

# Unit 4 Chemical Systems and Equilibrium

## ARE YOU READY?

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### Knowledge and Understanding

- solid, liquid, and gas
  - The system is considered closed because matter cannot flow in or out of the system. Removal of the lid allows water molecules to escape, creating an open system.
  - The reduction in size of the sugar cube as it dissolves proves that the solution is unsaturated.
  - The crystal remains the same size because the solution is saturated with sugar. Crystallization and dissolving are both occurring at the same rate.
  - The solution is saturated. The crystal would shrink in size if the solution was unsaturated.
- $$\text{Mg}_{(s)} + 2 \text{HCl}_{(aq)} \rightarrow \text{MgCl}_{2(aq)} + \text{H}_{2(g)}$$
  - $$n_{\text{HCl}} = v_{\text{HCl}} \times c_{\text{HCl}}$$

$$= 0.250 \text{ L} \times 0.8 \text{ mol/L}$$

$$n_{\text{HCl}} = 0.2 \text{ mol}$$

2:1 mol ratio

$$\therefore n_{\text{MgCl}_2} = 0.1 \text{ mol}$$

0.1 mol of magnesium chloride is produced.
  - $$c_{\text{MgCl}_2} = \frac{0.1 \text{ mol}}{0.250 \text{ L}}$$

$$c_{\text{MgCl}_2} = 0.4 \text{ mol/L}$$

The concentration of the magnesium chloride solution is 0.4 mol/L.
- A strong base, such as sodium hydroxide,  $\text{NaOH}_{(aq)}$ , raises the pH of water far more than a weak base like aqueous ammonia,  $\text{NH}_{3(aq)}$ .
  - An acid is a proton donor while a base is a proton acceptor.
  - $$\underset{\text{B}_2}{\text{HPO}_{4(aq)}^{2-}} + \underset{\text{A}_1}{\text{HSO}_{4(aq)}^-} \rightarrow \underset{\text{A}_2}{\text{H}_2\text{PO}_{4(aq)}^-} + \underset{\text{B}_1}{\text{SO}_{4(aq)}^{2-}}$$
- $$\text{C}_3\text{H}_{6(g)} + 4.5 \text{O}_{2(g)} \rightarrow 3 \text{CO}_{2(g)} + 3 \text{H}_2\text{O}_{(g)}$$

$$\Delta H = [3\Delta H_{f(\text{CO}_{2(g)})} + 3\Delta H_{f(\text{H}_2\text{O}_{(g)})}] - [\Delta H_{f(\text{C}_3\text{H}_{6(g)})}]$$

$$= [3 \text{ mol} \times (-393.5 \text{ kJ/mol}_{\text{CO}_{2(g)}}) + 3 \text{ mol} \times (-241.8 \text{ kJ/mol}_{\text{H}_2\text{O}_{(g)}})] - [+17.8 \text{ kJ/mol}_{\text{C}_3\text{H}_{6(g)}}]$$

$$\Delta H = -1923.7 \text{ kJ/mol}_{\text{C}_3\text{H}_6}$$

### Inquiry and Communication

#### 5. Procedure

- Put on eye protection and a lab apron.
  - Add about 600 mL of water to a 1-L beaker on a hot plate.
  - Raise the temperature of the water to 60°C and maintain the temperature at this level.
  - Add 100 mL of water to a 125-mL flask.
  - Add 0.020 g of calcium hydroxide to the flask.
  - Insert a thermometer into the flask.

7. Use water bath to warm the contents of the flask up to 60°C.
8. Note if the calcium hydroxide had dissolved.
9. If the calcium hydroxide did completely dissolve, add another 0.02 g to the flask.
10. Repeat steps 7 through 9 until some calcium hydroxide remains.

#### Safety Precautions

Wear eye protection and lab aprons.

- (b) If 0.10 g of calcium hydroxide dissolves in 100 mL, then 1.0 g will dissolve in 1 L of water.

$$n_{\text{Ca(OH)}_{2(\text{aq})}} = \frac{1.0 \text{ g}}{74.10 \text{ g/mol}}$$

$$n_{\text{Ca(OH)}_{2(\text{aq})}} = 0.0135 \text{ mol} \quad (\text{extra digits carried})$$

$$[\text{Ca(OH)}_{2(\text{aq})}] = \frac{0.0135 \text{ mol}}{1.0 \text{ L}}$$

$$[\text{Ca(OH)}_{2(\text{aq})}] = 0.0135 \text{ mol/L}$$

Since there are two hydroxide ions in each  $\text{Ca(OH)}_{2(\text{aq})}$

$$[\text{OH}^-_{(\text{aq})}] = 2 \times [\text{Ca(OH)}_{2(\text{aq})}]$$

$$[\text{OH}^-_{(\text{aq})}] = 0.027 \text{ mol/L}$$

The hydroxide concentration is 0.027 mol/L.

- (c) The calculation assumes that the ionization of water does not contribute a significant amount of hydroxide.
6. (a) Chemical equation:  $\text{NaOH}_{(\text{aq})} + \text{HCl}_{(\text{aq})} \rightarrow \text{H}_2\text{O}_{(\text{l})} + \text{NaCl}_{(\text{aq})}$
- Total ionic equation:  $\text{Na}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})} + \text{H}^+_{(\text{aq})} + \text{Cl}^-_{(\text{aq})} \rightarrow \text{H}_2\text{O}_{(\text{l})} + \text{Na}^+_{(\text{aq})} + \text{Cl}^-_{(\text{aq})}$
- Net ionic equation:  $\text{OH}^-_{(\text{aq})} + \text{H}^+_{(\text{aq})} \rightarrow \text{H}_2\text{O}_{(\text{l})}$

- (b) neutralization reaction
- (c) buret
- (d) titration
- (e) an acid–base indicator
- (f) **Procedure**

Add three drops of bromothymol blue indicator to the flask.

- Add base in small increments to the titration flask. Swirl the flask carefully during each addition.
- Continue adding base until a bromothymol blue endpoint.

#### Safety Precautions

Eye protection and a lab apron must be worn.

- (g) 15.00 mL
- (h) 7
- (i) Test the solution with pH test strips or a pH meter.
- (j)  $[\text{H}^+_{(\text{aq})}] = 1.0 \times 10^{-7} \text{ mol/L}$

$$7. (a) \frac{(0.020)(0.030)}{(0.10)x} = 2.3 \times 10^{-4}$$

$$\frac{6.0 \times 10^{-4}}{(0.10)x} = 2.3 \times 10^{-4}$$

$$\frac{6.0}{(0.10)x} = 2.3$$

$$\frac{60}{x} = 2.3$$

$$x = \frac{60}{2.3}$$

$$x = 26$$

$$(b) \quad \frac{(2x)^2}{(x - 0.20)^2} = 49$$

$$\sqrt{\frac{(2x)^2}{(x - 0.20)^2}} = \sqrt{49}$$

$$\frac{2x}{x - 0.20} = 7$$

$$7x - 1.4 = 2x$$

$$5x = 1.4$$

$$x = 0.28$$

$$(c) \quad \frac{(3x)^2}{(x - 1.0)(x - 3.0)} = 2.0$$

$$\frac{9x^2}{(x^2 - 4x + 3)} = 2.0$$

$$9x^2 = 2x^2 - 8x + 6$$

$$7x^2 + 8x - 6 = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-8 \pm \sqrt{8^2 - 4 \times 7(-6)}}{2 \times 1}$$

$$= 0.52 \text{ or } -1.7$$

8. Since the pH scale is logarithmic, a change in only 1 pH unit represents a 10-fold change in acidity. Sourville's water is on average over 10 times more acidic than neutral water. The August and September readings were approximately 100 times the acidity of neutral water. Although the acidity from the occasional soft drink or salad may not be a health risk, prolonged exposure to excess acid is a potential health risk. For example, below a pH of 5.5, tooth enamel begins to break down. The water commissioner should take the appropriate steps to raise the pH of the town's water supply.