CHAPTER 10 GAS MIXTURES AND REACTIONS

Try This Activity: Producing a "Natural" Gas

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- White cloudy mixture formed with many gas bubbles rising to the surface. Many droplets of liquid were spitting up from the surface.
- The lit match was extinguished.
- When the glass was tipped to "pour" the gas over the lit match, the match was also extinguished.

(a) Nitrogen, oxygen, and small quantities of other gases are present in the air.
(b) Carbon dioxide is likely present after the reaction, because the gas does not support combustion (a characteristic of carbon dioxide).
(c) If the gas is bubbled through limewater, and the limewater turns cloudy, then carbon dioxide is likely present.
(d) It suggests that the gas is more dense than air.
(e) Carbon dioxide is used as a fire extinguisher (and also as an effervescent).
(f) Carbon dioxide escapes from underground pockets of gas. Natural decomposition of limestone produces bubbles of carbon dioxide that escape from the surface of lakes. (Other examples include volcanoes and some hot springs.)

10.1 MIXTURES OF GASES

PRACTICE

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Understanding Concepts

1. The pressure of $CO_{2(g)}$ is constant at 2 kPa.
2. (a) The total pressure is (593.3 + 157 + 11 + 0.5) mm Hg = 762 mm Hg, or the total pressure is (79.11 + 20.9 + 1.5 + 0.07) kPa = 101.6 kPa.
   (b) $762\ \cancel{\text{mm Hg}} \times \dfrac{101.325\ \text{kPa}}{760\ \cancel{\text{mm Hg}}} = 102\ \text{kPa}$
   The pressures of 760 mm Hg and 102 kPa (which is 101.6 kPa rounded to 3 significant digits) are equivalent.
3. The partial pressure of helium is (14.0 – 1.1) atm = 12.9 atm.

Reflecting

4. (a) Both alloys and the atmosphere are solutions — homogeneous mixtures.
   (b) Alloy components are measured by mass, and the law of conservation of mass serves the same purpose for alloys that Dalton's law does for gas solutions.

PRACTICE

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Understanding Concepts

5. (a) Pressure exerted by a gas is the total force per unit area of the gas molecules striking the interior surface of the container.
   (b) Particles move in straight lines unless deviated by some outside force. Intermolecular forces are very small (negligible) for most gases, so the molecules travel in (essentially) straight lines.
6. (a) The pressure is directly proportional to the number of gas molecules present — so it should double.
   (b) The pressure should still double — the kind of gas molecule is unimportant.
   (c) Dalton's law of partial pressures is based on the concept that the kind of molecule is unimportant — the pressure depends only on the relative numbers of molecules.
7. If gases react, the number and kind of molecules, and therefore the pressure, will change because of the reaction.

PRACTICE

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Understanding Concepts

8. From Table 3, the vapour pressure of water at 23°C is 2.81 kPa, so that will be the partial pressure inside the container.
9. Use the Table 3 value for water vapour pressure at 20°C of 2.34 kPa. The partial pressure of nitrogen will be (98.1 – 2.34) kPa = 95.8 kPa.
10. (a) Calculate as before, using Table 3. The partial pressure of hydrogen will be (92.4 – 3.17) kPa = 89.2 kPa.

    (b) $p_1 = 89.2$ kPa

    $v_1 = 275$ mL

    $p_2 = 100$ kPa

    $v_2 = ?$

$$p_1 v_1 = p_2 v_2$$

$$v_2 = \frac{p_1 v_1}{p_2}$$

$$= \frac{89.2\ \cancel{\text{kPa}} \times 275\ \text{mL}}{}$$

$$v_2 = 245\ \text{mL}$$

or

$$v_2 = 275\ \text{mL} \times \frac{89.2\ \cancel{\text{kPa}}}{100\ \cancel{\text{kPa}}}$$

$$v_2 = 245\ \text{mL}$$

The final volume of hydrogen would be 245 mL.

Applying Inquiry Skills

11. **Experimental Design**

    Ammonia is collected by downward displacement of air in a fume hood, since it is much less dense than air.

    Note: In practice, ammonia liquifies easily under only moderate pressure because of hydrogen bonding — so it is usually collected and transported as a liquid, called anhydrous (waterless) ammonia.

Making Connections

12. The principal gases above the liquid are carbon dioxide and water vapour. The total pressure is noticeably higher than atmospheric, so must be significantly greater than 100 kPa.

SECTION 10.1 QUESTIONS

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Understanding Concepts

1. (a) The partial pressure of $O_{2(g)}$ is (385 – 240) kPa = 145 kPa.

   (b) We assume that the total pressure is the sum of the partial pressures.
2. (a) The total pressure in is (79.3 + 21.3 + 0.040 + 0.67) kPa = 101.3 kPa, and the total pressure out is (75.9 + 15.5 + 3.7 + 6.2) kPa = 101.3 kPa.

   (b) $101.3\ \cancel{\text{kPa}} \times \frac{1\ \text{atm}}{101.325\ \cancel{\text{kPa}}} = 1.000\ \text{atm}$

   (c) Since your lungs are open to the atmosphere when breathing, inhaled and exhaled air must begin and end at the same (ambient atmospheric) pressure. The change in proportions of the gases are biological evidence that animals need oxygen to live — and chemical evidence that reactions have occurred to produce carbon dioxide and water vapour.

3. Dalton's law works well for any gases that behave similarly to the "ideal" gas — that have small molecules and low intermolecular forces, and do not react.
4. Dalton's law can be explained by two concepts: gas particles act independently; and pressure is caused by particle collisions with the walls of the container.
5. Dalton's law works perfectly only for "ideal" gases; but to three significant digits, for most common gases, it works well.

Making Connections

6. Possibilities include the gradual absorption of emitted gases by physical, geological, and biological processes. For example, carbon dioxide dissolves in water (oceans), and is used by plants to generate sugars through photosynthesis. The carbon in the gas can be followed through biological processes until it is deposited as sediment and buried, eventually forming limestone.

Reflecting

7. Diagrams drawn by students should show the principle illustrated in Figure 2, in a similar fashion. The adding of amounts must be shown as proportional to the adding of pressures.
   Visual models are much easier for most people to understand than mathematical models.

10.2 REACTIONS OF GASES

PRACTICE

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Understanding Concepts

1. Avogadro's theory was needed to relate reacting volumes to equations.
2. Avogadro used empirical observations of coefficient values from equations, and reacting volume ratios of gases.
3. $C_3H_{8(g)} \quad + \quad 5\ O_{2(g)} \quad \rightarrow \quad 3\ CO_{2(g)} \quad + \quad 4\ H_2O_{(g)}$

   5.00 L $\qquad\qquad$ v

   Pressure and temperature conditions equal for all gases measured.

   $v_{O_2} = 5.00\ \text{L} \times \frac{5}{1}$

   $v_{O_2} = 25.0\ \text{L}$

or *Note:* The text example on page 468 uses a mole ratio for conversion, but the volume ratio shown here is more appropriate.

   $v_{O_2} = 5.00\ \cancel{\text{L}}\ \cancel{C_3H_8} \times \frac{5\ \text{L}\ O_2}{1\ \cancel{\text{L}}\ \cancel{C_3H_8}}$

   $v_{O_2} = 25.0\ \text{L}$

   The volume of oxygen required is 25.0 L.

4. $2\ NO_{(g)} \quad + \quad 2\ H_{2(g)} \quad \rightarrow \quad N_{2(g)} \quad + \quad 2\ H_2O_{(g)}$

   1.2 L $\qquad\qquad\qquad\qquad$ v

   Pressure and temperature conditions equal for all gases measured.

   $v_{N_2} = 1.2\ \text{L} \times \frac{1}{2}$

   $v_{N_2} = 0.60\ \text{L}$

or

   $v_{N_2} = 1.2\ \cancel{\text{L}}\ \cancel{NO} \times \frac{1\ \text{L}\ N_2}{2\ \cancel{\text{L}}\ \cancel{NO}}$

   $v_{N_2} = 0.60\ \text{L}$

   The volume of nitrogen produced is 0.60 L.