Past-paper walk-through

Deviation from Ideal Gas Law ▪ 3.6

eXercise

Questions in this set

- 2021 Q7
- 2019 Q4

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 7

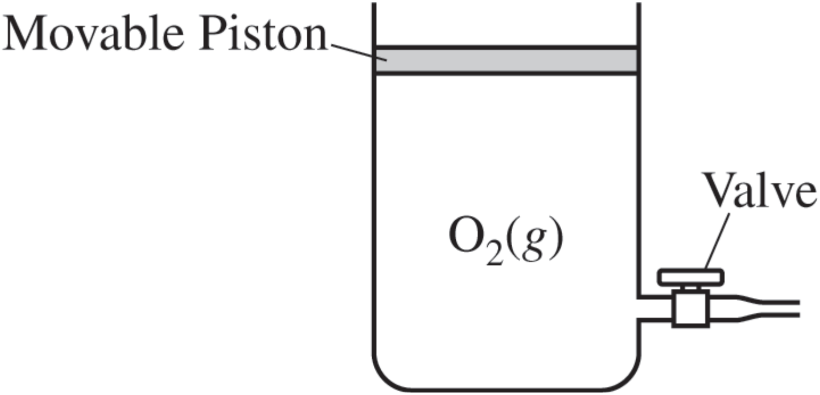
2021 ▪ Q7

[Diagram: A rigid cylindrical container standing upright, fitted with a "Movable Piston" (shown as a shaded bar) near the top that can slide up and down. Below the piston, the container holds "$O_2(g)$". A "Valve" is shown on the side of the container near the piston.]

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.

Question 7



Question 7

2021 ▪ Q7

[Diagram: A rigid cylindrical container standing upright, fitted with a "Movable Piston" (shown as a shaded bar) near the top that can slide up and down. Below the piston, the container holds "$O_2(g)$". A "Valve" is shown on the side of the container near the piston.]

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 $O_2(g)$.

(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.

Question 7

2021 ▪ Q7

[Diagram: A rigid cylindrical container standing upright, fitted with a "Movable Piston" (shown as a shaded bar) near the top that can slide up and down. Below the piston, the container holds "$O_2(g)$". A "Valve" is shown on the side of the container near the piston.]

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 $O_2(g)$.

(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.

Question 7

2021 ▪ Q7

[Diagram: A rigid cylindrical container standing upright, fitted with a "Movable Piston" (shown as a shaded bar) near the top that can slide up and down. Below the piston, the container holds "$O_2(g)$". A "Valve" is shown on the side of the container near the piston.]

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 $O_2(g)$.

(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 $-183°C$.)

Solution 7

(a) Mark scheme

- $0.325 \text{ mol } O_2 \times \dfrac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} = 10.4 \text{ g } O_2$; density $D = \dfrac{m}{V} = \dfrac{10.4 \text{ g}}{7.95 \text{ L}} = 1.31 \text{ g/L}$ (equivalently via $D = \dfrac{P(MM)}{RT} = \dfrac{(1.0 \text{ atm})(32.00 \text{ g/mol})}{(0.08206 \text{ L} \cdot \text{atm} \cdot \text{mol}^{-1}\text{K}^{-1})(298 \text{ K})} = 1.31 \text{ g/L}$).

Solution 7

(b) Mark scheme

- No, releasing some gas at constant temperature does not change the density of the O2 remaining in the cylinder, because P, R, and T all remain constant, and the mass and volume of O2 decrease proportionately as gas is released (density $D = \frac{m}{V} = \frac{n \times MM}{nRT/P} = \frac{P \times MM}{RT}$ depends only on P, molar mass, R, and T — not on the amount n of gas present — so D is unchanged).

Solution 7

(c)

Mark scheme

- As the gas cools, the average kinetic energy (speed) of the O2 molecules decreases, so the molecules rebound with less energy when they collide with each other and the container walls. To maintain a constant rate/force of collisions with the walls (i.e., to keep the pressure at 1.00 atm), the spacing between particles must decrease — so the volume occupied by the gas decreases.

Solution 7

(d) Mark scheme

- The ideal gas law assumes gas particles experience no interparticle (intermolecular) attractions. As the real O2 gas cools further toward its boiling point of -183°C, intermolecular (London dispersion) forces have an increasingly significant effect as the average molecular speed decreases, pulling molecules closer together than ideal behavior predicts (more inelastic/attractive collisions). To still maintain the gas pressure of 1.00 atm, the actual volume must decrease more than the ideal gas law predicts, so the measured volume is smaller than the calculated ideal-gas volume.

Question 4

2019 ▪ Q4

A student is doing experiments with $CO_2(g)$. Originally, a sample of the gas is in a rigid container at 299 K and 0.70 atm. The student increases the temperature of the $CO_2(g)$ in the container to 425 K.

(a) Describe the effect of raising the temperature on the motion of the $CO_2(g)$ molecules.

(b) Calculate the pressure of the $CO_2(g)$ in the container at 425 K.

(c) In terms of kinetic molecular theory, briefly explain why the pressure of the $CO_2(g)$ in the container changes as it is heated to 425 K.

(d) The student measures the actual pressure of the $CO_2(g)$ in the container at 425 K and observes that it is less than the pressure predicted by the ideal gas law. Explain this observation.

Solution 4

(a)

Mark scheme

- The average speed (and kinetic energy) of the CO_2 molecules increases as the temperature increases. 1 point for the correct answer.

Solution 4

(b)

Mark scheme

- Using Gay-Lussac's law (constant V, constant n): $P1/T1 = P2/T2 \Rightarrow 0.70$ atm / 299 K = P2 / 425 K $\Rightarrow$ P2 = 0.99 atm. 1 point for the correct answer.

Solution 4

(c)

Mark scheme

- As temperature increases, the CO2 molecules move faster, so they collide with the container walls more frequently and/or more forcefully, which increases the pressure. 1 point for a correct kinetic-molecular-theory explanation (frequency or force of collisions).

Solution 4

(d)

Mark scheme

- The measured pressure is lower than the ideal-gas-law prediction because real CO_2 molecules experience attractive intermolecular forces with each other, which reduce the force/frequency of their collisions with the container walls compared to an ideal (non-interacting) gas — an effect the ideal gas law ignores. 1 point for a correct explanation citing intermolecular attractive forces.