- 10-mL graduated cylinder
- 100-mL graduated cylinder
- stirring rod

Making Connections

7. Children's glue must be nontoxic and water washable. This means the chemical substance(s) must be unreactive and must have very polar molecules.

6.3 SOLUTION CONCENTRATION

PRACTICE

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Understanding Concepts

1. W/W (weight to weight), W/V (weight to volume), or V/V (volume to volume) ratios
2. $v_{\text{ethanol}} = 4.1\text{ L}$

   $v_{\text{gasohol}} = 55\text{ L}$

   $c_{\text{ethanol}} = \dfrac{4.1\text{ L}}{55\text{ L}} \times 100\%$

   $c_{\text{ethanol}} = 7.5\%\text{ V/V}$

   The ethanol concentration in fuel solution is 7.5% V/V (by volume).
3. $m_{\text{zinc chloride}} = 16\text{ g}$

   $v_{\text{solution}} = 50\text{ mL}$

   $c_{\text{zinc chloride}} = \dfrac{16\text{g}}{50\text{ m L}} \times 100\%$

   $c_{\text{zinc chloride}} = 32\%\text{ W/V}$

   The concentration of zinc chloride in the flux solution is 32% W/V.
4. $m_{\text{zinc}} = 1.7\text{ g}$

   $m_{\text{brass}} = 35.0\text{ g}$

   $c_{\text{zinc}} = \dfrac{1.7\text{ g}}{35.0\text{ g}} \times 100\%$

   $c_{\text{zinc}} = 4.9\%\text{ W/W}$

   The zinc concentration in the brass is 4.9% W/W (by mass).
5. 8 ppm = 8 mg/L

   $m_{\text{oxygen}} = \dfrac{8\text{ mg}}{1\cancel{\text{L}}} \times 1\cancel{\text{L}}$

   $m_{\text{oxygen}} = 8\text{ mg}$

   The mass of oxygen in each litre of water is 8 mg.
6. $m_{\text{formaldehyde}} = 3.2\text{ mg}$

   $m_{\text{air}} = 0.59\text{ kg}$

   $c_{\text{formaldehyde}} = \dfrac{3.2\text{ mg}}{0.59\text{ kg}}$

   $c_{\text{formaldehyde}} = 5.4\text{ mg/kg} = 5.4\text{ ppm}$

   The concentration of formaldehyde in air is 5.4 ppm.
7. (a) 1 ppb is 1/1000 of 1 ppm, or 0.001 ppm.

   (b) 1 ppb $= 1\text{ mg}/10^6\text{ mL}$ (1 mg/kL)

   $= 1\text{ mg}/1000\text{ L}$ (1 mg/m^3)

$= 1\ \mu g/L$

$= 1\ \mu g/kg$

$= 1\ ng/g$

(c) $30\ ppb = 30\ \mu g/kg$

8. $n_{CaCl_2} = 0.11\ mol$

$v_{CaCl_2} = 60\ mL = 0.060\ L$

$$C_{CaCl_2} = \frac{0.11\ mol}{0.060\ L}$$

$$C_{CaCl_2} = 1.8\ mol/L$$

The molar concentration of calcium chloride is 1.8 mol/L.

Making Connections

9. LD_{50} refers to a toxic substance dosage in mass per kilogram of the recipient (e.g., milligrams per kilogram of body mass) that will prove lethal to half of the organisms in a test sample. Descriptors of toxicity vary, so students may well find differing definitions of "extremely" toxic and "slightly" toxic in their research. However, a common definition for extremely toxic is less than 5 mg/kg, while slightly toxic is 5–15 g/kg. Above 15 g/kg is considered to be almost nontoxic.

   The quantity of toxin ingested depends on the concentration of the chemical to which one may be exposed. However, the LD_{50} levels express the concentration of toxin in the body (e.g., 15 mg/kg). Cumulative toxins may be ingested at very low concentrations for long periods of time and become toxic over time. Examples of cumulative toxins include mercury and lead.

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Reflecting

10. A report mark is a ratio of marks achieved/possible marks. Other common ratios are prices of bulk goods ($/kg), speeds (km/h), nutritional information (energy per serving, in kJ/g) and cooking times (min/kg).

PRACTICE

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Understanding Concepts

11. $c_{C_3H_7OH} = 70.0\%\ V/V = 70.0\ mL/100\ mL$

$v_{C_3H_7OH} = 500\ mL$

$$v_{C_3H_7OH} = 500\ \cancel{mL} \times \frac{70.0\ mL}{100\ \cancel{mL}}$$

$$v_{C_3H_7OH} = 350\ mL$$

The volume of rubbing alcohol present is 350 mL.

12. $c_{H_2O_2} = 3.0\%\ W/V = 3.0\ g/100\ mL = 3.0\ g/0.100\ L$

$$v_{H_2O_2} = 1000\ \cancel{bottles} \times \frac{0.250\ L}{1\ \cancel{bottle}} = 250\ L$$

$$m_{H_2O_2} = 250\ \cancel{L} \times \frac{3.0\ g}{0.100\ \cancel{L}}$$

$$m_{H_2O_2} = 7.5\ kg$$

The mass of hydrogen peroxide needed is 7.5 kg.

13. $c_{F^-} = 1.5\ ppm = 1.5\ mg/L$

$v_{F^-} = 0.250\ L$

$$m_{F^-} = 0.250\ \cancel{L} \times \frac{1.5\ mg}{1\ \cancel{L}}$$
$$m_{F^-} = 0.38\ mg$$

The mass of fluoride ions present in the glass of water is 0.38 mg.

14. $C_{MgCl_2} = 0.055\ mol/L$

$v_{MgCl_2} = 75\ L$

$$n_{MgCl_2} = 75\ \cancel{L} \times \frac{0.055\ mol}{1\ \cancel{L}}$$
$$n_{MgCl_2} = 4.1\ mol$$

The amount of magnesium chloride present is 4.1 mol.

15. $C_{HCl} = 5.0\ mol/L$

$v_{HCl} = 50\ mL = 0.050\ L$

$$n_{HCl} = 0.050\ \cancel{L} \times \frac{5.0\ mol}{1\ \cancel{L}}$$
$$n_{HCl} = 0.25\ mol$$

The amount of hydrogen chloride in the beaker is 0.25 mol.

16. $C_{NH_3} = 1.24\ mol/L$

$n_{NH_3} = 0.500\ mol$

$$v_{NH_3} = 0.500\ \cancel{mol} \times \frac{1\ L}{1.24\ \cancel{mol}}$$
$$v_{NH_3} = 0.403\ L$$

The volume of aqueous ammonia solution needed is 403 mL.

17. $C_{Na_2SO_4} = 2.6\ mol/L$

$n_{Na_2SO_4} = 0.14\ mol$

$$v_{Na_2SO_4} = 0.14\ \cancel{mol} \times \frac{1\ L}{2.6\ \cancel{mol}}$$
$$v_{Na_2SO_4} = 0.054\ L = 54\ mL$$

The volume of aqueous sodium sulfate solution needed is 54 mL.

Making Connections

18. Prediluted commercial solutions are usually more expensive for equal quantities of solute. If cost is the concern, you would calculate cost/quantity for the solute. On the other hand, prediluted solutions are both more convenient to use and less dangerous to store.

PRACTICE

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Understanding Concepts

19. $C_{NaOH} = 0.125\ mol/L$

$v_{NaOH} = 3.00\ L$

$M_{NaOH} = 40.00\ g/mol$

$$n_{NaOH} = 3.00\ \cancel{L} \times \frac{0.125\ mol}{1\ \cancel{L}}$$
$$= 0.375\ mol$$
$$m_{NaOH} = 0.375\ \cancel{mol} \times \frac{40.00\ g}{1\ \cancel{mol}}$$
$$m_{NaOH} = 15.0\ g$$

or

$$m_{NaOH} = 3.00\ \cancel{L} \times \frac{0.125\ \cancel{mol}}{1\ \cancel{L}} \times \frac{40.00\ g}{1\ \cancel{mol}}$$

$$m_{NaOH} = 15.0\ g$$

The mass of solid sodium hydroxide required is 15.0 g.

20. $C_{NaCl} = 0.56\ mol/L$

$v_{NaCl} = 5.0\ L$

$M_{NaCl} = 58.44\ g/mol$

$$n_{NaCl} = 5.0\ \cancel{L} \times \frac{0.56\ mol}{1\ \cancel{L}}$$

$$= 2.8\ mol$$

$$m_{NaCl} = 2.8\ \cancel{mol} \times \frac{58.44\ g}{1\ \cancel{mol}}$$

$$m_{NaCl} = 0.16\ kg$$

or

$$m_{NaCl} = 5.0\ \cancel{L} \times \frac{0.56\ \cancel{mol}}{1\ \cancel{L}} \times \frac{58.44\ g}{1\ \cancel{mol}}$$

$$m_{NaCl} = 0.16\ kg$$

The mass of sodium chloride in the sample is 0.16 kg.

21. (a) $c_{CO_2} = 355\ ppm = 355\ mg/L$

The mass of carbon dioxide present in a litre of acid rain is 355 mg.

(b) $M_{CO_2} = 44.01\ g/mol$

$m_{CO_2} = 0.355\ g$

$v_{CO_2} = 1.00\ L$

$$n_{CO_2} = 0.355\ \cancel{g} \times \frac{1\ mol}{44.01\ \cancel{g}}$$

$$= 8.07\ mmol$$

$$C_{CO_2} = \frac{8.07\ mmol}{1.00\ L}$$

$$C_{CO_2} = 8.07\ mmol/L$$

The molar concentration of aqueous carbon dioxide is 8.07 mmol/L.

22. (a) $m_{NaCl} = 235\ g$

$v_{NaCl} = 3.00\ L = 3.00 \times 10^3\ mL$

$$c_{NaCl} = \frac{235\ g}{3.00 \times 10^3\ mL} \times 100\%$$

$$c_{NaCl} = 7.83\%\ W/V$$

The percent concentration of sodium chloride in aqueous solution is 7.83% W/V.

(b) $M_{NaCl} = 58.44\ g/mol$

$m_{NaCl} = 235\ g$

$v_{NaCl} = 3.00\ L$

$$n_{NaCl} = 235\ \cancel{g} \times \frac{1\ mol}{58.44\ \cancel{g}}$$

$$= 4.02\ mol$$

$$C_{NaCl} = \frac{4.02\ mol}{3.00\ L}$$

$$C_{NaCl} = 1.34\ mol/L$$

The molar concentration of aqueous sodium chloride is 1.34 mol/L.

SECTION 6.3 QUESTIONS

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Understanding Concepts

1. Consumer products often have percentage concentrations given on the label because these units are more familiar to most consumers.
2. (a) $c_{\text{dextrose}} = 5.0\%\ W/V = 5.0\ \text{g}/100\ \text{mL}$

$v_{\text{solution}} = 500.0\ \text{mL}$

$$m_{\text{dextrose}} = 500.0\ \cancel{\text{mL}} \times \frac{5.0\ \text{g}}{100\ \cancel{\text{mL}}}$$

$$m_{\text{dextrose}} = 25\ \text{g}$$

The mass of dextrose in the bag is 25 g.

(b) $c_{\text{dextrose}} = 5.0\ \text{g}/100\ \text{mL} = 50\ \text{g/L} = 5.0 \times 10^4\ \text{ppm}$

The concentration of dextrose in the solution is 5.0×10^4 ppm.

3. $c_{\text{NaCl}} = 31.6\ \text{g}/100\ \text{mL}$

$v_{\text{NaCl}} = 250\ \text{mL}$

$$m_{\text{NaCl}} = 250\ \cancel{\text{mL}} \times \frac{31.6\ \text{g}}{100\ \cancel{\text{mL}}}$$

$$m_{\text{NaCl}} = 79.0\ \text{g}$$

The mass of sodium chloride that will dissolve is 79.0 g.

4. The nandrolone concentration of 1000 times 2 mg/L is 2×10^3 mg/L, so the test result concentration is 2×10^3 ppm or 2 ppt.
5. $c_{\text{PCBs}} = 18.9\ \text{mg/kg}$

$m_{\text{chick}} = 0.60\ \text{kg}$

$$m_{\text{PCBs}} = 0.60\ \cancel{\text{kg}} \times \frac{18.9\ \text{mg}}{1\ \cancel{\text{kg}}}$$

$$m_{\text{PCBs}} = 11\ \text{mg}$$

The chick would contain 11 mg of PCBs.

6. $c_{\text{PCBs}} = 4.00\ \text{ppm} = 4.00\ \text{mg/kg}$

$m_{\text{person}} = 64.0\ \text{kg}$

$$m_{\text{PCBs}} = 64.0\ \cancel{\text{kg}} \times \frac{4.00\ \text{mg}}{1\ \cancel{\text{kg}}}$$

$$m_{\text{PCBs}} = 256\ \text{mg}$$

The mass of PCBs in the person is 256 mg.

7. Assuming the 5 mL volume is a theoretical (exact) value, then the substance concentrations in g/L are, respectively

ammonium carbonate $\dfrac{153\ \cancel{\text{m}}\text{g}}{5\ \cancel{\text{m}}\text{L}} = 30.6\ \text{g/L}$

potassium bicarbonate $\dfrac{267\ \cancel{\text{m}}\text{g}}{5\ \cancel{\text{m}}\text{L}} = 53.4\ \text{g/L}$

menthol $\dfrac{22\ \cancel{\text{m}}\text{g}}{5\ \cancel{\text{m}}\text{L}} = 4.4\ \text{g/L}$

camphor $\dfrac{2.2\ \cancel{\text{m}}\text{g}}{5\ \cancel{\text{m}}\text{L}} = 0.44\ \text{g/L}$

8. $c_{\text{each sol'n}} = 0.10\ \text{mol/L}$
$v_{\text{each sol'n}} = 100\ \text{mL} = 0.100\ \text{L}$

$$n_{\text{each compound}} = 0.100\ \cancel{\text{L}} \times \frac{0.10\ \text{mol}}{1\ \cancel{\text{L}}} = 0.010\ \text{mol}$$

$M_{NaCl} = 58.44\ \text{g/mol}$

$M_{KCl} = 74.55\ \text{g/mol}$

$M_{CaCl_2} = 110.98\ \text{g/mol}$

(a) $m_{NaCl} = 0.010\ \cancel{\text{mol}} \times \frac{58.44\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{NaCl} = 0.58\ \text{g}$

or

$m_{NaCl} = 0.100\ \cancel{\text{L}} \times \frac{0.10\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \frac{58.44\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{NaCl} = 0.58\ \text{g}$

The mass of sodium chloride required is 0.58 g.

(b) $m_{KCl} = 0.010\ \cancel{\text{mol}} \times \frac{74.55\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{KCl} = 0.75\ \text{g}$

or

$m_{KCl} = 0.100\ \cancel{\text{L}} \times \frac{0.10\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \frac{74.55\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{KCl} = 0.75\ \text{g}$

The mass of potassium chloride required is 0.75 g.

(c) $m_{CaCl_2} = 0.010\ \cancel{\text{mol}} \times \frac{110.98\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{CaCl_2} = 1.1\ \text{g}$

or

$m_{CaCl_2} = 0.100\ \cancel{\text{L}} \times \frac{0.10\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \frac{110.98\ \text{g}}{1\ \cancel{\text{mol}}}$

$m_{CaCl_2} = 1.1\ \text{g}$

The mass of calcium chloride required is 1.1 g.

9. $c_{NaCl} = 25\ \text{g}/100\ \text{mL} = 25\ \text{g}/0.100\ \text{L}$

$M_{NaCl} = 58.44\ \text{g/mol}$

$C_{NaCl} = \frac{25\ \cancel{\text{g}}}{0.100\ \text{L}} \times \frac{1\ \text{mol}}{58.44\ \cancel{\text{g}}}$

$C_{NaCl} = 4.3\ \text{mol/L}$

The molar concentration of sodium chloride in the brine is 4.3 mol/L.

10. $m_{C_6H_{12}O_6} = 2.0\ \text{g}$
$M_{C_6H_{12}O_6} = 180.18\ \text{g/mol}$
$C_{C_6H_{12}O_6} = 0.055\ \text{mol/L}$

$n_{C_6H_{12}O_6} = 2.0\ \cancel{\text{g}} \times \frac{1\ \text{mol}}{180.18\ \cancel{\text{g}}}$

$n_{C_6H_{12}O_6} = 0.011\ \text{mol}$

$v_{C_6H_{12}O_6} = 0.011\ \cancel{\text{mol}} \times \frac{1\ \text{L}}{0.055\ \cancel{\text{mol}}}$

$v_{C_6H_{12}O_6} = 0.20\ \text{L}$

or

$v_{C_6H_{12}O_6} = 2.0\ \cancel{\text{g}} \times \frac{1\ \cancel{\text{mol}}}{180.18\ \cancel{\text{g}}} \times \frac{1\ \text{L}}{0.055\ \cancel{\text{mol}}}$

$v_{C_6H_{12}O_6} = 0.20\ \text{L}$

The volume of solution that contains 2.0 g of glucose is 0.20 L.

Making Connections

11. Points in favour: patients would have to swallow less of the medicine; the medicines would be more compact and could be sold in smaller bottles, which might result in a lower cost (although the saving is likely to be minimal).

    Points against: selling medicines in highly concentrated solutions would almost certainly increase the frequency of patients accidentally taking the wrong dose (an extra 5 mL would contain considerably more of the active ingredient in a concentrated solution than in a dilute solution); more precise equipment would be required for measuring the appropriate quantity for the prescription and the dose.
12. A common system of communication is crucial for clarity, so there is no confusion about concentrations of blood test results or drug dosages. There are currently several systems for communicating the concentration of medicines, although all are metric. That all systems are metric is important for international communication and for labelling of bottles of medicine.
    - Percent composition is very common for medicines dispensed in solution (e.g., salicylic acid in acne preparations and D5W intravenous (5% dextrose in water)).
    - Percent concentration may also be used for blood-test results such as percent of alcohol (e.g., a maximum limit of 0.080% for drinking and driving).
    - Molar concentrations are used for blood sugar analysis where units of millimoles per litre (e.g., 5.1 mmol/L) are employed.
    - Parts per million and/or milligrams per kilogram of body mass are used when very small concentrations are involved (e.g., testing for toxins or drug-enhanced sports performances). The effective concentration of medicines are determined by extensive research with animals and humans. Once the concentration is determined through research, the effective mass of medicine that needs to be ingested every so-many hours is calculated. Taking one capsule of a medicine every 8 h or at every meal maintains an effective concentration of the chemical in the body systems. Time-release medication and patches are newer technologies that release the medication slowly in order to keep the concentration of the medication fairly constant over time. Sometimes, such as in chemotherapy, the concentration of chemicals is kept near the toxic level for the patient. Very careful monitoring of the concentrations of the chemicals in the blood system is required.

    Miscommunication of concentration levels can, of course, result in death. Conventions of communication are not just convenient and money saving; they also save lives.

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6.4 DRINKING WATER

PRACTICE

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Understanding Concepts

1. Contaminants are biological (e.g., viruses, bacteria, protozoa), chemical (e.g., mercury, lead, PCBs) and physical (e.g., sand, mud, suspended particles of organic matter).
2. Some ways contaminants enter water are by leaching from landfills; from inadequate septic/sewage systems; from overuse of fertilizers, pesticides and herbicides; from livestock wastes; and from road salt runoff.
3. Leaking sewer pipes are environmental hazards because untreated sewage contains nitrates and phosphates (which can act as fertilizers in the environment) and bacteria (which can cause a variety of infections resulting in illness). Raw sewage also has a very unpleasant odour.
4. Water leaching from a landfill site may seep through the surrounding earth and rock, and into wells or streams, thus ending up in a drinking water supply. Such leachate could contain heavy metal ions (e.g., mercury, lead, and cadmium); bacteria; acids; and organic compounds (e.g., benzene and tetrachloromethylene). If not removed, these pollutants could have a negative influence on health: heavy metal ions interfere with brain and nerve development; bacteria can cause infections; acids can damage pipes; and organic compounds may be poisonous or carcinogenic.