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Examiners' report

CHEMISTRY A

H432

For first teaching in 2015

H432/03 Autumn 2020 series

Version 1

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

Reports for the Autumn 2020 series will provide a broad commentary about candidate performance, with the aim for them to be useful future teaching tools. As an exception for this series they will not contain any questions from the question paper nor examples of candidate answers.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Paper 3 series overview

H432/03 is one of the three examination units for A Level GCE Chemistry A. This unit is aimed to link together different areas of chemistry within different scenarios, some practical, some familiar and some within novel contexts.

The paper is much more application based that the other two A Level units, H432/01 and H432/02, which emphasise knowledge and understanding of the assessment outcomes from the specification. H432/03 also contains more questions set in a practical context than H432/01 and H432/02. Most candidates had prepared well for the examination and tackled all parts of the paper.

A small cohort of about 1,000 candidates, across a range of abilities, sat the examination. Although there were some high-scoring scripts from well-primed candidates, there was also a significant tail of candidates who scored low marks. The standard of difficulty of this paper was appropriate and the paper discriminated very well.

There was no evidence that any time constraints had led to a candidate underperforming.

Candidates who did well on this paper generally did the following:	***Candidates who did less well on this paper generally did the following:***
• Performed standard calculations following the required rubric (e.g. clear working, units, significant figures), e.g. 1b(ii) Ideal gas calculation 3a(i) Enthalpy change calculation 3b Enthalpy change from bond enthalpies 4a(iv) Unstructured titration calculation 4b(i) and (ii) Mole calculations • Produced clear and concise responses for Level of Response questions: 5(a)(i), 6(b). • Demonstrated an understanding that $y = mx + c$ is linked to the gradient (m) and intercept (c) of a straight-line graph, e.g. 5c, 5d • Displayed knowledge and understanding of important practical techniques, e.g. 1a(i) Use of apparatus for reflux 1a(ii) Filtration under reduced pressure • Drew curly arrows accurately for an unfamiliar organic mechanism, e.g. 6c	• Demonstrated limited knowledge and understanding of practical work, e.g. 1a(i) Use of apparatus for reflux 1a(ii) Filtration under reduced pressure • Did not always consider the information provided before answering questions, especially from provided experimental results, e.g. 3ai: Enthalpy calculation from results 4a(i) Writing equations from observations 4b(i) and (ii) Mole calculations • Did not organise working within unstructured calculations, e.g. 1b(ii) Ideal gas calculation 3a(i) Enthalpy change calculation 3b Enthalpy change from bond enthalpies 4a(iv) Unstructured titration calculation • Had difficulty in explaining and organising chemical ideas in extended responses, e.g. 1b(ii) Intermolecular forces 2 Transition metal complexes • Did not appreciate the significance of $y = mx + c$ to the gradient and intercept of a straight-line graph, e.g. 5c, 5d

Comments on specific questions

Question 1

1a(i) Most candidates labelled some of the apparatus correctly and identified the reflux technique. A significant number showed water flowing in the wrong direction and 'distillation' was given as the name of the technique. The 'condenser' was sometimes labelled incorrectly, e.g. 'condensation tube, 'distillation tube' and 'water jacket'. Only just over half the candidates were given both marks.

i	**OCR support**	Candidates are advised to learn the names of chemical apparatus and the practical techniques involved. Diagrams of distillation and reflux apparatus are provided in our Practical Activities Support Guide: https://www.ocr.org.uk/Images/598371-practical-activities-support-guide.pdf

1a(ii) Many diagrams were incomplete and it was comparatively rare for both of the two available marks to be given. Important labels were often missing. Some candidates drew diagrams of other techniques, such as distillation.

Many responses were not credited with marks and this question was often omitted. Candidates need practice in recognising practical techniques and in drawing acceptable diagrams.

1b(i) Candidates were expected to explain the different boiling points of three amines. Most candidates linked increased branching with less surface contact between molecules, leading to weaker induced dipole interactions (London forces). Fewer candidates linked the decreasing boiling points to less energy being required to break the intermolecular bonds.

The highest performing candidates recognised the **large** difference between the boiling points of the primary and tertiary amines. They then identified the cause: primary amines form hydrogen bonds but tertiary amines do not.

This question was answered reasonably well with fewer candidates than in the past describing relative strengths of covalent bonds, a common misconception.

1(b)(ii) Most candidates rearranged the ideal gas equation correctly to make n the subject. They then substituted correct values for p, V, R and T into the equation, with correct unit conversions. Most candidates then calculated n correctly as 2.32×10^{-3} and combined this value with the mass of 0.202 g to derive the molecular formula as 87.

Lower-attaining candidates often made an error in their conversion of cm^3 into m^3, by multiplying by 10^{-3} rather than 10^{-6}. This error resulted in a value of n as 2.32 and the unrealistic molecular mass of 8.7×10^{-3}, from which a molecular formula is impossible. Candidates in this position are advised to check back at the unit conversions in the working. Very few candidates did not convert 100ºC into 373 K.

Candidates with the correct molecular formula of 87 usually suggested $C_5H_{13}N$ as the molecular formula. A significant number quoted $C_5H_{11}NH_2$. This response was not credited as it is not a 'molecular' formula. There are several possible structures of $C_5H_{13}N$ with three ^{13}C NMR peaks and any were credited.

Error carried forward was applied from a different molecular mass for both the molecular formula and a structure. This emphasises the importance of working within calculation; credit will always be given for a correct method.

Instead of using the ideal gas equation, some candidates used the molar gas constant at room temperature and pressure, 24.0 dm^3, which gives a molecular mass of 67. This simplified approach could only gain the final 2 marks for this question: a molecular formula (with an error carried forward value of

67, e.g. C_4H_5N) and a structure of an amine with this molecular formula and 3 peaks in the ^{13}C NMR spectrum.

1(c) Candidates were supplied with information about an unfamiliar reaction of an amino acid and asked to predict a possible equation. Many candidates suggested H_2O as one product, being the difference in the formula of the amino acid and the C_3H_3NO cyclic organic product. Any cyclic structure of C_3H_3NO that met the bonding rules for C, H, N and O was credited. Examples included a 4-membered ring lactam and substituted cyclopropenes.

A significant number of candidates showed an equation for the reaction of two molecules of the amino acid to form 2 H_2O and a cyclic dipeptide. Although chemically feasible, the dipeptide could not be credited because the molecular formula was C_3H_3NO in the question. This error could have been avoided if the information in the question had been used.

Question 2

This question was assessed by level of response (LoR). The question required candidates to demonstrate their knowledge and understand of some important terms used in transition metal chemistry.

Level 3 candidates showed complete definitions of ligand, coordination number and ligand substitution, supported by suitable equations with clear diagrams of complex ions. The responses were concise with 3D diagrams of 6- and 4-coordinate complex ions displayed with wedges, correct connectivity to ligand atoms and showing the role of lone pairs in the formation of the coordinate bonds. 4-coordination was shown as either or both of tetrahedral (usually $CuCl_4^{2-}$) or square planar (e.g. platin). Ligand substitution was accompanied by a correct balanced equation, most commonly between $[Cu(H_2O_6]^{2+}$ and NH_3.

Level 2 candidates usually gave definitions of ligand, coordination number and ligand substitution. There was usually a balanced equation for ligand substitution and one correct 3D diagram. A second diagram often had an unsuitable shape for the complex ion chosen (often $CuCl_4^{2-}$ shown as square planar).

Level 1 candidates did produce definitions, but these were often incomplete. There was usually an attempt to show a 3D diagram or equation, but these often contained unsuitable examples.

This question rewarded the candidates who had learnt their chemistry and the levels enabled the amount of knowledge and understanding to be assessed. The question discriminated well.

Question 3

3(a)(i) Most candidates analysed the raw practical results supplied to correctly calculate the energy change as 10,241 J using $q = mc\Delta T$, and the amount of propane burnt as 0.0550 mol.

Candidates usually determined the energy change per mole of propane as 1862 kJ. The question asked for the enthalpy change of combustion to 3 significant figures, which gives -1860 kJ mol^{-1}. The mark for this final value was often not given because either the – sign was omitted or the answer was not quoted to the required 3 significant figures. Candidates are advised to read the requirements of each question more closely to eliminate such errors. A double-check on significant figure requirements is recommended before moving on to the next question.

Lower-attaining candidates often extracted the wrong data from the results table. Instead of the mass of water (100 cm^3), the mass of propane burnt (0.242 g) was often used in the $q = mc\Delta T$ calculation. Candidates are advised that the thermometer measures the temperature change of the material in which it is placed (the water).

3(a)(ii) One mark was available for identifying two reasons for the difference in enthalpy change. It was expected that candidates would respond with 'heat loss' and 'incomplete combustion'. Most candidates suggested heat loss but the other reason often suggested was equipment error, e.g. the thermometer did not reading correctly', 'the balance gave incorrect readings'. Candidates are advised that responses of faulty apparatus are unlikely to be creditworthy.

3(b) This question was assessed by LoR.

Level 3 candidates calculated the enthalpy change for **Equation 3.1** correctly as –2054 kJ mol^{-1}. They linked 4 × $\Delta_{vap}H$ with the enthalpy change for **Equation 3.1** in an energy cycle and calculated the enthalpy change of combustion as –2054 – (4 × 40.65) = –2216.6 kJ mol^{-1}. Most Level 3 candidates drew out bonds in the molecules involved in **Equation 3.1**, which allowed them to visually count the bonds broken and bonds made. This strategy is recommended to all candidates for any calculation based on bond enthalpies and is much more likely to generate the correct enthalpy change than visualising the relevant bonds solely from the equation.

Level 2 candidates often derived the correct enthalpy change for **Equation 3.1** but then tried to link this value with $\Delta_{vap}H$ instead of 4 × $\Delta_{vap}H$. Other Level 2 candidates calculated ΔH correctly for either the bonds broken or bonds made and combine this value with 4 × $\Delta_{vap}H$. A common error was the omission of the 2 C–C bonds in propane, use of 3 C–C, instead of 2 C–C, bonds, or use of 4, rather than 8 O–H bonds. These errors could have been avoided by drawing out the bonds as described above.

Level 1 candidates typically attempted to use the bond enthalpies to calculate energies for bonds broken and bonds made but made several errors. They then combined this value with $\Delta_{vap}H$.

This question discriminated extremely well across different abilities.

Question 4

4(a)(i) This question required candidates to write an overall equation and half equations for oxidation and reduction. Many candidates made errors within one or more equations. The overall equation was often written without state symbols, despite the question instruction 'with state symbols'. The oxidation half equation was more likely to be correct than the reduction half equation, which often used Cl instead of H^+. When H^+ was used, the half equation was often unbalanced or electrons had been omitted.

It is recommended that candidates carefully use the chemical information in the question.

4(a)(ii) Most candidates identified that all the metal would have reacted when it had all disappeared and that gas bubbles from the reaction would have stopped. Some responses did not emphasise that these observations would have stopped and this prevented credit being given.

4(a)(iii) The ionic equation for neutralisation of an acid with an alkali was well known and this question was answered correctly by most candidates.

4(a)(iv) Candidates were presented with information about a back titration, a technique that they would be unlikely to have encountered during their course. The question stem to 4a(iv) suggested a three-step strategy. Many candidates followed this guidance and were credited with many of the available marks. Marks were given for a correct method (by error carried forward) even if there was an error or omission in the multi-step calculation. This emphasises the importance of clear working.

Most candidates determined the correct mean titre of 27.25 cm^3. A few candidates did take the mean of all three titres rather than the closest. Most calculated that 8.72×10^{-3} mol of NaOH reacted with the same number of moles of HCl in the titration and then scaled up the HCl by a factor of 10 to 8.72×10^{-2} mol in the 250 cm^3 volumetric flask. These steps are standard for many titration calculations and gave a route to three of the six available marks. The more difficult back titration steps then followed and the higher-attaining candidates recognised the need to subtract this amount of HCl from the original amount of HCl used to react with metal M. These candidates then divide this value by two to find the moles of M that reacted (from the 1 : 2 stoichiometry of M : HC*l*). The correct calculation then gave a relative atomic mass of M as 112 and its identity as cadmium. It was common for candidates to omit the division by two and to arrive at a relative atomic mass of 56 for iron. The mark scheme shows the variety of metals that candidates identified from their calculations, the errors made, and the error carried forward marks that resulted.

Many lower-attaining candidates did not follow the 3 steps in the stem, using only the original amount of HCl and ignoring the titration. This approach was not credited with marks.

A large range of marks was seen, and the question discriminated extremely well.

4(b)(i) This straightforward mole calculation required candidates to determine the mass of CO_2 as 2.75 g from the table of results and to divide this value by the molar mass of CO_2 to arrive at 0.0625 mol. Most candidates were successful. As with other questions providing raw experimental results, lower-attaining candidates often chose the wrong data from the supplied results.

4(b)(ii) Many candidates used their value from 4b(i) with the mass of X_2CO_3 from the results table to obtain a value for the molar mass (233.13 from 14.57 ÷ 0.0625). Higher-attaining candidates obtained a value for the atomic mass of **X** (86.56 from 233.13) and identified **X** as the Group 1 metal rubidium. Some candidates did not recognise the significance of the formula of X_2CO_3 and identified **X** instead as strontium (A_r = 87.6).

Lower-attaining candidates often used incorrect data from the supplied information and made little progress with this calculation.

4(c)(i) Most candidates suggested that the mass of the flask and contents could be reweighed until the mass no longer changed. An alternative creditworthy suggestion was to attach a gas syringe and to measure the gas volume until it no longer changed. Vague suggestions such as 'leave for longer' were not credited with marks.

4(c)(ii) Candidates found this question challenging. Success required candidates to appreciate that some CO_2 dissolving would result in less mass of CO_2 being recorded as lost, meaning that less moles of CO_2 had apparently been formed and so less moles of X_2CO_3 had reacted. Using $n = m/M$, this would show that the calculated molar mass of X_2CO_3 appears to be greater.

Only the highest-attaining candidates successfully navigated this question.

Question 5

Question 5 related an unfamiliar mathematical relationship with the $y = mx + c$ equation for a straight line. Use of $y = mx + c$ is a mathematical requirement of A level chemistry and candidates were expected to apply their understanding of the Arrhenius equation (part of the specification) which makes use of this straight-line equation in a novel context. Many candidates were unable to use this mathematical concept. In contrast, higher-attaining candidates were able to be credited with marks throughout question 5.

ⓘ	**OCR support**	It is recommended that candidates consider all aspects of the mathematical requirements for A Level chemistry, including the meaning of *m* and *c* in the equation of a straight line. Our Maths Skills Handbook supports students with this and other mathematical skills: https://www.ocr.org.uk/Images/295468-chemistry-mathematical-skills-handbook.pdf

5(a) Candidates were expected to complete values for $1/T$ and $\ln K_p$ from supplied T and K_p values. Candidates were supplied with an example and this enabled most candidates to obtain both available marks.

5(b) Most candidates were aware that a decrease in K_p with increasing temperature signals that the forward reaction is exothermic.

The question also asked for the effect on the equilibrium position. A significant number of candidates omitted this part of the question. Candidates are advised to check back to all the requirements in a question.

5(c) Candidates were required to plot a graph using their calculated values from 5(a). The axes for the graph had been provided. It was expected that the plotting of 5 points, with a best-fit straight line, would be straightforward. Many candidates plotted one or more points incorrectly, particularly the point at $1/T = 1.25 \times 10^{-3}$.

Candidates then needed to recognise that the gradient is equal to $-\Delta H/R$ from **Equation 5.1**, to measure the gradient, and then to determine ΔH. Most candidates recognised that the gradient needed to be measured but its value was then not taken any further. The higher-attaining candidates correctly multiplied the gradient by R but did not always convert the calculated J mol^{-1} value into kJ mol^{-1}, or to express their value to 3 significant figures, as required in the question.

Significantly, nearly a third of candidates did not collect any of the four available marks. The question was an excellent discriminator.

5(d) Mathematically able candidates used the $y = mx + c$ equation for a straight line with the supplied mathematical relationship (**Equation 5.1**) to identify the y intercept as $\Delta S/R$. They then stated that ΔS could be determined by multiplying the value of the y intercept by R.

Many candidates found the mathematical requirements of parts 5(c) and 5(d) difficult. Responses for 5(d) were often in terms of the gradient instead of 'intercept'.

Question 6

6(a) Candidates were expected to use their knowledge and understanding of bond angles and shapes.

Most candidates were given both available marks. A significant number responded with incorrect names of shapes, or chose the wrong shape, such as pyramidal for the O–C–O bond angle in the carboxylic acid.

Candidates are recommended to learn this basic area of chemistry.

6(b) Most candidates completed a correct equilibrium equation and assigned the correct acid-base pairs. A significant number of candidates used ethanoic acid instead of water in the equation. The examiners allowed error carried forward in this case for the acid-base pairs.

Candidates found it much more difficult to explain whether the sulfonic acid had a lower pH value. The higher-attaining candidates answered concisely. They usually identifying that the sulfonic acid would have a lower pH as the pK_a value was lower (or the K_a value greater), leading to more dissociation than ethanoic acid. Lower-attaining candidates often produced unfocussed and lengthy responses, sometimes relating increased dissociation in an acid to a higher, rather than a lower, pH.

Some candidates approached their explanation mathematically, calculating pH values for ethanoic acid and sulfonic acid from their concentrations and pK_a values. If correct, this approach was fully credited.

6(c) Most candidates showed a good understanding and appreciation of drawing curly arrows. It must be stressed that curly arrows that do not start from a lone pair, negative charge or a bond cannot be credited.

Lower-attaining candidates often drew imprecisely positioned curly arrows, curly arrows in the wrong direction or to the wrong atoms.

For their response to be credited with marks, candidates should position curly arrows to ensure credit when outlining reaction mechanisms.

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