

IDEAL GASES AND THERMAL PROPERTIES

— PART ONE —

The Motion of Gas Particles

Gas particles are in **constant, random motion**. Their movement can be described using the **kinetic molecular theory**.

Constant motion

- Gas molecules are in **constant motion** and collide with each other and the walls of the container
- Particles move randomly and frequently change direction when they collide

Forces of attraction

- There are **forces of attraction** between molecules

Different speeds

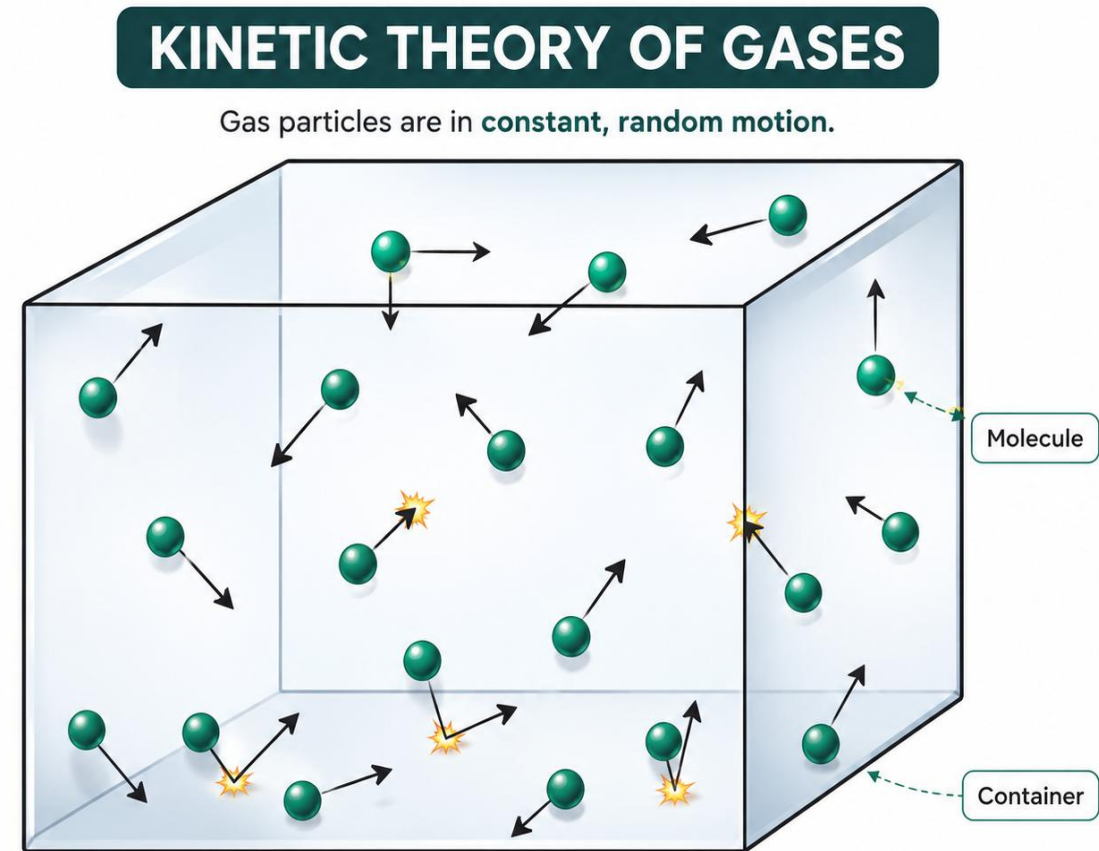
- Molecules in a gas **move at different speeds**.

Large spaces between particles

- Gas particles are far apart compared with their size.

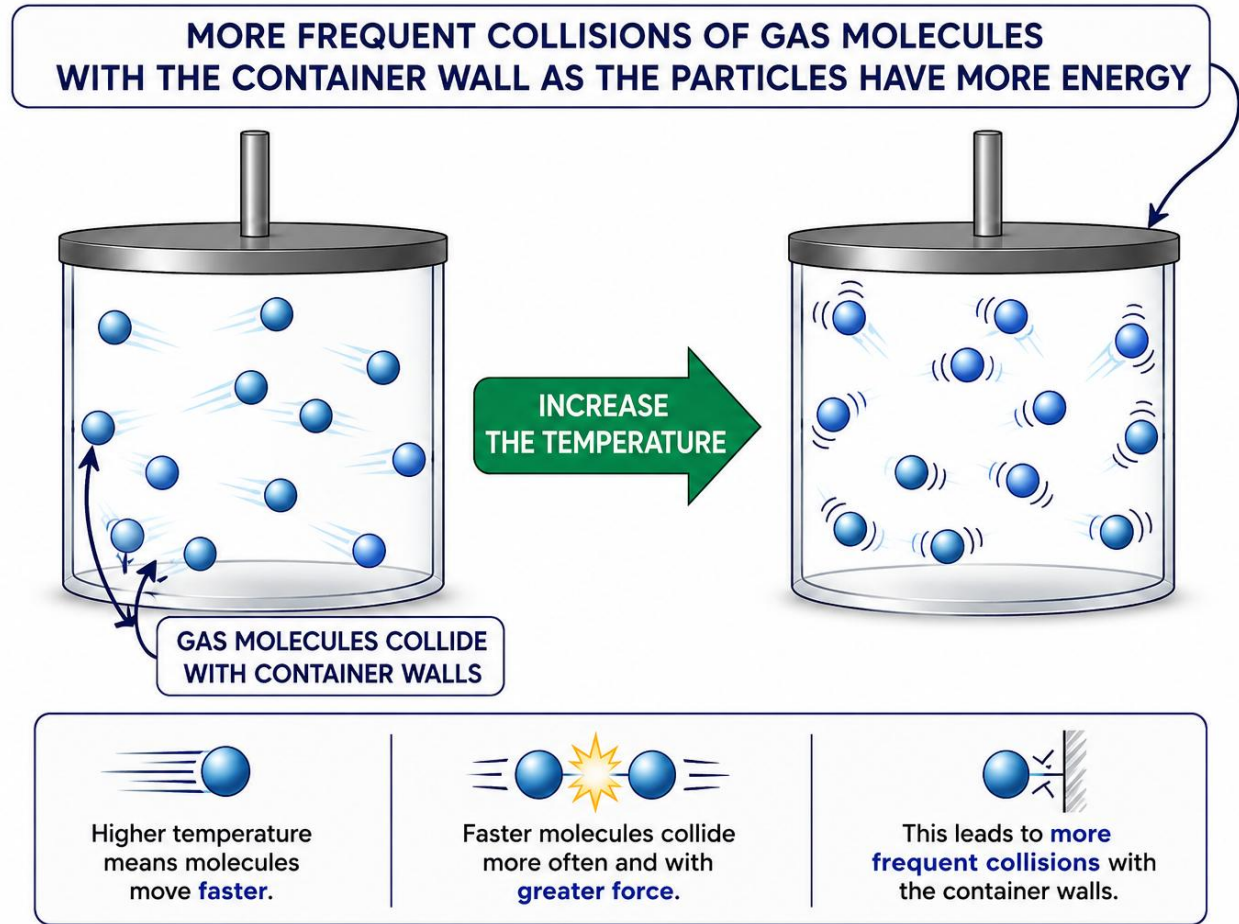
Collisions are elastic

- When particles collide with one another or with the walls of a container, there is no overall loss of kinetic energy.



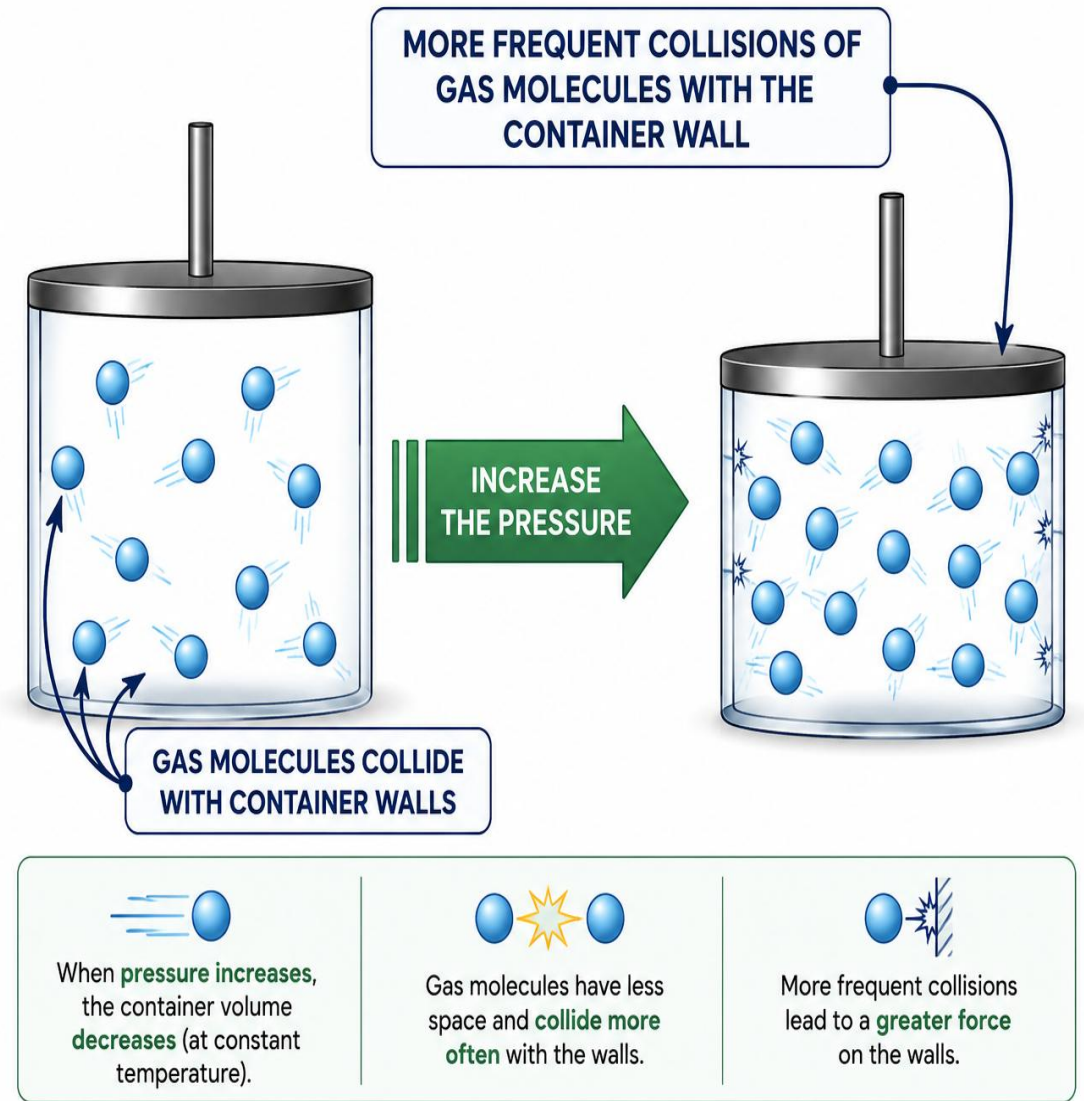
Temperature of a gas

- The temperature of a gas defined as the measure **average kinetic energy** of the molecules of the gas.
- When the **temperature of a gas increases**, the particles **gain** kinetic energy.
- The particles therefore **move faster**.
- Faster-moving particles collide with the container walls **more frequently**.
- These collisions also occur with **greater force**.
- **At a lower temperature** particles have less average kinetic energy and move **slower**.
- Temperature is measured in Kelvins (K) or degrees Celcius (°C)



Pressure of a gas

- Gas pressure is caused by gas particles colliding with the walls of their container.
- When the volume of a gas decreases, the particles have less space to move.
- The particles therefore collide with the container walls more frequently.
- More frequent collisions result in a greater force being exerted on the walls.
- The pressure of a gas is the force the gas exerts on the walls of its container due to the collision of the particles with the walls
- Pressure(P) is measured in Pascal (Pa)

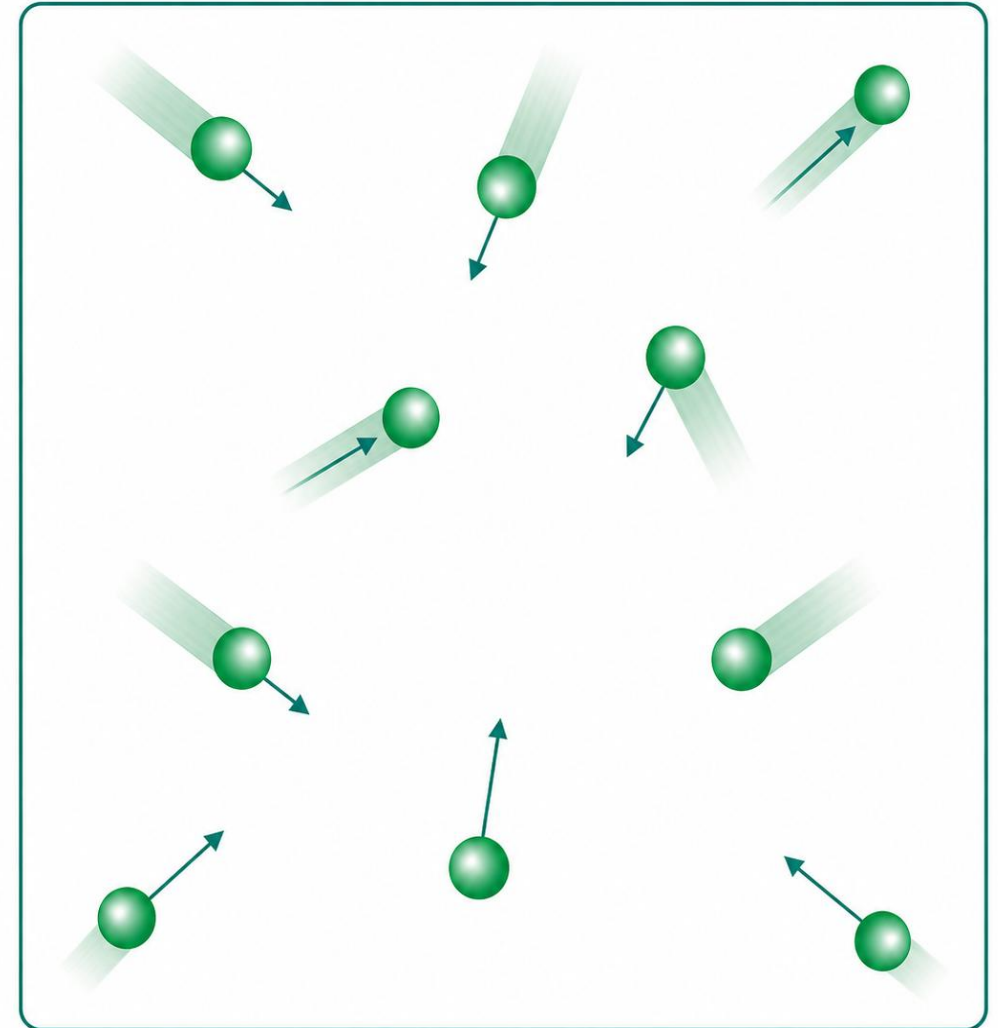


Ideal Gas

- An ideal gas is a theoretical concept describing a **gas that perfectly obeys all gas laws under all conditions.**
- It serves as a simplified model for understanding gas behavior, **particularly at relatively high temperatures and low pressures.**
- It makes certain assumptions, the most important of which are:
 1. The particles are **identical and are in constant motion.**
 2. The gas particles are **small and they have zero volume**
 3. There are **no intermolecular forces** between the particles.
 4. All **collisions of the molecules** with themselves or the walls of the container, **are perfectly elastic** i.e., there is no loss of total kinetic energy.

Ideal Gas

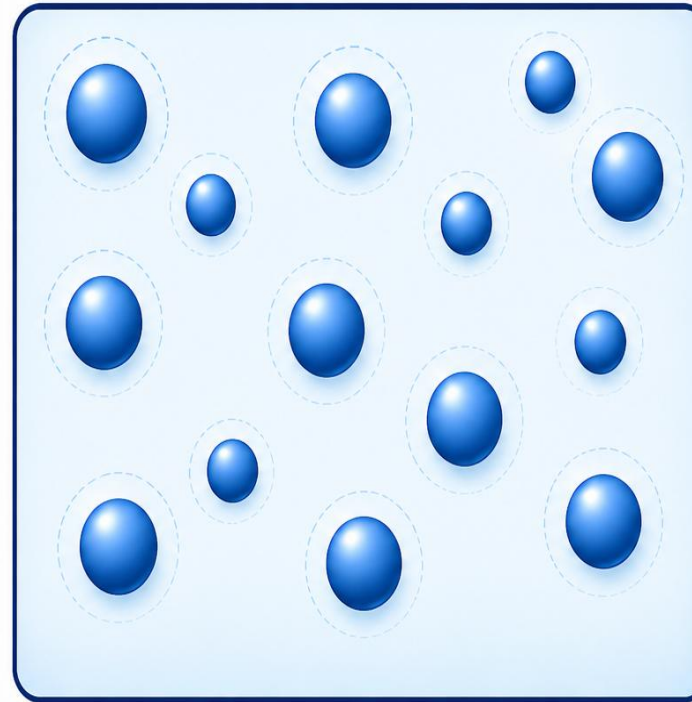
In an ideal gas, particles are far apart and move in random, **straight-line motion** in all directions.



Real Gase

- A real gas is an actual gas found in nature that does not strictly follow the ideal gas law.
- Its molecules take up real space and pull on each other with small force
- ❖ Real gases can be defined as **non-ideal gases** whose molecules occupy a **given amount of space and can interact with each other**

Real Gas



Irregularly spaced molecules
Molecules are randomly distributed.



Finite molecular volume
Molecules occupy a measurable space.



Intermolecular forces
Attractive forces exist between molecules.



Key Point:

Real gases deviate from ideal behaviour because their molecules have volume and attract each other.

REAL GAS vs IDEAL GAS

Comparing the behaviour of real gases and ideal gases

REAL GAS



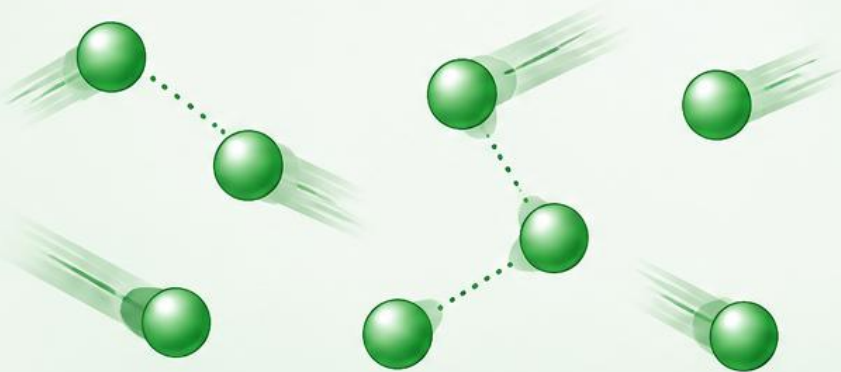
Particles have **volume**



Energy **lost** in collisions



Intermolecular **forces** exist



Real gases show deviations from ideal behaviour.

IDEAL GAS



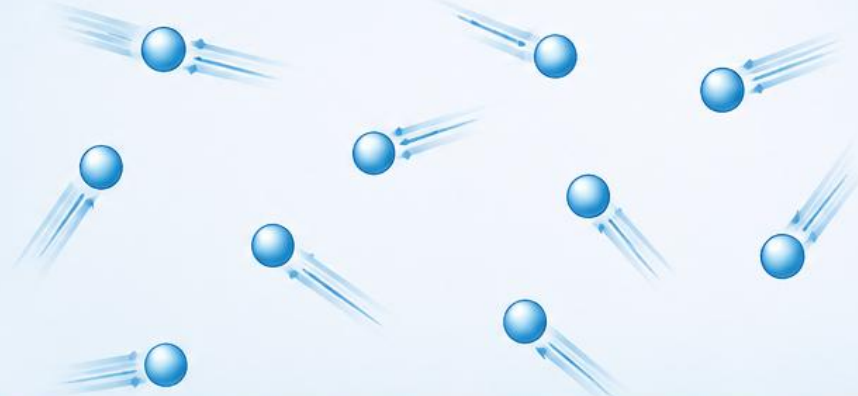
Particles have **no volume**



Collisions are **elastic**



No interactions between particles



Ideal gases follow the assumptions of the kinetic molecular theory exactly.



Key Point:

Real gases behave like ideal gases at **low pressure and high temperature**, where intermolecular forces and volume become negligible.

When do real gases behave most like ideal gases?

Real gases approach ideal behaviour at:

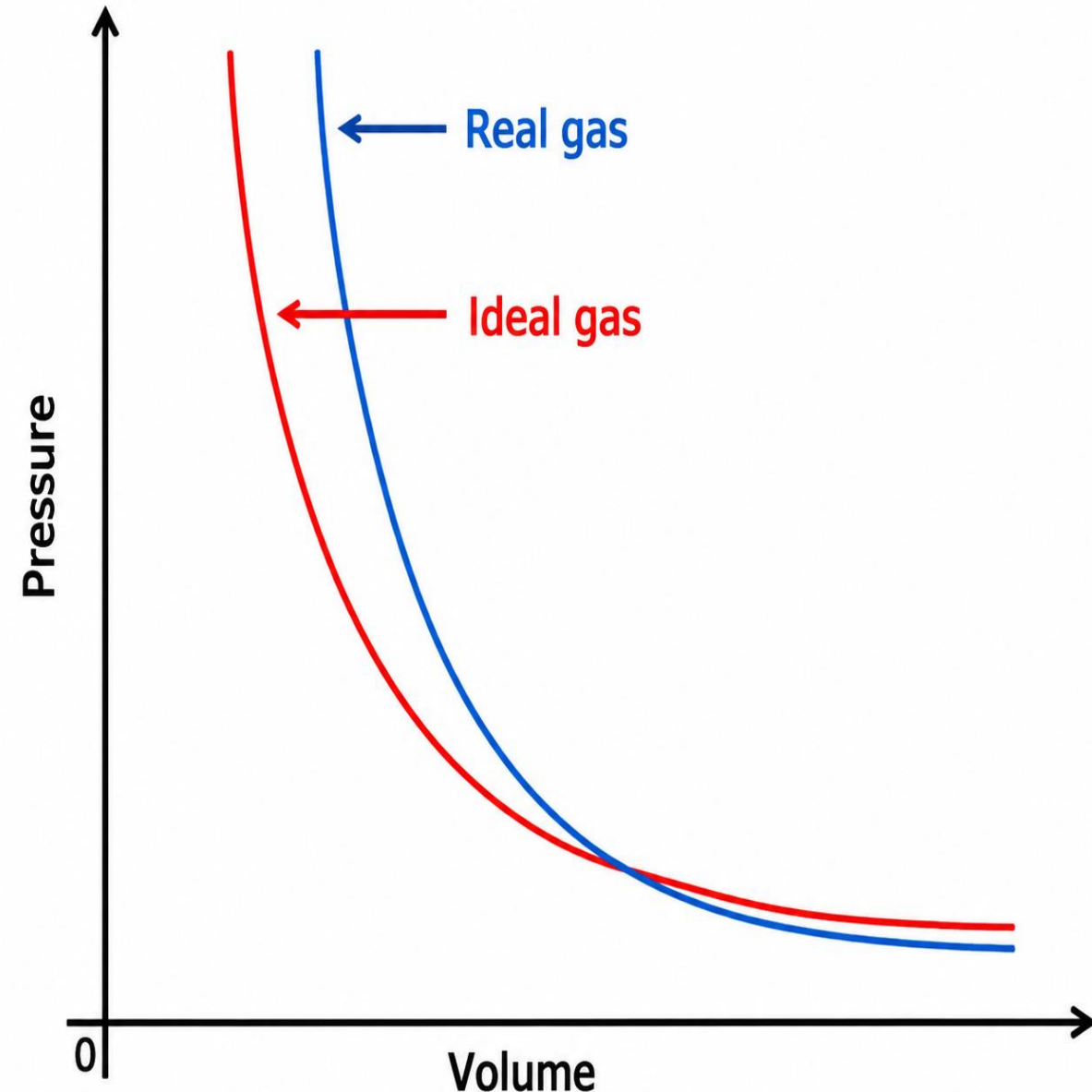
High temperatures

- Temperature is an indication of the average kinetic energy of the molecules of a gas.
- At high temperatures particles move faster, reducing the effect of attractive forces
- If the temperature of a gas decreases, the molecules move slower and closer together up to a point where the gas will start to condense and **not** behave like an ideal gas.

Low pressures

- At low pressure, particles are far apart, so their volume and intermolecular forces become less significant.
- The volume of the particles is most significant at high pressure

Plot of pressure vs volume of for **real gas** and **ideal gas**

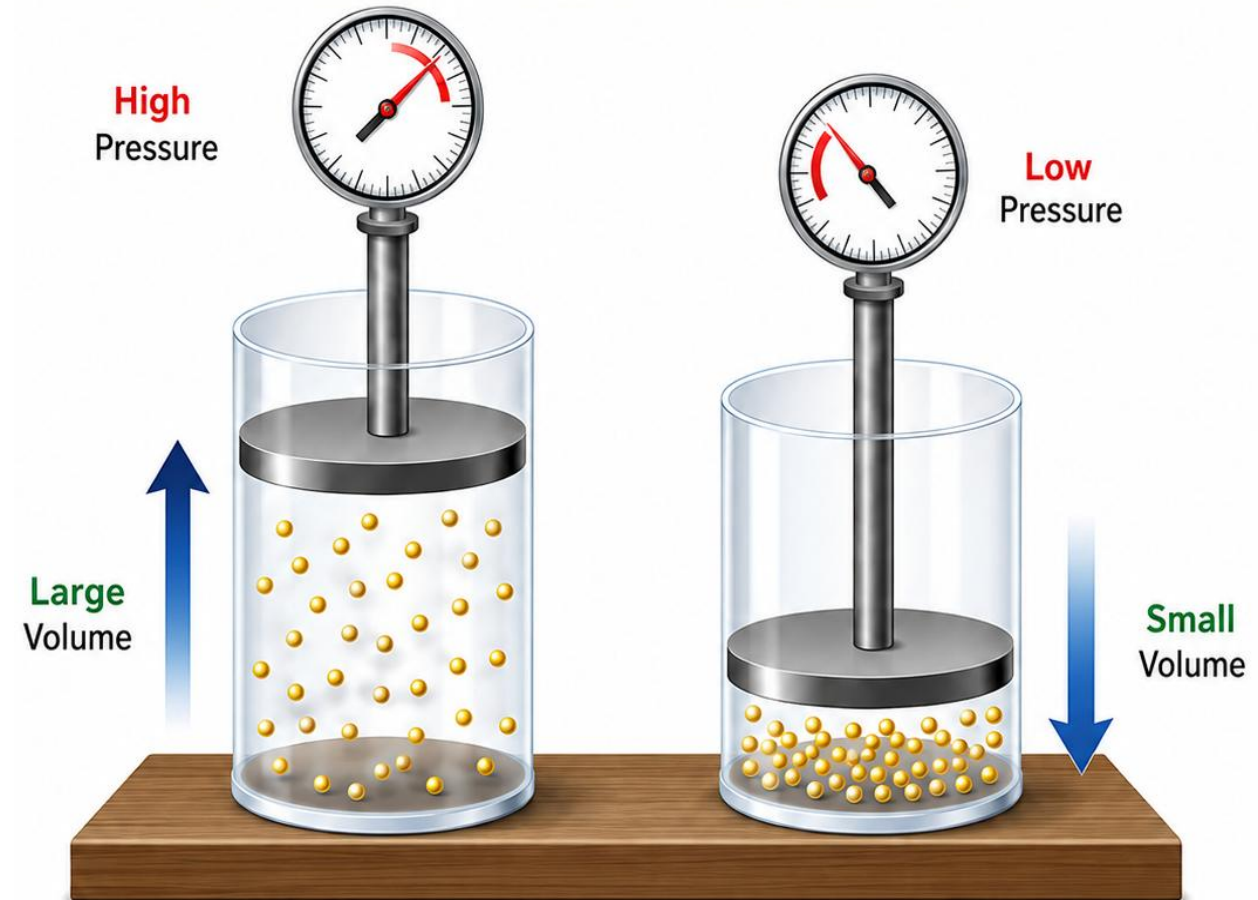


Boyle's Law

- Boyle's law is a gas law which relates **the pressure exerted by a gas** (of a given mass, kept at a constant temperature) and **the volume occupied by it**.
- Boyle's law states that the pressure of an enclosed gas is **inversely proportional to the volume it occupies at constant temperature**.
- As per Boyle's law, **any change in the volume** occupied by a gas (at constant quantity and temperature) will result in a **change in the pressure** exerted by it.

BOYLE'S LAW

For a fixed mass of gas at constant temperature, **pressure** is **inversely proportional** to **volume**.



$$P \propto 1/V$$

$$P_1 V_1 = P_2 V_2$$

P = Pressure

V = Volume

Boyles Law Formula

Constant Temperature

- The temperature and the amount (mass) of the gas must not change.

Inverse Relationship

- If volume goes up, pressure goes down. If volume goes down, pressure goes up.

BOYLE'S LAW

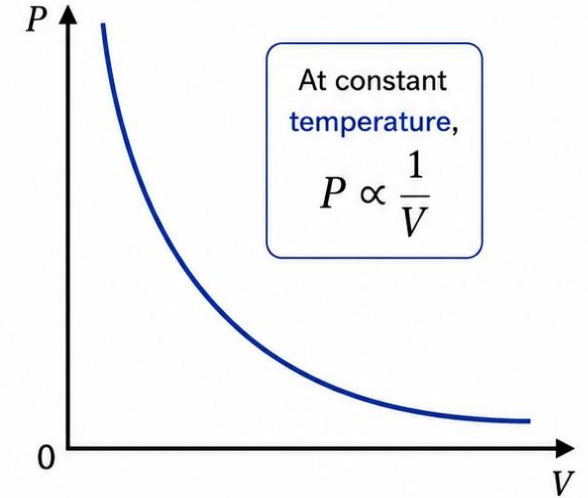
For a fixed mass of gas at **constant temperature**, the pressure of a gas is **inversely proportional** to its volume.

MATHEMATICAL FORM

$$PV = k$$

or

$$P \propto \frac{1}{V}$$



$$P_1 V_1 = P_2 V_2$$

- P = Pressure of the gas (Pa)
 V = Volume of the gas (m^3)
 k = Constant (for a given mass of gas at a given temperature)
 P_1, V_1 = Initial pressure and volume
 P_2, V_2 = Final pressure and volume

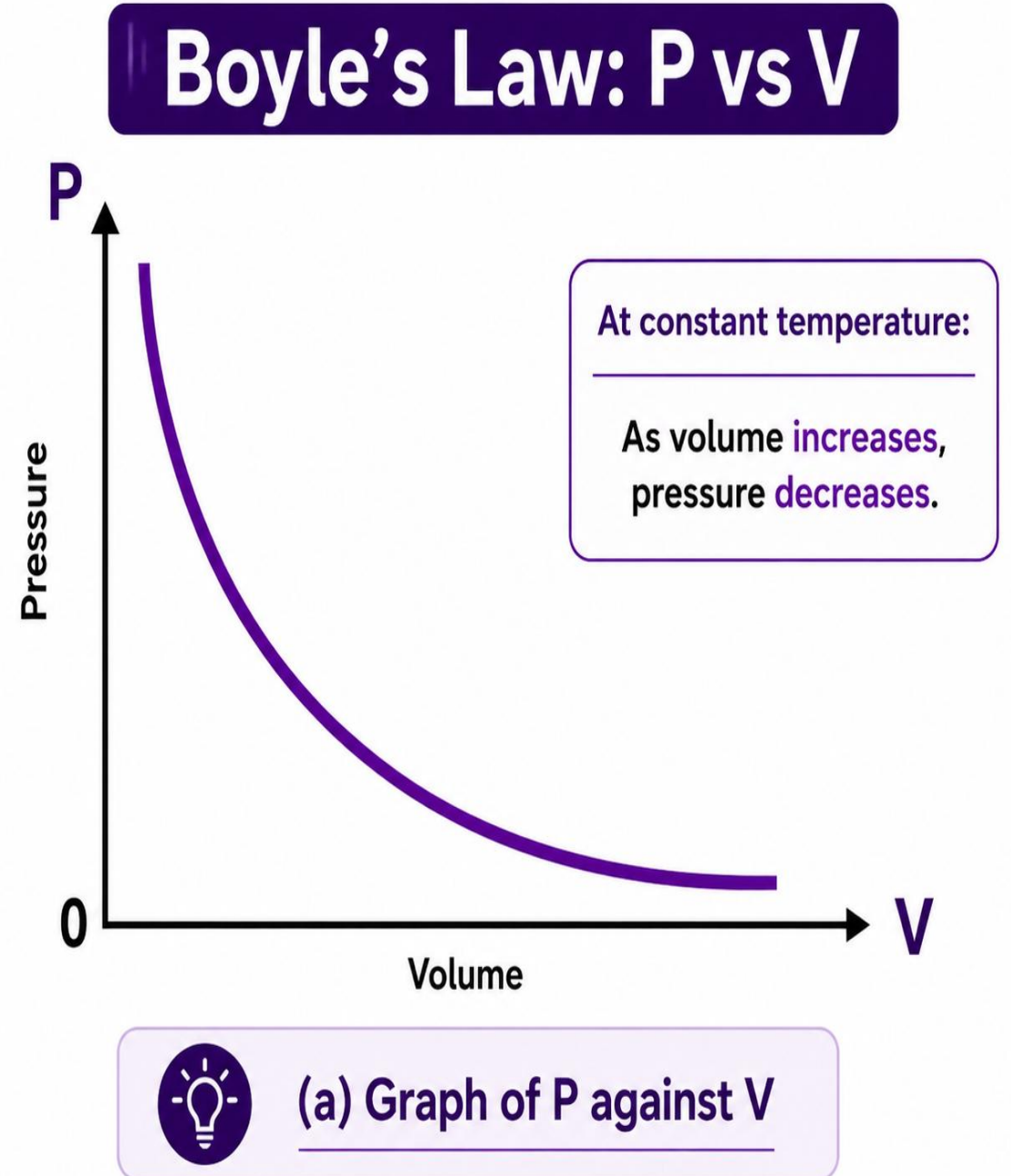
CONDITIONS

Temperature = constant
Mass of gas = constant

Boyle's Law Graphs

Pressure vs Volume

- When **pressure P** is plotted against **volume V** at constant temperature :
- The graph is a **curved inverse relationship**.
- As **volume increases**, **pressure decreases**.
- As **volume decreases**, **pressure increases**.
- The curve is a **hyperbola**.

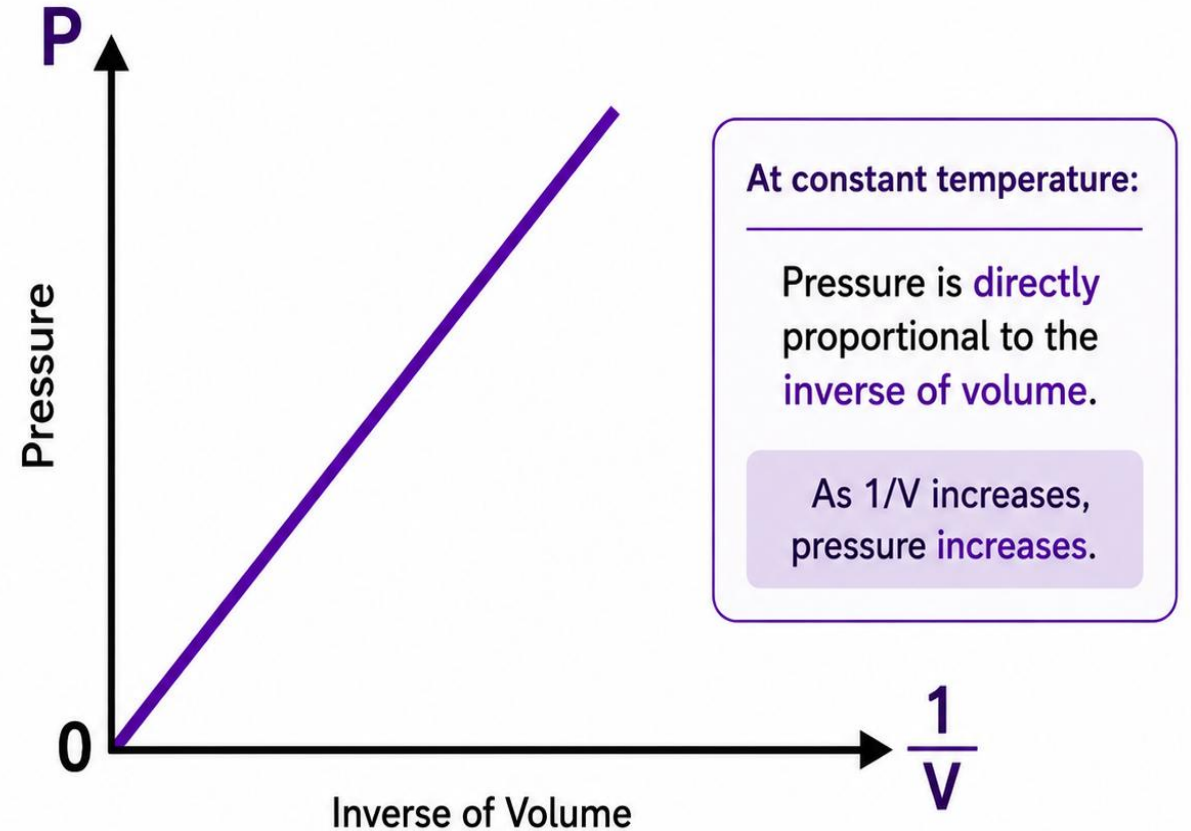


Pressure vs 1/V

When **pressure P** is plotted against $\frac{1}{V}$:

- The graph is a **straight line**.
- The line passes through the **origin**.
- This confirms that P is directly proportional to $\frac{1}{V}$.

Boyle's Law: P vs 1/V



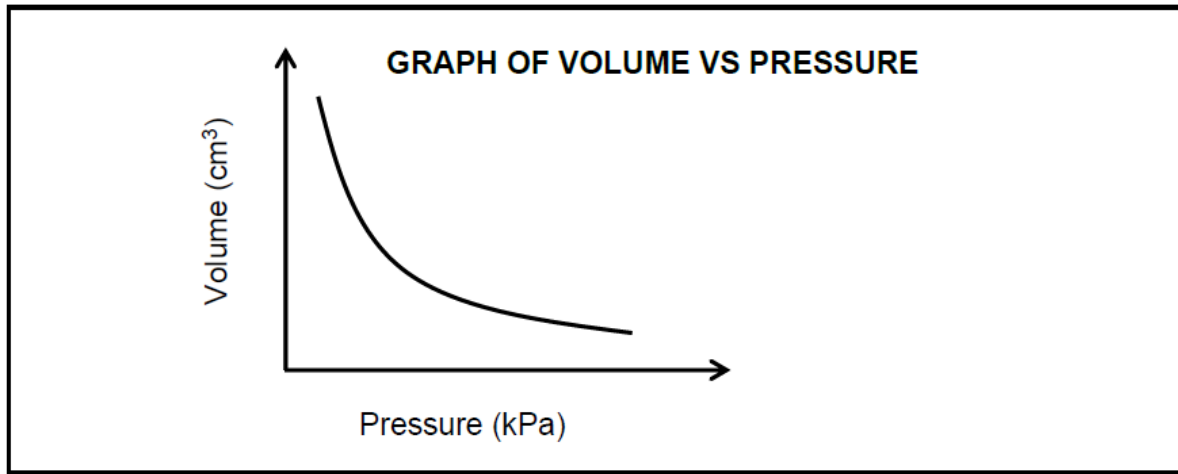
(a) Graph of P against $\frac{1}{V}$

PAST EXAM PAPERS

2019 Eastern Cape Exemplar Paper 2 Q 4.1

4.1 An experiment was conducted to investigate the relationship between pressure and volume of a fixed gas at a constant temperature of $20,5^{\circ}\text{C}$.

The following graph was obtained from the results.



4.1.1 Write down the name of the law which formulates the pressure-volume relationship shown by the graph. (1)

For the investigation write down the:

4.1.2 Investigative question (2)

4.1.3 Controlled variable (1)

4.1.4 Explanation for the relationship between pressure and volume as shown by the graph using the Kinetic Molecular Theory. (3)

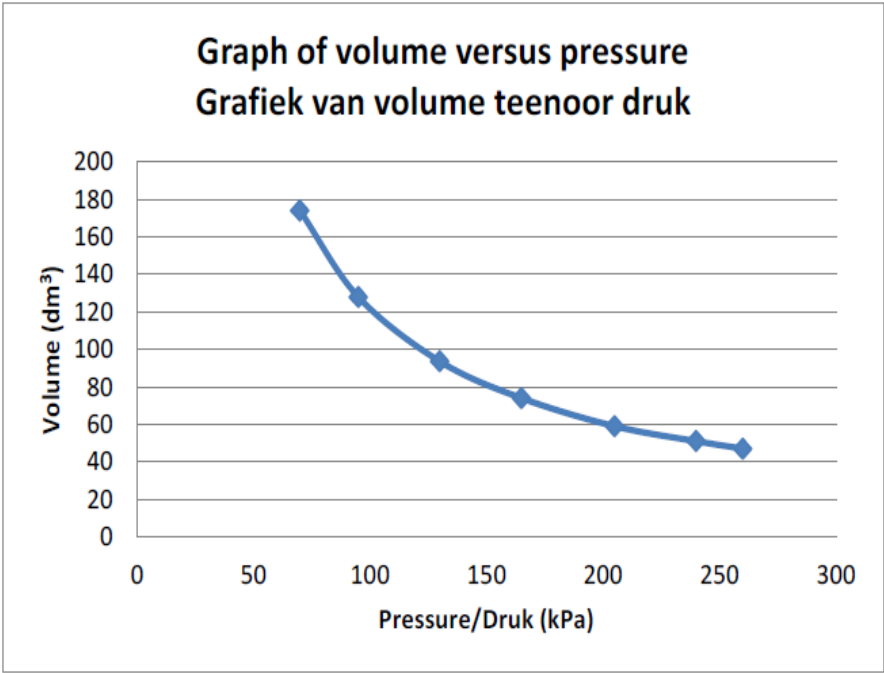
2018 November Paper 2 Q 4.1-4.7

A certain amount of gas is sealed in a container of which the volume can change. The relationship between the pressure and volume of the gas at 20°C is investigated. The results of the experiment are given in the table below

PRESSURE (kPa)	VOLUME (dm ³)
70	174
95	128
130	93,6
165	74
205	59
240	51
260	47

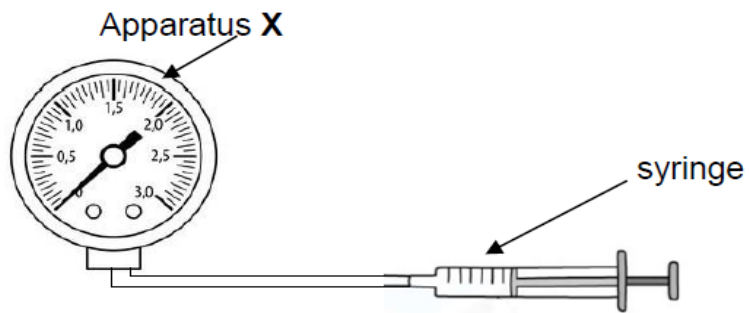
- 4.1 Name the gas law that is represented by the results of the experiment. (1)
- 4.2 Write down a hypothesis for the investigation. (2)
- 4.3 Draw a graph of volume versus pressure on the ANSWER SHEET attached. (3)
- 4.4 Calculate the volume of the gas at 300 kPa. (3)
- 4.5 When the volume of the gas is measured at 300 kPa, it is 44 dm³. Explain why the measured volume differs from the volume calculated in QUESTION 4.4. (2)

- 4.6 Which temperature condition will cause a gas to deviate from ideal behaviour? Write only HIGH or LOW. (1)
- 4.7 Explain the answer to QUESTION 4.6. (2)



2023 Eastern Cape November Paper 2 Q 4

A group of learners investigate the relationship between the pressure and the volume of a gas. The gas syringe is connected to apparatus X as shown below



The learners vary the volume and record the pressure and volume. They calculated the inverse of the volume and recorded it with the pressure readings in table shown below.

	Pressure (kPa)	1/volume (cm ⁻³)
1	92,5	0,05
2	111	0,06
3	129,5	0,07
4	148	0,08

4.1 Write down the name of the gas law that is being investigated. (1)

4.2 For this investigation, write down ONE controlled variable. (1)

4.3 Give the name of apparatus X. (1)

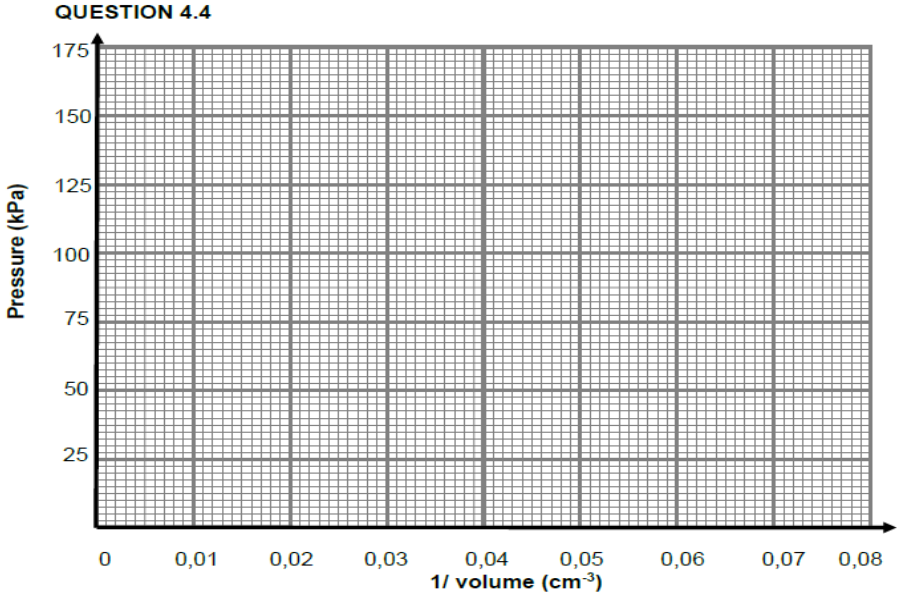
CONTINUED.....

4.4 Use the data in the table and draw a pressure against 1/ volume graph on the attached ANSWER SHEET marked ANNEXURE A. (4)

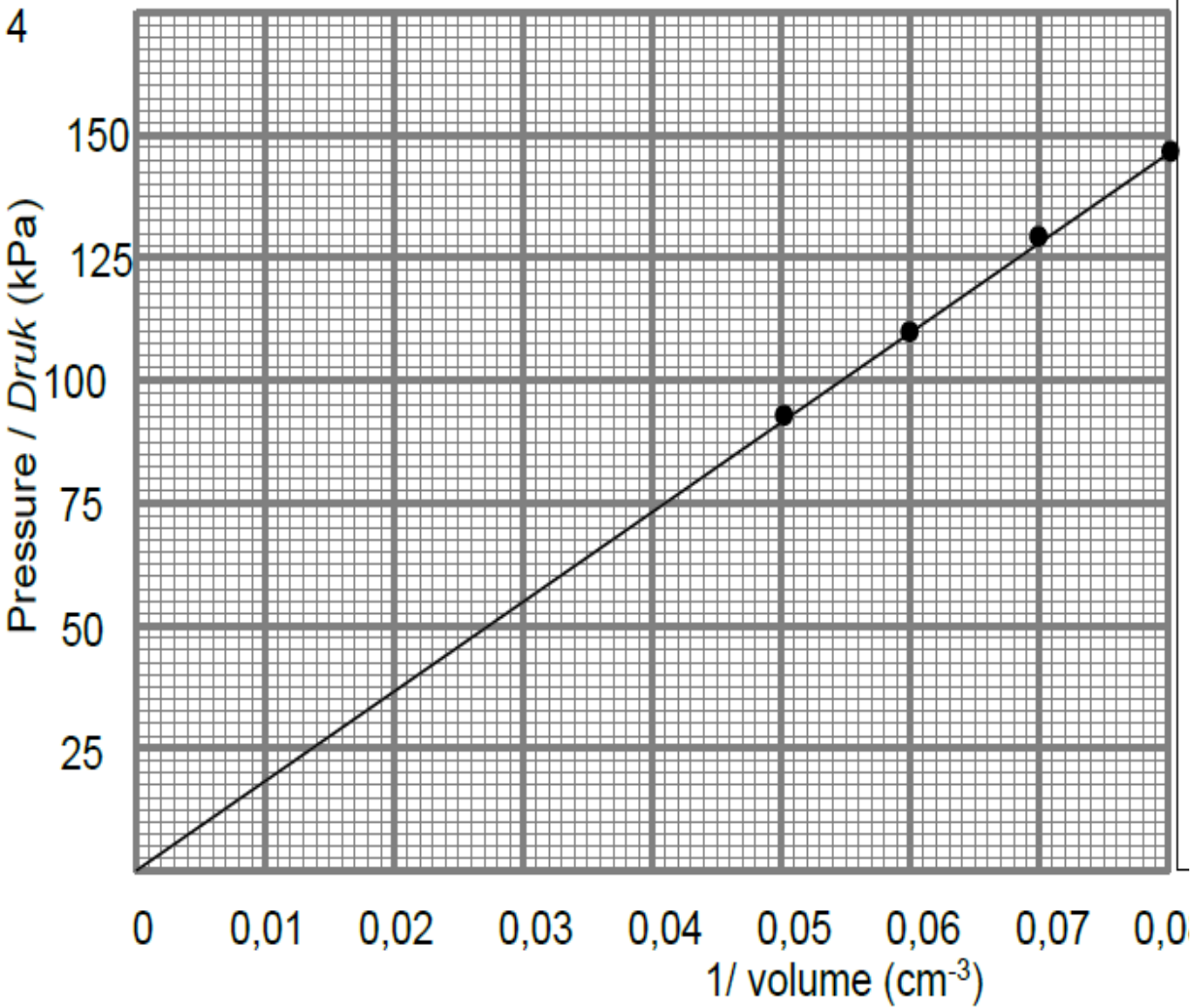
4.5 Using information from the graph write down the learners’ conclusion. (2)

4.6 Calculate the volume of the gas at a pressure of 184 kPa. (4)

	Pressure (kPa)	1/volume (cm ⁻³)
1	92,5	0,05
2	111	0,06
3	129,5	0,07
4	148	0,08

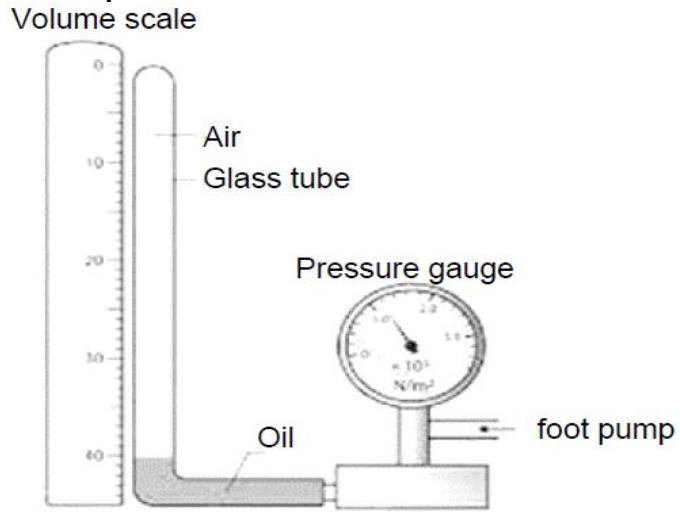


4. 4

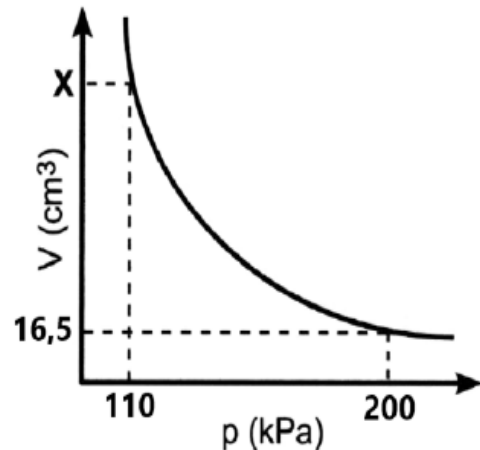


2023 Gauteng November Paper 2 Q 4

Learners conducted an investigation to determine the relationship between the pressure and volume of a given mass of O_2 gas, while keeping the temperature constant.



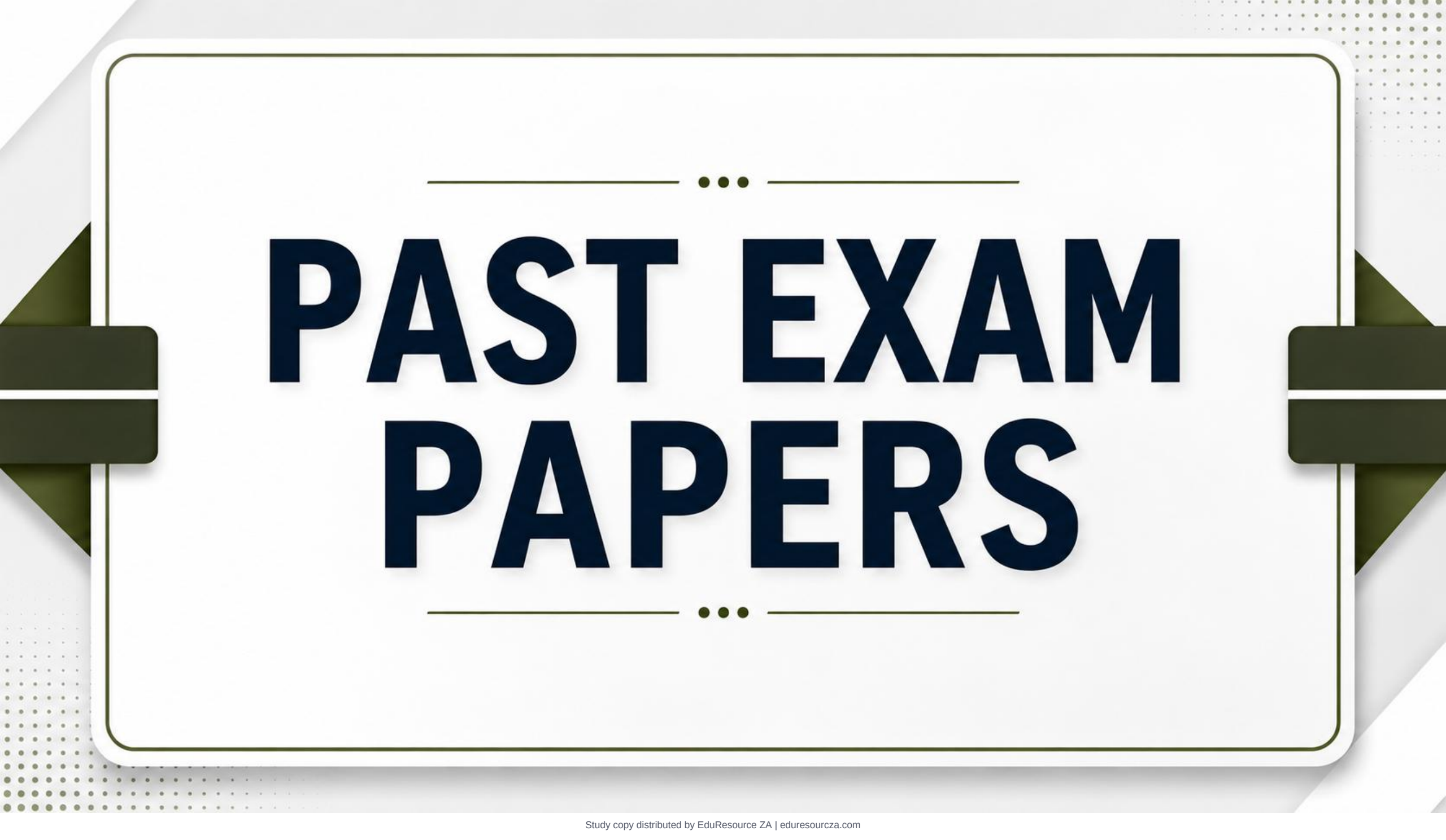
They made the sketch graph below, to show their results:



- 4.1. Write a suitable investigative question for this investigation. (2)
- 4.2. Write down the:
 - 4.2.1 Independent variable (1)
 - 4.2.2 Controlled variable (1)
- 4.3 Name and state the law that is being investigated here. (3)
- 4.4 Calculate the value of **X** using other values given on the graph. (3)

IDEAL GASES AND THERMAL PROPERTIES

PART TWO



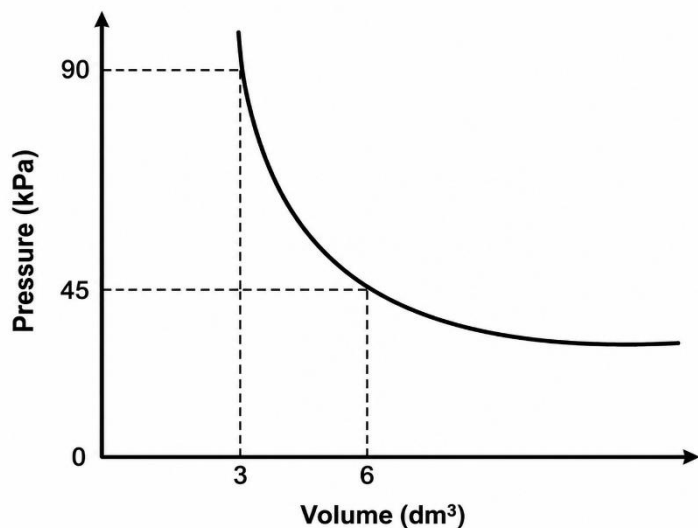
...

PAST EXAM PAPERS

...

2023 Limpopo Capricorn North September Paper 2 Q 4

The graph below represents the relationship between the pressure and the volume of oxygen gas at constant temperature.



7.1 State Boyle's law in words (2)

7.2 Write down the mathematical expression, in symbols for the relationship between the variables on the graph (1)

7.3 Write down two variables that must be kept constant during this investigation (2)

7.4 Define the pressure exerted by a gas (2)

7.5 Calculate the pressure in kPa, exerted on the gas when it is compressed to 5 dm³. (4)

7.6 State the conditions under which real gases approach ideal gas behaviour (2)

7.7 Tabulate the differences between ideal gases and real gases. (6)

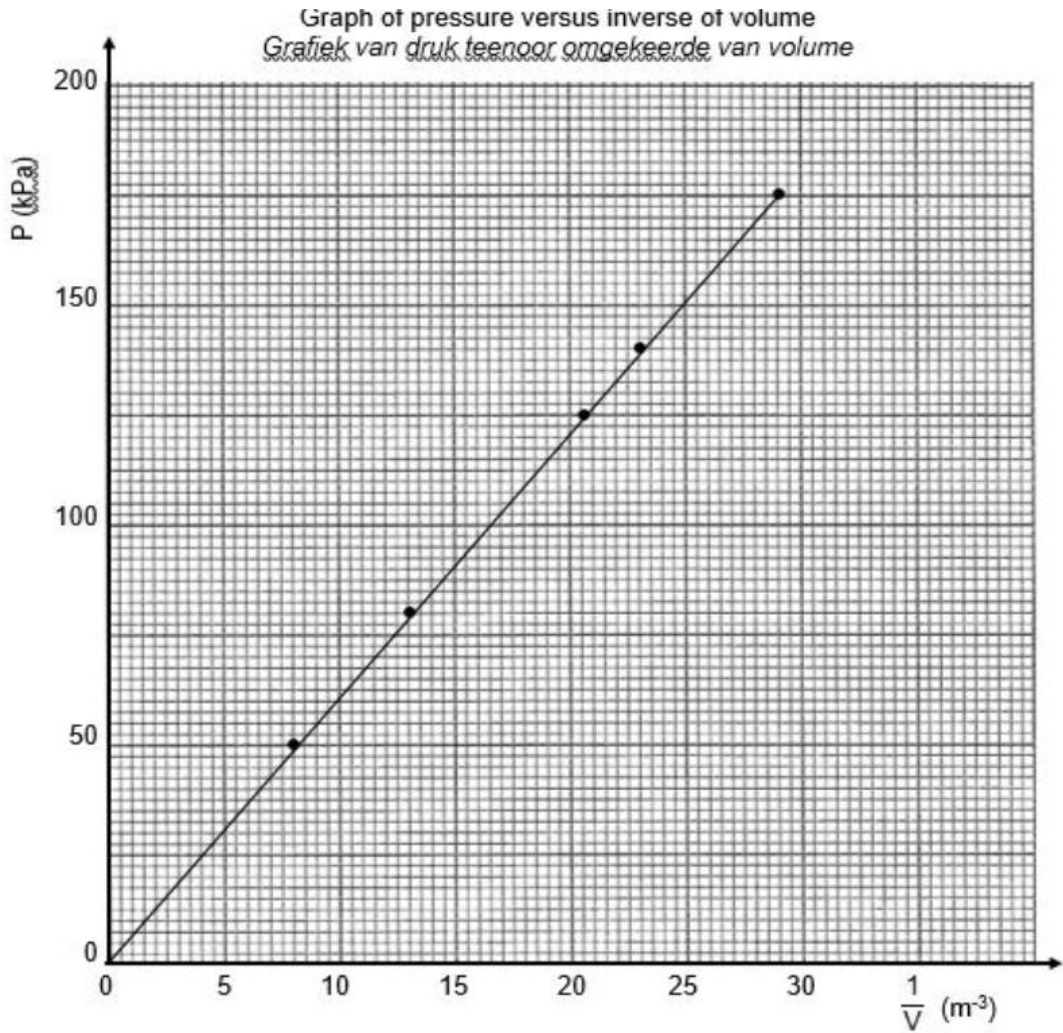
7.8 Give a reason why oxygen gas deviates from ideal gas at low temperatures. (1)

2019 November Paper 2 Q 4.1-4.4

The relationship between pressure and volume of an enclosed gas at 25 °C is investigated. The results obtained are shown in the table below.

PRESSURE (kPa)	VOLUME (m ³)	$\frac{1}{V}$ (m ⁻³)
50	0,121	8,2
80	0,076	13,2
125	0,049	20,6
140	0,043	23,1
175	0,035	28,8

- 4.1 State *Boyle's law* in words. (2)
- 4.2 ANSWER THIS QUESTION ON THE ATTACHED GRAPH PAPER.
Use the data in the table above to draw a graph of pressure (p) versus the inverse of the volume $\frac{1}{V}$ (on the attached graph paper). (3)
- 4.3 Which physical quantity can be determined from the gradient of the graph? Give a reason for the answer. (2)
- 4.4 It is found that, at high pressures, the shape of the graph deviates from that of the graph obtained in QUESTION 4.2. Explain this deviation. (3)



2022 KwaZulu Natal November Paper 2 Q 9

A researcher investigates the relationship between the pressure (p) and volume (V) of carbon tetrachloride (CCl₄) at a temperature of 200°C. The researcher varies the pressure, and records the volume of the CCl₄ to obtain the following results:

Result	P(kPa)	V(cm ³)
A	15	160
B	20	120
C	25	96
D	30	88
E	35	68,6

9.4.2 By means of a calculation, determine what the correct volume reading should be for the result identified in QUESTION 9.4.1 (3)

9.1 What is the name of the law under investigation? (1)

9.2 Write a suitable investigative question for this investigation. (2)

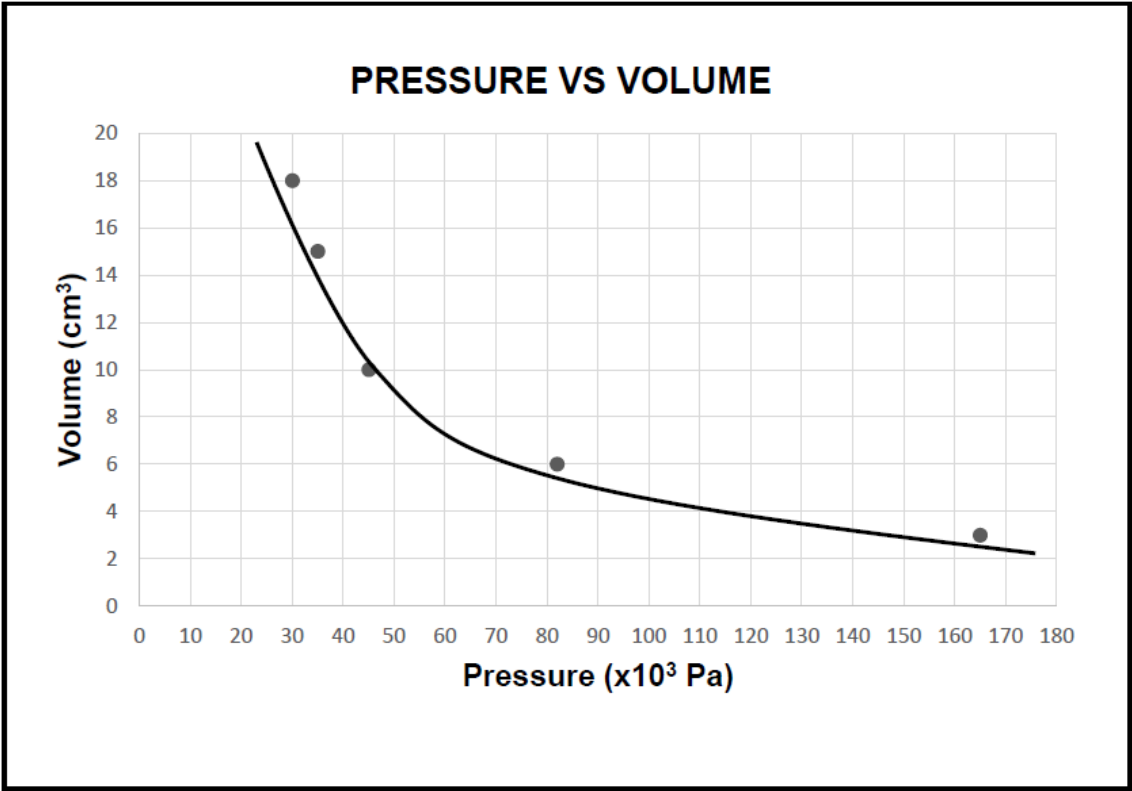
9.3 Give a reason why the experiment must be conducted at a high temperature (1)

9.4 For the results obtained, the first volume reading (A) is correct while one of the remaining volume readings is incorrect

9.4.1 For which result is the volume reading INCORRECT? Choose B,C,D or E (1)

2024 Eastern Cape November Paper 2 Q 4

Learners investigated the relationship between pressure and volume of a gas. The graph below shows the results obtained during the investigation.

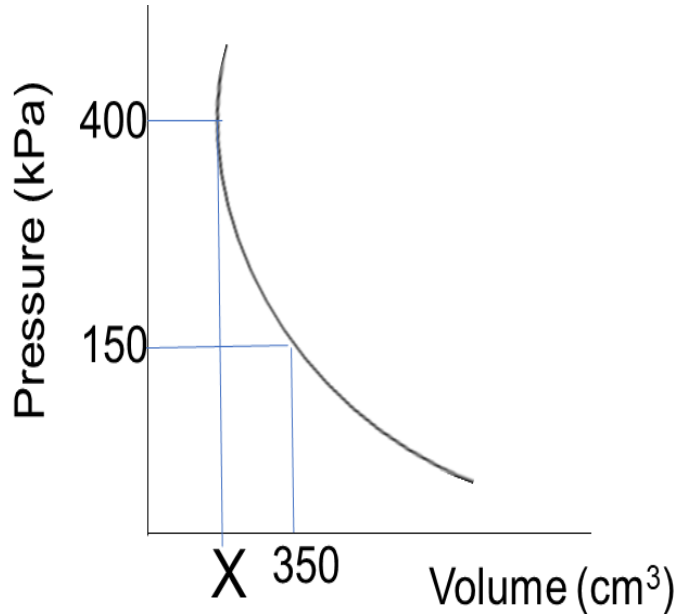


- 4.1 Name and state the law the experiment is based on. (3)
- 4.2 Write down a hypothesis for this investigation. (2)
- 4.3 Read and write down the pressure from the graph when the volume is 12 cm^3 . (1)

- 4.4 Calculate the volume at 200 kPa. (4)
- 4.5 Redraw the above graph and label it **A**.
On the same set of axes draw the graph to show how a real gas will deviate at a high pressure. Label this graph as **B**. (2)

2021 Gauteng November Paper 2 Q 4

Learners conducted an investigation to determine the relationship between the pressure and volume of a given mass of gas, while keeping the temperature constant. They plotted their results as shown in the graph below



4.1 Write a suitable investigative question for this investigation. (2)

4.2 Write down the following:

4.2.1 Independent variable (1)

4.2.2 Controlled variable (1)

4.3 State, in words, the law that is being investigated. (2)

4.4 Calculate the value of X using other values given on the graph. (3)

4.5 Like all real gases, this gas will liquefy under high pressures. Explain why this happens. (2)

2015 November Paper 2 Q 4.1-4.4

A learner investigates the relationship between the pressure and volume of an enclosed DIATOMIC gas at 25 °C. He records the volume of the gas for different pressures in the table below.

PRESSURE (kPa)	VOLUME (cm ³)	$\frac{1}{V}$ (cm ⁻³)
40	43	0,02
80	27	0,04
100	22	(a)
120	18	(b)

4.1 Write down the name of the gas law being investigated. (1)

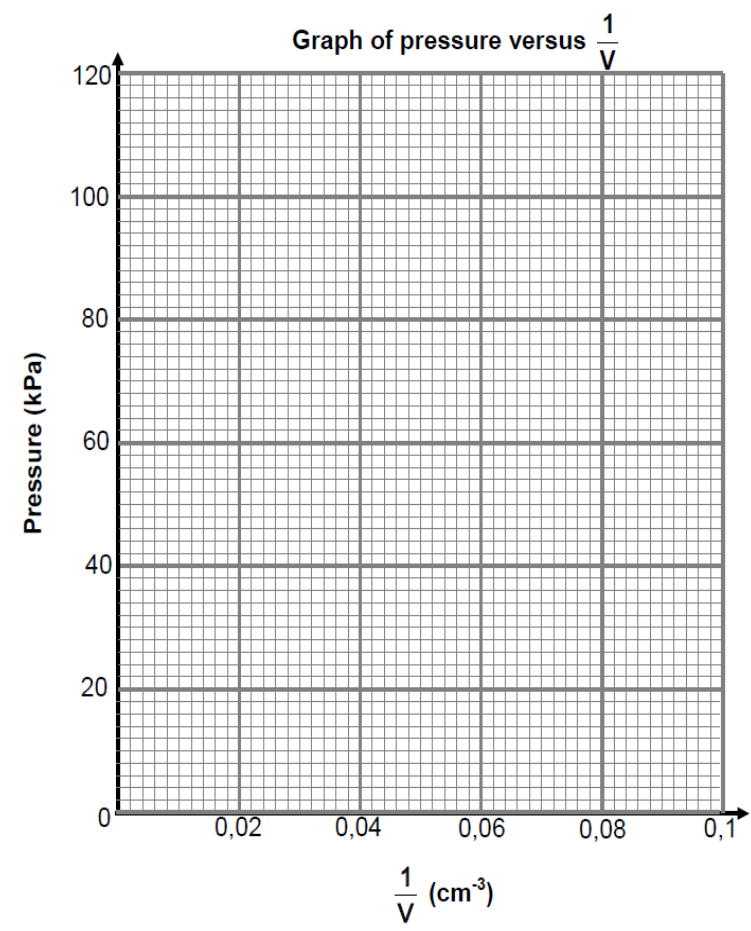
Answer QUESTION 4.2 and QUESTION 4.3 on the attached ANSWER SHEET.

4.2 Two $\frac{1}{V}$ values in the table, (a) and (b), have not been calculated. Calculate these values. (1)

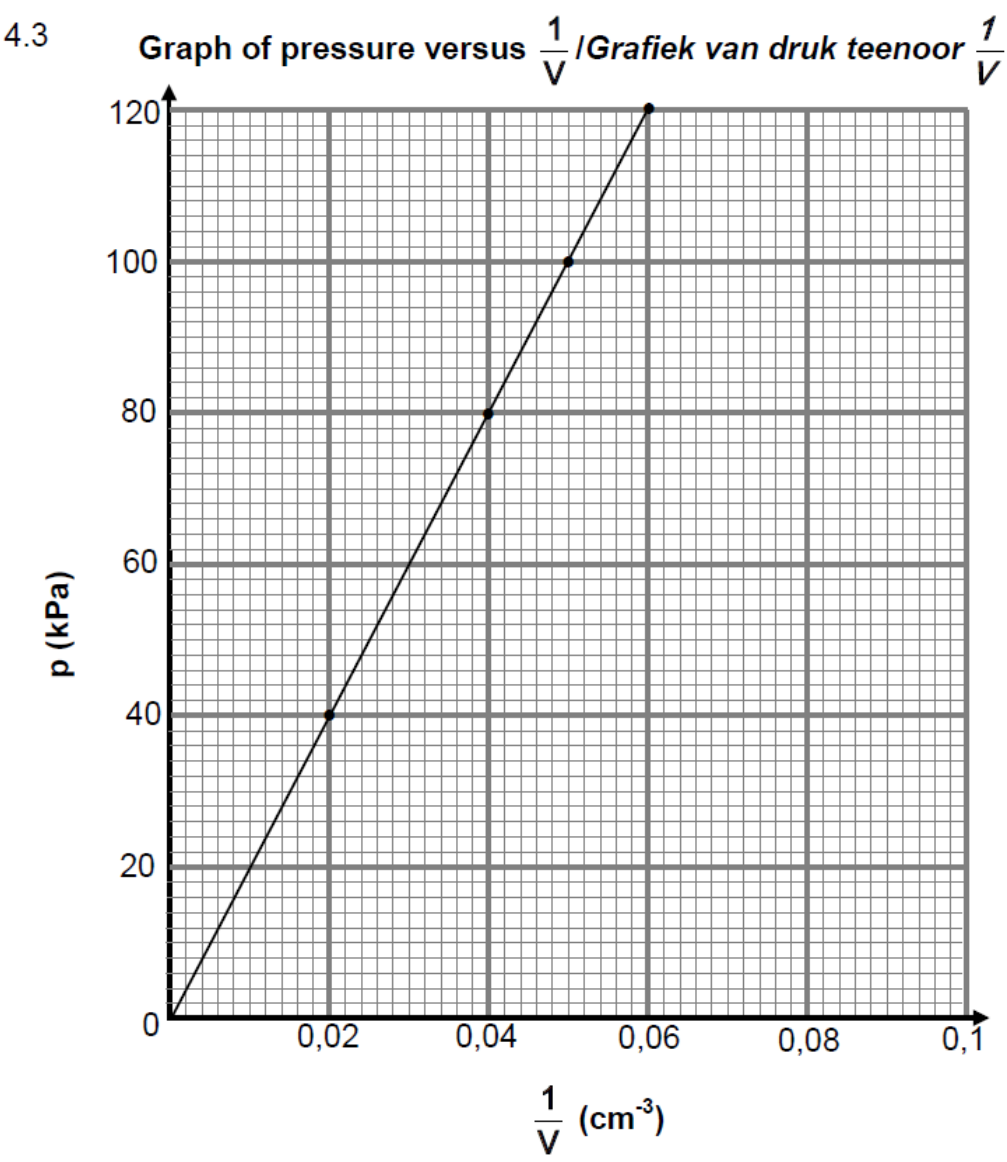
CONTINUED.....

4.3 Draw a graph of $\frac{1}{V}$ pressure versus on the attached ANSWER SHEET. (4)

4.4 Use the graph to determine the volume of the gas at 68 kPa. (2)



PRESSURE (kPa)	VOLUME (cm ³)	$\frac{1}{V}$ (cm ⁻³)
40	43	0,02
80	27	0,04
100	22	(a)
120	18	(b)



2022 Eastern Cape November Paper 2 Q 4

A group of learners investigate the relationship between pressure and the volume of an enclosed gas at room temperature. They recorded their results in the table below:

Pressure (kPa)	Volume (cm ³)
100,33	7,34
102,2	7,21
103,93	7,09
X	6,97

- 4.1 For this investigation, write down the:
- 4.1.1 Name of the gas law that is being investigated

(1)
- 4.1.2 Controlled variable

(1)
- 4.1.3 Relationship between pressure and volume of the gas as described by the first 3 data sets in the table

(2)
- 4.2 Calculate the value of X.

(4)
- 4.3 Write down the TWO conditions under which real gases behave more like an ideal gas.

(2)
- 4.4. Write down the NAME of a gas whose behaviour is close to that of an ideal gas, under the conditions mentioned in QUESTION 4.3 above.

(1)

2023 KwaZulu Natal November Paper 2 Q 4

The relationship between pressure and volume of an enclosed gas at 25°C is investigated by varying the pressure exerted by the gas, and observing the corresponding volume occupied by the gas in each case
The results obtained are shown in the table below:

17 PRESSURE (kPa)	Volume in cm ³	$\frac{1}{V}$ in cm ⁻³
60	50	0,020
D	35	0,029
100	30	0,033
150	20	0,050
200	15	0,067

4.1.1 NAME AND STATE the gas law being investigated. (3)

4.1.2 Write down the TWO controlled variable for this investigation (1)

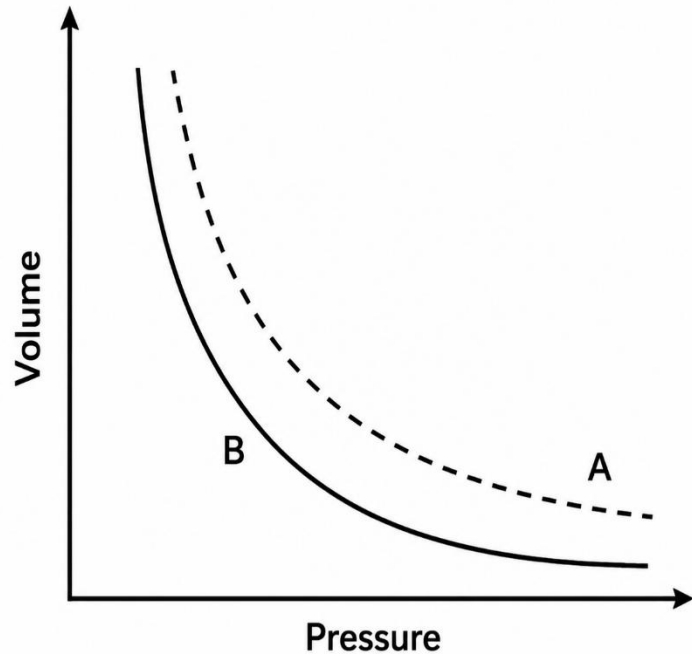
4.1.3 Write down the dependent variable for this investigation (1)

4.1.4 Use the results in the table to explain why a graph of pressure (p) verses the inverse of volume ($\frac{1}{V}$) will be a straight line graph (3)

4.1.5 Calculate the value represented by the letter D in the table (2)

CONTINUED.....

4.2 The graphs, A and B below were obtained during an investigation to identify the conditions under which a gas will deviate from ideal gas behaviour.



4.2.1 Which graph, A or B represents the deviation from ideal gas behaviour? (1)

4.2.2 State the relevant condition under which deviation from ideal gas behaviour referred to in QUESTION 4.2.1 occurs (2)

4.2.3 Explain the answer to question 4.2.2 (3)