

**A LEVEL**

**Examiners' report**

# **CHEMISTRY A**

**H432**

For first teaching in 2015

**H432/01 Summer 2023 series**

# Contents

Introduction .....	4
Paper 1 series overview.....	5
Section A overview.....	6
Question 1 .....	6
Question 2 .....	6
Question 3 .....	7
Question 4 .....	7
Question 5 .....	8
Question 6 .....	8
Question 7 .....	9
Question 8 .....	9
Question 9 .....	10
Question 10 .....	10
Question 11 .....	11
Question 12 .....	11
Question 13 .....	12
Question 14 .....	12
Question 15 .....	13
Section B overview.....	14
Question 16 (a) (i).....	14
Question 16 (a) (ii) .....	15
Question 16 (b) .....	16
Question 17* .....	17
Question 18 (a).....	18
Question 18 (b) .....	19
Question 18 (c) (i) .....	20
Question 18 (c) (ii) .....	21
Question 19 (a) (i) .....	23
Question 19 (a) (ii) .....	24
Question 19 (b) .....	24
Question 20 .....	25
Question 20 (a) (ii) .....	26
Question 20 (b) .....	26
Question 20 (c) (i) .....	27

Question 20 (c) (ii) .....	27
Question 20 (d) (i) .....	28
Question 20 (d) (ii) .....	28
Question 20 (e) (i) .....	29
Question 20 (e) (ii) .....	29
Question 20 (f) .....	30
Question 21 (a) (i).....	31
Question 21 (a) (ii) .....	31
Question 21 (iii) .....	32
Question 21 (b) .....	33
Question 22 (a)*.....	34
Question 22 (b) (i) .....	36
Question 22 (b) (ii) .....	36
Question 22 (c) .....	37
Question 22 (d) .....	37

## 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 is 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.

### Would you prefer a Word version?

Did you know that you can save this PDF as a Word file using Acrobat Professional?

Simply click on **File > Export to** and select **Microsoft Word**

(If you have opened this PDF in your browser you will need to save it first. Simply right click anywhere on the page and select **Save as . . .** to save the PDF. Then open the PDF in Acrobat Professional.)

If you do not have access to Acrobat Professional there are a number of **free** applications available that will also convert PDF to Word (search for PDF to Word converter).

## 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:	Candidates who did less well on this paper generally:
<ul style="list-style-type: none"> <li>• produced clearly structured working for calculations – Questions 18 (a), 18 (b), 19 (a) (i), 19 (b), 20 (b), 20 (e) (ii) and 21 (c)</li> <li>• applied equations to a graphical representation Question 18 (c) (ii)</li> <li>• produced clear and concise responses for the two Level of Response Questions 17 (a) and 22 (a)</li> <li>• produced clear and concise responses to descriptions in trends of ionisation energy Question 16 (b)</li> <li>• were able to make and justify predictions based on their knowledge Questions 20 (c), (d)</li> <li>• explained equilibrium changes Question 19 (a) (ii)</li> <li>• gave answers to the correct number of significant figures Questions 19 (a) (i), 20 (a) (i) and 20 (b)</li> <li>• converted between units when required Questions 18 (c) (ii) and 19 (b)</li> <li>• correctly explained experimental procedures using electrode potentials Question 21 (b)</li> <li>• wrote a balanced equation for unfamiliar compound Question 22 (d)</li> <li>• understood the effect of addition of chemical substances on the pH of a buffer solution Question 20 (f).</li> </ul>	<ul style="list-style-type: none"> <li>• found it difficult to apply what they had learned to unfamiliar situations</li> <li>• produced unstructured responses to Level of Response questions which were lacking in depth or explanation or contained inaccurate definitions Questions 17 (a) and 22 (a)</li> <li>• did not clearly set out calculations, making it difficult for marks to be given for working Questions 18 (a), 18 (b), 19 (a) (i), 19 (b), 20 (b), 20 (e) (ii) and 21 (c)</li> <li>• did not give answers to calculations to the specified number of significant figures Questions 19 (a) (i), 20 (a) (i) and 20 (b)</li> <li>• either did not realise the need to convert between units for some calculations or found this difficult Questions 18 (c) (ii) and 19 (b)</li> <li>• did not produce clear and concise responses to descriptions in trends of ionisation energy Question 16 (b)</li> <li>• did not write a balanced equation, and ionic equations, for reactions with group 2 metal and metal compounds Questions 20 (b), 20 (c) (i) and 20 (d).</li> </ul>

## Section A overview

Some candidates showed good practice by using the space around the multiple choice response to show working. There is no penalty for giving a wrong response.

### Question 1

1 Which sample contains the greatest number of molecules?

- A 35.0 g of  $C_2H_2$
- B 45.0 g of  $C_2H_6$
- C 60.0 g of  $C_4H_{10}$
- D 100.0 g of  $C_6H_6$

Your answer

[1]

Most candidates answered this question correctly with the answer B. D was a common error based on the highest mass.

### Question 2

2 0.688 g of an oxide of manganese is reduced by hydrogen gas to form manganese metal and 0.235 g of water.

What is the formula of the oxide of manganese?

- A MnO
- B  $MnO_2$
- C  $Mn_2O_3$
- D  $Mn_3O_4$

Your answer

[1]

Candidates found this question challenging with the correct answer being C. A or B were the common errors selected by most candidates.

### Question 3

3 How many hydrogen atoms are in 2.50 g of pharmacolite,  $\text{CaHAsO}_4 \cdot 2\text{H}_2\text{O}$  ( $M_r = 216.0$ )?

- A  $6.97 \times 10^{21}$
- B  $2.09 \times 10^{22}$
- C  $2.79 \times 10^{22}$
- D  $3.48 \times 10^{22}$

Your answer

[1]

The correct answer was D. Most candidates did not recognise the number of H atoms, 5, in the compound, choosing A as their final answer.

### Question 4

4  $40.0 \text{ cm}^3$  of  $0.200 \text{ mol dm}^{-3} \text{ HCl}$  is added to  $60.0 \text{ cm}^3$  of  $0.100 \text{ mol dm}^{-3} \text{ NaOH}$ .

What is the concentration of the resulting solution?

- A  $0.0200 \text{ mol dm}^{-3} \text{ HCl}$  and  $0.0200 \text{ mol dm}^{-3} \text{ NaCl}$
- B  $0.0200 \text{ mol dm}^{-3} \text{ HCl}$  and  $0.0400 \text{ mol dm}^{-3} \text{ NaCl}$
- C  $0.0200 \text{ mol dm}^{-3} \text{ HCl}$  and  $0.0600 \text{ mol dm}^{-3} \text{ NaCl}$
- D  $0.0600 \text{ mol dm}^{-3} \text{ HCl}$  and  $0.0200 \text{ mol dm}^{-3} \text{ NaCl}$

Your answer

[1]

This question was answered correctly for the most part with the answer being C.

## Question 5

5 Which compound has polar molecules?

A HCN

B  $\text{BCl}_3$

C  $\text{CO}_2$

D  $\text{C}_2\text{F}_4$

Your answer

[1]

Most candidates recognised HCN to be linear and therefore polar due to lack of symmetry – answer A. The most common error was D.

## Question 6

6 Which element has the largest third ionisation energy?

A Li

B F

C Ne

D Na

Your answer

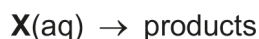
[1]

The correct answer was A. This question proved to be challenging, with the common incorrect answer being C.



## Question 7

7 The reaction below is first order with respect to reactant **X**.



When the initial concentration of **X** is  $1.0 \text{ mol dm}^{-3}$ , the half-life is 16 minutes.

What is the half-life when the initial concentration of **X** is  $2.0 \text{ mol dm}^{-3}$ ?

- A 2 minutes
- B 4 minutes
- C 8 minutes
- D 16 minutes

Your answer

[1]

Half of the candidates chose the correct half-life of D and a large proportion of the others chose 8 minutes, halving the time as the concentration was doubled, causing C to be a common error.

## Question 8

8 Which compound requires the most energy to convert one mole into its gaseous ions?

- A NaF
- B  $\text{Na}_2\text{O}$
- C  $\text{MgF}_2$
- D MgO

Your answer

[1]

This question was another challenging idea. The correct answer was D. Many candidates chose A or C, possibly due to fluorine's high electronegativity.

## Question 9

9 The table below shows standard entropies,  $S^\ominus$ .

Substance	SO <sub>2</sub> (g)	O <sub>2</sub> (g)	SO <sub>3</sub> (l)
$S^\ominus/\text{JK}^{-1}\text{mol}^{-1}$	248	204	96

What is the standard entropy change,  $\Delta S^\ominus$ , in  $\text{JK mol}^{-1}$ , for the formation of 1 mol of SO<sub>3</sub>(l) from SO<sub>2</sub>(g) and O<sub>2</sub>(g)?

- A -508
- B -254
- C +254
- D +508

Your answer

[1]

Most candidates were able to use the data correctly. The correct answer was B. The main error was from not recognising the need to make 1 mole of SO<sub>3</sub>, so the use of ½ mole of O<sub>2</sub>, and therefore using the wrong molar ratio.

## Question 10

10 What is the percentage dissociation of a 0.015 mol dm<sup>-3</sup> solution of methanoic acid, HCOOH ( $K_a = 1.60 \times 10^{-4} \text{ mol dm}^{-3}$ )?

- A 0.016%
- B 1.1%
- C 1.82%
- D 10.3%

Your answer

[1]

The most successful candidates showed their workings for the correct answer of D.

## Question 11

- 11 A student adds aqueous potassium carbonate to one test tube and aqueous silver nitrate to a second test tube.

The student adds dilute hydrochloric acid to each test tube.

Which row has the correct observations?

	Aqueous potassium carbonate	Aqueous silver nitrate
<b>A</b>	no change	precipitate
<b>B</b>	no change	no change
<b>C</b>	effervescence	no change
<b>D</b>	effervescence	precipitate

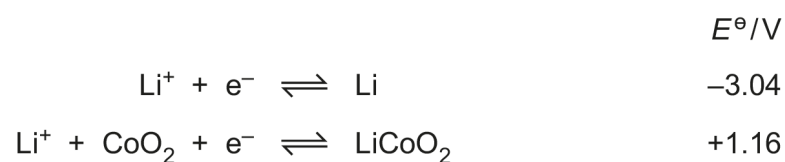
Your answer

[1]

Most candidates answered this correctly with D. Errors came from candidates not realising HCl provided Cl<sup>-</sup> ions that would react with AgNO<sub>3</sub> and therefore they did not recognise the formation of the white precipitate.

## Question 12

- 12 The equations show the electrode potentials of the half-cells used in a lithium-ion cell.



Which statement is correct in a lithium-ion cell?

- A** The cell potential is 2.88 V.
- B** The reaction at the positive electrode is:  $\text{LiCoO}_2 \rightarrow \text{Li}^+ + \text{CoO}_2 + \text{e}^-$
- C** The overall cell reaction is:  $\text{Li} + \text{CoO}_2 \rightarrow \text{LiCoO}_2$
- D** The oxidation number of Co changes from +2 to +1.

Your answer

[1]

Most candidates answered this question correctly with C.

## Question 13

13 Which substance(s) has/have induced dipole–dipole interactions (London forces) in the solid state?

1  $\text{C}_2\text{H}_6$

2  $\text{H}_2\text{O}$

3 Si

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer

[1]

The correct answer was B. Most candidates did not recognise that Si has covalent bonds between atoms so included it or did not recognise that water forms London forces as well as hydrogen bonds and therefore excluded it.

## Question 14

14 Which statement(s) is/are correct for the anti-cancer complex  $\text{Pt}(\text{NH}_3)_2\text{Cl}_2$ ?

1 It has bond angles of  $90^\circ$ .

2 The oxidation number of Pt is +4.

3 It forms both optical and *cis-trans* isomers.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

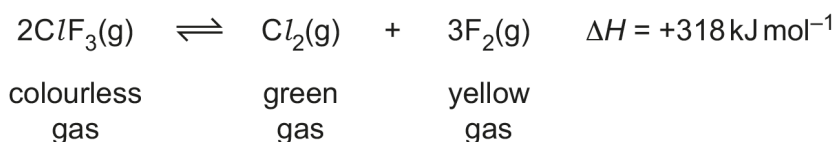
Your answer

[1]

The correct answer was D. Most candidates recognised that the complex represented cisplatin. Cisplatin has a bond angle of 90 degrees due to being square planar and shows cis/trans isomerism, but some candidates thought it showed optical isomerism too. Most could tell the oxidation number of platinum is not +4.

## Question 15

15 Chlorine trifluoride can be decomposed into its elements forming the equilibrium mixture below.



Which statement(s) is/are correct?

- 1 The decomposition is a redox reaction.
- 2 When the equilibrium mixture is cooled, the colour fades.
- 3 The decomposition has a negative entropy change.

- A 1, 2 and 3  
B Only 1 and 2  
C Only 2 and 3  
D Only 1

Your answer

[1]

This question was for the most part answered correctly with B. Errors came from not recognising the reaction is endothermic and therefore its equilibrium would shift to the left when the temperature decreases, ruling out option 2.

### Assessment for learning



Practice multiple choice questions can improve the skill in solving 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.

Multiple choice question quizzes can be found via the resource-finder on [Teach Cambridge](#) and there are [instructions](#) on how to use the online versions of the multiple choice quizzes.

## Section B overview

The section contained questions from all aspects of the specification. Candidates found many of the questions, including those with an extended response nature, straightforward and the majority managed to cope with the mathematical content. Candidates should use calculator values in their intermediate calculations to avoid rounding errors in their final answer. Well set out calculations which clearly indicate what each numerical value represents allow error carried forward marks to be awarded in the event of an incorrect answer.

Some candidates were less confident and knowledgeable with the less demanding aspects of some questions. These were specifically: ionic equations, equations involving group 2 metals and their compounds, equilibria shifts and enthalpy changes. There was evidence that candidates wrote far more than necessary in some responses. For example, Question 16 (b) was allotted a very generous 9 lines for an answer but many candidates provided repetitive responses and requoted the question. Many more effective responses provided 4 or 5 line answers but gained full marks. With the exception of questions marked using a level of response mark scheme, candidates should look to the marks available to give insight to the amount of detail, and discrete points, that needed to be made.

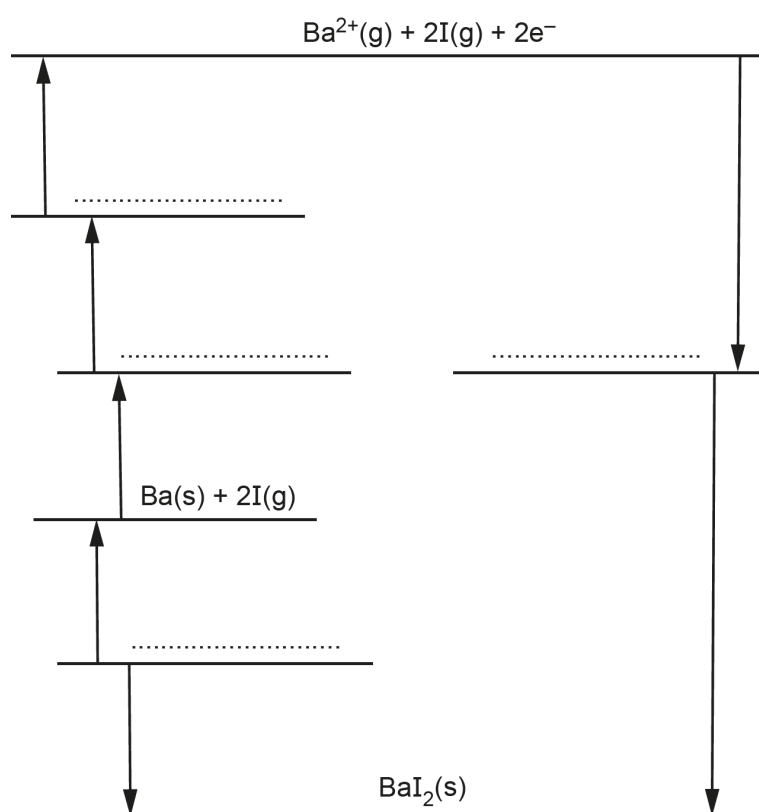
### Question 16 (a) (i)

**16** This question is about energy changes.

**(a)** Lattice enthalpies can be determined indirectly using Born-Haber cycles.

The table below shows the energy changes that are needed to determine the lattice enthalpy of barium iodide,  $\text{BaI}_2$ .

On the dotted lines, add the species present, including state symbols.



[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. Ba<sub>(s)</sub> or I<sub>2(s)</sub>. The convention is to use lower case letters of normal size, e.g. Ba(s) or I<sub>2</sub>(g). The most common errors were the iodine state symbol, with both (g) and (l) being used, and the use of 2I for I<sub>2</sub>. Some candidates missed state symbols in one species, missed electrons with the two ions, or gave a charge on the top left iodine.

### Question 16 (a) (ii)

(ii) Calculate the lattice enthalpy of barium iodide.

lattice enthalpy = ..... kJ mol<sup>-1</sup> [2]

The correct was answer seen frequently, along with lots of the common errors. Candidates tended to forget the mole ratio and did not multiply either -107 or +296 by two. Some candidates applied the cycle incorrectly and therefore used the wrong sign for an enthalpy change, leading to them attaining 1 mark.

## Question 16 (b)

- (b) The first and second ionisation energies of magnesium, Mg, and strontium, Sr, in Group 2 are given in the table below.

Element	First ionisation energy /kJ mol <sup>-1</sup>	Second ionisation energy /kJ mol <sup>-1</sup>
Mg	+738	+1451
Sr	+550	+1064

- Explain why the first ionisation energy of Mg is greater than the **first** ionisation energy of Sr.
- Explain why the second ionisation energy of Sr is greater than the **first** ionisation energy of Sr.

.....

.....

.....

.....

.....

.....

..... [4]

Most candidates were able to explain why the first ionisation energy of Mg is greater than that of Sr due to the Mg's smaller atomic radius/less shielding and therefore increased nuclear attraction. Candidates should be reminded that there is no requirement to restate the question in their answers. Terminology is important and some candidates lost marks as they referred to nuclear radius instead of atomic radius. However, most candidates did not recognise that the second ionisation energy of Sr involves removing an electron from a +1 ion and instead discussed the repulsion between electrons in the s orbital. Atomic radius instead of ionic radius was often seen when discussing the Sr<sup>+</sup> ion. Some candidates were still referring to Mg in this part of their answer and they should be advised to reread the question between each part to remain focused on the requirement.





## Question 18 (a)

**18** This question is about enthalpy changes of reactions involving hydrocarbons.

**(a)** A student determines the enthalpy change of combustion,  $\Delta_c H$ , of heptane,  $C_7H_{16}$ , using the method outlined below.

- Add 150 g of water to a beaker and measure its temperature.
- Weigh a spirit burner containing heptane and use it to heat the water.
- Extinguish the flame and record the maximum temperature reached by the water.
- Reweigh the spirit burner.

The temperature of the water increased by 10.5 °C.

The spirit burner decreased in mass by 0.133 g.

Use the student's results to determine the enthalpy change of combustion of heptane,  $\Delta_c H (C_7H_{16})$ , in  $\text{kJ mol}^{-1}$ .

$$\Delta_c H (C_7H_{16}) = \dots\dots\dots \text{kJ mol}^{-1} \quad \mathbf{[3]}$$

Many candidates calculated the correct value of  $q$  and scored all three marks. Common errors saw some candidates using the incorrect mass, of either 0.133 or that added to or subtracted from the 150. The temperature change was given but a few candidates added the 10.5 to 273 in order to, incorrectly, convert to K. The final mark required the candidate to link the temperature increase to an exothermic value and include a minus sign.

## Question 18 (b)

(b) Nonane,  $C_9H_{20}$ , can be broken down by heat to form pentane,  $C_5H_{12}$ , and ethene,  $C_2H_4$ .



The enthalpy changes of combustion of  $C_9H_{20}(g)$  and  $C_2H_4(g)$  are shown in the table below.

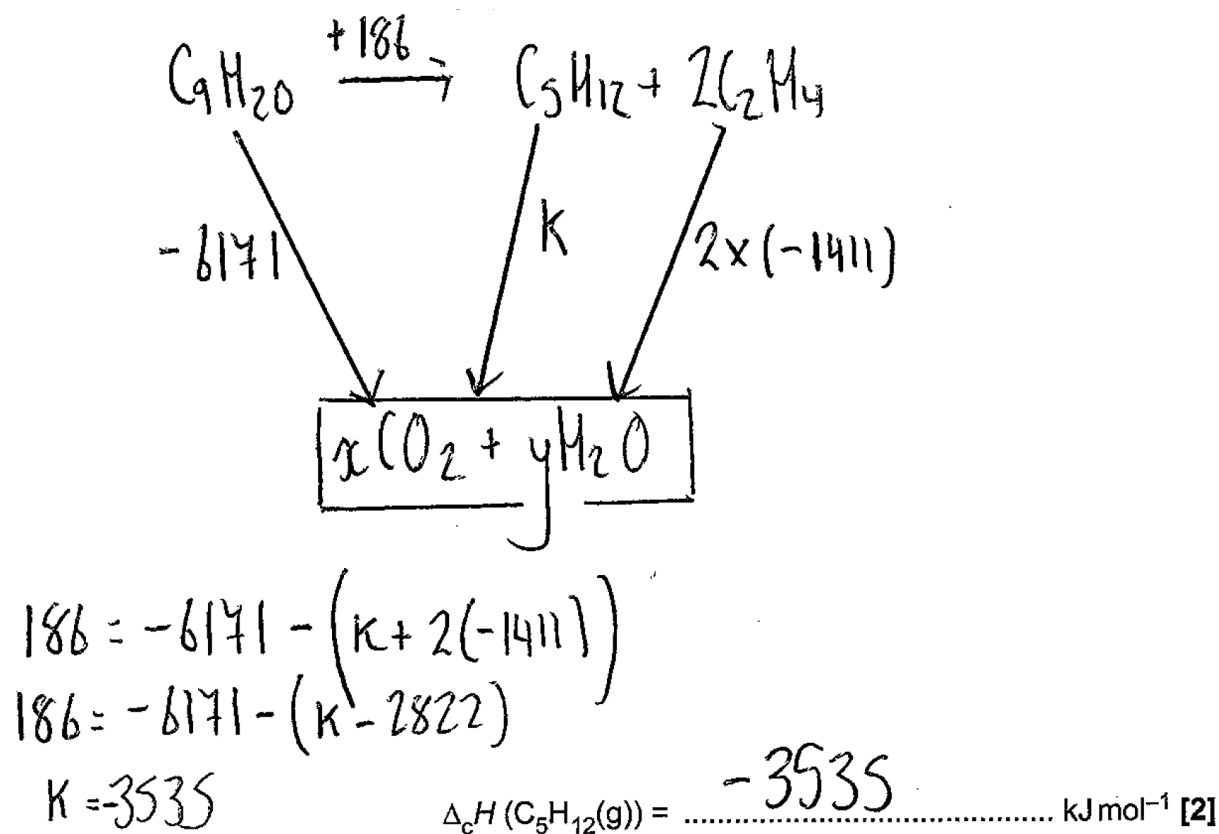
Hydrocarbon	$\Delta_c H / \text{kJ mol}^{-1}$
$C_9H_{20}(g)$	-6171
$C_2H_4(g)$	-1411

Use  $\Delta H$  in **Reaction 1** and the enthalpy changes of combustion in the table to determine the enthalpy change of combustion of  $C_5H_{12}(g)$ .

$$\Delta_c H (C_5H_{12}(g)) = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

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 candidates scored 1 mark for this question, which was gained as an error carried forward, in the enthalpy cycle. -3163 was a common error.

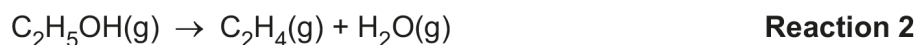
## Exemplar 1



This candidate showed clarity in their working by drawing a correct Hess cycle and then applying correct multiples and directions for the enthalpy changes.

## Question 18 (c) (i)

(c) Ethene can be produced from ethanol, as shown in **Reaction 2** below.



(i) Predict the sign of the entropy change,  $\Delta S$ , for **Reaction 2**.

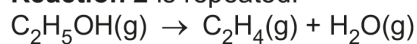
Explain your reasoning.

.....  
 .....  
 ..... [1]

Candidates needed to explain the correct sign and understand that entropy is a measure of the dispersal of energy in a system. Most candidates linked the increase in disorder with the number of moles increasing and therefore the + sign for  $\Delta S$ . Some candidates were not given the mark as they stated that entropy increases without giving the sign. Some candidates tried to answer using  $\Delta G$  statements by suggesting  $\Delta H$  and  $T$  values.

## Question 18 (c) (ii)

(ii) **Reaction 2** is repeated:



**Reaction 2**

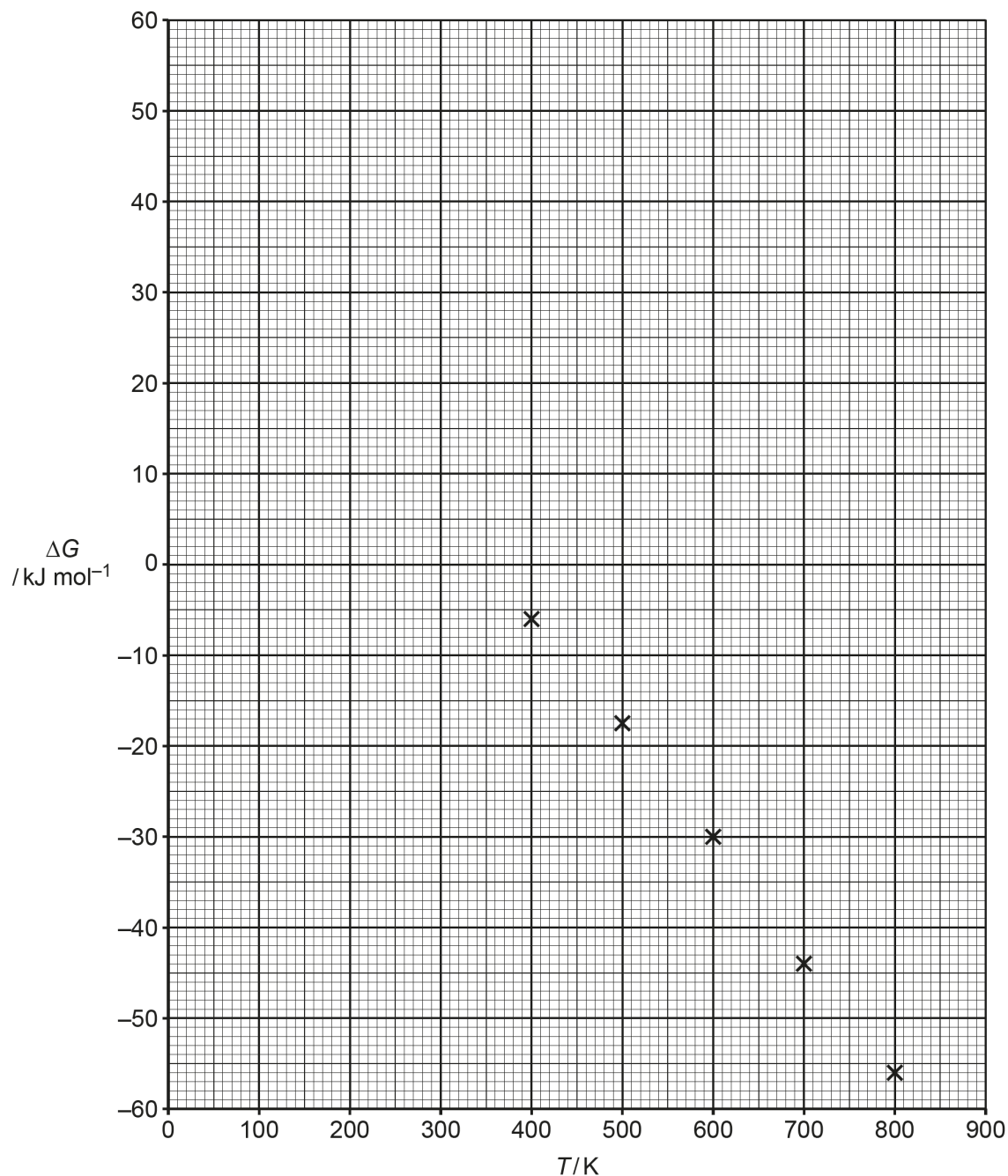
The Gibbs equation is shown below.

$$\Delta G = \Delta H - T\Delta S$$

The enthalpy change,  $\Delta H$ , and the entropy change,  $\Delta S$ , can be assumed to be constant at different temperatures.

**Fig. 18.1** shows values of the free energy change,  $\Delta G$ , in  $\text{kJ mol}^{-1}$ , at different temperatures,  $T$ , in K, for **Reaction 2**.

**Fig. 18.1**



Use the graph in **Fig. 18.1** to answer the following:

- Draw the best-fit line on the graph in **Fig. 18.1**.
- Determine  $\Delta S$ , in  $\text{JK}^{-1} \text{mol}^{-1}$ , for **Reaction 2**.
- Determine the minimum temperature,  $T$ , at which the reaction is feasible.
- Determine  $\Delta H$  for **Reaction 2**.

$$\Delta S = \dots\dots\dots \text{JK}^{-1} \text{mol}^{-1}$$

$$\text{minimum } T = \dots\dots\dots \text{K}$$

$$\Delta H = \dots\dots\dots \text{kJ mol}^{-1}$$

**[5]**

Nearly all candidates were able to draw the line of best fit and linked the equation of a straight line to the equation for delta G. Some hadn't used a ruler to draw a straight line and candidates should be reminded of this requirement. Candidates were able to recognise that the gradient corresponded to (-) delta S but some did not to use the scale correctly. Some candidates tried to use very small triangles to get the gradient and candidates would be advised to use the largest scale possible to minimise errors in the line of best fit. Most candidates recognised that the minimum temperature was the x-intercept (when delta G = 0) and that delta H was the y-intercept. Some did not use this approach and instead used the  $\Delta G = \Delta H - T\Delta S$  equation, using previously obtained value(s), to calculate the minimum temperature,  $\Delta S$  or  $\Delta H$ . Some candidates used  $\Delta H = -186$  from a previous question or attempted to solve both  $\Delta S$  and  $\Delta H$  by simultaneous equations.

## Question 19 (a) (i)

19 This question is about oxides of nitrogen.

(a) An investigation is carried out on the equilibrium system shown below.



(i) A sealed flask containing 6.00 moles of  $\text{NO}_2(\text{g})$  is heated to a constant temperature and allowed to reach equilibrium.

The equilibrium mixture contains 5.40 mol of  $\text{NO}_2(\text{g})$ , and the total pressure is 5.00 atm.

Determine the value of  $K_p$  and give your answer to 3 significant figures.

Include an expression for  $K_p$  and the units of  $K_p$  in your answer.

$K_p = \dots\dots\dots$  units  $\dots\dots\dots$  [5]

Candidates tend to find  $K_p$  calculations difficult and so a strategy to work their way through them could include:

- write the  $K_p$  expression, with units, ensuring square brackets are not used. Common mistakes with units included  $\text{atm}^{-1} \text{ mol}^{-1}$ ,  $\text{mol}^{-1} \text{ dm}^3$ ,  $\text{kPa}^{-1}$
- calculation of initial moles present, with careful consideration of the use of appropriate significant figures
- calculation of the change in moles present
- deduction of the number of moles present at equilibrium
- determination of total moles present at equilibrium.

These steps are often best completed as RICE tables (Ratio, Initial, Change, Equilibrium) and should look to use the appropriate amount of significant figures:

- calculation of mole fractions at equilibrium
- calculation of partial pressures at equilibrium
- inserting partial pressure values into the  $K_p$  expression and avoiding any unnecessary unit conversions
- writing an answer to the required number of significant figures.





This question was well answered by nearly all candidates and many scored all 5 marks. A number used the wrong units for the pressure and the volume so used both kPa and dm<sup>3</sup>. This resulted in the correct number of moles and scored 4 marks as error carried forward. Most candidates were able to find the formula from the molar mass and very few used the incorrect molar volume route.

## Question 20

20 This question is about acids and bases.

(a) **Table 20.1** shows the ionic product,  $K_w$ , of water at 25 °C and 40 °C.

**Table 20.1**

Temperature / °C	$K_w / \text{mol}^2 \text{dm}^{-6}$
25	$1.00 \times 10^{-14}$
40	$2.92 \times 10^{-14}$

(i) Calculate the pH of water at 40 °C.

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

pH = ..... [2]

Most candidates were given the first mark from a correct or rearranged equation. Many candidates then answered this question correctly and were given both marks. Those who didn't, either used  $1.00 \times 10^{-7}$  as  $[\text{OH}^-]$  when calculating  $[\text{H}^+] = K_w / [\text{OH}^-]$  or calculated pH as  $-\log(2.92 \times 10^{-14})$ .

## Question 20 (a) (ii)

- (ii) **Table 20.1** shows different  $K_w$  values at 25 °C and at 40 °C. A student suggests that water is neutral at these temperatures.

Explain why this student is correct.

.....  
 .....  
 ..... [1]

This question proved difficult with only a few candidates able to state that in neutral water,  $[H^+] = [OH^-]$ . Many candidates said that as the pH is close to 7, water is therefore neutral.

## Question 20 (b)

- (b) A student reacts strontium metal with water to make a 250.0 cm<sup>3</sup> solution of aqueous strontium hydroxide, Sr(OH)<sub>2</sub>. The solution contains 0.145 g of strontium hydroxide.

- Write an equation for the reaction of strontium with water.
- Calculate the pH of this 250.0 cm<sup>3</sup> solution of strontium hydroxide at 40 °C. You should refer back to **Table 20.1** at the start of (a).

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

Equation .....

Calculation

pH = ..... [5]

Most candidates wrote the correct equation. Common errors were using Sr<sup>2+</sup> as reactant, not balancing the H<sub>2</sub>O and not having the H<sub>2</sub> as second product.

Most candidates calculated the moles of Sr(OH)<sub>2</sub> correctly but fewer recognised that  $[OH^-] = \text{twice the } [Sr(OH)_2]$ . As a result, most candidates scored 3 calculation marks. A few candidates chose the incorrect  $K_w$  value.

## Question 20 (c) (i)

(c) A student reacts 1.00 g of strontium carbonate,  $\text{SrCO}_3$ , with an excess of dilute nitric acid,  $\text{HNO}_3$ . A gas is produced.

(i) Construct the equation for this reaction.

..... [1]

This was often answered correctly but some candidates gave the incorrect formulae for  $\text{Sr}(\text{NO}_3)_2$  and either no other product or  $\text{H}_2$  gas.

## Question 20 (c) (ii)

(ii) The student then reacts 1.00 g of calcium carbonate,  $\text{CaCO}_3$ , with an excess of dilute nitric acid,  $\text{HNO}_3$ .

Explain why the student's two reactions produce different volumes of gas.

.....  
.....  
.....  
.....  
..... [2]

Only a few candidates used the mass value given in the question to link the number of moles of the group 2 metal carbonate and the number of moles, and hence volume, of gas produced.

**Misconception**

Many candidates answered this question in terms of the relative reactivity, or solubility of Ca and Sr and then continuing by explaining their respective ionisation energies.

**Question 20 (d) (i)**

- (d) A student reacts an excess of magnesium with 25.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> hydrochloric acid, HCl.

The student also reacts an excess of magnesium with 25.0 cm<sup>3</sup> of 0.500 mol dm<sup>-3</sup> ethanoic acid, CH<sub>3</sub>COOH.

- (i) Construct an ionic equation for the reaction of magnesium with an acid.

..... [1]

Ionic equations still present candidates with a challenge. A few candidates scored the mark but many candidates gave a full equation or one that contained a mismatch of spectator ions as well as the correct ions.

**Question 20 (d) (ii)**

- (ii) Explain why these two reactions of magnesium produce the same volume of gas but at different rates.

.....  
.....  
.....  
.....  
..... [3]

This question proved challenging for the candidates to identify the three ideas: Those of comparing acids, comparing moles and comparing rates. Very few candidates were able to score the 3 marks. Most candidates recognised the different strength of the two acids, but some only used comparative language. Some linked the moles of acid used to the volume of gas produced but many simply restated the same volume and concentration which is given within the question. Only a few candidates linked the higher initial [H<sup>+</sup>] in HCl to the increased rate through more frequent collisions. A common issue was describing the rate of dissociation rather than the [H<sup>+</sup>] present in determining the rate of the reactions or mentioning that it dissociates more but not linking this to the H<sup>+</sup> concentration.

## Question 20 (e) (i)

(e) Butanoic acid,  $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ , is a weak monobasic acid.

(i) Explain what is meant by the term **monobasic acid**.

.....  
..... [1]

Very few candidates wrote the complete definition of a monobasic acid. Most wrote "donates one proton" only, omitting mole or molecule. Some candidates described donating electrons or  $\text{OH}^-$ .

## Question 20 (e) (ii)

(ii) A buffer solution is prepared by dissolving 3.39 g of potassium hydroxide in  $250\text{ cm}^3$  of  $0.376\text{ mol dm}^{-3}$  butanoic acid.

This buffer solution has a pH of 5.07 at  $25^\circ\text{C}$ .

Calculate the acid dissociation constant,  $K_a$ , of butanoic acid at  $25^\circ\text{C}$ .

Assume that the volume of the solution remains constant at  $250\text{ cm}^3$  when the potassium hydroxide is dissolved.

$K_a = \dots\dots\dots\text{ mol dm}^{-3}$  [4]

This calculation proved difficult with many figures and sums appearing with little indication as to their relevance. 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. Few candidates scored all 4 marks.

Most found the concentration of  $\text{H}^+$  from the pH and the moles of KOH correctly but did not recognise they had to take away the moles of KOH from those of HA to find the remaining concentration of HA. Some candidates then used the  $[\text{H}^+]$  as the  $[\text{HA}]$ . A few candidates tried a  $[\text{H}^+]$  squared expression of a weak acid.

Exemplar 2

Assume that the volume of the solution remains constant at 250 cm<sup>3</sup> when the potassium hydroxide is dissolved.

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$[H^+] = 10^{-5.07} = 8.51 \times 10^{-6}$$

mol of ~~KOH~~ butanoic acid = 0.25 × 0.376 = 0.094

concentration of A<sup>-</sup>

$$\text{mol of } A^- = \frac{\text{mass}}{M_r} = \frac{3.39}{56.1} = 0.0604 \text{ mol}$$

$$\text{conc of } A^- = \frac{0.0604}{0.25} = 0.2417$$

~~KOH~~  $K_a = \frac{8.51 \times 10^{-6} \times 0.2417}{0.376}$

$$K_a = 5.470649125 \times 10^{-6}$$

$$K_a = \dots\dots\dots 5.47 \times 10^{-6} \text{ mol dm}^{-3} \text{ [4]}$$

The candidate has clearly set out the calculation so each numerical value can be linked and the steps understood. The only error is not calculating the excess acid (i.e. not subtracting moles OH<sup>-</sup> from initial moles acid) so 3 marks were given.

Question 20 (f)

(f) A buffer solution has a pH of 4.50.

When a small volume of water is added to this buffer solution, the pH does **not** change.

Explain why the pH does **not** change.

.....  
 .....  
 ..... [1]

### Misconception



Only the most successful candidates linked the pH not changing to the ratio of [HA] and [A<sup>-</sup>] not changing on addition of water. The majority of candidates described the buffer being able to minimise pH change on addition of small amounts of acid or base or that water being neutral would not affect the pH.

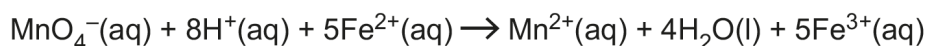
### Question 21 (a) (i)

21 Some grass fertilisers contain compounds of iron.

During heavy rain, a fertiliser is washed into a nearby river causing the water to be polluted with a mixture of iron(II) and iron(III) ions.

(a) A student determines the concentration of iron(II) ions in a sample of river water by titration with potassium manganate(VII).

25.0 cm<sup>3</sup> portions of river water are acidified with dilute sulfuric acid. Each portion is titrated with 0.00250 mol dm<sup>-3</sup> potassium manganate(VII) until a colour change is seen.



(i) State the colour change seen at the end point of the titration.

from ..... to ..... [1]

Only a few candidates were given this mark. Some had the colour change inverted and most stated a variety of different colours.

### Question 21 (a) (ii)

(ii) The student's titration results are shown in the table below.  
The trial titre has been omitted.

	1	2	3
<b>Final volume / cm<sup>3</sup></b>	12.65	25.60	38.35
<b>Initial volume / cm<sup>3</sup></b>	0.00	12.65	25.60
<b>Titre volume / cm<sup>3</sup></b>			

Complete the table above and calculate the mean titre that the student should use to determine the concentration of iron(II) ions in the river water.

mean titre = ..... cm<sup>3</sup> [2]

Almost all candidates calculated the titres correctly. A significant number used all three titre values to derive their mean value.

### OCR support



Links to the legacy coursework tasks and PAG practice question sets can be found on Teach Cambridge and can help students prepare for practical-based questions like this one. [Exam hints for students](#) is useful to share with candidates.

### Question 21 (iii)

(iii) Determine the concentration, in  $\text{mol dm}^{-3}$ , of iron(II) ions in the river water.

concentration = .....  $\text{mol dm}^{-3}$  [3]

Candidates made good progress with this calculation, many gaining 2 or 3 marks, including error carried forward from incorrect titres. Common errors included, in various combinations: transposing volumes, not using the stoichiometry of the equation and using the same volume twice.



## Question 21 (b)

- (b) The student modifies the experiment in (a) to determine the combined concentration of iron(II) and iron(III) ions in the river water.

The student's method is shown below.

- Step 1** Add excess zinc to a 250.0 cm<sup>3</sup> sample of river water and warm gently.
- Step 2** Cool the solution and remove excess zinc by filtration.
- Step 3** Acidify 25.0 cm<sup>3</sup> portions of the filtrate from **Step 2**. Then titrate each portion with 0.00250 mol dm<sup>-3</sup> potassium manganate(VII) until a colour change is seen.

The table below shows information about three redox systems.

Redox system	Half-equation	$E^\circ/V$
1	$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	-0.76
2	$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
3	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

Use the information in the table above to explain the reasons for **Step 1** and **Step 2**.

Reason(s) for **Step 1** .....

.....

.....

.....

Reason(s) for **Step 2** .....

.....

.....

.....

[4]

Most candidates were able to successfully explain Step 1, scoring the first 2 marks. When comparing electrode potentials, candidates should avoid the use of higher/lower as these phrases are ambiguous due to the negative signs involved. Describing them as 'more negative' or 'more positive' is clearer.

Candidates are advised to read the instructions contained within the question and to use or comment on all the data presented. Very few candidates linked Step 2 to the reducing effect of zinc to manganate(VII) ions hence the need for filtration. A few candidates explained Step 2 in terms of the warming/cooling and zinc crystallising rather than explaining the redox chemistry given in the table.



Exemplar 3

transition element.

Explain why some d-block elements are **not** transition elements.

- d block }  
- transition }  
Sc + Zn?

Use electron configurations to support your explanations.

D-block elements are elements where their last, outer most electron lies in the d subshell.

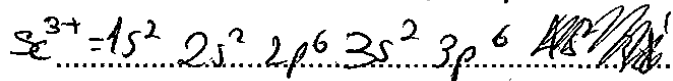
For example, Titanium is a d-block element because its last electron is in 3d :  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

A transition element is an element which forms ions which have a partially filled d-subshell.

An example would be Vanadium, it forms  $V^{3+}$  ions which have an incomplete d-subshell :  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$

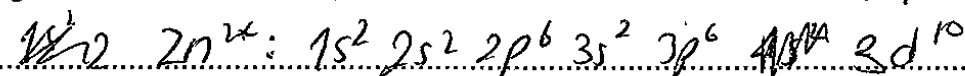
Some d-block elements aren't considered transition elements because their ions do not form incomplete d-subshells.

→ For example, Sc is not a transition metal because its  $Sc^{3+}$  ions don't have an incomplete d-subshell:



→ Another example is zinc, its  $Zn^{2+}$  ion forms a full [6]

d-subshell instead of incomplete, so although it is a d-block element it isn't a transition metal.



This candidate has mentioned outer electrons rather than highest energy but was this is a minor slip and they were still given a Level 3 response as everything else is correct. A holistic approach for LoRs is used and not a point-based marking system.

### Question 22 (b) (i)

(b) (i) Describe precipitation reactions using **either** copper **or** chromium ions as examples.

Include equations.

.....

.....

.....

..... [2]

Most candidates scored 1 mark. Most used  $\text{Cu}^{2+}$  as their example and recognised  $\text{Cu}(\text{OH})_2$  forms a blue precipitate. Some candidates either did not give the colour of the precipitate or were unable to write a balanced equation. Some candidates defined rather than described precipitation.

### Question 22 (b) (ii)

(ii) Describe ligand substitution reactions using **either** copper **or** chromium ions as examples.

Include equations.

.....

.....

.....

..... [2]

Only the highest-attaining candidates on the paper were able to give an example of a ligand substitution reaction with the colour of the new complex ion. Some candidates confused a precipitation reaction for a ligand substitution and some candidates were perhaps a little ambitious in giving 'unusual' complex ions for which they did not know the colour. Cu was often chosen over Cr, usually the formation of  $[\text{CuCl}_4]^{2-}$ , but  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$  was also chosen. With both, there were issues with charges of the complex, and with the latter some were confused with how many  $\text{NH}_3$  were coordinated. Some candidates defined rather than described ligand substitution.

## Question 22 (c)

(c) The ethanedioate ion,  $\text{C}_2\text{O}_4^{2-}$ , is a bidentate ligand.

A complex ion of cobalt(III) contains two ethanedioate ligands and two water ligands.

Determine the charge of this complex ion **and** the coordination number of cobalt in the complex ion.

Charge of complex ion .....

Coordination number of cobalt ..... [2]

Most candidates identified the charge as -1 and a coordination number of 6. A few candidates identified the coordination number as 4 as they did not spot that ethanedioate is bidentate and charge of +3 stated.

## Question 22 (d)

(d) An acidified solution containing  $\text{Cr}_2\text{O}_7^{2-}$  ions reacts with vanadium(III) ions in a redox reaction to form a solution containing  $\text{Cr}^{3+}$  ions and  $\text{VO}_2^+$  ions.

Construct the overall equation for this reaction.

..... [2]

Very few candidates were able to produce the balanced overall equation; a few had the correct reactants and products but not balanced. Candidates are advised to look for the information contained within the question. The formulas were given, and it was stated that the solution was acidified, leaving only water to be identified. Some candidates approached this through two half equations whereas others used oxidation numbers to balance their equations.

---

# Supporting you

---

## Teach Cambridge

Make sure you visit our secure website [Teach Cambridge](#) to find the full range of resources and support for the subjects you teach. This includes secure materials such as set assignments and exemplars, online and on-demand training.

**Don't have access?** If your school or college teaches any OCR qualifications, please contact your exams officer. You can [forward them this link](#) to help get you started.

## Reviews of marking

If any of your students' results are not as expected, you may wish to consider one of our post-results services. For full information about the options available visit the [OCR website](#).

## Access to Scripts

For the June 2023 series, Exams Officers will be able to download copies of your candidates' completed papers or 'scripts' for all of our General Qualifications including Entry Level, GCSE and AS/A Level. Your centre can use these scripts to decide whether to request a review of marking and to support teaching and learning.

Our free, on-demand service, Access to Scripts is available via our single sign-on service, My Cambridge. Step-by-step instructions are on our [website](#).

## Keep up-to-date

We send a monthly bulletin to tell you about important updates. You can also sign up for your subject specific updates. If you haven't already, [sign up here](#).

## OCR Professional Development

Attend one of our popular CPD courses to hear directly from a senior assessor or drop in to a Q&A session. Most of our courses are delivered live via an online platform, so you can attend from any location.

Please find details for all our courses for your subject on **Teach Cambridge**. You'll also find links to our online courses on NEA marking and support.

## Signed up for ExamBuilder?

**ExamBuilder** is the question builder platform for a range of our GCSE, A Level, Cambridge Nationals and Cambridge Technicals qualifications. [Find out more](#).

ExamBuilder is **free for all OCR centres** with an Interchange account and gives you unlimited users per centre. We need an [Interchange](#) username to validate the identity of your centre's first user account for ExamBuilder.

If you do not have an Interchange account please contact your centre administrator (usually the Exams Officer) to request a username, or nominate an existing Interchange user in your department.

## Active Results

Review students' exam performance with our free online results analysis tool. It is available for all GCSEs, AS and A Levels and Cambridge Nationals.

[Find out more](#).

## Need to get in touch?

If you ever have any questions about OCR qualifications or services (including administration, logistics and teaching) please feel free to get in touch with our customer support centre.

Call us on  
**01223 553998**

Alternatively, you can email us on  
**support@ocr.org.uk**

For more information visit

 **ocr.org.uk/qualifications/resource-finder**

 **ocr.org.uk**

 **facebook.com/ocrexams**

 **twitter.com/ocrexams**

 **instagram.com/ocrexaminations**

 **linkedin.com/company/ocr**

 **youtube.com/ocrexams**

## We really value your feedback

Click to send us an autogenerated email about this resource. Add comments if you want to. Let us know how we can improve this resource or what else you need. Your email address will not be used or shared for any marketing purposes.



**I like this**



**I dislike this**

Please note – web links are correct at date of publication but other websites may change over time. If you have any problems with a link you may want to navigate to that organisation's website for a direct search.



OCR is part of Cambridge University Press & Assessment, a department of the University of Cambridge.

For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored. © OCR 2023 Oxford Cambridge and RSA Examinations is a Company Limited by Guarantee. Registered in England. Registered office The Triangle Building, Shaftesbury Road, Cambridge, CB2 8EA. Registered company number 3484466. OCR is an exempt charity.

OCR operates academic and vocational qualifications regulated by Ofqual, Qualifications Wales and CCEA as listed in their qualifications registers including A Levels, GCSEs, Cambridge Technicals and Cambridge Nationals.

OCR provides resources to help you deliver our qualifications. These resources do not represent any particular teaching method we expect you to use. We update our resources regularly and aim to make sure content is accurate but please check the OCR website so that you have the most up to date version. OCR cannot be held responsible for any errors or omissions in these resources.

Though we make every effort to check our resources, there may be contradictions between published support and the specification, so it is important that you always use information in the latest specification. We indicate any specification changes within the document itself, change the version number and provide a summary of the changes. If you do notice a discrepancy between the specification and a resource, please [contact us](#).

You can copy and distribute this resource freely if you keep the OCR logo and this small print intact and you acknowledge OCR as the originator of the resource.

OCR acknowledges the use of the following content: N/A

Whether you already offer OCR qualifications, are new to OCR or are thinking about switching, you can request more information using our [Expression of Interest form](#).

Please [get in touch](#) if you want to discuss the accessibility of resources we offer to support you in delivering our qualifications.