Practice Problems (Unit 5): Gas Laws

1. What is the root mean squared velocity of hydrogen gas (H_2) at 28.4°C?

→ 2.016

→ 28.4 + 273 = 301.4K

$$v_{rms} = \sqrt{\frac{3000\left(8.31 \frac{J}{mol \cdot K}\right)(301.4\,K)}{2.016\ g/mol}}$$

Answer: 1930 $\frac{m}{s}$

$T = \overline{KE} = \frac{1}{2}mv^2$

$\therefore \uparrow T = \uparrow v$

2. **a)** If all curves represent the same gas at different temperatures, which curve represents the highest temperature?

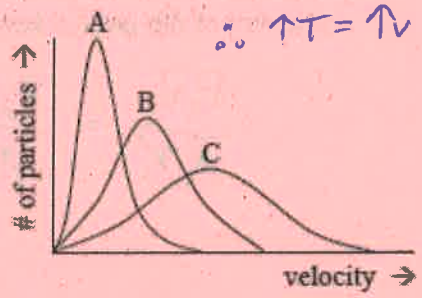
b) If each curve represents a different gas at the same temperature, which curve represents the gas with the highest molar mass?

Answers:

C

A

big = slower



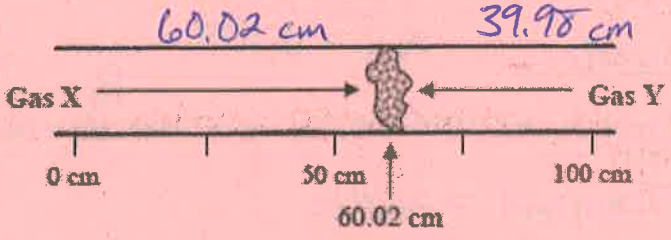
3. Which gas effuses faster, NH_3 or CCl_4? How much faster does it effuse?

→ 17.03 g/mol → 153.81 g/mol

$$\frac{V_2}{V_1} = \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{153.81\ g/mol}{17.03\ g/mol}} = 3.0$$

Answer: NH_3 effuses 3 times faster than CCl_4

4. Gases X and Y react to form a solid. If the molar mass of gas X is 20.008 g/mol, then what is the molar mass of gas Y?



(x) (y) $\frac{V_2}{V_1} = \frac{60.02\ cm}{39.98\ cm}$

$= 1.50 \times$ faster

$$\frac{V_2}{V_1} = \sqrt{\frac{m_1}{m_2}}$$

$$1.50 = \sqrt{\frac{m_1}{20.008\ g/mol}}$$

Answer: 45.09 g/mol

$m_1 = 45.09\ g/mol$

→ 297.8 K

5. A large balloon filled with helium gas (occupying 293.1 L at 24.8°C and 769.2 torr) is released. What volume (in L) would the balloon occupy when it reaches an altitude where the conditions are –18.7°C and 383.6 torr?

254.3 K

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2} \qquad \frac{(769.2\ \text{torr})(293.1\ \text{L})}{297.8\ \text{K}} = \frac{(383.6\ \text{torr})V_2}{254.3\ \text{K}}$$

$$V_2 = 501.88\ \text{L}$$

Answer: 502 L

6. A gas in a 975 mL cylinder is at 835 torr. If the gas is compressed by a piston to 225 mL, what is the pressure of the gas (in atm)?

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2T_2}{n_2T_2} \qquad (835\ \text{torr})(0.975\ \text{L}) = P_2(0.225\ \text{L})$$

$$P_2 = 3618\ \text{torr}$$

or

$$4.76\ \text{atm}$$

Answer: 3620 torr or 4.76 atm

7. Hydrogen gas is collected over water at 27.0°C and 748.9 torr. If 3.978 L of gas is collected, how many moles of hydrogen are in the container? (P_{H_2O} = 26.5 torr at 27.0°C)

Any gas collection in an aqueous environment will be influenced by the presence of water evaporation (P_{H_2O}) adding to gas moles and therefore pressure.

$$P_T = P_{H_2} + P_{H_2O}$$

$$748.9\ \text{torr} = P_{H_2} + 26.5\ \text{torr}$$

$$P_{H_2} = 722.4\ \text{torr}$$

$$P_TV = n_TRT$$

$$(748.9\ \text{torr})(3.978\ \text{L}) = n\left(62.4\ \tfrac{\text{torr}\cdot\text{L}}{\text{mol}\cdot\text{K}}\right)(300\ \text{K})$$

$$n_{gas} = 0.159$$

$$P_{H_2} = \frac{n_{H_2}}{n_T}P_T \qquad 722.4\ \text{torr} = \frac{n_{H_2}}{0.159}(748.9\ \text{torr})$$

$$n_{H_2} = 0.153\ \text{mol}$$

Answer: 0.153 mol

8. If 0.598 mol N_2, 0.153 mol O_2, and 0.079 mol CO_2 are exhaled into a balloon, what volume would the balloon occupy at STP?

↳ 1 mol = 22.4 L

$$n_T = 0.598 + 0.153 + 0.079$$

$$= 0.83\ \text{mol}$$

$$0.83\ \text{mol}\left(\frac{22.4\ \text{L}}{1\ \text{mol}}\right) = 18.6\ \text{L}$$

Answer: 18.6 L

9. 32.42 mol Gas A, 28.15 mol Gas B, and 19.69 mol Gas C are in a 1799 L chamber at STP. What is the partial pressure of Gas B (in atm)?

$n_T = 32.42 + 28.15 + 19.69$
$= 80.26 \text{ mol}$

$P_T V = n_T RT$

$P_T(1799\text{ L}) = (80.26\text{ mol})\left(0.0821 \frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}}\right)(273\text{ K})$

$P_T = 1.000 \text{ atm}$

$P_B = X_B P_T$

$P_B = \frac{28.15 \text{ mol}}{80.26 \text{ mol}}(1.000 \text{ atm})$

$P_B =$ 0.3507 atm or 266.5 torr

Answer: 0.3507 atm or 266.5 torr

10. How many liters of CO_2 (at STP) are produced when 250. g of octane (C_8H_{18}) are combusted according to the following equation?

$$2\,C_8H_{18\,(l)} + 25\,O_{2\,(g)} \rightarrow 16\,CO_{2\,(g)} + 18\,H_2O_{(g)}$$
250. g

$250.\text{ g } C_8H_{18}\left(\frac{1\text{ mol}}{114.22\text{ g}}\right)\left(\frac{16\text{ mol } CO_2}{2\text{ mol } C_8H_{18}}\right) = 17.5\text{ mol } CO_2\left(\frac{22.4\text{ L}}{1\text{ mol}}\right) = 392\text{ L}$ @STP

Answer: 392 L

11. Ammonia (NH_3) is produced industrially at high temperatures and pressures. What is the density of ammonia gas at 550.°C and 245 atm?

↳ g/mL (need mol & volume)

$PV = nRT$

$\frac{n}{V} = \frac{P}{RT} = \frac{245 \text{ atm}}{\left(0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(823\text{ K})} = 3.63 \frac{\text{mol}}{\text{L}}\left(\frac{17.03\text{ g}}{1\text{ mol}}\right) = 61.7\text{ g/L}$

$61.7\text{ g/L}\left(\frac{1\text{ L}}{1000\text{ mL}}\right) = 0.0617\text{ g/mL}$

Answer: 0.0617 g/mL

12. Using the van der Waals equation, calculate the observed pressure of 25.85 moles of xenon gas in a 150.0 L chamber at –25.0°C ($a = 4.19\ \text{atm}\cdot\text{L}^2/\text{mol}^2$, $b = 0.0511$ L/mol).

$\left[P + a\left(\frac{n}{V}\right)^2\right]\left(\frac{V}{n} - b\right) = RT$

$\left[P + 4.19\left(\frac{25.85\text{ mol}}{150.0\text{ L}}\right)^2\right]\left(\frac{150.0\text{ L}}{25.85\text{ mol}} - 0.0511\right) = \left(0.0821 \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(248\text{ K})$

$[P + 0.1244](5.752) = 20.36$

Answer:

$P + 0.1244 = 3.5396$

$P = 3.42 \text{ atm}$

FYI, ideal gas law predicts 3.50 atm, why is it lower?

Questions 13-14 refer to the following pure substances, which are gases at 25°C and 1 atmosphere.

(A) $NH_3(g)$
(B) $BH_3(g)$
(C) $H_2(g)$
(D) $CH_4(g)$
(E) $HBr(g)$

13. Is a strong electrolyte in aqueous solution.

E (strong acid ionizes completely)

14. Is the slowest to effuse through a small opening at 25°C and 1 atmosphere.

E (heaviest = slowest @ same temp)

15. According to the equation below, how many moles of potassium chlorate, $KClO_3$, must be decomposed to generate 1.0 L of O_2 gas at standard temperature and pressure?

$$2KClO_3(s) \xrightarrow{MnO_2} 2\,KCl(s) + 3\,O_2(g)$$

(A) $\frac{1}{3}\left(\frac{1}{22.4}\right)mol$ (B) $\frac{1}{2}\left(\frac{1}{22.4}\right)mol$

(C) $\frac{2}{3}\left(\frac{1}{22.4}\right)mol$ (D) $\frac{3}{2}\left(\frac{1}{22.4}\right)mol$

(E) $2\left(\frac{1}{22.4}\right)mol$

$1.0\,L\left(\frac{1\,mol}{22.4\,L}\right) = \frac{1}{22.4}\,mol$ @ STP

$\frac{1}{22.4}\,mol\,O_2\left(\frac{2\,mol\,KClO_3}{3\,mol\,O_2}\right) = \frac{2}{3}\left(\frac{1}{22.4}\right)mol$

16. The pressure, in atm, exerted by 1.85 mol of an ideal gas placed in a 3.00 L container at 35°C is given by which of the following expressions?

(A) $\frac{(1.85)(0.0821)(308)}{3.00}atm$

(B) $\frac{(1.85)(35.0)}{(3.00)(0.0821)}atm$

(C) $\frac{3.00}{(1.85)(0.0821)(308)}atm$

(D) $\frac{(1.85)(8.314)(308)}{3.00}atm$

(E) $\frac{(3.00)(1.85)}{(0.0821)(35.0)}atm$

$P = \frac{nRT}{V} = \frac{(1.85)(0.0821)(308)}{3.00\,L}$

17. Equal masses of He and Ne are placed in a sealed container. What is the partial pressure of He if the total pressure in the container is 6 atm?

(A) 1 atm (B) 2 atm (C) 3 atm
(D) 4 atm (E) 5 atm

(4 g/mol 20 g/mol)

$1g\,He\left(\frac{1\,mol}{4\,g}\right) = 0.25\,mol$

$1g\,Ne\left(\frac{1\,mol}{20\,g}\right) = 0.05\,mol$

$\frac{0.25\,mol}{0.30\,mol\,total}$

$P_{He} = X_{He}P_T = \frac{0.25}{0.30}(6\,atm) = 5\,atm$

18. Under which of the following conditions of temperature and pressure would 1.0 mol of the real gas $CO_2(g)$ behave most like an ideal gas?

(for fewer phase changes)

↓P & ↑T

	Temperature (K)	Pressure (atm)
(A)	100	0.1
(B)	100	100
(C)	800	10
(D)	800	0.1
(E)	800	100

19. At standard temperature and pressure, a 0.50 mol sample of H_2 gas and a separate 1.0 mol sample of O_2 gas have the same

(A) average molecular kinetic energy T = KE
(B) average molecular speed H_2 faster
(C) volume H_2 ↓n = ↓V
(D) effusion rate H_2 faster
(E) density H_2 less per volume

Questions 20-22 refer to the following gases at 0° C and 1 atm.

A. Ne 20 g/mol
B. Xe 131 g/mol
C. O_2 32 g/mol
D. CO 28 g/mol
E. NO 30 g/mol

20. Has an average atomic or molecular speed closest to that of N_2 = 28 g/mol Molecules at 0° C and 1 atm. D (same mass = same KE @ same T)

21. Has the greatest density. B

22. Has the greatest rate of effusion through a pinhole. A (lightest = fastest)

23. A flask contains 0.25 mole of $SO_2(g)$, 0.50 mole of $CH_4(g)$, and 0.50 mole of $O_2(g)$. The total pressure of the gases in the flask is 800 mm Hg. What is the partial pressure of the $SO_2(g)$ in the flask?

A. 800 mm Hg
B. 600 mm Hg
C. 250 mm Hg
D. 200 mm Hg
E. 160 mm Hg

$P_{SO_2} = \frac{0.25}{1.25}(800\,mm\,Hg) = 160\,mm\,Hg$

24. What volume of $O_2(g)$ is required to react with excess $CS_2(l)$ to produce 4.0 L of $CO_2(g)$? (Assume all gases are measured at 0°C and 1 atm.)

A. 12 L
B. 22.4 L
C. 1/3 x 22.4 L
D. 2 x 22.4 L
E. 3 x 22.4 L

$3O_2(g) + CS_2(l) \rightarrow CO_2 + 2SO_2$

12 L 4 L 4 L

25. An excess of Mg(s) is added to 100. mL of 0.400 M HCl. At 0°C and 1 atm pressure, what volume of H_2 gas can be obtained?

A. 22.4 mL
B. 44.8 mL
C. 224 mL
D. 448 mL
E. 896 mL

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

$0.100\,L\,HCl\left(\frac{0.400\,mol\,HCl}{1\,L}\right)\left(\frac{1\,mol\,H_2}{2\,mol\,HCl}\right)\left(\frac{22.4\,L}{1\,mol\,H_2}\right)\left(\frac{1000\,mL}{1\,L}\right) = 448\,mL$

26. A 2 L container will hold about 4 g of which of the following gases at 0°C and 1 atm?

A. SO_2 64 g/mol
B. N_2 28 g/mol
C. CO_2 44 g/mol
D. C_4H_8 56 g/mol
E. NH_3 17 g/mol

$2\,L\left(\frac{1\,mol}{22.4\,L}\right) = 0.0893\,mol$

$4\,g\left(\frac{1\,mol}{X\,g}\right) = 0.0893\,mol$

Molar Mass $= 44.8\,g/mol$

27. A hot-air balloon rises. Which of the following is the best explanation for this observation?

A. The pressure on the walls of the balloon increases with increasing temperature.
B. The difference in temperatures between the air inside and outside the balloon produces convection currents.
C. The cooler air outside of the balloon pushes on the walls of the balloon.
D. The rate of diffusion of cooler air is less than warmer air.
E. The air density inside the balloon is less than the surrounding air.

28. A rigid metal tank contains oxygen gas. Which of the following applies to the gas in the tank when additional oxygen is added at constant temperature.

A. The volume of the gas increase — constant (rigid)
B. The pressure of the gas decreases — $\uparrow n = \uparrow P$
C. The average speed of the gas molecules remains the same — Constant T = constant $\overline{KE}$
D. The total number of moles of gas remains the same — $\uparrow n$
E. The average distance between the gas molecules increases — $\uparrow n$ w/ const. V = $\uparrow$ density

1.20 atm 1.60 atm

$W(g) + X(g) \longrightarrow Y(g) + Z(g)$

1.0 1.40 .2 ?.2

29. Gases W and X react in a closed, rigid vessel to form gases Y and Z according to the equation above. The initial pressure of W(g) is 1.20 atm and that of X(g) is 1.60 atm. No Y(g) or Z(g) is initially present. The experiment is carried out at constant temperature. What is the partial pressure of Z(g) when the partial pressure of W(g) has decreased to 1.0 atm?

A. 0.20 atm
B. 0.40 atm
C. 1.0 atm
D. 1.2 atm
E. 1.4 atm

$\downarrow 0.20$ atm = 20% W reacted $\left(\frac{0.20}{1.20}\right)$
= 20% Y & Z created
= 20% X used

0.03 mol

$NH_4NO_3(s) \longrightarrow N_2O(g) + 2H_2O(g)$

0.03 mol 0.06 mol

30. A 0.03 mol sample of NH_4NO_3 is placed in a 1 L evacuated flask which is then sealed and heated. The NH_4NO_3 decomposes completely according to the equation above. The total pressure of the flask at 400K would be closest to which of the following?

A. 3 atm B. 1 atm C. 0.5 atm
D. 0.1 atm E. 0.03atm

4 g/0.1 L

$P_T V = n_T RT$

$P_T(1\,L) = (0.09\,mol)(0.0821)(400K)$

$P_T = 3$ atm