

OCR A-Level Chemistry A

Module 3: Periodic table and energy

Questions only

All 50 questions in Module 3: Periodic table and energy

Questions

50

Total marks

240

Name

Class or teacher

Date

Instructions

- Answer all questions in the spaces provided.
- Use black ink. Show your working for every calculation.
- You may use a scientific calculator and the OCR Data Sheet.
- Print the separate mark scheme when you are ready to mark your answers.

For marking

Total _____ / 240 Percentage _____ %

Questions from OCR past papers, 2017–2025, reproduced for revision. Practise these topics online, with instant marking:

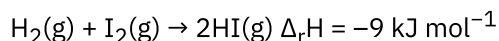
whiteboardchemistry.com/revision/exam-questions/ocr-a-level-chemistry/?topics=enthalpy-changes,group-2-and-the-halogens,periodicity,reaction-rates-and-equilibrium&len=0

Questions

Enthalpy changes, Group 2 and the halogens, Periodicity and Reaction rates and equilibrium · 50 questions · 240 marks

Q1 · Enthalpy changes · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q9 · [1 mark]

Enthalpy values are provided below.



Bond	Bond enthalpy / kJ mol^{-1}
H-H	+436
I-I	+151

What is the bond enthalpy, in kJ mol^{-1} , of the H-I bond?

Tick (✓) one box.

- ☐ A -596
- ☐ B -298
- ☐ C +298
- ☐ D +596

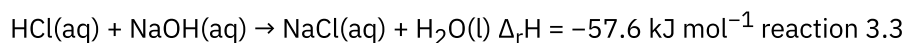
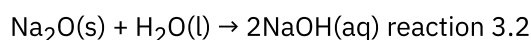
Q2 · Enthalpy changes · June 2017 · Paper 3 (Unified chemistry) · Q2 · [14 marks]

This question also needs Acids and redox reactions, Amount of substance and Basic concepts of organic chemistry.

A student plans to determine the enthalpy change of reaction 3.1 shown below.



This enthalpy change can be determined indirectly using Hess' Law from the enthalpy changes of reaction 3.2 and reaction 3.3 shown below.



The student will determine the enthalpy change of reaction 3.2 as outlined below.

- Weigh a bottle containing $\text{Na}_2\text{O}(\text{s})$ and weigh a polystyrene cup.
- Add about 25 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $\text{Na}_2\text{O}(\text{s})$, stir the mixture, and measure the maximum temperature reached.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + $\text{Na}_2\text{O}(\text{s}) = 16.58 \text{ g}$

Mass of empty bottle = 15.34 g

Mass of empty polystyrene cup = 21.58 g

Mass of polystyrene cup + final solution = 47.33 g

Temperature readings

Initial temperature of water = 20.5 °C

Maximum temperature of final solution = 55.5 °C

The density and specific heat capacity, c , of the solution are the same as for water.

2(a) Calculate the enthalpy change of reaction 3.2 and the enthalpy change of reaction 3.1.

Show all your working.

[6 marks]

2(b) The uncertainty in each temperature reading is ± 0.1 °C.

The uncertainty in each mass reading is ± 0.005 g.

Determine whether the mass of Na_2O or the temperature change has the greater percentage uncertainty.

Show all your working.

[2 marks]

2(c) Suggest a modification to this experiment, using the same apparatus, which would reduce the percentage errors in the measurements.

Explain your reasoning.

[2 marks]

Sodium oxide, Na_2O , can be prepared by the redox reaction of NaNO_2 and sodium metal.

Nitrogen gas is also formed.

2(d)(i) What is the systematic name for NaNO_2 ?

[1 mark]

2(d)(ii) Using oxidation numbers, with signs, show the element that is oxidised and the element that is reduced in this reaction.

Element oxidised

Oxidation number change from to

Element reduced

Oxidation number change from to

[2 marks]

2(d)(iii) Construct the equation for this reaction.

Equation

[1 mark]

Q3 · Enthalpy changes · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q13 · [1 mark]

This question also needs Lattice enthalpy, entropy and free energy.

Which enthalpy change(s) is/are endothermic?

- 1 The bond enthalpy of the C–H bond
- 2 The second electron affinity of oxygen
- 3 The standard enthalpy change of formation of magnesium

Tick (✓) one box.

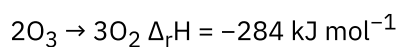
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q4 · Enthalpy changes · June 2019 · Paper 1 (Periodic table, elements and physical chemistry) · Q10 · [1 mark]

This question also needs Alcohols and haloalkanes and Basic concepts of organic chemistry.

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

The overall equation is shown below.



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

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

Tick (✓) one box.

- ☐ **A** 56.8
- ☐ **B** 113.6
- ☐ **C** 355
- ☐ **D** 710

Q5 · Enthalpy changes · June 2019 · Paper 3 (Unified chemistry) · Q5 · [13 marks]

This question also needs Basic concepts of organic chemistry, Electrons, bonding and structure, Lattice enthalpy, entropy and free energy and Redox and electrode potentials.

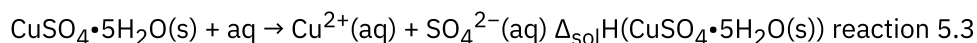
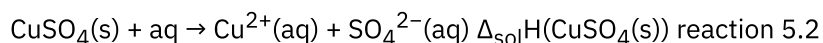
This question is about copper(II) sulfate, CuSO_4 , and sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$.

The enthalpy change of reaction, $\Delta_r H$, for converting anhydrous copper(II) sulfate to hydrated copper(II) sulfate is difficult to measure directly by experiment.



The enthalpy changes of solution of anhydrous and hydrated copper(II) sulfate can be measured by experiment. The reactions are shown below.

In the equations, 'aq' represents an excess of water.



Experiment 1

A student carries out an experiment to find $\Delta_{\text{sol}}\text{H}(\text{CuSO}_4(\text{s}))$ for reaction 5.2.

Student's method

- Weigh a bottle containing $\text{CuSO}_4(\text{s})$ and weigh a polystyrene cup.
- Add about 50 cm^3 of water to the polystyrene cup and measure its temperature.
- Add the $\text{CuSO}_4(\text{s})$, stir the mixture, and measure the final temperature.
- Weigh the empty bottle and weigh the polystyrene cup with final solution.

Mass readings

Mass of bottle + $\text{CuSO}_4(\text{s})$ / g	28.04
Mass of empty bottle / g	20.06
Mass of polystyrene cup / g	23.43
Mass of polystyrene cup + final solution / g	74.13

Temperature readings

Initial temperature of water / °C	20.5
Temperature of final solution / °C	34.0

Experiment 2

The student carries out a second experiment with $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (reaction 5.3). The student uses the same method as in Experiment 1.

The student calculates $\Delta_{\text{sol}}\text{H}(\text{CuSO}_4 \cdot 5\text{H}_2\text{O}(\text{s}))$ as $+8.43 \text{ kJ mol}^{-1}$.

5(a)(i) Calculate $\Delta_{\text{sol}}\text{H}(\text{CuSO}_4(\text{s}))$ for reaction 5.2 and determine the enthalpy change of reaction 5.1, $\Delta_r\text{H}$.

Assume that the specific heat capacity, c , of the solution is the same as for water.

Show your working, including an energy cycle linking the enthalpy changes.

[6 marks]

5(a)(ii) The thermometer had an uncertainty in each temperature reading of $\pm 0.1\text{ }^{\circ}\text{C}$.

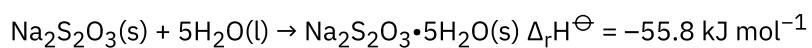
The student calculates a 20% uncertainty in the temperature change in Experiment 2.

Calculate the temperature change in Experiment 2.

temperature change = $^{\circ}\text{C}$

[1 mark]

5(b) The standard enthalpy change of reaction, $\Delta_r H^\ominus$, and the standard free energy change, $\Delta G^\ominus$, for converting anhydrous sodium thiosulfate to hydrated sodium thiosulfate are shown below.



$$\Delta G^\ominus = -16.1 \text{ kJ mol}^{-1}$$

Standard entropies are given in the table.

Compound	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}(\text{s})$	372.4
$\text{H}_2\text{O}(\text{l})$	69.9

Determine the standard entropy, $S^\ominus$, of anhydrous sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{s})$.

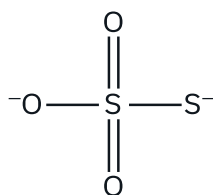
Give your answer to 3 significant figures.

$$S^\ominus = \text{J K}^{-1} \text{ mol}^{-1}$$

[4 marks]

Sodium thiosulfate contains the thiosulfate ion, $\text{S}_2\text{O}_3^{2-}$.

The displayed formula of $\text{S}_2\text{O}_3^{2-}$ can be shown as below.



thiosulfate ion

5(c)(i) Predict the O–S–S bond angle and name of the shape of the thiosulfate ion.

[1 mark]

Bond angle

Name of shape

5(c)(ii) In some of its reactions, the thiosulfate ion forms the tetrathionate ion, $\text{S}_4\text{O}_6^{2-}$.

The $\text{S}_4\text{O}_6^{2-}$ ion is a 'dimer' of $\text{S}_2\text{O}_3^{2-}$.

Draw a displayed formula for the $\text{S}_4\text{O}_6^{2-}$ ion.

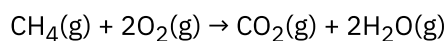
[1 mark]

Q6 · Enthalpy changes · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q7 · [1 mark]

Bond enthalpies are shown in the table.

Bond	C–C	C–H	O–H	C–O	C=O	O–O	O=O
Bond enthalpy / kJ mol ⁻¹	347	435	464	358	805	144	498

What is the enthalpy change, in kJ mol⁻¹, for the reaction below?



Tick (✓) one box.

☐ **A** -730

☐ **B** -544

☐ **C** +544

☐ **D** +730

Q7 · Enthalpy changes · June 2022 · Paper 3 (Unified chemistry) · Q5 · [10 marks]

This question also needs Lattice enthalpy, entropy and free energy.

This question is about energy changes.

5(a) A student plans to determine the enthalpy change of hydration of calcium ions.

The student finds the information below from data tables.

Enthalpy change	$\Delta H / \text{kJ mol}^{-1}$
Lattice enthalpy of calcium chloride	-2223
Enthalpy change of hydration of chloride ions	-378

The student carries out an experiment to find the enthalpy change of solution of calcium chloride.

Student's method:

- Weigh a bottle containing calcium chloride and weigh a polystyrene cup.
- Add water from a measuring cylinder to the polystyrene cup and measure its temperature.
- Add the calcium chloride, stir the mixture, and measure the maximum temperature of the final solution.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + calcium chloride / g	27.45
Mass of empty bottle / g	18.17
Mass of polystyrene cup / g	21.24
Mass of polystyrene cup + final solution / g	127.84

Temperature readings

Initial temperature of water / °C	21.0
Maximum temperature of final solution / °C	39.5

Calculate the enthalpy change of solution of calcium chloride and determine the enthalpy change of hydration of calcium ions.

Show your working, including an energy cycle linking the energy changes.

Assume that the density and specific heat capacity, c , of the solution are the same as for water.

[6 marks]

Internal combustion engines have historically used fuels obtained from crude oil as a source of power.

The environmental effects of fossil fuel use can be reduced by blending petrol with biofuels such as ethanol.

A fuel is being developed using a 1:1 molar ratio of octane and ethanol.

5(b)(i) Write the equation for the complete combustion of this fuel.

[1 mark]

5(b)(ii) Calculate the energy released, in kJ, by the complete combustion of 8.00 kg of this fuel.

$$\Delta_c H(\text{C}_8\text{H}_{18}) = -5470 \text{ kJ mol}^{-1}; \Delta_c H(\text{C}_2\text{H}_5\text{OH}) = -1367 \text{ kJ mol}^{-1}.$$

energy released = kJ

[3 marks]

Q8 · Enthalpy changes · June 2023 · Paper 3 (Unified chemistry) · Q2 · [11 marks]

This question also needs Acids, bases and buffers and Aromatic compounds and phenols.

These questions are from different areas of chemistry.

This question is about two salts of rubidium (atomic number 37): RbClO_3 and RbClO_4 .

2(a)(i) The oxidation number of chlorine is different in the two rubidium salts, RbClO_3 and RbClO_4 .

What is the name of RbClO_4 ?

[1 mark]

2(a)(ii) A student carries out an experiment to determine the enthalpy change of solution of RbClO_3 using the method below.

- A 2.00 g sample of solid RbClO_3 is added to water in a well-insulated container. The initial temperature is 23.0 °C.
- The mixture is stirred until all the RbClO_3 has dissolved. The final temperature is 21.5 °C. The final solution has a mass of 102 g.

Determine the enthalpy change of solution, $\Delta_{\text{sol}}H$, of RbClO_3 in kJ mol^{-1} .

Assume that the specific heat capacity of the solution is the same as that of pure water.

$\Delta_{\text{sol}}H (\text{RbClO}_3) = \text{kJ mol}^{-1}$

[3 marks]

2(b) A student investigates the rate of a reaction that is 1st order with respect to hydrochloric acid, HCl(aq).

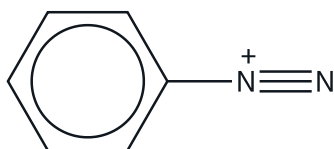
- The student carries out a reaction using $0.680 \text{ mol dm}^{-3}$ HCl(aq). The initial rate is $9.52 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$.
- The student dilutes a different sample of $0.680 \text{ mol dm}^{-3}$ HCl(aq) with water. The pH of this diluted acid is 1.50.
- The student repeats the reaction using the same volume of this diluted acid.

Determine the initial rate using this diluted acid.

initial rate = $\text{mol dm}^{-3} \text{ s}^{-1}$

[3 marks]

2(c) The benzenediazonium ion, shown below, is stable at temperatures below 10 °C.



Benzenediazonium

Above 10 °C, the benzenediazonium ion reacts with water to form phenol.

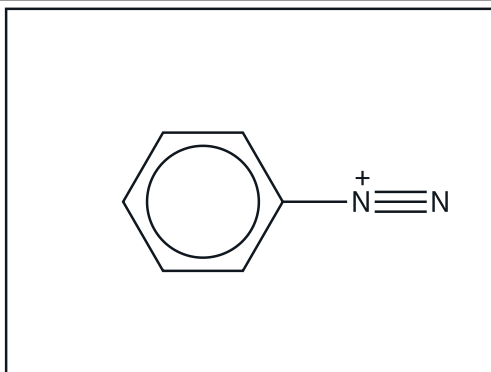
The reaction proceeds in a three-step mechanism.

Step 1 Elimination of nitrogen gas to form a carbocation.

Step 2 Nucleophilic attack by water.

Step 3 Proton loss to form the organic product.

Complete the boxes below with intermediates and curly arrows to show the mechanism for this reaction.

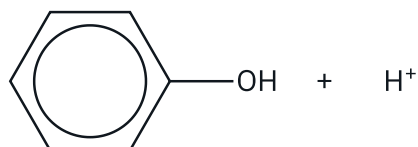


Step 1 →



↓

Step 2

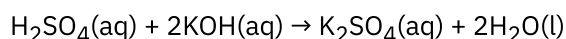


← Step 3

[4 marks]

Q9 · Enthalpy changes · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q7 · [1 mark]

The equation for the reaction of sulfuric acid with potassium hydroxide is shown below.



25 cm³ of 1.00 mol dm⁻³ H₂SO₄ is reacted with excess KOH.

The energy given out is 2.8 kJ.

What is the enthalpy change of neutralisation, in kJ mol⁻¹?

Tick (✓) one box.

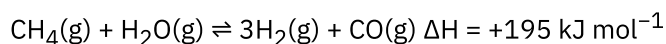
- ☐ **A** -56
- ☐ **B** -70
- ☐ **C** -112
- ☐ **D** -224

Q10 · Enthalpy changes · June 2024 · Paper 3 (Unified chemistry) · Q2 · [14 marks]

This question also needs Amount of substance.

This question is about different areas of chemistry.

Hydrogen gas is manufactured by the chemical industry from the reversible reaction of methane and steam, shown below.



Average bond enthalpies are shown in the table.

Bond	H–H	O–H	C≡O
Average bond enthalpy / kJ mol ⁻¹	+436	+464	+1077

2(a)(i) Why do all average bond enthalpies have a positive value?

[1 mark]

2(a)(ii) Determine the C–H bond enthalpy, in kJ mol^{-1} , using the information above.

C–H bond enthalpy = kJ mol^{-1}

[3 marks]

2(a)(iii) Hydrogen gas is being considered as a household fuel to replace methane.

The enthalpy change of formation, $\Delta_f H$, for $\text{H}_2\text{O}(\text{l})$ is $-285.8 \text{ kJ mol}^{-1}$.

Determine the energy released when 60.0 m^3 of hydrogen is used as a household fuel at RTP.

Give your answer to **3** significant figures and in **standard form**.

energy released = kJ

[2 marks]

Compound A is a chloride of a Period 3 element.

A student carries out the 2 steps below to find the formula of compound A.

Step 1 The student adds $5.00 \times 10^{-4} \text{ mol}$ of compound A to water.

A colourless solution is formed.

Step 2 The colourless solution reacts with exactly 60.0 cm^3 of $2.50 \times 10^{-2} \text{ mol dm}^{-3} \text{ AgNO}_3(\text{aq})$ to form a white precipitate.

2(b)(i) Write an ionic equation, with state symbols, for the reaction in Step 2.

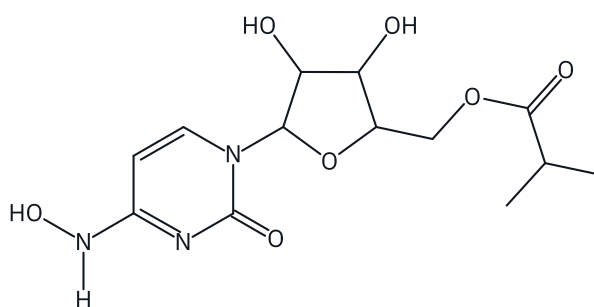
[1 mark]

2(b)(ii) Determine the formula of compound A.

formula of A =

[3 marks]

Compound B, shown below, is an antiviral medicine.



compound B

2(c)(i) What is the molecular formula of compound B?

[1 mark]

2(c)(ii) How many chiral carbon atoms are there in one molecule of compound B?

[1 mark]

2(c)(iii) A research chemist synthesises two related compounds, compound C and compound D, from compound B.

- In compound C, the N atoms in compound B had been replaced by P atoms.
- In compound D, the O atoms in compound B had been replaced by S atoms.

What is the difference between the relative molecular masses of compound C and compound D?

difference =

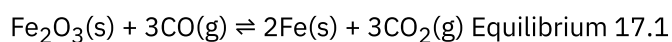
[2 marks]

Q11 · Enthalpy changes · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q17 · [16 marks]

This question also needs Equilibrium constants K_c and K_p and Lattice enthalpy, entropy and free energy.

This question is about carbon monoxide and carbon as reducing agents in industry.

Iron(III) oxide, Fe_2O_3 , can be reduced by carbon monoxide to form iron.



Some standard enthalpy change of formation, $\Delta_f H^\ominus$, and standard entropy, $S^\ominus$, values are shown in the table.

Substance	$\text{Fe}_2\text{O}_3(\text{s})$	$\text{CO}(\text{g})$	$\text{Fe}(\text{s})$	$\text{CO}_2(\text{g})$
$\Delta_f H^\ominus / \text{kJ mol}^{-1}$	-824	-111	0	-394
$S^\ominus / \text{J K}^{-1} \text{mol}^{-1}$	87	198	To calculate in part (a)(iv)	214

17(a)(i) Explain why the standard enthalpy change of formation of Fe has a value of 0 kJ mol^{-1} .

[1 mark]

17(a)(ii) Calculate the enthalpy change, $\Delta_r H$, for the forward reaction in Equilibrium 17.1.

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

[2 marks]

17(a)(iii) Explain why the standard entropy of CO_2 is greater than the standard entropy of Fe_2O_3 .

[2 marks]

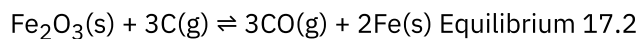
17(a)(iv) The standard entropy change, $\Delta S^\ominus$, for the forward reaction in Equilibrium 17.1 has a value of $+15 \text{ J K}^{-1} \text{ mol}^{-1}$.

Use data from the table to calculate the standard entropy, $S^\ominus$, of Fe.

$$S^\ominus = \text{J K}^{-1} \text{ mol}^{-1}$$

[2 marks]

17(b) Carbon can also reduce $\text{Fe}_2\text{O}_3(\text{s})$ to iron as shown in Equilibrium 17.2.



$$\Delta H = +491 \text{ kJ mol}^{-1}$$

$$\Delta S = +543 \text{ J K}^{-1} \text{ mol}^{-1}$$

The forward reaction is only feasible at high temperatures.

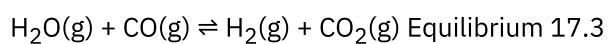
- Show that the forward reaction is **not** feasible at 100 °C.
- Calculate the minimum temperature, in K, for the forward reaction to be feasible.

Give the minimum temperature to the nearest whole number.

T = K

[3 marks]

Steam can be reduced by carbon monoxide in a reversible reaction.



$$\Delta H = -39.9 \text{ kJ mol}^{-1}$$

At 700 K the value of K_p is 8.13.

17(c)(i) Explain why K_p for Equilibrium 17.3 has no units.

[1 mark]

17(c)(ii) An equal number of moles of steam and carbon monoxide are left at 700 K in a sealed container until equilibrium is reached.

At equilibrium, both H_2 and CO_2 have a partial pressure of 211 kPa.

Calculate the partial pressures of H_2O and CO at equilibrium.

Partial pressure of H_2O = kPa

Partial pressure of CO = kPa

[3 marks]

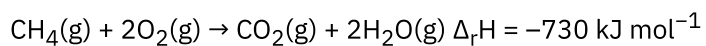
17(c)(iii) At a second temperature the value of K_p for Equilibrium 17.3 is 129.

Explain whether the second temperature is higher or lower than 700 K.

[2 marks]

Q12 · Enthalpy changes · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1 mark]

Methane reacts with oxygen as shown in the equation:



The table shows some bond enthalpies.

Bond	O–H	O=O	C=O
Bond enthalpy / kJ mol^{-1}	+464	+498	+805

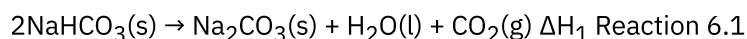
What is the bond enthalpy, in kJ mol^{-1} , of the C–H bond in methane?

Tick (✓) one box.

- ☐ **A** +109
- ☐ **B** +367
- ☐ **C** +435
- ☐ **D** +568

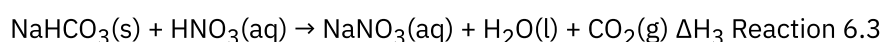
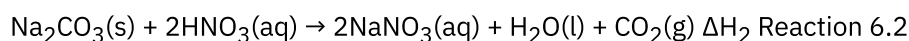
Q13 · Enthalpy changes · June 2025 · Paper 3 (Unified chemistry) · Q6 · [6 marks]

6 The enthalpy change of Reaction 6.1, ΔH_1 , shown below, is difficult to measure directly by experiment.



The enthalpy changes of reaction for the reactions of Na_2CO_3 and NaHCO_3 with excess $\text{HNO}_3(\text{aq})$ can be measured by experiment.

The reactions are shown below as Reaction 6.2 and Reaction 6.3.



A student reacts $\text{Na}_2\text{CO}_3(\text{s})$ with $\text{HNO}_3(\text{aq})$ to find ΔH_2 for Reaction 6.2.

Student's method

Weigh a bottle containing $\text{Na}_2\text{CO}_3(\text{s})$ and weigh a polystyrene cup.

Add about 30 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ HNO}_3(\text{aq})$ to the polystyrene cup and measure its temperature.

Add the $\text{Na}_2\text{CO}_3(\text{s})$, stir the mixture, and measure the maximum temperature reached.

Weigh the empty bottle and weigh the polystyrene cup with the final solution.

Mass readings

Mass of bottle + $\text{Na}_2\text{CO}_3(\text{s})$ / g	3.26
Mass of empty bottle / g	1.29
Mass of polystyrene cup / g	21.08
Mass of polystyrene cup + final solution / g	54.58

Temperature readings

Initial temperature of $\text{HNO}_3(\text{aq})$ / °C	20.0
Maximum temperature of final solution / °C	24.0

The student follows a similar method and reacts $\text{NaHCO}_3(\text{s})$ with $\text{HNO}_3(\text{aq})$ to find ΔH_3 for Reaction 6.3.

The student calculates ΔH_3 for Reaction 6.3 as $+19.8 \text{ kJ mol}^{-1}$.

Calculate ΔH_2 for Reaction 6.2 and determine the enthalpy change of Reaction 6.1, ΔH_1 .

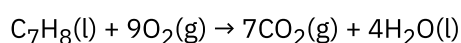
Assume that the density and specific heat capacity, c , of the final solution are the same as for water.

Show your working, including an energy cycle linking the enthalpy changes.

[6 marks]

Q14 • Enthalpy changes • November 2020 • Paper 1 (Periodic table, elements and physical chemistry) • Q6 • [1 mark]

The equation for the combustion of C_7H_8 is shown in the following equation.



Enthalpy changes of formation are shown in the table.

Substance	$C_7H_8(l)$	$CO_2(g)$	$H_2O(l)$
$\Delta_f H / kJ mol^{-1}$	+12	-394	-286

Calculate the enthalpy of combustion, in $kJ mol^{-1}$, for the hydrocarbon C_7H_8 .

Tick (✓) one box.

☐ **A** -3914

☐ **B** -692

☐ **C** +692

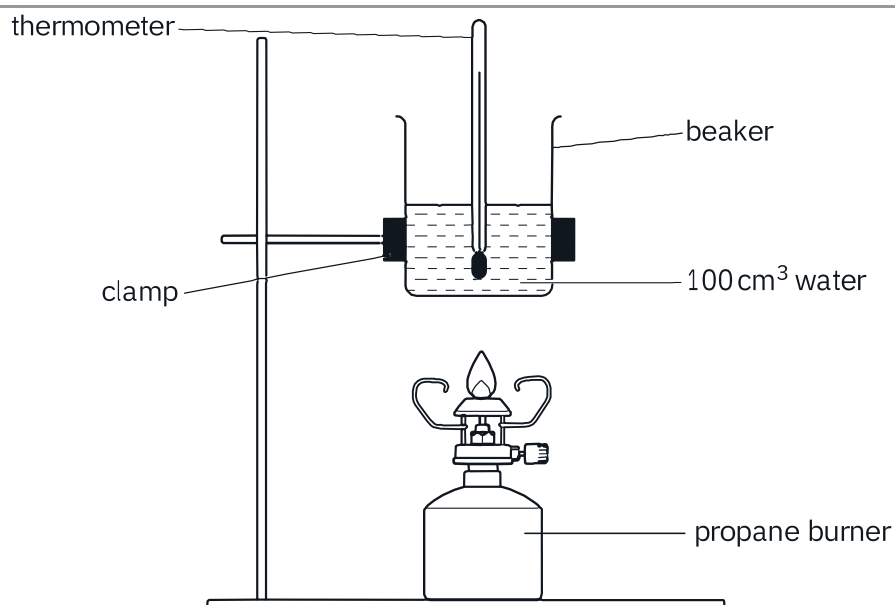
☐ **D** +3914

Q15 • Enthalpy changes • November 2020 • Paper 3 (Unified chemistry) • Q3 • [10 marks]

This question also needs Alkanes.

Propane, C_3H_8 , (boiling point $-42^\circ C$) is used as 'camping gas'. A student plans to determine the enthalpy change of combustion of propane, $\Delta_c H (C_3H_8)$, by two methods.

The student first carries out an experiment using the apparatus below.



Results

Mass of propane burner before burning / g	99.218
Mass of propane burner after burning / g	98.976
Initial temperature / °C	21.60
Maximum temperature reached / °C	46.10

3(a)(i) Determine the enthalpy change of combustion of propane, in kJ mol^{-1} .

Give your answer to 3 significant figures.

$\Delta_c H (\text{C}_3\text{H}_8) = \text{kJ mol}^{-1}$

[3 marks]

3(a)(ii) The student finds that the experimental enthalpy change $\Delta_c H$ (C_3H_8) is much less exothermic than the accurate standard enthalpy change $\Delta_c H$ (C_3H_8) in databases.

One reason could be that the student's experiment had not been carried out under standard conditions.

Suggest two other reasons for this difference in enthalpy change.

[1 mark]

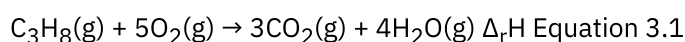
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3(b) The student determines the standard enthalpy change of combustion of propane using the bond enthalpies in the table. An experiment is not needed.

Bond	Bond enthalpy / kJ mol ⁻¹
C-H	+413
C-C	+347
C=O	+805
O=O	+498
O-H	+464

The bond enthalpies can be used to determine the standard enthalpy change of reaction, $\Delta_r H$, for equation 3.1:



Enthalpy change of vaporisation, $\Delta_{\text{vap}} H$

The standard enthalpy change of vaporisation of water, $\Delta_{\text{vap}} H$, is the enthalpy change for the conversion of 1 mol of $\text{H}_2\text{O}(\text{l})$ into 1 mol of $\text{H}_2\text{O}(\text{g})$ under standard conditions:



Determine the standard enthalpy change of combustion of propane (boiling point -42°C)

using the $\Delta_r H$ value for equation 3.1 and $\Delta_{\text{vap}} H$ for water.

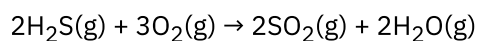
[6 marks]

Q16 • Enthalpy changes • November 2021 • Paper 1 (Periodic table, elements and physical chemistry) • Q8 • [1 mark]

Bond enthalpies are given in the table.

Bond	H–S	O=O	S=O	O–H
Bond enthalpy / kJ mol ⁻¹	+346	+498	+531	+464

What is the enthalpy change, in kJ mol⁻¹, for the reaction below?



Tick (✓) one box.

- ☐ **A** -174
- ☐ **B** -1102
- ☐ **C** -1794
- ☐ **D** -2098

Q17 • Group 2 and the halogens • June 2017 • Paper 1 (Periodic table, elements and physical chemistry) • Q17 • [12 marks]

This question also needs Acids and redox reactions, Amount of substance, Basic concepts of organic chemistry and Lattice enthalpy, entropy and free energy.

This question is about Group 2 and Group 17 (7).

17(a) Barium chloride can be prepared from barium hydroxide in a neutralisation reaction.

Write the equation for this reaction. State symbols are not required.

[1 mark]

17(b) The reactivity of the Group 2 elements Mg–Ba increases down the group.

Explain why.

[3 marks]

On gently heating, the compound KClO_3 reacts as shown in the equation.



This reaction is an example of disproportionation.

17(c)(i) State what is meant by disproportionation and use oxidation numbers to show that disproportionation has taken place.

[3 marks]

17(c)(ii) What is the systematic name for KClO_4 ?

[1 mark]

Two changes are described below.

For each change,

- write an equation, including state symbols,
- state and explain how the entropy changes.

17(d)(i) The reaction of aqueous barium nitrate with aqueous sodium sulfate.

[2 marks]

Full equation with state symbols

Explanation of entropy change

17(d)(ii) The change that accompanies the standard enthalpy change of atomisation of iodine.

[2 marks]

Equation with state symbols

Explanation of entropy change

Q18 · Group 2 and the halogens · June 2017 · Paper 1 (Periodic table, elements and physical chemistry) · Q8 · [1 mark]

Four pairs of solutions are mixed.

Which pair of solutions forms a white precipitate?

Tick (✓) one box.

- ☐ **A** $\text{NH}_4\text{Cl}(\text{aq})$ and $\text{NaOH}(\text{aq})$
- ☐ **B** $\text{KBr}(\text{aq})$ and $\text{AgNO}_3(\text{aq})$
- ☐ **C** $\text{FeCl}_3(\text{aq})$ and $\text{NH}_3(\text{aq})$
- ☐ **D** $\text{Cr}_2(\text{SO}_4)_3(\text{aq})$ and $\text{BaCl}_2(\text{aq})$

Q19 · Group 2 and the halogens · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1 mark]

In the Periodic Table, element X is in Group 2 and element Y is in Group 15 (5).

What is the likely formula of an ionic compound of X and Y?

Tick (✓) one box.

- ☐ **A** X_2Y_5
- ☐ **B** X_2Y_3
- ☐ **C** X_3Y_2
- ☐ **D** X_5Y_2

Q20 • Group 2 and the halogens • June 2019 • Paper 1 (Periodic table, elements and physical chemistry) • Q2 • [1 mark]

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

Tick (✓) one box.

- ☐ **A** $\text{I}_2(\text{aq})$ can oxidise $\text{Br}^-(\text{aq})$.
- ☐ **B** $\text{Cl}_2(\text{aq})$ can reduce $\text{Br}^-(\text{aq})$.
- ☐ **C** $\text{Br}^-(\text{aq})$ can reduce $\text{Cl}_2(\text{aq})$.
- ☐ **D** $\text{Cl}^-(\text{aq})$ can oxidise $\text{I}_2(\text{aq})$.

Q21 • Group 2 and the halogens • June 2019 • Paper 1 (Periodic table, elements and physical chemistry) • Q8 • [1 mark]

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?

Tick (✓) one box.

- ☐ **A** magnesium
- ☐ **B** calcium
- ☐ **C** strontium
- ☐ **D** barium

Q22 • Group 2 and the halogens • June 2019 • Paper 1 (Periodic table, elements and physical chemistry) • Q9 • [1 mark]

This question also needs Acids, bases and buffers.

Which statement is not correct for Group 2 hydroxides?

Tick (✓) one box.

- ☐ **A** $\text{Mg}(\text{OH})_2$ can be used to treat indigestion.
- ☐ **B** $\text{Ca}(\text{OH})_2$ is used in agriculture to neutralise alkaline soils.
- ☐ **C** The anion in $\text{Sr}(\text{OH})_2$ contains 10 electrons.
- ☐ **D** $\text{Ba}(\text{OH})_2$ is a product from the reaction of barium and water.

Q23 · Group 2 and the halogens · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q1 · [1 mark]

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

$\text{AgNO}_3(\text{aq})$ is added to this mixture, followed by an excess of dilute $\text{NH}_3(\text{aq})$.

The resulting mixture is then filtered.

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

Tick (✓) one box.

- ☐ **A** AgCl only
- ☐ **B** AgCl and AgBr
- ☐ **C** AgBr only
- ☐ **D** AgBr and AgI

Q24 · Group 2 and the halogens · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q21 · [14 marks]

This question also needs Acids, bases and buffers and Amount of substance.

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

A student adds magnesium to dilute hydrochloric acid in one test tube.

The student adds calcium to dilute hydrochloric acid in a second test tube.

A redox reaction takes place in each test tube.

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

[1 mark]

1

2

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

Oxidation half-equation:

Reduction half-equation:

[2 marks]

A sample of barium oxide is added to distilled water at 25 °C.

A colourless solution forms containing barium hydroxide, Ba(OH)₂.

The solution is made up to 250.0 cm³ with distilled water.

The pH of this solution is 13.12.

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

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

mass of barium oxide = g

[5 marks]

21(b)(ii) 10 cm³ of dilute sulfuric acid is added to 10 cm³ of the colourless solution of Ba(OH)₂.

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

[1 mark]

Limestone and huntite are two calcium minerals.

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

Fertiliser Z, $\text{Ca}_5\text{NH}_4(\text{NO}_3)_{11} \cdot 10\text{H}_2\text{O}$ ($M_r = 1080.5 \text{ g mol}^{-1}$) can be made from limestone.

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

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

mass of limestone = g

[3 marks]

21(c)(ii) Huntite is a carbonate mineral with the chemical formula $\text{Mg}_3\text{Ca}(\text{CO}_3)_4$.

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

Construct the equation for the reaction. Include state symbols.

[2 marks]

Q25 · Group 2 and the halogens · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q11 · [1 mark]

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?

Tick (✓) one box.

- ☐ **A** Aqueous potassium carbonate: no change · Aqueous silver nitrate: precipitate
- ☐ **B** Aqueous potassium carbonate: no change · Aqueous silver nitrate: no change
- ☐ **C** Aqueous potassium carbonate: effervescence · Aqueous silver nitrate: no change
- ☐ **D** Aqueous potassium carbonate: effervescence · Aqueous silver nitrate: precipitate

Q26 • Group 2 and the halogens • June 2024 • Paper 1 (Periodic table, elements and physical chemistry) • Q4 • [1 mark]

Which compounds of magnesium can be used as 'antacids'?

Tick (✓) one box.

- ☐ **A** Chlorides
- ☐ **B** Hydroxides
- ☐ **C** Nitrates
- ☐ **D** Sulfates

Q27 • Group 2 and the halogens • June 2024 • Paper 1 (Periodic table, elements and physical chemistry) • Q6 • [1 mark]

Which equation does **not** represent a disproportionation reaction?

Tick (✓) one box.

- ☐ **A** $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{HCl}$
- ☐ **B** $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaClO} + \text{NaCl} + \text{H}_2\text{O}$
- ☐ **C** $4\text{KClO}_3 \rightarrow \text{KCl} + 3\text{KClO}_4$
- ☐ **D** $4\text{HCl} + \text{MnO}_2 \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$

Q28 • Group 2 and the halogens • June 2025 • Paper 1 (Periodic table, elements and physical chemistry) • Q14 • [1 mark]

Barium is in Group 2 of the periodic table.

Which statement(s) about barium is / are correct?

- 1 Its outer shell electrons are in an s-orbital.
- 2 It reacts more vigorously with water than magnesium.
- 3 It has a higher first ionisation energy than magnesium.

Tick (✓) one box.

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

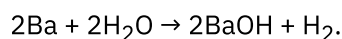
Q29 · Group 2 and the halogens · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q14 · [1 mark]

Which statement(s) for Group 2 elements is/are correct?

1 The 2nd ionisation energy of magnesium is greater than the 2nd ionisation energy of calcium.

2 A strontium ion, Sr^{2+} , contains a total of 6 electrons in s orbitals.

3 The equation for the reaction of barium with water is:



Tick (✓) one box.

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

Q30 · Group 2 and the halogens · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q15 · [1 mark]

$\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ is a hydrated 'double salt'.

A student analyses this double salt using test tube tests.

Which row(s) gives/give correct result(s) for the stated test?

	Test	Results
1	Reaction with cold $\text{NaOH}(\text{aq})$	Green precipitate
2	Reaction with $\text{Ba}(\text{NO}_3)_2(\text{aq})$	White precipitate
3	Reaction with warm $\text{NaOH}(\text{aq})$	Red-brown precipitate and an alkaline gas

Tick (✓) one box.

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

Q31 • Periodicity • June 2018 • Paper 1 (Periodic table, elements and physical chemistry) • Q5 • [1 mark]

Which statement best explains why nitrogen has a larger first ionisation energy than oxygen?

Tick (✓) one box.

- ☐ **A** N atoms have less repulsion between p-orbital electrons than O atoms.
- ☐ **B** N atoms have a smaller nuclear charge than O atoms.
- ☐ **C** N atoms lose an electron from the 2s subshell, while O atoms lose an electron from the 2p subshell.
- ☐ **D** N atoms have an odd number of electrons, while O atoms have an even number.

Q32 • Periodicity • June 2018 • Paper 3 (Unified chemistry) • Q1 • [13 marks]

This question also needs Acids and redox reactions, Amount of substance, Electrons, bonding and structure and Transition elements.

This question refers to the elements in the first three periods (H→Ar) of the Periodic Table.

Select an element from the first three periods that fits each of the following descriptions.

1(a)(i) The element that forms a 1– ion with the same electron configuration as helium.

[1 mark]

1(a)(ii) The element with the highest first ionisation energy.

[1 mark]

1(a)(iii) The element in Period 3 which has the successive ionisation energies shown below.

Ionisation number	1st	2nd	3rd	4th
Ionisation energy/kJ mol ⁻¹	738	1451	7733	10541

[1 mark]

1(a)(iv) The element which forms a compound with fluorine that has octahedral molecules.

[1 mark]

1(a)(v) An element which reacts with water to form an acidic solution.

[1 mark]

1(a)(vi) The element X, which forms a compound with hydrogen, XH_3 , with a molar mass of 34.0 g mol^{-1} .

[1 mark]

1(a)(vii) An element which forms a compound with hydrogen in which the element has an oxidation number of –4.

[1 mark]

1(a)(viii) The element which has a density of $1.33 \times 10^{-3} \text{ g cm}^{-3}$ at room temperature and pressure.

[1 mark]

1(b) Table 1.1 shows some properties of Period 3 chlorides.

Group		1	2	14 (4)	15 (5)	16 (6)
Chloride		NaCl	MgCl ₂	SiCl ₄	PCl ₃	SCl ₂
Electrical conductivity	Solid	poor	poor	poor	poor	poor
	Liquid	good	good	poor	poor	poor
Melting point		high	high	low	low	low

Table 1.1

Explain the properties shown in Table 1.1 in terms of bonding and structure.

[5 marks]

Q33 • Periodicity • June 2019 • Paper 1 (Periodic table, elements and physical chemistry) • Q7 • [1 mark]

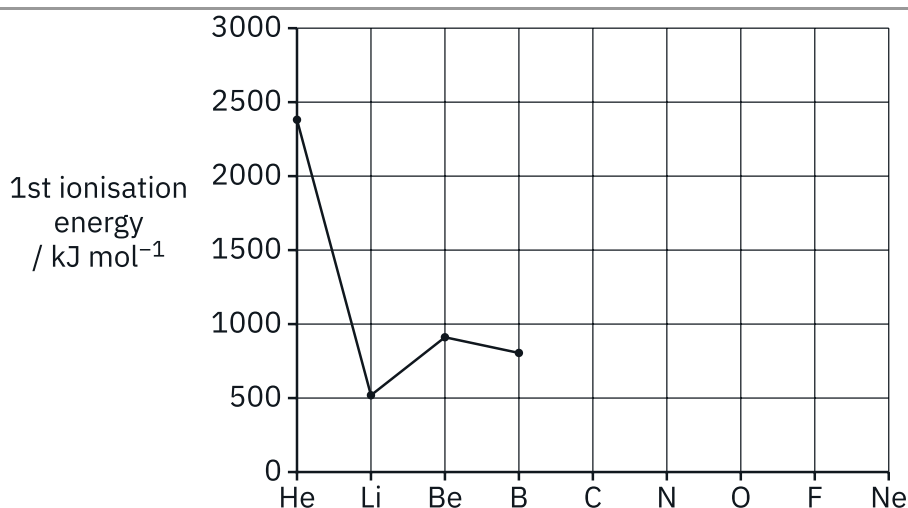
Which set of elements in the solid state contain a simple molecular lattice, a giant covalent lattice and a giant metallic lattice?

Tick (✓) one box.

- ☐ **A** S, Si, Al
- ☐ **B** P, Si, C
- ☐ **C** S, P, Si
- ☐ **D** Mg, P, S

Q34 • Periodicity • June 2022 • Paper 1 (Periodic table, elements and physical chemistry) • Q18 • [9 marks]

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



18(a) Complete the graph for C, N, O, F and Ne.

[2 marks]

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

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

energy = kJ

[1 mark]

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

Explanation for He:

Explanation for Be:

[4 marks]

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

[2 marks]

Q35 · Periodicity · June 2023 · Paper 1 (Periodic table, elements and physical chemistry) · Q6 · [1 mark]

Which element has the largest third ionisation energy?

Tick (✓) one box.

- ☐ **A** Li
- ☐ **B** F
- ☐ **C** Ne
- ☐ **D** Na

Q36 · Periodicity · June 2023 · Paper 3 (Unified chemistry) · Q1 · [9 marks]

This question is about the first 36 elements in the periodic table:

H																He	
Li	Be										B	C	N	O	F	Ne	
Na	Mg										Al	Si	P	S	Cl	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr

From these 36 elements **only**, write the symbol for the element(s) that fit each description.

1(a) The **three** elements that, when in a molecule, can form hydrogen bonds with other suitable molecules.

[1 mark]

1(b) The element in Period 2 with the successive ionisation energies shown below.

Ionisation number	1st	2nd	3rd	4th	5th	6th	7th	8th
Ionisation energy / kJ mol^{-1}	1000	2251	3361	4564	7012	8496	27 107	31 671

[1 mark]

1(c) An element that is a solid at RTP with a simple molecular lattice structure.

[1 mark]

1(d) The **two** elements with atoms containing five unpaired electrons.

[2 marks]

1(e) The element in Period 3 that exists in the solid state as a network of atoms bonded by strong covalent bonds.

[1 mark]

1(f) The p-block element in Period 3 that forms a compound with fluorine with octahedral molecules.

[1 mark]

1(g) The element that forms $1-$ ions most readily.

[1 mark]

1(h) The element with an average atomic mass of 1.244×10^{-22} g.

[1 mark]

Q37 · Periodicity · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q15 · [1 mark]

Which statement(s) about elements in the periodic table is/are correct?

- 1 The position of an element is determined by its relative atomic mass.
- 2 The elements in a group have similar chemical properties.
- 3 Transition elements are used as catalysts in the manufacture of chemicals.

Tick (✓) one box.

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

Q38 · Periodicity · June 2024 · Paper 1 (Periodic table, elements and physical chemistry) · Q20 · [11 marks]

This question also needs Rate equations.

This question is about elements in the periodic table.

Chlorine has many uses.

20(a)(i) Chlorine is used to treat water in large-scale water treatment plants.

Suggest why chlorine is added to water in large-scale water treatment plants.

[1 mark]

20(a)(ii) Sea water contains aqueous bromide ions.

Chlorine is used to extract bromine from sea water.

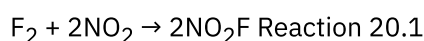
Construct the ionic equation for this reaction and explain why chlorine is suitable for this extraction of bromine but iodine is **not**.

[2 marks]

Equation

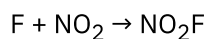
Explanation

20(b) Fluorine, F_2 , reacts with nitrogen dioxide, NO_2 , to form nitryl fluoride, NO_2F , as shown in Reaction 20.1 below.



The mechanism for this reaction involves two steps. Step 1 is the 'slow' step and Step 2 is the 'fast' step.

The equation for Step 2 is shown below:



Suggest the equation for Step 1 and the rate equation for Reaction 20.1.

Equation for Step 1:

Rate equation for Reaction 20.1:

[2 marks]

20(c) The table shows the melting points of some of the elements in Period 3 of the periodic table.

Element	Al	Si	P ₄	S ₈
Melting point / °C	660	1410	44	119

Explain the melting points in terms of bonding and structure.

[6 marks]

Q39 · Periodicity · June 2024 · Paper 2 (Synthesis and analytical techniques) · Q1 · [1 mark]

All organic compounds have covalent bonds.

What is the electrostatic attraction in a covalent bond between?

Tick (✓) one box.

- ☐ **A** A shared pair of electrons and the nuclei of the bonded atoms
- ☐ **B** Cations and delocalised electrons
- ☐ **C** Oppositely charged ions
- ☐ **D** Two molecules

Q40 · Periodicity · November 2020 · Paper 1 (Periodic table, elements and physical chemistry) · Q21 · [9 marks]

This question also needs Amount of substance and Lattice enthalpy, entropy and free energy.

This question is about halogens.

21(a) A student adds a solution of bromine in an organic solvent to two test tubes.

The student adds aqueous sodium chloride to one test tube, and aqueous sodium iodide to the other test tube.

The student shakes the mixtures, allows them to settle, and records the colour of the organic layer in each mixture.

Sodium halide	Colour of organic layer
Sodium chloride	orange
Sodium iodide	violet

Explain how the student's results provide evidence for the trend in reactivity of the halogens down group 17(7) and write an ionic equation for any reaction that takes place.

Use your chemical knowledge to explain the trend in reactivity.

[5 marks]

21(b) Chlorine is used in water treatment.

State one benefit and one risk of using chlorine in water treatment.

[1 mark]

Benefit

Risk

21(c) Compound A contains bromine and fluorine only, and has a boiling point of 41 °C.

1.26 g of compound A is heated to 80 °C.

The volume of gas produced is 0.209 dm³.

Under the conditions used, 1 mol of gas molecules has a volume of 29.0 dm³.

Determine the molecular formula of compound A.

molecular formula =

[3 marks]

Q41 · Periodicity · November 2021 · Paper 1 (Periodic table, elements and physical chemistry) · Q7 · [1 mark]

Which row shows elements in order of increasing first ionisation energy?

Tick (✓) one box.

- ☐ **A** Ca < Si < P < N
- ☐ **B** N < P < Si < Ca
- ☐ **C** Ca < N < P < Si
- ☐ **D** C < Si < P < Ca

Q42 · Reaction rates and equilibrium · June 2018 · Paper 1 (Periodic table, elements and physical chemistry) · Q14 · [1 mark]

Which statement(s) explain(s) why reaction rates increase as temperature increases?

1 The activation energy is less.

2 Collisions between molecules are more frequent.

3 A greater proportion of molecules have energy greater than the activation energy.

Tick (✓) one box.

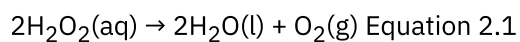
- ☐ **A** 1, 2 and 3
- ☐ **B** Only 1 and 2
- ☐ **C** Only 2 and 3
- ☐ **D** Only 1

Q43 · Reaction rates and equilibrium · June 2018 · Paper 3 (Unified chemistry) · Q2 · [13 marks]

This question also needs Amount of substance, Electrons, bonding and structure, Redox and electrode potentials and Transition elements.

This question looks at reactions of hydrogen peroxide and of cobalt(II) ions.

Aqueous hydrogen peroxide decomposes as shown in equation 2.1.



The reaction is catalysed by manganese(IV) oxide, MnO_2 .

A student investigates the decomposition of a hydrogen peroxide solution as outlined below.

- The student adds 50.00 cm^3 of $\text{H}_2\text{O}_2(\text{aq})$ to a conical flask.
- The student adds a small spatula measure of MnO_2 and quickly connects the flask to a gas syringe.
- The student measures the volume of oxygen every 200 seconds.

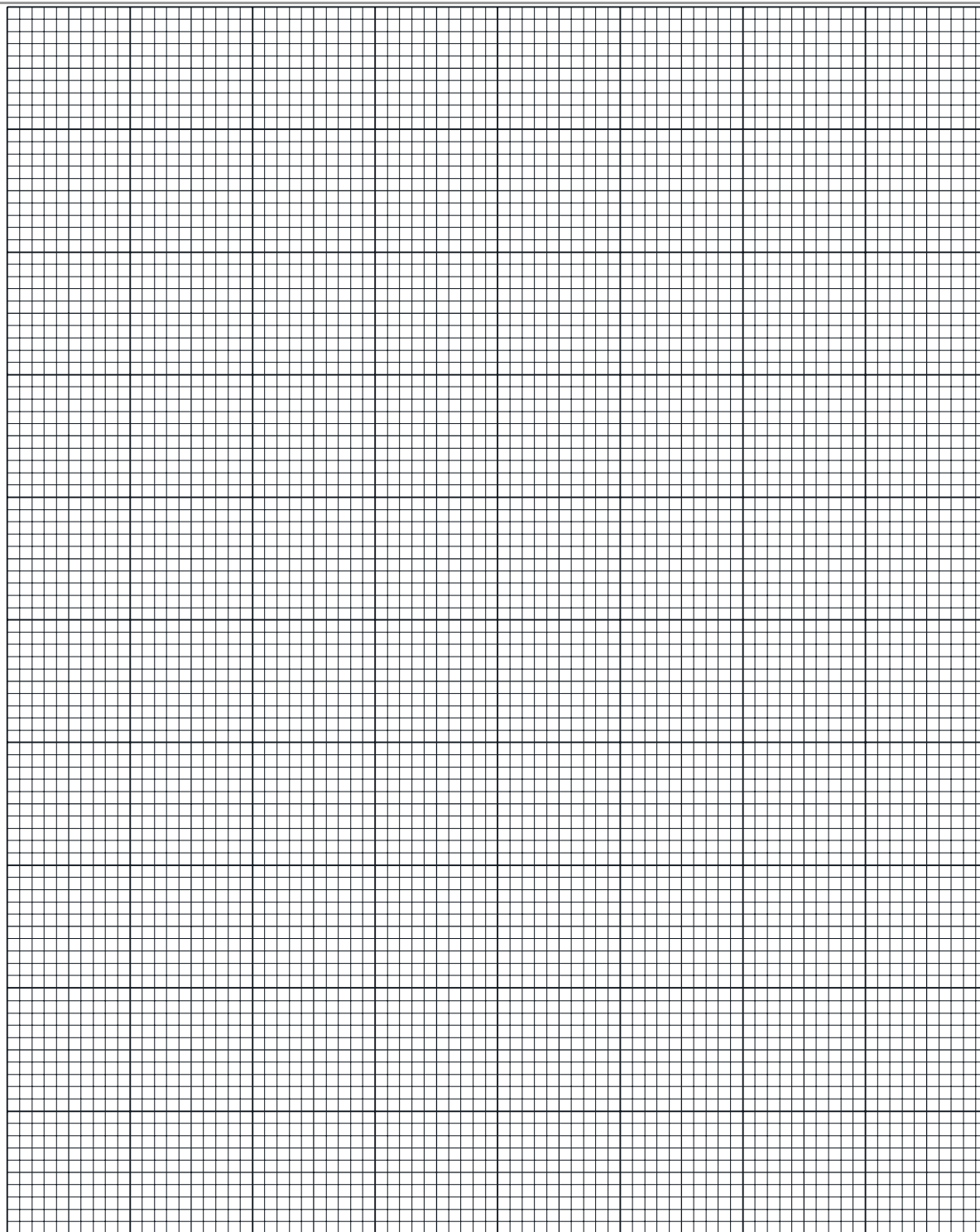
Results

Time/s	Volume of O ₂ /cm ³
0	0
200	15
400	28
600	36
800	41
1000	46
1200	48
1400	50

2(a)(i) Process the results as outlined below.

- On page 5, plot a graph of volume of O₂ against time.
- Use your graph to find the rate of the reaction, in cm³ s⁻¹, at t = 500 s.

Show your working on the graph and in the space below.



rate = $\text{cm}^3 \text{s}^{-1}$

[5 marks]

Draw your answer on the figure above.

2(a)(ii) The student allows the reaction in equation 2.1 to proceed until no more gas is evolved.

The volume of O_2 in the syringe is now 55 cm^3 , measured at RTP.

Calculate the initial concentration of the H_2O_2 .

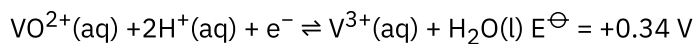
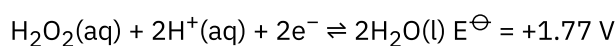
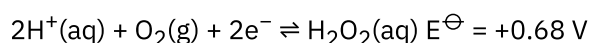
Give your answer to two significant figures.

initial concentration of $H_2O_2 = \text{mol dm}^{-3}$

[3 marks]

2(b) Hydrogen peroxide can act as an oxidising agent or as a reducing agent.

Some standard electrode potentials are shown below.



Use this information to write an equation for a reaction in which hydrogen peroxide acts as a reducing agent.

[2 marks]

Cobalt(II) forms complex ions with water ligands and with chloride ligands.

- With water ligands, cobalt(II) forms a pink octahedral complex ion, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.
- With chloride ligands, cobalt(II) forms a blue tetrahedral complex ion.

A student dissolves cobalt(II) sulfate in water in a boiling tube. A pink solution forms.

Experiment 1

The student places the boiling tube in a water bath at 100 °C.

Concentrated hydrochloric acid is added dropwise.

The colour of the solution changes from pink to blue.

Experiment 2

The student places the boiling tube from experiment 1 in an ice/water bath at 0 °C.

The colour of the solution changes from blue to pink.

2(c)(i) Write the equilibrium equation for the reaction that takes place when the colour of the solution changes.

[1 mark]

2(c)(ii) Explain the observations and predict whether the formation of the blue colour is exothermic or endothermic.

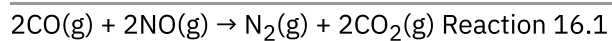
[2 marks]

Q44 · Reaction rates and equilibrium · June 2022 · Paper 1 (Periodic table, elements and physical chemistry) · Q16 · [10 marks]

This question also needs Rate equations.

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

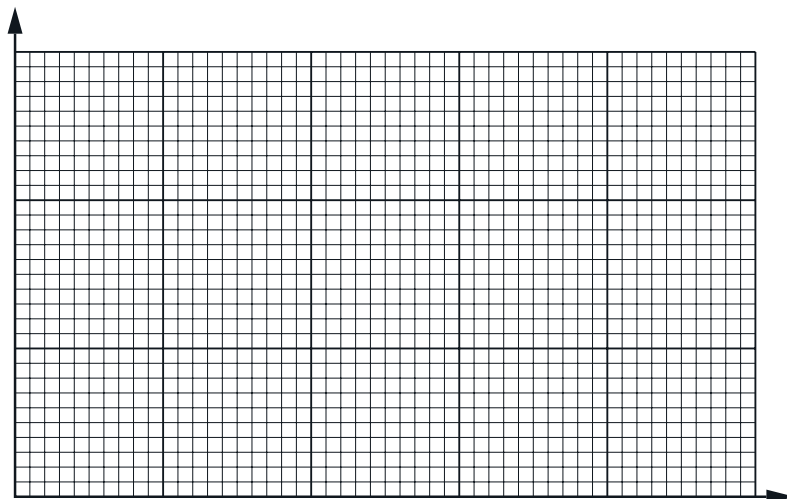
One reaction that happens in a catalytic converter is shown below.



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

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

Label the axes.



[3 marks]

Draw your answer on the figure above.

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

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

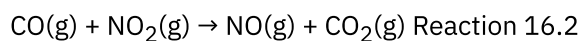
Determine the orders with respect to NO and CO, the rate equation, and the rate constant, k, including units.

Explain your reasoning.

k = units

[5 marks]

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



The rate equation for Reaction 16.2 is shown below:

$$\text{rate} = k [\text{NO}_2\text{(g)}]^2$$

Suggest a possible two-step mechanism for Reaction 16.2.

The first step is much slower than the second step.

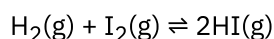
[2 marks]

step 1

step 2

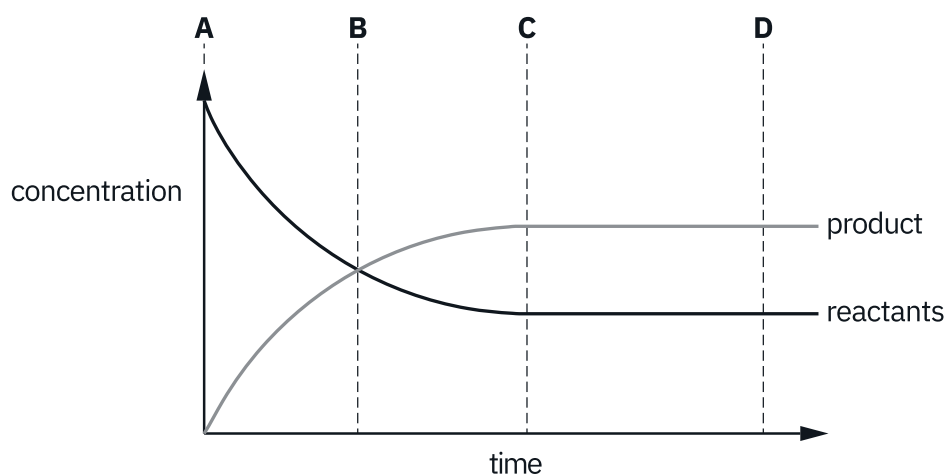
Q45 • Reaction rates and equilibrium • June 2024 • Paper 1 (Periodic table, elements and physical chemistry) • Q11 • [1 mark]

The reversible reaction between hydrogen and iodine to form hydrogen iodide is



The graph shows how the concentrations of the reactants and product change as the reaction reaches a dynamic equilibrium.

At which point on the graph is the equilibrium reached?



Tick (✓) one box.

- ☐ **A** A
- ☐ **B** B
- ☐ **C** C
- ☐ **D** D

Q46 • Reaction rates and equilibrium • June 2024 • Paper 1 (Periodic table, elements and physical chemistry) • Q8 • [1 mark]

Which row in the table explains how a catalyst affects the activation energy (E_a) and the proportion of molecules with energy $> E_a$?

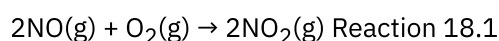
Tick (✓) one box.

- ☐ **A** How the activation energy changes: decreases • Proportion of molecules with energy $> E_a$: decreases
- ☐ **B** How the activation energy changes: decreases • Proportion of molecules with energy $> E_a$: increases
- ☐ **C** How the activation energy changes: increases • Proportion of molecules with energy $> E_a$: decreases
- ☐ **D** How the activation energy changes: increases • Proportion of molecules with energy $> E_a$: increases

Q47 • Reaction rates and equilibrium • June 2025 • Paper 1 (Periodic table, elements and physical chemistry) • Q18 • [14 marks]

This question also needs Rate equations.

Nitrogen monoxide, NO, reacts with oxygen to form nitrogen dioxide, NO₂.



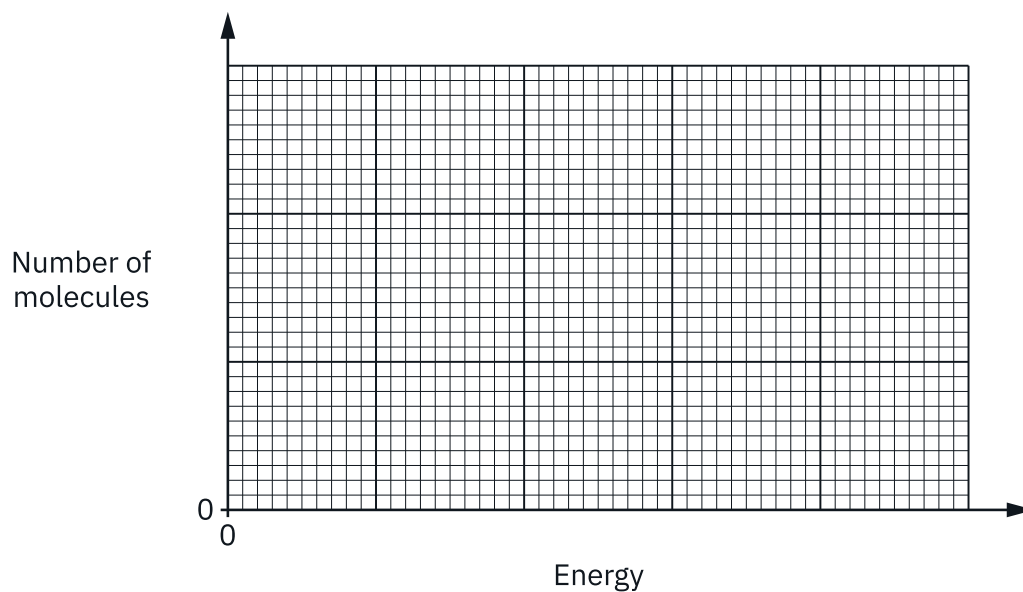
The rate of reaction increases in the presence of a heterogeneous platinum catalyst.

18(a)(i) Explain why platinum is an example of a heterogeneous catalyst for Reaction 18.1.

[1 mark]

18(a)(ii) Explain how the platinum catalyst increases the rate of reaction.

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



[2 marks]

Draw your answer on the figure above.

18(a)(iii) In industry, catalysts have great economic importance and benefits for increased sustainability.

Explain how the use of catalysts is beneficial to the environment.

[1 mark]

18(b) The following data was obtained in a series of experiments on the rate of the reaction for Reaction 18.1 at a constant temperature.

Experiment	[NO] / mol dm ⁻³	[O ₂] / mol dm ⁻³	rate / mol dm ⁻³ s ⁻¹
1	0.040	0.035	7.45×10^{-4}
2	0.040	0.070	1.49×10^{-3}
3	0.060	0.035	1.68×10^{-3}

Determine the orders with respect to NO and O₂. Explain your reasoning.

Determine the rate equation and calculate the rate constant, k, including units.

k = units

[5 marks]

The rate constant varies with temperature, according to the Arrhenius equation.

A technician determines the activation energy for Reaction 18.1 by determining the rate constant, k , at different temperatures.

The table shows the technician's results.

Temperature / K	$1/T / \text{K}^{-1}$	k	$\ln k$
1500	6.7×10^{-4}	1.81×10^3	7.50
1750	5.7×10^{-4}	8.51×10^4	
2000	5.0×10^{-4}	2.79×10^5	12.5
2250	4.4×10^{-4}	1.47×10^6	14.2
2500	4.0×10^{-4}	5.70×10^6	15.6

18(c)(i) Complete the table by adding the missing value of $\ln k$.

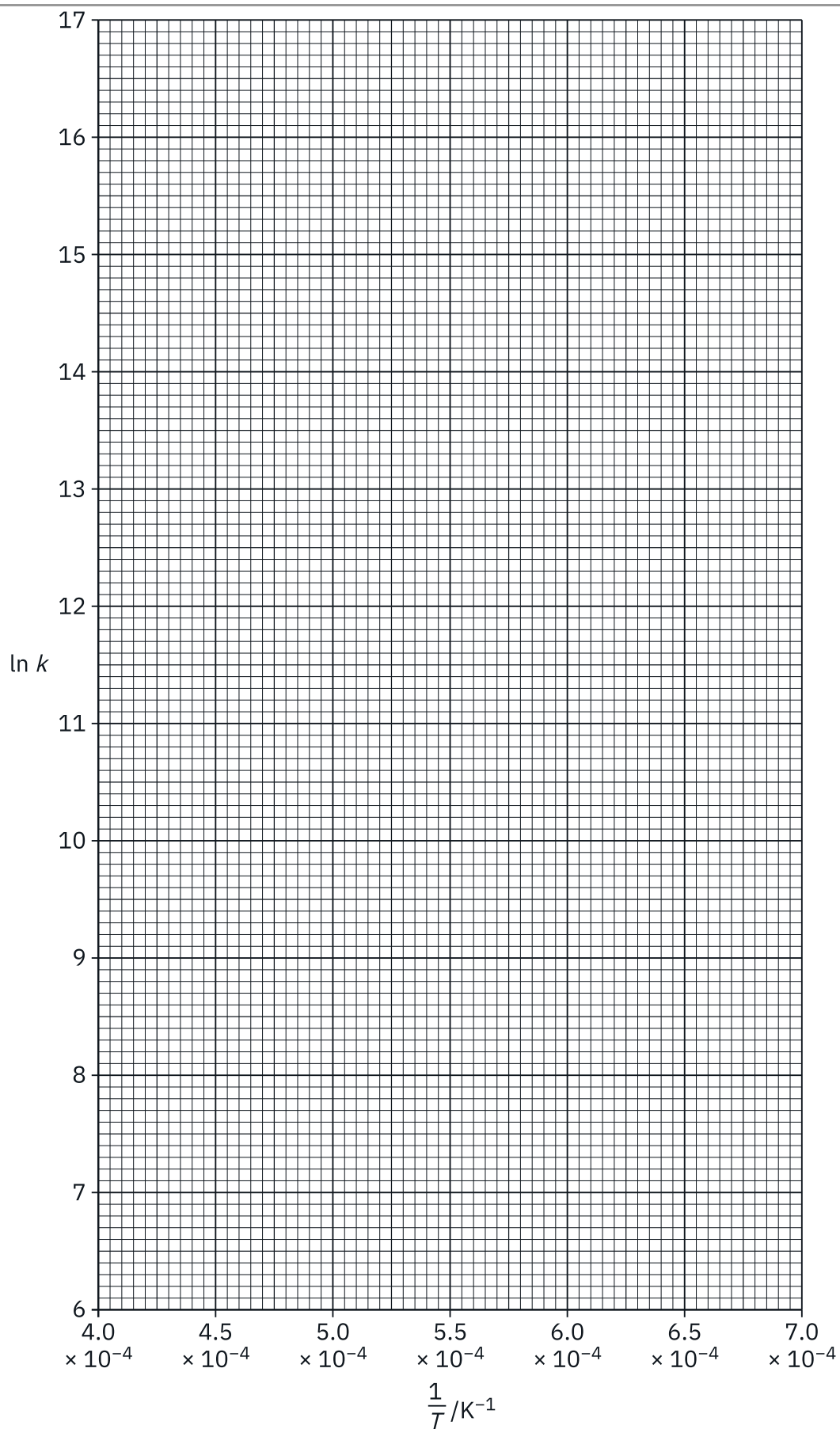
[1 mark]

18(c)(ii) Plot a graph of $\ln k$ against $1/T$ on the grid opposite.

Use your graph to calculate the value of the activation energy, E_a , in kJ mol^{-1} .

Give your answer to **2** significant figures.

$E_a = \text{kJ mol}^{-1}$

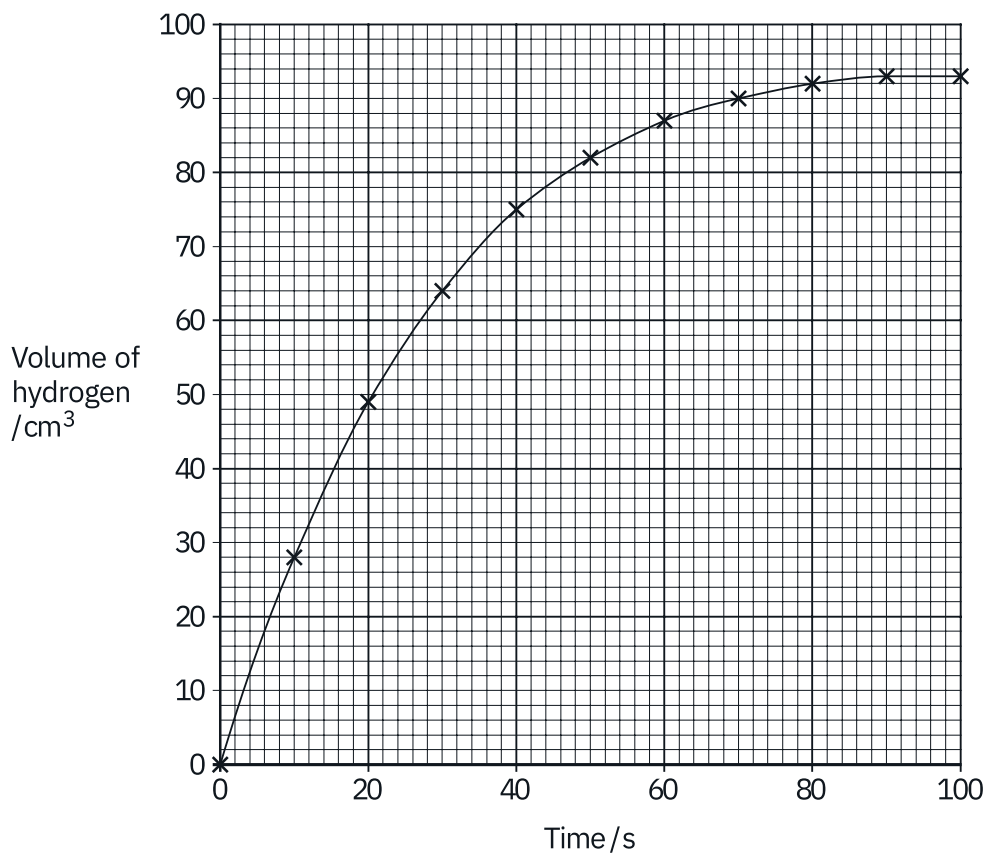


[4 marks]

Draw your answer on the figure above.

Q48 · Reaction rates and equilibrium · June 2025 · Paper 1 (Periodic table, elements and physical chemistry) · Q5 · [1 mark]

The graph shows the volume of hydrogen released over time in a chemical reaction.



What is the rate of reaction, in $\text{cm}^3 \text{s}^{-1}$, at 30 seconds?

Tick (✓) one box.

- ☐ **A** 0.8
- ☐ **B** 1.2
- ☐ **C** 2.1
- ☐ **D** 2.4

Q49 • Reaction rates and equilibrium • November 2020 • Paper 1 (Periodic table, elements and physical chemistry) • Q13 • [1 mark]

This question also needs Equilibrium constants K_c and K_p .

Which statement(s) is/are correct when a catalyst is added to a system in dynamic equilibrium?

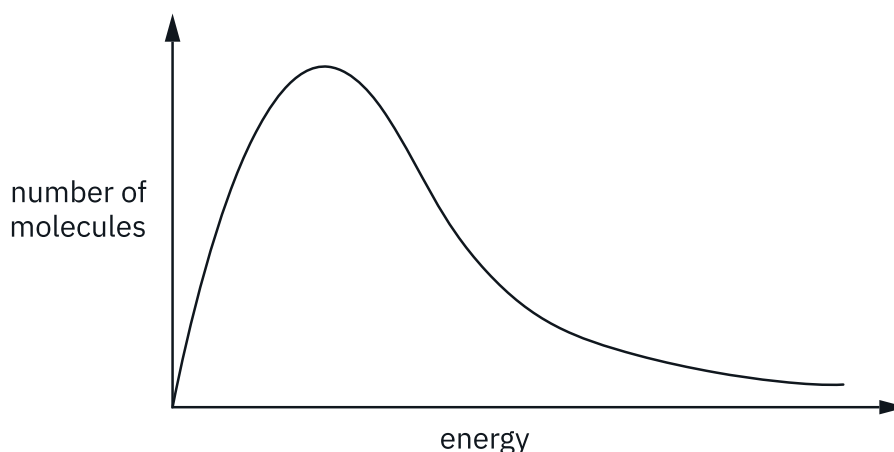
- 1 The rates of the forward and reverse reactions increase by the same amount.
- 2 The concentrations of the reactants and products do not change.
- 3 The value of K_c increases.

Tick (✓) one box.

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

Q50 • Reaction rates and equilibrium • November 2020 • Paper 1 (Periodic table, elements and physical chemistry) • Q7 • [1 mark]

The diagram represents a Boltzmann distribution curve of molecules at a given temperature.



Which statement for this Boltzmann distribution curve is correct at a higher temperature?

Tick (✓) one box.

- ☐ **A** The peak increases in height and moves to the left.
- ☐ **B** The peak increases in height and moves to the right.
- ☐ **C** The peak decreases in height and moves to the left.
- ☐ **D** The peak decreases in height and moves to the right.

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