Chapter 3

Solutions to Supplementary *Check for Understanding* Problems

Classification of Matter

1. Identify each of the following as a pure substance or a mixture.

   a) air
   b) 14-karat gold
   c) propane
   d) milk
   e) aluminum foil
   f) sewing thread
   g) gasoline

Answers:
a) mixture
b) mixture
c) pure substance
d) mixture
e) pure substance
f) mixture
g) mixture

Solutions

A pure substance (an element or compound) has a fixed composition while a mixture does not.

a) Air is a combination of nitrogen gas and oxygen gas with various amounts of other materials such as water vapor, carbon dioxide and particulates. Air quality (based on its composition) varies on a daily basis. Thus it is a mixture.

b) 14-karat gold is an alloy of gold and other metals such as copper and silver. Alloys are homogeneous mixtures. Pure gold is referred to as 24-karat gold.

c) Propane is a chemical compound so it is a pure substance.

d) Milk is a complex blend of water, carbohydrates, fats, proteins and many other components such as calcium-containing compounds. There are various grades of milk. Thus it is a mixture.

e) Aluminum is a chemical element so it is a pure substance.

f) Sewing thread can be made from cotton, polyester, nylon or many other materials and is usually treated with a surface coating. Thus it is a mixture.

g) Gasoline is a complex blend of compounds made from petroleum. There are various grades of gasoline. Thus it is a mixture.

2. A classmate claims that brass and silver are both pure substances because they have a uniform composition throughout. Do you agree or disagree? Explain why.

Solution

While both brass and silver have a uniform composition throughout, brass is not a pure substance because it does not have a definite composition. Brass is an alloy of copper and zinc and the proportions of these two metals are varied to produce brass having different properties.

3. Distinguish between a pure substance and a heterogeneous mixture at (a) the macroscopic level and (b) at the microscopic level.

Solution

a) At the macroscopic level the pure substance displays a single phase while the heterogeneous mixture has two or more distinct phases. Compare a pure substance like copper metal to a heterogeneous mixture like wood.

b) At the microscopic level the pure substance has a uniform composition throughout while the heterogeneous mixture has a composition that varies as you move from phase to phase.

4. Is a sample containing two or more substances necessarily heterogeneous? Explain.

Solution

No. If the components are blended together so that the sample has a uniform composition, such as is found for a metal alloy or a solid completely dissolved in water and thoroughly mixed, a homogeneous mixture forms.

5. How would you classify an element that is a gas at room temperature?

Solution

This element is a nonmetal. The only elements that are gases at room temperature are nonmetals.

Chemical and Physical Changes

1. Identify each of the following as a physical or a chemical property.

a) chromium conducts heat
b) zinc generates a colorless gas in acid
c) carbon crystallizes as diamond
d) white phosphorus ignites in air

Answers: a) physical property c) physical property

b) chemical property d) chemical property

Solutions

A physical property does not involve a change in composition while a chemical property involves a substance undergoing a change into a new substance (chemical reaction).

a) There is no change in composition so this is a physical property.

b) A new substance (colorless gas) is formed so this is a chemical property.

c) There is no change in composition so this is a physical property.

d) This describes a chemical reaction so this is a chemical property.

2. Identify each of the following as primarily a physical or a chemical change.

a) sawing wood
b) a penny tarnishing
c) stirring cake batter
d) formation of a snowflake
e) formation of bubbles when a pot of water is first heated
f) etching glass with an etching cream
g) disappearance of dry ice as it warms
h) fizzing of hydrogen peroxide when it is applied to a cut

Answers: a) physical change e) physical change

b) chemical change f) chemical change

c) physical change g) physical change

d) physical change h) chemical change

Solutions

Recall that the fundamental difference between physical and chemical changes is that a new substance is formed in a chemical change but not in a physical change.

a) Sawing wood does not produce a new substance. Thus it is a physical change.

b) Pennies get dull over time because the shiny copper metal on the surface reacts with air to form copper compounds. Thus it is a chemical change.

c) Stirring cake batter does not produce a new substance. Thus it is a physical change.

d) Snowflakes form when liquid water turns to ice. Small particles of dust and dirt may get trapped in the ice but no new substances are formed. Thus it is a physical change.

e) When water is heated initially small bubbles of nitrogen and oxygen gas form from the air dissolved in the water. Since no new substances are created this is a physical change.

f) The etching cream is a mix of compounds that will react with the glass to produce a frosted appearance. Since a new substance is formed this is a chemical change.

g) As dry ice warms it undergoes a change in physical state from a solid to a gas but no new substance is formed. Thus it is a physical change.

h) The fizzing is due to hydrogen peroxide (H_2O_2) being decomposed into water and oxygen gas. The small bubbles are oxygen gas. Since new substances are formed, this is a chemical change.

2. You are given a mixture of sugar and sand and are asked to separate the two components of the mixture? Explain how you would do this. Is your approach based on physical or chemical properties. Explain.

Solution

Place the sample in a large container of water and thoroughly mix until all of the sugar is dissolved. Filter the mixture through a sheet of cloth and rinse the cloth several times with water. The colth now contains the sand and the water contains the sugar. You can dry both samples to recover the separated sand and sugar.

Since no chemical reactions are involved, this approach depends on physical properties. The sugar will dissolve in water but the sand will not.

Atomic Structure and Chemical Elements

1. Describe the general arrangement of the subatomic particles in an atom.

Solution

The protons and neutrons are found in the nucleus of the atom and the electrons are in motion outside the nucleus.

2. If the nucleus of an atom were the size of a golf ball (diameter ~ 4 cm), what would be the diameter of the atom?

   A. 4000 cm

   B. 4000,000 m

   C. 4000 m

   D. 40 km

Answer: C

Solution

The diameter of the atom is about 10^5 times as large as the diameter of the nucleus, thus the diameter of the atom would be about 4×10^5 cm. This is the same as 4000 m.

$$4 \times 10^5 \ \cancel{\text{cm}} \times \frac{10^{-2} \text{ m}}{1 \ \cancel{\text{cm}}} = 4 \times 10^3 \text{ m}$$

3. Write the shorthand notation for an atom containing:

   a) 27 protons, 32 neutrons and 27 electrons

   b) 82 protons, 125 neutrons and 82 electrons

Answers: a) ^{59}Co

b) ^{207}Pb

Solutions

Recall that the number of protons in the atom uniquely identifies the element. The superscript is the mass number (A) which is equal to the sum of the protons plus neutrons in the atom.

a) 27 protons ➔ Co and A = 27 + 32 = 59 ➔ ^{59}Co

b) 82 protons ➔ Pb and A = 82 + 125 = 207 ➔ ^{207}Pb

4. Which of the following contains the fewest number of neutrons per atom?

A. ^{112}Cd

B. ^{114}Sn

C. ^{115}I

D. ^{110}Ag

Answer: ^{115}I

Solution

The number of neutrons (N) in an atom is obtained by subtracting the atomic number (Z) from the mass number (A).

^{112}Cd N = 112 - 48 = 64

^{114}Sn N = 114 - 50 = 64

^{115}I N = 115 - 53 = 62 ← smallest

^{110}Ag N = 110 - 47 = 63

5. Write the name or symbol, as appropriate, for each of the following chemical elements.

P	phosphorus	gold	Au
Mg	magnesium	arsenic	As
Sr	strontium	potassium	K
Pt	platinum	tin	Sn
Mn	manganese	mercury	Hg

You should memorize the names and symbols of the common elements shown in Table 3.1.

6. What are the differences between an atom and an ion?

Solution

An atom is electrically neutral. An ion has a net electric charge because the number of protons does not equal the number of electrons present.

7. Write the chemical formula for an ion containing:

a) 56 protons and 54 electrons

b) 34 protons and 36 electrons

Answers: a) Ba^{2+}

b) Se^{2-}

Solutions

The number of protons in the atom uniquely identifies the element. The difference between the number of protons and the number of electrons present will give the ion charge.

a) 56 protons ➔ Ba and ion charge = 56 - 54 = 2 ➔ Ba^{2+}

b) 34 protons ➔ Se and ion charge = 34 - 36 = -2 ➔ Se^{2-}

8. What arrangements of elements in the periodic table have similar chemical properties? What part of the atom's structure has the largest influence on its chemical properties?

Solution

Elements that are in the same vertical grouping (group) have similar chemical properties. The number and arrangement of the electrons in an atom largely determine the chemical properties of an element.

Compounds and Chemical Nomenclature

1. What is the basis for distinguishing one chemical compound from another?

Solution

A chemical compound is a pure substance with a unique composition. Differences in composition result in different properties which distinguish one compound from another.

2. Which of the following are diatomic molecules?

a) H_2 d) H_2O g) CCl_4
b) SO_2 e) NO h) FeS
c) HBr f) KCl

Answers: (a), (c) and (e)

Solutions

A diatomic molecule is two-atom molecule of an element or molecular compound. Item (a) is an elemental form while (c) and (e) are molecular compounds. The other choices contain only two elements each, but the molecular compounds (b), (d) and (g) contain more than two atoms in each molecule while (f) and (h) are ionic compounds and do not consist of molecules.

3. How many total atoms constitute each formula unit of the following compounds?

a) H_3PO_4 b) $Ca(NO_3)_2$ c) $(NH_4)_2S_2O_3$

Answers: a) 8 atoms

b) 9 atoms

c) 15 atoms

Solutions

The total number of atoms is determined by adding up all of the atoms indicated in the chemical formula of the compound. For portions of the formula enclosed in parentheses, the number of atoms designated in the parentheses is multiplied by the subscript used with the parentheses.

4. What physical state is expected for an ionic compound?

Solution

An ionic compound is expected to be a solid at room temperature because the ions are held together in a rigid 3-dimensional structure by strong electrostatic attractions.

5. Write the chemical formula and name for the ionic compound formed from each combination of cations and anions below.

	OH^-	CO_3^{2-}	S^{2-}	PO_4^{3-}
NH_4^+	NH_4OH ammonium hydroxide	$(NH_4)_2CO_3$ ammonium carbonate	$(NH_4)_2S$ ammonium sulfide	$(NH_4)_3PO_4$ ammonium phosphate
Mg^{2+}	$Mg(OH)_2$ magnesium hydroxide	$MgCO_3$ magnesium carbonate	MgS magnesium sulfide	$Mg_3(PO_4)_2$ magnesium phosphate
Ag^+	$AgOH$ silver hydroxide	Ag_2CO_3 silver carbonate	Ag_2S silver sulfide	Ag_3PO_4 silver phosphate
Fe^{3+}	$Fe(OH)_3$ iron(III) hydroxide	$Fe_2(CO_3)_3$ iron(III) carbonate	Fe_2S_3 iron(III) sulfide	$FePO_4$ iron(III) phosphate

Solutions

It is important that you learn the names and formulas for the ions in Table 3.3 and Table 3.4.

The ionic formula indicates the smallest whole number of cations and the smallest whole number of anions needed for charge balance. When the charges of the cation and anion are not the same, use the value of the anion charge as the subscript for the cation and use the value of the cation charge as the subscript for the anion. The formula for a polyatomic ion is enclosed in parentheses before attaching the subscript. When the charges of the cation and anion are the same, a 1:1 ratio of ions is needed and both the cation and anion will have a subscript of 1.

The ionic compound name is obtained by using the cation name followed by the anion name. For transition elements that typically form more than one type of ion, use the element name followed by a Roman numeral (in parentheses) equal to the ion charge.

6. Write the chemical formula and name for each of six oxoacids.

Solutions

Recall that the name for an oxoacid is derived from the name of the anion that forms when one or more hydrogen ions break away from the original oxoacid molecule. An *-ate* anion results in an *-ic* acid and an *-ite* anion results in an *-ous* acid.

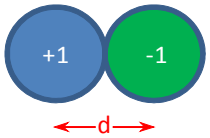
Possible answers include:

HNO_2	nitrous acid
HNO_3	nitric acid
$HC_2H_3O_2$	acetic acid
HClO	hypochlorous acid
$HClO_2$	chlorous acid
$HClO_3$	chloric acid
$HClO_4$	perchloric acid
H_2CO_3	carbonic acid
H_2SO_3	sulfurous acid
H_2SO_4	sulfuric acid
$H_2C_2O_4$	oxalic acid
H_3PO_4	phosphoric acid

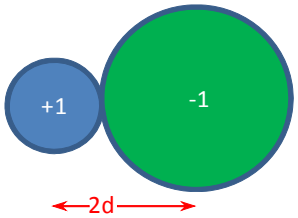
Coulomb's Law

1. Arrange the following combinations of electric charges in order of increasing electrostatic attraction.

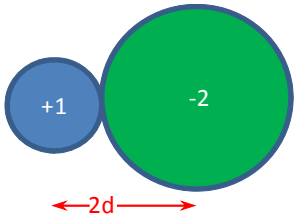
a)



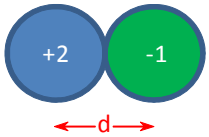
b)



c)



d)



Answer: (d) > (a) > (c) > (b)

Solution

The strength of the electrostatic attraction between electric charges is given by Coulomb's law, $F = k\frac{q_1 q_2}{r^2}$. Since *k* is a constant the force of attraction depends on the magnitude of the electric charges (q_1 and q_2) and the distance between their centers (r). The numerical value of *r* is not given but we must assume that *d* is constant in the above examples.

$$F_a = k\frac{q_1 q_2}{r^2} = k\frac{(1)(-1)}{(d)^2} = \frac{-k}{d^2}$$

$$F_b = k\frac{q_1 q_2}{r^2} = k\frac{(1)(-1)}{(2d)^2} = -k\frac{1}{4d^2} = \left(\frac{1}{4}\right)\frac{-k}{d^2}$$

$$F_c = k\frac{q_1 q_2}{r^2} = k\frac{(1)(-2)}{(2d)^2} = -k\frac{2}{4d^2} = \left(\frac{1}{2}\right)\frac{-k}{d^2}$$

$$F_d = k\frac{q_1 q_2}{r^2} = k\frac{(2)(-1)}{(d)^2} = -k\frac{2}{d^2} = 2\frac{-k}{d^2}$$

➔ $F_d > F_a > F_c > F_b$