Section 12.1 The Combined Gas Law

Solutions for Practice Problems

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11. Practice Problem (page 549)

At STP, 1.0 mol of carbon dioxide gas has a volume of 22.41 L. What mass of carbon dioxide is present in 3.0 L?

What Is Required?

You need to find the mass of 3.0 L of carbon dioxide gas, CO_2(g).

What Is Given?

You know the volume of 1.0 mol of carbon dioxide at STP: V_1 = 22.41 L

You know the volume of the sample of carbon dioxide: V_2 = 3.0 L

You know the amount in moles of carbon dioxide: n_1 = 1.0 mol

Plan Your Strategy

Use Avogadro's law to solve for the amount in moles of CO_2(g): $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

Determine the molar mass of CO_2(g).

Calculate the mass of CO_2(g) using the relationship $m = n \times M$.

Act on Your Strategy

Amount in moles, n_2, of CO_2(g):

$$\frac{n_1}{V_1} = \frac{n_2}{V_2}$$

$$\frac{1.0\text{ mol}}{22.41\text{ L}} = \frac{n_{CO_2}}{3.0\text{ L}}$$

$$n_{CO_2} = \frac{(1.0\text{ mol})(3.0\text{ L})}{22.41\text{ L}}$$

$$= 0.133868\text{ mol}$$

Molar mass, M, of CO_2(g):

$$M_{CO_2} = 1M_C + 2M_O$$

$$= 1(12.01\text{ g/mol}) + 2(16.00\text{ g/mol})$$

$$= 44.01\text{ g/mol}$$

Mass, *m*, of CO_2(g):

$$m_{CO_2} = n \times M$$
$$= 0.133868\ \cancel{\text{mol}} \times 44.01\ \text{g}/\cancel{\text{mol}}$$
$$= 5.89156\ \text{g}$$
$$= 5.9\ \text{g}$$

The mass of carbon dioxide gas is 5.9 g.

Alternative Solution

Plan Your Strategy
You know that the volume of carbon dioxide is less than the molar volume.
Determine a ratio of the molar volume and the volume of carbon dioxide that is less than 1. Multiply 1.0 mol by this volume ratio.
Determine the molar mass of CO_2(g).
Calculate the mass of CO_2(g) using the relationship $m = n \times M$.

Act on Your Strategy
Volume ratio:
$V_1 = 22.41$ L
$V_2 = 3.0$ L

$$\text{volume ratio} < 1 \text{ is } \frac{3.0\ \text{L}}{22.41\ \text{L}}$$

Amount in moles, n_2, of CO_2(g):

$$n_2 = n_1 \times \text{volume ratio}$$
$$= 1.0\ \text{mol} \times \frac{3.0\ \cancel{\text{L}}}{22.41\ \cancel{\text{L}}}$$
$$= 0.133868\ \text{mol}$$

Molar mass, *M*, of CO_2(g):

$$M_{CO_2} = 1M_C + 2M_O$$
$$= 1(12.01\ \text{g/mol}) + 2(16.00\ \text{g/mol})$$
$$= 44.01\ \text{g/mol}$$

Mass, *m*, of CO_2(g):

$$m_{CO_2} = n \times M$$
$$= 0.133868\ \cancel{\text{mol}} \times 44.01\ \text{g}/\cancel{\text{mol}}$$
$$= 5.89156\ \text{g}$$
$$= 5.9\ \text{g}$$

The mass of carbon dioxide gas is 5.9 g.

Check Your Solution
Round the volumes and estimate the mass of carbon dioxide:

$$\frac{3.0\ \cancel{\text{L}}}{22.4\ \cancel{\text{L}}} \approx \frac{1}{7}$$

$$\frac{1}{7}\ \cancel{\text{mol}} \times 44\ \text{g}/\cancel{\text{mol}} \approx 6\ \text{g}$$

The estimated answer is close to the calculated answer. The calculated answer is reasonable and correctly shows two significant digits.

12. Practice Problem (page 549)
At STP, 1.0 mol of nitrogen gas occupies a volume of 22.41 L. Find the volume that 15.50 g of nitrogen gas occupies at STP.

What Is Required?
You need to find the volume of 15.50 g of nitrogen gas, $N_2(g)$, at STP.

What Is Given?
You know that, at STP, 1.0 mol of nitrogen gas occupies a volume of 22.41 L:
$n_1 = 1.0$ mol
$V_1 = 22.41$ L
You know the mass of the sample of nitrogen gas: $m = 15.5$ g

Plan Your Strategy
Determine the molar mass of $N_2(g)$.

Calculate the amount in moles of $N_2(g)$ using the relationship $n = \frac{m}{M}$.

Use Avogadro's law to solve for the volume of $N_2(g)$: $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

Act on Your Strategy
Molar mass, M, of $N_2(g)$:

$$\begin{aligned} M_{N_2} &= 2M_N \\ &= 2(14.07\ \text{g/mol}) \\ &= 28.14\ \text{g/mol} \end{aligned}$$

Amount in moles, n_2, of $N_2(g)$:

$$n_2 = \frac{m}{M}$$
$$= \frac{15.5\ \cancel{g}}{28.14\ \cancel{g}/\text{mol}}$$
$$= 0.550817\ \text{mol}$$

Mole ratio:
$n_1 = 1.0$ mol
$n_2 = 0.550817$ mol
mole ratio < 1 is $\dfrac{0.550817\ \text{mol}}{1.0\ \text{mol}}$

Volume, V_2, of $N_2(g)$:

$$V_2 = V_1 \times \text{ mole ratio}$$
$$= 22.41\ \text{L} \times \frac{0.550817\ \cancel{\text{mol}}}{1.0\ \cancel{\text{mol}}}$$
$$= 12.3438\ \text{L}$$
$$= 12\ \text{L}$$

The volume of 15.50 g of nitrogen gas at STP is 12 L.

Check Your Solution
Since 15.5 g of nitrogen gas, $N_2(g)$, is a little more than half a mole, it is reasonable that the volume will be a little more than half the molar volume. An estimate of half the molar volume is

$$\frac{1}{2} \times 22.41\ \text{L} \approx 11\ \text{L}$$

The estimated answer is close to the calculated answer. The answer is reasonable and correctly shows three significant digits.

13. Practice Problem (page 549)
Find the volume that 20.0 g of carbon monoxide gas, $CO(g)$, occupies at SATP.

What Is Required?
You need to find the volume of carbon monoxide gas at SATP.

What Is Given?
You know that, at SATP, 1.0 mol of carbon monoxide gas occupies a volume of 24.8 L:
$n_1 = 1.0$ mol
$V_1 = 24.8$ L
You know the mass of the sample of carbon monoxide gas: $m = 20.0$ g

Plan Your Strategy
Determine the molar mass of CO(g).

Calculate the amount in moles of CO(g) using the relationship $n = \frac{m}{M}$.

Use Avogadro's law to solve for the volume of CO(g): $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

Act on Your Strategy
Molar mass, M, of CO(g):

$$\begin{aligned} M_{CO} &= 1M_C + 1M_O \\ &= 1(12.01 \text{ g/mol}) + 1(16.00 \text{ g/mol}) \\ &= 28.01 \text{ g/mol} \end{aligned}$$

Amount in moles, n_2, of CO(g):

$$\begin{aligned} n_2 &= \frac{m}{M} \\ &= \frac{20.0 \cancel{\text{g}}}{28.01 \cancel{\text{g}}/\text{mol}} \\ &= 0.71403 \text{ mol} \end{aligned}$$

Volume, V_2, of CO(g):

$$\frac{n_1}{V_1} = \frac{n_2}{V_2}$$

$$\frac{1.0 \text{ mol}}{24.8 \text{ L}} = \frac{0.71403 \text{ mol}}{V_2}$$

$$\begin{aligned} V_2 &= \frac{(24.8 \text{ L})(0.71403 \cancel{\text{mol}})}{1.0 \cancel{\text{mol}}} \\ &= 17.70796 \text{ L} \\ &= 17.7 \text{ L} \end{aligned}$$

The volume that 20.0 g of carbon monoxide gas occupies at SATP is 17.7 L.

Alternative Solution

Plan Your Strategy
Determine the molar mass of CO(g).

Calculate the amount in moles of CO(g) using the relationship $n = \frac{m}{M}$.

You know that the mass of carbon monoxide is less than the molar mass. Determine a ratio of the molar mass and the mass of carbon monoxide that is less than 1. Multiply the volume of 1.0 mol by this mole ratio.

Act on Your Strategy
Molar mass, M, of CO(g):

$$\begin{aligned} M_{CO} &= 1M_C + 1M_O \\ &= 1(12.01 \text{ g/mol}) + 1(16.00 \text{ g/mol}) \\ &= 28.01 \text{ g/mol} \end{aligned}$$

Amount in moles, n_2, of CO(g):

$$\begin{aligned} n_2 &= \frac{m}{M} \\ &= \frac{20.0 \cancel{\text{g}}}{28.01 \cancel{\text{g}}\text{/mol}} \\ &= 0.71403 \text{ mol} \end{aligned}$$

Mole ratio:
$n_1 = 1.0$ mol
$n_2 = 0.71403$ mol
mole ratio < 1 is $\frac{0.71403 \text{ mol}}{1.0 \text{ mol}}$

Volume, V_2, of CO(g):

$$\begin{aligned} V_2 &= V_1 \times \text{ mole ratio} \\ &= 24.8 \text{ L} \times \frac{0.71403 \cancel{\text{mol}}}{1.0 \cancel{\text{mol}}} \\ &= 17.70796 \text{ L} \\ &= 17.7 \text{ L} \end{aligned}$$

The volume that 20.0 g of carbon monoxide gas occupies at SATP is 17.7 L.

Check Your Solution

Estimate the answer: 20.0 g of carbon monoxide gas is about $\frac{5}{7}$ of the molar mass:

$$\frac{20}{28.01} \approx \frac{5}{7}$$

It is reasonable that the volume of carbon monoxide will be about $\frac{5}{7}$ of the molar volume at SATP: $\frac{5}{7} \times 25\text{ L} \approx 18\text{ L}$. The estimated answer is close to the calculated answer. The calculated answer is reasonable and correctly shows three significant digits.

14. Practice Problem (page 549)

An experiment generates 0.152 g of hydrogen gas. What volume of gas was generated at STP?

What Is Required?

You need to find the volume of hydrogen gas, $H_2(g)$, that was generated at STP.

What Is Given?

You know the mass of the sample of hydrogen gas: m = 0.152 g

Plan Your Strategy

Determine the molar mass of $H_2(g)$.

Calculate the amount in moles of $H_2(g)$ using the relationship $n = \frac{m}{M}$.

Use Table 12.2 on page 546 to find the molar volume of $H_2(g)$ at STP.

Use Avogadro's law to solve for the volume of $H_2(g)$: $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

Act on Your Strategy

Molar mass, M, of $H_2(g)$:

$$\begin{aligned} M_{H_2} &= 2M_H \\ &= 2(1.01\text{ g/mol}) \\ &= 2.02\text{ g/mol} \end{aligned}$$

Amount in moles, n_2, of $H_2(g)$:

$$n_2 = \frac{m}{M}$$
$$= \frac{0.152 \not{g}}{2.02 \not{g}/\text{mol}}$$
$$= 0.075247 \text{ mol}$$

Mole ratio:
$n_1 = 1.0$ mol
$n_2 = 0.075247$ mol
mole ratio < 1 is $\frac{0.075247 \text{ mol}}{1.0 \text{ mol}}$

Volume, V_2, of $H_2(g)$:

$$V_2 = V_1 \times \text{ mole ratio}$$
$$= 22.43 \text{ L} \times \frac{0.075247 \not{\text{mol}}}{1.0 \not{\text{mol}}}$$
$$= 1.68780 \text{ L}$$
$$= 1.69 \text{ L}$$

The volume of hydrogen gas generated at STP was 1.69 L.

Check Your Solution
The given mass of hydrogen gas is small. The calculated volume of hydrogen is also small. This seems to be a reasonable answer that correctly shows three significant digits.

15. Practice Problem (page 549)
A solid block of carbon dioxide has a mass of 2.50×10^2 g. Once the block has totally sublimated, what volume would it occupy at SATP?

What Is Required?
You need to find the volume of carbon dioxide, $CO_2(g)$.

What Is Given?
You know that at SATP, 1.0 mol of carbon dioxide, $CO_2(g)$, occupies a volume of 24.8 L:
$n_1 = 1.0$ mol
$V_1 = 24.8$ L
You know the mass of the sample of carbon dioxide gas: $m = 2.50 \times 10^2$ g

Plan Your Strategy
Determine the molar mass of CO_2(g).

Calculate the amount in moles of CO_2(g) using the relationship $n = \frac{m}{M}$.

Use Avogadro's law to solve for the volume of CO_2(g): $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

Act on Your Strategy
Molar mass, M, of CO_2(g):

$$\begin{aligned} M_{CO_2} &= 1M_C + 2M_O \\ &= 1(12.01 \text{ g/mol}) + 2(16.00 \text{ g/mol}) \\ &= 44.1 \text{ g/mol} \end{aligned}$$

Amount in moles, n_2, of CO_2(g):

$$\begin{aligned} n_2 &= \frac{m}{M} \\ &= \frac{2.50\times10^2 \cancel{\text{g}}}{44.01 \cancel{\text{g}}\text{/mol}} \\ &= 5.680527 \text{ mol} \end{aligned}$$

Volume, V_2, of CO_2(g):

$$\frac{n_1}{V_1} = \frac{n_2}{V_2}$$

$$\frac{1.0 \text{ mol}}{24.8 \text{ L}} = \frac{5.680527 \text{ mol}}{V_2}$$

$$\begin{aligned} V_2 &= \frac{(24.8 \text{ L})(5.68047 \cancel{\text{mol}})}{1.0 \cancel{\text{mol}}} \\ &= 140.8770 \text{ L} \\ &= 141 \text{ L} \end{aligned}$$

The volume that would be occupied is 141 L.

Alternative Solution

Plan Your Strategy
Determine the molar mass of CO_2(g).

Calculate the amount in moles of CO_2(g) using the relationship $n = \frac{m}{M}$.

You know that the mass of carbon dioxide is greater than the molar mass. Determine a ratio of the molar mass and the mass of carbon dioxide that is greater than 1. Multiply the volume of 1.0 mol by this mole ratio.

Act on Your Strategy

Molar mass, M, of CO_2(g):

$$\begin{aligned} M_{CO_2} &= 1M_C + 2M_O \\ &= 1(12.01 \text{ g/mol}) + 2(16.00 \text{ g/mol}) \\ &= 44.1 \text{ g/mol} \end{aligned}$$

Amount in moles, n_2, of CO_2(g):

$$\begin{aligned} n_2 &= \frac{m}{M} \\ &= \frac{2.50 \times 10^2 \text{ g}}{44.01 \text{ g/mol}} \\ &= 5.680527 \text{ mol} \end{aligned}$$

Mole ratio:

$n_1 = 1.0$ mol

$n_2 = 5.680527$ mol

mole ratio > 1 is $\frac{5.680527 \text{ mol}}{1.0 \text{ mol}}$

Volume, V_2, of CO_2(g):

$$\begin{aligned} V_2 &= V_1 \times \text{ mole ratio} \\ &= 24.8 \text{ L} \times \frac{5.680527 \text{ mol}}{1.0 \text{ mol}} \\ &= 140.8770 \text{ L} \\ &= 141 \text{ L} \end{aligned}$$

The volume that would be occupied is 141 L.

Check Your Solution

Estimate the answer: 2.50×10^2 g of carbon dioxide gas is about 5.5 times the molar mass: $\frac{2.50 \times 10^2}{45} \approx 5.5$

It is reasonable that the volume of carbon dioxide will be about 5.5 times the molar volume at SATP: $5.5 \times 25 \text{ L} \approx 140$ L. The estimated answer is close to the calculated answer. The calculated answer is reasonable and correctly shows three significant digits.

Molar mass, M, of NH_3(g):

$$M_{NH_3} = 1M_N + 3M_H$$
$$= 1(14.01 \text{ g/mol}) + 3(1.01 \text{ g/mol})$$
$$= 17.04 \text{ g/mol}$$

Mass, m, of NH_3(g):

$$m_{NH_3} = n \times M$$
$$= 0.504032 \cancel{\text{mol}} \times 17.04 \text{ g/}\cancel{\text{mol}}$$
$$= 8.588705 \text{ g}$$
$$= 8.59 \text{ g}$$

The mass of ammonia gas released is 8.59 g.

Number of molecules, N, of NH_3(g):

$$N = n \times N_A$$
$$= 0.504032 \cancel{\text{mol}} \times 6.02 \times 10^{23} \text{ molecules/}\cancel{\text{mol}}$$
$$= 3.03427 \times 10^{23} \text{ molecules}$$
$$= 3.03 \times 10^{23} \text{ molecules}$$

The number of molecules of ammonia gas released is 3.03×10^{23}.

Check Your Solution

Round off the volumes and estimate the amount in moles of ammonia:

$$\frac{12 \cancel{\text{L}}}{25 \cancel{\text{L}}} \approx \frac{1}{2}$$

Estimate the mass of ammonia:

$$\frac{1}{2} \cancel{\text{mol}} \times 17 \text{ g/}\cancel{\text{mol}} \approx 8.5 \text{ g}$$

Estimate the number of molecules of ammonia:

$$\frac{1}{2} \cancel{\text{mol}} \times 6 \times 10^{23} \text{ molecules/}\cancel{\text{mol}} \approx 3 \times 10^{23} \text{ molecules}$$

The estimated answers are close to the calculated answers. The calculated answers are reasonable and correctly show three significant digits.

17. Practice Problem (page 549)

A 6.98 g sample of chlorine gas has a volume of 2.27 L at 0.0°C and 1.0 atm. Find the molar volume of the chlorine gas at 25°C and 100.0 kPa.

What Is Required?

You need to find the molar volume, v, of 1.0 mol of chlorine gas, Cl_2(g), at SATP.

What Is Given?
You know the initial temperature, pressure, and volume of the gas:
$T_1 = 0.0°C$
$P_1 = 1.0$ atm
$V_1 = 2.27$ L
You know the mass of chlorine: 6.98 g
You know the conditions of SATP:
$T_2 = 25°C$
$P_2 = 100.0$ kPa

Plan Your Strategy
Convert the temperatures from the Celsius scale to the Kelvin scale.
Convert the initial pressure from atmospheres to kilopascals.
Determine the molar mass of $Cl_2(g)$.
Calculate the amount in moles of $Cl_2(g)$ using the relationship $n = \frac{m}{M}$.
Use the combined gas law to find the volume, V_2, that the chlorine would occupy at SATP.
Find the volume of 1.0 mol of chlorine at SATP by dividing the volume of chlorine by the amount in moles.

Act on Your Strategy
SATP is 298.15 K and 100.0 kPa.

Initial temperature conversion:
$$\begin{aligned} T_1 &= 0.0°C + 273.15 \\ &= 273.15 \text{ K} \end{aligned}$$

Final temperature conversion:
$$\begin{aligned} T_2 &= 25°C + 273.15 \\ &= 298.15 \text{ K} \end{aligned}$$

Initial pressure conversion:
$$\begin{aligned} P_1 &= 1.0 \cancel{\text{atm}} \times \frac{101.325 \text{ kPa}}{1.0 \cancel{\text{atm}}} \\ &= 101.325 \text{ kPa} \end{aligned}$$

Molar mass, M, of $Cl_2(g)$:
$$\begin{aligned} M_{Cl_2} &= 2M_{Cl} \\ &= 2(35.45 \text{ g/mol}) \\ &= 70.90 \text{ g/mol} \end{aligned}$$

Amount in moles, n, of $Cl_2(g)$:

$$\begin{aligned} n_{Cl_2} &= \frac{m}{M} \\ &= \frac{6.98\ \cancel{g}}{70.90\ \cancel{g}/\text{mol}} \\ &= 0.984485\ \text{mol} \end{aligned}$$

Volume, V_2, of $Cl_2(g)$ at SATP:

$$\begin{aligned} \frac{P_1V_1}{T_1} &= \frac{P_2V_2}{T_2} \\ V_2 &= \frac{P_1V_1T_2}{P_2T_1} \\ &= \frac{(101.325\ \cancel{\text{kPa}})(2.27\ \text{L})(298.15\ \cancel{\text{K}})}{(100.0\ \cancel{\text{kPa}})(273.15\ \cancel{\text{K}})} \\ &= 2.51059\ \text{L} \end{aligned}$$

Molar volume, v, of $Cl_2(g)$ at SATP:

$$\begin{aligned} v &= \frac{V_2}{n} \\ &= \frac{2.51059\ \text{L}}{0.0984485\ \text{mol}} \\ &= 25.50155\ \text{L/mol} \\ &= 26\ \text{L/mol} \end{aligned}$$

Alternative Solution

Plan Your Strategy

Convert the temperatures from the Celsius scale to the Kelvin scale.
Convert the initial pressure from atmospheres to kilopascals.
Determine the molar mass of $Cl_2(g)$.
Calculate the amount in moles of $Cl_2(g)$ using the relationship $n = \frac{m}{M}$.
You know that the volume increases when the pressure decreases. Determine the ratio of the initial pressure and the final pressure that is greater than 1.
You know that the volume increases when the temperature increases. Determine the ratio of the initial temperature and the final temperature that is greater than 1.
Multiply the initial volume by the temperature and pressure ratios to obtain the final volume, V_2, of the chlorine gas.

There is less than 1.0 mol of chlorine gas present, so the molar volume will be greater than the volume that you calculated above. To find the molar volume, multiply by a mole ratio that is greater than 1.
The molar volume, *v*, is equal to the calculated volume divided by 1.0 mol.

Act on Your Strategy
SATP is 298.15 K and 100.0 kPa.

Initial temperature conversion:

$$\begin{aligned} T_1 &= 0.0°\text{C} + 273.15 \\ &= 273.15 \text{ K} \end{aligned}$$

Final temperature conversion:

$$\begin{aligned} T_2 &= 25°\text{C} + 273.15 \\ &= 298.15 \text{ K} \end{aligned}$$

Initial pressure conversion:

$$\begin{aligned} P_1 &= 1.0 \cancel{\text{atm}} \times \frac{101.325 \text{ kPa}}{1.0 \cancel{\text{atm}}} \\ &= 101.325 \text{ kPa} \end{aligned}$$

Molar mass, *M*, of Cl_2(g):

$$\begin{aligned} M_{\text{Cl}_2} &= 2M_{\text{Cl}} \\ &= 2(35.45 \text{ g/mol}) \\ &= 70.90 \text{ g/mol} \end{aligned}$$

Amount in moles, *n*, of Cl_2(g):

$$\begin{aligned} n_{\text{Cl}_2} &= \frac{m}{M} \\ &= \frac{6.98 \cancel{\text{g}}}{70.90 \cancel{\text{g}}/\text{mol}} \\ &= 0.984485 \text{ mol} \end{aligned}$$

Temperature ratio:

$$T_1 = 273.15 \text{ K}$$

$$T_2 = 298.15 \text{ K}$$

temperature ratio >1 is $\dfrac{298.15 \text{ K}}{273.15 \text{ K}}$

Pressure ratio:
P_1 = 101.325 kPa
P_2 = 100.0 kPa
pressure ratio > 1 is $\dfrac{101.325 \text{ kPa}}{100.0 \text{ kPa}}$

Final volume, V_2, of the chlorine gas:

$$\begin{aligned} V_2 &= V_1 \times \text{ temperature ratio } \times \text{ pressure ratio} \\ &= 2.27 \text{ L} \times \frac{298.15 \cancel{\text{K}}}{273.15 \cancel{\text{K}}} \times \frac{101.325 \cancel{\text{kPa}}}{100.0 \cancel{\text{kPa}}} \\ &= 2.51059 \text{ L} \end{aligned}$$

Molar volume, v, of $Cl_2(g)$ at SATP:

$$\begin{aligned} v &= \frac{V_2 \times \text{ mole ratio}}{1.0 \text{ mol}} \\ &= \frac{2.51059 \text{ L} \times \dfrac{1.0 \cancel{\text{mol}}}{0.0984485 \cancel{\text{mol}}}}{1.0 \text{ mol}} \\ &= 25.50155 \text{ L/mol} \\ &= 26 \text{ L/mol} \end{aligned}$$

The molar volume of the chlorine gas at SATP is 26 L/mol.

Check Your Solution

The molar volume would be expected to be slightly greater because the change in conditions from STP to SATP results in changes to the temperature and pressure that both cause the volume to increase. The answer is reasonable and is correctly expressed to two significant digits.

18. Practice Problem (page 549)

A sample of helium gas has a mass of 11.28 g. At STP, the sample has a volume of 63.2 L.
What is the molar volume of this gas at 32.2°C and 98.1 kPa?

What Is Required?

You need to find the molar volume, v, of helium gas, He(g), at 32.2°C and 98.1 kPa.

Check Your Solution
The molar volume would be expected to be slightly greater because the change in conditions from STP to SATP results in changes to the temperature and pressure that both cause the volume to increase. The answer is reasonable and is correctly expressed to three significant digits.

19. Practice Problem (page 549)
Magnesium, Mg(s), was reacted with hydrochloric acid, HCl(aq), in excess according to the following equation:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

When 0.0354 g of magnesium was reacted, 35.63 mL of hydrogen gas was collected.

a. How many moles of magnesium were reacted?
b. How many moles of hydrogen were collected?
c. If the hydrogen gas was collected at 20.0°C and 99.5 kPa, determine the molar volume of hydrogen gas from the experimental data.

What Is Required?
You need to find
a. the amount in moles of magnesium, Mg(s), that reacts.
b. the amount in moles of hydrogen gas, $H_2(g)$, produced.
c. the molar volume, *v*, of $H_2(g)$ at 20.0°C and 99.5 kPa.

What Is Given?
You know the mass of magnesium that reacted: $m = 0.0354$ g
You know the volume of hydrogen gas produced: $V = 35.63$ L
You know from the balanced chemical equation that the mole ratio of Mg(s):$H_2(g)$ is 1:1.
You know the temperature and pressure at which the hydrogen gas was produced:
$T = 20.0$°C
$P = 99.5$ kPa
You know the molar mass of Mg(s): $M = 24.31$ g/mol (from the periodic table)

Plan Your Strategy
a. Calculate the amount in moles of Mg(s) using the relationship $n = \dfrac{m}{M}$.
b. Use the mole ratio in the balanced chemical equation to determine the amount in moles of $H_2(g)$ produced.
c. Convert the volume of $H_2(g)$ from millilitres to litres: $1 \text{ mL} = 1 \times 10^{-3} \text{ L}$

Calculate the molar volume, *v*, of H_2(g) using the relationship $v = \frac{V}{n}$.

Act on Your Strategy

a. Amount in moles, *n*, of Mg(s):

$$\begin{aligned} n_{\text{Mg}} &= \frac{m}{M} \\ &= \frac{0.0354\ \cancel{\text{g}}}{24.31\ \cancel{\text{g}}\text{/mol}} \\ &= 1.45619 \times 10^{-3}\ \text{mol} \\ &= 1.46 \times 10^{-3}\ \text{mol} \end{aligned}$$

The amount in moles of magnesium is 1.46×10^{-3} mol.

b. Amount in moles, *n*, of H_2(g) produced:

$$\frac{1\ \text{mol Mg}}{1\ \text{mol H}_2} = \frac{1.45619 \times 10^{-3}\ \text{mol Mg}}{n_{\text{H}_2}}$$

$$\begin{aligned} n_{\text{H}_2} &= 1.45619 \times 10^{-3}\ \text{mol}\ \cancel{\text{Mg}} \times \frac{1\ \text{mol H}_2}{1\ \text{mol}\ \cancel{\text{Mg}}} \\ &= 1.45619 \times 10^{-3}\ \text{mol} \\ &= 1.46 \times 10^{-3}\ \text{mol} \end{aligned}$$

The amount in moles of H_2(g) produced is 1.46×10^{-3} mol.

c. Molar volume, *v*, of H_2(g) produced:

Volume of H_2(g):

$$\begin{aligned} V &= 35.63\ \cancel{\text{mL}} \times 1 \times 10^{-3}\ \text{L}/\cancel{\text{mL}} \\ &= 0.03563\ \text{L} \end{aligned}$$

Molar volume, *v*, of H_2(g):

$$\begin{aligned} v &= \frac{V}{n} \\ &= \frac{0.03563\ \text{L}}{1.45619 \times 10^{-3}\ \text{mol}} \\ &= 24.4679\ \text{L/mol} \\ &= 24.5\ \text{L/mol} \end{aligned}$$

Check Your Solution
The answers are expressed on the correct units. The calculated molar volume is very close to the molar volume at STP. This is a reasonable answer and it is correctly expressed to three significant digits.

20. Practice Problem (page 549)
Helium has a density of 0.179 g/L at STP. Calculate its molar volume at these conditions.

What Is Required?
You need to find the molar volume of helium gas, He(g).

What Is Given?
You know the density of helium at STP is 0.179 g/L:
$V = 1.00$ L
$m = 0.179$ g
You know the molar mass of helium: $M = 4.00$ g/mol (from the periodic table)

Plan Your Strategy
Calculate the amount in moles of He(g) using the relationship $n = \frac{m}{M}$.

Calculate the molar volume of He(g) using the relationship $v = \frac{V}{n}$.

Act on Your Strategy
Amount in moles, n, of He(g):

$$\begin{aligned} n_{\text{He}} &= \frac{m}{M} \\ &= \frac{0.179\ \cancel{\text{g}}}{4.00\ \cancel{\text{g}}\text{/mol}} \\ &= 0.04475\ \text{mol} \end{aligned}$$

Molar volume of He(g):

$$\begin{aligned} v &= \frac{V}{n} \\ &= \frac{1.00\ \text{L}}{0.04475\ \text{mol}} \\ &= 22.3463\ \text{L/mol} \\ &= 22.3\ \text{L/mol} \end{aligned}$$

The molar volume of helium gas at STP is 22.3 L/mol.