Chapter 3

Summary of Terms

Atomic symbol An abbreviation for an element or atom.

Chemical bond The force of attraction between two atoms that holds them together.

Chemical change The formation of new substance(s) by rearranging the atoms of the original material(s).

Chemical formula A notation that indicates the composition of a compound, consisting of the atomic symbols for the different elements of the compound and numerical subscripts indicating the ratio in which the atoms combine.

Chemical property A type of property that characterizes the ability of a substance to change into a different substance under specific conditions.

Chemical reaction A term synonymous with chemical change.

Compound A material in which atoms of different elements are bonded to one another.

Element A material consisting of only one type of atom.

Elemental formula A notation that uses the atomic symbol and (sometimes) a numerical subscript to denote how many atoms are bonded in one unit of an element.

Group A vertical column in the periodic table, also known as a family of elements.

Heterogeneous mixture A mixture in which the different components can be seen as individual substances.

Homogeneous mixture A mixture in which the components are so finely mixed that anyone region of the mixture has the same ratio of substances as any other region.

Impure The state of a material that is a mixture of more than one element or compound.

Metal An element that is shiny, opaque, and able to conduct electricity and heat.

Metalloid An element that exhibits some properties of metals and some properties of nonmetals. Six elements recognized as metalloids include boron, B; silicon, Si; germanium, Ge; arsenic, As; antimony, Sb; and tellurium, Te.

Mixture A combination of two or more substances in which each substance retains its properties.

Nonmetal An element located toward the upper right of the periodic table, with the exception of hydrogen, that is neither a metal nor a metalloid.

Period A horizontal row in the periodic table.

Periodic table A chart in which all known elements are organized by physical and chemical properties.

Periodic trend The gradual change of any property in the elements across a period of the periodic table.

Physical change A change in which a substance changes its physical properties without changing its chemical identity.

Physical property Any physical attribute of a substance, such as color, density, or hardness.

Pure The state of a material that consists solely of a single element or compound.

Scanning Probe Microscope A tool of nanotechnology that detects and characterizes the surface atoms of materials by way of an ultrathin probe tip, which is detected by laser light as it is mechanically dragged over the surface.

Solution A homogeneous mixture in which all components are dissolved in the same phase.

Suspension A homogeneous mixture in which the various components are finely mixed, but not dissolved.

Review Questions

3.1 Matter Has Physical and Chemical Properties

1. What happens to the chemical identity of a substance during a physical change?
2. What changes during a chemical reaction?
3. Why is it sometimes difficult to decide whether an observed change is physical or chemical?
4. Why is melting ice an example of a physical change?

3.2 Elements Are Made of Atoms

5. How many types of atoms can you expect to find in a pure sample of any element?
6. Distinguish between an atom and an element.
7. What information is given by the elemental formula?

3.3 The Periodic Table Helps Us to Understand the Elements

8. How many periods are there in the periodic table? How many groups?
9. Do properties change or remain the same for elements across any period of the periodic table?
10. Why are the lanthanides and actinides placed beneath the main body of the periodic table?
11. What groups of the periodic table comprise the transition metals?

3.4 Elements Can Combine to Form Compounds

12. What is the difference between an element and a compound?
13. What does the chemical formula of a substance tell us about that substance?
14. How are the properties of a compound related to the properties of the elements used to make that compound?

3.5 There Is A System for Naming Compounds

15. What is the chemical formula for the compound titanium dioxide?
16. What is the name of the compound with the formula $NaNO_3$?
17. How many carbon atoms are there in magnesium cyanide, $Mg(CN)_2$?

3.6 Most Materials Are Mixtures

18. What defines a material as being a mixture?
19. How can the components of a mixture be separated from one another?
20. How does distillation separate the components of a mixture?

3.7 Matter Can Be Classified as Pure or Impure

21. Why is it not practical to have a macroscopic sample that is 100 percent pure?
22. How is a solution different from a suspension?
23. How can a solution be distinguished from a suspension?

3.8 The Advent of Nanotechnology

24. How soon will nanotechnology give rise to commercial products?
25. What are the two main approaches to building nanoscale materials and devices?
26. Who is the ultimate expert at nanotechnology?

Quantitative Questions

27. The Colorado River water in Colorado has a salinity of about 50 ppm. By the time this water passes into Mexico its salinity has increased to about 1000 ppm. How many milligrams of salts have been added to each liter of water?

28. Rainwater is naturally acidic containing about 48 micrograms of acidity per liter. Express this concentration in units of ppm, ppb, and ppt.

29. Dioxins are highly toxic compounds that form upon the burning of certain plastics, especially PVC. Dioxins bioaccumulate, which means that animals higher in the food chain tend to have greater concentrations within their bodies. Most of our exposure to dioxins comes from the food we eat rather than the air we breathe. How many milligrams of dioxins are there in a liter of milk containing 0.16 ppt?

30. Drinking water is routinely disinfected by adding chlorine to a concentration of about 2 ppm. How many milligrams is this per liter of water?

31. Sea water has a salt concentration of about 3.5%. Express this in units of ppm.

32. As a follow up to the previous question, express the concentration of salt in seawater in units of ppb.

Solutions (Odd-Numbered)

1. Nothing. During a physical change, the chemical identity of a substance remains the same.

3. Determining whether a change is physical or chemical can be difficult because both involve changes in appearance.

5. An element consists of only one type of atom.

7. The elemental formula tells us how the atoms within an element are grouped. Within nitrogen, N_2, for example, nitrogen atoms are paired.

9. Across any period, the properties of elements gradually change.

11. The transition metals are those from group 3 – 10.

13. The chemical formula tells us the ratio in which atoms come together to form one unit a particular substance.

15. The formula for titanium dioxide is TiO_2.

17. There are two carbon atoms within magnesium cyanide.

19. Filtration or distillation can separate mixtures. These methods take advantage of differences in the components' physical properties.

21. Atoms and molecules are very small so if one atom or molecule out of a trillion is different then the sample is no longer pure.

23. A centrifuge can be used to determine if a mixture is a solution or a suspension because it will separate the components of a suspension.

25. The top-down approach in which nanostructures are carved out of larger materials and the bottom-up approach in which nanostructures are pieced together atom by atom.

27. The difference between these two concentrations is 950 ppm or 950 milligrams per liter. The amount of salts added to the river water is 950 milligrams per liter.

29. A concentration of 0.16 ppt is 0.16 nanograms per liter. Convert nanograms to milligrams using these equalities: 1 gram = 10^3 mg, 1 gram = 10^9 ng.

    (0.16 ng)(1 gram/10^9 ng)(10^3 mg/1 gram) = 1.6×10^{-7} mg = 0.00000016 mg

31. The "per cent" is "per 100". So the concentration of salt in seawater is about 3.5 parts per hundred, or 3.5 pph. There are 10,000 hundreds in a million so the conversion factors will look like this:

    (3.5 parts/hundred)(10,000 hundreds/1 million) = 35,000 ppm

Solutions to Chapter 3

Calculation Corner

How Pure Is Pure?

1. One liter of 1.0 ppm fluoridated drinking water contains 1.0 mg of fluoride.

2. A dissolved oxygen concentration of 6 ppm corresponds to 6 mg/L. With one liter, you have 6 mg:

   (6 mg/L)(1 L) = 6 mg

   Use a conversion unit to express 6 mg as 0.006 grams:

   (6 mg)(1 gram/1000 mg) = 0.006 grams

3. A concentration of 25 ppb is 25 micrograms per liter. Convert from micrograms into milligrams as follows:

   (25 micrograms)(1 milligram/1000 micrograms) = 0.025 milligrams

   Thus, there are 0.025 milligrams of chloroform in each liter of this water.

4. Assuming you live in the U.S., which has a population of about 330 million, then your concentration is about 1/0.33 billion = 3.0 ppb. The concentration of you in the whole world is about 1/8 billion = 0.125 ppb, which is about 125 ppt. If you can imagine how few of you there are compared to national or world populations, then you have a sense of how dilute a dissolved substance is when its concentration is measured by the ppb or ppt