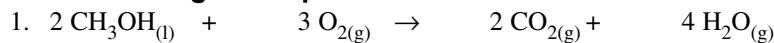


10.4 GAS STOICHIOMETRY

PRACTICE

(Page 483)

Understanding Concepts



15 g

v

32.05 g/mol 22.4 L/mol (STP)

$$n_{\text{CH}_3\text{OH}} = 15 \text{ g} \times \frac{1 \text{ mol}}{32.05 \text{ g}}$$

$$n_{\text{CH}_3\text{OH}} = 0.47 \text{ mol}$$

$$n_{\text{O}_2} = 0.47 \text{ mol} \times \frac{3}{2}$$

$$n_{\text{O}_2} = 0.70 \text{ mol}$$

$$v_{\text{O}_2} = 0.70 \text{ mol} \times \frac{22.4 \text{ L}}{1 \text{ mol}}$$

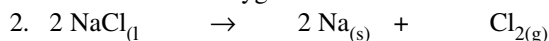
$$v_{\text{O}_2} = 16 \text{ L}$$

or

$$v_{\text{O}_2} = 15 \text{ g CH}_3\text{OH} \times \frac{1 \text{ mol CH}_3\text{OH}}{32.05 \text{ g CH}_3\text{OH}} \times \frac{3 \text{ mol O}_2}{2 \text{ mol CH}_3\text{OH}} \times \frac{22.4 \text{ L O}_2}{1 \text{ mol O}_2}$$

$$v_{\text{O}_2} = 16 \text{ L}$$

The volume of oxygen needed is 16 L



105 kg

v

22.99 g/mol

24.8 L/mol (SATP)

$$n_{\text{Na}} = 105 \text{ kg} \times \frac{1 \text{ mol}}{22.99 \text{ g}}$$

$$n_{\text{Na}} = 4.57 \text{ kmol}$$

$$n_{\text{Cl}_2} = 4.57 \text{ kmol} \times \frac{1}{2}$$

$$n_{\text{Cl}_2} = 2.28 \text{ kmol}$$

$$v_{\text{Cl}_2} = 2.28 \text{ kmol} \times \frac{24.8 \text{ L}}{1 \text{ mol}}$$

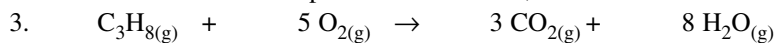
$$v_{\text{Cl}_2} = 56.6 \text{ kL}$$

or

$$v_{\text{Cl}_2} = 105 \text{ kg Na} \times \frac{1 \text{ mol Na}}{22.99 \text{ g Na}} \times \frac{1 \text{ mol Cl}_2}{2 \text{ mol Na}} \times \frac{24.8 \text{ L Cl}_2}{1 \text{ mol Cl}_2}$$

$$v_{\text{Cl}_2} = 56.6 \text{ kL}$$

The volume of chlorine produced is 56.6 kL, or 56.6 m³.



m

v

44.11 g/mol 24.8 L/mol (SATP)

$$v_{\text{O}_2} = 125 \text{ L} \times 20\% = 25 \text{ L}$$

$$n_{\text{O}_2} = 25 \text{ L} \times \frac{1 \text{ mol}}{24.8 \text{ L}}$$

$$\begin{aligned}
 n_{\text{O}_2} &= 1.0 \text{ mol} \\
 n_{\text{C}_3\text{H}_8} &= 1.0 \text{ mol} \times \frac{1}{5} \\
 n_{\text{C}_3\text{H}_8} &= 0.20 \text{ mol} \\
 m_{\text{C}_3\text{H}_8} &= 0.20 \text{ mol} \times \frac{44.11 \text{ g}}{1 \text{ mol}} \\
 m_{\text{C}_3\text{H}_8} &= 8.9 \text{ g}
 \end{aligned}$$

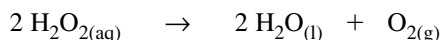
or

$$\begin{aligned}
 m_{\text{C}_3\text{H}_8} &= 25 \cancel{\text{ L O}_2} \times \frac{1 \cancel{\text{ mol O}_2}}{24.8 \cancel{\text{ L O}_2}} \times \frac{1 \cancel{\text{ mol C}_3\text{H}_8}}{5 \cancel{\text{ mol O}_2}} \times \frac{44.11 \text{ g C}_3\text{H}_8}{1 \cancel{\text{ mol C}_3\text{H}_8}} \\
 m_{\text{C}_3\text{H}_8} &= 8.9 \text{ g}
 \end{aligned}$$

The mass of propane that can be burned is 8.9 g.

Applying Inquiry Skills

4. (a) Prediction



50.0 mL v (lab p & T conditions)

0.88 mol/L

$$n_{\text{H}_2\text{O}_2} = 50.0 \cancel{\text{ mL}} \times \frac{0.88 \text{ mol}}{1 \cancel{\text{ L}}}$$

$$n_{\text{H}_2\text{O}_2} = 44 \text{ mmol}$$

$$n_{\text{O}_2} = 44 \text{ mmol} \times \frac{1}{2}$$

$$n_{\text{O}_2} = 22 \text{ mmol}$$

$$p = (94.6 - 2.49) \text{ kPa} = 92.1 \text{ kPa (corrected for water vapour pressure)}$$

$$T = 21^\circ\text{C} = 294 \text{ K}$$

$$v_{\text{O}_2} = ?$$

$$R = 8.31 \text{ kPa} \cdot \text{L}/(\text{mol} \cdot \text{K})$$

$$pv = nRT$$

$$v_{\text{O}_2} = \frac{nRT}{p}$$

$$= \frac{22 \cancel{\text{ mmol}} \times \frac{8.31 \cancel{\text{ kPa}} \cdot \text{L}}{\cancel{\text{ mol}} \cdot \cancel{\text{ K}}} \times 294 \cancel{\text{ K}}}{92.1 \cancel{\text{ kPa}}}$$

$$v_{\text{O}_2} = 5.8 \times 10^3 \text{ mL} = 0.58 \text{ L}$$

or

$$v_{\text{O}_2} = 50.0 \cancel{\text{ mL H}_2\text{O}_2} \times \frac{0.88 \cancel{\text{ mol H}_2\text{O}_2}}{1 \cancel{\text{ L H}_2\text{O}_2}} \times \frac{1 \cancel{\text{ mol O}_2}}{2 \cancel{\text{ mol H}_2\text{O}_2}} \times \frac{8.31 \cancel{\text{ kPa}} \cdot \text{L O}_2}{1 \cancel{\text{ mol O}_2} \cdot \cancel{\text{ K}}} \times \frac{294 \cancel{\text{ K}}}{92.1 \cancel{\text{ kPa}}}$$

$$v_{\text{O}_2} = 5.8 \times 10^3 \text{ mL} = 0.58 \text{ L}$$

According to the ideal gas law, the volume of oxygen at room pressure and temperature is predicted to be 0.58 L.

(b) Analysis

According to the evidence, the volume of oxygen gas produced at room conditions is 556 mL = 0.556 L.

(c) Evaluation

$$\text{difference} = |0.556 - 0.58| \text{ L} = 0.02 \text{ L}$$

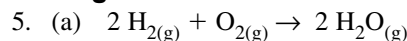
$$\% \text{ difference} = \frac{0.02 \cancel{\text{L}}}{0.58 \cancel{\text{L}}} \times 100\% = 4\%$$

The evidence agrees well with the predicted value, within 4%.

(d) **Evaluation**

The ideal gas law is judged to be verified by this investigation, since the evidence agrees well with the prediction.

Making Connections



300 L

All gases measured at 40°C and 1.50 atm.

$$v_{\text{O}_2} = 300 \text{ L} \times \frac{1}{2}$$

$$v_{\text{O}_2} = 150 \text{ L}$$

or

$$v_{\text{O}_2} = 300 \cancel{\text{L}} \cancel{\text{H}_2} \times \frac{1 \text{ L O}_2}{2 \cancel{\text{L}} \cancel{\text{H}_2}}$$

$$v_{\text{O}_2} = 150 \text{ L}$$

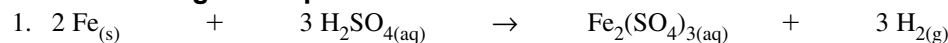
The volume of oxygen required is 150 L.

(b) A vehicle burning hydrogen fuel by using oxygen from the air (which contains nitrogen) could still produce NO_x pollutants if the combustion temperature were high enough.

SECTION 10.4 QUESTIONS

(Page 486)

Understanding Concepts



10 g

v

55.85 g/mol

22.4 L/mol (STP)

$$n_{\text{Fe}} = 10 \cancel{\text{g}} \times \frac{1 \text{ mol}}{55.85 \cancel{\text{g}}}$$

$$n_{\text{Fe}} = 0.18 \text{ mol}$$

$$n_{\text{H}_2} = 0.18 \text{ mol} \times \frac{3}{2}$$

$$n_{\text{H}_2} = 0.27 \text{ mol}$$

$$n_{\text{H}_2} = 0.27 \cancel{\text{mol}} \times \frac{22.4 \text{ L}}{1 \cancel{\text{mol}}}$$

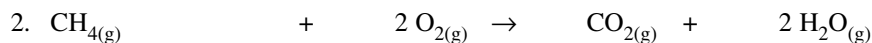
$$n_{\text{H}_2} = 6.0 \text{ L}$$

or

$$n_{\text{H}_2} = 10 \cancel{\text{g}} \cancel{\text{Fe}} \times \frac{1 \cancel{\text{mol}} \cancel{\text{Fe}}}{55.85 \cancel{\text{g}} \cancel{\text{Fe}}} \times \frac{3 \cancel{\text{mol}} \cancel{\text{H}_2}}{2 \cancel{\text{mol}} \cancel{\text{Fe}}} \times \frac{22.4 \text{ L H}_2}{1 \cancel{\text{mol}} \cancel{\text{H}_2}}$$

$$n_{\text{H}_2} = 6.0 \text{ L}$$

The volume of hydrogen produced will be 6.0 L.



2.00 ML, 0°C, 120 kPa ν (SATP)

$$\nu_{\text{O}_2} = 2.00 \text{ ML} \times \frac{2}{1}$$

$$\nu_{\text{O}_2} = 4.00 \text{ ML} \quad (\text{at } 0^\circ\text{C} = 273 \text{ K, } 120 \text{ kPa})$$

$$p_1 = 120 \text{ kPa}$$

$$T_1 = 0^\circ\text{C} = 273 \text{ K}$$

$$\nu_1 = 2.00 \text{ ML}$$

$$p_2 = 100 \text{ kPa}$$

$$T_2 = 25^\circ\text{C} = 298 \text{ K}$$

$$\nu_{\text{O}_2} = ?$$

$$\frac{p_1 \nu_1}{T_1} = \frac{p_2 \nu_2}{T_2}$$

$$\nu_{\text{O}_2} = \frac{T_2 p_1 \nu_1}{T_1 p_2}$$

$$= \frac{298 \text{ K} \times 120 \text{ kPa} \times 2.00 \text{ ML}}{273 \text{ K} \times 100 \text{ kPa}}$$

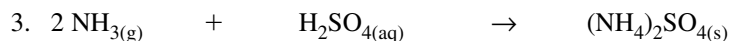
$$\nu_{\text{O}_2} = 2.62 \text{ ML}$$

or

$$\nu_{\text{O}_2} = 2.00 \text{ ML } \cancel{\text{CH}_4} \times \frac{2 \text{ L O}_2}{1 \text{ L } \cancel{\text{CH}_4}} \times \frac{120 \text{ kPa}}{100 \text{ kPa}} \times \frac{298 \text{ K}}{273 \text{ K}}$$

$$\nu_{\text{O}_2} = 2.62 \text{ ML}$$

The SATP volume of oxygen required is 2.62 ML, or $2.62 \times 10^3 \text{ m}^3$.



75.0 kL, 10°C = 283 K, 110 kPa

m

$R = 8.31 \text{ kPa} \cdot \text{L}/(\text{mol} \cdot \text{K})$

132.16 g/mol

$$pv = nRT$$

$$n_{\text{NH}_3} = \frac{pv}{RT}$$

$$= \frac{110 \text{ kPa} \times 75.0 \text{ kL}}{8.31 \text{ kPa} \cdot \text{L} \cdot \text{K} \times 283 \text{ K}}$$

$$n_{\text{NH}_3} = 3.51 \text{ kmol}$$

$$n_{(\text{NH}_4)_2\text{SO}_4} = 3.51 \text{ kmol} \times \frac{1}{2}$$

$$n_{(\text{NH}_4)_2\text{SO}_4} = 1.75 \text{ kmol}$$

$$m_{(\text{NH}_4)_2\text{SO}_4} = 1.75 \text{ kmol} \times \frac{132.16 \text{ g}}{1 \text{ mol}}$$

$$m_{(\text{NH}_4)_2\text{SO}_4} = 232 \text{ kg}$$

or

$$m_{(\text{NH}_4)_2\text{SO}_4} = 75.0 \text{ kL } \cancel{\text{NH}_3} \times \frac{1 \text{ mol } \cancel{\text{NH}_3} \cdot \text{K}}{8.31 \text{ kPa} \cdot 1 \text{ L } \cancel{\text{NH}_3}} \times \frac{100 \text{ kPa}}{283 \text{ K}}$$

$$(\text{continued}) \times \frac{1 \cancel{\text{mol}} (\text{NH}_4)_2\text{SO}_4}{\cancel{124.17 \text{ g}}} \times \frac{132.16 \text{ g } (\text{NH}_4)_2\text{SO}_4}{\cancel{1 \text{ mol}}}$$

$$m_{(\text{NH}_4)_2\text{SO}_4} = 232 \text{ kg}$$

The mass of ammonium sulfate that can be produced is 232 kg.



$$1.0 \text{ kg} \quad v (20^\circ\text{C} = 293 \text{ K}, 95 \text{ kPa})$$

$$124.17 \text{ g/mol}$$

$$R = 8.31 \text{ kPa} \cdot \text{L}/(\text{mol} \cdot \text{K})$$

$$n_{\text{CH}_4 \cdot 6\text{H}_2\text{O}} = 1.0 \text{ kg} \times \frac{1 \text{ mol}}{124.17 \text{ g}}$$

$$n_{\text{CH}_4 \cdot 6\text{H}_2\text{O}} = 0.00805 \text{ kmol}$$

$$n_{\text{CH}_4} = 0.00805 \text{ kmol} \times \frac{1}{1}$$

$$n_{\text{CH}_4} = 0.00805 \text{ kmol}$$

$$pv = nRT$$

$$v_{\text{CH}_4} = \frac{nRT}{p}$$

$$= \frac{0.00805 \cancel{\text{kmol}} \times \frac{8.31 \cancel{\text{kPa}} \cdot \text{L}}{\cancel{\text{mol}} \cdot \cancel{\text{K}}} \times 293 \cancel{\text{K}}}{95 \cancel{\text{kPa}}}$$

$$v_{\text{CH}_4} = 0.21 \text{ kL}$$

or

$$v_{\text{CH}_4} = 1.0 \text{ kg } \text{CH}_4 \cdot 6\text{H}_2\text{O} \times \frac{1 \cancel{\text{mol}} \text{CH}_4 \cdot 6\text{H}_2\text{O}}{\cancel{124.17 \text{ g}}} \times \frac{1 \cancel{\text{mol}} \text{CH}_4}{1 \cancel{\text{mol}} \text{CH}_4 \cdot 6\text{H}_2\text{O}}$$

$$(\text{continued}) \times \frac{8.31 \cancel{\text{kPa}} \cdot \text{L } \text{CH}_4}{1 \cancel{\text{mol}} \text{CH}_4 \cdot \cancel{\text{K}}} \times \frac{293 \cancel{\text{K}}}{95 \cancel{\text{kPa}}}$$

$$v_{\text{CH}_4} = 0.21 \text{ kL}$$

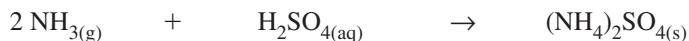
The volume of methane gas produced is 0.21 kL, or 0.21 m³.

Making Connections

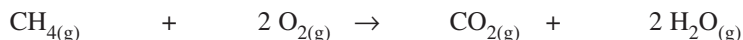
5. One consumer reaction that produces and consumes gases is the burning of propane in an outdoor barbeque. The reaction is:



One industrial reaction that consumes a gas is the production of ammonium sulfate fertilizer. The reaction is:



One laboratory reaction that produces and consumes gases is the burning of methane (natural gas) in a lab burner. The reaction is:



Reflecting

6. (a) All stoichiometry involves the numerical ratios of reactants and products, that is, the ratios of amounts in moles.
 (b) In an industry using a chemical reaction, knowledge of stoichiometry is essential to determine how much of reactant to purchase and use. For example, in the reaction

$$2 \text{NH}_{3(\text{g})} + \text{H}_2\text{SO}_{4(\text{aq})} \rightarrow (\text{NH}_4)_2\text{SO}_{4(\text{s})}$$
 used to make fertilizer, the reacting amounts of ammonia and sulfuric acid would have to be calculate beforehand.
 (c) Adding “just the right amount” of baking powder to a baking mix is an example of consumer use of stoichiometry.