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Paper 9701/12
Multiple Choice

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

General comments

The majority of candidates were able to finish the paper within the hour allowed.

Candidates found **Questions 1**, **2**, **3**, **5**, **7**, **8**, **9**, **11**, **14**, **15**, **16**, **23**, **28**, **31**, **32** and **35** straightforward. **Questions 6**, **21**, **24**, **25**, **26**, **33** and **40** were more challenging.

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Comment on specific questions

Question 6

The most commonly chosen incorrect option was **B**. The choice of **B** comes about if the units of AgC*l*(s) are included as mol dm^{-3}; since it is a pure solid, it doesn't have a concentration.

Question 21

The most commonly chosen incorrect option was **A**. The majority of candidates knew that the starting material must have three carbon atoms per molecule. Since HCN is a very weak acid it results in a very low concentration of CN^- ions, so NaCN must be used to produce a higher concentration of CN^- ions.

Question 24

The most commonly chosen incorrect option was **B**. Candidates found this question particularly challenging. It was approached by identifying the repeat unit of the polymer and then drawing the monomer on the question paper. It should then be seen that the C=C group has a hydrogen atom and a methyl group on one end, and an ethyl group and a $–CH(CH_3)_2$ group on the other end. From here, monomer **A** can be identified as the correct option.

Question 25

The most commonly chosen incorrect option was **C**. The six isomers are:

- pent-1-ene
- *cis* pent-2-ene
- *trans* pent-2-ene
- 2-methylbut-1-ene
- 3-methylbut-1-ene
- 2-methylbut-2-ene.

Question 26

The most commonly chosen incorrect option was **B**. This suggests that while most candidates understood Markovnikov addition at a double bond, the substitution reaction between the –OH group and HBr was less well known.

Question 33

The most commonly chosen incorrect option was **B**. For the majority of candidates, this question rested on the truth or otherwise of statement 2. The equation in the question is not for complete combustion, so its $\Delta H^{\ominus}$ is not a $\Delta H_c^{\ominus}$; therefore, statement 2 is not correct.

Question 40

The most commonly chosen incorrect option was **B**. For the majority of candidates, this question rested on the truth or otherwise of statement 3. When 0.01 mol of either ethene or ethane undergoes complete combustion at room temperature and pressure 0.02 mol of CO_2 is produced. Although different masses of water are produced, this water is a liquid at room temperature and pressure. Therefore, the same volume of gas is produced in both cases and statement 3 is true.

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Paper 9701/22
AS Level Structured Questions

Key messages

- Candidates are reminded to read questions carefully and check answers thoroughly, especially in extended answers where more writing is required. The accurate use of chemical terminology is welcomed, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument.
- Candidates are reminded to address 'explain' questions fully — not merely to state facts or rules of thumb, but to show how these combine to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules, in particular for organic species, linking structural feature to mechanistic probabilities.
- Candidates are reminded that their working in calculations should be shown to ensure that due credit can be awarded. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

General comments

Candidates must be clear about the difference between items that ask them to *state* information and those that ask them to *explain*. In this latter case, it is not sufficient to quote a 'rule' by way of evidence; proper reasoning needs to be incorporated into an answer.

Scripts were generally clear and well presented. As a general point of presentation, it is difficult for examiners to read scripts where answers written in pencil have been overlaid with ink without rubbing out the pencil. Papers should be cleaned of debris from erasers, as this too affects the legibility of responses.

Comments on specific questions

Question 1

This question was predominantly based on physical chemistry. Candidates are reminded to look carefully at the detail of each question and to be precise in their inclusion of detail and vocabulary. Calculations should be checked to ensure stoichiometry has been accounted for. Fractions are not acceptable as answers referencing physical quantities.

(a) (i) Some candidates were not able to give the correct formula for $Ca(OH)_2$; other answers erroneously gave H_2 as a by-product of the addition reaction.

(ii) Most candidates answered this question correctly.

(b) Candidates were usually able to write in terms of weaker forces of attraction and larger cations; fewer were able complete the answer by identifying the constant charge (and therefore decreasing charge density) of the cations down the group.

(c) This was well answered by many candidates.

(d) Candidates who were unable to deduce $Be(OH)_2$ as linear most often suggested it to have the regular tetrahedral bond angle.

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(e) (i) This was well answered by many candidates.

(ii) Some candidates seemed to be confused by the likening to aluminium oxide and gave Be_2O_3 as the formula of the oxide. Others added OH^-, forming $Be(OH)_4^{2-}$, but neglected to add H_2O to the left-hand side of the equation.

(f) (i) Candidates gave several variations on the themes of equilibrium systems, though often restated one property in different ways (e.g. concentration of reactants and products remain constant and macroscopic properties remain constant). Some candidates gave non-specific answers, such as 'rates of forward and backward reactions are constant', which were insufficient.

(ii) Candidates' common errors were to neglect the 2:1 stoichiometry of the reaction or to try incorrectly to include solid-state substances in the equilibrium law equation. Candidates are reminded to take care with rounding and to avoid such when part of the way through a calculation. The units 1/Pa were not accepted.

(g) (i) Many candidates could answer this; some gave −2 as the answer, imitating the total charge of the ion.

(ii) Common inaccuracies in candidates' definitions were to omit the reference to elements in their standard states; this is not the same as *standard conditions*. Others were too specific, such as saying the 'enthalpy/energy released' or 'enthalpy/energy required', rather than simply 'enthalpy change'.

(iii) This was answered well by many candidates; although often the value for ΔH_f was included on the wrong side of the equation, giving an answer that differed from the correct value by 192 ($kJ\,mol^{-1}$).

(iv) Similar errors to **(g)(iii)** gave answers that differed by 1200 $kJ\,mol^{-1}$.

Question 2

The main focus of this question was inorganic chemistry, with some inclusion of physical and organic questions. Candidates should be clear when making statements about particular properties not to be overly general and therefore to contradict their correct answers.

(a) This was answered well by most candidates.

(b) (i) This was answered well by most candidates.

(ii) Candidates were mostly able to identify the structure as simple but could not sufficiently link its covalency with the *hydrolysis* of the molecule.

(c) (i) Many candidates were able to identify the cream precipitate. Loose wording prevented the second mark, silver bromide *partially* dissolves in ammonia, from being awarded to many. Answers identifying different behaviour between dilute and concentrated ammoniacal solutions were given credit.

(ii) This item proved to be the most challenging to candidates, who frequently neglected to identify the acidic behaviour of H_2SO_4 with chloride. Many were able to write about the oxidising properties of H_2SO_4 with iodide and to identify the products of the reaction. Credit could not be awarded when H_2SO_4/Cl^- was misidentified as a redox reaction.

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

(ii) Candidates are reminded to be specific in their reference to H—Hal when answering about bond enthalpy.

(e) (i) This was answered well by most candidates. Common errors were to answer as if for *heterogeneous* catalysis, or to suggest that the definition depended on the state of the products.

(ii) Some candidates attempted to substitute an atom other than the central hydroxyl radical; others gave an incorrect carbon backbone, often 2-methylbutyl.

(iii) Candidates are reminded to avoid ambiguity in their structures, by the use of brackets in condensed structural formulae, or by being clear with atom connectivity in displayed structures.

(iv) This was answered well by most candidates.

Question 3

This question based on organic chemistry was well answered by many. A thorough knowledge and identification of functional groups and their chemical properties was necessary to perform well. Candidates are expected to be clear and explicit in structural determination.

(a) (i) Candidates are reminded that dichromate(VI) and manganate(VII) need to be acidified. Manganate(VII) must not be used with HC*l*; complete oxidation takes place when the reaction mixture is heated under reflux.

(ii) Some candidates showed confusion between the different mechanisms in this syllabus.

(iii) Candidates are reminded to specify the formation of a *precipitate* when applicable.

(iv) This was well answered by many candidates.

(v) This was well answered by many candidates; many candidates mistakenly took the esterification reaction to be an addition process.

(b) (i) A common omission was the stoichiometric coefficient 4 between the amount of O_2 and nitroglycerine. Many candidates were also unpractised at converting volumes from dm^3 to m^3.

(ii) Some candidates ignored Avogadro's Law of equal moles of gas, preferring to use 24 dm^3 to convert to and from moles. Many candidates did not correctly count the total number of moles of gas in the equation.

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

(ii) Candidates are reminded of the need for clarity when showing the connectivity of atoms in organic structures.

(iii) Many candidates used partial skeletal formulae for clarity, which was acceptable. To avoid confusion in such cases, candidates must be entirely *explicit* or entirely *implicit* in their depiction of H atoms, to avoid hybrid structures which are difficult to interpret.

The origin and destination of curly arrows should be shown clearly.

Some candidates oriented the dipole in Br_2 incorrectly.

Curly arrows from anions need to originate from the lone pair, not from the negative charge.

(d) (i) Some candidates incorrectly swapped the position of the Br substituent from one carbon to another, rather than alter the stereochemistry of the C=C double bond. When describing the origins of the diastereoisomerism, candidates were mostly able to talk about the numbers of different groups on each carbon but neglected to identify the lack of free rotation (about the pi bond).

(ii) This was well answered by many candidates.

(iii) Candidates showed themselves well practised at answering questions of this style, though their attention is brought to being careful not to include wavenumber (ranges) outside the values given for particular absorptions. In reference to the carboxylic acid O—H stretch, it is best to be explicit; mention of O—H on its own does not distinguish it from alcoholic stretches. CO_2—H is acceptable as an abbreviation for this.

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Paper 9701/33
Advanced Practical Skills 1

Key messages

- Candidates are advised to read the instructions given in the question paper carefully. Underlining or highlighting key words may help some provide apposite answers.
- Candidates should be encouraged to think carefully before answering so that important differences between, for example, heat energy and temperature are considered.
- Candidates should be reminded to indicate clearly changes in both colour and state in observational exercises.
- If candidates are not to be disadvantaged, it is important that they spend the expected 20% (or more) contact time with teachers in the laboratory. This is to carry out or observe practical work to illustrate or to develop the understanding of the theory and also to note and discuss the limitations of quantitative procedures.

General comments

Centres were required to supply experimental data for **Questions 1**, **2** and **3** for each Session/Laboratory.

The following documentation for each session and for each laboratory within a session was required to be included in each script packet:
- a list of the candidates present and a seating plan for the laboratory
- a copy of the examination paper with the Supervisor's experimental results.

Invigilators/Supervisors at centres running more than one session, and/or using more than one laboratory should instruct their candidates to complete the Session/Laboratory boxes on the front of the examination paper.

Almost all candidates completed the paper indicating that there were no time constraints.

Comments on specific questions

Question 1

Many candidates were able to complete the practical work to a high standard. It was apparent that most candidates were well acquainted with the titration method and the presentation of results. The calculation caused problems for some as parts of the information given in the question were disregarded.

(a) Common errors were omitting the burette readings for the rough titration; recording the accurate burette readings to an integer or to only one decimal place and providing incorrect or incomplete headings for the accurate titration table. In some centres, there was little agreement between a candidate's titres, between the candidates or between the candidates and supervisor making the accuracy marks difficult to access.

(b) The majority of candidates gained credit for the mean titre. The most common error was to omit working or to give an answer that was not correct to two decimal places. Some candidates incorrectly included the value for the rough titre or used a spread of titres that was greater than 0.20 cm^3.

(c) (i) Candidates are instructed to show appropriate significant figures in final answers to all parts and they were reminded of this in this question.

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(ii) Most candidates calculated the moles of potassium manganate(VII) correctly. However, some candidates omitted dividing by 1000 to convert the mean titre in cm^3 to dm^3.

(iii) A large majority of candidates correctly used the mole ratio of 5/2 in the first step of the calculation. Fewer candidates completed the second step successfully, as a common error was to multiply by 1000/250 instead of the expected 1000/25.

(iv) Many candidates gained credit by correctly multiplying the final answer in **(iii)** by 250/25; others who made a mistake in the second step of **(iii)** used a method in **(iv)** which led to their answer for **(iv)** being 10 times their answer for **(iii)**. Even though the working was incorrect, this was treated as a type of 'error carried forward' and allowed such candidates to be awarded credit for **(iv)**.

(v) Many candidates correctly used the mole ratio given in the question and the majority answering the question correctly multiplied the moles of oxygen by 24 to find the 'volume strength'. However, some candidates used their answer to the first part of **(iii)** rather than either **(iv)** or the default value.

(d) Many candidates correctly calculated the maximum percentage error for each of the pipette and burette and showed the pipette was the more accurate. Some candidates stated the error in a burette was 0.5 cm^3 even though their burette readings were given to at least 0.1 cm^3. In many cases it was unclear whether the candidate was considering the error in a single burette reading or the error in delivering 25.0 cm^3 of solution. The instruction to 'Show by calculation …' was ignored by some.

Question 2

Candidates achieved a wide range of marks in this question with a large minority gaining over half the marks available. Correct responses were seen to all parts of the question. It was noticeable that many had a limited understanding of the reaction occurring and the limitations of this procedure.

(a) Most candidates clearly tabulated the data; a small minority omitted the values for the change in temperature. A common error was to give the thermometer readings as integers. Some candidates incorrectly gave thermometer readings to two decimal places. The syllabus states that the thermometers used are to be calibrated at 1 °C, hence they should be read to the nearest 0.5 °C and the readings should reflect this by ending in either .0 or .5. Almost all candidates gained at least one accuracy mark either against the mean supervisor value or for self-consistency.

(b) (i) Almost all candidates calculated the moles of H_2O_2.

(ii) Some candidates used 50 cm^3 rather than 30 cm^3, omitted division by 1000, or gave the answer to only one significant figure.

(iii) Many candidates calculated the enthalpy change. The most common errors were to give the sign as + for the exothermic reaction or to give the answer to more than four significant figures.

(c) (i) A minority of candidates correctly identified **FA 5** as a catalyst. Far fewer linked this to there being no alteration in heat energy produced.

(ii) This part showed a lack of understanding by some candidates in the difference between heat and temperature. Some candidates confused moles of hydrogen peroxide and concentration of the solution. The concentration of **FA 3** was unchanged in the two experiments, so more moles reacted in the second experiment. This meant more heat energy was evolved but as a larger volume of solution was heated the temperature rise remained the same. Many candidates answered in terms of quantities of **FA 5**, which was inappropriate. One of the incorrect responses involving **FA 5** was that manganese(IV) oxide was the limiting reagent. Others simply stated their changes in temperature for the two experiments were concordant without offering an explanation.

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Question 3

Candidates needed to heed the instructions given at the start of the Qualitative Analysis section. Correct responses were seen to all parts of the question.

(a) (i) Candidates should make it clear at what stage a reaction is happening. 'Green ppt' is insufficient for 'green ppt insoluble in excess (NaOH)'. 'Turns brown in air' does not indicate that it is the precipitate which is changing colour. The presence of ammonia can only be credited from use of 'gas turns (damp) red litmus paper blue' and not for 'pungent smell'. The most common error was in the colour of the initial precipitate with many candidates reporting it as 'grey-green' and some reporting it was soluble in excess. The latter observation is extremely unlikely, and the subsequent darkening or browning of the precipitate should have alerted candidates to the true identity of the transition metal ion present thus making it possible to correct the initial colour of the precipitate. A few candidates went on to test **FA 6** with aqueous ammonia, which was contrary to the instruction that 'No additional tests for ions present should be attempted'. Many candidates gained credit for the identities of the cations from only partially correct observations. Care in writing was needed by some as 'NH^{4+}' was seen from a small number of candidates.

(ii) The question specified that 'observations' should be recorded so a single observation was insufficient. The most common error was to omit the effervescence seen as oxygen was produced. A few candidates successfully tested for the gas.

(iii) The majority of candidates attempted a half-equation but a substantial number of these did not check the arithmetic: '$Fe^{2+} + e^- \rightarrow Fe^{3+}$' was typical of the incorrect answers seen.

(b) (i) Performance varied considerably on this question.
Test 1: an error with **FA 7** was to add too much solid sodium carbonate or not to shake the test-tube so the solid did not all dissolve. The remaining solid was often described incorrectly as a precipitate. Most candidates reported effervescence on adding the sodium carbonate to **FA 8** but far fewer went on to test the gas contrary to the instructions at the beginning of the question.

Test 2: it was important to give the change of colour and state on adding the aqueous potassium manganate(VII). 'Purple solution' did not indicate that **FA 1** was not decolourised on addition to **FA 8**. 'Orange' and 'red', unless qualified by brown, are not colours associated with aqueous iodine so should be avoided. Many candidates reported the expected iodine-starch colour; others did not qualify 'blue' with 'dark' so could not be credited.

Test 3: a substantial minority of candidates reported the results of this test correctly. A common error was to describe the mixtures as milky or creamy solutions instead of giving a definitive colour of a precipitate. Another common error was in describing the precipitate with **FA 7** as cream or off-white. Many of these candidates then mistakenly described this precipitate as partially soluble in aqueous ammonia.

(ii) Many candidates identified the anion in **FA 7** as iodide/I^- but could only be awarded credit if the observations in **(i)** supported this. One of the incorrect responses seen was 'iodine', which is not an anion.

(iii) Fewer candidates successfully identified **FA 8**. A common error was to only give the anion. Another error was to identify it as hydrogen chloride. This is inappropriate as hydrogen chloride is covalently bonded and does not exist in aqueous solution. Others suggested ammonium chloride or aluminium chloride with no or contrary observations for either cation.

(iv) Credit was only available to candidates who had identified the cation in **FA 8** as H^+; those suggesting hydrogen chloride were given the benefit of the doubt. Many correct responses were seen with the common reagents selected being Universal Indicator and magnesium ribbon. However, some candidates lost the mark when using magnesium ribbon by stating 'gas evolved' (a conclusion instead of an observation) or giving an incorrect gas test. An observation of 'pops with a lighted splint' does not indicate that a gas was tested; 'gas pops with a glowing splint' is incorrect. Those reporting effervescence with the magnesium ribbon gained credit. Some of the observations recorded could not have arisen from use of the reagent selected, suggesting that some candidates did not actually carry out their test.

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Paper 9701/42
A Level Structured Questions

Key messages

- Candidates should write clearly in dark blue or black pen.
- Candidates need to ensure that corrected work is clear to read; work that is crossed out should be very clearly crossed out and never overwritten with the new answer.
- On a chemistry paper, it is essential for an examiner to be able to read the chemical symbols, the subscripts used in formulae and the charges of ions.
- 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 is a key part in the description of the mechanisms.

General comments

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

Comments on specific questions

Question 1

(a) (i) Many candidates gave the correct answer. Weaker responses gave an insufficient answer based on properties of a transition element.

(ii) This question was usually answered correctly.

(iii) This was well known. A common error included answers with $3d^6 4s^2$.

(iv) This was generally well answered. Some candidates stated that light energy is emitted and many omitted that the colour seen is complementary to the colour absorbed.

(b) (i) Most candidates gave a correct answer.

(ii) This question was usually answered well. Some candidates gave an unbalanced equation.

(iii) This was normally correct.

(iv) This proved difficult for many candidates. Common errors included just stating that ‘one dative bond is formed’ and omitting that a lone pair is donated.

(v) Many fully correct answers were seen. A common error was omitting 3D bonds in the structure.

(vi) Many candidates stated that the energy gap, ΔE, would be different but did not mention that this would lead to a different frequency of light being absorbed. A common error was stating this was due to different amounts of energy being absorbed.

(c) (i) This was often correct. A common error was ‘number of ligands bonded to the central metal ion’.

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(ii) Approximately half the candidates managed to draw the structure of the optical isomer of **E**. The structure of the *trans* isomer was found to be more challenging.

(iii) This proved difficult for many candidates. A minority of candidates gained full credit here.

Question 2

(a) (i) Most candidates answered this well. It was common to see a statement regarding increasing stability and increasing cation radius down Group 2. Decreasing polarisation of the carbonate anion was less frequently seen. Some candidates suggested there was polarisation of the cation, or that polarisation was caused 'by the anion'.

(ii) The trend and its explanation were well understood by candidates. It was common to see a statement regarding decreasing solubility due to ΔH_{latt} and ΔH_{hyd} decreasing down Group 2. The decrease in ΔH_{hyd} is more, and the ΔH_{sol} becomes more endothermic, were less frequently seen.

(b) (i) Approximately half the candidates managed to write a correct equation. A common error was '$Al_2O_3 + 3C \rightarrow 3CO + 2Al$'.

(ii) Many candidates answered this well. Common errors were 1.1×10^6 g (no division by 3 in **M3** of the mark scheme); 1.8×10^5 g ($\times$ 6 used in **M3** of the mark scheme) and 5880 g (60 not squared in **M1** of the mark scheme).

(iii) Many fully correct answers were seen.

Question 3

(a) (i) Some candidates confused the definition of the standard cell potential with the standard electrode potential. Some did not point out that to measure the *standard* electrode potential, gases need to be at 1 atm and solutions need to be at 1 mol dm^{-3}.

(ii) This question was generally well answered. Some clear, labelled diagrams were seen. Common errors were omitting the standard conditions and using a hydrogen electrode.

(iii) Many fully correct answers were seen.

(iv) This was often correct.

(v) This question was found to be difficult by most candidates. Many candidates were able to state the effect of the use of these acids on the position of equilibrium and/or *E* values of half-equations 2 and 3. Only a few candidates stated that *E*(3) became greater than *E*(2).

(b) (i) This question was usually fully credited.

(ii) Many candidates were able to use the data to explain why the reaction is first order with respect to $AuCl_3$ and H_2O_2. Common errors were omitting the rate equation, stating that the reaction was 2nd order with respect to H_2O_2 and not showing enough reasoning in the explanation.

(iii) Most candidates correctly calculated a value for the rate constant. A common error was stating that the units were mol^{-1} dm^3 s^{-1}.

(c) (i) This answer was usually correct.

(ii) Many candidates completed this calculation successfully. Candidates should be reminded to show their working as this means that where an incorrect answer is given, it may be possible to award some credit for the method used. Common errors involved an incorrect multiplier with '158', for example −6457 (use of 3 $\times$ 158 not 1.5 $\times$ 158), −6062 (use of 0.5 $\times$ 158 not 1.5 $\times$ 358), −5983 (omission of 1.5 $\times$ 158).

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(iii) This was found difficult. Many candidates were not specific about the exothermic nature of the lattice energy; a full explanation was seen rarely. Candidates had to state that the lattice energy of ScF_3 should be less exothermic/less negative and give an explanation based on the relative cation sizes and how this would affect the attraction between ions.

(d) (i) Most candidates gave the correct expression. Common errors were $[Al^{3+}][3F^-]$ and $[Al][F]^3$.

(ii) This was often correct. A common error was omission of the $\times$ 3 in the calculation.

Question 4

(a) (i) Most candidates gave a correct answer, incorrect answers included ketone and carboxylic acid for **A** and peptides and amine for **B**.

(ii) This was answered well.

(b) Many candidates found this question difficult. Many correctly identified ethanol and phenylalanine as the products, however only a small number managed to protonate the amine as an excess of hydrochloric acid was used. Some candidates did not know how to hydrolyse this molecule.

(c) (i) This question was usually fully credited.

(ii) Approximately half the candidates only described one reason – the directing effect of one of the substituents, OH or COOH. Weaker candidates described only the directing effect of the incoming chlorine group in their reasoning.

(d) (i) Many candidates answered this well.

(ii) This was generally well answered.

Question 5

(a) This question was found to be difficult by candidates. Many did not explain acid strength in terms of the strength of the O–H bond or the stability of the carboxylate ion linked to the effect of the C=O group. Some stated that phenol is more acidic than a carboxylic acid.

(b) (i) Most candidates knew the definition in the syllabus. Some did not give a precise definition, stating the pH would remain unchanged or stay constant.

(ii) Many candidates answered this well. A common error was 4.31. Nearly all the candidates managed to calculate a pH from their working.

(iii) This was generally well answered. The equation with the alkali was more successful. Common errors were the use of incorrect formulae (omission of charges or use of $C_7H_5O^-$ or C_7H_6O) and writing a reaction with water such as $C_7H_5O_5^- + H_2O \rightarrow C_7H_6O_5 + OH^-$.

(c) (i) Many candidates gave a correct answer. Some gave SO_4^-, NO_2 and $H_3SO_4^+$ as products or the charges were unbalanced.

(ii) Better performing candidates could recall the electrophilic substitution mechanism.

Errors were frequently seen in the following areas:

- careless drawing of the curly arrow from the benzene ring to the N of the NO_2^+, which should start inside the ring system
- careless drawing of the partly delocalised ring
- incorrect position of the positive charge on the intermediate, which should be inside the partially delocalised ring system rather than on the sp^3 carbon
- careless drawing of the curly arrow as the C–H bond breaks, which should start on or near the C–H bond, not on the hydrogen atom.

(iii) This was often correct. Common errors included electrophilic addition and nucleophilic substitution.

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(iv) Many candidates gave a correct answer. A common error was omitting 'concentrated' with HC*l*.

(v) Many diagrams were well drawn. Common errors included:
- the positive charge on the terminal nitrogen for the diazonium salt R–N≡N^+
- omitting the Cl^- counterion
- substituting C*l* for H into the benzene ring.

(vi) This was not well known. Incorrect responses included $KMnO_4$ and $LiAlH_4$.

(d) (i) Candidates did not perform well on this question. Many suggested two, three or seven peaks, rather than five peaks.

(ii) This question was found to be difficult. Many candidates did not follow the guidance to state the number of peaks, expected splitting patterns or chemical shift range in the proton NMR spectrum.

Question 6

(a) (i) Many candidates found this question difficult. The majority of candidates omitted the water by-product from the equation.

(ii) Most candidates gave a correct answer.

(iii) This question was usually fully credited.

(b) This was answered well. Some incorrect peptide linkages and tripeptides with the same amino acid were seen. Some candidates ignored the instruction to 'draw a tripeptide' and gave a section of a polypeptide with these three amino acids.

(c) (i) Many candidates correctly identified optical isomerism and could draw two 3D isomers of valine. Common errors included diagrams without any 3D bonds and stating *cis-trans* isomerism.

(ii) This question was usually fully credited.

(iii) This was answered well by many candidates. Some candidates made careless errors, such as ionic charges outside the final square brackets and including H_2O in the expression.

(iv) Most candidates stated that **Z** would have a higher stability. Many did not relate this to the K_{stab} equilibrium.

(v) This was answered well.

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CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

- Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus. It was apparent that many candidates did not recognise the simple techniques needed in **Questions 1(f)** and **1(g)(i)**.

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

- Candidates should be aware that lines of best fit need to split the plotted points in such a way as to have an approximately equal number of points, excluding anomalies, either side of the line. Lines drawn from the first point to last point seldom tend to be the line of best fit

General comments

Candidates are advised to clearly show plotted points on a graph by using a diagonal cross, 'x', with the intersect of the lines being the exact co-ordinates on the grid. Alternatively, a point within a circle, ⊙, would be suitable with the point being the exact co-ordinates on the grid. Candidates should be aware that a single point, with no circle, will likely not show up if a line of best fit needs to be drawn over it.

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

Comments on specific questions

Question 1

(a) The concept of 'weighing by difference' was not well known.

Weighing by difference involves:
- adding the approximate mass of solid required to a weighing boat
- recording this mass
- transferring the solid from the weighing boat to the reaction vessel
- reweighing the weighing boat.

In this way, the *exact* amount of brass powder added to the reaction vessel can be determined.

Most candidates suggested recording the mass of an empty weighing boat; adding 2 g of brass; reweighing the boat + brass; then transferring the brass to the reaction vessel. This does not allow for any residual deposits of brass powder remaining in the weighing boat after transfer.

(b) Most candidates knew that if a fume cupboard was used, then a toxic gas (nitrogen dioxide) must be given off.

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(c) Many candidates did not realise that the question involved the conversion of an aqueous solution (of indeterminate volume) to 250 cm^3 of aqueous solution and wrote, unnecessarily, about dissolving solids prior to transfer.

Most candidates knew a solution must be transferred to a 250 cm^3 volumetric flask and should be topped up to the mark with distilled water. Only a few realised that the essential rinsing with distilled water of the small beaker containing the reaction mixture, should be done as part of the transfer. Weaker responses suggested using volumetric apparatus to measure the volume of solution in the volumetric flask; this overlooks the essential fact about a volumetric flask, which is that the volume of solution in the flask is indicated by the line on the neck of the volumetric flask and is not arrived at by adding measured volumes of distilled water using pipettes or burettes.

(d) Nearly all candidates provided the correct response that a volumetric pipette should be used.

(e) Apart from a minority of candidates who opted to describe a change in a non-existent indicator, most knew that it would be the lack of gas production, i.e. no more effervescence, which would indicate the reaction had finished.

(f) The variety of responses seen indicated that candidates were not familiar with the practicalities of carrying out a titration. Vague statements such as 'fill the burette' gained no credit. It was expected that candidates would realise the burette needed to be rinsed with the solution which was to be used in the burette before filling and some of this solution then had to be run through the tap to fill the jet area beneath the tap. A significant minority of candidates knew the first point; hardly any referred to the second.

(g) (i) Neary all candidates correctly subtracted initial burette readings from final burette readings but frequently this answer was not given to the second decimal place. Only titres within 0.10 cm^3 of each other should be averaged to calculate a mean titre; a skill many were unaware of. Many candidates averaged all three titres, thus including non-concordant titres, and some also included the rough titre in their averaging.

(ii) Candidates were asked to show working. There was a reason for this as determining a percentage error involves the use of half a graduation, rather than the graduation itself. Thus $(2 \times 0.05) \div 19.90$ expressed as a percentage (0.503%) gain credit whereas $0.1 \div 19.90$ did not. Candidates needed to make it clear that 0.1 was derived from multiplying half the graduation by 2 (because two readings were taken in obtaining the titre) and not using the graduation itself. Some candidates were on the right lines but multiplied the graduation itself by 2.

(iii) There were many good answers such as increasing the mass of brass or diluting the sodium thiosulfate solution or using a larger volume of solution **B**, but simply doing more titrations did not answer the question.

(h) (i) Most candidates coped well with this straightforward calculation. Several ignored the titre given in the question and used their own average titre. No credit was given for using non-existent, but typical, titration values as titres, such as 25.0 cm^3.

(ii) This calculation was done relatively well, the most common error being the omission of a factor of 10 when considering the 250 cm^3 volume. One common error was to use a rounded value of the calculated answer part way through the calculation e.g. 1.05 or 1.04, instead of keeping 1.04775 in the calculator and rounding at the end of the calculation.

(i) Most candidates realised that silver ions would be precipitated out as silver iodide by iod**ide** ions and therefore removed from solution. The use of iod**ine** to precipitate silver ions received no credit.

Question 2

(a) Most candidates did not appreciate that the steps given only measured an initial temperature and therefore a final temperature would also be needed prior to averaging. Recording the temperature at regular intervals was also accepted.

(b) The table was completed correctly by most candidates. Incorrect rounding of 1/T was occasionally seen as was the use of three decimal points instead of three significant figures.

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(c) Few answers were detailed enough to gain full credit, usually due to the omission of an increased percentage error caused by smaller time values.

(d) Nearly all candidates knew that time was the dependent variable.

(e) The graph work was good. Points were correctly plotted and the line of best fit was usually correct; although many opted to join the first and last points. Many candidates automatically circle a point they consider to be anomalous. This is a good trait as it makes clear to the examiner that this point has no influence upon the line of best fit.

(f) (i) The coordinates were usually read correctly; although some candidates did not use a wide enough spread of points and chose pairs of coordinates too close to one another. The calculation was completed correctly by a vast majority of candidates.

(ii) The relationship between the gradient and activation energy was recognised by most and the activation energy was usually correctly calculated. The unit of E_a was known; at A Level it is expected the term (k)J mol^{-1} should be used for the unit rather than (k)J / mol.