



Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

AS CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 13 May 2025 Morning Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do **all** rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice

- You are advised to spend 65 minutes on **Section A** and 25 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
Section B	
TOTAL	



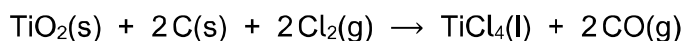
J U N 2 5 7 4 0 4 1 0 1

Section A

Answer **all** questions in this section.

0 1

This question is about the extraction of titanium.

The first stage in the extraction of titanium is the formation of titanium(IV) chloride, TiCl_4 

0 1 . 1

Calculate the percentage atom economy to form TiCl_4 in this first stage of the extraction.

[2 marks]

$$M_r \text{ TiCl}_4 = 47.9 + 4(35.5) = 189.9$$

$$M_r \text{ reactants} = 79.9 + 2(12.0) + 2(71.0) = 245.9$$

$$\% \text{ atom economy} = (189.9 \div 245.9) \times 100 = 77.2 \%$$

Percentage atom economy 77.2 %

0 1 . 2

Suggest **one** economic advantage of using a process with a high percentage atom economy.

[1 mark]

More of the mass of the reactants ends up in the useful product, so
there is less waste (by-product) to dispose of.



The second stage of the extraction is the reaction between TiCl_4 and magnesium.

0 1 . 3 Give the equation for the reaction between TiCl_4 and magnesium.

State the role of magnesium in this reaction.

[2 marks]

Equation



Role of magnesium Reducing agent (electron donor)

0 1 . 4 Titanium is an expensive metal because its extraction process uses magnesium.

Suggest why magnesium is expensive.

[1 mark]

Magnesium is extracted by electrolysis, which uses a lot of (electrical)
energy.

6

Turn over for the next question

Turn over ►



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outside the
box*

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ANSWER IN THE SPACES PROVIDED**



0 2

This question is about the halogens and their compounds.

0 2 . 1

Table 1 shows the boiling points of some halogens.

Table 1

Halogen	Boiling point / °C
Fluorine	−188
Chlorine	−35
Bromine	59

Explain the trend in the boiling points of these halogens.

[2 marks]

*Boiling point increases down the group because the molecules get larger,
with more electrons.*

*So there are stronger van der Waals' forces (London forces) between the
molecules, which need more energy to overcome.*

0 2 . 2

Chlorine is toxic but is added to drinking water.

State why chlorine is added to drinking water.

Explain why this is safe to do even though chlorine is toxic.

[2 marks]

Why chlorine is added *To kill bacteria (sterilise the water) and prevent
water-borne diseases such as cholera.*

Why this is safe *Only a very small concentration of chlorine is used, too
low to harm humans.*

Question 2 continues on the next page

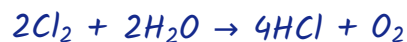
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0 2 . 3

Give an equation for the reaction of chlorine with water in sunlight.

[1 mark]



0 2 . 4

Give the equation for the reaction between NaOH and Cl₂ to form NaClO

[1 mark]



0 2 . 5

When gently warmed in aqueous solution, NaClO reacts to form NaCl and NaClO₃

Complete the equation to ensure that it is correctly balanced.

Deduce the oxidation state of Cl in NaClO₃

[2 marks]

Oxidation state of Cl in NaClO₃ +5

0 2 . 6

Deduce the half-equation, in acidic conditions, for the conversion of ClO₃⁻ into Cl⁻

[1 mark]



0 2 . 7

A halide ion X^- reduces concentrated sulfuric acid to hydrogen sulfide.

Identify the halide ion.

Give an equation for the reaction.

[2 marks]

Halide ion Iodide, I^-

Equation



0 2 . 8

Some solid sodium halides react with concentrated sulfuric acid without any redox reaction taking place.

Identify a sodium halide that behaves in this way.

Give an equation for the reaction.

State the role of the halide ion in this reaction.

[3 marks]

Sodium halide Sodium chloride, $NaCl$

Equation



Role of halide ion Base (proton acceptor)

14

Turn over for the next question

Turn over ►



0 3

This question is about atomic structure and time of flight (TOF) mass spectrometry.

0 3 . 1

Give the full electron configuration of a fluoride ion (F^-).

[1 mark]

$1s^2 2s^2 2p^6$

0 3 . 2

The Q^{2+} ion has electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

Identify Q.

[1 mark]

Manganese, Mn

0 3 . 3

Give the meaning of the term relative atomic mass.

[2 marks]

The average mass of one atom of the element compared with 1/12 of the mass of one atom of carbon-12.

0 3 . 4

A TOF mass spectrometer is used to determine the relative atomic mass of a metal.

Explain why the sample of the metal must be ionised before passing into the flight tube.

Describe how the ion is detected.

Describe how the abundance of each isotope is determined.

[3 marks]

Why sample must be ionised *So that the ions can be accelerated by the electric field (and then detected).*

How ion is detected *Each positive ion hits the detector (negative plate) and gains an electron, creating a current.*

How abundance is determined *The abundance is proportional to the size of the current produced at the detector.*



A sample of metal was analysed using a TOF mass spectrometer.

The mass spectrum showed four peaks.

Table 2 shows data about the four peaks in this spectrum.

Table 2

m/z	Percentage abundance
50	4.3
52	82.8
53	10.5
54	2.4

0 3 . 5 State the m/z value of the ion that would be the last to reach the detector.

[1 mark]

54

0 3 . 6 Calculate the relative atomic mass of this sample of metal.

Give your answer to 1 decimal place.

[2 marks]

$$\begin{aligned}
 A_r &= [(50 \times 4.3) + (52 \times 82.8) + (53 \times 10.5) + (54 \times 2.4)] \div 100 \\
 &= (215 + 4305.6 + 556.5 + 129.6) \div 100 \\
 &= 5206.7 \div 100 = 52.067
 \end{aligned}$$

Relative atomic mass 52.1

Question 3 continues on the next page

Turn over ►



0 3 7

These are the data for one of the isotopes in this analysis.

Length of flight tube = 0.850 m

Time of flight = 6.41×10^{-4} s

$KE = 7.59 \times 10^{-20}$ J

The kinetic energy of an ion is given by the equation $KE = \frac{1}{2}mv^2$

KE = kinetic energy / J

m = mass / kg

v = speed / m s^{-1}

Calculate the mass, in g, of one ion of this isotope.

[3 marks]

$$v = d \div t = 0.850 \div (6.41 \times 10^{-4}) = 1326 \text{ m s}^{-1}$$

$$m = 2KE \div v^2 = (2 \times 7.59 \times 10^{-20}) \div (1326)^2$$

$$= 8.63 \times 10^{-26} \text{ kg}$$

$$\text{mass in g} = 8.63 \times 10^{-26} \times 1000 = 8.63 \times 10^{-23} \text{ g}$$

Mass 8.63×10^{-23} g

13



0 4

This question is about the Group 2 metals Mg to Ba

0 4 . 1

Strontium and calcium have the same metallic structure.

Explain why strontium has a lower melting point than calcium.

[2 marks]

Strontium ions are larger (they have more electron shells and more shielding), so they have a lower charge density.

So there is weaker attraction between the Sr^{2+} ions and the delocalised electrons (weaker metallic bonding).

0 4 . 2

The atomic radius increases down Group 2 from Mg to Ba

Give a reason for this trend.

[1 mark]

The atoms have more electron shells (energy levels) down the group.

0 4 . 3

Give an equation, including state symbols, for the reaction between barium and water.

[1 mark]



0 4 . 4

Give an equation, including state symbols, for the process that occurs when the second ionisation energy of calcium is measured.

[1 mark]



0 4 . 5

Identify the Group 2 metal with the lowest second ionisation energy.

[1 mark]

Barium, Ba

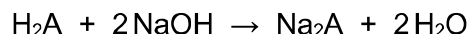
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0 5

An experiment is done to determine the relative molecular mass of a solid acid, H_2A

H_2A reacts with sodium hydroxide as shown.



Method

- 2.09 g of H_2A are dissolved in water and the solution is made up to 250.0 cm^3 in a volumetric flask.
- 25.0 cm^3 of this solution are transferred to a conical flask using a pipette.
- A few drops of phenolphthalein are added.
- $0.380 \text{ mol dm}^{-3}$ sodium hydroxide solution is added from a burette until the indicator changes colour.

Table 3 shows the results of the experiment.

Table 3

	Rough	1	2	3
Final burette reading / cm^3	11.05	23.40	34.25	44.80
Initial burette reading / cm^3	0.00	12.75	23.40	34.25
Titre / cm^3	11.05	10.65	10.85	10.55

0 5 . 1

Calculate the relative molecular mass of H_2A

[5 marks]

$$\text{mean titre (concordant titres 1 and 3)} = (10.65 + 10.55) \div 2 = 10.60 \text{ cm}^3$$

$$n(\text{NaOH}) = 0.380 \times 10.60 \div 1000 = 4.028 \times 10^{-3} \text{ mol}$$

$$n(\text{H}_2\text{A}) \text{ in } 25.0 \text{ cm}^3 = 4.028 \times 10^{-3} \div 2 = 2.014 \times 10^{-3} \text{ mol}$$

$$n(\text{H}_2\text{A}) \text{ in } 250.0 \text{ cm}^3 = 2.014 \times 10^{-3} \times 10 = 2.014 \times 10^{-2} \text{ mol}$$

$$\begin{aligned} M_r &= \text{mass} \div \text{moles} = 2.09 \div (2.014 \times 10^{-2}) \\ &= 103.8 = 104 \end{aligned}$$



Relative molecular mass of H_2A 104

0 5 . 2

The uncertainty in the use of the burette in each titration is $\pm 0.15 \text{ cm}^3$

Calculate the percentage uncertainty in the use of the burette in titration 1.

[1 mark]

$$(0.15 \div 10.65) \times 100 = 1.41 \%$$

Percentage uncertainty 1.41 %

0 5 . 3

Suggest **one** way to reduce the percentage uncertainty in each titration without changing the apparatus.

Justify your answer.

[2 marks]

Suggestion Use a more dilute solution of sodium hydroxide (or a larger mass of H_2A in the 250.0 cm^3 solution).

Justification This gives a larger titre, so the fixed uncertainty of $\pm 0.15 \text{ cm}^3$ is a smaller percentage of the volume measured.



0 6 . 1 A student completes a series of test-tube reactions on two solutions, **A** and **B**.

Each solution contains an unknown inorganic compound.

Table 4 shows the observations in these reactions.

Table 4

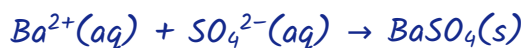
	Solution A	Solution B
Test 1 Add $\text{H}_2\text{SO}_4(\text{aq})$	White precipitate formed	Effervescence
Test 2 Add $\text{HNO}_3(\text{aq})$ followed by $\text{AgNO}_3(\text{aq})$	White precipitate formed	Effervescence
Test 3 Add $\text{NaOH}(\text{aq})$ and warm gently. Hold a piece of damp red litmus paper over the end of the test tube.	No visible change	Red litmus turns blue

Show how the observations can be used to identify the inorganic compound in **Solution A** and the inorganic compound in **Solution B**.

Give **ionic** equations for the reactions that occur.

[6 marks]

Solution A: in Test 1 a white precipitate forms with H_2SO_4 , so Solution A contains Ba^{2+} ions (an insoluble sulfate, BaSO_4 , forms).



In Test 2 a white precipitate forms with acidified AgNO_3 , so Solution A contains Cl^- ions (silver chloride forms).



No change in Test 3 shows there are no NH_4^+ ions in A. So Solution A is barium chloride, BaCl_2 .



Solution B: effervescence with H_2SO_4 in Test 1 and with HNO_3 in Test 2 shows that carbon dioxide gas is given off, so Solution B contains carbonate ions, CO_3^{2-} .



In Test 3, warming with NaOH gives a gas that turns damp red litmus blue. This gas is ammonia, so Solution B contains ammonium ions, NH_4^+ .



No precipitate forms with acidified AgNO_3 , so B contains no halide ions. So Solution B is ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$.

0 6 . 2

Describe a test to confirm that a solution contains hydroxide ions.

[1 mark]

Add a few drops of universal indicator: it turns blue / purple (alkaline).



0 7

This question is about chemical equilibria.

A mixture of hydrogen and iodine is allowed to reach equilibrium in a sealed container.

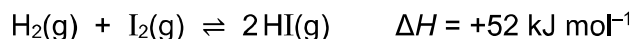
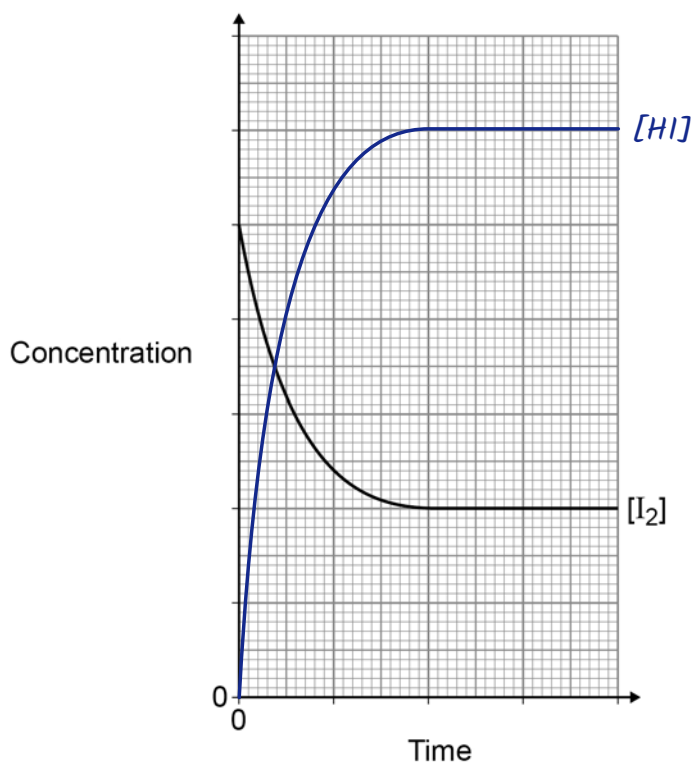


Figure 1 shows how the concentration of iodine changes with time.

Figure 1



0 7 . 1

Draw a line on **Figure 1** to show how the concentration of hydrogen iodide changes with time.

[2 marks]

0 7 . 2

State and explain the effect of increasing the temperature on the equilibrium yield of hydrogen iodide.

[3 marks]

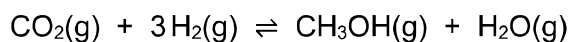
Effect on yield The yield of hydrogen iodide increases.

Explanation The forward reaction is endothermic ($\Delta H = +52 \text{ kJ mol}^{-1}$), so the position of equilibrium shifts in the endothermic direction, to the right.

This opposes the increase in temperature (it lowers the temperature).



Carbon dioxide can react with hydrogen to form methanol.



2.50 mol of CO_2 are mixed with 6.00 mol of H_2 in a sealed container with a volume of 4.60 dm^3

The mixture is left to reach equilibrium at a fixed temperature.

At equilibrium, 1.30 mol of CO_2 remain.

0 7 . 3

Give an expression for the equilibrium constant, K_c , for this reaction.

Calculate a value for the equilibrium constant at this fixed temperature.

Give the units of the equilibrium constant.

[6 marks]

Expression for K_c

$$K_c = \frac{[\text{CH}_3\text{OH}][\text{H}_2\text{O}]}{[\text{CO}_2][\text{H}_2]^3}$$

Calculation

$$n(\text{CO}_2) \text{ reacted} = 2.50 - 1.30 = 1.20 \text{ mol}$$

$$\text{At equilibrium: } n(\text{CO}_2) = 1.30, \quad n(\text{H}_2) = 6.00 - (3 \times 1.20) = 2.40 \text{ mol}$$

$$n(\text{CH}_3\text{OH}) = 1.20 \text{ mol}, \quad n(\text{H}_2\text{O}) = 1.20 \text{ mol}$$

$$[\text{CO}_2] = 1.30 \div 4.60 = 0.283 \text{ mol dm}^{-3}$$

$$[\text{H}_2] = 2.40 \div 4.60 = 0.522 \text{ mol dm}^{-3}$$

$$[\text{CH}_3\text{OH}] = [\text{H}_2\text{O}] = 1.20 \div 4.60 = 0.261 \text{ mol dm}^{-3}$$

$$K_c = (0.261 \times 0.261) \div (0.283 \times 0.522^3)$$

$$= 0.06805 \div 0.04014 = 1.70$$

$$\text{Units: } (\text{mol dm}^{-3})^2 \div (\text{mol dm}^{-3})^4 = \text{mol}^{-2} \text{ dm}^6$$

K_c 1.70

Units $\text{mol}^{-2} \text{ dm}^6$

11

Turn over ►



Section B

Answer **all** questions in this section.Only **one** answer per question is **allowed**.For each question **completely fill** in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 8

What is the formula of gallium sulfate(VI)?

[1 mark]

A $\text{Ga}_2(\text{SO}_4)_3$ B $\text{Ga}_3(\text{SO}_4)_2$ C $\text{Ga}_2(\text{SO}_3)_3$ D GaSO_4 

0 9

What is the mass, in kg, of 2000 m^3 of carbon monoxide gas at 100 kPa and 25 °C? $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

[1 mark]

A 2.261



B 2.696



C 2261



D 2696



1	0
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What is the percentage by mass of sodium in sodium sulfate(VI)?

[1 mark]

A 19.3

☐

B 22.3

☐

C 32.4

☒

D 36.5

☐

Turn over for the next question

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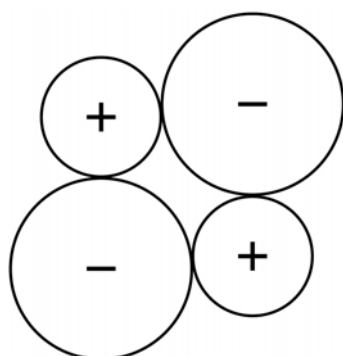


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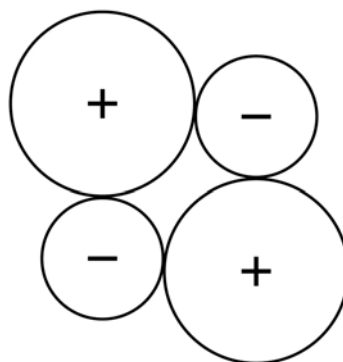
Which diagram best shows the arrangement and the relative sizes of the ions in solid sodium chloride?

[1 mark]

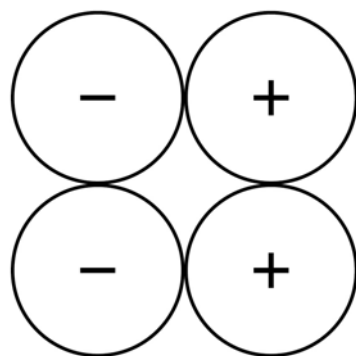
A



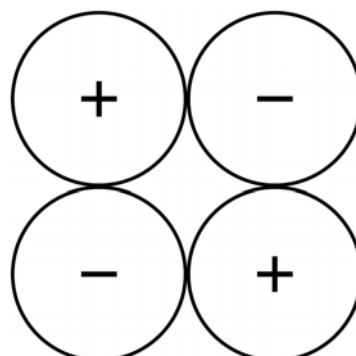
B



C



D



1 2

Which row shows the order of discovery?

[1 mark]

	Earliest	→	Latest	
A	electron	neutron	nucleus	☐
B	electron	nucleus	neutron	☒
C	nucleus	electron	neutron	☐
D	nucleus	neutron	electron	☐

1 3

What is the maximum mass of sodium chloride that can be made from 10.0 g of sodium and 10.0 g of chlorine?

[1 mark]

- A** 8.24 g ☐
- B** 16.5 g ☒
- C** 20.0 g ☐
- D** 25.4 g ☐

1 4

Which Period 3 element has these successive ionisation energies?

[1 mark]

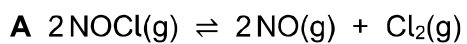
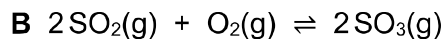
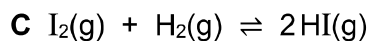
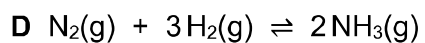
	1st	2nd	3rd	4th	5th	6th
Ionisation energy / kJ mol ⁻¹	786	1580	3230	4360	16 000	20 000

- A** Al ☐
- B** Si ☒
- C** P ☐
- D** S ☐

Turn over ►

1 5

Which equilibrium has a lower yield of product when the pressure in the system is increased at constant temperature?

[1 mark]☒☐☐☐**1 6**

Which element has atoms that contain only two unpaired electrons?

[1 mark]

A cobalt

☐

B magnesium

☐

C nickel

☒

D phosphorus

☐**1 7**

Which silver halide(s) react(s) with concentrated ammonia solution to form a colourless solution?

[1 mark]

A silver chloride only

☐

B silver chloride and silver bromide

☒

C silver bromide and silver iodide

☐

D silver iodide only

☐

1 8

The reaction between hydrochloric acid and sodium hydroxide is exothermic.

Which row shows the solutions that will give the greatest temperature increase when mixed?

[1 mark]

	HCl(aq)		NaOH(aq)		
	Volume / cm ³	Concentration / mol dm ⁻³	Volume / cm ³	Concentration / mol dm ⁻³	
A	200	1.0	200	1.0	☐
B	50	1.0	50	1.0	☐
C	50	1.5	100	1.0	☐
D	50	1.5	50	1.5	☒

1 9

Which of these molecules is polar?

[1 mark]

- A** BF₃ ☐
- B** CO₂ ☐
- C** CCl₄ ☐
- D** SCl₂ ☒

2 0

Which statement about SO₂ acting as a reducing agent is correct?

[1 mark]

- A** SO₂ gains electrons and the oxidation state of sulfur decreases. ☐
- B** SO₂ gains electrons and the oxidation state of sulfur increases. ☐
- C** SO₂ loses electrons and the oxidation state of sulfur decreases. ☐
- D** SO₂ loses electrons and the oxidation state of sulfur increases. ☒

Turn over for the next question

Turn over ►



2	1
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A student is asked to prepare a solution of hydrochloric acid with a concentration of $0.0400 \text{ mol dm}^{-3}$

What volume of distilled water should the student add to 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid to prepare this solution?

[1 mark]

A 25 cm^3

☐

B 50 cm^3

☐

C 1225 cm^3

☒

D 1250 cm^3

☐

2	2
---	---

At temperature T and pressure P , 0.287 g of nitrogen has a volume of 25.0 cm^3

Which quantity of substance at temperature T and pressure P contains the same number of **atoms** as 0.287 g of nitrogen in 25.0 cm^3 ?

[1 mark]

A 25.0 cm^3 of argon

☐

B 1.312 g of sulfur dioxide

☐

C 0.287 g of carbon dioxide

☐

D 25.0 cm^3 of oxygen

☒

15

END OF QUESTIONS



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outside the
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ANSWER IN THE SPACES PROVIDED**



[illegible]

[illegible]