(c) Methanol: neutral solution; neither colour of litmus changes from its original colour.
(d) Sodium hydrogen carbonate: neutral solution; neither colour of litmus changes from its original colour.

Applying Inquiry Skills

7. (a)

Predicting Properties of Compounds

Substance	Acidic/Basic/Neutral	Electrolyte/Nonelectrolyte
$C_3H_7OH_{(l)}$ (a rubbing alcohol)	neutral	nonelectrolyte
calcium hydroxide (slaked lime)	basic	electrolyte
$H_3PO_{4(aq)}$ (for manufacturing fertilizer)	acidic	electrolyte
glucose (a product of photosynthesis)	neutral	nonelectrolyte
sodium fluoride (in toothpaste)	neutral	electrolyte

(b) Each compound is dissolved in pure water, and the resulting solutions are tested with litmus. They are also tested for electrical conductivity.

Making Connections

8. Using gasoline as a cleaner in a basement is unsafe because the liquid is very volatile (evaporates very readily), and the vapours are very flammable. Gasoline should only be used in a very well-ventilated area, with no sources of ignition anywhere nearby — preferably outdoors.

Reflecting

9. If water really were a universal solvent, everything (and everyone) on Earth would be part of a huge unchanging sphere of homogeneous solution.

6.2 EXPLAINING SOLUTIONS

PRACTICE

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Understanding Concepts

1. Most molecules are polar. The four categories of polar molecules are:
AB (e.g., $HCl_{(g)}$, $CO_{(g)}$)
N_xA_y (e.g., $NH_{3(g)}$, $NF_{3(g)}$)
O_xA_y (e.g., $H_2O_{(l)}$, $OCl_{2(g)}$)
$C_xA_yB_z$ (e.g., $CHCl_{3(l)}$, $C_2H_5OH_{(l)}$)
2. Nonpolar molecules are those in which no part of the molecule is significantly more (or less) electronegative than any other part. The two categories of nonpolar molecules are
molecular elements (e.g., $N_{2(g)}$ or $P_{4(s)}$);
compounds consisting only of carbon and one other type of atom, with a general formula C_xA_y (e.g., $CH_{4(g)}$, $CO_{2(g)}$, and $C_8H_{18(l)}$).

PRACTICE

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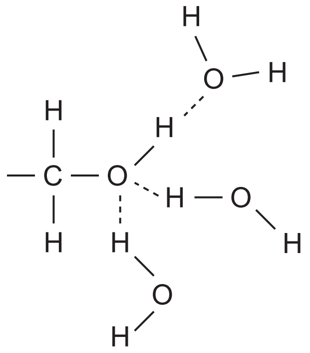
Understanding Concepts

3. Intramolecular forces act between atoms within a molecule; intermolecular forces act between molecules.
4. (a) No, gasoline will not dissolve in water. The film floating on puddles of water at gas stations is evidence that supports this statement.
(b) the "like dissolves like" rule
(c) Since gasoline is nonpolar and water is highly polar, the two liquids would not be miscible.

5. (a) The —OH groups of both methanol and water molecules allow hydrogen bonds to form among them, so these liquids will dissolve well in each other.

   (b)



   (c) The more hydrogen bonds that can form, the higher the solubility should be. This occurs because the molecules will attract each other better if they can form many intermolecular bonds.

PRACTICE

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Understanding Concepts

6. (a) Observations might include: the solids disappear; the change of refraction of water near each solid as it dissolves; and the solutions are colourless. Depending on the type of salt used, the rate of dissolving will vary. If table salt is used, the solution remains cloudy because virtually all brands of table salt have insoluble additives that help to keep the crystals from bonding together.
   (b) In both cases, the solids are separated into particles too small to see, theoretically, by the attraction of the water molecules.
   (c) In theory, the solutions are different because the particles in the sugar solution are neutral molecules, and those in the salt solution are ions.
   (d) Theoretically, the high polarity of water molecules explains why they strongly attract ions in ionic compounds, and the presence of many —OH groups on a sugar molecule allows a lot of hydrogen bonding (hence high solubility) with water.
7. (a) $NaF_{(s)} \rightarrow Na^+_{(aq)} + F^-_{(aq)}$
   (b) $Na_3PO_{4(s)} \rightarrow 3\ Na^+_{(aq)} + PO^{3-}_{4(aq)}$
   (c) $KNO_{3(s)} \rightarrow K^+_{(aq)} + NO^-_{3(aq)}$
   (d) $Al_2(SO_4)_{3(s)} \rightarrow 2\ Al^{3+}_{(aq)} + 3\ SO^{2-}_{4(aq)}$
   (e) $(NH_4)_2HPO_{4(s)} \rightarrow 2\ NH^+_{4(aq)} + HPO^{2-}_{4(aq)}$
   (f) $CoCl_2{\cdot}6H_2O_{(s)} \rightarrow Co^{2+}_{(aq)} + 2\ Cl^-_{(aq)}$

PRACTICE

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Understanding Concepts

8. Answers will vary but may include the following.
   Empirical properties: melting and boiling points; heat capacity; colour and clarity; excellence as a solvent; expansion upon solidification, formation of hexagonal crystals from vapour state; necessity for life; other observable, measurable properties.
   Theoretical properties: formation of hydrogen bonds; dissociation of dissolved ionic compounds, explaining the expansion of ice and hexagonal-form snowflakes by theorizing V-shaped molecules that hydrogen bond to each other in 6-sided patterns; other imagined, explanatory properties.
9. A nonpolar solvent such as mineral spirits (Varsol or turpentine) should dissolve grease, according to the "like dissolves like" rule, because grease is a nonpolar substance.
10. (a) $C_6H_{12}O_{6(s)}$, because it is polar.

(b) $C_2H_5OH_{(l)}$, because it has hydrogen bonding.
(c) $Na_2CO_{3(s)}$, because it is an ionic compound containing sodium ions.

11. (a) $CH_3Cl_{(l)}$, $CH_2Cl_{2(l)}$, and $CHCl_{3(l)}$ are most likely to be water soluble because they are polar molecules.
(b) $CH_{4(g)}$ and $CCl_{4(l)}$ are most likely to be soluble in nonpolar solvents because they are nonpolar.

12. A logical hypothesis would be that butanol has more C and H atoms, which reduce its polarity, making it more soluble in nonpolar solvents.

Applying Inquiry Skills

13. Explanations are accepted by the scientific community only if they are *logical*, relatively *simple*, and are *consistent* with evidence and other related explanations.

Making Connections

14. Dry cleaning solvents are chosen for their ability to dissolve nonpolar "dirt and grease" from clothing and to evaporate completely from the fabric. Health regulations apply to all such chemicals — most are toxic/noxious substances. One such solvent that was used for years both domestically and commercially is carbon tetrachloride, $CCl_{4(l)}$. Carbon tetrachloride was subsequently found to cause liver damage. Its first substitute, trichloroethene, $C_2HCl_{3(l)}$, was also found to produce liver damage. Eventually trichloroethane, $C_2H_3Cl_{3(l)}$, was found to be a safe replacement that neither caused liver damage nor was carcinogenic.

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SECTION 6.2 QUESTIONS

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Understanding Concepts

1. Water is an effective solvent because its molecules are very polar. This polarity enables it to separate the particles of the solute, surrounding each of them with water molecules. The polar —OH bonds result in polar molecules that strongly attract any charged ion or other polar molecules.
A second reason that water is an effective solvent for a few solutes is hydrogen bonding. Although the number of solutes that can hydrogen bond to water in solution is limited, solutes that have an unpaired electron on a N, O, or F atom, or have a hydrogen bonded to an N, O, or F atom, have much higher than expected (from polarity) solubility in water.
2. (a) Soluble combinations are (iii), (iv), and (v).
(b) Empirical: answers based on observations are by definition empirical.
3. (a) Not soluble: one is polar and the other is nonpolar.
(b) Soluble: both are polar.
(c) Not soluble: one is nonpolar and the other is polar.
(d) Soluble: both have hydrogen bonding.
(e) Not soluble: one is nonpolar and the other is polar.
4. Methane, methanol, ammonia. Methane is nonpolar, methanol has hydrogen bonding from one —OH bond, and ammonia has hydrogen bonding from three —NH bonds.

Applying Inquiry Skills

5. The experimental design is unacceptable because it involves too many variables; the presence of water will make it impossible to decide anything about the mutual solubility of the other two substances.

6. **Question**
Which of $C_6H_{6(l)}$ and $C_6H_5OH_{(l)}$ is more soluble in water?

Prediction
$C_6H_5OH_{(l)}$ is predicted to be more soluble.

Experimental Design
Each liquid will be added, in 1-mL increments, to 100 mL of water (in separate beakers) while stirring, until no more will dissolve.

Materials

- $C_6H_{6(l)}$ and $C_6H_5OH_{(l)}$
- two 250-mL beakers
- pure water

- 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. $v_{\text{ethanol}} = 4.1\text{ L}$

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

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

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

   The ethanol concentration in fuel solution is 7.5% V/V (by volume).

3. $m_{\text{zinc chloride}} = 16\text{ g}$

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

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

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

   The concentration of zinc chloride in the flux solution is 32% W/V.

4. $m_{\text{zinc}} = 1.7\text{ g}$

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

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

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

   The zinc concentration in the brass is 4.9% W/W (by mass).

5. 8 ppm = 8 mg/L

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

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

   The mass of oxygen in each litre of water is 8 mg.

6. $m_{\text{formaldehyde}} = 3.2\text{ mg}$

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

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

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

   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)