CHAPTER 6 REVIEW

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Understanding Concepts

1. All concentration units express the ratio of the quantity of solute to the quantity of solution.
2. (a) Highly polar solvents
   (b) Polar solvents
   (c) Nonpolar solvents
3. (a) Water dissolves very many substances because it is liquid over a wide temperature range and because it is made up of highly polar molecules that strongly attract (electrostatically) both ions and polar molecules. Water also hydrogen bonds to substances with N, O and F atoms.
   (b) Substances are dissolved in water to make them easier to store, easier to manipulate, and to control when and how rapidly they react. Examples:
   - Ammonia gas is so corrosive and toxic in pure form that it is very dangerous to handle, but when dissolved in water can be stored, shipped, and easily handled in ordinary plastic bottles, such as in window cleaner solutions, or "household" ammonia cleaner.
   - Baking soda (sodium hydrogen carbonate) is an example of a substance that doesn't react (in cooking) until dissolved. Solid plant fertilizers are another good example of this point.
   - All-purpose cleansers are examples of solutions that react more rapidly and to greater extent when they are made with a higher solute/solvent ratio (more concentrated).

   (c) The ability of water to dissolve so many substances is a problem when it comes to the purification of water for drinking, because often a large number of toxic or noxious solutes must be removed.
4. (a) solute: sodium chloride — solvent: water
   (b) solute: acetic acid — solvent: water
   (c) solute: sodium carbonate decahydrate — solvent: water
   (d) solute: sucrose — solvent: water
   (e) solute: ethanol — solvent: water
5. $c_{\text{MF}} = 2 \text{ g/100 mL}$

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

   $$m_{\text{fat}} = 250 \cancel{\text{mL}} \times \frac{2.0 \text{ g}}{100 \cancel{\text{mL}}}$$

   $$m_{\text{fat}} = 5.0 \text{ g}$$

   The mass of fat in one glass of milk is 5.0 g.
6. $c_{\text{MF}} = 5.9\%, 2.0\%, \text{ and } 1.2\%$, therefore,
   $c_{\text{MF}} = 5.9 \text{ g/100 mL}, 2.0 \text{ g/100 mL}, \text{ and } 1.2 \text{ g/100 mL}$, respectively.
   $m_{\text{fat}} = 3.0 \text{ g}$ maximum in each serving

   $$m_{\text{serving}} = 3.0 \cancel{\text{g fat}} \times \frac{100 \text{ g}}{5.9 \cancel{\text{g fat}}}$$

   $$m_{\text{serving}} = 51 \text{ g or } 0.051 \text{ kg}$$

   $$m_{\text{serving}} = 3.0 \cancel{\text{g fat}} \times \frac{100 \text{ g serving}}{2.0 \cancel{\text{g fat}}}$$

   $$m_{\text{serving}} = 0.15 \text{ kg}$$

   $$m_{\text{serving}} = 3.0 \cancel{\text{g fat}} \times \frac{100 \text{ g serving}}{1.2 \cancel{\text{g fat}}}$$

   $$m_{\text{serving}} = 0.25 \text{ kg}$$

   The serving sizes containing 3.0 g of fat for the three choices of yogurt are as follows: for 5.9% MF yogurt, a 51 g or 0.051 kg serving; for 2.0% MF yogurt, a 0.15 kg serving; and for 1.2% MF yogurt, a 0.25 kg serving.

7. (White) vinegar is most commonly sold in stores as a 5% (by volume) solution of acetic acid, $HC_2H_3O_{2(aq)}$, by volume. Assume a *minimum* of 5 mL of acetic acid in 100 mL of solution. (Commercial labelling is always a *guaranteed legal minimum*. Significant digits do not apply to this value, because the 5% is *not* a measurement.)

$$c_{HC_2H_3O_2} = 5\% = 5 \text{ mL}/100 \text{ mL}$$

$$v_{HC_2H_3O_2} = 15 \text{ mL}$$

$$v_{HC_2H_3O_2} = 15 \text{ mL} \times \frac{100 \cancel{\text{mL}}}{5 \cancel{\text{mL}}}$$

$$v_{HC_2H_3O_2} = 0.30 \text{ L}$$

The volume of vinegar containing 15 mL of acetic acid is 0.30 L.

8. $c_{\text{ nitrate}} = 55 \text{ ppm} = 55 \text{ mg/L}$

$$v_{\text{ water}} = 200 \text{ mL} = 0.200 \text{ L}$$

$$m_{\text{ nitrate}} = 0.200 \cancel{\text{L}} \times \frac{55 \text{ mg}}{1 \cancel{\text{L}}}$$

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

The mass of nitrate ion in the water is 11 mg.

9. (a) $n_{\text{ Cu(NO}_3)_2} = 0.35 \text{ mol}$

$$v_{\text{ Cu(NO}_3)_2} = 500 \text{ mL} = 0.500 \text{ L}$$

$$C_{\text{ Cu(NO}_3)_2} = \frac{0.35 \text{ mol}}{0.500 \text{ L}}$$

$$C_{\text{ Cu(NO}_3)_2} = 0.70 \text{ mol/L}$$

The molar concentration of the solution is 0.70 mol/L.

(b) $M_{\text{ NaOH}} = 40.00 \text{ g/mol}$

$$m_{\text{ NaOH}} = 10.0 \text{ g}$$

$$v_{\text{ NaOH}} = 2.00 \text{ L}$$

$$n_{\text{ NaOH}} = 10.0 \cancel{\text{g}} \times \frac{1 \text{ mol}}{40.00 \cancel{\text{g}}}$$

$$= 0.250 \text{ mol}$$

$$C_{\text{ NaOH}} = \frac{0.250 \text{ mol}}{2.00 \text{ L}}$$

$$C_{\text{ NaOH}} = 0.125 \text{ mol/L}$$

or

$$C_{\text{ NaOH}} = 10.0 \cancel{\text{g}} \times \frac{1 \text{ mol}}{40.00 \cancel{\text{g}}} \times \frac{1}{2.00 \text{ L}}$$

$$C_{\text{ NaOH}} = 0.125 \text{ mol/L}$$

The molar concentration of the solution is 0.125 mol/L.

(c) $v_i = 25 \text{ mL}$

$$v_f = 145 \text{ mL}$$

$$C_i = 11.6 \text{ mol/L}$$

$$C_f = ?$$

$$v_iC_i = v_fC_f$$

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

$$C_f = \frac{25 \cancel{\text{mL}} \times 11.6 \text{ mol/L}}{145 \cancel{\text{mL}}}$$

C_f = 2.0 mol/L

or

$$C_f = 25\ \cancel{\text{mL}} \times \frac{11.6\ \text{mol/L}}{145\ \cancel{\text{mL}}}$$

C_f = 2.0 mol/L

The final molar concentration of the solution is 2.0 mol/L.

(d) 16 ppm of $Mg^{2+}_{(aq)}$ = 16 mg/L

$M_{Mg^{2+}}$ = 24.31 g/mol

$m_{Mg^{2+}}$ = 16 mg

v = 1.00 L (assume one litre of solution, with a certainty that does not limit the certainty of the answer)

$$n_{Mg^{2+}} = 16\ \text{m}\cancel{\text{g}} \times \frac{1\ \text{mol}}{24.31\ \cancel{\text{g}}}$$

$$= 0.66\ \text{mmol}$$

$$C_{Mg^{2+}} = \frac{0.66\ \text{mmol}}{1.00\ \text{L}}$$

$C_{Mg^{2+}}$ = 0.66 mmol/L

or

$$C_{Mg2+} = 16\ \text{m}\cancel{\text{g}} \times \frac{1\ \text{mol}}{21.43\cancel{\text{g}}} \times \frac{1}{1.00\text{L}}$$

C_{Mg2+} = 0.66 mmol/L

The molar concentration of the solution is 0.66 mmol/L.

10. (a) The labelled compounds are (by formula and class of compound):

water	$H_2O_{(l)}$	neutral molecular
glucose	$C_6H_6O_{11(l)}$	neutral molecular
citric acid	$C_3H_4OH(COOH)_{3(s)}$	acid molecular
potassium citrate	$K_3C_3H_4OH(COO)_{3(s)}$	ionic
sodium chloride	$NaCl_{(s)}$	ionic
potassium phosphate	$K_3PO_{4(s)}$	ionic

(b) Dissolved glucose would make the drink taste sweet, and dissolved citric acid would make it taste tangy.

(c) Note that the ion mass values in this question are from a commercial label. They thus represent required legal *minimum* content, and are not *measured* values. Significant digits can not be assigned to such values, so the certainty for this calculation must be taken from (related to) the given serving volume value, 400 mL (3 significant digits).

m_{Na^+} = 50 mg

m_{K^+} = 55 mg

v_{solution} = 400 mL = 0.400 L

$$c_{Na^+} = \frac{50\ \text{mg}}{0.400\ \text{L}}$$

c_{Na^+} = 125 mg/L = 125 ppm

The concentration of sodium ions is 125 ppm.

$$c_{K^+} = \frac{55\ \text{mg}}{0.400\ \text{L}}$$

c_{K^+} = 138 mg/L = 138 ppm

The concentration of potassium ions is 138 ppm.

11. $M_{Na_2C_2O_4} = 134.00$ g/mol

$v_{Na_2C_2O_4} = 250.0 \text{ mL} = 0.2500 \text{ L}$

$C_{Na_2C_2O_4} = 0.375 \text{ mol/L}$

$$n_{Na_2C_2O_4} = 0.2500 \cancel{\text{L}} \times \frac{0.375 \text{ mol}}{1 \cancel{\text{L}}}$$

$$= 0.0938 \text{ mol}$$

$$m_{Na_2C_2O_4} = 0.0938 \cancel{\text{mol}} \times \frac{134.00 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{Na_2C_2O_4} = 12.6 \text{ g}$$

or

$$m_{Na_2C_2O_4} = 0.2500 \cancel{\text{L}} \times \frac{0.375 \cancel{\text{mol}}}{1 \cancel{\text{L}}} \times \frac{134.00 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{Na_2C_2O_4} = 12.6 \text{ g}$$

The mass of sodium oxalate required is 12.6 g.

12. $v_i = ?$

$v_f = 500$ mL

$C_i = 14.6$ mol/L

$C_f = 1.25$ mol/L

$$v_i C_i = v_f C_f$$

$$v_i = \frac{v_f C_f}{C_i}$$

$$v_i = \frac{500 \text{ mL} \times 1.25 \cancel{\text{mol/L}}}{14.6 \cancel{\text{mol/L}}}$$

$$v_i = 42.8 \text{ mL}$$

or

$$v_i = 500 \text{ mL} \times \frac{1.25 \cancel{\text{mol}}/\text{L}}{14.6 \cancel{\text{mol}}/\text{L}}$$

$$v_i = 42.8 \text{ mL}$$

The required volume of the initial phosphoric acid solution is 42.8 mL.

13. $c_{HCl} = 36\% \text{ W/V} = 0.36 \text{ kg/L}$

$M_{HCl} = 36.46$ g/mol

$$C_{HCl} = \frac{0.36 \text{ k}\cancel{\text{g}}}{1 \text{ L}} \times \frac{1 \text{ mol}}{36.46 \cancel{\text{g}}}$$

$$= 0.0099 \text{ kmol/L} = 9.9 \text{ mol/L}$$

$v_i = ?$

$v_f = 5.00$ L

$C_i = 9.9$ mol/L

$C_f = 0.12$ mol/L

$$v_i C_i = v_f C_f$$

$$v_i = \frac{v_f C_f}{C_i}$$

$$v_i = \frac{5.00\text{ L} \times 0.12\ \cancel{\text{mol/L}}}{9.9\ \cancel{\text{mol/L}}}$$

$$v_i = 0.061\text{ L} = 61\text{ mL}$$

or

$$v_i = 5.00\text{ L} \times \frac{0.12\ \cancel{\text{mol}}\text{/L}}{9.9\ \cancel{\text{mol}}\text{/L}}$$

$$v_i = 0.061\text{ L} = 61\text{ mL}$$

The required initial volume of the hydrochloric acid is 61 mL.

Applying Inquiry Skills

14. Standard solutions are prepared either by dissolving a measured mass of a solid solute to make a known volume of solution; or by diluting an existing (more concentrated) solution of known concentration to decrease its concentration.
15. A standard solution is one for which the concentration is accurately known. It is necessary for accurate chemical analysis or for precise control of chemical reactions.
16. (a) Electrolytes can be distinguished from nonelectrolytes by testing solutions of the compound with an ohmmeter, or conductivity meter. Electrolytes form conducting solutions; nonelectrolytes form nonconducting solutions.

    (b) Acids, bases, and neutral compounds can be distinguished by testing a solution of each compound with blue and pink litmus. In an acidic solution, blue litmus will change to pink (but pink litmus will be unchanged); in a basic solution, pink litmus will change to blue (but blue litmus will be unchanged); and in a neutral solution, neither pink nor blue litmus will change colour.

17. (a)

$$M_{KHC_4H_4O_6} = 188.19\text{ g/mol}$$

$$v_{KHC_4H_4O_6} = 100.0\text{ mL} = 0.1000\text{ L}$$

$$C_{KHC_4H_4O_6} = 0.150\text{ mol/L}$$

$$n_{KHC_4H_4O_6} = 0.1000\ \cancel{\text{L}} \times \frac{0.150\text{ mol}}{1\ \cancel{\text{L}}}$$

$$= 0.0150\text{ mol}$$

$$m_{KHC_4H_4O_6} = 0.0150\ \cancel{\text{mol}} \times \frac{188.19\text{ g}}{1\ \cancel{\text{mol}}}$$

$$m_{KHC_4H_4O_6} = 2.82\text{ g}$$

or

$$m_{KHC_4H_4O_6} = 0.1000\ \cancel{\text{L}} \times \frac{0.150\ \cancel{\text{mol}}}{1\ \cancel{\text{L}}} \times \frac{188.19\text{ g}}{1\ \cancel{\text{mol}}}$$

$$m_{KHC_4H_4O_6} = 2.82\text{ g}$$

The mass of potassium hydrogen tartrate measured is 2.82 g.

(b) **Procedure**

1. Put on eye protection and a lab apron.
2. Calculate the mass of solid potassium hydrogen tartrate needed to prepare 100.0 mL of a 0.150 mol/L solution. (2.82 g, as shown above.)
3. Obtain the calculated mass of potassium hydrogen tartrate in a clean, dry 150 mL beaker.
4. Dissolve the solid in 40 to 50 mL of pure water.
5. Transfer the solution into a 100 mL volumetric flask. Rinse the beaker and funnel two or three times with small quantities of pure water, transferring the rinsings into the volumetric flask.
6. Add pure water to the flask until the volume is 100.0 mL.
7. Stopper the flask and mix the contents thoroughly by repeatedly inverting the flask.

18. (a) $v_i = ?$

$v_f = 100.0\text{ mL}$

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

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

$$v_iC_i = v_fC_f$$

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

$$v_i = \frac{100.0\ \text{mL} \times 0.100\ \cancel{\text{mol}}/\text{L}}{0.400\ \cancel{\text{mol}}/\text{L}}$$

$$v_i = 25.0\ \text{mL}$$

or

$$v_i = 100.0\ \text{mL} \times \frac{0.100\ \cancel{\text{mol}}/\text{L}}{0.400\ \cancel{\text{mol}}/\text{L}}$$

$$v_i = 25.0\ \text{mL}$$

The required initial volume of the stock solution is 25.0 mL.

(b) **Procedure**

1. Wear eye protection and a lab apron.
2. Calculate the volume of a 0.400 mol/L stock solution (25.0 mL, as shown above) that will be required to prepare 100.0 mL of a 0.100 mol/L solution by dilution.
3. Add 40 to 50 mL of pure water to a 100-mL volumetric flask.
4. Use a 25-mL volumetric pipet to transfer 25.00 mL of the stock solution into the 100-mL volumetric flask.
5. Add pure water until the final volume of 100.0 mL is reached.
6. Stopper the flask and mix the solution thoroughly.

19. **Analysis**

Solution A shows acidic properties, turning blue litmus red and conducting current; so according to our current knowledge it must be the sulfuric acid.
Solution B shows neutral molecular properties, not changing litmus and not conducting current; so according to our current knowledge it must be the glucose.
Solution C shows basic properties, turning red litmus blue and conducting current; so so according to our current knowledge it must be the calcium hydroxide.
Solution D shows neutral ionic properties, not changing litmus but conducting current; so according to our current knowledge it must be the potassium chloride.

Making Connections

20. (a) Oil and water will not dissolve in each other because water is polar and oils are not. Essentially, water molecules attract each other so strongly with hydrogen bonding that oil molecules cannot intermix with them. Depending on the density of the oil, it will either float on top of the water in a thin layer, or sink to the bottom in discrete globs.
(b) Oil on the surface of the water prevents the exchange of oxygen and carbon dioxide between the air and the water. It also clogs the fine filaments of organisms, such as fishes' gills and invertebrates' tentacles, as well as coating the feathers and fur of marine birds and mammals, thus destroying their insulation and waterproofing. Together, these problems result in the death of much marine life, as well as making the area unsightly.
(c) Oil is cleaned up with steam, solvents, absorbent materials, and physical collectors (skimmers and scrapers). Sometimes it is also treated to make it sink to the bottom, but this does not necessarily solve the problem.
(d) Risks of transportation by large oil tanker: oil leakage; introduction of alien species in ballast water; control is in the hands of relatively few extremely large companies.

Benefits of transportation by large oil tanker: relatively inexpensive; relatively safe (if ships are well built and well handled); the system is already established, including fleets of ships, ports, loading and off-loading facilities.
Alternatives: no transoceanic transportation of oil; transportation in smaller ships; air transportation.

Stopping tanker oil transport would mean a major change in our civilization, which largely runs on fairly cheap energy from fossil fuels. But continuing this shipping of oil inevitably means environmental damage will occur. A risk–benefit analysis should focus on minimizing the risks, in this case, for example, by requiring that tankers be double-hulled for increased safety, or that tankers not be allowed to travel near sensitive areas such as the Galapagos Islands.

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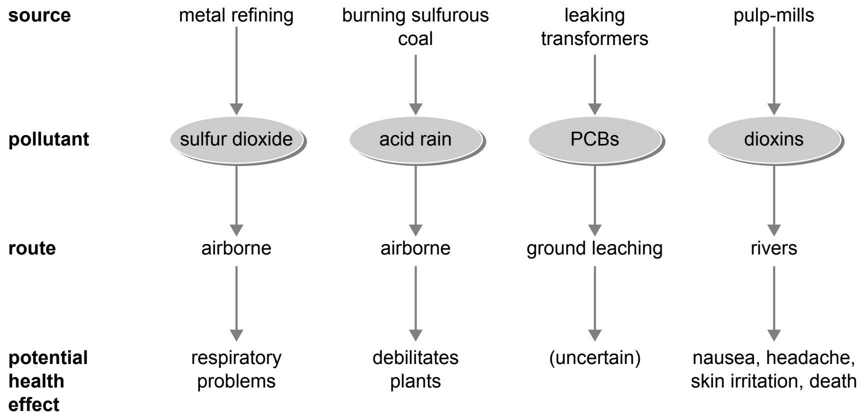
21. Solutions collected might include examples such as:
    - rubbing alcohol (isopropanol): 70% (V/V) $CH_3CHOHCH_{3(l)}$ in water (a liquid solute in a liquid solvent); not to be taken internally; toxic by ingestion;
    - decongestant (oxymetazoline hydrochloride): 0.05% in water (a solid solute in a liquid solvent); limit two uses per nostril per day; not to be used by children; causes increase in nasal congestion when use is discontinued;
    - bleach (sodium hypochlorite): 5.25% $NaOCl_{(s)}$ in water (a solid solute in a liquid solvent); corrosive; toxic fumes; reacts with acids and bases to produce toxic products;
    - window cleaner (household ammonia): $NH_{3(g)}$ in water (a gaseous solute in a liquid solvent); irritant to eyes, nose and throat; concentrated fumes (not in the product mentioned) are toxic and may be fatal;
    - metal ornaments (pewter): 4-7% Sb, 1-2%Cu in tin, $Sn_{(s)}$ (solid solutes in a solid solvent); no safety precautions;
    - air: about 20% oxygen in nitrogen (gasesous solute in a gaseous solvent); no safety precautions.
22. Research should turn up examples such as
    - glucose or dextrose (5%); to provide nourishment to a patient by placing sugar directly in the bloodstream for use by body cells;
    - multivitamin infusion (1 vial vitamin concentrate in 1000 mL of IV fluid); to eliminate risk of vitamin deficiency in patients receiving nutrition primarily through IV feeding;
    - antibacterial agent such as gatifloxacin (200 mg (100 ml) or 400 mg (200 ml) of gatifloxacin (2 mg/ml) in 5% dextrose); to treat bacterial infections;
    - heart drug, esmolol HCl (10 mg/mL infusion by adding one 2500 mg ampule to a 250 mL container of a compatible intravenous solution); to control heartbeat in patients recovering from surgery;
    - lidocaine (2% (20 mg/mL)); a local anaesthetic, particularly recommended for use while setting broken bones.
23. A typical chart would show examples as follows:

(a) Animal waste washed by heavy rain into a stream that feeds a river, from which water is extracted for a town or city's water supply.
(b) Human waste migrates underground from an outdoor toilet or an underground septic tank to a well drilled downhill from the waste.
(c) Industrial waste is released into a river system from which water is extracted for domestic purposes farther down river.
(d) Municipal waste leaches into the ground and into the aquifer from which well water is extracted for domestic use.
(e) Natural waste from nondomestic plants and animals is washed by flooding into a river from which water is removed for municipal use.



Note: Student research is required for this answer. Other controversial chemicals include alcohol, asbestos, benzene, CFCs, chlorine, cigarette smoke, DDT, lead, mercury, nitrites, nitrogen oxides, ozone, phosphates, radon, and vinyl chloride. See *Controversial Chemicals: A Citizen's Guide* by P. Kruus and I.M. Valeriote (ISBN: 0-9198868-22-3).

24. See a summary of *Guidelines for Canadian Drinking Water Quality*, published by Health Canada, for acceptable water organism and impurity levels.
    (a) One potentially dangerous contaminant is cryptosporidium, a microorganism and parasite. There is no legal requirement to test for cryptosporidium, and thus there is no MAC for this contaminant. Many town water supplies are not tested for cryptosporidium.

(b) In April/May 2001, there was an outbreak of illnesses in North Battleford, Saskatchewan, that were caused by cryptosporidium.
(c) The symptoms are flulike with severe stomach cramps, nausea, and diarrhea. This outbreak resulted in at least three deaths from the cryptosporidium in the drinking water. Only people with immune deficiencies died or were seriously threatened by the contaminant. Cryptosporidium effects are not generally as severe as *E. coli* effects, such as those experienced in Walkerton, Ontario, in 2000, where seven people died.
(d) A water advisory and then a boil-water order was issued. It was discovered that the drinking-water filtration system malfunctioned after it was shut down for semi-annual maintenance. Provincial authorities considered legislation to require testing for cryptosporidium. The counterargument was that the testing is imprecise and that the cryptosporidium is in such low concentrations that its presence may not even be detected by the testing. The water management design, with the drinking water intake pipe downstream from the used-water treatment plant, was also a concern.

Exploring

25. The report will be in the form of a sales brochure containing information such as the pressure needed to extract pure water through a reverse osmosis membrane from sea water (theoretically about 2500 kPa minimum, empirically about 60 000 kPa – 90 000 kPa in practice). There are many commercially operating plants in Israel and the United States using sea water, and one in Yuma, Arizona using saline river water. Reverse osmosis used to be relatively expensive but is rapidly decreasing in cost with more widespread use. A plant near Tampa Bay in Florida, scheduled for completion in 2002, will treat 45 million U.S. gallons (170 million litres) of sea water each day and produce enough fresh pure water to supply about 10% of the needs of that area.

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26. Chlorine treatment is used to kill harmful organisms (protozoa, bacteria, and viruses) in drinking water. For example, one Redi Chlor tablet will make one gallon of water suitable for drinking. One system, Pristine, by a Canadian company, Advanced Chemicals, mixes solution A (inactivated chlorine dioxide) with solution B (5% phosphoric acid) to produce activated chlorine dioxide, which is then mixed with the water to purify it. Information on ingredients and effects can also be obtained from a package label.

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