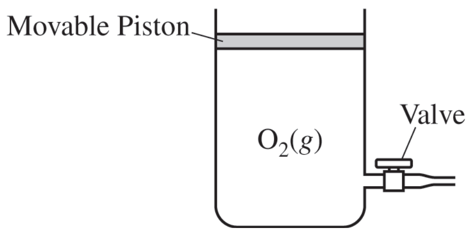
Begin your response to **QUESTION 7** on this page.



7. A student investigates gas behavior using a rigid cylinder with a movable piston of negligible mass, as shown in the diagram above. The cylinder contains 0.325 mol of $O_2(g)$.

(a) The cylinder has a volume of 7.95 L at 25°C and 1.00 atm. Calculate the density of the $O_2(g)$, in g/L, under these conditions.

(b) Attempting to change the density of the $O_2(g)$, the student opens the valve on the side of the cylinder, pushes down on the piston to release some of the gas, and closes the valve again. The temperature of the gas remains constant at 25°C. Will this action change the density of the gas remaining in the cylinder? Justify your answer.

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Continue your response to **QUESTION 7** on this page.

(c) The student tries to change the density of the $O_2(g)$ by cooling the cylinder to $-55°C$, which causes the volume of the gas to decrease. Using principles of kinetic molecular theory, explain why the volume of the $O_2(g)$ decreases when the temperature decreases to $-55°C$.

(d) The student further cools the cylinder to $-180°C$ and observes that the measured volume of the $O_2(g)$ is substantially smaller than the volume that is calculated using the ideal gas law. Assume all equipment is functioning properly. Explain why the measured volume of the $O_2(g)$ is smaller than the calculated volume. (The boiling point of $O_2(l)$ is $-183°C$.)

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Question 7: Short Answer — 4 points

(a) For the correct calculated value: **1 point**

Accept one of the following:

- $0.325 \text{ mol } O_2 \times \dfrac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 10.4 \text{ g } O_2$

  $D = \dfrac{m}{V} = \dfrac{10.4 \text{ g}}{7.95 \text{ L}} = 1.31 \text{ g/L}$

- $D = \dfrac{m}{V} = \dfrac{P(MM)}{RT} = \dfrac{(1.0 \text{ atm})(32.00 \text{ g/mol})}{(0.08206 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}})(298 \text{ K})} = 1.31 \text{ g/L}$

(b) For the correct answer and a valid justification: **1 point**

Accept one of the following:

- *No, the density of the gas remains constant because P, R, and T remain constant AND the mass and volume of O_2 decrease proportionately.*
- *A mathematical justification is shown below.*

$$D = \frac{m}{V} = \frac{n \text{ moles of } O_2 \times \text{molar mass of } O_2}{\frac{nRT}{P}} = \frac{P \times (\text{molar mass of } O_2)}{RT}$$

(c) For a valid explanation: **1 point**

Accept one of the following:

- *As the gas cools, the average kinetic energy (speed) of the O_2 molecules decreases. The molecules rebound with less energy when they collide with each other and the walls of the container. The spacing between particles decreases, causing the volume occupied by the gas to decrease.*

- *As the gas cools, the average kinetic energy (speed) of the O_2 molecules decreases. The molecules rebound with less energy when they collide with each other and the walls of the container. The only way for the molecules to maintain a constant rate of collisions with the walls of the container (maintaining a pressure of 1.00 atm) is for the volume of the gas to decrease.*

(d) For a valid explanation: **1 point**

The ideal gas law assumes that gas particles do not experience interparticle attractions. As a real gas cools further, the intermolecular forces have greater effect as the average speed of the molecules decreases, resulting in inelastic collisions. To maintain a gas pressure of 1.00 atm, the volume must decrease to accommodate more collisions with less energy.

Total for question 7 — 4 points