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A LEVEL

Examiners' report

CHEMISTRY A

H432

For first teaching in 2015

H432/01 Summer 2022 series

Contents

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Introduction

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

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. A selection of candidate answers are also provided. 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.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

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

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

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Paper 1 series overview

H432/01 is the first of the three examination components for GCE Chemistry A. This component is focused on physical and inorganic chemistry and brings together topics from modules 3 and 5 of the specification, including relevant practical techniques. In this paper and H432/02 there is more of an emphasis on knowledge and understanding of the assessment outcomes from the specification, as compared to H432/03 which involves more application of knowledge. The paper consists of two sections, comprised of multiple choice questions, and a mixture of short and long response questions respectively.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• Produced clearly structured working for calculations – Questions: 17 (a) (i), 17 (b) (ii), 17 (c) (ii),19 (a) (ii), 19 (b) (ii), 21 (b), 21 (c). • Produced clear and concise responses for the two Level of Response questions – Question 20 (a) and 22 (c). • Produced clear and concise responses to descriptions in trends of ionisation energy – Question 18 (c) and 18 (d). • Were able to make and justify predictions based on their knowledge – Question 17 (a) (ii). • Explained equilibrium changes in terms of buffer and Kp – Question 19 (b) (iii) and 20 (b) (ii). • Gave answers to the correct number of significant figures – Questions: 17 (a) (i), 18 (b), 19 (a) (ii). 19 (b) (ii), 21 (b) (i), 21 (c) (i). • Ably converted between units when required – 17 (c) (ii), 19 (a) (ii). • Correctly recorded titre values to 2 decimal places (to ±0.05 cm3) – Question 19 (a) (i). • Write a balanced equation for unfamiliar compound – Question 21 (c) (ii).	• Found it difficult to apply what they had learned to unfamiliar situations. • Produced unstructured responses to Level of Response questions which were lacking in depth or explanation, or contained contradictory information – Questions 20 (a) and 22 (c). • Did not clearly set out calculations, making it difficult for marks to be given for working – Questions: 17 (a) (i), 17 (b) (ii), 17 (c) (ii),19 (a) (ii), 19 (b) (ii), 21 (b), 21 (c). • Did not give answers to calculations to the specified number of significant figures – Questions: 17 (a) (i), 18 (b), 19 (a) (ii). 19 (b) (ii), 21 (b) (i), 21 (c) (i). • Either did not realise the need to convert between units for some calculations, or found this difficult – Question 17 (c) (ii) and 19 (a) (ii). • Did not record titre values to 2 decimal places and found calculating the mean titre challenging – Question 19 (a) (i). • Did not produced clear and concise responses to descriptions in trends of ionisation energy – Question 18 (c) and 18 (d).

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Section A overview

A significant number of candidates did not provide an answer to every multiple choice question, either due to not attempting them, or for some, there was working shown but nothing given in box. Whether this was deliberate or caused by forgetting to return to the question at a later point in the examination is not certain, but centres should advise candidates to provide an answer to every multiple choice question. There is no penalty for giving a wrong answer.

Assessment for learning

Practising multiple choice questions can improve the skill in solving them and identifying the distractors. Exposure to this type of question style will decrease the time taken over each question. These can often form the basis of end of topic tests.

OCR support

Multiple choice question banks can be found on the 'Planning and Teaching' section of the qualification page, under 'Teaching activities' → 'Multiple choice topic quizzes'.

They can also be found via the resource-finder page on the OCR web site:

https://www.ocr.org.uk/qualifications/resource-finder/

Our quizzes come in both Microsoft Word and online formats.

Details on how to use the online multiple choice quizzes can be found on:

https://www.ocr.org.uk/Images/594811-digital-mcq-quiz-instructions.pdf

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Question 1

1 An aqueous solution contains a mixture of chloride, bromide and iodide ions.

$AgNO_3$(aq) is added to this mixture, followed by an excess of dilute NH_3(aq).

The resulting mixture is then filtered.

Which compound(s) is/are present in the residue on the filter paper?

A Ag*Cl* only

B Ag*Cl* and AgBr

C AgBr only

D AgBr and AgI

Your answer **[1]**

This question proved to be difficult, with only the most able candidates selecting the correct answer of D. A was often given as an incorrect answer as candidates recognised that AgCl would be the only halide precipitate to show a change with dilute ammonia but did not realise that as it would redissolve, it would be the only one not in the filtrate.

Question 2

2 20 cm^3 of nitrogen gas reacts with 10 cm^3 of oxygen gas to form 20 cm^3 of a gaseous product.

Which equation is the most likely for the reaction?

A $N_2(g) + O_2(g) \rightarrow 2NO(g)$

B $N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$

C $2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$

D $2N_2(g) + 2O_2(g) \rightarrow 4NO(g)$

Your answer **[1]**

This question was quite well answered with many candidates identifying the correct response as C. Candidates had to link the volume of gas with the moles of each gas and then match to the stoichiometry of the equation. Some candidates calculated the moles of gas and then appeared to choose an answer at random.

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Question 3

3 0.541 g of an element **X** is reacted with oxygen to form 0.790 g of the oxide $\mathbf{X}_2O_3$.

What is the element **X**?

A A*l*

B Cr

C Ga

D Sc

Your answer [1]

> This was a challenging question, the correct answer being B. The candidates would be advised to use the space around the question to perform the calculation. A was a common error as the Al ion was seen as the obvious choice without doing any calculations due to being Al^{3+}.

Question 4

4 Hydrogen peroxide, H_2O_2, can be oxidised by manganate(VII) ions under acid conditions as shown below.

$$2MnO_4^-(aq) + 5H_2O_2(aq) + 6H^+(aq) \longrightarrow 2Mn^{2+}(aq) + 5O_2(g) + 8H_2O(l)$$

In a titration, 25.00 cm^3 of a disinfectant containing hydrogen peroxide reacts with 22.00 cm^3 of 0.125 mol dm^{-3} $KMnO_4$(aq).

What is the concentration of H_2O_2, in mol dm^{-3}, in the disinfectant?
Assume that $KMnO_4$ only reacts with H_2O_2 in the disinfectant.

A 0.0440

B 0.110

C 0.275

D 0.550

Your answer [1]

> The correct answer C required candidates to calculate the moles of manganate (VII) ions and then to use the stoichiometry of the equation to calculate the moles of H_2O_2 before calculating the concentration. Option A provided a distractor with the incorrect ratio. Option B was obtained without the reference to the molar ratio.

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Question 5

5 The mass of 4 molecules of a substance is 2.125×10^{-22} g.

What is the possible formula of the substance?

A CH_4

B O_2

C SO_2

D I_2

Your answer [ ] **[1]**

The correct answer B required the candidate to calculate the number of moles of the gas using Avogadro's number. Then link this numerical value to the M_r of the gas so that the formula could be deduced from calculating the M_r of the molecules suggested. Incorrect answers, often if appeared that option C had been guessed as an answer, rather than being arrived at by mistake.

Question 6

6 Prussian blue, $C_{18}Fe_7N_{18}$, is a deep blue pigment containing Fe^{2+}, Fe^{3+} and CN^- ions.

What are the numbers of Fe^{2+} and Fe^{3+} ions in one formula unit of $C_{18}Fe_7N_{18}$?

A 2 Fe^{2+} and 5 Fe^{3+}

B 3 Fe^{2+} and 4 Fe^{3+}

C 4 Fe^{2+} and 3 Fe^{3+}

D 5 Fe^{2+} and 2 Fe^{3+}

Your answer [ ] **[1]**

This was generally well answered. The key to candidates quickly arriving at the correct answer of B was to focus on identifying the number of CN^- ions and calculating the total of 18 negatively charge ions. More successful candidates could clearly see that the combination of iron ions must add up to the total of 18 positively charged ions. Some candidates lost time here by working out formulae and trying to write out the structure of Prussian blue.

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Question 7

7 Bond enthalpies are shown in the table.

Bond	C–C	C–H	O–H	C–O	C=O	O–O	O=O
Bond enthalpy / $kJ\,mol^{-1}$	347	435	464	358	805	144	498

What is the enthalpy change, in $kJ\,mol^{-1}$, for the reaction below?

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

A –730

B –544

C +544

D +730

Your answer ☐ **[1]**

This was another challenging question, with fewer candidates choosing the correct answer of A. The distractor, D, was obtained by swapping products and reactants in the calculation or in an incorrect enthalpy cycle. Candidates should have ruled out C and D straight away as enthalpy of combustion is always exothermic. Where working was shown, candidates omitted one or more of the multiples in the bonds formed or broken.

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Question 8

8 The half-life for a first order reaction is 80 s.

What is the rate constant *k*, in s^{-1}, for this reaction?

A 8.66×10^{-3}

B 0.0125

C 55.5

D 115

Your answer ☐ **[1]**

This question was quite well answered with many candidates realising that for a first order reaction, determination of the rate constant, k, from the constant half-life, $t^{1/2}$, they should use the relationship: $k = \ln 2/t^{1/2}$. A common error was option B, as many used 1/t used for $\ln 2/t^{1/2}$.

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Question 9

9 Which equation represents the change that accompanies the standard enthalpy change of atomisation of bromine?

A ½ $Br_2(l) \rightarrow Br(g)$

B $Br_2(l) \rightarrow 2Br(g)$

C ½ $Br_2(g) \rightarrow Br(g)$

D $Br_2(g) \rightarrow 2Br(g)$

Your answer ☐ **[1]**

This question proved to be difficult, with fewer candidates selecting the correct answer of A. Option C was the most common distractor as many candidates did not know the standard state of bromine. Option B was selected by those candidates who confused the definitions of average bond enthalpy with the enthalpy change of atomisation.

Question 10

10 For the condensation of ammonia gas, what are the signs of ΔH and ΔS?

A ΔH –ve ΔS –ve

B ΔH –ve ΔS +ve

C ΔH +ve ΔS +ve

D ΔH +ve ΔS –ve

Your answer ☐ **[1]**

Only some candidates chose the correct answer of A. Option D was a common incorrect answer through not recognising that the enthalpy change for condensation is negative.

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Question 11

11 The equilibrium equation for an indicator, HA, is shown below.

Equation:	HA(aq)	$\rightleftharpoons$	A^-(aq)	+	H^+(aq)
Colour:	Blue		Yellow		

The indicator is added to a solution. The indicator turns a yellow colour.
An excess of aqueous sodium hydroxide is then added.

Which statement describes how the colour of this solution would be expected to change?

A Colour changes from yellow to blue.

B Colour changes from yellow to green.

C Colour changes from yellow to green and then to blue.

D Colour stays yellow.

Your answer [1]

This was well answered, with many candidates understanding that the addition of an alkali will react with the H^+ ions and will keep the position of equilibrium on the right hand side.

Question 12

12 Ammonia and water react to set up an acid–base equilibrium.

What are the Brønsted–Lowry acids in the equilibrium mixture?

A H_2O and OH^-

B OH^- and NH_3

C NH_4^+ and H_2O

D NH_4^+ and NH_3

Your answer [1]

This was generally well answered. The key to candidates arriving at the correct answer ,C, was to write out the equation for ammonia reacting with water. The correct identification of the acids can then be made. Option B was chosen as the candidate identified the B-L bases and option D was chosen by candidates who linked up a B-L acid – base pair.

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Question 13

13 Standard electrode potentials for two redox systems are shown below.

$Cr^{3+}(aq) + 3e^- \rightleftharpoons Cr(s)$ –0.74 V

$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$ –0.42 V

What is the standard electrode potential for $Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$?

A –0.32 V

B –0.90 V

C –1.16 V

D –1.80 V

Your answer ☐ **[1]**

In the interests of fairness, we decided to award the mark for this question to all candidates as this question related to theory [or a process] that was not required within our specification.

Question 14

14 The three reactions below each form one product only.

Which reaction(s) form(s) a product with non-polar molecules?

1 $2CO + O_2 \rightarrow$

2 $Si + 2Cl_2 \rightarrow$

3 $S + 3F_2 \rightarrow$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

This question was not well answered, with many candidates giving the other options rather than the correct answer of A. The candidates who were successful tended to draw out the shape of the molecules.

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Question 15

15 Which ion(s) contain(s) one or more unpaired electrons?

1 Mn^{3+}

2 V^{3+}

3 Cu^{+}

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer [ ] **[1]**

This was another challenging question, with fewer candidates choosing the correct answer of B. Successful candidates often had the electronic configuration written down and focused on the higher energy electrons as to whether they were paired or not. Missing the $4s^1$ in Cu was the main omission to identify the correct answer.

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Section B overview

Question 16 (a) (i)

16 A catalytic converter in a car removes nitrogen monoxide, NO, and carbon monoxide, CO, from the exhaust gases.

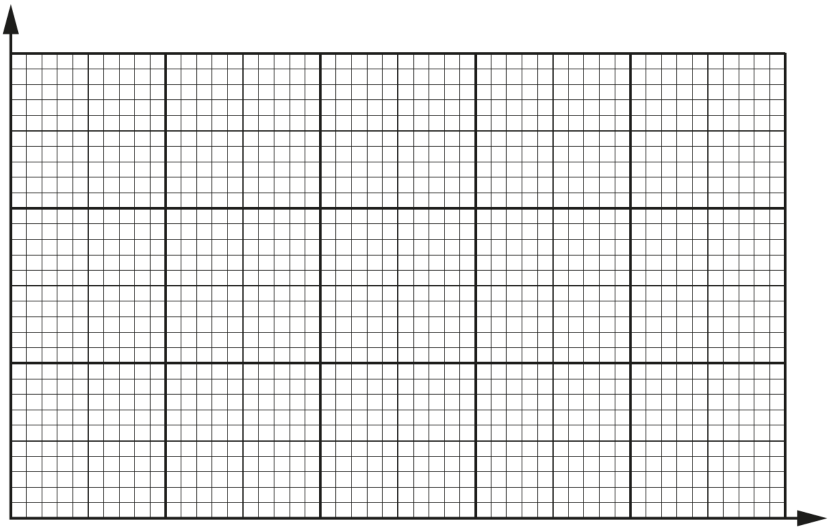
(a) One reaction that happens in a catalytic converter is shown below.

$2CO(g) + 2NO(g) \rightarrow N_2(g) + 2CO_2(g)$ **Reaction 16.1**

(i) Explain how increasing the temperature increases the rate of **Reaction 16.1**.

Include a labelled sketch, using Boltzmann distributions, on the grid below.

Label the axes.



....

....

....

....

.... **[3]**

Almost all candidates produced a graph which showed the correct shape curve, although they sometimes incorrectly identified the quantities on the axes, e.g. rate versus time. Those who produced an incorrect diagram were able to discuss 'more' particles reaching the activation energy threshold. A few limited their answer to discussing successful collisions. Candidates needed to identify which curve was the higher temperature and to make sure that the curves did intersect more than once.

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Question 16 (a) (ii)

(ii) The rate of **Reaction 16.1** is investigated by carrying out three experiments at the same temperature. The results are shown below.

Experiment	**[NO(g)] / mol dm^{-3}**	**[CO(g)] / mol dm^{-3}**	**Initial rate / mol dm^{-3} s^{-1}**
1	2.75×10^{-4}	7.25×10^{-4}	1.85×10^{-4}
2	5.50×10^{-4}	7.25×10^{-4}	7.40×10^{-4}
3	1.10×10^{-3}	2.90×10^{-3}	1.18×10^{-2}

Determine the orders with respect to NO and CO, the rate equation, and the rate constant, *k*, including units.

Explain your reasoning.

....

....

....

....

....

k = ... units .... **[5]**

Many candidates were able to explain clearly the second order dependence on [NO] but many found it more challenging to identify and explain the first order relationship for [CO], where the candidate had to consider the second order dependence on [NO] to work out the effect on rate for the change in [CO]. Most gave a rate equation of the correct format based on the orders they had stated, and worked out a value for k. Although some did not determine the correct units, there was an encouraging number who managed this either from memory or by cancelling. The most common error was not including s^{-1}

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Question 16 (b)

(b) Carbon monoxide also reacts with nitrogen dioxide as shown in **Reaction 16.2**.

$CO(g) + NO_2(g) \rightarrow NO(g) + CO_2(g)$ **Reaction 16.2**

The rate equation for **Reaction 16.2** is shown below:

rate = $k[NO_2(g)]^2$

Suggest a possible two-step mechanism for **Reaction 16.2**.
The first step is much slower than the second step.

step 1 ....

step 2 ....

[2]

Many candidates recognised the need for $2NO_2$ in the first step, with slightly less then adding an appropriate second step. Errors included unbalanced species and unbalanced charges. A wide range of suggested possible mechanisms were seen, including several which led to multiple correct versions of the overall equation. Both balanced equations needed to combine to form the overall equation. However, a few inventive candidates gave a first step of $NO_2 + NO_2 \rightarrow 2NO_2$, followed by the full balanced equation for the second step – this was not given marks.

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Question 17 (a) (i)

17 This question is about energy changes.

(a) Magnesium reacts with aqueous silver nitrate, $AgNO_3(aq)$ as shown below.

$$Mg(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Mg(NO_3)_2(aq) \qquad \Delta H = -678\,kJ\,mol^{-1}$$

A student adds an excess of magnesium to 100.0 cm^3 of 0.400 $mol\,dm^{-3}$ $AgNO_3(aq)$.
The initial temperature is 20.0 °C.

(i) Determine the maximum temperature reached in this reaction.
Give your answer to **3** significant figures.

Assume that the specific heat capacity and density of the solution are the same as for water, and that there are no heat losses.

maximum temperature reached = ... °C **[4]**

Many candidates made some attempt at this unusual twist on a $Q = mc\Delta T$ calculation, but only a minority of candidates produced a fully correct answer. A temperature of 84.9 °C was seen much more often than 52.4 °C. The calculation of n($AgNO_3$) was performed well. Common errors were not dividing the moles by 2, not recognising the need to calculate the energy released per mole of $AgNO_3$, confusing the mass of water with the mass of the silver nitrate solid or of using an energy in kJ alongside a value of c based on J.

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Question 17 (a) (ii)

(ii) The student wants to repeat the experiment, but there is not enough $AgNO_3$(aq) left to use another 100.0 cm^3 portion.

The student decides to modify the method by adding an excess of magnesium to 50.0 cm^3 of 0.400 mol dm^{-3} $AgNO_3$(aq).

Predict, with reasons, how this modification would affect the maximum temperature reached. Assume that there are no heat losses.

....

....

....

.... **[1]**

Although there were a few well explained, correct answers, this question proved challenging for most candidates. Candidates needed to link the changes as a proportion (e.g. half) to be given the mark. Candidates often only considered the change to energy or mass, but not both, e.g. dealt only with the decrease in moles reacting leading to a smaller temperature rise.

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Question 17 (b) (i)

(b) Nitric acid is manufactured from ammonia in a multi-stage process.
The equation for the first stage in this process is shown in **Reaction 17.1**.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$ $\Delta H^\ominus = -1172\ kJ\ mol^{-1}$ **Reaction 17.1**

Some standard enthalpy changes of formation are shown in the table.

Compound	$\Delta_f H^\ominus$ / kJ mol^{-1}
$NH_3(g)$	–46
$H_2O(l)$	–286

(i) Explain the term **enthalpy change of formation**.

....

....

.... **[1]**

The majority of candidates gave the required definition correctly, frequently going beyond to include ideas about standard states and conditions. The smaller number of incorrect responses covered a range of errors, including assuming that 1 mole of elements were reacting and (perhaps as a result of later work on lattice enthalpies) bringing in a requirement for the compound or the elements to be gaseous.

Question 17 (b) (ii)

(ii) Calculate the standard enthalpy change of formation, $\Delta_f H^\ominus$, of NO(g).

$\Delta_f H^\ominus$ of NO(g) = ... kJ mol^{-1} **[2]**

This calculation proved difficult. Many candidates did not deduce the correct cycle. Of those who did, a significant majority did not appreciate the stoichiometry and/or use the correct signs from the cycle. Many students scored 1 mark for this question which was gained as an error carried forward, providing all the values had been used in the enthalpy cycle. -90 was a common error.

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Question 17 (c) (i)

(c) Carbon disulfide, CS_2, reacts with dinitrogen oxide, N_2O, as shown in **Reaction 17.2**.

$4CS_2(l) + 8N_2O(g) \rightarrow S_8(s) + 4CO_2(g) + 8N_2(g)$ **Reaction 17.2**

Standard entropies, $S^\ominus$, are shown in the table.

Substance	$CS_2(l)$	$N_2O(g)$	$S_8(s)$	$CO_2(g)$	$N_2(g)$
$S^\ominus$/ J K^{-1} mol^{-1}	151	220	256	214	192

(i) Explain the term **entropy**.

....

....

.... **[1]**

Candidates needed to explain that entropy is a measure of the dispersal of energy in a system which is greater, the more disordered a system. A good number of correct answers but quite a few did not get across the required idea of 'a measure of'.

Question 17 (c) (ii)

(ii) The free energy change, ΔG, of **Reaction 17.2** is –2672 kJ mol^{-1} at 25 °C.

Calculate the enthalpy change, ΔH, of **Reaction 17.2**, in kJ mol^{-1}.

ΔH = ... kJ mol^{-1} **[3]**

Almost all candidates had a good attempt at this calculation, with many gaining full marks. Most were able to calculate the entropy change. Almost all could reproduce the equation for free energy. Of those who did not get the correct final answer, the most common error was not converting the entropy value into kJ and/or the temperature to K There were also a few candidates who did not manipulate the equation correctly.

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Question 17 (c) (iii)

(iii) A student concludes that **Reaction 17.2** is feasible at all temperatures.

Explain whether the student is correct or not.

....

....

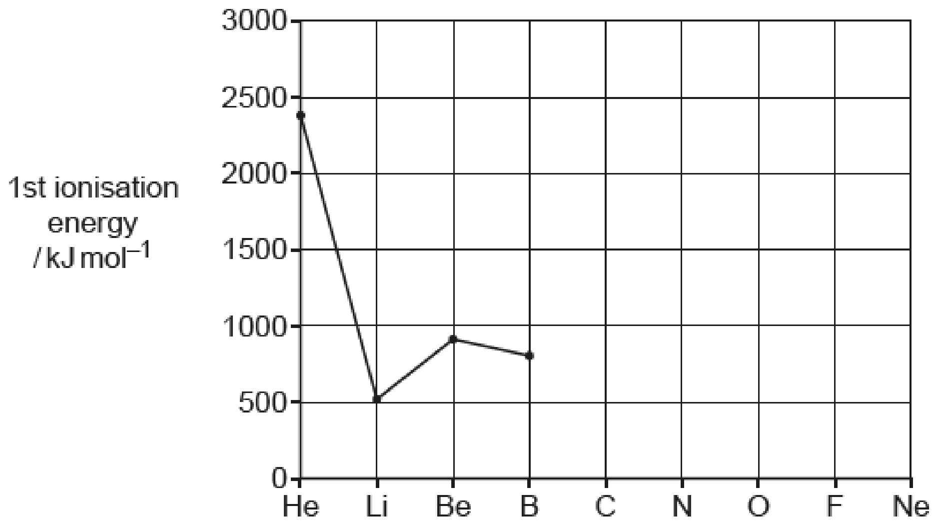
....

.... **[2]**

Many candidates realised the significance of a negative free energy change, but they seemed to struggle to link this to the previous question, giving a more general answer about feasibility, rather than using their values of entropy change and enthalpy change to determine feasibility. If temperature of feasibility was calculated as -9110K many still thought that meant a temperature existed below this which was feasible.

Question 18 (a)

18 The graph shows the first ionisation energies for elements from helium, He, to boron, B, in the periodic table.



(a) Complete the graph for C, N, O, F and Ne. **[2]**

Few candidates scored full marks here, with some candidates not increasing the 1st IE across the period, and many getting the dip for the wrong element (not O) and finishing too high with Ne. Less successful candidates had clearly confused it with MP trend across the period.

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Question 18 (b)

(b) Estimate the energy required to form **one** $Li^+(g)$ ion from one Li(g) atom.

Give your answer in kJ, in standard form, and to **two** significant figures.

energy = ... kJ **[1]**

This question proved demanding for candidates, with many simply quoting a molar value taken from the graph and converting into standard form. Of those who recognised the need to use the Avogadro constant, a few tried to multiply it by the molar ionisation enthalpy. For those who worked out the correct answer, several lost marks due to the requirement of 2 significant figures.

Question 18 (c)

(c) Explain why the first ionisation energies of He and Be are both higher than the first ionisation energy of Li.

Explanation for He: ....

....

....

....

Explanation for Be: ....

....

....

....
[4]

Some very wordy responses to this straightforward question were seen, with many candidates going onto the extra pages. Candidates are reminded that keeping responses concise and to the point can make their answer clearer and potentially avoid contradicting themselves in the process. There were a good number of excellent answers seen, although many candidates were distracted by arguments about the stability of full shells or subshells rather than explaining why nuclear attraction would be greater. Some students mixed up the explanation for Be/Li with the difference in ionisation energies between groups 5 and 6 (electron pair repulsion).

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Question 18 (d)

(d) Explain why the first ionisation energy of Be is higher than the first ionisation energy of B.

....

....

....

.... **[2]**

Many candidates did not achieve full marks as they did not discriminate between the three different comparisons that were being tested in Question 18 (c) and 18 (d). Few candidates did identify the electron being in the s or p but then explained the ionisation energy in terms of full subshells, electron pair repulsion and described the 2s sub-shell as closer to the nucleus rather than as lower energy.

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Question 19 (a) (i)

19 This question is about acids and buffer solutions.

(a) Succinic acid, $HOOC(CH_2)_2COOH$, is a weak dibasic acid that is used in tablet form in health supplements.

A student plans to determine the mass of succinic acid in one tablet of a succinic acid health supplement.

The student carries out a titration with potassium hydroxide.

The end point occurs when both acidic protons in succinic acid have been replaced as shown in **Equation 19.1**.

$HOOC(CH_2)_2COOH + 2KOH \rightarrow KOOC(CH_2)_2COOK + 2H_2O$ **Equation 19.1**

The student uses the following method.

Stage 1 The student crushes four tablets of the health supplement and dissolves the powdered tablets in distilled water.

Stage 2 The student makes up the solution from **Stage 1** to 250.0 cm^3 in a volumetric flask.

Stage 3 The student titrates 10.0 cm^3 portions of the solution obtained in **Stage 2** with 0.0600 mol dm^{-3} potassium hydroxide, using phenolphthalein as the indicator.

The student carries out a trial titration, followed by three further titrations.
The results are shown below.

Titration	Trial	1	2	3
Final burette reading / cm^3	25.25	23.75	25.35	25.75
Initial burette reading / cm^3	2.50	1.30	2.65	3.20
Titre / cm^3				

(i) Complete the table and calculate the mean titre that the student should use for analysing the results.

mean titre = ... cm^3 **[2]**

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Almost all candidates calculated the titres correctly, but a significant number were penalised for recording 22.70 as 22.7. A significant number also used this result and the trial titre to derive their mean value. There were also very small numbers of candidates who used all 4, or all of titres 1, 2 and 3, to calculate their mean.

OCR support

Links to the legacy coursework tasks and PAG practice question sets can be found on OCR Interchange. Exam hints for students can be found at:

https://www.ocr.org.uk/Images/592305-exam-hints-for-students.pdf.

Question 19 (a) (ii)

(ii) Use the student's results and **Equation 19.1** to calculate the mass, in mg, of succinic acid in **one** tablet of the health supplement.

Give you answer to **3** significant figures.

mass = ... mg **[5]**

Candidates made good progress with this calculation, many gaining 4 or 5 marks, including error carried forward from incorrect titres. Common errors included, in various combinations: not converting the final answer into mg, not converting volume to dm^3, missed ratio, multiplying the moles in $10cm^3$ acid by 10 instead of 25 and/or wrong M_r. Responses to Question 19 (a) (ii) often featured rows of figures and random sums without a single word about what the figures, or sums, were set to calculate. Candidates should remember to provide written indications of what it is they are working out – presenting the calculations without any annotations can make it harder for error carried forward marks to be given if there is an error in their calculation.

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Exemplar 1

n = V × c

n(KOH) = $\frac{10}{1000}$ × 0.06 = 6 × 10⁻⁴ mols

in 10 cm³
n(succinic acid) = 6 × 10⁻⁴ / 2 = 3 × 10⁻⁴ mols

n(succinic acid) in 250 cm³ = 3 × 10⁻⁴ × 25 = 7.5 × 10⁻³

n = $\frac{m}{Mr}$ n × Mr = mass   Mr = 118

mass of 4 tablets
= 7.5 × 10⁻³ × 118 = 0.885 g

in 1 tablet
$\frac{0.885}{4}$ = 0.22125 ≈ 0.221 g (3sf)
→ mg 0.22125 ÷ 1000 = 2.21 × 10⁻⁴ mg

mass = 2.21 × 10⁻⁴ mg **[5]**

The exemplar here shows a good use of annotation. There is a clear indication of the mathematical process so that the error carried forward is easily identified and the candidate gains the method marks.

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Question 19 (b) (i)

(b) Glycolic acid, $HOCH_2COOH$, (pK_a = 3.83) is a weak monobasic acid used in some skincare products.

A buffer solution is prepared by adding 60.0 cm^3 of 0.750 mol dm^{-3} glycolic acid to 40.0 cm^3 of 0.625 mol dm^{-3} potassium hydroxide, KOH.

(i) Explain why a buffer solution is formed.

....

....

.... **[1]**

Many candidates did not answer the question and instead described what a buffer was. Very few candidates correctly explained that a weak acid was being added to a base, sometimes mentioning the formation of the salt or conjugate base. The majority also did not include the importance of there being excess acid, or some acid remaining, after the partial neutralisation.

Question 19 (b) (ii)

(ii) Calculate the pH of the buffer solution that has been prepared.

Give your answer to **2** decimal places.

pH = ... **[4]**

Most candidates were able to derive a value for K_a from pK_a and calculate the number of moles of glycolic acid and potassium hydroxide reacting. Less were successful in determining the moles or concentrations present in the buffer solution causing many to get the common error of 3.57. Many candidates tried to calculate pH for the weak acid, without considering changes to concentrations or the buffering effect. Clarity of working is essential and in questions such as this, candidates are advised to include word descriptions of what they are calculating, even if it is abbreviations such as 'n' for number of moles.

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Question 19 (b) (iii)

(iii) A small amount of aqueous ammonia, $NH_3(aq)$, is added to the buffer solution.

Explain, in terms of equilibrium, how the buffer solution would respond to the added $NH_3(aq)$.

....

....

....

....

.... **[2]**

Most candidates correctly described the ammonia reacting with the glycolic acid or with hydrogen ions, although some thought that ammonia was acidic. Many of them then went on to say that "the equilibrium will move to the right" without realising that the equilibrium had not itself appeared within the question, and so they needed to write it out to gain marks. A few candidates thought that ammonia was an acid, due to the 3 x Hs in the molecule.

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Question 20 (a)*

20 This question is about equilibria involving hydrogen.

(a)* Hydrogen is used industrially to manufacture ammonia.

The equilibrium is shown below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92\,kJ\,mol^{-1}$ **Equilibrium 20.1**

1.20 mol $N_2(g)$ is mixed with 3.60 mol $H_2(g)$ in a 8.00 dm^3 container.

The mixture is heated to 550 °C with an iron catalyst and allowed to reach equilibrium.

The equilibrium mixture contains 0.160 mol of NH_3.

Determine the equilibrium constant K_c for **Equilibrium 20.1**, and explain why the operational conditions used by industry may be different from those required for a maximum equilibrium yield of ammonia. **[6]**

This Level of Response question was generally well answered with many candidates achieving maximum marks by simply considering what was required in the question. Responses were often split between a calculation on the main paper and the conditions explanation on extra pages. The calculation errors included no shift or incorrect shift in the equilibrium values. Not calculating the concentration or incorrectly multiplying by 8 rather than dividing by 8. Some candidates attempted a 'hybrid' calculation of Kp by trying to calculate a mole fraction and partial pressures. There was a number of candidates who confidently worked out the value of K_c. There were also some very good analyses of the operational conditions. Many of those who had done well on the calculation treated the explanation as an afterthought, not giving it enough attention to give them an answer that would access Level 3.

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Exemplar 2

	$N_{2(g)}$	$+ 3H_{2(g)}$	$\rightleftharpoons 2NH_{3(g)}$
I	1.2	3.6	0
C	−0.08	−0.24	+0.16
E	1.12 mol	3.36 mol	0.16 mol at equil'm

$[N_{2(g)}] = \frac{1.12}{8} = 0.14\ mol\,dm^{-3}$ $[H_{2(g)}] = \frac{3.36}{8} = 0.42\ mol\,dm^{-3}$

$[NH_{3(g)}] = 0.02\ mol\,dm^{-3}$

$$K_c = \frac{[NH_{3(g)}]^2}{[N_{2(g)}] \times [H_{2(g)}]^3}$$

$$K_c = \frac{0.02^2}{0.14 \times 0.42^3} \quad K_c = 0.0386\ dm^6\,mol^{-2}$$

A high pressure shifts equilibrium right ~~towards~~ as there are fewer gaseous molecules on the right hand side / product side which gives maximum yield. However a high pressure is a safety risk and expensive hence may be lower. A ~~temp~~ ~~low~~ low temperature shifts the equilibrium right as the forward reaction is exothermic however a low temperature gives a slower rate of reaction hence a higher temperature may need to be used to increase rate

An example of a complete answer, showing a good level of communication in the description and the calculation layout, achieving Level 3 (6 marks) is shown above.

This candidate gave a clear method using an "ICE" table to calculate the number of moles at equilibrium. The calculation of the new concentrations can be seen by the use of [ ] and division by 8. The candidate then shows the Kc expression and substitutes the numerical values before successfully calculating the value and includes the units. This is followed by a concise explanation of the conditions used by industry.

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Question 20 (b) (i)

(b) In industry, hydrogen is also used to reduce the iron oxide Fe_3O_4 as shown in **Equilibrium 20.2**.

The reaction is carried out at 500 °C.

$Fe_3O_4(s) + 4H_2(g) \rightleftharpoons 3Fe(s) + 4H_2O(g)$ **Equilibrium 20.2**

(i) When the temperature is decreased, the value of $\boldsymbol{K_p}$ decreases.

Determine whether the forward reaction is exothermic or endothermic.
Explain your answer.

....

....

....

.... **[1]**

Candidates coped well with this question, but many candidates did not gain the mark due to ambiguous statements. Some identified the forward reaction as endothermic, but stated that Kp decreased which was given in the question. Others simply stated that the forward reaction was endothermic as the reverse reaction was exothermic.

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Question 20 (b) (ii)

(ii) Two students are discussing the effect of pressure on the equilibrium position of **Equilibrium 20.2**.

Student 1 says:

"There are more moles of products than reactants, so increasing the pressure will shift the equilibrium to the left hand side."

Student 2 disagrees.

Determine which student is correct. Justify your answer.

....

....

....

.... **[1]**

Many candidates gave the correct reason to agree with student 2. Those who agreed with student 1 did not see the equation as a heterogeneous equilibrium system. There were a small number of responses agreeing with student 2 but for the wrong reason – such as a confusion about how the position of equilibrium can change when the value of K_p stays constant. Candidates are advised to read through and address all parts of the question as a minority of students didn't identify which student was correct but gave a correct explanation.

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Question 21 (a) (i)

21 This question is about the reactions of Group 2 metals and their compounds.

(a) A student adds magnesium to dilute hydrochloric acid in one test tube.
The student adds calcium to dilute hydrochloric acid in a second test tube.

A redox reaction takes place in each test tube.

(i) Suggest **two** observations from the student's experiment that would show that calcium is more reactive than magnesium.

1 ....

....

2 ....

.... **[1]**

Very few candidates made two valid statements where both clearly indicated an idea of relative rate – in almost all cases one of the descriptions would be about quantity of gas rather than rate of gas production. Some candidates identified a precipitate being formed, colour change, or gave a general answer of the reaction happening quicker.

Question 21 (a) (ii)

(ii) Write half-equations for the reaction of magnesium with hydrochloric acid.

Oxidation half-equation: ....

Reduction half-equation: ....
[2]

Some candidates coped well with this question which was based on the AS part of the specification and gained both marks. More candidates gained 1 mark through writing one half equation, usually the oxidation of magnesium. Common errors were for chlorine to featuring in the reduction half equation and the lack of electrons in their answers. Very few candidates mixed up the oxidation and reduction equations.

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Question 21 (b) (i)

(b) A sample of barium oxide is added to distilled water at 25 °C.
A colourless solution forms containing barium hydroxide, $Ba(OH)_2$.

The solution is made up to 250.0 cm^3 with distilled water.
The pH of this solution is 13.12.

(i) Determine the mass of barium oxide that was used.

Give your answer to **3** significant figures.

mass of barium oxide = ... g **[5]**

Although few candidates got the correct final answer, however almost all achieved some marks from this calculation through error carried forward, with marks spread across the available range. Almost all candidates were able to find the concentrations of hydrogen and hence hydroxide ions. A few candidates successfully used p[OH^-] method. Most were able to calculate the moles of hydroxide ions in 250cm^3. Many then did not realise the need to half this number to find the moles of barium, and/or used the M_r for barium hydroxide instead of barium oxide.

Question 21 (b) (ii)

(ii) 10 cm^3 of dilute sulfuric acid is added to 10 cm^3 of the colourless solution of $Ba(OH)_2$.

Write an ionic equation, including state symbols, for the reaction.

.... **[1]**

This question was answered well, with many candidates giving one of the equations in the 'ALLOW' part of the mark scheme. Those candidates who did not gain this mark gave full equations or missed out state symbols.

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Question 21 (c) (i)

(c) Limestone and huntite are two calcium minerals.

(i) A typical sample of limestone contains 95.0% by mass of calcium carbonate, $CaCO_3$.

Fertiliser **Z**, $Ca_5NH_4(NO_3)_{11}{\bullet}10H_2O$ (M_r = 1080.5 g mol^{-1}) can be made from limestone.

Calculate the mass, in g, of limestone needed to make 1.50 kg of fertiliser **Z**.

Give your answer to **3** significant figures.

mass of limestone = ... g **[3]**

This proved a difficult question for most candidates. Most were able to correctly calculate the moles of fertiliser by converting kg to g. The next step was to deduce that 5 moles of calcium carbonate would be required for each mole of Z and multiply by 5, rather than the common error of dividing by 5. Few candidates were able to multiply by 100/95, to account for the impurities in limestone, with many multiplying by 95/100.

Question 21 (c) (ii)

(ii) Huntite is a carbonate mineral with the chemical formula $Mg_3Ca(CO_3)_4$.

Huntite reacts with dilute hydrochloric acid to produce bubbles of a gas and a colourless solution.

Construct the equation for the reaction. Include state symbols.

.... **[2]**

This was another very challenging question using an unfamiliar mineral. Most candidates identified a formula of salts containing both magnesium and calcium, or carbonates of the separate elements. Only the most successful candidates were able to give the correct formula. Common errors, for those who solved the formulae, were the use of "4"HCl in balancing and the absence of state symbols.

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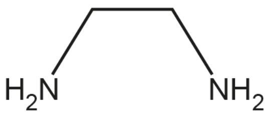
Question 22 (a) (i)

22 This question is about reactions of transition metal compounds.

(a) Ethane-1,2-diamine, $H_2NCH_2CH_2NH_2$, is a bidentate ligand.

The structure of ethane-1,2-diamine is shown below.



(i) Explain why ethane-1,2-diamine can act as a bidentate ligand.

....

....

.... **[1]**

There were some good answers to this standard question, but candidates did not gain the mark due to missing one of the three key ideas of "donation, electron pairs and forming two coordinate bonds".

Question 22 (a) (ii)

(ii) The iron(III) ion, Fe^{3+}, forms a complex ion **A** with two ethane-1,2-diamine ligands and two chloride ligands.

Complex ion **A** has *cis* and *trans* stereoisomers.
One of these stereoisomers exists as optical isomers.

Determine the empirical formula, with charge, of complex ion **A** and draw the 3-D structures of the three stereoisomers.

Empirical formula with charge ....

Structures

[4]

Most candidates did not seem to understand how to apply their knowledge of what an empirical formula should look like to this situation. Many giving the formula of the complex ion instead. Those candidates who were successful often had the incorrect overall charge on the ion with 3+ as the common error, not considering the 2 Cl^- ligands. Conversely, most candidates did very well at representing the isomers of the complex. Most were able to use the wedge and broken line notation to suggest the geometry of what they were drawing. Although a small number drew the trans isomer in three different orientations, most correctly drew the trans and cis forms and managed to show the optical isomers – even when they did not make use of the top pair of answer boxes to assist them with their mirror images. Candidates are advised to focus on the mirror image and avoid subsequent rotations and inversions of the molecule. This can often lead to two of the same isomers being drawn. Candidates showed a good accuracy with their connectivity of the N atom.

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Question 22 (b) (i)

(b) Aqueous sodium hydroxide is added to an aqueous solution of iron(II) sulfate.
A pale green precipitate forms which turns brown when left to stand in air.

(i) Write an ionic equation for the formation of the pale green precipitate.

.... **[1]**

Most students scored this mark, although several gave no response.

Question 22 (b) (ii)

(ii) Use the information below to explain why the pale green precipitate turns brown when left to stand in air and construct an equation for the reaction which occurs.

Redox System	Equation	$E^{\ominus}$ / V
1	$Fe(OH)_3(s) + e^- \rightleftharpoons Fe(OH)_2(s) + OH^-(aq)$	–0.56 V
2	$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40 V

....

....

....

....

....

.... **[4]**

Although a spread of marks across the full available range was seen, a good proportion of candidates gained 3 or 4 marks. Most candidates were able to produce a balanced equation, but candidates should take care cancelling out any species present on both side of the equation, e.g. the hydroxide ions. A common error within the formula of iron (III) hydroxide was to place the number of hydroxide ions within the brackets, e.g. $Fe(OH_3)$. Candidates are advised to read the instructions contained within the equation and to use or comment on all the data presented. When commenting on electrode potentials, candidates should avoid the use of higher/lower as these phrases are meaningless due to the negative signs involved.

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Question 22 (c)

(c)* This question is about copper and copper compounds.

Experiment 1
Hydrochloric acid, $HCl(aq)$, is added to an aqueous solution containing $[Cu(H_2O)_6]^{2+}$ complex ions.
A yellow-green solution forms containing complex ion **B**.

Experiment 2
A piece of copper metal is heated with concentrated sulfuric acid.
A reaction takes place forming a pale blue solution **C** and $45\,cm^3$ of a gas **D**, measured at RTP. The mass of gas **D** is 0.12 g.

Experiment 3
An excess of copper(II) oxide is heated with dilute nitric acid. The resulting mixture is filtered. The filtrate is a blue solution **E**.
Aqueous potassium iodide, KI(aq), is added to the blue solution **E**.
A white precipitate **F** and a brown solution **G** form.

Determine the formulae of **B**–**G**.
Construct equations for the reactions taking place, include any changes in oxidation number, and show your working where appropriate. **[6]**

Answers were distributed across all 3 levels of achievement. Most of the candidates managed to identify at least some of the substances. Of the equations, the reaction of copper (II) oxide with nitric acid was most regularly seen correct, although many students could also represent the ligand replacement in Experiment 1. Many candidates were able to calculate M_r for gas D but some of those suggesting SO_2 as a possible formula preferred to have an equation in experiment 2 producing hydrogen. A few candidates used the M_r to suggest that the gas was $2O_2$ and as such candidates found the equation between copper and sulphuric acid challenging. A good number of candidates identified F and G, recognising what they had learned from their work on redox titrations, and some were able to reproduce the equation. Incorrect formula of copper (I) iodide (CuI_2) was a common error. Many candidates made no attempt at identifying changes in oxidation states. Candidates are advised to address all parts of the question in order to access the higher levels and to allow sufficient time to attempt the LoR questions.

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Exemplar 3

Experiment 1

$[Cu(H_2O)_6]^{2+}_{(aq)} + 4Cl^-_{(aq)} \rightarrow [CuCl_4]^{2-}_{(aq)} + 6H_2O_{(l)}$

B – $[CuCl_4]^{2-}_{(aq)}$

No change in oxidation number

Experiment 2

gas D $n = \frac{45}{24000} = 1.875 \times 10^{-3}$ mol $n = \frac{m}{Mr}$

$Mr = \frac{m}{n} = \frac{0.12}{1.875 \times 10^{-3}} = 64$ gas D – $SO_{2(g)}$

pale blue solution C – $CuSO_{4(aq)}$

$Cu_{(s)} + 2H_2SO_{4(aq)} \rightarrow CuSO_{4(aq)} + SO_{2(g)} + 2H_2O_{(l)}$

copper is oxidised as it goes from oxidation number of 0 in Cu to +2 in $CuSO_{4(aq)}$. sulfur is reduced from +6 in H_2SO_4 to +4 in SO_2

Experiment 3

$CuO_{(s)} + 2HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + H_2O_{(l)}$

E – $Cu(NO_3)_{2(aq)}$

$2Cu^{2+}_{(aq)} + 4I^-_{(aq)} \rightarrow 2CuI_{(s)} + I_{2(aq)}$

$2Cu(NO_3)_{2(aq)} + 4KI_{(aq)} \rightarrow 2CuI_{(s)} + I_{2(aq)} + 4KNO_{3(aq)}$

white precipitate F – $CuI_{(s)}$ Iodine oxidation number changes from

Brown solution G – $I_{2(aq)}$ –1 to 0 and is oxidised

oxidation number of Cu changes from Cu^{2+} in $Cu(NO_3)_{2(aq)}$ to Cu^+ in $CuI_{(s)}$ hence copper is reduced

The candidate has clearly set out the three experiments, written the equation and followed with a clear identification of each of the formulae B-G. The calculation is well laid out and the response clearly indicates how the final value has been calculated. Oxidation numbers have then been commented on where appropriate.

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The AS delivery guide 'Theme: Identifying Unknowns'

https://www.ocr.org.uk/Images/208563-identifying-unknowns.pdf

'Transition elements': Delivery Guide for OCR AS/A Level Chemistry A

The colours of the transition metal ions and complexes can be reviewed at: A Level Chemistry A - Colours of inorganic ions and complexes (ocr.org.uk)

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