Making Connections

6. Water treatment is designed to remove physical, biological, and chemical contaminants. Physical contaminants are removed through coagulation, flocculation, sedimentation, and filtration; biological contaminants are removed through disinfection and postchlorination; chemical contaminants are removed through aeration and softening.

   Water treatment on a large scale is usually a continuous process (rather than a batch process) in order to provide a continuous flow of treated water into the water system. Continuous-flow designs are much more difficult to create and monitor because they must be timed correctly. The size of the container, the mixing of the fluids, and the time that a sample of water remains in the container must all be pre-engineered in order for the process to be effective. In a batch process, there are fewer variables to control and manipulate — the water is relatively static (still) while being treated.
7. In support of the statement: Almost any contamination problem eventually becomes a human (personal) problem because of the interconnectedness of the entire ecosystem, which, of course, includes us. Most ground water contamination is caused by people, so it is our responsibility to clean it up.
   In opposition to the statement: Contamination is a problem regardless of whether it affects people and should be avoided if at all possible. Humans are not the only organisms damaged by contamination.
   Presentations should include suppporting information and reasoned arguments.
8. Precise equipment is required for water testing because "safe" levels of toxic and noxious materials are so low that they are hard to measure with imprecise equipment.

6.5 SOLUTION PREPARATION

PRACTICE

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Understanding Concepts

1. In solid form, ammonium oxalate is a monohydrate, so the calculation of molar mass must take this into account.

$$C_{(NH_4)_2C_2O_4} = 0.250 \text{ mol/L}$$
$$v_{(NH_4)_2C_2O_4} = 100.0 \text{ mL} = 0.1000 \text{ L}$$
$$M_{(NH_4)_2C_2O_4 \cdot H_2O} = 142.14 \text{ g/mol}$$
$$n_{(NH_4)_2C_2O_4} = 0.1000 \cancel{\text{L}} \times \frac{0.250 \text{ mol}}{1 \cancel{\text{L}}}$$
$$= 0.0250 \text{ mol}$$
$$m_{(NH_4)_2C_2O_4 \cdot H_2O} = 0.0250 \cancel{\text{mol}} \times \frac{142.14 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{(NH_4)_2C_2O_4 \cdot H_2O} = 3.55 \text{ g}$$

or

$$m_{(NH_4)_2C_2O_4 \cdot H_2O} = 0.1000 \cancel{\text{L}} \times \frac{0.250 \cancel{\text{mol}}}{1 \cancel{\text{L}}} \times \frac{142.14 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{(NH_4)_2C_2O_4 \cdot H_2O} = 3.55 \text{ g}$$

The mass of ammonium oxalate monohydrate required is 3.55 g.

2.

$$C_{NaOH} = 10.0 \text{ mol/L}$$
$$v_{NaOH} = 500 \text{ mL} = 0.500 \text{ L}$$
$$M_{NaOH} = 40.00 \text{ g/mol}$$
$$n_{NaOH} = 0.500 \cancel{\text{L}} \times \frac{10.0 \text{ mol}}{1 \cancel{\text{L}}}$$
$$= 5.00 \text{ mol}$$
$$m_{NaOH} = 5.00 \cancel{\text{mol}} \times \frac{40.00 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{NaOH} = 200 \text{ g}$$

or

$$m_{NaOH} = 0.500 \cancel{\text{L}} \times \frac{10.0 \cancel{\text{mol}}}{1 \cancel{\text{L}}} \times \frac{40.00 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{NaOH} = 200\ g$$

The mass of sodium hydroxide required is 200 g.

3. Typical answers may include sugar (in coffee, tea, lemonade), salt (in cooking water), fruit drink crystals, and soap solutions.

Applying Inquiry Skills

4. (a) In solid form cobalt (II) chloride is a dihydrate, so the calculation of molar mass must take this into account.

$$C_{CoCl_2} = 0.100\ mol/L$$
$$v_{CoCl_2} = 2.00\ L$$
$$M_{CoCl_2 \cdot 2H_2O} = 168.57\ g/mol$$
$$n_{CoCl_2} = 2.00\ \cancel{L} \times \frac{0.100\ mol}{1\ \cancel{L}}$$
$$= 0.200\ mol$$
$$m_{CoCl_2 \cdot 2H_2O} = 0.200\ \cancel{mol} \times \frac{165.87\ g}{1\ \cancel{mol}}$$
$$m_{CoCl_2 \cdot 2H_2O} = 33.2\ g$$

or

$$m_{CoCl_2 \cdot 2H_2O} = 2.00\ \cancel{L} \times \frac{0.100\ \cancel{mol}}{1\ \cancel{L}} \times \frac{165.87\ g}{1\ \cancel{mol}}$$
$$m_{CoCl_2 \cdot 2H_2O} = 33.2\ g$$

The mass of cobalt (II) chloride dihydrate required is 33.2 g.

(b) **Procedure**

1. Wear eye protection and a laboratory apron.
2. Calculate the mass of $CoCl_2 \cdot 2H_2O_{(s)}$ required to prepare 2.00 L of 0.100 mol/L solution.
3. Obtain the calculated mass of $CoCl_2 \cdot 2H_2O_{(s)}$ in a clean dry 400-mL beaker.
4. Dissolve the solid in about 200 mL of water.
5. Transfer the solution into a clean 2-L volumetric flask, making sure to rinse the beaker and funnel several times. Transfer the rinsings into the flask.
6. Add pure water to make the final volume 2.00 L.
7. Stopper the flask and mix the contents thoroughly by inverting the flask repeatedly.

5. (a)

$$C_{KMnO_4} = 75.0\ mmol/L = 0.0750\ mol/L$$
$$v_{KMnO_4} = 500.0\ mL = 0.5000\ L$$
$$M_{KMnO_4} = 158.04\ g/mol$$
$$n_{KMnO_4} = 0.5000\ \cancel{L} \times \frac{0.0750\ mol}{1\ \cancel{L}}$$
$$= 0.0375\ mol$$
$$m_{KMnO_4} = 0.0375\ \cancel{mol} \times \frac{158.04\ g}{1\ \cancel{mol}}$$
$$m_{KMnO_4} = 5.93\ g$$

or

$$m_{KMnO_4} = 0.5000\ \cancel{L} \times \frac{0.0750\ \cancel{mol}}{1\ \cancel{L}} \times \frac{158.04\ g}{1\ \cancel{mol}}$$
$$m_{KMnO_4} = 5.93\ g$$

The mass of potassium permanganate required is 5.93 g.

(b) **Procedure**

1. Wear eye protection and a laboratory apron.
2. Calculate the mass of $KMnO_{4(s)}$ required to prepare 500.0 mL of 75.0 mmol/L solution.
3. Obtain the calculated mass of $KMnO_{4(s)}$ in a clean, dry 250-mL beaker.
4. Dissolve the solid in about 100 mL of water.

5. Transfer the solution into a clean 500-mL volumetric flask, being sure to rinse the beaker and funnel several times. Transfer the rinsings into the flask.
6. Add pure water to make the final volume 500.0 mL.
7. Stopper the flask and mix the contents thoroughly by inverting the flask repeatedly.

ACTIVITY 6.5.2: A STANDARD SOLUTION BY DILUTION

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Analysis

(a) Some water is always placed in the volumetric flask initially for safety reasons, so that when concentrated acids are diluted their heat of solution will be dissipated through this water, and will not cause the flask contents to boil and spurt out. The rule is "Add concentrated acid to water; NEVER add water to concentrated acid." When the concentrated solution is not an acid, the rule is followed anyway, for consistency and to build the habit.

(b) If 100 mL of water had initially been placed in the flask, adding the concentrated solution and rinse water during transfer would make the final volume too great.

PRACTICE

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Understanding Concepts

6. $v_i = ?$

$v_f = 2.00 \text{ L}$

$C_i = 17.8 \text{ mol/L}$

$C_f = 0.200 \text{ mol/L}$

$$v_iC_i = v_fC_f$$

$$v_i = \frac{v_fC_f}{C_i}$$

$$v_i = \frac{2.00 \text{ L} \times 0.200 \cancel{\text{mol/L}}}{17.8 \cancel{\text{mol/L}}}$$

$$v_f = 0.0225 \text{ L} = 22.5 \text{ mL}$$

or

$$v_i = 2.00 \text{ L} \times \frac{0.200 \cancel{\text{mol}}/\text{L}}{17.8 \cancel{\text{mol}}/\text{L}}$$

$$v_i = 0.0225 \text{ L} = 22.5 \text{ mL}$$

The initial volume of 17.8 mol/L hydrochloric acid required is 22.5 mL.

7. (a) $v_i = 5.00 \text{ mL}$

$v_f = 100.0 \text{ mL}$

$C_i = 0.05000 \text{ mol/L}$

$C_f = ?$

$$v_iC_i = v_fC_f$$

$$C_f = \frac{v_iC_i}{v_f}$$

$$= \frac{5.00 \cancel{\text{mL}} \times 0.05000 \text{ mol/L}}{}$$

$$C_f = 0.00250 \text{ mol/L} = 2.50 \text{ mmol/L}$$

or

$$C_f = \frac{0.05000\text{ mol}}{\text{L}} \times \frac{5.00\ \cancel{\text{mL}}}{100.0\ \cancel{\text{mL}}}$$

$$C_f = 0.00250\text{ mol/L} = 2.50\text{ mmol/L}$$

The final concentration of copper(II) sulfate solution is 2.50 mmol/L.

(b) $C_{CuSO_4} = 2.50\text{ mmol/L} = 0.00250\text{ mol/L}$

$v_{CuSO_4} = 10.0\text{ mL} = 0.0100\text{ L}$

$M_{CuSO_4} = 159.61\text{ g/mol}$

$$n_{CuSO_4} = 0.0100\ \cancel{\text{L}} \times \frac{2.50\text{ mmol}}{1\ \cancel{\text{L}}}$$

$$= 0.0250\text{ mmol}$$

$$m_{CuSO_4} = 0.0250\text{ m}\cancel{\text{mol}} \times \frac{159.61\text{ g}}{1\ \cancel{\text{mol}}}$$

$$m_{CuSO_4} = 3.99\text{ mg}$$

or

$$m_{CuSO_4} = 0.0100\ \cancel{\text{L}} \times \frac{2.50\text{ m}\cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \frac{159.61\text{ g}}{1\ \cancel{\text{mol}}}$$

$$m_{CuSO_4} = 3.99\text{ mg}$$

The mass of copper(II) sulfate in the solution sample is 3.99 mg.

(c) This final dilute solution would be quite difficult to prepare directly, since the entire 100.0 mL volume would only contain 39.9 mg of solute. This mass could only be measured accurately by using a balance with a precision of at least tenths of milligrams (ten-thousandths of grams), which is on the order of a *hundred times* more precise than standard school lab (centigram) balances. Even more difficult to measure would be the 3.99 mg needed to prepare the 10.0 mL of the solution. The technique of dilution solves this problem.

Furthermore, mass measurements this precise must be done with the balance pan in an enclosed space in order to prevent error caused by air currents. The sample must be enclosed in a solid container so that a correction for the buoyant force of air will not be required.

8. (a) The volume increase is 250.0 mL/10.00 mL or 25.00 times.
Concentration decrease is thus 1/25.00 or 0.04000 times or 4.000%.
(b) The reacting volume would now be 25.00 times as much.
(c) We would expect the speed of the reaction to be slower with the diluted solution, since the particles that react would be spread out more in the solvent and would not collide as often.
9. Typical examples of dilutions may include liquid soap solutions (hand cleaner), fruit juice concentrates, chocolate syrup in milk, and bleach in laundry loads.

Reflecting

10. The statement will not be true if the instrument available for measuring mass is very precise, and the equipment available for measuring liquid volumes is not very precise.

SECTION 6.5 QUESTIONS

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Understanding Concepts

1. Scientists make solutions for chemical analysis, as well as for precise control of reactions. Solutions make substances easy to handle and measure and safer to use, and many reactions only occur in solution.
2. (a) Solutions may be made by dissolving a known mass of solute up to a known volume, or by diluting an existing solution of higher concentration.
(b) The method used normally depends on the form (pure substance or concentrated solution) in which the desired reagent is available. A solution is prepared from a solid solute by measuring the mass of the solute and adding water (e.g., the preparation of a sodium carbonate solution). A solution is prepared from an available (more concentrated) solution by diluting the available solution (e.g., hydrochloric acid solutions are prepared by diluting concentrated hydrochloric acid).

3. $C_{Ba(NO_3)_2} = 0.125 \text{ mol/L}$

$v_{Ba(NO_3)_2} = 100 \text{ mL} = 0.100 \text{ L}$

$M_{Ba(NO_3)_2} = 261.35 \text{ g/mol}$

$$n_{Ba(NO_3)_2} = 0.100 \cancel{\text{L}} \times \frac{0.125 \text{ mol}}{1 \cancel{\text{L}}}$$
$$= 0.0125 \text{ mol}$$
$$m_{Ba(NO_3)_2} = 0.0125 \cancel{\text{mol}} \times \frac{261.35 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{Ba(NO_3)_2} = 3.27 \text{ g}$$

or

$$m_{Ba(NO_3)_2} = 0.100 \cancel{\text{L}} \times \frac{0.125 \text{ mol}}{1 \cancel{\text{L}}} \times \frac{261.35 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{Ba(NO_3)_2} = 3.27 \text{ g}$$

The mass of pure barium nitrate required is 3.27 g.

4. $v_i = 1.00 \text{ L}$

$v_f = ?$

$C_i = 17.4 \text{ mol/L}$

$C_f = 0.400 \text{ mol/L}$

$$v_iC_i = v_fC_f$$
$$v_f = \frac{v_iC_i}{C_f}$$
$$v_f = \frac{1.00 \text{ L} \times 17.4 \cancel{\text{mol/L}}}{0.400 \cancel{\text{mol/L}}}$$
$$v_f = 43.5 \text{ L}$$

or

$$v_f = 1.00 \text{ L} \times \frac{17.4 \cancel{\text{mol}}\text{/L}}{0.400 \cancel{\text{mol}}\text{/L}}$$
$$v_f = 43.5 \text{ L}$$

The final volume of diluted acetic acid is 43.5 L

5. $v_i = 10.00 \text{ mL}$

$v_f = 250.0 \text{ mL}$

$c_i = ?$

$c_f = 0.274 \text{ g/L}$

$$v_ic_i = v_fc_f$$
$$c_i = \frac{v_fc_f}{v_i}$$
$$c_i = \frac{250.0 \cancel{\text{mL}} \times 0.274 \text{ g/L}}{10.00 \cancel{\text{mL}}}$$
$$c_i = 6.85 \text{ g/L}$$

or

$$c_i = \frac{0.274 \text{ g}}{1 \text{ L}} \times \frac{250.0 \text{ mL}}{10.00 \text{ mL}}$$

$c_i = 6.85$ g/L

The initial concentration of the solution was 6.85 g/L.

Applying Inquiry Skills

6. $C_{KSCN} = 0.155$ mol/L

$v_{KSCN} = 100$ mL $= 0.100$ L

$M_{KSCN} = 97.18$ g/mol

$$n_{KSCN} = 0.100\ \cancel{L} \times \frac{0.155\ \text{mol}}{1\ \cancel{L}}$$
$$= 0.0155\ \text{mol}$$
$$m_{KSCN} = 0.0155\ \cancel{\text{mol}} \times \frac{97.18\ \text{g}}{1\ \cancel{\text{mol}}}$$
$$m_{KSCN} = 1.51\ \text{g}$$

or

$$m_{KSCN} = 0.100\ \cancel{L} \times \frac{0.155\ \cancel{\text{mol}}}{1\ \cancel{L}} \times \frac{97.18\ \text{g}}{1\ \cancel{\text{mol}}}$$
$$m_{KSCN} = 1.51\ \text{g}$$

The mass of potassium thiocyanate required is 1.51 g.

Procedure

1. Wear eye protection and a laboratory apron.
2. Calculate the mass of $KSCN_{(s)}$ (1.51 g) required to prepare 100 mL of 0.155 mol/L solution.
3. Obtain the calculated mass of $KSCN_{(s)}$ in a clean, dry, 250-mL beaker.
4. Dissolve the solid in about 50 mL of water.
5. Transfer the solution into a clean 100-mL volumetric flask, being sure to rinse the beaker and funnel several times. Transfer the rinsings into the flask.
6. Add pure water to make the final volume 100.0 mL.
7. Stopper the flask and mix the contents thoroughly by inverting the flask repeatedly.

7. $v_i = ?$

$v_f = 1.00$ L

$C_i = 5.00$ mol/L

$C_f = 0.125$ mol/L

$$v_i C_i = v_f C_f$$
$$v_i = \frac{v_f C_f}{C_i}$$
$$v_i = \frac{1.00\ \text{L} \times 0.125\ \cancel{\text{mol/L}}}{5.00\ \cancel{\text{mol/L}}}$$
$$v_f = 0.0250\ \text{L} = 25.0\ \text{mL}$$

or

$$v_i = 1.00\ \text{L} \times \frac{0.125\ \cancel{\text{mol}}/\text{L}}{5.00\ \cancel{\text{mol}}/\text{L}}$$
$$v_i = 0.0250\ \text{L} = 25.0\ \text{mL}$$

The initial volume of 5.00 mol/L sulfuric acid required is 25.0 mL.

Procedure

1. Wear eye protection and a laboratory apron.
2. Calculate the initial volume of 5.00 mol/L $H_2SO_{4(aq)}$ (25.0 mL) that is required to prepare 1.00 L of 0.125 mol/L solution.

3. Add 400–500 mL of pure water to a 1-L volumetric flask.
4. Use a 25-mL volumetric pipet to transfer 25.00 mL of 5.00 mol/L acid to the flask.
5. Add pure water to make the final volume 1.000 L (to the mark on the flask).
6. Stopper the flask and mix the contents thoroughly by inverting the flask repeatedly.
7. This solution may be safely disposed of down the sink, provided it is washed down with plenty of water.
8. (a) In solid form, the sample of cobalt (II) chloride is a hexahydrate, so the calculation of molar mass must take this into account.

$$C_{CoCl_2} = 0.100 \text{ mol/L}$$
$$v_{CoCl_2} = 100.0 \text{ mL} = 0.1000 \text{ L}$$
$$M_{CoCl_2 \cdot 6H_2O} = 237.95 \text{ g/mol}$$
$$n_{CoCl_2} = 0.1000 \cancel{\text{L}} \times \frac{0.100 \text{ mol}}{1 \cancel{\text{L}}}$$
$$= 0.0100 \text{ mol}$$
$$m_{CoCl_2 \cdot 6H_2O} = 0.0100 \cancel{\text{mol}} \times \frac{237.95 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{CoCl_2 \cdot 6H_2O} = 2.38 \text{ g}$$

or

$$m_{CoCl_2 \cdot 6H_2O} = 0.1000 \cancel{\text{L}} \times \frac{0.100 \cancel{\text{mol}}}{1 \cancel{\text{L}}} \times \frac{237.95 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{CoCl_2 \cdot 6H_2O} = 2.38 \text{ g}$$

The mass of solid cobalt (II) chloride hexahydrate required is 2.38 g.

(b) $v_i = ?$

$v_f = 100.0 \text{ mL}$

$C_i = 0.100 \text{ mol/L}$

$C_f = 0.0100 \text{ mol/L}$

$$v_i C_i = v_f C_f$$
$$v_i = \frac{v_f C_f}{C_i}$$
$$v_i = 100.0 \text{ mL} \times \frac{0.0100 \cancel{\text{mol}}/\text{L}}{0.100 \cancel{\text{mol}}/\text{L}}$$
$$v_i = 10.0 \text{ mL}$$

The initial volume of 0.100 mol/L $CoCl_{2(aq)}$ required is 10.0 mL.

(c) **Materials**

- lab apron
- eye protection
- $CoCl_2 \cdot 6H_2O_{(s)}$
- wash bottle with pure water
- centigram balance
- 250-mL beaker
- stirring rod
- funnel
- 2 100-mL volumetric flasks with stoppers
- 10-mL volumetric pipet with pipet bulb
- medicine dropper
- meniscus finder

Procedure

1. Wear eye protection and a laboratory apron.
2. Calculate the mass of $CoCl_2 \cdot 6H_2O_{(s)}$ required to prepare 100.0 mL of 0.100 mol/L solution.
3. Obtain the calculated mass (2.38 g) of $CoCl_2 \cdot 6H_2O_{(s)}$ in a clean, dry 250-mL beaker.

4. Dissolve the solid in about 50 mL of water.
5. Transfer the solution into a clean 100-mL volumetric flask, being sure to rinse the beaker and funnel several times. Transfer the rinsings into the flask.
6. Add pure water to make the final volume 100.0 mL.
7. Stopper the flask and mix the contents thoroughly by inverting the flask repeatedly.
8. Calculate the volume of 0.100 mol/L $CoCl_{2(aq)}$ required to make 100.0 mL of 0.0100 mol/L solution by dilution (according to the above calculations: 10.0 mL).
9. Use a 10-mL volumetric pipet to obtain and transfer 10.0 mL of 0.100 mol/L $CoCl_{2(aq)}$ solution to a clean 100-mL volumetric flask.
10. Add pure water to the flask until the final 100.0 mL volume is reached.
11. Stopper and invert the flask to thoroughly mix the contents.
12. Solutions may be disposed of down the sink with plenty of water.

Making Connections

9. Arguments for the position: There will be a fuel saving from transporting concentrated reagents (less mass and volume); fewer trucks will be required for their transportation, resulting in less traffic on the roads; loading and unloading will be quicker.
   Arguments against the position: Any spills or careless handling would be much more dangerous; the recipient will likely have the inconvenience of diluting the product upon its arrival.
10. The common system that concentrates pollutants (bioaccumulation) is the "web of life" or "food chain." Organisms that ingest pollutants can concentrate them in their bodies and pass this concentration on to predators. An example of such a chain is aquatic microorganisms → plankton → fish → seabird chicks → eagles.

Reflecting

11. The procedure should show serial dilution, that is, begin by diluting stock $HCl_{(aq)}$ solution and then use samples of each new dilution to produce a further dilution of, say, one-tenth the concentration each time. These solutions can then easily be compared according to how rapidly they react with equal samples of zinc.

Make a Summary

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