be noted that these two species are participating in different reactions in different places.

Question 29

This question can be made more straightforward to answer if structures are drawn. If both double bonds are cis this is one isomer, if both double bonds are trans this is a second isomer. If one double bond is cis and one is trans this is the third isomer. It can be seen from diagrams that in this third case it does not matter which double bond is cis and which is trans – the two structures are the same.

Question 35

The most commonly chosen incorrect answer was **D**. Compound D has a tertiary alcohol group, which cannot be oxidised, and an aldehyde group which is oxidised to a carboxylic acid group. Therefore the oxidation product has no carbonyl group to form orange crystals with the 2,4-DNPH reagent. Compound A has a primary alcohol group which is oxidised to a carboxylic acid group and a secondary alcohol group which is oxidised to a ketone. Therefore the oxidation product has an –OH group to produce hydrogen gas with sodium metal and a carbonyl group to form orange crystals with the 2,4-DNPH reagent.

Question 38

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

The six esters are:

1. methyl butanoate, $CH_3CH_2CH_2CO_2CH_3$
2. methyl methylpropanoate, $(CH_3)_2CHCO_2CH_3$
3. ethyl propanoate, $CH_3CH_2CO_2CH_2CH_3$
4. propyl ethanoate, $CH_3CO_2CH_2CH_2CH_3$
5. butyl methanoate, $HCO_2CH_2CH_2CH_2CH_3$
6. 2-methylpropyl methanoate, $HCO_2CH_2CH(CH_3)_2$

Question 40

The most commonly chosen incorrect answer was **A**. The five peaks will have masses of 32, 33, 34, 35 and 36. Candidates who gave **A** as an answer may have been thinking of peaks with masses of 32, 34 and 36 only. However mass 33 arises from $^{16}O^{17}O$ and mass 35 arises from $^{17}O^{18}O$.

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Paper 9701/13
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CHEMISTRY

Paper 9701/21
AS Level Structured Questions 21

General comments

Definitions and basic concepts of chemistry are still causing candidates difficulties, particularly with enthalpy and isomerism topics. Definitions should explain accurately what the term means.

The use of brackets to surround side-chain groups, should be encouraged, when writing structural formulae.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to complete the table to show the number of electrons in the 3p subshells of P, S and Cl, as 3, 4 and 5 respectively.

   The total number of unpaired electrons in these elements proved challenging for some candidates, Common incorrect answers were 1, 0 and 1 respectively.

(ii) The equation to represent the first ionisation of P was well answered. A common error was to omit the state symbols of (g) throughout.

(ii) The question required candidates to choose one of three possible values, given in the question, to represent the first ionisation energy of S and to explain their choice.

   Most candidates did not mention that S has a pair of electrons in a 3p **orbital**, which experience spin-pair repulsion. This results in S having an ionisation energy value of $1000 \, kJ \, mol^{-1}$, which is lower than both P and Cl. The explanation required candidates to recall that whilst S has a nuclear charge higher than P and lower than Cl, its nuclear attraction to the outer electrons is the lowest of these three elements.

   Many candidates chose a value between P and Cl and supported their choice with a incorrect statement that the 'nuclear attraction to the outer electrons' increased across the period.

(b) (i) The full electronic configuration of the P^{3-} ion was well answered as: $1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^6$.

(ii) The decrease in ionic radius from P^{3-} to S^{2-} and Cl^- was well answered. Many correct explanations included mention of an increased attraction of the outer electron to the nucleus resulting from an increased nuclear charge with each ionic species having the same shielding.

(c) Observations were required for three tests carried out on separate samples of NaCl(aq).

   When Br_2(aq) is added to a sample no reaction occurs, and the colourless solution of NaCl(aq) turns orange (because of the added Br_2).

   Most answers stated that the observation from the addition of concentrated H_2SO_4 to NaCl(aq) is misty/steamy fumes, not recognising that the NaCl is in aqueous solution (and not a solid). The solution remains colourless as there is no visible reaction.

   A white precipitate is formed when $AgNO_3$(aq) is added to NaCl(aq).

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(d) (i) This question provided information that the chemical behaviour of $POCl_3$ is similar to that of PCl_5; $POCl_3$ has a low melting and boiling points and reacts vigorously with water suggesting that the structure and bonding of $POCl_3$ is simple covalent.

A small number of candidates gave a good explanation for this information and appreciated that the '*simple*' structure of $POCl_3$ was related to weak intermolecular forces of attractions and that the '*covalent*' nature of the compound is linked to the *hydrolysis* reaction with water.

(ii) The equation for the reaction of $POCl_3$ with water was generally quite well answered. Errors included an incorrect formula for H_3PO_4 and/or incorrect ratio between the water molecules and HCl product.

(iii) Most candidates were awarded full marks for the dot-and-cross diagram. A common error was the use of a dative bond between the P and O atoms.

(e) (i) Most candidates were awarded the first mark for the definition of the enthalpy change of formation, for stating 'enthalpy change when 1 mole of a compound is formed'. However, very few correctly stated the second requirement that it is 'from its elements in their standard states'.

Many answers mentioned standard conditions which was not a requirement.

(ii) The calculation of the bond energy of P=O (in PCl_3), using ΔH_f and bond energy (O_2) data, proved challenging for most candidates.

Use of incorrect energy cycles was the major problem and full marks were rarely awarded.

A correct energy cycle is:

$$\Delta H_r$$
$$2PCl_3(g) + O_2(g) \quad \rightarrow \quad 2POCl_3(g)$$
$$2(-289) \qquad\qquad 2(-592)$$
$$2P + 3Cl_2 + O_2$$

$\Delta H_r = 2(-592) - 2(-289) = -606$ kJmol^{-1}

bonds broken	bonds formed
~~6 P–Cl~~	~~6 P–Cl~~
1 O=O (496)	2 P=O

$$496 - 2P{=}O = -606$$
$$-2P{=}O = -1102$$
P=O = 551kJmol^{-1}

Question 2

(a) (i) The solubilities of group 2 hydroxides 'increases' down the group; this variation in solubilities was correctly stated by many candidates

(ii) When barium oxide is added to water the observation is that the white solid dissolves/disappears to form a colourless solution. A common error was that there was bubbling/effervescence seen.

(iii) In the given reaction scheme, reaction 2 involved the formation of $BaCO_3$ and water from adding a reactant to $Ba(OH)_2$. Carbon dioxide, CO_2, is a reactant that would form both the carbonate and water. Many answers included a metal carbonate which would not give water as a product.

(iv) The addition of ethanoic acid to $Ba(OH)_2$ gave barium ethanoate, $(CH_3COO)_2Ba$, as the product.

Many candidates appreciated that barium ethanoate was formed but opted to answer using a formula of $(CH_3COO)Ba$, which was not creditworthy.

(v) $Ba(OH)_2$ and hydrogen are formed when Ba is added to water and the equation is:

$$Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$$

A common error was to use only 1 mole of water molecules and water formed as a product.

(b)(i) The thermal stability of group 2 carbonates increases down the group; hence, when barytocalcite, $BaCa(CO_3)_2$, is heated $CaCO_3$ will decompose first. Most answers correctly stated that $CaCO_3$ would decompose first but explanations compared the reactivity of Ca with Ba.

(ii) The equation to represent the thermal decomposition of $BaCa(CO_3)_2$ was often correct.

$$BaCa(CO_3)_2 \rightarrow BaO + CaO + 2CO_2$$

Common errors included answers with BaCa as a product or omitting $2CO_2$ as a product.

(c) Full credit for the hydrolysis reaction was rarely awarded. The two organic products are methanol, CH_3OH, and the diacid.

That both the $-CN$ and $-CO_2CH_3$ groups will undergo hydrolysis was not recognised by many candidates. The $-CN$ group was frequently left unhydrolysed and the product methanol was not given as the second organic product.

Question 3

(a) The definition of an oxidising agent, as a species that oxidises another species, and is reduced in the process by the gain of electrons, was overall generally well answered.

(b) This question required the completion of an energy diagram/energy profile to represent the catalytic effect of $MnO_2(s)$ on the decomposition of $KClO_3(s)$. This entailed drawing two labelled curves representing the uncatalysed and the catalysed profiles.

Many answers were awarded full credit. Common errors included unlabelled diagrams or profiles with only one curve.

(c) The term *disproportionation* is used to describe the oxidation and reduction of a single element, in the same chemical reaction. Here the reaction involved $KClO_3$ being converted to $KClO_4$ and KCl, in which the Cl is both oxidised and reduced in this reaction.

Many chose the correct element; there were, however, several answers that identified K or $KClO_3$ as the species undergoing simultaneous redox.

(d)(i) PV=nRT was successfully used by many candidates to calculate the volume of 1 mole of gas, in a reaction of glucose with molten $KClO_3$, to give the correct answer of $0.0524\ m^3$, to 3 significant figures.

$$4KClO_3 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 4KCl$$

Several candidates did not appear to read the question carefully and gave answers with an incorrect number of sig. figs and/or incorrect rounding of their answers.

(ii) This question required the calculation of the moles of glucose, (5/180) and to use this value, together with their answer from 3**(d)(i)**, to calculate total volume of the gaseous CO_2 and H_2O in the equation.

Many candidates were able to correctly calculate the moles of glucose but then failed to multiply this value by 12 to determine the total moles of CO_2 and H_2O produced.

Several answers then continued to repeat the calculation in 3**(d)(i)** instead of using their answer from 3**(d)(i)**.

(e) (i) A high proportion of candidates correctly identified the number of primary, secondary and tertiary alcohol groups, in glucose, as 1, 4 and zero, respectively.

(ii) This question required observations for three tests.

The observation for a reaction of glucose + warm, acidified $KMnO_4(aq)$ is that the solution changes from purple to colourless.

Many candidates were given credit for a correct observation.

Glucose + warm, Fehling's reagent gave an orange/red precipitate which again was recognised by many candidates. Several candidates omitted the precipitate or stated that a silver mirror formed.

Glucose + warm, alkaline $I_2(aq)$ was incorrectly stated as a yellow precipitate by many candidates. There is no reaction with glucose, so the solution remains colourless.

(iii) Several candidates were able to correctly define *structural isomers* as 'molecules with the same molecular formula but different structural formulae'.

Question 4

(a) (i) Most candidates correctly gave the systematic name of the alkene **D**, with a molecular formula of C_5H_{10}, as **3-methylbut-1-ene**.

(ii) Few candidates gave a correct explanation of why the alkenes, **C** and **D**, did not exhibit geometric isomerism.

In **C**, one C (in the C=C bond) has two methyl groups and in **D**, one C (in the C=C) has two hydrogen atoms; neither will exhibit geometrical isomerism.

(iii) Many candidates gave pent-2-ene, or **C** or **D** as examples of a positional isomer.

(iv) When **D** is reacted with $H_2(g)$, 2-methylbutane, $CH_3CH(CH_3)CH_2CH_3$, is formed. Many candidates omitted the brackets surrounding the side-chain methyl group, on the CH group.

(v) Many candidates gave a monomer containing only two methyl groups or structures that still contained a double bond.

(b) The question contained information regarding the relative intensities of the M and (M + 1) ions, from a mass spectrum of **C**, which showed a molecular ion peak at 70.

Many candidates correctly calculated that C contained 5C atoms but then failed to use this information, in conjunction with the molecular ion peak, 70, to confirm that the molecular formula of C was C_5H_{10}.

(c) (i) The mechanism for the addition of HBr to **C,** 2-methylbut-2-ene, was quite well answered. Common errors included full charges on the H-Br, instead of a dipole, curly arrows, from C=C to $H^{\delta+}$ of HBr, arrows starting at one end of the C=C bond and intermediates with both a –ve charge and a partial negative charge.

(ii) This question was well answered with a common error being the use of C_3H_7, instead of the unambiguous expanded version, $(CH_3)_2CH–$.

(iii) This question required an explanation as to why different major products were formed when HBr reacts separately with C and D.

Many candidates appreciated that methyl/alkyl groups are responsible for a positive inductive effect and that the more alkyl groups, surrounding the carbocation, the more stable is the carbocation intermediate. However, the application of this concept to the intermediates of C and D was not well recognised.

Common errors were statements that the tertiary halogenoalkane was more stable, in C, and the secondary halogenoalkane was more stable, in D, rather than their respective intermediate carbocations.

Many candidates quoted Markovnikov's rule without any further explanation.

(d)   *Please note that due to an issue with diagram labelling in this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged. This has been corrected in the published version of the paper.*

The question required completion of a table of reagents and conditions for a reaction scheme.

The formation of alcohol, **F**, from a halogenoalkane, **E**, required the use of NaOH(aq).

Cleavage of the double bond, in **C**, to form a carboxylic acid, **G**, and propanone, was carried out using hot acidified <u>concentrated</u> $KMnO_4$.

The formation of ester, **H**, from **F** and **G**, needed <u>concentrated</u> H_2SO_4 (as a catalyst).

CHEMISTRY

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

Key messages

- Candidates who demonstrated a good knowledge of key definitions and applied well-rehearsed arguments to appropriate situations scored more marks.
- Candidates who produced vague, imprecise definitions and used details of knowledge with less accuracy and, on occasions, indiscriminately scored lower marks.

General comments

Candidates are expected to balance all chemical equations.

Representation of equations to show specific reactions, for example ionisation energy of an element, should contain all relevant details including state symbols.

Comments on specific questions

Question 1

(a) (i) The variation in atomic radius from silicon to sulfur was, in general, well known.

(ii) Many candidates appreciated that the differences in melting points were a consequence of the differences in structures. Identification of the types and relative strengths of the forces of attraction broken during melting were referred to less often. Common misconceptions included the presence of intermolecular forces in silicon or did not refer to intermolecular forces, neither in general terms, nor as instantaneous dipole induced dipole attractions in sulfur.

(b) (i) Most candidates correctly calculated the number of electrons in p subshells.

(ii) Many equations showed appropriate species. State symbols, essential in any equation to represent the first ionisation energy process, were included less often.

(iii) Candidates with an excellent knowledge of the trend in ionisation energy across a period identified the correct ionisation energy for phosphorus. They explained both the general trend and the effect of spin pair repulsion on a pair of electrons in a p orbital of sulfur compared to phosphorus. Weaker candidates either identified the value which represents a general trend in ionisation energy across the period and explained this trend or identified the correct value for ionisation energy with details that only explained why sulfur had a lower first ionisation energy than phosphorus.

(iv) This was answered well by most candidates.

(v) Appropriate description of the shape of an SCl_2 molecule as 'bent' or 'v-shape' was seen often. 'Linear' was a common incorrect answer.

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Question 2

(a)   Some candidates appeared to confuse graphs of rate versus time with those showing concentration versus time.

(b)   Well-rehearsed arguments related the significance of increasing temperature on the position of equilibrium to the example given. More able candidates showed no ambiguity and made explicit reference to the effect of an increase in temperature on the position of this equilibrium in terms of either the '*forward reaction is exothermic*' or '*the reverse reaction is endothermic*'. Less precise answers included '*the reaction moves backwards as it's an exothermic reaction*'.

(c)   This question proved to be demanding. A few candidates found K_p using an appropriate method; they worked out the mole fraction of the components, converted them into partial pressures and then substituted these values into the correct expression for K_p. Weaker candidates calculated K_p directly from moles and included moles in the units. Deduction of units also presented difficulties. Many answers gave units in terms of Pa with no attempt to convert kPa to Pa within the calculation.

(d)   Lightning was well known as a natural process responsible for formation of atmospheric NO and NO_2. 'Catalytic converter' as the man-made process was a common incorrect answer.

(e) (i)   Many correct definitions of the term free radical were seen. Ambiguous descriptions referred to '*unpaired electron*' as '*unshared*' or '*unbonded*' or '*free*'. Common incorrect answers referred to a free radical as '*a species with a lone pair of electrons*'.

(ii)   The pair of equations which showed the catalytic role of NO_2 in the oxidation of SO_2 were not well known. The equation to represent the regeneration of NO_2 appeared to cause most difficulties with many incorrectly balanced equations seen.

(iii)   The environmental consequence of the oxidation of sulfur dioxide was well known.

(f) (i)   Identification of a magnesium containing base was relatively common. Incorrect answers included salts, rather than bases, which contained magnesium or bases that were not made from magnesium. The formula of the compound identified was not always correct.

(ii)   This equation proved challenging for many. Some answers incorrectly balanced equations which included all correct species. Use of an incorrect formula for magnesium nitrate was a common error, including Mg_3N_2.

(iii)   Identification of the change in thermal stability down Group 2 nitrates was fairly well known.

Question 3

(a) (i)   Fully balanced equations were seen by more able candidates.

(ii)   This definition was described accurately in most candidates answers. A common misconception was seen in weaker responses that described a weak acid as one that '*did not completely dissolve*'.

(b) (i)   Many candidates gave a definition of the enthalpy change which occurs when 'one mole of product is formed from its elements'. It was less common for the elements to be described as 'in their standard states'.

(ii)   More able candidates gave excellent and logical workings that contained clearly labelled energy cycles. It was common to see an expression for the different bond energies added or subtracted from each other, in a variety of possible incorrect combinations, with no attempt to show how these expressions were deduced. The stoichiometry of the equation was ignored by some.

(iii)   Excellent answers were seen which identified phosphorus in H_3PO_3 as both oxidised and reduced and linked the process of oxidation and reduction to the relevant changes in oxidation number for the three phosphorus containing species. Weaker responses were less specific, for example '*H_3PO_3 is oxidised and reduced*'. Oxidation numbers were sometimes described incorrectly.

(c) (i) Some candidates identified **A** as steam or $H_2O(g)$, other candidates were less precise and identified **A** as water. A common incorrect answer was NaOH.

(ii) Many unambiguous representations of 2-bromopropane were seen. Occasionally the central carbon atom was drawn with a valency of 3.

(iii) Description of this esterification reaction as a condensation reaction was relatively well known. Incorrect answers included hydrolysis and oxidation.

(iv) This question proved to be demanding. Candidates were expected to ignore all bonds which were common to both reactant and product. While the appropriate bond, C=O, was identified in many answers C-O and C-H were also seen. Most candidates only identified a range of wavenumbers where a change in absorption occurs rather than described if the absorption appeared, disappeared or moved.

(d) (i) More able candidates deduced a formula for the correct organic product in the equation. The inclusion of H_2O as the additional product was less common, even when included the equation was not always balanced.

(ii) The appropriate formula to deduce the number of carbon atoms present in **T** was not well known and many confused calculations were seen. It was common for candidates to give a structural formula for **T** rather than the required molecular formula.

Question 4

(a) (i) Some candidates gave clear explanations of the presence of a chiral carbon in the lactic acid structure. A few candidates stated that optical isomers had chiral centres or described the behaviour of an optical isomer in the presence of polarised light.

(ii) Many candidates were unable to give the systematic name of lactic acid. 'Carboxylic acid' was seen frequently.

(iii) It was common for diagrams to show **more** than one water molecule or **multiple** hydrogen bonds. Candidates should be advised to respond as directed by the question. It was quite common for answers, showing more than one hydrogen bond, to contradict a correct representation.

(b) (i) Some clear and precise reaction mechanisms were shown with partial charges assigned to relevant atoms and unambiguous representation of curly arrows to show bonds broken and bonds made. When drawing mechanisms of this type candidates should be encouraged to consider what the curly arrows represent and whether their representation is clear, use partial charges correctly and discriminately and check that the number of carbon atoms on the intermediate is correct.

(ii) The equations described sometimes contained only pyruvic acid as a product or identified H_2 rather than H_2O as a product.

(iii) This question was demanding. Many candidates confused the reagents and conditions required to convert halogenoalkanes to nitriles with those required to convert ethanal to a hydroxynitrile. Deduction of the reagents and conditions used in the second step of both synthesis from propene and ethanal proved demanding for most candidates. Oxidising agents were more commonly seen for the third steps, however, some candidates represented the oxidising agents with incorrect formulae or with no reference to acid conditions.

CHEMISTRY

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Paper 9701/23

AS Level Structured Questions 23

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General comments

Definitions and basic concepts of chemistry are still causing candidates difficulties, particularly with enthalpy and isomerism topics. Definitions should explain accurately what the term means.

The use of brackets to surround side-chain groups, should be encouraged, when writing structural formulae.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to complete the table to show the number of electrons in the 3p subshells of P, S and Cl, as 3, 4 and 5 respectively.

The total number of unpaired electrons in these elements proved challenging for some candidates, Common incorrect answers were 1, 0 and 1 respectively.

(ii) The equation to represent the first ionisation of P was well answered. A common error was to omit the state symbols of (g) throughout.

(ii) The question required candidates to choose one of three possible values, given in the question, to represent the first ionisation energy of S and to explain their choice.

Most candidates did not mention that S has a pair of electrons in a 3p **orbital**, which experience spin-pair repulsion. This results in S having an ionisation energy value of $1000\,kJ\,mol^{-1}$, which is lower than both P and Cl. The explanation required candidates to recall that whilst S has a nuclear charge higher than P and lower than Cl, its nuclear attraction to the outer electrons is the lowest of these three elements.

Many candidates chose a value between P and Cl and supported their choice with a incorrect statement that the 'nuclear attraction to the outer electrons' increased across the period.

(b) (i) The full electronic configuration of the P^{3-} ion was well answered as: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6$.

(ii) The decrease in ionic radius from P^{3-} to S^{2-} and Cl^- was well answered. Many correct explanations included mention of an increased attraction of the outer electron to the nucleus resulting from an increased nuclear charge with each ionic species having the same shielding.

(c) Observations were required for three tests carried out on separate samples of $NaCl$(aq).

When Br_2(aq) is added to a sample no reaction occurs, and the colourless solution of $NaCl$(aq) turns orange (because of the added Br_2).

Most answers stated that the observation from the addition of concentrated H_2SO_4 to $NaCl$(aq) is misty/steamy fumes, not recognising that the $NaCl$ is in aqueous solution (and not a solid). The solution remains colourless as there is no visible reaction.

A white precipitate is formed when $AgNO_3$(aq) is added to $NaCl$(aq).

(d) (i) This question provided information that the chemical behaviour of $POCl_3$ is similar to that of PCl_5; $POCl_3$ has a low melting and boiling points and reacts vigorously with water suggesting that the structure and bonding of $POCl_3$ is simple covalent.

A small number of candidates gave a good explanation for this information and appreciated that the '*simple*' structure of $POCl_3$ was related to weak intermolecular forces of attractions and that the '*covalent*' nature of the compound is linked to the *hydrolysis* reaction with water.

(ii) The equation for the reaction of $POCl_3$ with water was generally quite well answered. Errors included an incorrect formula for H_3PO_4 and/or incorrect ratio between the water molecules and HCl product.

(iii) Most candidates were awarded full marks for the dot-and-cross diagram. A common error was the use of a dative bond between the P and O atoms.

(e) (i) Most candidates were awarded the first mark for the definition of the enthalpy change of formation, for stating 'enthalpy change when 1 mole of a compound is formed'. However, very few correctly stated the second requirement that it is 'from its elements in their standard states'.

Many answers mentioned standard conditions which was not a requirement.

(ii) The calculation of the bond energy of P=O (in PCl_3), using ΔH_f and bond energy (O_2) data, proved challenging for most candidates.

Use of incorrect energy cycles was the major problem and full marks were rarely awarded.

A correct energy cycle is:

$$\Delta H_r$$
$$2PCl_3(g) + O_2(g) \rightarrow 2POCl_3(g)$$

$$2(-289) \qquad 2(-592)$$

$$2P + 3Cl_2 + O_2$$

ΔH_r = 2(-592) - 2(-289) = -606 kJmol^{-1}

bonds broken	bonds formed
~~6 P-Cl~~	~~6 P-Cl~~
1 O=O (496)	2 P=O

$$496 - 2P{=}O = -606$$
$$-2P{=}O = -1102$$
$$\textbf{P{=}O = 551kJmol}^{\textbf{-1}}$$

Question 2

(a) (i) The solubilities of group 2 hydroxides 'increases' down the group; this variation in solubilities was correctly stated by many candidates

(ii) When barium oxide is added to water the observation is that the white solid dissolves/disappears to form a colourless solution. A common error was that there was bubbling/effervescence seen.

(iii) In the given reaction scheme, reaction 2 involved the formation of $BaCO_3$ and water from adding a reactant to $Ba(OH)_2$. Carbon dioxide, CO_2, is a reactant that would form both the carbonate and water. Many answers included a metal carbonate which would not give water as a product.

(iv) The addition of ethanoic acid to $Ba(OH)_2$ gave barium ethanoate, $(CH_3COO)_2Ba$, as the product.

Many candidates appreciated that barium ethanoate was formed but opted to answer using a formula of $(CH_3COO)Ba$, which was not creditworthy.

(v) $Ba(OH)_2$ and hydrogen are formed when Ba is added to water and the equation is:

$$Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$$

A common error was to use only 1 mole of water molecules and water formed as a product.

(b)(i) The thermal stability of group 2 carbonates increases down the group; hence, when barytocalcite, $BaCa(CO_3)_2$, is heated $CaCO_3$ will decompose first. Most answers correctly stated that $CaCO_3$ would decompose first but explanations compared the reactivity of Ca with Ba.

(ii) The equation to represent the thermal decomposition of $BaCa(CO_3)_2$ was often correct.

$$BaCa(CO_3)_2 \rightarrow BaO + CaO + 2CO_2$$

Common errors included answers with BaCa as a product or omitting $2CO_2$ as a product.

(c) Full credit for the hydrolysis reaction was rarely awarded. The two organic products are methanol, CH_3OH, and the diacid.

That both the –CN and $-CO_2CH_3$ groups will undergo hydrolysis was not recognised by many candidates. The –CN group was frequently left unhydrolysed and the product methanol was not given as the second organic product.

Question 3

(a) The definition of an oxidising agent, as a species that oxidises another species, and is reduced in the process by the gain of electrons, was overall generally well answered.

(b) This question required the completion of an energy diagram/energy profile to represent the catalytic effect of $MnO_2(s)$ on the decomposition of $KClO_3(s)$. This entailed drawing two labelled curves representing the uncatalysed and the catalysed profiles.

Many answers were awarded full credit. Common errors included unlabelled diagrams or profiles with only one curve.

(c) The term *disproportionation* is used to describe the oxidation and reduction of a single element, in the same chemical reaction. Here the reaction involved $KClO_3$ being converted to $KClO_4$ and KCl, in which the Cl is both oxidised and reduced in this reaction.

Many chose the correct element; there were, however, several answers that identified K or $KClO_3$ as the species undergoing simultaneous redox.

(d)(i) PV=nRT was successfully used by many candidates to calculate the volume of 1 mole of gas, in a reaction of glucose with molten $KClO_3$, to give the correct answer of $0.0524 \, \text{m}^3$, to 3 significant figures.

$$4KClO_3 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 4KCl$$

Several candidates did not appear to read the question carefully and gave answers with an incorrect number of sig. figs and/or incorrect rounding of their answers.

(ii) This question required the calculation of the moles of glucose, (5/180) and to use this value, together with their answer from 3**(d)(i)**, to calculate total volume of the gaseous CO_2 and H_2O in the equation.

Many candidates were able to correctly calculate the moles of glucose but then failed to multiply this value by 12 to determine the total moles of CO_2 and H_2O produced.

Several answers then continued to repeat the calculation in 3**(d)(i)** instead of using their answer from 3**(d)(i)**.

(e) (i) A high proportion of candidates correctly identified the number of primary, secondary and tertiary alcohol groups, in glucose, as 1, 4 and zero, respectively.

(ii) This question required observations for three tests.

The observation for a reaction of glucose + warm, acidified $KMnO_4(aq)$ is that the solution changes from purple to colourless.

Many candidates were given credit for a correct observation.

Glucose + warm, Fehling's reagent gave an orange/red precipitate which again was recognised by many candidates. Several candidates omitted the precipitate or stated that a silver mirror formed.

Glucose + warm, alkaline $I_2(aq)$ was incorrectly stated as a yellow precipitate by many candidates. There is no reaction with glucose, so the solution remains colourless.

(iii) Several candidates were able to correctly define *structural isomers* as 'molecules with the same molecular formula but different structural formulae'.

Question 4

(a) (i) Most candidates correctly gave the systematic name of the alkene **D**, with a molecular formula of C_5H_{10}, as **3-methylbut-1-ene**.

(ii) Few candidates gave a correct explanation of why the alkenes, **C** and **D**, did not exhibit geometric isomerism.

In **C**, one C (in the C=C bond) has two methyl groups and in **D**, one C (in the C=C) has two hydrogen atoms; neither will exhibit geometrical isomerism.

(iii) Many candidates gave pent-2-ene, or **C** or **D** as examples of a positional isomer.

(iv) When **D** is reacted with $H_2(g)$, 2-methylbutane, $CH_3CH(CH_3)CH_2CH_3$, is formed. Many candidates omitted the brackets surrounding the side-chain methyl group, on the CH group.

(v) Many candidates gave a monomer containing only two methyl groups or structures that still contained a double bond.

(b) The question contained information regarding the relative intensities of the M and (M + 1) ions, from a mass spectrum of **C**, which showed a molecular ion peak at 70.

Many candidates correctly calculated that C contained 5C atoms but then failed to use this information, in conjunction with the molecular ion peak, 70, to confirm that the molecular formula of C was C_5H_{10}.

(c) (i) The mechanism for the addition of HBr to **C,** 2-methylbut-2-ene, was quite well answered. Common errors included full charges on the H-Br, instead of a dipole, curly arrows, from C=C to $H^{\delta+}$ of HBr, arrows starting at one end of the C=C bond and intermediates with both a –ve charge and a partial negative charge.

(ii) This question was well answered with a common error being the use of C_3H_7, instead of the unambiguous expanded version, $(CH_3)_2CH–$.

(iii) This question required an explanation as to why different major products were formed when HBr reacts separately with C and D.

Many candidates appreciated that methyl/alkyl groups are responsible for a positive inductive effect and that the more alkyl groups, surrounding the carbocation, the more stable is the carbocation intermediate. However, the application of this concept to the intermediates of C and D was not well recognised.

Common errors were statements that the tertiary halogenoalkane was more stable, in C, and the secondary halogenoalkane was more stable, in D, rather than their respective intermediate carbocations.

Many candidates quoted Markovnikov's rule without any further explanation.

(d) *Please note that due to an issue with diagram labelling in this question, full marks have been awarded to all candidates to make sure that no candidates were disadvantaged. This has been corrected in the published version of the paper.*

The question required completion of a table of reagents and conditions for a reaction scheme.

The formation of alcohol, **F**, from a halogenoalkane, **E**, required the use of NaOH(aq).

Cleavage of the double bond, in **C**, to form a carboxylic acid, **G**, and propanone, was carried out using hot acidified <u>concentrated</u> $KMnO_4$.

The formation of ester, **H**, from **F** and **G**, needed <u>concentrated</u> H_2SO_4 (as a catalyst).

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Paper 9701/31
Advanced Practical Skills 31

Key messages

- Candidates should display their working to calculations clearly and use the data values given in the paper.
- Candidates should use the correct terminology when describing their observations.
- Supervisors should alert examiners to any difficulties in providing the chemicals listed in the Confidential Instructions via the report. Changes to chemicals agreed by Cambridge should be clearly listed in the Supervisor's report.
- Supervisors should carry out and record all their **qualitative** analysis results as well as their quantitative analysis results, as instructed in the Confidential Instructions

General comments

Few candidates were unable to complete the exam paper within the time limit.

Use of the relevant Principal Examiners' Reports for Teachers together with the mark schemes will allow teachers to help their learners to answer questions in the style expected.

Comments on specific questions

Question 1

Experiment 1

(a) Most candidates recorded the data required correctly, the values recorded suggested they were able to collect the expected volume of carbon dioxide. The number of decimal places used when recording data should be appropriate for the apparatus used. A few candidates were penalised for omitting units from table headings.

(b) (i) Most candidates gained this mark.

(ii) Most candidates recognised the calculation required to gain this mark. When the mark was lost, it was often because an inappropriate number of significant figures was used in the final answer.

(iii) Most candidates were familiar with the steps required to calculate a value for **x** and followed the instruction to show working. A common error was to round the final answer to an integer. Candidates should read all the information provided in the question carefully and highlight key points that may be relevant to the question.

(c) (i) Few candidates scored this mark. The solubility of the gas being a possible source of error was not well understood by candidates. Many candidates focused incorrectly on the possible effect on the rate of the reaction rather than on the effect on the volume of gas collected.

(ii) Few candidates scored this mark. More able candidates did appreciate that there was a link between the value of **x** and the volume of carbon dioxide gas collected.

Experiment 2

Most candidates are familiar with titration exercises and this was reflected in the marks for the practical and much of the following calculation.

(d) Most candidates recorded a value for the rough titre although there were some who did not record the relevant burette readings. Marks were also lost by a few candidates because the burette readings for the accurate titrations were only given to one decimal place. Burettes are calibrated at $0.10\,cm^3$ so should be read to the nearest $0.05\,cm^3$. Candidates should be advised to stop experimenting once they have an accurate titre that is within $0.10\,cm^3$ of any other accurate titre. Most candidates were able to gain at least 1 of the 3 marks available.

(e) The mean was generally calculated correctly. A 3 decimal place mean (e.g. 25.275) is no longer accepted.

(f) (i) The precision of the apparatus used and the accuracy with which the concentrations of the solutions have been prepared means that all answers should have been to 3 or 4 significant figures.

(ii) Most candidates gained this mark.

(iii) Most candidates scored well on this calculation question.

(iv) Most candidates were familiar with the processing required.

(g)(i) Candidates found this question challenging. Many candidates were able to give a correct value for the uncertainty in a single reading but few then went on to use that value in a correct expression. A common error was failing to double the value for a single reading when two readings are required.

(ii) More able candidates were awarded this mark. A common error was the failure to divide the answer to **part (i)** by 100.

Question 2

Candidates should be guided by the qualitative analysis notes at the end of the paper when stating tests and observations. They should also carefully read the general instructions at the start of the question.

(a) (i) Most candidates appreciated that they were trying to distinguish between samples of nitrate, nitrite and ammonium ions and many provided a suitable table in which to record their observations.

Candidates should be reminded that if the question states 'positively identify' then a relevant positive test is required rather than an attempt at a process of elimination.

Candidates scored well when selecting the correct reagents for each of the ions although some omissions were seen when more than one reagent or condition was required. For the ammonia test, candidates should make it clear that for the test to be positive it is the gas that is turning the litmus paper blue and not the solution.

Unless otherwise stated in either the question or the qualitative analysis notes, each test should be done separately on a fresh sample of the substance provided.

(ii) Most candidates deduced which ion was in which solution with very few making the mistake of giving the name rather than the formula of the ions.

(b)(i) This question was not answered well. Few candidates managed to score all three marks. Where a test or reaction is unfamiliar, candidates should take particular care to note down every observation and to be thorough when testing for gases.

(ii) Many candidates scored one mark here but few candidates scored both marks. Candidates should be advised to note down the starting colour for observations involving a colour change.

(iii) Many candidates scored one mark here as many observations were incomplete. This is a case where the qualitative analysis notes could have been used to give all three parts of the observation.

(iv) Candidates frequently gave the formula of an ion or the name of an element plus an oxidation state rather than the formula/name of an element required to gain the mark.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 33

Key messages

- Candidates should display their working to calculations clearly and use the data values given in the exam paper.
- Candidates should use the correct terminology when describing their observations.
- Supervisors should alert examiners to any difficulties in providing the chemicals listed in the Confidential Instructions. Changes to chemicals agreed by Cambridge should be clearly listed in the Supervisor's report.
- Supervisors should carry out and record their **qualitative** analysis results as well as their quantitative analysis results, as instructed in the Confidential Instructions.

General comments

Most candidates were able to complete the paper in the time allowed.

Use of the relevant Principal Examiners' Reports for Teachers, together with the mark schemes, will allow teachers to help their learners to answer questions in the style expected.

Supervisors who do not record results for a **quantitative** or **qualitative** procedure may disadvantage their candidates.

Comments on specific questions

Question 1

Most candidates are familiar with titration exercises. Candidates should be encouraged to highlight or underline information in the question stem that may have significance later in the question.

(a)   Most candidates recorded their burette readings for the rough titration. Some did not read the burette to the expected level of accuracy. Burettes are calibrated at $0.10\,cm^3$ so should be read to the nearest $0.05\,cm^3$. Candidates should stop experimenting once they have an accurate titre that is within $0.10\,cm^3$ of any other accurate titre. Most candidates were able to gain at least 1 of the 3 marks available for accuracy.

(b)   The mean was generally calculated correctly. Candidates should be reminded that the mean should be recorded to 2 decimal places.

(c) (i)   The precision of the apparatus used and the accuracy with which the concentrations of the solutions have been prepared means that all answers should have been to 3 or 4 significant figures. This degree of precision is common to most titration exercises.

   (ii)   Most candidates gained this mark.

   (iii)   Use of both equations was required to produce the correct ratio of thiosulfate to manganate(VII) ions. Some candidates were confused by the combined stoichiometry. Several scored the mark for the number of moles of manganate(VII) but did not convert it to a concentration. Some candidates simply used the moles in **(c)(ii)** without considering the stoichiometry.

(iv) This was a novel calculation and better candidates were able to think their way through it. Most of these candidates calculated the amount of $KMnO_4$ in 50.0 g and then divided that answer by their answer to **(c)(iii)**.

(d) Many candidates seemed unfamiliar with iodine-thiosulfate titrations. Potassium iodide is always used in excess, a fact that was stated in line 2 of the introduction. For that reason, accurate measurement of the volume of KI used does not improve the accuracy of the procedure. Most candidates incorrectly focused on the better precision of the pipette compared with a measuring cylinder.

Question 2

Most candidates were familiar with the procedure and the equations needed for processing the data collected. A minority of candidates did not attempt some parts of the question. Sometimes this was due to individual centre problems with the chemicals required. Care is taken by Examiners to ensure candidates are not disadvantaged in such situations provided the problem has been reported by the Supervisor.

(a) (i) Many candidates did not record their thermometer readings to the nearest half-degree. Most gave their balance readings consistently to either 2 or 3 dp. Candidates should always record all their data in the spaces provided, not alongside the steps in the method. The drawing of a results table prior to starting the experiment would help candidates check they have recorded all the required data.

(ii) Most candidates showed familiarity of the energy change equation, $q = mc\Delta T$. Many lost the mark by inputting the mass of **FA 6** used, as opposed to the volume of **FA 7**. Common errors were to use 4.2 as the value for c instead of the 4.18 given on page 11 of the paper or to quote the answer to 5 sf. Some added 273 to their value of ΔT which was inappropriate as the difference in Kelvin is the same as the difference in temperature in ºC.

(iii) Most candidates calculated the amount of MgO correctly. Some candidates gave an incorrect sign for their answer, one that did not agree with their practical results.

(b) (i) Most candidates who attempted this part gained the mark for the table of results. Many candidates gained at least 1 of the 2 marks for accuracy with the majority gaining both.

(ii) Few candidates were successful in this part as only a small minority considered which of **FA 7** and **FA 8** was in excess. Some of those realising the acid was the limiting reagent did not consider the stoichiometry of the equation.

(c) Most candidates understood that a subtraction was required. However, the values were often reversed so an incorrect sign was given.

Question 3

Many candidates found this question to be the most difficult. Some were able to gain almost all the marks available. One problem was incorrect use of terminology: 'soluble precipitate' is a contradiction, 'insoluble precipitate' is not stating whether the ppt was insoluble when excess reagent was added.

(a) Weaker candidates found it challenging to organise their own scheme of analysis. Few gained full marks. This was most often caused by not understanding that a solution had to be formed before testing for the cation. This meant that the 'white ppt' on adding an aqueous alkali to **FA 9** was in fact the undissolved solid: this led to an incorrect identification of Mg^{2+}. Those using the solution formed after adding acid (while testing for carbonate) were more successful. Some candidates could not be credited for the limewater test as they did not make it clear that it was the gas forming a white ppt with limewater and a few added the limewater to the solution. Many candidates did not realise that 'goes milky' is no longer accepted as a description of a positive limewater test.

(b) Some centres were unable to source the ammonium iron(III) sulfate (**FA 10**), while a few others supplied ammonium iron(II) sulfate in error. In both cases, **part (b)** was marked using an alternative mark scheme to ensure that candidates were not disadvantaged.

(i) Some candidates lost marks by failing to describe colours precisely, e.g., 'red' for I_2 and $Fe(OH)_3$. When a ppt is formed in a coloured solution (as in Test 2) candidates should allow some of the ppt to settle so they can see the correct colour at the bottom of the test-tube. Some candidates did not add aqueous ammonia in Test 3 presumably as there had been no ppt on adding aqueous silver nitrate. All boxes in a table of observations should have an entry: 'no change' is the suggested observation where there is no visible reaction. In Test 4 it was important for candidates to state that it was the gas being tested with (damp red) litmus paper. The most able candidates were successful in testing for hydrogen on adding aluminium. A few candidates ignored the instruction to start each test with a new sample of **FA 10** and ran the tests sequentially on a single sample.

(ii) Most candidates correctly identified Fe^{3+} but many missed the SO_4^{2-} ion, possibly owing to recording an incorrect colour of ppt in Test 2. Candidates who gained most marks in **(b)(i)** usually scored both marks here.

(iii) The best candidates gained both marks. A sizable minority gave Tests 1 and 4 as being those involving redox reactions but the justifications were often incorrect. Errors included K^+ being reduced to K and N in NH_4^+ being reduced to NH_3.

(iv) Most candidates were unable to write a correct ionic equation for the reaction of $OH^-(aq)$ with any of the cationic species they thought were present. Many equations were unbalanced. Those who succeeded in this often omitted the state symbols.

CHEMISTRY

Paper 9701/34
Advanced Practical Skills 34

Key messages

- Supervisors should carry out and record all their **qualitative** analysis results as well as their quantitative analysis results, as instructed in the Confidential Instructions.
- Supervisors should alert examiners to any difficulties in providing the chemicals listed in the Confidential Instructions via the Supervisor's report. Changes to chemicals agreed by Cambridge should be clearly listed in the Supervisor's report.
- Candidates should display their working to calculations clearly and use the data values given in the paper.
- Candidates should use the correct terminology when describing their observations.

General comments

Most candidates completed all parts of the paper.

Use of the relevant Principal Examiners' Reports for Teachers, together with the mark schemes, will allow teachers to help their learners to answer questions in the style expected.

Comments on specific questions

Question 1

Most candidates answered this question well. Some centres made the required solutions with insufficient accuracy. This resulted in confusion for the candidates with either very long or extremely short reaction times being recorded. The practical ability of the candidates may then not be reflected accurately.

(a) Candidates who had the correct solutions usually answered accurately. Mark **II** was occasionally lost because of a wrong unit for 'rate' or the omission of 'volume' in the heading for **FB 1**. Mark **III** was lost more often as candidates omitted to record burette readings to the nearest $0.05\,cm^3$ or times to the nearest second. For mark **IV**, most candidates, realising the need to 'spread' their readings, chose volumes at least $2.00\,cm^3$ away from the other volumes used. In mark **VI**, a few candidates made rounding errors when calculating the rate. Many candidates were able to score all three accuracy marks.

(b) Almost all candidates were awarded mark **I**. Many candidates were not awarded the remaining three marks. Candidates were instructed on page 4 to include the origin and many did not. Scales should be easy to use and allow for the origin plus plotted points to cover more than half the axes in both directions. Candidates are reminded to use a sharp pencil or fine pen and not use large 'blobs' to plot points as these do not show values to the accuracy required. If the experiment had been performed correctly, the points should result in a curved line starting at the origin. Many candidates drew a straight line even when their data clearly suggested otherwise.

(c) Few candidates were awarded this mark even though straight lines were marked as 'error carried forward.' Only a relationship leading to straight line plot from the origin can be deemed 'directly proportional'.

(d) (i) The calculation was often correct however many candidates lost the mark because they did not give their answer to at least two significant figures.

(ii) Few candidates got this calculation correct. Some made use of the balanced equation (shown in **(d)(iii)**) and their answer for **(d)(i)** but this was not appropriate. Candidates should be reminded to read questions and information carefully.

(iii) The answer to **(d)(iii)** should have been calculated using either the amount of **FB 1** or of **FB 2**, depending on which was the limiting factor.

(iv) Many candidates got one of the steps in **(iv)** correct but few obtained the correct answer.

Question 2

Most candidates were familiar with the procedure and many were able to make a good attempt at the processing of results.

(a) Candidates should always record their results in the space provided rather than alongside steps in the method. The drawing of a results table or list prior to starting the experiment would also help candidates check they have recorded all the required data. A few candidates failed to record the temperature change or mass of **FB 5** used. Some candidates wrongly used 'weight' in place of mass, some suggested the units for temperature are C° and some recorded temperature as an integer value rather than to the nearest half-degree. Most scored the mark for the accuracy of their results.

(b)(i) Most candidates were familiar with the energy change equation, $q = mc\Delta T$, but many lost the mark by using their calculated mass of **FB 5** rather than the mass of water. Common errors were to use a value of 4.2 for the specific heat capacity instead of the 4.18 given on page 15 or to add 273 to the temperature change. Candidates should always check an answer is given to an appropriate number of significant figures.

(ii) The most common error was to forget the factor of 1000 required in the conversion of kJ to J (or vice versa).

(iii) This calculation was more challenging and few candidates completed both steps. Many divided the mass by their answer to **(ii)** but then either forgot to subtract 136 or, because of an incorrect calculation previously, were left with a value that was clearly not sensible so did not attempt the second step. Candidates should be reminded to work a calculation through to its conclusion as errors are carried forward during marking but they should also check their previous working if the answer appears incorrect.

(c) Few candidates realised that the temperature drop would be smaller with extra water, therefore increasing the inaccuracy of the measurement. Common incorrect suggestions were that the solid would dissolve quicker, more water decreases the percentage error in volume measurement or that the thermometer bulb would be completely immersed in the water.

Question 3

Candidates should always make use of the qualitative analysis notes at the end of the paper and the terminology it exemplifies.

(a) Many candidates do not record their observations in the detail expected at this level. For Test 1, few candidates recorded seeing condensation at the top of the test-tube or reported the correct colour changes. Most candidates reported effervescence for Test 2 but few reported any of the other observations listed in the mark scheme or tested the gas produced in either Test 1 or Test 2. When the test of carbon dioxide is carried out, candidates should clearly state that the gas is bubbled into the lime water and the precise description 'gives a white precipitate' reported rather than 'goes milky or cloudy'.

(b) Most candidates were familiar with the use of the aqueous alkalis sodium hydroxide and ammonia to identify a cation. As the cation in **FB 6** is Zn^{2+} only ammonia was required in this case although, if both alkalis were used, both results needed to be correct to gain the second mark. Few candidates reported that the white precipitate dissolved in excess ammonia which may be because they used too large a volume of **FB 6** for the test. Consequently, few candidates were able to score

the mark for the conclusion. Few candidates identified the carbonate ion and a large number of candidates incorrectly suggested that **FB 6** contained two cations.

(c) (i) This question was challenging and a significant number of candidates did not attempt it. When asked to choose reagents, candidates should give the entire name or formula, e.g. silver nitrate or $AgNO_3$, not Ag^+. When testing for ammonia as part of the test for nitric acid, it should be clear that it is the gas which turns (damp red) litmus blue. 'No observation' is not an acceptable alternative to 'no change' when no visible reaction occurs.

(ii) Candidates frequently identified the correct two acids but some were not awarded the mark either because they used names instead of formulae or wrote an incorrect formula for nitric acid.

(iii) Most candidates were unable to write a correct ionic equation. The formation of silver chloride was the most common equation attempted but state symbols were too frequently missing or incorrect.

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Advanced Practical Skills 35

Key messages

- Candidates should display their working to calculations clearly and use the data values given in the paper.
- Candidates should use the correct terminology when describing their observations.
- Supervisors should alert examiners to any difficulties in providing the chemicals listed in the Confidential Instructions via the report. Changes to chemicals agreed by Cambridge should be clearly listed in the Supervisor's report.
- Supervisors should carry out and record all their **qualitative** analysis results as well as their quantitative analysis results, as instructed in the Confidential Instructions

General comments

Few candidates were unable to complete the exam paper within the time limit.

Use of the relevant Principal Examiners' Reports for Teachers together with the mark schemes will allow teachers to help their learners to answer questions in the style expected.

Comments on specific questions

Question 1

Experiment 1

(a)   Most candidates recorded the data required correctly, the values recorded suggested they were able to collect the expected volume of carbon dioxide. The number of decimal places used when recording data should be appropriate for the apparatus used. A few candidates were penalised for omitting units from table headings.

(b) (i)   Most candidates gained this mark.

   (ii)   Most candidates recognised the calculation required to gain this mark. When the mark was lost, it was often because an inappropriate number of significant figures was used in the final answer.

   (iii)   Most candidates were familiar with the steps required to calculate a value for **x** and followed the instruction to show working. A common error was to round the final answer to an integer. Candidates should read all the information provided in the question carefully and highlight key points that may be relevant to the question.

(c) (i)   Few candidates scored this mark. The solubility of the gas being a possible source of error was not well understood by candidates. Many candidates focused incorrectly on the possible effect on the rate of the reaction rather than on the effect on the volume of gas collected.

   (ii)   Few candidates scored this mark. More able candidates did appreciate that there was a link between the value of **x** and the volume of carbon dioxide gas collected.

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Experiment 2

Most candidates are familiar with titration exercises and this was reflected in the marks for the practical and much of the following calculation.

(d)   Most candidates recorded a value for the rough titre although there were some who did not record the relevant burette readings. Marks were also lost by a few candidates because the burette readings for the accurate titrations were only given to one decimal place. Burettes are calibrated at $0.10 \, cm^3$ so should be read to the nearest $0.05 \, cm^3$. Candidates should be advised to stop experimenting once they have an accurate titre that is within $0.10 \, cm^3$ of any other accurate titre. Most candidates were able to gain at least 1 of the 3 marks available.

(e)   The mean was generally calculated correctly. A 3 decimal place mean (e.g. 25.275) is no longer accepted.

(f) (i)   The precision of the apparatus used and the accuracy with which the concentrations of the solutions have been prepared means that all answers should have been to 3 or 4 significant figures.

    (ii)   Most candidates gained this mark.

    (iii)   Most candidates scored well on this calculation question.

    (iv)   Most candidates were familiar with the processing required.

(g)(i)   Candidates found this question challenging. Many candidates were able to give a correct value for the uncertainty in a single reading but few then went on to use that value in a correct expression. A common error was failing to double the value for a single reading when two readings are required.

    (ii)   More able candidates were awarded this mark. A common error was the failure to divide the answer to **part (i)** by 100.

Question 2

Candidates should be guided by the qualitative analysis notes at the end of the paper when stating tests and observations. They should also carefully read the general instructions at the start of the question.

(a)(i)   Most candidates appreciated that they were trying to distinguish between samples of nitrate, nitrite and ammonium ions and many provided a suitable table in which to record their observations.

       Candidates should be reminded that if the question states 'positively identify' then a relevant positive test is required rather than an attempt at a process of elimination.

       Candidates scored well when selecting the correct reagents for each of the ions although some omissions were seen when more than one reagent or condition was required. For the ammonia test, candidates should make it clear that for the test to be positive it is the gas that is turning the litmus paper blue and not the solution.

       Unless otherwise stated in either the question or the qualitative analysis notes, each test should be done separately on a fresh sample of the substance provided.

    (ii)   Most candidates deduced which ion was in which solution with very few making the mistake of giving the name rather than the formula of the ions.

(b)(i)   This question was not answered well. Few candidates managed to score all three marks. Where a test or reaction is unfamiliar, candidates should take particular care to note down every observation and to be thorough when testing for gases.

    (ii)   Many candidates scored one mark here but few candidates scored both marks. Candidates should be advised to note down the starting colour for observations involving a colour change.

    (iii)   Many candidates scored one mark here as many observations were incomplete. This is a case where the qualitative analysis notes could have been used to give all three parts of the observation.

(iv) Candidates frequently gave the formula of an ion or the name of an element plus an oxidation state rather than the formula/name of an element required to gain the mark.

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Paper 9701/36
Advanced Practical Skills 36
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Key messages

- Candidates should display their working to calculations clearly and use the data values given in the paper.
- Candidates should use the correct terminology when describing their observations.
- Supervisors should ensure that they alert examiners to any difficulties in providing the chemicals listed in the Confidential Instructions. Changes of chemical agreed by Cambridge should be clearly listed in the Supervisor's report.
- Supervisors should carry out and record their **qualitative** analysis results as well as their quantitative analysis results, as instructed in the Confidential Instructions.

General comments

Use of the relevant Principal Examiners' Reports for Teachers, together with the mark schemes, will allow teachers to help their learners to answer questions in the style expected.

Supervisors who do not record results for a quantitative or qualitative procedure may disadvantage their candidates.

Comments on specific questions

Question 1

Some candidates followed a route based on a misunderstanding of the role of the manganese(IV) oxide. Greater discussion of the best ways of carrying out practical procedures would benefit many candidates. Most centres showed good agreement between the candidates' and the Supervisor's mass loss.

This question provided reliable results even when solutions of hydrogen peroxide had been made up incorrectly or the mass of manganese(IV) oxide provided was incorrect.

Most candidates were awarded accuracy marks unless they had altered their results when they found that the final mass of flask and solution was greater than the original. Good candidates realised this was due to the addition of a catalyst and calculated appropriately. More able candidates performed the calculation correctly: the final section, **1(c)**, proved the greatest challenge to candidates.

(a)   Candidates who recorded all the weighing's often scored at least two marks. Most candidates were awarded the accuracy mark provided they had recorded all the necessary data. The majority gave their balance readings consistently to either 2 or 3 dp.

(b)(i)   Subtracting the initial mass of flask and solution from the final mass of flask and contents was a common error. The more able candidates were awarded this mark.

(ii)   There were many ways candidates lost this mark including no state symbols, incorrect state symbols, incorrect balancing, hydrogen as a product or MnO_2 as a reactant.

(iii)   Most candidates provided an answer to **(b)(i)** but few used this value in the calculation. Some used the relative formula mass of hydrogen peroxide instead of oxygen as their denominator. Some used the volume of aqueous hydrogen peroxide added to the flask. Others did not apply the

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stoichiometry they had given in the equation for the reaction. Few candidates were awarded both marks.

(iv) Those awarded marks in **(b)(iii)** were generally successful in this part.

(c) (i) Many candidates were able to answer this part correctly either with reference to their experiment or more generally. Both answers (effervescence or mass) were seen though some candidates' responses appeared unclear or contradictory.

(ii) A common incorrect answer was that the cotton wool plug would prevent the escape of oxygen. Very few candidates appeared to notice the rapid evolution of gas on adding the MnO_2. The use of the conical flask in **(a)** was designed to reduce loss of solution: a cotton wool plug would have ensured there would be even less loss of solution due to frothing.

(iii) Few candidates realised MnO_2 was a catalyst so would not change in mass.

Question 2

Most candidates are familiar with titration exercises and this was reflected in the answers given. Candidates should be encouraged to highlight or underline information in the method (or question stem) that may have significance later in the question.

(a) Most candidates recorded their burette readings for the rough titration. Some did not read the burette to the expected level of accuracy. Burettes are calibrated at $0.10\,cm^3$ so should be read to the nearest $0.05\,cm^3$. Candidates should be advised to stop experimenting once they have an accurate titre that is within $0.10\,cm^3$ of any other accurate titre.

Most candidates were able to gain at least 1 of the 3 marks available for accuracy: the tolerances for the accuracy marks were widened compared to those normal for titrations as a dilution had to be carried out by candidates prior to the titration. Where the burette needed refilling owing to an incorrect concentration of hydrogen peroxide, the candidates had a greater chance of making errors.

(b) The mean was generally calculated correctly. The mean should be recorded to 2 decimal places, 1 dp is not accepted unless there is an error carried forward from inaccurate burette readings.

(c) (i) The precision of the apparatus used and the accuracy with which the concentrations of the solutions have been prepared means that all answers should have been to 3 or 4 significant figures.

(ii) Most candidates gained this mark, some omitted the conversion of the mean titre volume from cm^3 to dm^3.

(iii) Most candidates applied the stoichiometry of the equation correctly.

(iv) Few candidates gained this mark with many multiplying their answer for **(c)(iii)** by 100 or 250 instead of by 1000. Careful reading of the method would have shown them that both x $^{250}/_{10}$ and x $^{1000}/_{25}$ were required.

(d) (i) Few correct answers were seen showing that candidates find it hard to compare two different procedures critically. Many discussed the precision of a burette compared to a measuring cylinder in measuring volumes. The most common correct answer involved the sharpness of the endpoint in the titration. Some candidates wrote about repeating the titration to obtain a mean but very few mentioned the <u>concordance</u> of titres.

(ii) Few candidates gained this mark, though many candidates wrote that the burette is read twice which doubles the error they did not go on to show the correct effect of this numerically.

Question 3

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Candidates found this the most challenging question in the paper. Problems using correct terminology were seen such as 'insoluble precipitate' which is not saying whether the ppt was insoluble when excess reagent was added.

(a) (i) Many candidates reported a precipitate of a suitable colour even though the ppt was faint initially.

(ii) The information given in the question pointed the candidates towards testing for a halide and for an anion containing nitrogen. Some candidates did not add sufficient NaOH(aq) to neutralise **FA 6** before heating with aluminium foil. Candidates should not ignore results of other tests within a part question: only an acid would react with aqueous sodium thiosulfate to form a slowly appearing precipitate. Some candidates did not make it clear that the acidified aqueous potassium manganate(VII) was added to a separate sample of **FA 6**. Others stated the reagent 'turned purple' when it is purple initially and a change to colourless would indicate its reduction.

(iii) HNO_2 seemed as common an answer as HNO_3. Candidates suggested various metal nitrates for the identity of **FA 6**. 'NO_3^-' was also a popular response from those who did not work out the identity of the cation.

(b) (i) When testing with aqueous alkalis candidates should always record their observations on adding a small volume and then on adding excess if a precipitate was formed. Candidates should take when describing colours and reference the qualitative analysis notes. Candidates generally gained marks for Tests 1 and 2. Unacceptable colours of solution were recorded in Test 3 and the gas evolved was tested by very few candidates. Candidates are expected to record the change of colour of reagent when adding acidified $KMnO_4$(aq) so 'colourless' gave insufficient information and could not be credited in Test 4.

(ii) Very few candidates gained both marks for the equation. As aqueous ammonia is an alkali the ion reacting with the metal ion in **FB 8** is OH^-. Some of those who gave a (balanced) correct equation omitted state symbols so could not access the second mark.

(iii) Candidates who were awarded both marks did so with the first strand given in the mark scheme. The second mark was for justifying the statement about the species being oxidised (or undergoing disproportionation). There were many candidates who correctly stated that 'Fe^{2+} was oxidised to Fe^{3+}' and that 'oxygen was produced': the second statement was not a justification of the first so could not be credited.

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A Level Structured Questions 41

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows are a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.

General comments

The paper enabled candidates to demonstrate their knowledge and understanding of a wide range of chemistry topics.

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

Comments on specific questions

Question 1

(a) (i) This question was well answered. Candidates had to suggest two equations for this mechanism that was consistent with the given information. Common errors included:
- step 1 not being a molar ratio (1:1) consistent with the orders of reaction,
- steps in the mechanism that were not balanced.

(ii) This proved difficult for some candidates. Answers should be linked to the rate determining step (step 1) which contains one mole of F_2 and one mole of ClO_2.

(b) (i) Most candidates gave the correct rate equation. A common error was to square the concentration of ClO_2.

(ii) Candidates usually answered this correctly.

(c) (i) Candidates performed well on this question.

(ii) Most candidates plotted the points accurately and gave a suitable best fit curve.

(iii) This question discriminated well. Candidates were required to draw a suitable tangent on their line at $0.00100 \, mol \, dm^{-3}$ and calculate its gradient. A common error was omitting a tangent which scored no credit.

Question 2

(a) Candidates usually answered this correctly.

(b) (i) This calculation proved challenging to many candidates. They had to recognize that HCl and $NaOH$ are both fully dissociated and differ by 11 pH units, so **V** has a pH of 1.5. The concentration of HCl can be calculated using $10^{-1.5}$ to give 0.0316.

(ii) Many candidates correctly identified the solution as sodium chloride with pH 7. A common error was identifying the solution as water. Some candidates gave the incorrect pH for this solution.

(iii) Most candidates estimated the pH of both solutions correctly.

(c) (i) This question was well answered. The trend in acid strength was usually correct and many excellent explanations were seen. Some referred to C=O group as being electron-withdrawing which did not distinguish between the two organic acids.

(ii) The concept of conjugate acid-base pairs did not seem to be well understood. Many candidates gave incorrect species such as $H_2SO_3^+$, OH^- and SO_4^-.

(d) (i) Most candidates answered this question well. Weaker candidates omitted to reference an equilibrium. Some stated solubilities of the solutes instead of concentrations.

(ii) Most candidates calculated the mass of **Q** correctly.

(iii) This question discriminated well. Many candidates gave volumes of water 7.84 times the volume of hexane.

(iv) This question was well answered. Many candidates correctly identified **Q** as pentan-1-ol, although some stated that this was a non-polar molecule rather than the least polar molecule. A number of answers stated that **Q** was KCl.

Question 3

(a) (i) This definition was well known.

(ii) This question was well answered. Most candidates correctly identified that ΔS was positive and clearly described their reasoning.

(b) Candidates performed well on this question and clearly showed how -196 was calculated. Some candidates did not realise that four moles of O–H bonds were broken as well as formed in this reaction.

(c) This question was well answered. A good understanding of energy cycles was shown and correct application of the Gibbs equation. It is important to emphasise the value of showing working. Common errors included two marks for +64.1 (omission x 1000) and –76.9 (sign error –141 used).

(d) Most candidates correctly identified the catalyst as $FeCl_3$ stating it was in the same phase as H_2O_2.

(e) (i) Most candidates identified H_2O_2 as the positive half-cell but some incorrectly gave +1.77 V or +1.36 V.

(ii) This question was well answered. Common errors included +421 (sign error) and –341.6 (use of 1.77 instead of 2.18 for the E_{cell}).

(f) (i) This question was found to be difficult. Many incorrect versions of the Nernst equation were seen. Some common errors were +1.94 and +1.76.

(ii) This question was well answered. The cell reaction was frequently written the wrong way around.

(g) (i) This definition was well known.

(ii) Many good answers were seen here. Some candidates did not use arrowheads to show the direction of the energy changes.

(iii) Candidates performed well on this question.

Question 4

(a) (i) This question was answered well. Common errors included $[Co(NH_3)_4(H_2O)_2]^{2+}$, $[CoCl_4]^{2+}$ and $[CoCl_4]^{-}$.

(ii) Most candidates correctly identified the colour change.

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

(ii) Many excellent answers were seen. Some candidates did not use the decomposition temperature for calcium nitrate given and suggested inappropriate temperatures for the decomposition of magnesium nitrate and barium nitrate. Many candidates gave a correct statement regarding increasing cation radius down Group 2. Decreasing polarisation of the nitrate anion was less frequently seen.

Question 5

(a) Most candidates suggested that variable oxidation states were needed for transition elements to act as catalysts. Less candidates were able to recall that vacant d-orbitals that are energetically accessible (to accept lone pairs from ligands) are also required.

(b) (i) Candidates found this question difficult. Many suggested the coordination number was six instead of eight.

(ii) Candidates performed well on this question. Some did not clearly label bond angles on their diagrams and showed the angle going from the bond to the atom instead of the bond to the bond. Another common error was drawing an incorrect tetrahedral three-dimensional diagram.

(c) (i) This question was answered correctly. Some candidates put charges outside the concentration brackets or had the inverse of the expression.

(ii) This question was answered well.

(d) (i) Candidates performed well on this question. The most common error was 4.02×10^{-4}.

(ii) This question discriminated well. Many candidates lost this mark by multiplying their answer to **(i)** by 2 instead of by 8.

(iii) This question was answered well. Many candidates scored credit by error carried forward.

(iv) This question proved difficult for some candidates. Many did not reference that Cu^{2+} is d^9 / had partially filled d subshell and Cu^+ is d^{10} / full d subshell.

Question 6

(a) (i) Most candidates completed the table correctly. A common error was suggesting $EDTA^{4-}$ was a bidentate ligand instead of a polydentate ligand.

(ii) Most candidates gave a correct definition for a tridentate ligand.

(iii) Candidates often gave the correct answer here.

(b)(i) Most candidates completed the table correctly.

(ii) Most candidates gave a correct description.

Question 7

(a) This question discriminated well. Many correct answers were seen. Some common errors were $C_{16}H_{10}N_2O_6S_2$ and $C_{16}H_{11}N_2O_7S_2$.

(b) This question was answered well. The structures of **E** and **G** were normally correct. A common error was placing the positive charge on the incorrect N on the diazo compound **F**.

(c) Many candidates were able to identify the correct reagents and conditions. Common errors included:
- in step 1: use of HNO_3 instead of HNO_2 or suggesting an incorrect temperature,
- in step 2: omitting alkaline conditions / NaOH(aq).

(d) This question proved difficult for many candidates.

Question 8

(a) Candidates found this a difficult compound to identify all the functional groups. The incorrect groups 'alcohol' or 'ketone' were often given in candidates' answers.

(b) Many candidates thought HBr was a product of the addition of bromine across the C=C bond and some did not add bromine to the C=C bond.

(c) The reduction of the benzene ring was well understood but far fewer candidates reduced the alkene functional group.

(d)(i) These conditions were not well known and 'concentrated' was frequently omitted with the description of potassium manganate(VII).

(ii) This question was answered well. Many candidates correctly identified the chemical shift values. Fewer candidates were able to select the correct splitting patterns that would be seen. Common errors included stating the CH environment was a quartet (instead of a multiplet) or COOH was a doublet (instead of a singlet). The explanation for the splitting patterns was well known.

(e)(i) This question discriminated well. Some excellent answers were seen. Some common errors are shown.

(ii) This question proved difficult for candidates. Oxidation and substitution were common incorrect answers.

(f) Although correct answers were seen, many candidates reduced the C=O to an alcohol or C=C to an alkane.

Question 9

(a)(i) Most candidates gave a correct answer. A common error was including an additional CH_2 group to give $C_6H_5CH_2COOH$.

(ii) This question was answered correctly.

(iii) This question was well answered. A common error was condensation for step 2.

(b)(i) Many candidates completed the mechanism diagrams well, most gaining some credit. Common errors included:
- adding an additional charge (normally negative) on the O in the phenol (box 1)
- the curly arrow in the intermediate starting at the H not on the O–H bond to the O atom (box 2)
- the curly arrow in the intermediate starting at the C–O bond not on the O⁻ or going to the C atom (box 2).

(ii) This question was well answered. A common error was nucleophilic substitution.

(c) This piece of factual recall was known by many candidates. Some thought chloroethane was harder to hydrolyse than chlorobenzene. Weaker candidates omitted any reference to the strengthening / weakening of C–Cl bond.

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Paper 9701/42
A Level Structured Questions 42
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Key messages

- The question paper asked for several definitions. Candidates who had learnt these carefully, rather than attempting a loose description, scored more marks.
- Candidates are still losing marks due to bad handwriting. It still appears possible that words are being written in such a way that they could be read in more than one way – for example as either exothermic or endothermic. Marks are never awarded in such cases.
- If a candidate wishes to change an answer they must cross out their original answer completely. If there is insufficient space to write their replacement answer there is plenty of blank space on the question paper. A comment such as 'continued on page 5' is helpful however.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- Answers to calculations should be given to a minimum of 2 sf but 3 sf is preferred. In a calculation that involves two or more stages the full number should be left on the calculator after each stage, then the final answer should be rounded to 3 sf.
- Care should be taken when drawing curly arrows and labelling partial charges to show organic reaction mechanisms. A curly arrow should start clearly on a bond or on a lone pair, and the arrow head should point clearly in the direction of the destination of the electron pair.

General comments

Once again it needs to be emphasised that both care and the correct following of convention is needed when writing the formulae of substances. In **Question 7(a)** those candidates who chose to write out the formula of the manganate(VII) ion should have written MnO_4^-, not MnO_4^{2-}, MNO_4^-, mNO_4^-, or mno_4^-.

The majority of candidates were able to work through to the end of the paper. Some candidates may have given up. this was a great shame as many candidates found later questions such as **Question 7** and parts of **Question 9** very accessible.

Many candidates are clearly improving in their ability to show the skills needed to answer an examination paper of this type. Areas where such improvement was apparent included:

- correct rounding of answers at the end of a calculation
- annotation of calculations to explain each step
- the use of three dimensional bonds to show e.g. the shape of an octahedral complex
- drawing the stages of a reaction mechanism.

Comments on specific questions

Question 1

(a) This question was answered well.

(b)(i) This question was found to be difficult. Candidates who were able to calculate that the value of $[I_2]$ falls to 0.77×10^{-5} mol dm^{-3} after ten seconds usually went on to score the mark.

(ii) This mark was rarely awarded. Comparatively few candidates appreciated the relevance of the concentrations of propanone and H^+ ions being unknown.

(c)   This question was answered well.

(d) (i)   This question discriminated well.

(ii)   Care was required for the mark to be scored. It was necessary to number the bottom axis in a correct manner, and the three points had to be calculated and then plotted with care.

(e) (i)   This question discriminated well. To score the mark candidates had to appreciate that the four steps add up to the overall equation given on the paper.

(ii)   Many candidates failed to appreciate the significance of step one involving the same species as the rate equation, and so lost the mark.

(iii)   Answers here were disappointing. On many scripts the conjugate base had a higher positive charge than the conjugate acid.

Question 2

(a)   This mark was usually awarded. Errors that were seen included 'A buffer keeps the pH constant'.

(b) (i)   This question discriminated well. In general candidates wrote correct, balanced equations. Ionic equations, or equations that included Na^+ ions, were acceptable.

(ii)   This question discriminated well. Some candidates gave the formula of nitric acid as NH_3. Ionic equations, or molecular equations, were acceptable.

(c)   Most candidates were able to calculate $[H^+]$ from the pH value given. A smaller number were able to access data from the question and so calculated $[C_6H_5COOH]$ correctly. The mark for $[C_6H_5COO^-Na^+]$ was scored least often. Some candidates used $Ka = [H^+]^2 \div [C_6H_5COOH]$. This does not work for buffer calculations since $[H^+]$ and $[C_6H_5COO^-Na^+]$ are not equal.

(d)   This was found to be extremely difficult. Since the pH has changed by a large amount all of the benzoic acid must have reacted, leaving an excess of KOH.

(e) (i)   One mark was often scored. Some candidates did not use the M_r value that was given in the question, so the second mark was lost.

(ii)   A question like this, on the subject of the common ion effect, is usually found to be easier than it was on this paper. It is possible that the different context made the question more difficult for some candidates.

Question 3

(a) (i)   This was answered well.

(ii)   Many candidates scored this mark. Some candidates used the terms 'anode' and 'cathode'. These terms are best avoided when describing electrochemical cells, as the positive and negative polarity involved is found confusing by many candidates. The terms 'anode' and 'cathode' are best used only when discussing electrolysis.

(b) (i)   Quoting and using $E^\ominus$ values to make correct predictions about the reactions that will (or won't) take place is still found to be extremely difficult by many candidates. The question was made more difficult by the two possibilities, since Fe^{2+} can be reduced to Fe or oxidised to Fe^{3+}. One very clear way of answering was to name a vanadium-containing species and then state that the E_{cell} is negative e.g. 'V^{2+} cannot reduce Fe^{2+} to Fe, while itself being oxidised to V^{3+}, as the E_{cell} is –0.18 V.'

(ii)   This was found to be very difficult.

(iii)   We saw many correct equations. However the following errors were all seen on many occasions;
- equations that were unbalanced
- equations in in which the vanadium species and the Fe^{2+} were both oxidised or both reduced
- equations where the iron-containing species was Fe or Fe^{3+}.

(c) (i) This question discriminated well. Candidates who knew the Nernst equation usually scored one or two marks.

(ii) This question discriminated well. Many candidates answered with a correct balanced equation.

(d) This question discriminated well. As with **Q3(c)(i)** it is very important to learn the equations and relationships specified in the syllabus.

(e) This question discriminated well. Many candidates were able to demonstrate their understanding with a clear and well-organised calculation. Some candidates used 96 500 C, the value of the Faraday from page 27 of the examination paper, as part of their answer. This cannot be a correct method, since this value is itself based partly on the accepted value of L.

(f) (i) Many good answers were seen here.

(ii) This question discriminated well. The question was best answered by a description of the effect of higher temperature on $T\Delta S$ or ΔG. It was pleasing to see how many candidates had used specific terms like 'less negative' or 'more positive' for $-T\Delta S$ or ΔG, rather than less specific terms like 'larger' or 'smaller'.

Question 4

(a) This was answered well by many candidates.

(b) (i) This mark was scored by a majority of candidates.

(c) This discriminated well. The key information in the question is that the named complex is octahedral. Each $EDTA^{4-}$ ligand must donate six lone pairs for this to be true.

(d) This mark was scored by a majority of candidates.

(e) This was often answered well. Some candidates were unable to use a correct expression for K_{stab}.

(f) This discriminated well. Candidates who realised they were being asked to explain the colour difference between two complexes often scored two marks.

Question 5

(a) This discriminated well. Some candidates did not complete the equation, perhaps because they had not noticed the instruction to do so. Many answers suggested oxygen as one of the two gases. Since the other gas must be carbon dioxide this is not possible.

(b) This question was answered well by those candidates who appreciated the importance of cationic radius and polarisation of the anion. The unusual context of the $C_2O_4^{2-}$ ion caused difficulty to some candidates.

(c) This calculation was often very well managed. Many candidates explained clearly what each step of their calculation meant. It was much easier to award marks in such cases.

Question 6

(a) (i) The marks was usually awarded.

(ii) The marks was usually awarded.

(iii) This was found more difficult than parts **(i)** and **(ii)**. 'Energetically accessible' was the component of the answer that was most often omitted.

(b) (i) Candidates struggled with this question. Candidates had to use the information in the question and also use knowledge from their studies, for example that 1,2-diaminoethane is a bidentate ligand.

(ii) This discriminated well. It was expected that candidates would write an equation for a ligand exchange process in which $[Au(dien)(H_2O)_2Cl]^{2+}$ reacts with more chloride ions to form $Au(dien)Cl_3$, or the reverse process. An equation in which the two gold complexes react with each other was also possible, but was found to be more difficult to complete.

(iii) This mark was rarely awarded. Comparatively few candidates appreciated the importance of the information that when 'The *dien* ligand forms three bonds to the gold ion… these three bonds lie in the same plane.'

(iv) This discriminated well. The commonest error was to think that $Ni(PH_3)_2Cl_2$ is square planar. If this were correct the complex would show cis-trans isomerism, however Table 6.1 states that it does not. Although many correctly rendered three-dimensional structures were seen, some poor diagrams were also submitted by candidates. It is worth looking at four examples here.
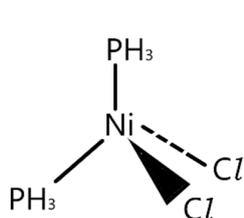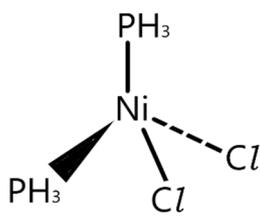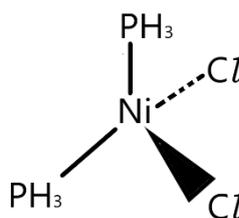
diagram 1   diagram 2   diagram 3   diagram 4
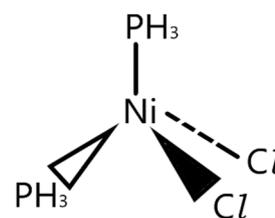
Diagram 1 is a **correct** diagram of this tetrahedral complex. Three different conventions have been used correctly to show three-dimensional bonds. It can be seen that it is not necessary to show the PH_3 ligand at the lower left as H_3P.

Diagram 2 is **incorrect** because the middle of the three lower bonds is in-plane with the bond to the PH_3 ligand shown above the Ni atom. This cannot be tetrahedral.

Diagram 3 is **incorrect** because one chlorine ligand is drawn further up the diagram, at the top right. This means that the bond angle between the upper PH_3–Ni bond and the upper Cl–Ni bond is less than 90°. This is a gross distortion of the tetrahedral bond angle which is 109.5°.

Diagram 4 is **incorrect** because four different conventions have been used to show three-dimensional bonds. The bond at the lower left to a PH_3 ligand may be approaching the observer, or receding from the observer, but an interpretation cannot be made with certainty.

(v) This discriminated well. Candidates who realised that the complex described is $[Rh(en)_2Cl_2]^+$ usually want on to complete a good answer.

(vi) Two marks were often scored. However some candidates decided that the two structures were optical isomers and drew two renditions of the cis isomer that were actually identical.

Question 7

(a) Many candidates scored two marks here.

(b) This was found to be difficult. Some candidates did not appreciate that a description of a carbon-13 NMR spectrum should include the number of peaks in each chemical shift range. The question stated that 'Methylbenzene and benzoic acid each have five different peaks…' but this information was often ignored.

(c) (i) Many candidates scored four marks here.

(ii) This discriminated well. Candidates often scored the mark for M, and for the reagents and conditions needed to form M. L was found to be more difficult, with $C_6H_5CO_2Cl$ a commonly seen wrong answer.

Question 8

(a) (i) This discriminated well. Some candidates did not realise that PLA must be a polyester and so found this very difficult. A significant number of diagrams were seen with basic errors, like five-valent carbon atoms, which lost marks.

(ii) The majority of candidates were able to write an answer that had some merit. Common errors were 'addition' on line one and 'carboxylic acid' on line two.

(iii) Those who were able to deduce that PLA is a condensation polymer usually scored this mark.

(b) (i) This discriminated well. Unfortunately some candidates missed, or ignored, the instruction to use Fig 8.1. and so copied shift ranges from Table 8.1 without making reference to the d values in the proton NMR spectrum. For the most part the spelling of words such as doublet and quadruplet was correct, this is good to see.

(ii) This discriminated well. Specific factual knowledge like this should always be one of a candiate's priorities. Some lost the mark because they answered with an incorrect abbreviation, such as THS or TMC.

(iii) This discriminated well. A specific reference to $CDCl_3$ not giving a peak or absorption, or to $CHCl_3$ giving a peak or absorption, was required for the mark. Less precise statements about $CDCl_3$ not giving a signal or a reading, or not being detected, did not score the mark.

(c) Many candidates struggled to answer **(c)** parts **(i)**, **(ii)** and **(iii)** due to a lack of relevant factual knowledge. Some answered the question as if it was about paper or thin layer chromatography, such answers very rarely scored marks. A number of excellent answers were seen however.

(c) (i) The answer is neither 'the time spent by the sample in the stationary phase' nor is it 'the time spent by the sample in the mobile phase'. Good correct answers include 'the total time spent by the sample in the stationary and mobile phases' and 'the time spent in the column by the sample between injection and detection'.

(ii) Correct answers were rarely seen. General descriptions such as 'unreactive gas and non-volatile liquid', and correct examples, were both acceptable for the mark.

(iii) The mark was rarely awarded.

Question 9

(a) The majority of candidates found this very difficult. The syllabus allowed for a number of different approaches. It was expected that candidates would choose the nucleophilic substitution reaction between ethylamine and chloroethane in hot ethanol, and the reduction reaction between ethylethanamide and lithium aluminium hydride in dry ether. However other syntheses, such as the hydrolysis of the N,N-diethylethanamide (the compound that forms in part **(d)**) were also acceptable.

(b) This question was highly discriminating. Some candidates showed very poor knowledge of the material, referring to the number of hydrogen atoms in each structure as evidence of 'more acidic' behaviour, or describing factors that influence covalent bond strengths within the three molecules.

It is still common to read an answer that describes a lone pair as 'attracting' an H^+ ion. While this is true it is not sufficient, any negative ion or d– region of a molecule will attract an H^+ ion. When comparing the basicity of different molecules the availability of the lone pair to be **donated** to an H^+ ion, or to **form a coordinate bond** to an H^+ ion should be compared.

Other candidates knew that basicity is due to the donation of the lone pair on the nitrogen atom to form a dative bond with a proton. Answers that began here often scored two or three marks.

(c)   The marks here were rarely awarded. Errors that lost marks included:

- failure to circle the azo group (–N=N–). Reading the instructions on the examination paper remains a key issue for some candidates.
- drawing a triple bonded azo group (–N≡N–)
- drawing an azo group with an electric charge (–N=N$^+$–) .

(d) (i)   This discriminated well. Many excellent answers were seen. The structure given on the question paper may have helped some candidates to show their knowledge.

(ii)   This discriminated well.

CHEMISTRY

Paper 9701/43
A Level Structured Questions 43

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows are a key part in the description of the mechanisms. Curly arrows should always start in a precise place and should be pointing towards a precise place.

General comments

The paper enabled candidates to demonstrate their knowledge and understanding of a wide range of chemistry topics.

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

Comments on specific questions

Question 1

(a) (i) This question was well answered. Candidates had to suggest two equations for this mechanism that was consistent with the given information. Common errors included:
- step 1 not being a molar ratio (1:1) consistent with the orders of reaction,
- steps in the mechanism that were not balanced.

(ii) This proved difficult for some candidates. Answers should be linked to the rate determining step (step 1) which contains one mole of F_2 and one mole of ClO_2.

(b) (i) Most candidates gave the correct rate equation. A common error was to square the concentration of ClO_2.

(ii) Candidates usually answered this correctly.

(c) (i) Candidates performed well on this question.

(ii) Most candidates plotted the points accurately and gave a suitable best fit curve.

(iii) This question discriminated well. Candidates were required to draw a suitable tangent on their line at $0.00100 \, \text{mol dm}^{-3}$ and calculate its gradient. A common error was omitting a tangent which scored no credit.

Question 2

(a)   Candidates usually answered this correctly.

(b)(i)   This calculation proved challenging to many candidates. They had to recognize that HCl and $NaOH$ are both fully dissociated and differ by 11 pH units, so **V** has a pH of 1.5. The concentration of HCl can be calculated using $10^{-1.5}$ to give 0.0316.

(ii)   Many candidates correctly identified the solution as sodium chloride with pH 7. A common error was identifying the solution as water. Some candidates gave the incorrect pH for this solution.

(iii)   Most candidates estimated the pH of both solutions correctly.

(c)(i)   This question was well answered. The trend in acid strength was usually correct and many excellent explanations were seen. Some referred to C=O group as being electron-withdrawing which did not distinguish between the two organic acids.

(ii)   The concept of conjugate acid-base pairs did not seem to be well understood. Many candidates gave incorrect species such as $H_2SO_3^+$, OH^- and SO_4^-.

(d)(i)   Most candidates answered this question well. Weaker candidates omitted to reference an equilibrium. Some stated solubilities of the solutes instead of concentrations.

(ii)   Most candidates calculated the mass of **Q** correctly.

(iii)   This question discriminated well. Many candidates gave volumes of water 7.84 times the volume of hexane.

(iv)   This question was well answered. Many candidates correctly identified **Q** as pentan-1-ol, although some stated that this was a non-polar molecule rather than the least polar molecule. A number of answers stated that **Q** was KCl.

Question 3

(a)(i)   This definition was well known.

(ii)   This question was well answered. Most candidates correctly identified that ΔS was positive and clearly described their reasoning.

(b)   Candidates performed well on this question and clearly showed how -196 was calculated. Some candidates did not realise that four moles of O–H bonds were broken as well as formed in this reaction.

(c)   This question was well answered. A good understanding of energy cycles was shown and correct application of the Gibbs equation. It is important to emphasise the value of showing working. Common errors included two marks for +64.1 (omission x 1000) and –76.9 (sign error –141 used).

(d)   Most candidates correctly identified the catalyst as $FeCl_3$ stating it was in the same phase as H_2O_2.

(e)(i)   Most candidates identified H_2O_2 as the positive half-cell but some incorrectly gave +1.77 V or +1.36 V.

(ii)   This question was well answered. Common errors included +421 (sign error) and –341.6 (use of 1.77 instead of 2.18 for the E_{cell}).

(f)(i)   This question was found to be difficult. Many incorrect versions of the Nernst equation were seen. Some common errors were +1.94 and +1.76.

(ii)   This question was well answered. The cell reaction was frequently written the wrong way around.

(g)(i)   This definition was well known.

(ii) Many good answers were seen here. Some candidates did not use arrowheads to show the direction of the energy changes.

(iii) Candidates performed well on this question.

Question 4

(a) (i) This question was answered well. Common errors included $[Co(NH_3)_4(H_2O)_2]^{2+}$, $[CoCl_4]^{2+}$ and $[CoCl_4]^{-}$.

(ii) Most candidates correctly identified the colour change.

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

(ii) Many excellent answers were seen. Some candidates did not use the decomposition temperature for calcium nitrate given and suggested inappropriate temperatures for the decomposition of magnesium nitrate and barium nitrate. Many candidates gave a correct statement regarding increasing cation radius down Group 2. Decreasing polarisation of the nitrate anion was less frequently seen.

Question 5

(a) Most candidates suggested that variable oxidation states were needed for transition elements to act as catalysts. Less candidates were able to recall that vacant d-orbitals that are energetically accessible (to accept lone pairs from ligands) are also required.

(b) (i) Candidates found this question difficult. Many suggested the coordination number was six instead of eight.

(ii) Candidates performed well on this question. Some did not clearly label bond angles on their diagrams and showed the angle going from the bond to the atom instead of the bond to the bond. Another common error was drawing an incorrect tetrahedral three-dimensional diagram.

(c) (i) This question was answered correctly. Some candidates put charges outside the concentration brackets or had the inverse of the expression.

(ii) This question was answered well.

(d) (i) Candidates performed well on this question. The most common error was 4.02×10^{-4}.

(ii) This question discriminated well. Many candidates lost this mark by multiplying their answer to **(i)** by 2 instead of by 8.

(iii) This question was answered well. Many candidates scored credit by error carried forward.

(iv) This question proved difficult for some candidates. Many did not reference that Cu^{2+} is d^9 / had partially filled d subshell and Cu^+ is d^{10} / full d subshell.

Question 6

(a) (i) Most candidates completed the table correctly. A common error was suggesting $EDTA^{4-}$ was a bidentate ligand instead of a polydentate ligand.

(ii) Most candidates gave a correct definition for a tridentate ligand.

(iii)   Candidates often gave the correct answer here.

(b)(i)   Most candidates completed the table correctly.

(ii)   Most candidates gave a correct description.

Question 7

(a)   This question discriminated well. Many correct answers were seen. Some common errors were $C_{16}H_{10}N_2O_6S_2$ and $C_{16}H_{11}N_2O_7S_2$.

(b)   This question was answered well. The structures of **E** and **G** were normally correct. A common error was placing the positive charge on the incorrect N on the diazo compound **F**.

(c)   Many candidates were able to identify the correct reagents and conditions. Common errors included:
- in step 1: use of HNO_3 instead of HNO_2 or suggesting an incorrect temperature,
- in step 2: omitting alkaline conditions / NaOH(aq).

(d)   This question proved difficult for many candidates.

Question 8

(a)   Candidates found this a difficult compound to identify all the functional groups. The incorrect groups 'alcohol' or 'ketone' were often given in candidates' answers.

(b)   Many candidates thought HBr was a product of the addition of bromine across the C=C bond and some did not add bromine to the C=C bond.

(c)   The reduction of the benzene ring was well understood but far fewer candidates reduced the alkene functional group.

(d)(i)   These conditions were not well known and 'concentrated' was frequently omitted with the description of potassium manganate(VII).

(ii)   This question was answered well. Many candidates correctly identified the chemical shift values. Fewer candidates were able to select the correct splitting patterns that would be seen. Common errors included stating the CH environment was a quartet (instead of a multiplet) or COOH was a doublet (instead of a singlet). The explanation for the splitting patterns was well known.

(e)(i)   This question discriminated well. Some excellent answers were seen. Some common errors are shown.

(ii)   This question proved difficult for candidates. Oxidation and substitution were common incorrect answers.

(f)   Although correct answers were seen, many candidates reduced the C=O to an alcohol or C=C to an alkane.

Question 9

(a)(i)   Most candidates gave a correct answer. A common error was including an additional CH_2 group to give $C_6H_5CH_2COOH$.

(ii)   This question was answered correctly.

(iii)   This question was well answered. A common error was condensation for step 2.

(b)(i) Many candidates completed the mechanism diagrams well, most gaining some credit. Common errors included:
- adding an additional charge (normally negative) on the O in the phenol (box 1)
- the curly arrow in the intermediate starting at the H not on the O–H bond to the O atom (box 2)
- the curly arrow in the intermediate starting at the C–O bond not on the O⁻ or going to the C atom (box 2).

(ii)   This question was well answered. A common error was nucleophilic substitution.

(c)   This piece of factual recall was known by many candidates. Some thought chloroethane was harder to hydrolyse than chlorobenzene. Weaker candidates omitted any reference to the strengthening / weakening of C–Cl bond.

CHEMISTRY

> **Paper 9701/51**
> **Planning, Analysis and Evaluation 51**

Key messages

Candidates cannot be adequately prepared for this exam without extensive laboratory work of A Level standard during their course of study.

Candidates are weak at understanding the consequences of performing experiments in a particular way and should be advised to examine, in detail, how and why experimental methods are chosen each time they work in the laboratory.

Question 1

(a)(i) When recording results of an experiment it is important that candidates show the precision of the apparatus used in the data recorded. For burette readings this is **half** the smallest graduation marking, in other words to $\pm0.05\,cm^3$. Both burette readings and titre values should therefore be recorded to 2 decimal places.

Most candidates were able to calculate the titre values missing from Table 1.1. A small number did not give all the values to two decimal places.

The mean titre should be calculated using concordant titres within $\pm0.10\,cm^3$ of each other. In this question titres from runs 2 and 3 should be used as they are the only concordant results. The most common incorrect mean was $26.83\,cm^3$, obtained by using titres from runs 1, 2 and 3.

(ii) Whilst there are several methods of carrying out this calculation the simplest and most obvious involves three steps.

1. Calculate amount of sodium thiosulfate used in the mean titre.
2. Use the chemical equations given to determine the stoichiometric ratio of amount of sodium thiosulfate to amount of oxygen dissolved in $25.0\,cm^3$ of the water sample.
3. Calculate the concentration of oxygen in the water sample.

Whilst most candidates appeared to understand the general flow of this calculation and were able to perform steps 1 and 3 successfully, step 2 proved to be much more difficult. Dividing by 2 or 1 in step 2 of the calculation led to the most frequent incorrect answers, 5.35×10^{-4} and 1.07×10^{-3}.

(b) Most candidates selected a suitable piece of apparatus. It is important to distinguish the type of pipette to be used when answering this type of question. Simply describing the required apparatus as 'pipette' alone is ambiguous – a **volumetric** pipette is needed here.

(c) Few candidates managed to produce a full enough explanation to gain a mark.

A good answer would include:

- *(extra) oxygen from the air trapped in the flask.*
- *Dissolves in the water*
- *increasing concentration OR reacts with/oxidises Mn(OH)$_2$*

(d)(i) Plotting of the points on the provided grid was done well by most candidates. A small number of candidates plotted points to the nearest grid line. Data points should be plotted correctly even if they do not correspond exactly to a grid line intersection.

The line of best fit was also drawn smoothly and reasonably accurately by most candidates.

(ii) Most candidates could read the coordinates of the intersection of the line of best fit with the 25 °C gridline. A much smaller number noticed that the y-axis is labelled 'concentration of oxygen $\times 10^{-4}$' and, consequently, gave an answer 10,000 times the correct answer.

(iii) Selection and labelling of the most anomalous point did not pose a significant problem to most candidates. Explaining the anomaly was more difficult. Correct use of key terms was central to the production of a correct response.

Question 2

(a) Candidates should be able to describe the arrangement of apparatus by use of words or labelled diagrams. Suitable diagrams should be neatly drawn using a ruler, **fully labelled** and follow the usual conventions for representing apparatus.

Most candidates achieved the first mark by drawing leakproof apparatus capable of delivering a sample of gas. Extension of the delivery tube into the reaction vessel contents and failure to seal the reaction vessel were common mistakes. Many did not realise that the $C_6H_5N_2Cl$ (aq) contained the water needed for the reaction to take place and added more water to the reaction mixture. This was not penalised.

The second mark was awarded to most candidates for the collection and measurement of the gas in a gas syringe or over water in a suitable vessel.

A method for maintaining the temperature at 50 °C, i.e. a thermostatically controlled water bath, required for the third mark, was included by fewer candidates.

(b)(i) Drawing an accurate tangent at t = 0 can be tricky therefore some variation in the lines was allowed. The tangent should be a straight line that has the same gradient of the curve at 0,0 and only touches the curve at that point. Most unacceptable lines were too steep.

(ii) Many candidates stated that using the concentrations at the beginning and end of a time period over which the reaction rate is decreasing results in the calculation of an **average rate** for the reaction over this time interval.

(iii) Boyle's Law states that for a fixed amount of gas at a fixed temperature the volume is inversely proportional to the applied pressure. (i.e. $P \propto 1/V$). If the pressure is increased, then the volume of the gas will be smaller throughout the experiment. Many candidates thought that the reaction rate would increase – this would only happen if gaseous reactants were involved in the reaction.

(iv) Most candidates who attempted this part produced acceptable curves. There were many candidates who gave no response (NR).

(c)(i) Most candidates were able to complete the table correctly. A few were unable to follow the instructions given in the question, producing values equal to concentration divided by the time taken or vice versa.

(ii) Candidates were expected to show clearly how the data in the table supported the rate equation given. The data given in Table 2.1 is experimental and in some instances does not support the statement. Some candidates chose to use data of this type in their answer and did not gain a mark as a result.

A successful response had to include data values from the table that supported the rate equation and explain how it did so.

(iii) A variable is dependent if its value changes because of the experimenter changing the independent variable. Other variables involved in this experiment were given as incorrect responses.

(iv) Candidates were required to describe the laboratory practice used when making up a standard solution by dilution of a more concentrated solution. It was clear that many candidates had learned

the method of preparing a standard solution from a solid and included unnecessary steps in their method. For example, it is not necessary to add water to the 40 cm^3 of 0.500 moldm^{-3} solution to dissolve it as it is already a solution.

(v)   The temperature was kept below 5 °C to **prevent** decomposition of benzene diazonium chloride during the preparation of the 0.200 moldm^{-3} solution. If this did occur, then the concentration of the solution would have been lower than desired.

(d)(i)   The responses listed in the mark scheme can be deduced from the information given in the question. A wide variety of other sensible suggestions were given credit. Some candidates gave answers including unnecessarily detailed chemistry, which was often incorrect.

(ii)   If the sample had not been fully dried, the melting point would have a broad range, i.e. would not be sharp, and have a lower value than that of the pure solid. A common misconception was that extra energy would be needed to evaporate the water present, so the melting point would be higher than that of the pure solid.

CHEMISTRY

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Paper 9701/52
Planning, Analysis and Evaluation 52

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Key messages

Candidates should access past papers to recognise expected answers to similar planning, analysis and evaluation questions.

Many candidates opt to draw their line of best fit directly from the first point to the last point without due regard to the plotted points. Candidates are reminded that lines of best fit should be drawn through the maximum number of points on a scatter plot, balancing about an equal number of points above and below the line.

Candidates should round numerical answers at the final stage of a multistage question. Early rounding will lead to incorrect final answers.

General comments

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

Numerical answers should reflect the appropriate number of significant figures, usually three significant figures. One significant figure will usually be insufficient.

Candidates should be aware of the difference between three significant figures and three decimal places.

Comments on specific questions

Question 1

(a) (i) Most candidates plotted the points correctly. Occasionally the first point at $(0.00 \, cm^3, 18.8 \, °C)$ was sometimes plotted at $(0.00 \, cm^3, 18.0 \, °C)$ or was omitted entirely.

The two straight lines of best fit proved more challenging. The line of best fit for the fall in temperature should have omitted the point at $(40.00 \, cm^3, 23.2 \, °C)$ as it was anomalous. Many weaker candidates simply drew this line from 'first point' to last point' and therefore included the anomaly.

Many candidates contrived their lines of best fit to intersect at the point plotted at $(20.00 \, cm^3, 27.4 \, °C)$ presumably because this was the highest temperature value in Table 1.1.

(ii) More able candidates coped well with this question. A common error was to give the highest temperature reached, i.e. the temperature of the intersect, rather than subtracting 18.8 °C from this value.

Weaker candidates drew a correct intersect but chose 27.4 °C, the highest temperature value in Table 1.1, as the highest temperature reached.

(iii) More able candidates coped well with this question, but many weaker candidates had problems with the x-axis scale. For example, 17.50 cm^3 being interpreted as 15.50 cm^3 and 18.00 cm^3 was frequently interpreted as 15.60 cm^3.

(iv) The calculation proved challenging. Weaker candidates used the answer in **(a)(iii)** as a volume of HCl(aq) rather than NaOH(aq). Rounding also caused a problem for those with a value of 18.00 cm^3 in **(a)(iii)** where the answer of 0.1388 was frequently incorrectly rounded to 0.140.

(v) Candidates found difficulty in suggesting why a titration using an indicator is more accurate than a thermometric titration. Some received credit for focusing upon the lack of heat loss when using an indicator, or the immediacy of the colour change but many simply repeated the question by re-stating that indicator titrations are more accurate.

(b) This was very well answered with most candidates correctly stating that a (25.00 cm^3) volumetric pipette should be used. Graduated pipettes and burettes were also credited.

(c) Percentage error calculations continue to cause problems. Using a thermometer to measure a temperature increase involves two readings, each with an error of $\pm$ half a graduation (0.1 °C) therefore the working needed to include 0.1×2. Many candidates omitted this. Others chose the temperature after 5.00 cm^3 (21.3 °C) instead of the temperature increase (2.5 °C).

(d) This was not such a straightforward calculation as **1(a)(iv)**. First, candidates needed to insert values into the expression $\Delta H = mc\Delta T$ to find the value of energy change in J.

For m, it should have been the total mass of solutions mixed, 47.1 g. Many candidates chose either 25 g, from the volume of HCl(aq) used or 22.1 g from the volume of NaOH(aq) used. Occasionally candidates made m equal to 1.

For c, candidates were expected to find this in the table of 'Important values, constants and standards' given on page 11 of the question paper. Occasionally an incorrect value of 4.2 for c was used.

For ΔT, candidates were expected simply insert the value of 6.0 °C given in the question, but many assumed that 6.0 °C was a temperature reading and converted to Kelvin by adding 273 to 6.0.

The second step involved a conversion into molar quantities by division by the number of moles of the limiting factor, i.e. 0.0221 mol of NaOH.

Frequently the division was by 0.025, the number of moles of HCl or by 0.0471, the combined moles of HCl + NaOH.

Also, at some stage the final answer needed a division by 1000 to convert J to kJ.

Many candidates rounded their answer to the first part before calculating the second part, thus producing an incorrect final answer due to this early rounding.

(e) Most candidates knew that the experimental value was lower than the theoretical value because of heat loss, although the fact that the experiment was not carried out under standard conditions was also acceptable.

(f)   Most candidates scored the first mark for stating that ethanoic acid was a weaker acid or dissociated partially (compared to hydrochloric acid). Vague phrases such as 'ethanoic acid is less acidic' were not given credit.

Only a few candidates were able to explain that energy was needed to complete the dissociation of ethanoic acid, so the measured enthalpy of neutralisation was less exothermic in comparison to hydrochloric acid.

The most common misconception was that because the ethanoic acid was only partially dissociated it would produce fewer water molecules – hence less exothermic.

Question 2

(a)   Most candidates were able to draw an air-tight apparatus for one mark and were able to gain a second mark by drawing either a gas syringe or inverted measuring cylinder above water as a means of determining the volume of hydrogen gas collected.

The most difficult mark, which few candidates scored, was for mixing Zn with HCl(aq) without loss of gas. This was usually accomplished by using a test-tube or weighing boat containing Zn on a thread within the reaction vessel which contained HCl(aq). Bifurcated flasks were also credited.

(b)   The key points of making up a standard solution from a solution of known concentration were known by most candidates. Common errors included:

Calculating an incorrect volume of 2.00 mol dm^{-3} HCl(aq).

Using non-volumetric apparatus, usually a measuring cylinder, to measure the volume of 2.00 mol dm^{-3} HCl(aq).

Using the correct volumetric apparatus for the transfer of the calculated volume of 2.00 mol dm^{-3} HCl(aq) – a burette was needed if this volume was 12.5 cm^3, (a pipette was allowed if the volume of 2.00 mol dm^{-3} HCl(aq) was incorrectly calculated as 25.0 cm^3) but then rinsing the burette (or pipette) into the volumetric flask thus increasing the amount of HCl in the volumetric flask.

Not using *distilled* water when topping up the volumetric flask to 250 cm^3.

(c) (i)   Most candidates realised that 6.00 mol dm^{-3} HCl(aq) was likely to be corrosive or an irritant or cause burns. Vague responses such as 'harmful' or 'dangerous' received no credit.

(ii)   Table 2.1 was completed correctly but there are still many candidates who do not appreciate the difference between significant figures and decimal places. Also 1/t (t =10.41s) was often incorrectly rounded to 0.0960 rather than 0.0961.

(iii)   Most candidates understood that a straight line starting at the origin was required. Common errors included drawing straight lines which did not include the origin or drawing curves indicating that 1/t decreased with concentration increase.

(iv)   Candidates who drew a straight line in **(c)(iii)** almost always drew a straight line in this question and most with the gradient being steeper.

(v) The data in Table 2.1 indicated that 1/t (which was proportional to the initial rate of the reaction) doubled with a doubling of concentration therefore the order was first order with respect to HC*l*(aq) and rate = k[HC*l*(aq)]^1 (rate = k[HC*l*(aq)] was accepted). More able candidates scored this mark and a few went on to correctly calculate k and include the value, 0.032, in their rate equation.

Weaker candidates tended to include Zn in their rate equation.

(d)(i) This was a challenging question, and the complexity of the concentration *and* temperature change confused many candidates. This would result in a curve with continually increasing gradient, which even more able candidates found difficult to describe. Weaker candidates offered no explanation for the change in gradient of line A or wrote about the effect of concentration on rate of reaction without mentioning the increase in temperature.

(ii) The idea of using an ice bath to keep the temperature constant was well known. Additional correct, answers were also accepted, such as using less zinc or using a larger volume of the acid.

(e)(i) Rubbing with sandpaper or other physically abrasive methods to remove the oxide layer were well known. Some candidates suggested chemical methods to remove the oxide layer but most of these ignored the need to wash and dry the foil afterwards.

(ii) This was a challenging question, as candidates had to remember that the rate was measured by timing the volume of hydrogen formed. They then needed to explain that whilst the hydrochloric acid was reacting with the zinc oxide layer that no hydrogen gas given off. This only happened when the acid started to react with the zinc itself and very few candidates explained that the production of hydrogen (or gas) would be delayed.

CHEMISTRY

Key messages

Candidates cannot be adequately prepared for this exam without extensive laboratory work of A Level standard during their course of study.

Candidates are weak at understanding the consequences of performing experiments in a particular way and should be advised to examine, in detail, how and why experimental methods are chosen each time they work in the laboratory.

Question 1

(a)(i) When recording results of an experiment it is important that candidates show the precision of the apparatus used in the data recorded. For burette readings this is **half** the smallest graduation marking, in other words to $\pm 0.05\,cm^3$. Both burette readings and titre values should therefore be recorded to 2 decimal places.

Most candidates were able to calculate the titre values missing from Table 1.1. A small number did not give all the values to two decimal places.

The mean titre should be calculated using concordant titres within $\pm 0.10\,cm^3$ of each other. In this question titres from runs 2 and 3 should be used as they are the only concordant results. The most common incorrect mean was $26.83\,cm^3$, obtained by using titres from runs 1, 2 and 3.

(ii) Whilst there are several methods of carrying out this calculation the simplest and most obvious involves three steps.

1. Calculate amount of sodium thiosulfate used in the mean titre.
2. Use the chemical equations given to determine the stoichiometric ratio of amount of sodium thiosulfate to amount of oxygen dissolved in $25.0\,cm^3$ of the water sample.
3. Calculate the concentration of oxygen in the water sample.

Whilst most candidates appeared to understand the general flow of this calculation and were able to perform steps 1 and 3 successfully, step 2 proved to be much more difficult. Dividing by 2 or 1 in step 2 of the calculation led to the most frequent incorrect answers, 5.35×10^{-4} and 1.07×10^{-3}.

(b) Most candidates selected a suitable piece of apparatus. It is important to distinguish the type of pipette to be used when answering this type of question. Simply describing the required apparatus as 'pipette' alone is ambiguous – a **volumetric** pipette is needed here.

(c) Few candidates managed to produce a full enough explanation to gain a mark.

A good answer would include:

- *(extra) oxygen from the air trapped in the flask.*
- *Dissolves in the water*
- *increasing concentration OR reacts with/oxidises Mn(OH)$_2$*

(d)(i) Plotting of the points on the provided grid was done well by most candidates. A small number of candidates plotted points to the nearest grid line. Data points should be plotted correctly even if they do not correspond exactly to a grid line intersection.

The line of best fit was also drawn smoothly and reasonably accurately by most candidates.

(ii) Most candidates could read the coordinates of the intersection of the line of best fit with the 25 °C gridline. A much smaller number noticed that the y-axis is labelled 'concentration of oxygen $\times 10^{-4}$' and, consequently, gave an answer 10,000 times the correct answer.

(iii) Selection and labelling of the most anomalous point did not pose a significant problem to most candidates. Explaining the anomaly was more difficult. Correct use of key terms was central to the production of a correct response.

Question 2

(a) Candidates should be able to describe the arrangement of apparatus by use of words or labelled diagrams. Suitable diagrams should be neatly drawn using a ruler, **fully labelled** and follow the usual conventions for representing apparatus.

Most candidates achieved the first mark by drawing leakproof apparatus capable of delivering a sample of gas. Extension of the delivery tube into the reaction vessel contents and failure to seal the reaction vessel were common mistakes. Many did not realise that the $C_6H_5N_2Cl$ (aq) contained the water needed for the reaction to take place and added more water to the reaction mixture. This was not penalised.

The second mark was awarded to most candidates for the collection and measurement of the gas in a gas syringe or over water in a suitable vessel.

A method for maintaining the temperature at 50 °C, i.e. a thermostatically controlled water bath, required for the third mark, was included by fewer candidates.

(b)(i) Drawing an accurate tangent at t = 0 can be tricky therefore some variation in the lines was allowed. The tangent should be a straight line that has the same gradient of the curve at 0,0 and only touches the curve at that point. Most unacceptable lines were too steep.

(ii) Many candidates stated that using the concentrations at the beginning and end of a time period over which the reaction rate is decreasing results in the calculation of an **average rate** for the reaction over this time interval.

(iii) Boyle's Law states that for a fixed amount of gas at a fixed temperature the volume is inversely proportional to the applied pressure. (i.e. P ∝ 1/V). If the pressure is increased, then the volume of the gas will be smaller throughout the experiment. Many candidates thought that the reaction rate would increase – this would only happen if gaseous reactants were involved in the reaction.

(iv) Most candidates who attempted this part produced acceptable curves. There were many candidates who gave no response (NR).

(c)(i) Most candidates were able to complete the table correctly. A few were unable to follow the instructions given in the question, producing values equal to concentration divided by the time taken or vice versa.

(ii) Candidates were expected to show clearly how the data in the table supported the rate equation given. The data given in Table 2.1 is experimental and in some instances does not support the statement. Some candidates chose to use data of this type in their answer and did not gain a mark as a result.

A successful response had to include data values from the table that supported the rate equation and explain how it did so.

(iii) A variable is dependent if its value changes because of the experimenter changing the independent variable. Other variables involved in this experiment were given as incorrect responses.

(iv) Candidates were required to describe the laboratory practice used when making up a standard solution by dilution of a more concentrated solution. It was clear that many candidates had learned

the method of preparing a standard solution from a solid and included unnecessary steps in their method. For example, it is not necessary to add water to the $40\,cm^3$ of $0.500\,moldm^{-3}$ solution to dissolve it as it is already a solution.

(v) The temperature was kept below $5\,^\circ C$ to **prevent** decomposition of benzene diazonium chloride during the preparation of the $0.200\,moldm^{-3}$ solution. If this did occur, then the concentration of the solution would have been lower than desired.

(d)(i) The responses listed in the mark scheme can be deduced from the information given in the question. A wide variety of other sensible suggestions were given credit. Some candidates gave answers including unnecessarily detailed chemistry, which was often incorrect.

(ii) If the sample had not been fully dried, the melting point would have a broad range, i.e. would not be sharp, and have a lower value than that of the pure solid. A common misconception was that extra energy would be needed to evaporate the water present, so the melting point would be higher than that of the pure solid.