

Gas laws and particle motion

AP Chemistry · Worksheet answers

Each answer shows the formula, the substitution and the result with units. Gas calculations need kelvin and consistent units, so check those first if your result differs. Differences in the last significant figure from rounding are acceptable.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 3

Problem 1 Pressure units

- $0.750 \times 101.3 = \mathbf{76.0 \text{ kPa}}$; $0.750 \times 760 = \mathbf{570 \text{ mmHg}}$.
- $95.0 / 101.3 = \mathbf{0.938 \text{ atm}}$.

Problem 2 Kelvin conversions

- 298 K, 233 K, 373 K** (add 273.15).
- $350 - 273.15 = \mathbf{77 \text{ }^\circ\text{C}}$.

Problem 3 Compressing a syringe

- Boyle's law:** $P_1V_1 = P_2V_2$ at constant n and T .
- $P_2 = 100 \times 6.0 / 2.0 = \mathbf{300 \text{ kPa}}$.

Problem 4 Heating a balloon

- 300.15 K and 360.15 K.
- $V_2 = 2.40 \times 360.15 / 300.15 = \mathbf{2.88 \text{ L}}$.

Problem 5 Reading a Boyle graph

- 200 kPa at 2 L, 50 kPa at 8 L.
- $200 \times 2 = 400 \text{ kPa}\cdot\text{L}$; $50 \times 8 = 400 \text{ kPa}\cdot\text{L}$. **PV is constant**, so $P \propto 1/V$.
- $P = 400 / 10 = \mathbf{40 \text{ kPa}}$.

Problem 6 Kinetic theory statements

- False:** collisions are elastic, so no kinetic energy is lost.
- True.**
- False:** the volume of the particles is negligible compared with the space between them.

Problem 7 Pressure from the ideal gas law

$$T = 293.15 \text{ K.}$$

$$P = nRT/V = 0.500 \times 8.314 \times 293.15 / 12.0 = \mathbf{102 \text{ kPa.}}$$

Problem 8 Identify a gas from its molar mass

$$1. n = PV/RT = 100.0 \times 0.500 / (8.314 \times 300.15) = \mathbf{0.0200 \text{ mol.}}$$

$$2. M = 1.29 / 0.02004 = \mathbf{64.4 \text{ g/mol.}}$$

3. The gas is **C₂H₅Cl**.

Problem 9 Density of carbon dioxide

$$\rho = PM/RT = 101.3 \times 44.01 / (8.314 \times 298.15) = \mathbf{1.80 \text{ g/L.}}$$

Air (about 29 g/mol) has a density near 1.18 g/L, so CO₂ is denser and sinks.

Problem 10 Partial pressures in a tank

$$1. n_{\text{total}} = 1.50 \text{ mol; } P = 1.50 \times 8.314 \times 298.15 / 20.0 = \mathbf{186 \text{ kPa.}}$$

$$2. x(\text{O}_2) = 0.300/1.50 = 0.200; P(\text{O}_2) = 0.200 \times 186 = \mathbf{37.2 \text{ kPa.}}$$

Problem 11 Gas over water

$$1. P(\text{H}_2) = 101.3 - 3.17 = \mathbf{98.1 \text{ kPa.}}$$

$$2. n = 98.13 \times 0.125 / (8.314 \times 298.15) = \mathbf{4.95 \times 10^{-3} \text{ mol.}}$$

Problem 12 Two speed distributions

1. **B** is hotter: its peak is at higher speed and the curve is wider.

2. A peaks at about 420 m/s and B at about 600 m/s. $T_B = 300 \times (600/420)^2 = \mathbf{\text{about } 600 \text{ K.}}$

3. The areas are **equal**, because both represent the same number of molecules.

Problem 13 Pressure and temperature

Higher temperature gives a higher average kinetic energy, so particles hit the walls harder and more often.

$$P_2 = 100.0 \times 353.15 / 293.15 = \mathbf{120 \text{ kPa.}}$$

Problem 14 Effusion rates

$$\text{Rate}(\text{H}_2)/\text{Rate}(\text{O}_2) = \sqrt{(32.00/2.016)} = \sqrt{15.87} = \mathbf{3.98.}$$

Problem 15 Gas from a reaction

$$n(\text{CaCO}_3) = 2.50 / 100.09 = 0.02498 \text{ mol} = n(\text{CO}_2).$$

$$V = nRT/P = 0.02498 \times 8.314 \times 298.15 / 101.3 = \mathbf{0.611 \text{ L.}}$$

Problem 16 Speeds of gas molecules

N₂: $\sqrt{(3 \times 8.314 \times 300 / 0.028014)} = \sqrt{267\,106} = \mathbf{517\text{ m/s}}$.

He: $\sqrt{(7482.6 / 0.004003)} = \mathbf{1.37 \times 10^3\text{ m/s}}$.

At the same temperature He atoms have the same average kinetic energy but a much smaller mass, so more of them reach escape speed.

Problem 17 A real gas calculation

1. $P = 0.08314 \times 300 / 1.00 = \mathbf{24.9\text{ bar}}$.

2. $P = nRT/(V - nb) - an^2/V^2 = 24.94/0.9573 - 3.64 = 26.05 - 3.64 = \mathbf{22.4\text{ bar}}$.

3. The real pressure is lower because attractions between CO₂ molecules reduce the force of wall collisions; the correction for particle volume is smaller than the attraction term here.

Problem 18 Mixture from masses

1. $n(\text{O}_2) = 0.250\text{ mol}$; $n(\text{N}_2) = 14.0/28.01 = 0.500\text{ mol}$.

2. $P = 0.750 \times 8.314 \times 300 / 10.0 = \mathbf{187\text{ kPa}}$.

3. $x(\text{O}_2) = 0.250/0.750 = \mathbf{0.333}$; $P(\text{O}_2) = 0.333 \times 187 = \mathbf{62.4\text{ kPa}}$.

Problem 19 Interpreting compressibility

1. $Z = 1$.

2. X is hydrogen: weak attractions, so particle volume dominates and $Z > 1$ at all pressures. Y is methane: stronger attractions give $Z < 1$.

3. At moderate pressure attractions reduce the pressure below the ideal value ($Z < 1$). At high pressure particles are crowded, particle volume matters more, and the volume is larger than ideal ($Z > 1$).

Problem 20 Molar mass of a volatile liquid

1. $n = PV/RT = 101.3 \times 0.255 / (8.314 \times 373.15) = 0.008326\text{ mol}$; $M = 0.617 / 0.008326 = \mathbf{74.1\text{ g/mol}}$.

2. The gas temperature must equal the known T in $PV = nRT$.

3. If the liquid was not fully vaporised or some vapour leaked before sealing, the measured mass of vapour is too low.