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Examiners' report

CHEMISTRY A

H432
For first teaching in 2015

H432/01 Summer 2019 series

Version 1

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Contents

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. 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 exam paper can be downloaded from OCR.

Subject information update

Candidates sitting their A Level Chemistry exams this summer may have noticed they had additional line space to write their answers to Level of Response questions. We made this change having noticed in previous exam series that some candidates were writing answers that were longer than could fit in the space provided. The extra line space was clearly labelled as additional and was only there should candidates have required it. There is not an expectation that candidates will necessarily need to use the extra space and we would encourage teachers to continue reminding candidates about the importance of writing concise answers to questions. We will continue to make the extra line space available for Level of Response questions in future exam series too.

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.

Candidate performance overview

Candidates who did well on this paper generally:

- Produced clearly structured working for calculations – 16(d)(ii), 18(c)(ii), 19(a)(ii), 19(a)(iii), 19(b)(ii), 20(b)(iii).
- Produced clear and concise responses for the two Level of Response questions – 17(a) and 21.
- Were able to make and justify predictions based on their knowledge – 16(e)(i), 16(e)(ii).
- Had a strong recall of transition metal chemistry – 18(a)(i) to 18(a)(v).
- Gave answers to the correct number of significant figures or decimal places – 16(b) 18(c(ii) 19(b)(ii), 20(a), 20(b)(ii).
- Ably converted between units when required – 18(c)(ii), 19(a)(ii).

Candidates who did less well on this paper generally:

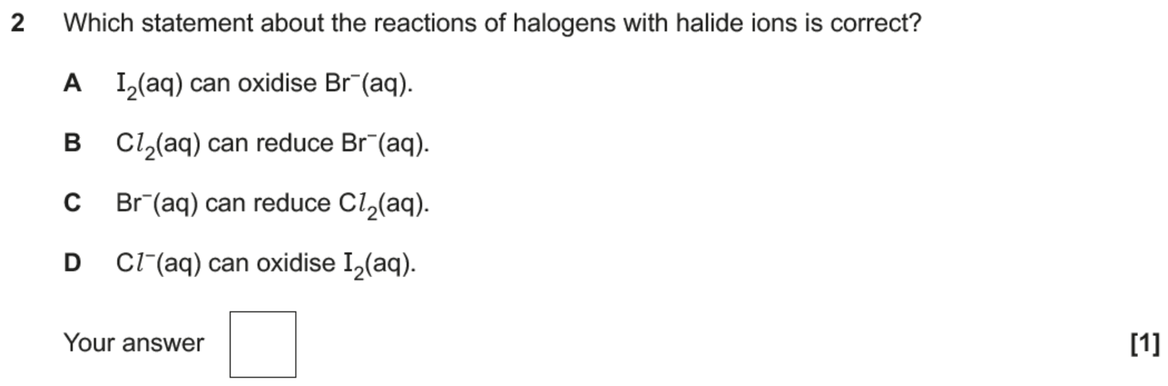
- Found it difficult to apply what they had learned to unfamiliar situations.
- Produced unstructured responses to Level of Response questions which were lacking in depth or explanation, or, contained contradictory information – 17(a) and 21.
- Did not clearly set out calculations, making it difficult for marks to be given for working – 16(d)(ii), 18(c)(ii), 19(a)(ii), 19(a)(iii), 19(b)(ii), 20(b)(iii).
- Did not give answers to calculations to the specified number of significant figures or decimal places – 16(b) 18(c(ii) 19(b)(ii), 20(a), 20(b)(ii).
- Either did not realise the need to convert between units for some calculations, or found this difficult – 18(c)(ii), 19(a)(ii).

There was no evidence that any time constraints had led to a candidate underperforming and scripts where there was no response to the final question also had large sections of the paper which had not been tackled.

Section A overview

A significant number of candidates did not provide an answer to every multiple choice question. 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.

Question 2



2 Which statement about the reactions of halogens with halide ions is correct?

A I_2(aq) can oxidise Br^-(aq).

B Cl_2(aq) can reduce Br^-(aq).

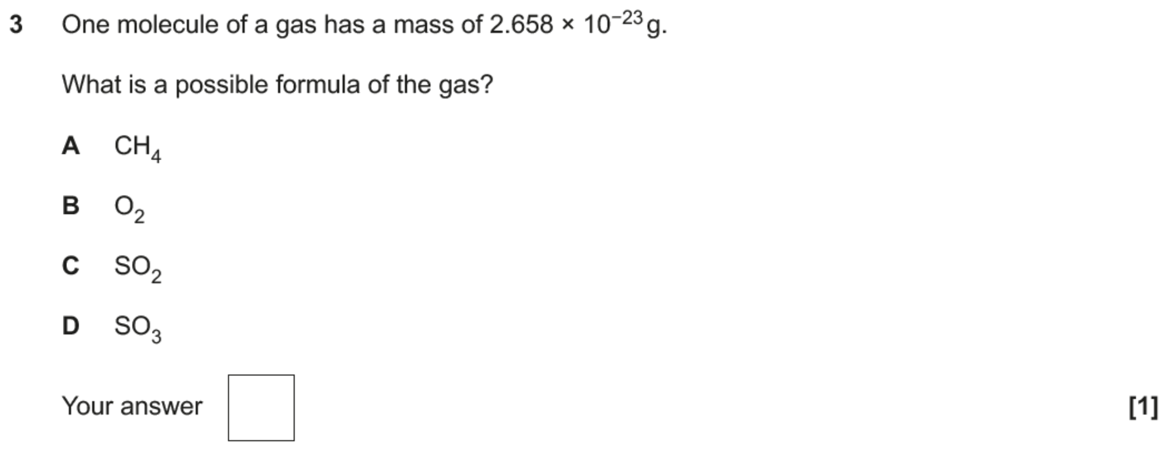
C Br^-(aq) can reduce Cl_2(aq).

D Cl^-(aq) can oxidise I_2(aq).

Your answer ☐ **[1]**

This question proved to be difficult, with only the most able candidates selecting the correct answer of C. Many candidates confused the trends in oxidising power of the halogens with trends in the reducing power of the halide ions. Down the group, the oxidising power of the halogens decreases but the reducing power of the halide ions increases. Option A is incorrect because iodine is a weaker oxidising agent than bromine, option B (the most common incorrect answer) is incorrect because chlorine is not a reducing agent (it's an oxidising agent) and option D is incorrect because the chloride ion is not an oxidising agent (it's a reducing agent).

Question 3



3 One molecule of a gas has a mass of 2.658×10^{-23} g.

What is a possible formula of the gas?

A CH_4

B O_2

C SO_2

D SO_3

Your answer ☐ **[1]**

This question was quite well answered with many candidates calculating the Mr by multiplying the mass by Avogadro's number. This gave the answer as 16, which matches the Mr of CH_4, giving A as the correct answer. Option B provided a distractor as oxygen atoms have a relative mass of 16 whereas option B relates to O_2 molecules with a relative mass of 32. Some candidates got part way through the calculation and then appeared to choose an answer at random.

Question 4

4 In the laboratory, acid spills can be cleaned up and made safe by spreading anhydrous sodium carbonate over the spill to neutralise the acid.

A student accidentally spills 50.0 cm^3 of 2.00 mol dm^{-3} $HCl(aq)$ on the bench.

What is the minimum mass of anhydrous sodium carbonate required to neutralise the acid?

A 4.15 g

B 5.30 g

C 8.30 g

D 10.6 g

Your answer ☐ **[1]**

This was a challenging question, the correct answer being B. Candidates had to know the correct formula for sodium carbonate in order to deduce the 2:1 molar ratio of HCl to Na_2CO_3 and to calculate its Mr (106). Option D was arrived at by assuming the molar ratio was 1:1, option A by incorrectly thinking the formula was $NaCO_3$, and option C by making both of these mistakes.

Question 5

5 What is the oxidation number of N in $Mg(NO_2)_2•3H_2O$?

A +2

B +3

C +4

D +5

Your answer ☐ **[1]**

The correct answer B required candidates to assign correct oxidation numbers to Mg and O. The most common error was option A (+2), obtained by candidates thinking that O has an oxidation number of -1

Question 6

6 Which reaction is a redox reaction?

A $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

B $NaNO_2 + HCl \rightarrow NaCl + HNO_2$

C $CaSO_3 + 2HCl \rightarrow CaCl_2 + H_2O + SO_2$

D $3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$

Your answer ☐ **[1]**

This was generally well answered. The key to candidates quickly arriving at the correct answer (D) was to focus on the first compound in each equation. Good candidates could see clearly that the CuO in option D had been reduced to Cu. Some candidates lost time here by working out oxidation numbers for all the elements in all the equations.

Question 8

8 3.528 g of a Group 2 metal, **M**, is reacted with an excess of chlorine.
The reaction forms 9.775 g of a chloride.

What is metal **M**?

A magnesium

B calcium

C strontium

D barium

Your answer ☐ **[1]**

This question was quite well answered with many candidates realising that the formula of the metal chloride was MCl_2. The most reliable way of tackling the calculation was to calculate the mass of chlorine which reacted (the difference between the two given masses), working out the number of moles of chlorine and then calculating the Ar of the metal. This led them to identify the metal as calcium (option B). Some candidates took the long route by taking each option in turn, working out the number of moles and seeing which value matched the moles of chlorine. Candidates who chose incorrect answers could not complete all the calculation steps and appeared to choose one at random.

Question 9

9 Which statement is **not** correct for Group 2 hydroxides?

A $Mg(OH)_2$ can be used to treat indigestion.

B $Ca(OH)_2$ is used in agriculture to neutralise alkaline soils.

C The anion in $Sr(OH)_2$ contains 10 electrons.

D $Ba(OH)_2$ is a product from the reaction of barium and water.

Your answer ☐ **[1]**

This question was not well answered, with many candidates giving option C rather than the correct answer of B. Many candidates mis-read option B as acidic soil rather than alkaline soil, so thought that option B was correct, whereas in fact it was the only incorrect statement. Many candidates opted for option C, not realising the anion is OH^- which does have 10 electrons.

Question 10

10 Radical reactions are responsible for the catalysed breakdown of the ozone layer.

The overall equation is shown below.

$2O_3 \rightarrow 3O_2 \qquad \Delta_r H = -284\,kJ\,mol^{-1}$

The molar gas volume in the ozone layer is approximately $2.5\,m^3\,mol^{-1}$.

What is the energy released, in kJ, during the breakdown of $1.0\,m^3$ of ozone in the ozone layer?

A 56.8

B 113.6

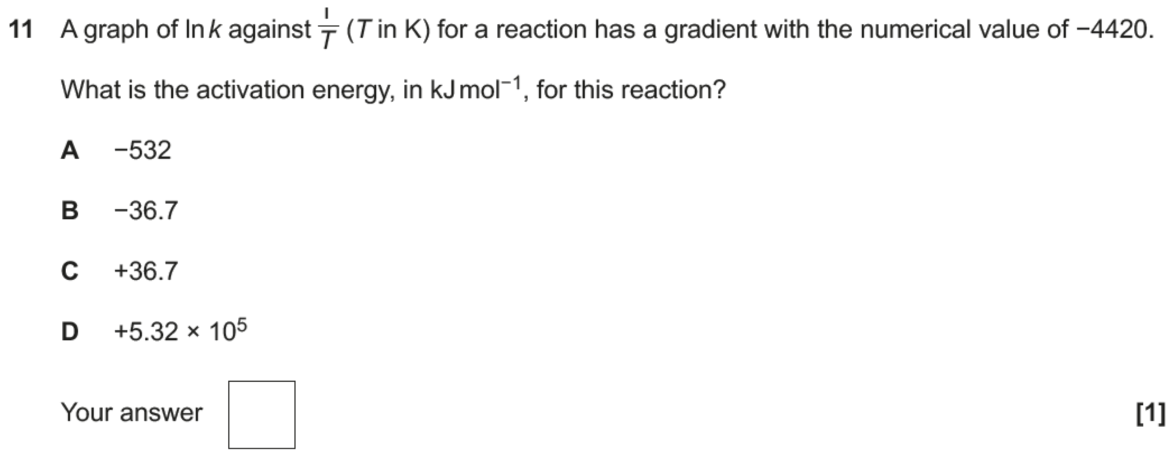
C 355

D 710

Your answer ☐ **[1]**

This was another challenging question, with only the most able candidates choosing the correct answer of A. Candidates had to calculate the number of moles of O_3 (by dividing 1.0 by 2.5) and then had to use the information in the equation (that 2 moles of O_3 releases 284 kJ). The most common error was option B, presumably because candidates thought that 1 mole of O_3 releases 284 kJ (rather than 2 moles). Candidates should be aware that a given enthalpy change relates to the molar quantities as shown in the equation.

Question 11



11 A graph of ln *k* against $\frac{1}{T}$ (*T* in K) for a reaction has a gradient with the numerical value of −4420.

What is the activation energy, in kJ mol^{-1}, for this reaction?

A −532

B −36.7

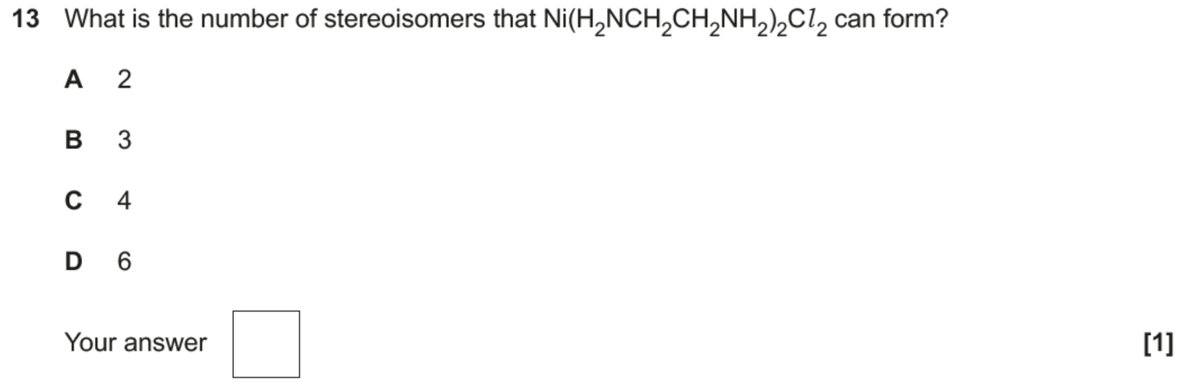
C +36.7

D $+5.32 \times 10^5$

Your answer ☐ **[1]**

This was well answered, with many candidates understanding that the activation energy in kJmol^{-1} is equal to (- gradient x R) divided by 1000, leading to C as the correct answer. Common errors included dividing the gradient by R, giving option A. or forgetting the minus sign and opting for B.

Question 13



13 What is the number of stereoisomers that $Ni(H_2NCH_2CH_2NH_2)_2Cl_2$ can form?

A 2

B 3

C 4

D 6

Your answer ☐ **[1]**

This was a challenging question, with only the most able candidates giving the correct response of B (one trans isomer and two optical cis isomers). Many candidates drew out the shapes of the isomers but some missed the two optical cis isomers (giving option A) while others thought there were two cis and two trans optical isomers, giving option C.

Question 14

14 Which property/properties is/are correct for a transition element?

1 The element has atoms with a partially filled d sub-shell.

2 The existence of more than one oxidation state in its compounds.

3 The formation of coloured ions.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

Only the highest attaining candidates chose the correct answer of C. Many candidates thought all 3 statements were correct (giving option A as their answer), not realising that statement 1 referred to atoms not ions

Question 15

15 Four redox systems relevant to hydrogen–oxygen fuel cells are shown below.

			$E^\ominus$/V
$H_2O(l) + e^-$	$\rightleftharpoons$	$OH^-(aq) + \frac{1}{2}H_2(g)$	−0.83
$H^+(aq) + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00
$\frac{1}{2}O_2(g) + H_2O(l) + 2e^-$	$\rightleftharpoons$	$2OH^-(aq)$	+0.40
$\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^-$	$\rightleftharpoons$	$H_2O(l)$	+1.23

Which statement(s) is/are correct for an alkaline hydrogen–oxygen fuel cell?

1 The reaction at the positive electrode is: $\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$.

2 The overall cell reaction is: $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$.

3 The cell potential is 1.23 V.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

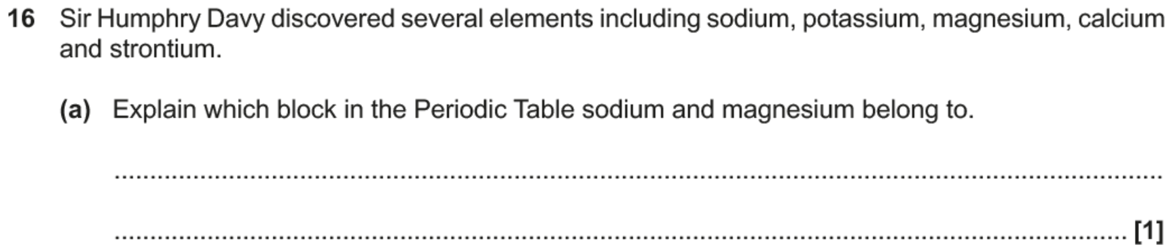
D Only 1

Your answer ☐ **[1]**

Only the higher attaining candidates opted for the correct answer of C. Many candidates thought statement 1 was correct, (giving option A as the answer), not realising that this equation refers to acidic conditions not alkaline conditions (as mentioned in the question). Others did not recognise that the cell potential was 1.23V (obtained by calculating the difference between +0.40 and –0.83), and so opted for option B.

Section B overview

Question 16 (a)



16 Sir Humphry Davy discovered several elements including sodium, potassium, magnesium, calcium and strontium.

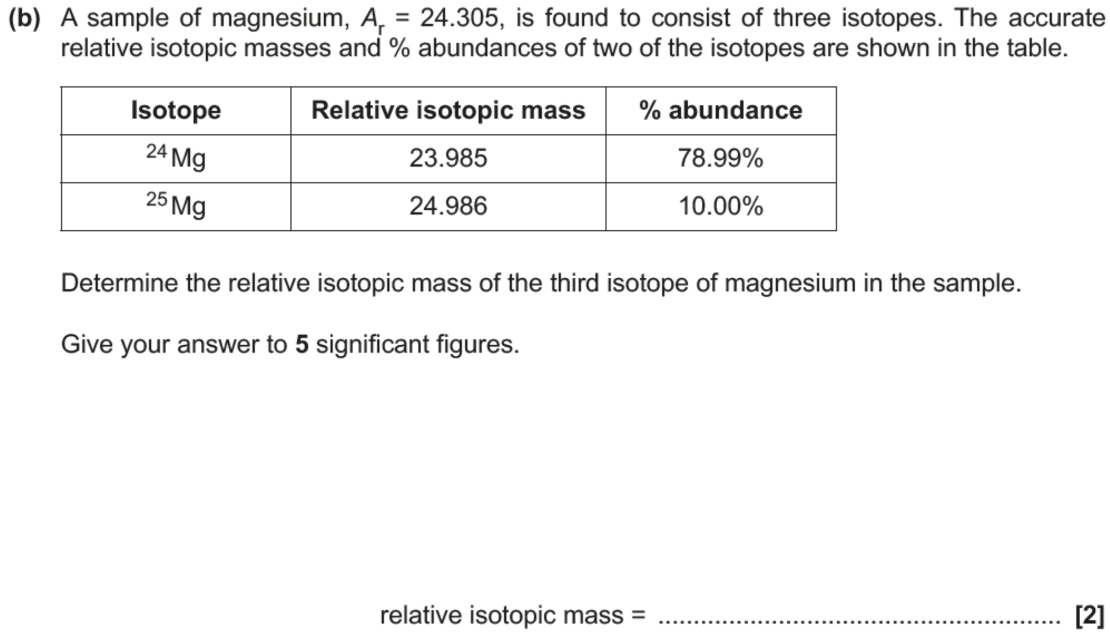
(a) Explain which block in the Periodic Table sodium and magnesium belong to.

....

.... **[1]**

Many candidates knew the block magnesium belonged but only very few could explain this was because magnesium's highest energy electron was in a s sub-shell or s orbital.

Question 16 (b)



(b) A sample of magnesium, A_r = 24.305, is found to consist of three isotopes. The accurate relative isotopic masses and % abundances of two of the isotopes are shown in the table.

Isotope	**Relative isotopic mass**	**% abundance**
^{24}Mg	23.985	78.99%
^{25}Mg	24.986	10.00%

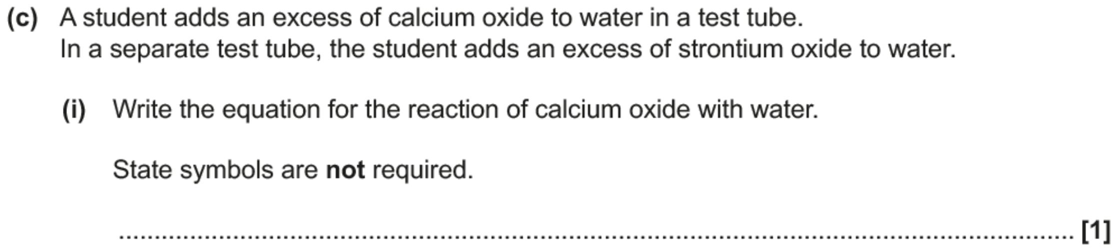
Determine the relative isotopic mass of the third isotope of magnesium in the sample.

Give your answer to **5** significant figures.

relative isotopic mass = ... **[2]**

This was mathematically challenging, but candidates who did not arrive at the correct answer were able to get partial credit for showing working.

Question 16 (c) (i)



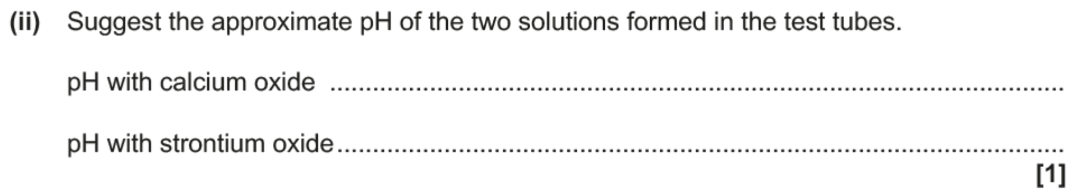
(c) A student adds an excess of calcium oxide to water in a test tube.
In a separate test tube, the student adds an excess of strontium oxide to water.

(i) Write the equation for the reaction of calcium oxide with water.

State symbols are **not** required.

.... **[1]**

Question 16 (c) (ii)



(ii) Suggest the approximate pH of the two solutions formed in the test tubes.

pH with calcium oxide ....

pH with strontium oxide ....

[1]

These two sub-questions were well answered.

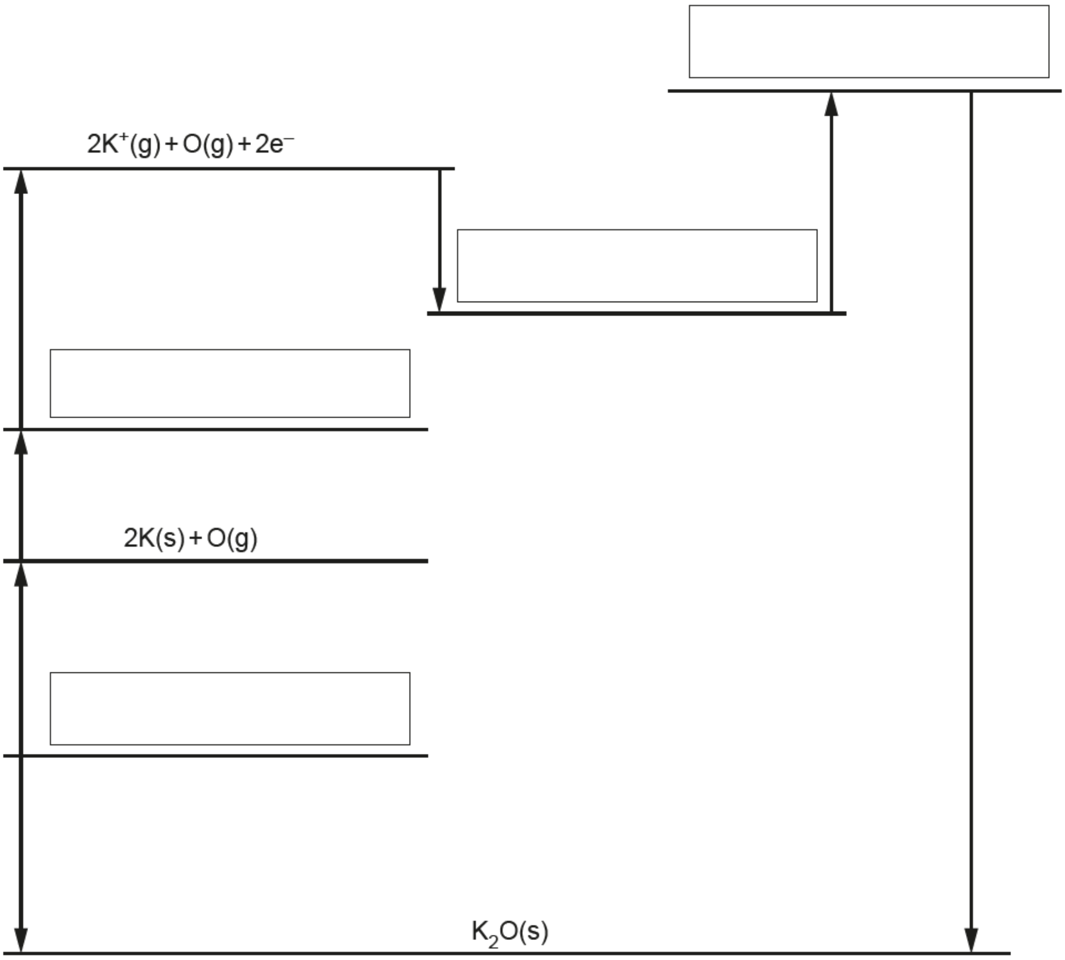
Question 16 (d) (i)

(d) The table below shows enthalpy changes involving potassium, oxygen and potassium oxide, K_2O.

	Enthalpy change / kJ mol^{-1}
formation of potassium oxide	–363
1st electron affinity of oxygen	–141
2nd electron affinity of oxygen	+790
1st ionisation energy of potassium	+419
atomisation of oxygen	+249
atomisation of potassium	+89

(i) The incomplete Born–Haber cycle below can be used to determine the lattice enthalpy of potassium oxide.

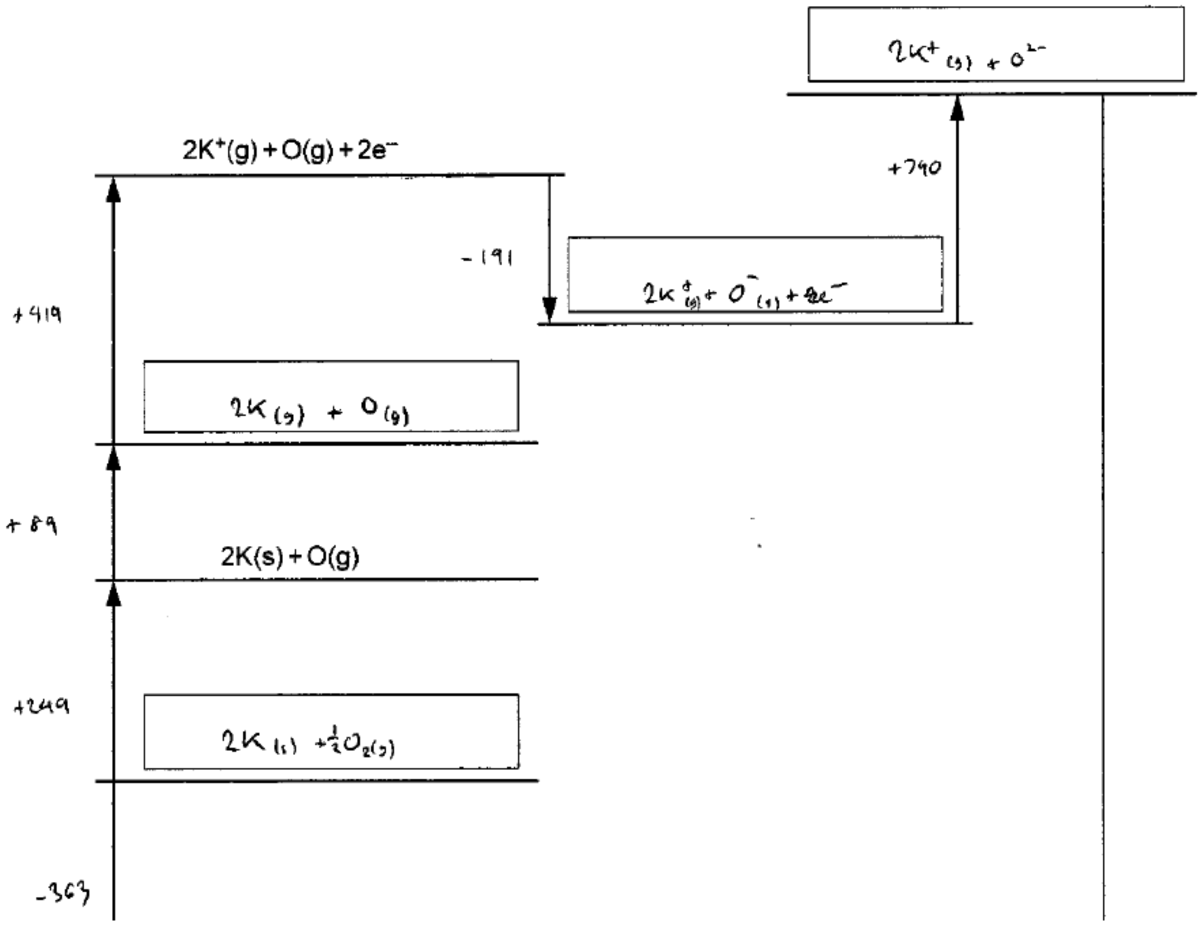
In the boxes, complete the species present in the cycle.
Include state symbols for the species.



[4]

Some candidates wrote illegible state symbols where (g) and (s) were impossible to tell apart. Also, many candidates choose to write state symbols as a very small sub-script e.g. $2K_{(s)} + \frac{1}{2}O_{2(g)}$. The convention is to use lower case letters of normal size e.g. $2K(s) + \frac{1}{2}O_2(g)$

Exemplar 1



In this exemplar it was impossible to tell if K had (s) or (g) as a state symbol. Consequently, no marks could be given.

Question 16 (d) (ii)

(ii) Calculate the lattice enthalpy of potassium oxide.

lattice enthalpy = ... kJ mol^{-1} **[2]**

Most candidates scored both marks. Candidates tended to forget the mole ratio of K meant its values should be multiplied by 2 in two places during this calculation.

Question 16 (e) (i)

(e) A similar Born–Haber cycle to potassium oxide in **(d)** can be constructed for sodium oxide.

(i) The first ionisation energy of sodium is more endothermic than that of potassium.

Explain why.

[2]

Candidates coped well with this question which was based on the AS part of the specification. Some candidates gave vague and unnecessarily long responses to this question.

Question 16 (e) (ii)

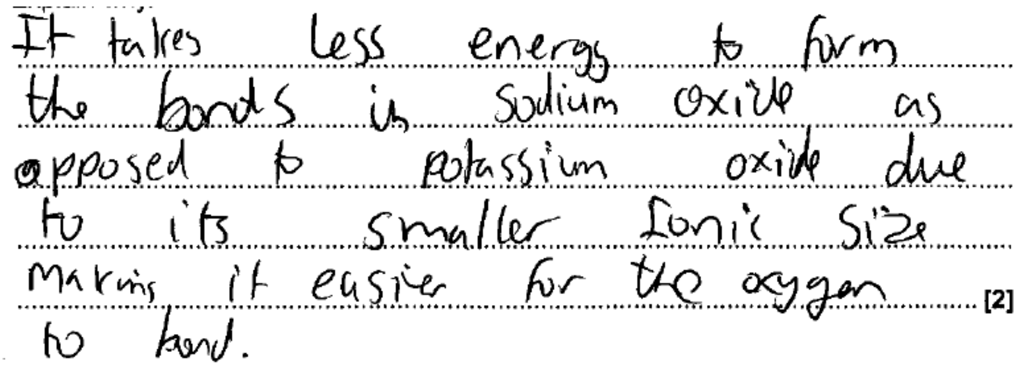
(ii) The lattice enthalpy of sodium oxide is more exothermic than that of potassium oxide.

Explain why.

[2]

Many candidates did not achieve full marks, often through ambiguous statements. A typical example is shown in the exemplar below.

Exemplar 4



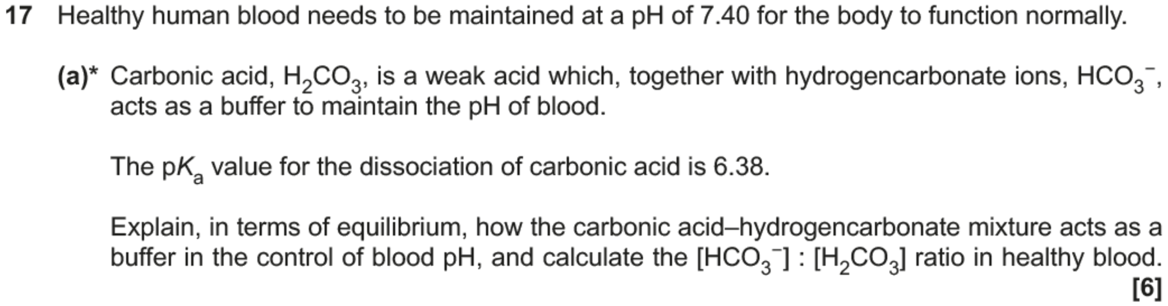
It takes less energy to form the bonds in sodium oxide as apposed to potassium oxide due to its smaller Ionic Size making it easier for the oxygen to bond.

[2]

The exemplar here uses the vague term 'due its smaller ionic size'. It is unclear which of the ions the candidate is referring to (or if they're assuming that the metal oxide entity is an ion) and so they could not be given marks..

Also, it is oxygen ions that 'bond' – the reference to oxygen bonding in the response is not specific enough.

Question 17 (a)



17 Healthy human blood needs to be maintained at a pH of 7.40 for the body to function normally.

(a)* Carbonic acid, H_2CO_3, is a weak acid which, together with hydrogencarbonate ions, HCO_3^-, acts as a buffer to maintain the pH of blood.

The pK_a value for the dissociation of carbonic acid is 6.38.

Explain, in terms of equilibrium, how the carbonic acid–hydrogencarbonate mixture acts as a buffer in the control of blood pH, and calculate the $[HCO_3^-] : [H_2CO_3]$ ratio in healthy blood. **[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.

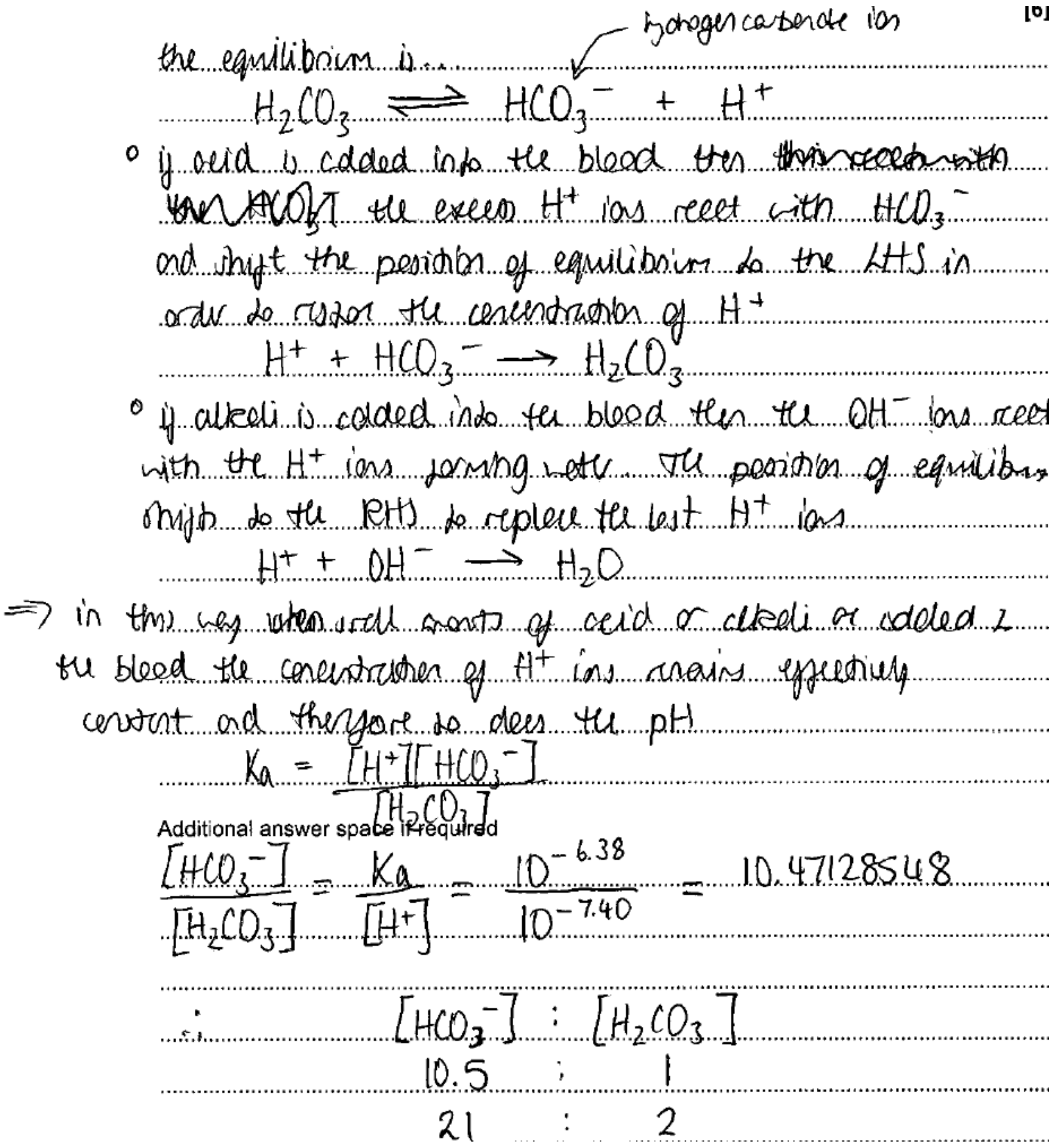
The calculation of the $[HCO_3^-] : [H_2CO_3]$ ratio was well described although sometimes the final expression of the ratio left ambiguity as it was hard to tell whether the ratio given referred to the $[HCO_3^-] : [H_2CO_3]$ ratio or the $[H_2CO_3] : [HCO_3^-]$ ratio

The buffer reactions on separate addition of acid (H^+ ions) and alkali (OH^- ions) were explained and, better still, shown in equation form.

The direction of shift on the $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ equilibrium was invariably correct, but many candidates did not achieve credit for responses such as 'Addition of H^+ ions shifts the equilibrium to the left' because they did not give the equilibrium which was undergoing shift.

An example of a complete answer gaining L3 (6 marks) is given.

Exemplar 5



[6]

hydrogencarbonate ion

the equilibrium is...

$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$

- if acid is added into the blood then ~~this reacts with the HCO_3^-~~ the excess H^+ ions react with HCO_3^- and shift the position of equilibrium to the LHS in order to restore the concentration of H^+

  $H^+ + HCO_3^- \longrightarrow H_2CO_3$

- if alkali is added into the blood then the OH^- ions react with the H^+ ions forming water. The position of equilibrium shifts to the RHS to replace the lost H^+ ions

  $H^+ + OH^- \longrightarrow H_2O$

⇒ in this way when small amounts of acid or alkali are added to the blood the concentration of H^+ ions remains effectively constant and therefore so does the pH

$$K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

Additional answer space if required

$$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{K_a}{[H^+]} = \frac{10^{-6.38}}{10^{-7.40}} = 10.47128548$$

$\therefore$ $[HCO_3^-] : [H_2CO_3]$

10.5 : 1

21 : 2

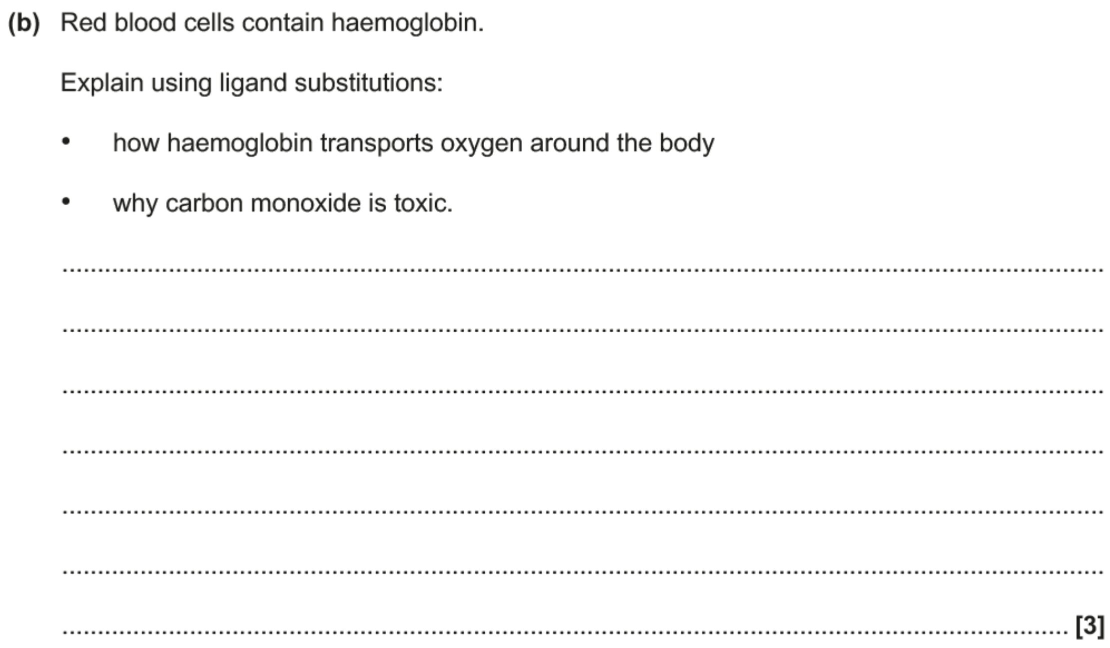
The candidate clearly writes the equilibrium at the top.

The first bullet point gives a chemical equation for the reaction occurring when H^+ ions are added as well as the shift in equilibrium.

The second bullet point gives a chemical equation for the reaction occurring when OH^- ions are added as well as the shift in equilibrium.

The steps in the calculation are clearly shown and the ratio is clear.

Question 17 (b)



(b) Red blood cells contain haemoglobin.

Explain using ligand substitutions:

- how haemoglobin transports oxygen around the body
- why carbon monoxide is toxic.

[3]

The key chemistry that candidates needed to discuss in their response was as follows:

- O_2 molecules forming ***coordinate bonds*** with and Fe^{2+} ions in haemoglobin.
- O_2 **molecules** being replaced by another **ligand** (e.g. H_2O or CO)
- CO ligands forming **very strong** coordinate bonds

The mark scheme allowed 'oxygen binding' but candidates did need to specify what the oxygen was binding to. Loose terminology, such as CO having a 'greater affinity' should be avoided.

Question 18 (a) (i)

18 This question is about reactions of ions and compounds of transition elements.

(a) A student carries out two experiments on a solution containing $[Cr(H_2O)_6]^{3+}(aq)$.

Experiment 1
The student adds an excess of aqueous ammonia to a solution containing $[Cr(H_2O)_6]^{3+}(aq)$ until a purple solution is formed.

Experiment 2
The student carries out the following reaction sequence.

Step 1 NaOH(aq) is added slowly to a solution containing $[Cr(H_2O)_6]^{3+}(aq)$ in a boiling tube.
A grey–green precipitate forms.

Step 2 An excess of NaOH(aq) is added to the boiling tube.
The precipitate dissolves and a green solution forms containing a 6 coordinate complex ion.

Step 3 H_2O_2 is added to the mixture and the boiling tube is heated.
A yellow solution forms.

Step 4 The solution in the boiling tube is acidified.
The solution now contains $Cr_2O_7^{2-}(aq)$.

(i) What is the formula of the complex ion in the purple solution that forms in **Experiment 1**?

.... **[1]**

Most candidates knew the correct formula. There was some confusion with ammoniacal copper ions and $[Cr(NH_3)_4(H_2O)_2]^{2+}$ was a frequently seen incorrect answer.

Question 18 (a) (ii)

(ii) Suggest an equation for the reaction in **Experiment 2**, **Step 1**.
Include state symbols.

.... **[1]**

The most common error for this question was to omit the state symbols, sometimes on only one species. Both a correct equation and the correct state symbols were required for the mark.

Question 18 (a) (iii)

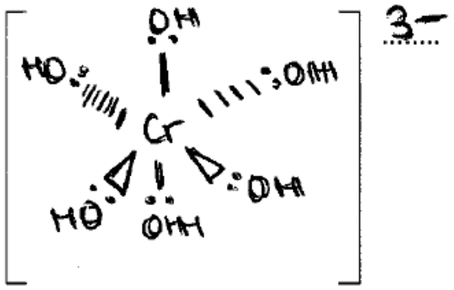
(iii) Draw a 3-D diagram for the shape of the complex ion that forms in **Experiment 2**, **Step 2**.
Include the charge of the ion.

[ ] ....

[2]

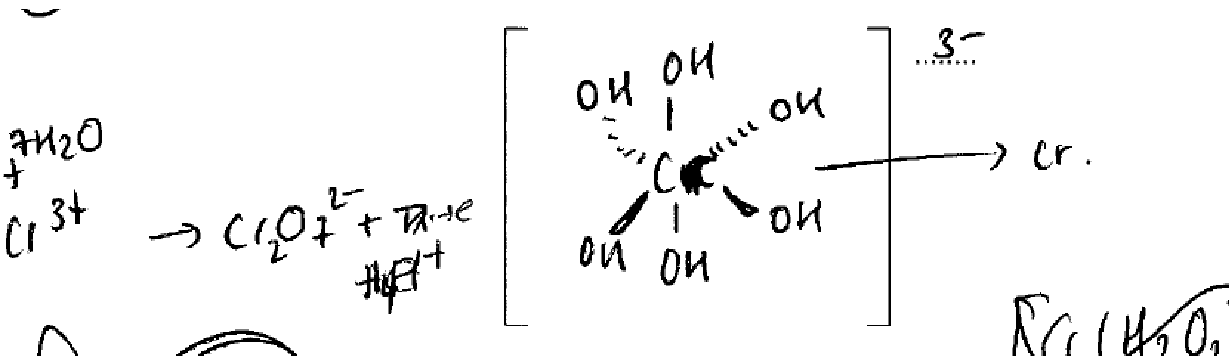
The drawing of simple 3-D diagrams of relevant shapes is a skill that is assessed in A Level chemistry. Common errors are listed in the exemplars.

Exemplar 6



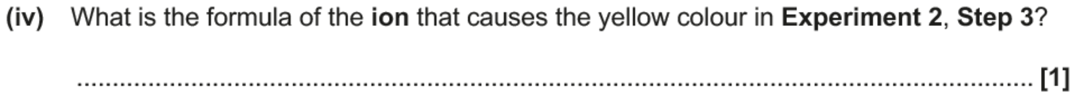
Some candidates drew in pencil then over-wrote in ink. Candidates need to remember that the scanned image does not differentiate between pencil and ink, so it is not necessary for them to do this.

Exemplar 7



Candidates should avoid incorrect connectivity between the ligand and the central metal ion. Candidates should be taught which atom within the ligand supplies the lone pair to form the coordinate bond. In this case oxygen has lone pairs, not hydrogen as suggested by the candidate in the bonding involving the bottom left hand ligand.

Question 18 (a) (iv)

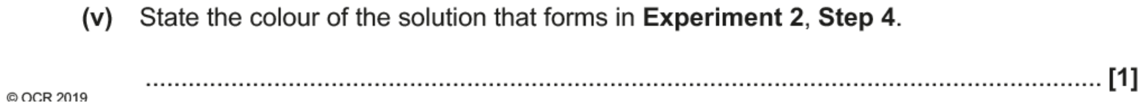


(iv) What is the formula of the **ion** that causes the yellow colour in **Experiment 2**, **Step 3**?

.... **[1]**

Very few candidates correctly identified the CrO_4^{2-} ion here. Candidates should be aware that oxidation of $Cr(OH)_3$ produces CrO_4^{2-} (which can then be acidified to produce $Cr_2O_7^{2-}$).

Question 18 (a) (v)



(v) State the colour of the solution that forms in **Experiment 2**, **Step 4**.

.... **[1]**

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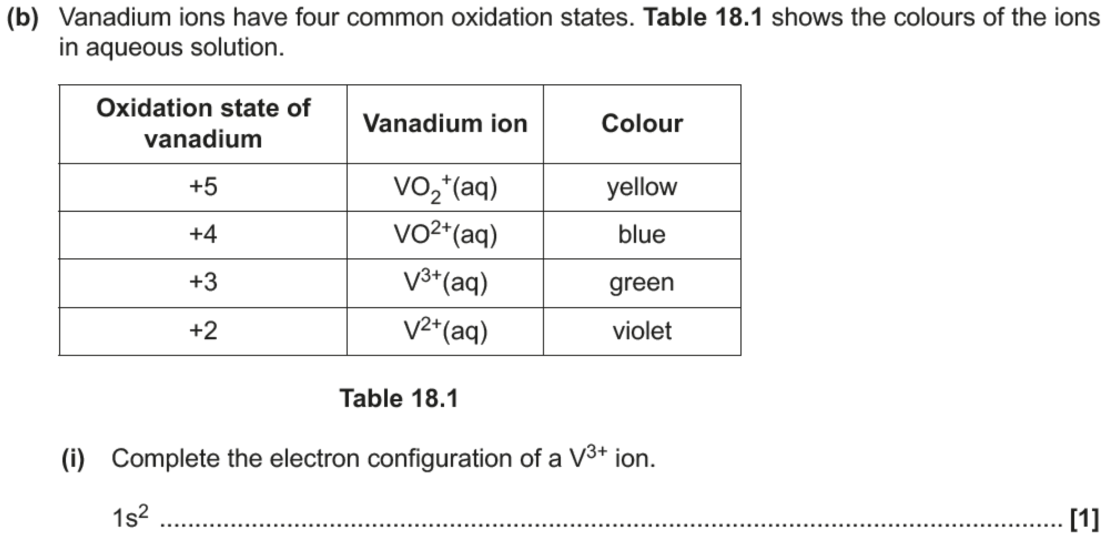
Invariably, the answer given by candidates here was either orange or green, indicating some knowledge of the colours of chromium ions. Those who stated orange received credit

Question 18 (b) (i)



(b) Vanadium ions have four common oxidation states. **Table 18.1** shows the colours of the ions in aqueous solution.

Oxidation state of vanadium	Vanadium ion	Colour
+5	$VO_2^+(aq)$	yellow
+4	$VO^{2+}(aq)$	blue
+3	$V^{3+}(aq)$	green
+2	$V^{2+}(aq)$	violet

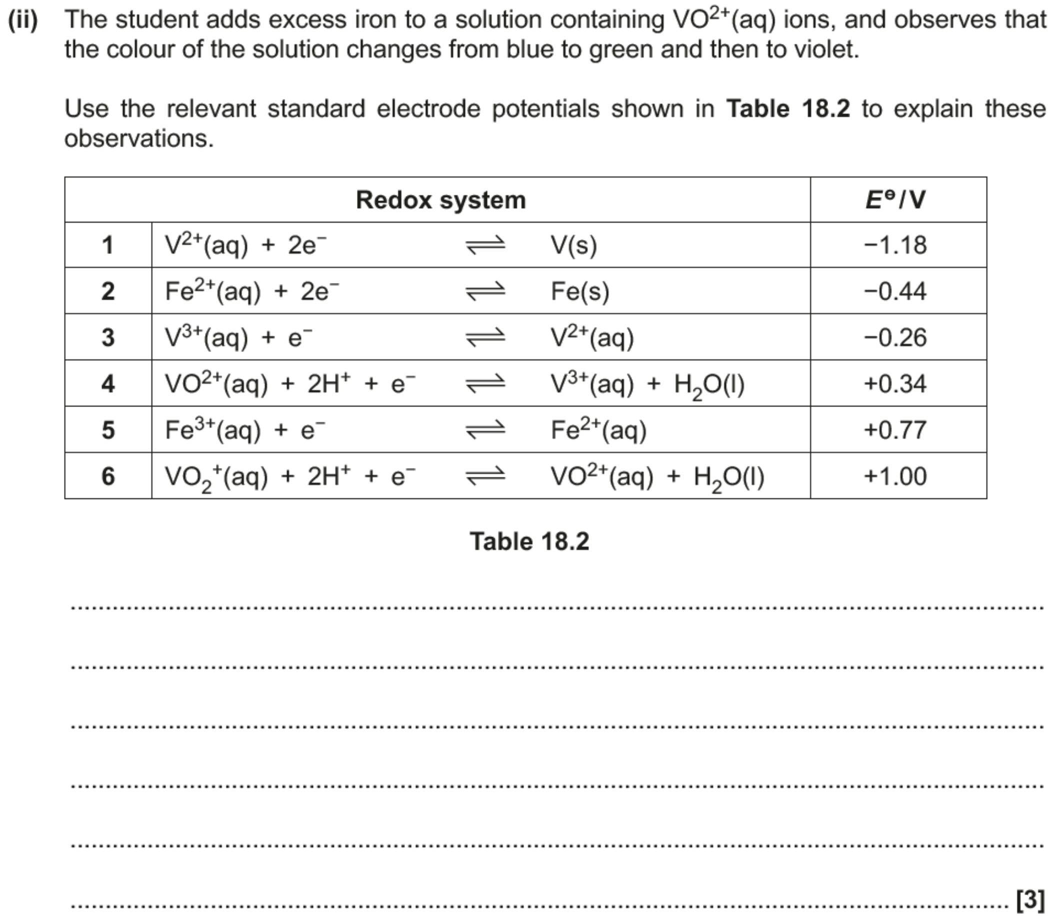
Table 18.1

(i) Complete the electron configuration of a V^{3+} ion.

$1s^2$ .... **[1]**

Many candidates did not realise that when transition metal ions are formed, the first electrons removed from atoms are the 4s electrons and so wrote $2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$.

Question 18 (b) (ii)



(ii) The student adds excess iron to a solution containing $VO^{2+}(aq)$ ions, and observes that the colour of the solution changes from blue to green and then to violet.

Use the relevant standard electrode potentials shown in **Table 18.2** to explain these observations.

	Redox system			$E^{\ominus}$/V
1	$V^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$V(s)$	−1.18
2	$Fe^{2+}(aq) + 2e^-$	$\rightleftharpoons$	$Fe(s)$	−0.44
3	$V^{3+}(aq) + e^-$	$\rightleftharpoons$	$V^{2+}(aq)$	−0.26
4	$VO^{2+}(aq) + 2H^+ + e^-$	$\rightleftharpoons$	$V^{3+}(aq) + H_2O(l)$	+0.34
5	$Fe^{3+}(aq) + e^-$	$\rightleftharpoons$	$Fe^{2+}(aq)$	+0.77
6	$VO_2^+(aq) + 2H^+ + e^-$	$\rightleftharpoons$	$VO^{2+}(aq) + H_2O(l)$	+1.00

Table 18.2

....

....

....

....

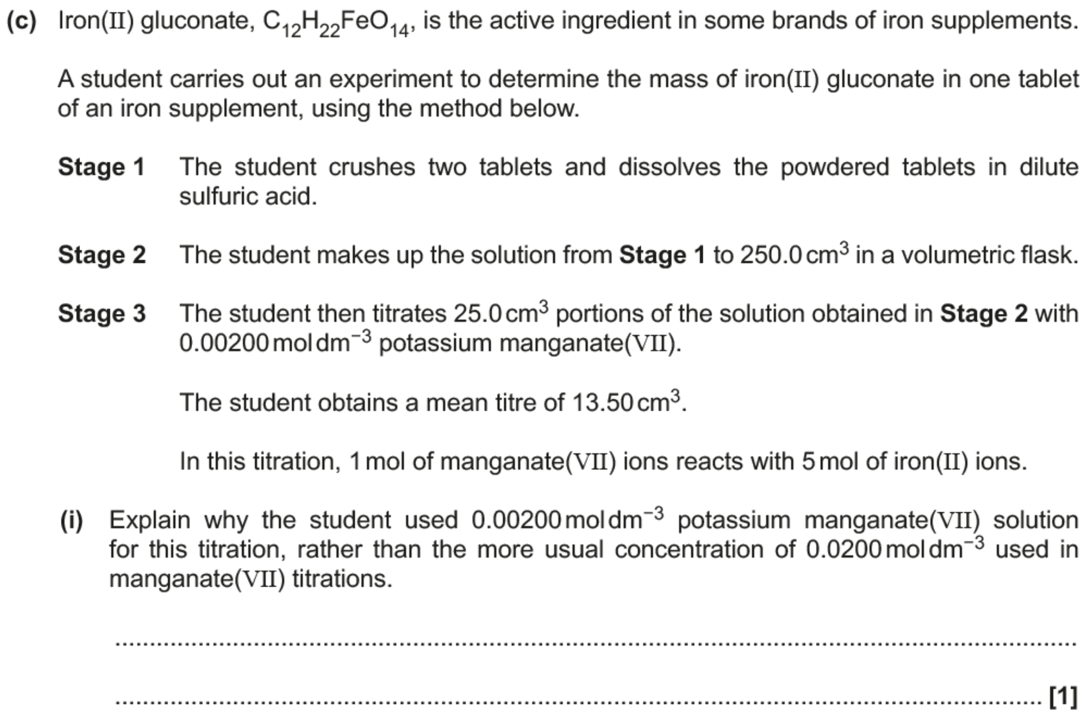
....

.... **[3]**

Most candidates did not state that the direction of reaction of redox equilibria is dependent on the relative negativity/positivity of the standard electrode potentials.

Higher ability candidates described two reductions of the relevant vanadium ions to end up with V^{2+} ions.

Question 18 (c) (i)



(c) Iron(II) gluconate, $C_{12}H_{22}FeO_{14}$, is the active ingredient in some brands of iron supplements.

A student carries out an experiment to determine the mass of iron(II) gluconate in one tablet of an iron supplement, using the method below.

Stage 1 The student crushes two tablets and dissolves the powdered tablets in dilute sulfuric acid.

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

Stage 3 The student then titrates 25.0 cm^3 portions of the solution obtained in **Stage 2** with 0.00200 $mol\,dm^{-3}$ potassium manganate(VII).

The student obtains a mean titre of 13.50 cm^3.

In this titration, 1 mol of manganate(VII) ions reacts with 5 mol of iron(II) ions.

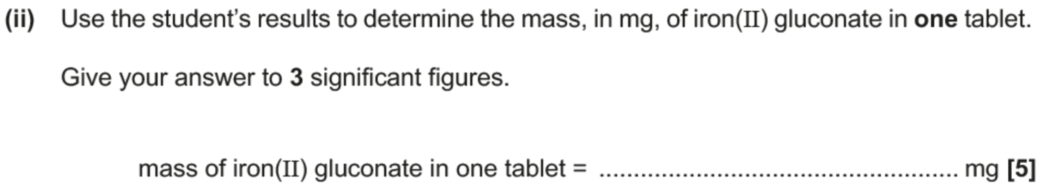
(i) Explain why the student used 0.00200 $mol\,dm^{-3}$ potassium manganate(VII) solution for this titration, rather than the more usual concentration of 0.0200 $mol\,dm^{-3}$ used in manganate(VII) titrations.

....

.... **[1]**

Only a very small minority of candidates appreciated that a larger titre reduces percentage error in titre values. Most erroneously described a reading of 1.35 cm^3 as being less accurate than a reading of 13.5(0) cm^3. The accuracy of these is equal in the same scaled apparatus.

Question 18 (c) (ii)



(ii) Use the student's results to determine the mass, in mg, of iron(II) gluconate in **one** tablet.

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

mass of iron(II) gluconate in one tablet = ... mg **[5]**

Many candidates coped well with this multi-step calculation. The common errors were:

- determining the mass of $C_{12}H_{22}FeO_{14}$ in two tablets instead of just one tablet as required in the question
- determining the mass of Fe in a tablet instead of the mass of $C_{12}H_{22}FeO_{14}$
- failing to convert from grams to milligrams

Question 19 (a) (i)

19 Sulfuric acid is an important chemical used to make detergents, fertilisers and dyes. It is manufactured in a multi-step process.

(a) In the first step of the manufacture of sulfuric acid, sulfur dioxide, SO_2, can be made from the combustion of hydrogen sulfide, H_2S, shown in **Reaction 1**.

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(l)$ $\Delta_r H = -1125\,kJ\,mol^{-1}$ **Reaction 1**

(i) Explain why the enthalpy change for **Reaction 1** has a negative value.

Use ideas about enthalpy changes associated with bond breaking and bond making.

....

....

.... **[1]**

This question caused problems for candidates. The main error was careless phrasing.

Many candidates correctly referred to the energy being required for bond breaking, but then also discussed bond making in terms of the energy used, suggesting that bond making was endothermic.

Responses simply stating more bonds were made than broken were ignored.

Question 19 (a) (ii)

(ii) Some standard entropy values are given below.

Substance	$H_2S(g)$	$O_2(g)$	$SO_2(g)$	$H_2O(l)$
$S^\circ / J\,K^{-1}\,mol^{-1}$	206	205	248	70

Using calculations, explain whether **Reaction 1** is feasible at 20 °C.

Calculations

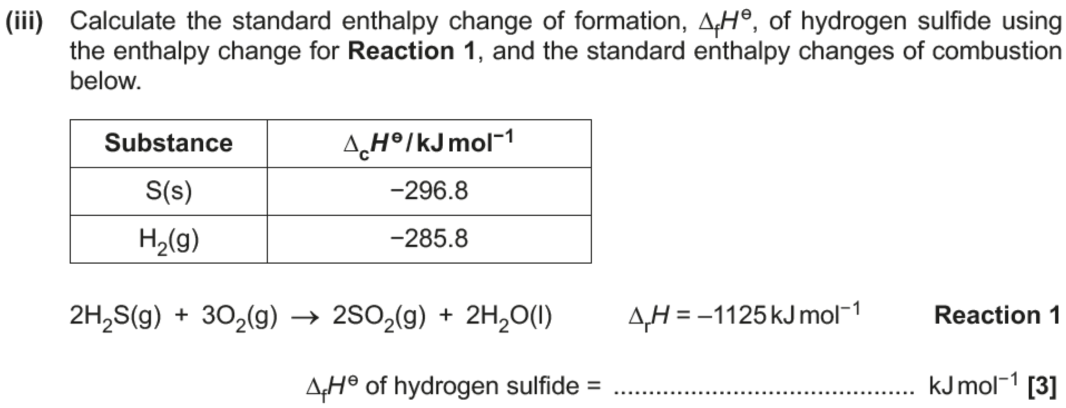
Explanation for feasible or non feasible ....

.... **[4]**

The calculation was done well. Some candidates found it difficult to convert ΔS values from J to kJ or temperature values from °C to K, and this was frequently seen in responses.

The final mark was often lost through vague phrasing. 'Yes' was an insufficient answer, as it does not identify the reaction as feasible or non-feasible. 'Gibbs free energy is negative' was also insufficient, as it should be identified that ΔG is negative.

Question 19 (a) (iii)



(iii) Calculate the standard enthalpy change of formation, $\Delta_f H^\circ$, of hydrogen sulfide using the enthalpy change for **Reaction 1**, and the standard enthalpy changes of combustion below.

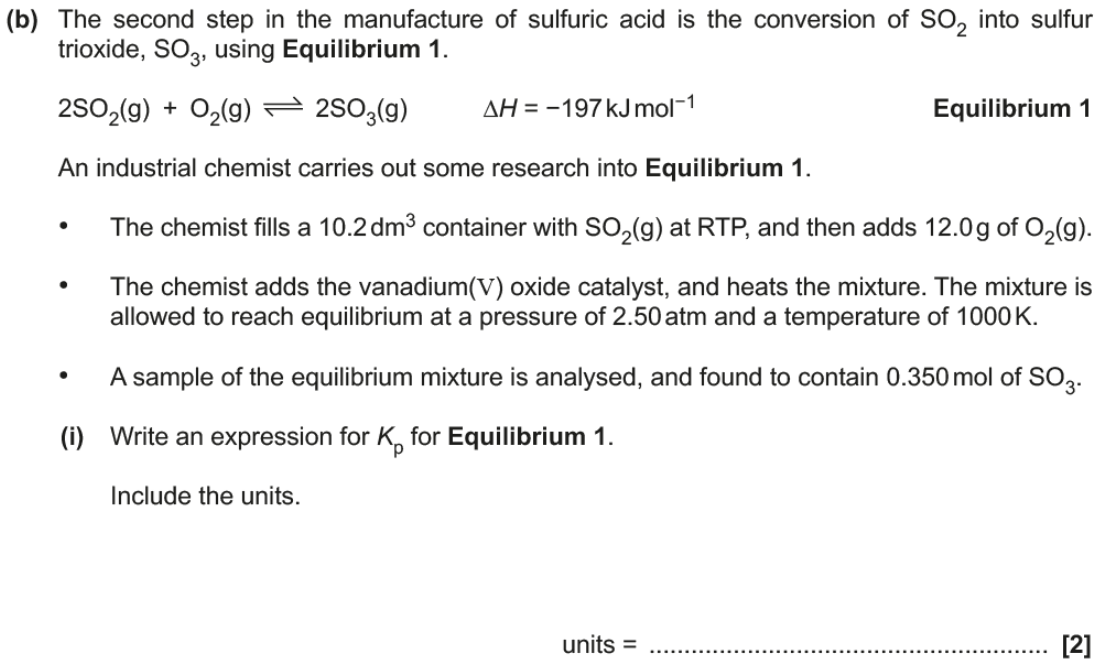
Substance	$\Delta_c H^\circ$ / kJ mol^{-1}
S(s)	−296.8
H_2(g)	−285.8

$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(l)$ $\Delta_r H = -1125\ \text{kJ mol}^{-1}$ **Reaction 1**

$\Delta_f H^\circ$ of hydrogen sulfide = ... kJ mol^{-1} **[3]**

This calculation proved very difficult. Many candidates did not deduce the correct cycle. Of those who did, a significant majority did not appreciate the stoichiometry of the equation and did not double the $\Delta_c H$ values or half the initially calculated value of $\Delta_f H(H_2S)$.

Question 19 (b) (i)



(b) The second step in the manufacture of sulfuric acid is the conversion of SO_2 into sulfur trioxide, SO_3, using **Equilibrium 1**.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -197\ \text{kJ mol}^{-1}$ **Equilibrium 1**

An industrial chemist carries out some research into **Equilibrium 1**.

- The chemist fills a 10.2 dm^3 container with SO_2(g) at RTP, and then adds 12.0 g of O_2(g).
- The chemist adds the vanadium(V) oxide catalyst, and heats the mixture. The mixture is allowed to reach equilibrium at a pressure of 2.50 atm and a temperature of 1000 K.
- A sample of the equilibrium mixture is analysed, and found to contain 0.350 mol of SO_3.

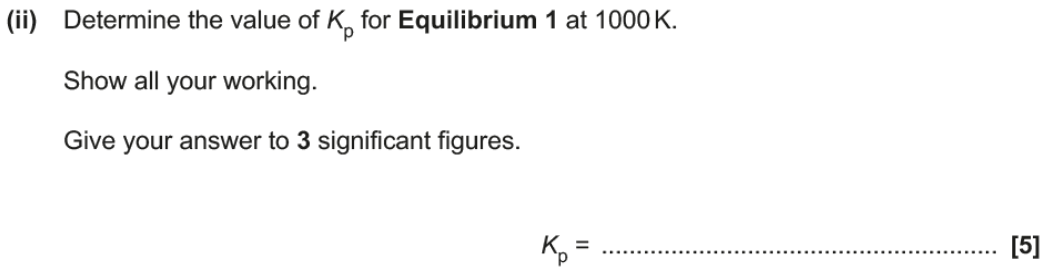
(i) Write an expression for K_p for **Equilibrium 1**.

Include the units.

units = ... **[2]**

The equilibrium expression was correct in most responses. Occasionally incorrect square brackets were used instead of round brackets. Candidates should be reminded that square brackets indicate a concentration and are not appropriate for use in K_p expressions.

Question 19 (b) (ii)



(ii) Determine the value of K_p for **Equilibrium 1** at 1000 K.

Show all your working.

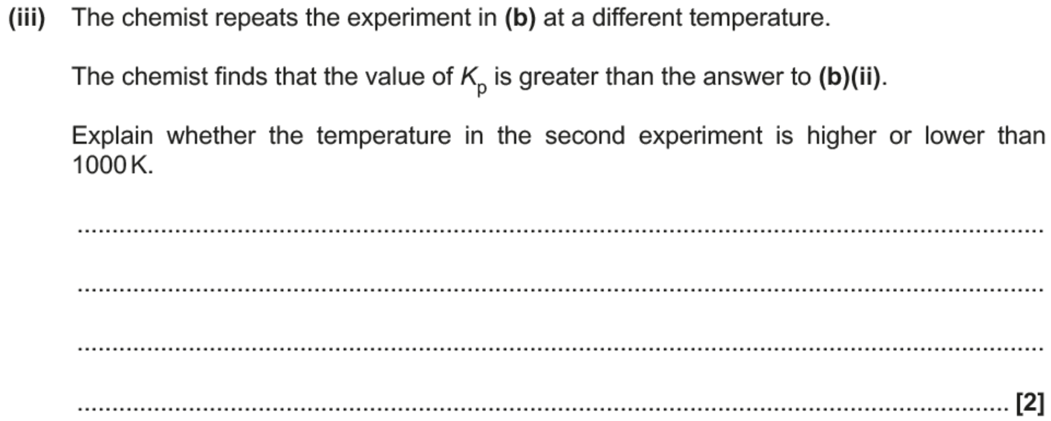
Give your answer to **3** significant figures.

K_p = ... **[5]**

Candidates tend to find Kp calculations difficult and so may need guidance in developing a strategy to work their way through them. A typical approach is:

- Calculation of initial moles present
- Calculation of the change in moles present
- Deduction of the number of moles present at equilibrium
- Determination of total moles present at equilibrium
- Calculation of mole fractions at equilibrium
- Calculation of partial pressures at equilibrium
- Inserting partial pressure vales into the Kp expression
- Writing an answer to the required number of significant figures.

Question 19 (b) (iii)



(iii) The chemist repeats the experiment in **(b)** at a different temperature.

The chemist finds that the value of K_p is greater than the answer to **(b)(ii)**.

Explain whether the temperature in the second experiment is higher or lower than 1000 K.

....

....

....

.... **[2]**

Some very wordy responses to this straightforward question were seen. Candidates are reminded that keeping responses concise and to the point can make their answer clearer, and there is no need to fill the whole question space provided if an answer can be provided more succinctly.

Question 19 (b) (iv)

(iv) Explain the significance of the expression: $K_p \gg 1$.

....

.... **[1]**

Most candidates realised that the symbol indicated the equilibrium was (far) to the right hand side. The common error was to tell the examiner that K_p was bigger than 1.

Question 19 (c) (i)

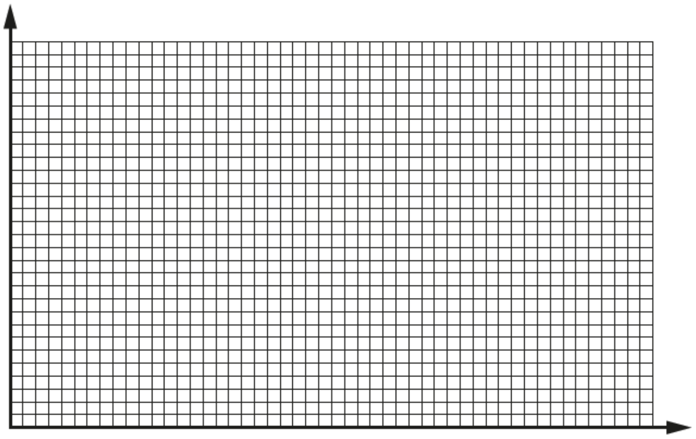
(c) Vanadium(V) oxide, $V_2O_5(s)$, is used as a catalyst in **equilibrium 1**.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197\,kJ\,mol^{-1}$ **Equilibrium 1**

(i) Explain how the presence of $V_2O_5(s)$ increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution, on the grid below.

Label the axes.



....

....

....

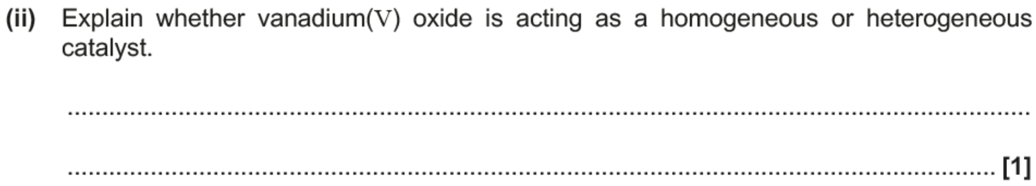
....

.... **[4]**

Most candidates were able to achieve all four marks.

Occasionally candidates didn’t start their graph from zero or mislabelled the x-axis as ‘progress of reaction’.

Question 19 (c) (ii)



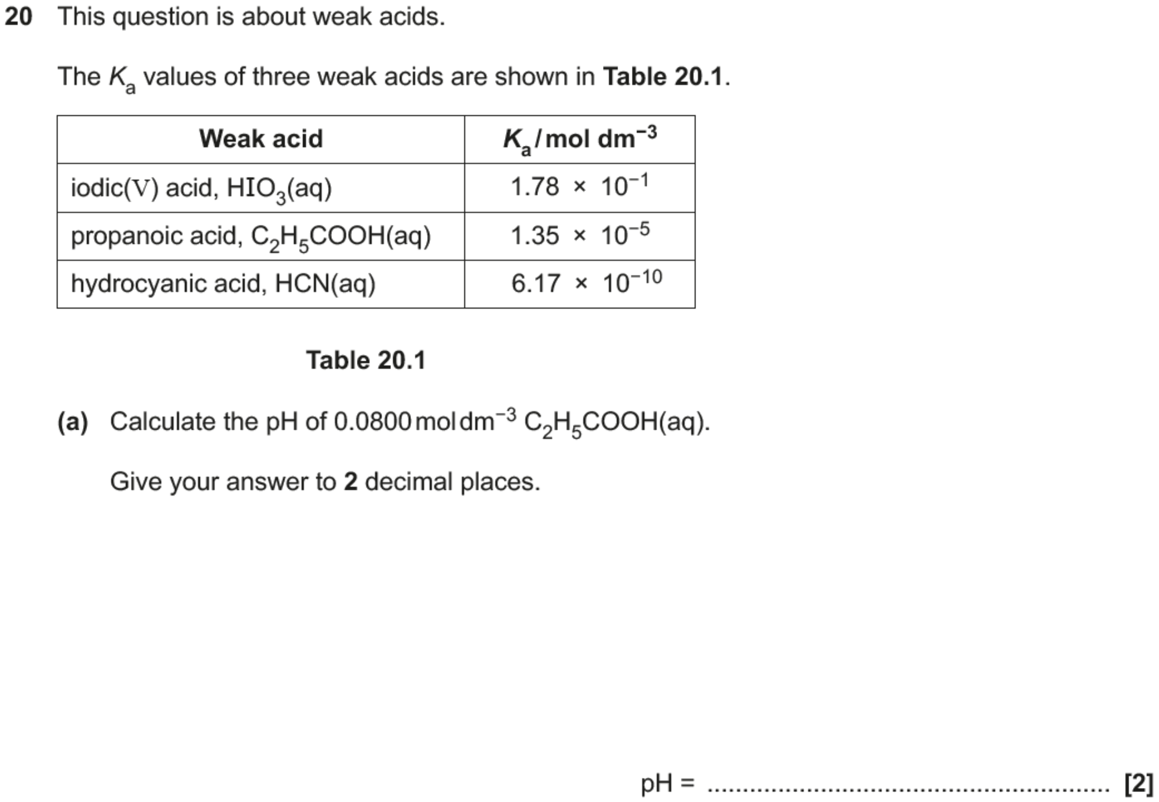
(ii) Explain whether vanadium(V) oxide is acting as a homogeneous or heterogeneous catalyst.

....

.... **[1]**

The number of candidates who considered V_2O_5 to be a homogeneous catalyst was small.

Question 20 (a)



20 This question is about weak acids.

The K_a values of three weak acids are shown in **Table 20.1**.

Weak acid	K_a / mol dm^{-3}
iodic(V) acid, $HIO_3(aq)$	1.78×10^{-1}
propanoic acid, $C_2H_5COOH(aq)$	1.35×10^{-5}
hydrocyanic acid, $HCN(aq)$	6.17×10^{-10}

Table 20.1

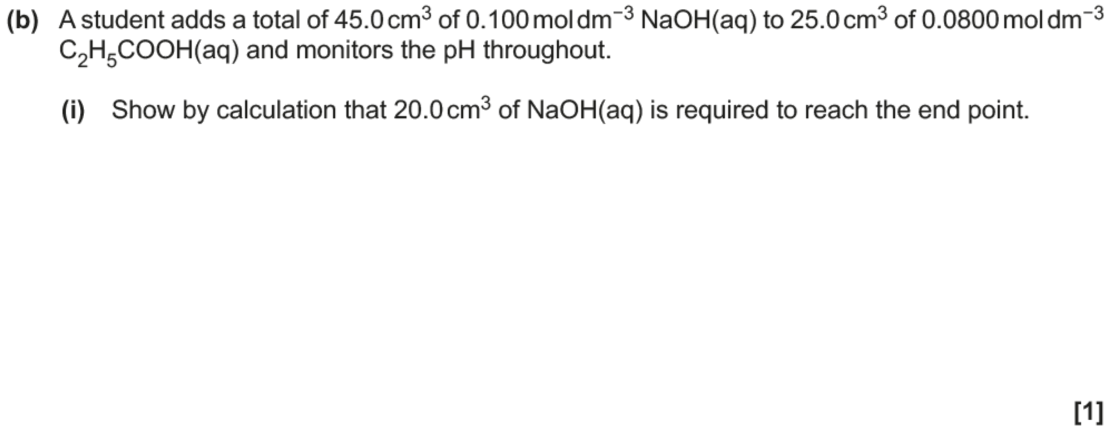
(a) Calculate the pH of 0.0800 mol dm^{-3} $C_2H_5COOH(aq)$.

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

pH = ... **[2]**

Most candidates could calculate the pH of a weak acid although a significant number gave the answer as 3.0, presumably confusing the demand for two decimal points with two significant figures.

Question 20 (b) (i)



(b) A student adds a total of 45.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq) to 25.0 cm^3 of 0.0800 mol dm^{-3} C_2H_5COOH(aq) and monitors the pH throughout.

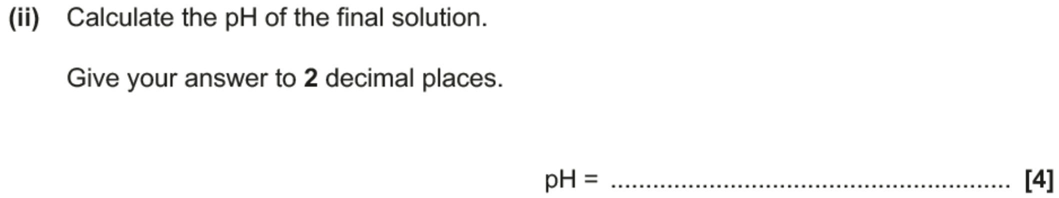
(i) Show by calculation that 20.0 cm^3 of NaOH(aq) is required to reach the end point.

[1]

Showing by calculation something already known is a skill that some candidates find challenging. Many responses included rows of figures with '20 cm^3' appearing at the end.

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.

Question 20 (b) (ii)



(ii) Calculate the pH of the final solution.

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

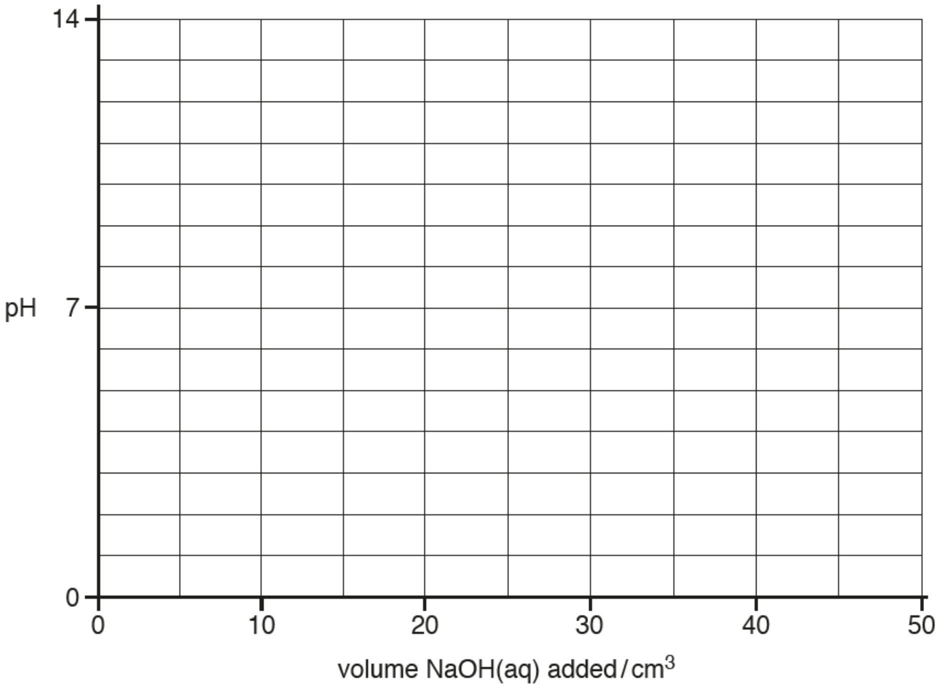
pH = ... **[4]**

This calculation proved difficult with once again, many figures and sums appearing with little indication as to their relevance.

Responses to 20bi/ii often featured rows of figures and random sums without a single word about what the figures were or sums were set to calculate. Candidates should remember to provide written indications of what it is they're 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.

Question 20 (b) (iii)

(iii) On the axes below, sketch a pH curve for the pH changes during the addition of 45.0 cm^3 of 0.100 mol dm^{-3} NaOH(aq) to 25.0 cm^3 of 0.0800 mol dm^{-3} C_2H_5COOH(aq).



[3]

This weak acid / strong alkali titration curve required candidates to apply their knowledge. Some candidates found it difficult to draw an adequate titration curve.

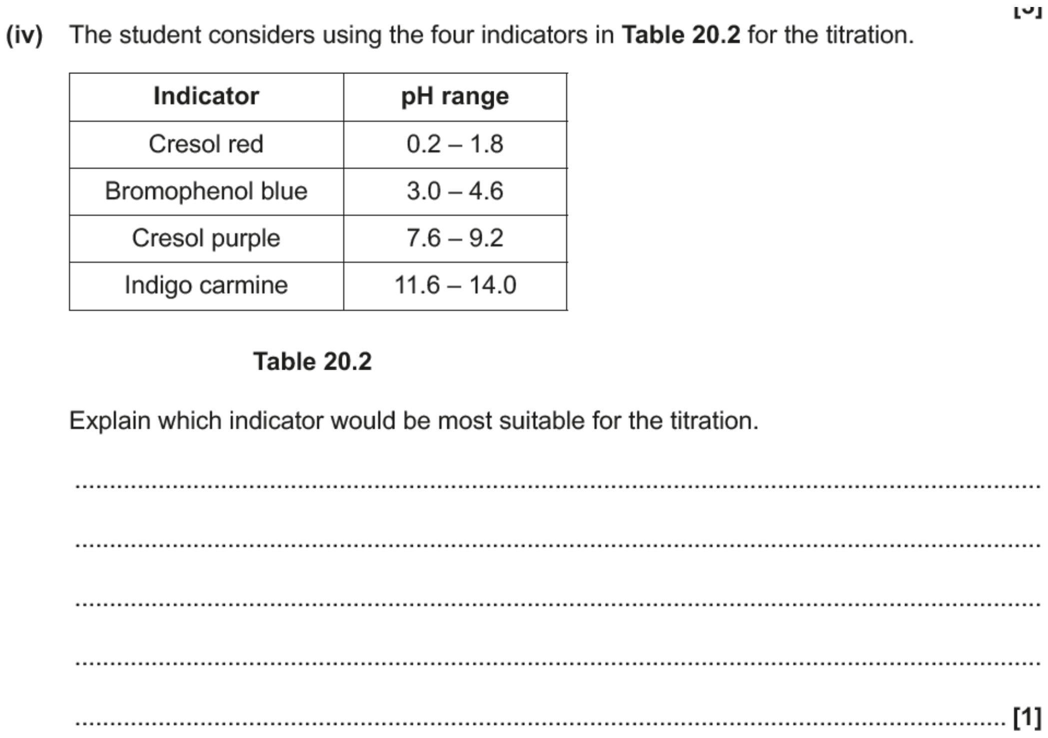
The key points to titration curves are:

- A 'vertical' section at the end point
- The vertical section with pH range correct to relative to the strength of acid/alkali
- A correct equivalence point relative to pH 7 with respect to the strength of acid/alkali
- A 'shallow curve' leading from 0 cm3 to vertical section
- A 'shallow curve' leading from the vertical section to the total volume added

For this reaction:

- The vertical section was at 20 cm^3 (given in 20bi)
- As it was a weak acid and strong alkali reacting, the vertical section should start above pH 5 and finish around pH 11
- The equivalence point (half-way up the vertical section) for a weak acid / strong alkali titration should be above pH 7
- The starting pH should be that of the weak acid, C_2H_5COOH (answer to 20(a))
- The final pH should be that of the final solution (answer to 20(b)(ii))

Question 20 (b) (iv)



(iv) The student considers using the four indicators in **Table 20.2** for the titration.

Indicator	**pH range**
Cresol red	0.2 – 1.8
Bromophenol blue	3.0 – 4.6
Cresol purple	7.6 – 9.2
Indigo carmine	11.6 – 14.0

Table 20.2

Explain which indicator would be most suitable for the titration.

....

....

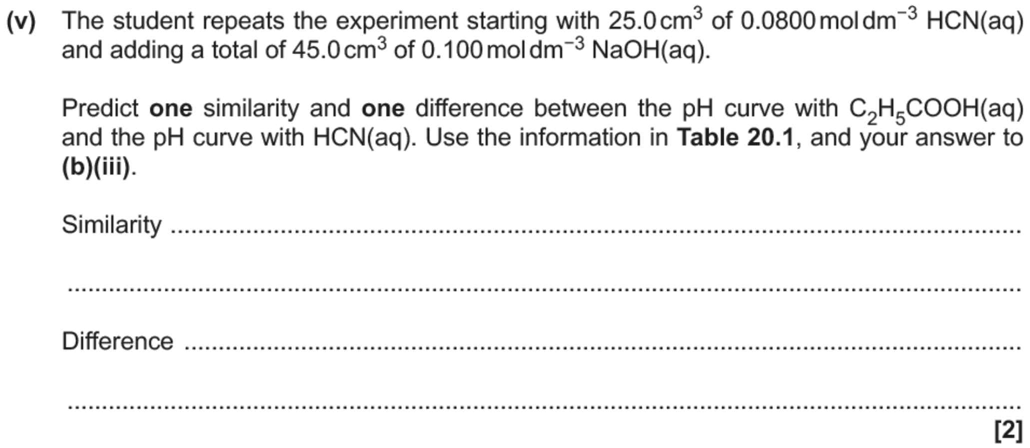
....

....

.... **[1]**

Some candidates realised that the most suitable indicator for a weak acid / strong alkali titration would be cresol purple. For incorrect responses, other indicators appeared to be selected at random, suggesting that candidates were unclear on the criteria for selected a suitable indicator.

Question 20 (b) (v)



(v) The student repeats the experiment starting with 25.0 cm^3 of 0.0800 $mol\,dm^{-3}$ HCN(aq) and adding a total of 45.0 cm^3 of 0.100 $mol\,dm^{-3}$ NaOH(aq).

Predict **one** similarity and **one** difference between the pH curve with C_2H_5COOH(aq) and the pH curve with HCN(aq). Use the information in **Table 20.1**, and your answer to **(b)(iii)**.

Similarity ....

....

Difference ....

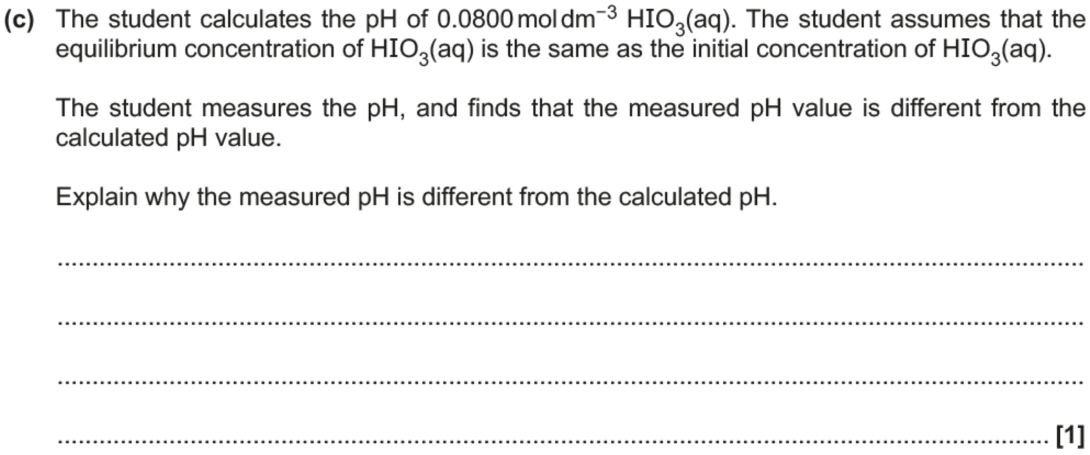
....

[2]

When identifying a similarity, many candidates confused the term 'equivalence point' with the term 'end point'.

For differences, many candidates realised that HCN had a different K_a to C_2H_5COOH but often did not appreciate that this would lead to a starting point with a higher pH.

Question 20 (c)



(c) The student calculates the pH of 0.0800 mol dm^{-3} $HIO_3(aq)$. The student assumes that the equilibrium concentration of $HIO_3(aq)$ is the same as the initial concentration of $HIO_3(aq)$.

The student measures the pH, and finds that the measured pH value is different from the calculated pH value.

Explain why the measured pH is different from the calculated pH.

....

....

....

.... **[1]**

Very few candidates scored the mark for this question.

The most common error was to write 'HIO_3 dissociates'. While correct, this is true of all weak acids.

The subtlety in this question was to realise that because K_a was relatively high, the resultant acid strength would mean that the degree of dissociating was significant enough so initial [HIO_3] was significantly less than [HIO_3] at equilibrium. In other words, the assumption [HIO_3]initial = [HIO_3]equilibrium is not valid in this case.

Question 21

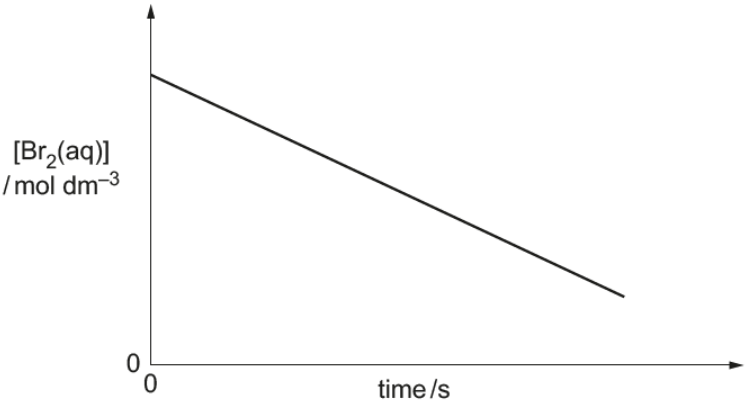
21* Three students carry out a rates investigation on the reaction between bromine and propanone in the presence of hydrochloric acid.

$CH_3COCH_3(aq) + Br_2(aq) \rightarrow CH_3COCH_2Br(aq) + HBr(aq)$

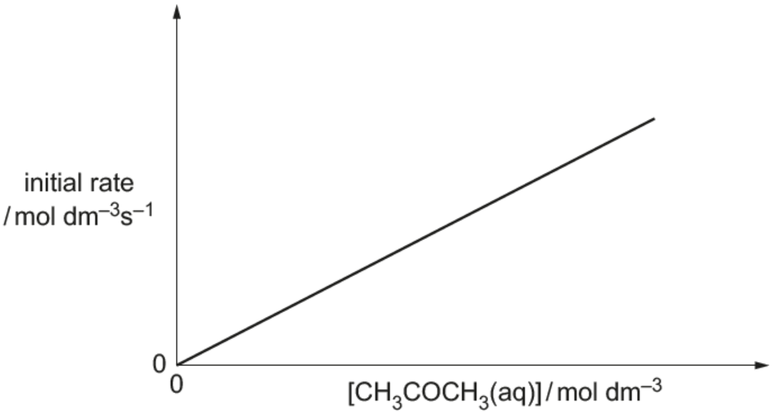
Each student investigates the effect of changing the concentration of one of the reactants whilst keeping the other concentrations constant.

Their results are shown below.

Results of student 1



Results of student 2



Results of student 3

Experiment	[Br_2(aq)] / mol dm^{-3}	[CH_3COCH_3(aq)] / mol dm^{-3}	[H^+(aq)] / mol dm^{-3}	Initial rate / 10^{-5} mol dm^{-3} s^{-1}
1	0.004	1.60	0.20	1.25
2	0.004	1.60	0.40	2.50

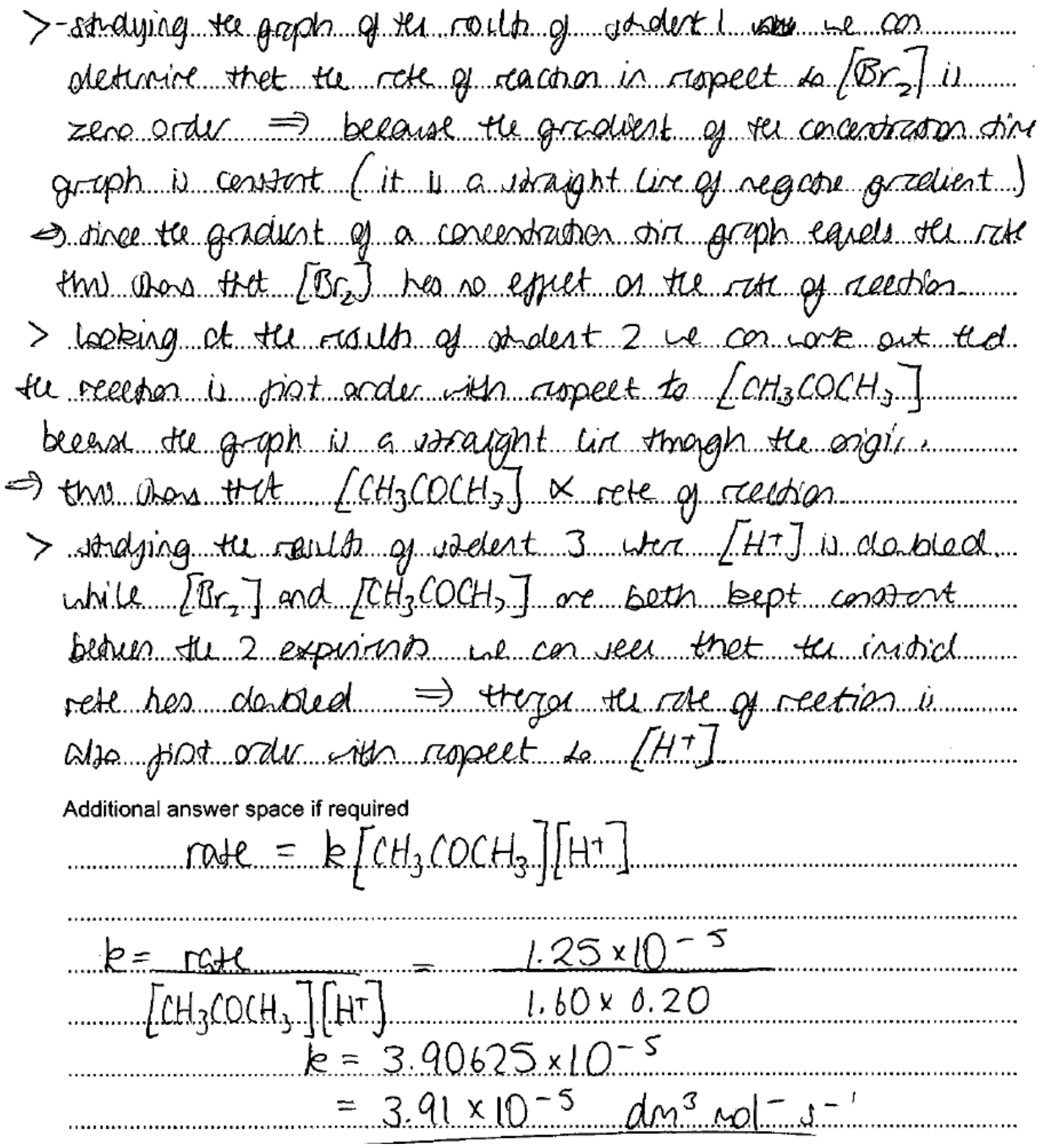
Explain how the reaction orders can be determined from the students' results, and determine the rate equation and rate constant. **[6]**

The second Level of Response question in the paper was also answered very well. Almost all candidates determined the order with respect to H^+ to be first order and gave suitable explanations. A very high proportion of candidates determined the order with respect to CH_3COCH_3 to be first order and related this to the direct proportionality shown on the graph. The zero order with respect to Br_2 proved a little more problematic with many candidates just giving an order with no attempted explanation.

Having determined orders, nearly all candidates were able to give a corresponding rate equation and could calculate a value for the rate constant, albeit with frequent omission of units and forgetting that the initial rates given were in terms of 10^{-5}.

An example of a complete answer achieving L3 (6 marks) is given.

Exemplar 8



$>$ - studying the graph of the results of student 1 we can determine that the rate of reaction in respect to $[Br_2]$ is zero order $\Rightarrow$ because the gradient of the concentration time graph is constant (it is a straight line of negative gradient)

$\Rightarrow$ since the gradient of a concentration time graph equals the rate this shows that $[Br_2]$ has no effect on the rate of reaction.

$>$ looking at the results of student 2 we can work out that the reaction is first order with respect to $[CH_3COCH_3]$ because the graph is a straight line through the origin

$\Rightarrow$ this shows that $[CH_3COCH_3] \propto$ rate of reaction

$>$ studying the results of student 3 when $[H^+]$ is doubled while $[Br_2]$ and $[CH_3COCH_3]$ are both kept constant between the 2 experiments we can see that the initial rate has doubled $\Rightarrow$ therefore the rate of reaction is also first order with respect to $[H^+]$

Additional answer space if required

$$\text{rate} = k[CH_3COCH_3][H^+]$$

$$k = \frac{\text{rate}}{[CH_3COCH_3][H^+]} = \frac{1.25 \times 10^{-5}}{1.60 \times 0.20}$$

$$k = 3.90625 \times 10^{-5}$$

$$= \underline{3.91 \times 10^{-5}\ dm^3\ mol^{-1}\ s^{-1}}$$

This candidate gave each order clearly followed by a concise explanation of each choice.

The rate equation (based on the orders given) is clearly stated, the calculation clearly shows working and correct units are given.

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