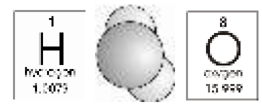
Chapter 2: Atoms and Molecules



CHAPTER OUTLINE

2.1 Symbols and Formulas
2.2 Inside the Atom
2.3 Isotopes
2.4 Relative Masses of Atoms and Molecules
2.5 Isotopes and Atomic Weights
2.6 Avogadro's Number: The Mole
2.7 The Mole and Chemical Formulas

LEARNING OBJECTIVES/ASSESSMENT

When you have completed your study of this chapter, you should be able to:

1. Use symbols for chemical elements to write formulas for chemical compounds. (Section 2.1; Exercise 2.4)
2. Identify the characteristics of protons, neutrons, and electrons. (Section 2.2; Exercises 2.10 and 2.12)
3. Use the concepts of atomic number and mass number to determine the number of subatomic particles in isotopes and to write correct symbols for isotopes. (Section 2.3; Exercises 2.16 and 2.22)
4. Use atomic weights of the elements to calculate molecular weights of compounds. (Section 2.4; Exercise 2.32)
5. Use isotope percent abundances and masses to calculate atomic weights of elements. (Section 2.5; Exercise 2.38)
6. Use the mole concept to obtain relationships between number of moles, number of grams, and number of atoms for elements, and use those relationships to obtain factors for use in factor-unit calculations. (Section 2.6; Exercises 2.44 a & b and 2.46 a & b)
7. Use the mole concept and molecular formulas to obtain relationships between number of moles, number of grams, and number of atoms or molecules for compounds, and use those relationships to obtain factors for use in factor-unit calculations. (Section 2.7; Exercise 2.50 b and 2.52 b)

LECTURE HINTS AND SUGGESTIONS

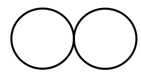
1. The word "element" has two usages: (1) a homoatomic, pure substance; and (2) a kind of atom. This dual usage confuses the beginning student. It often helps the beginning student for the instructor to distinguish the usage intended in a particular statement. e.g. "There are 112 elements, meaning 112 kinds of atoms." or "Each kind of atom (element) has a name and a symbol." or "Water contains the element (kind of atom) oxygen."
2. Emphasize that the term "molecule" can mean: (1) the limit of physical subdivision of a molecular compound; (2) the smallest piece of a molecular compound; or (3) the basic building block of which a molecular compound is made. Do not try to differentiate at this time the differences between ionic solids, molecular compounds, or network solids.
3. Many students fail to make a connection that a given pure substance has only one kind of constituent particle present; i.e., pure water contains only one kind of molecule, the water molecule. The molecule of water is made up of atoms of hydrogen and oxygen, but there are no molecules of hydrogen or oxygen in pure water.
4. The student will memorize the names and symbols for approximately one-third of the 112 elements to be dealt with-those commonly encountered in this course or in daily living. Mentioning both the name and the symbol whenever an element is mentioned in the lecture will aid the student's memorizing.
5. While memorization of the names and symbols is important, it should not become the major outcome of this class. Avoid reinforcing the mistaken notion that chemistry is merely learning formulas and equations.

6. It should be emphasized that the mole is a convenient way of measuring out needed numbers of atoms and molecules In the correct ratios for chemical reactions. Explain that the term "mole" is the same type of term as "dozen," "pair," or "gross," except that it specifies a much larger number of items.

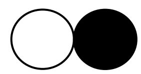
SOLUTIONS FOR THE END OF CHAPTER EXERCISES

SYMBOLS AND FORMULAS (SECTION 2.1)

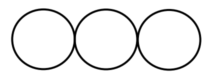
2.1 a. A diatomic molecule of an element*



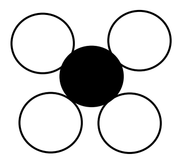
b. A diatomic molecule of a compound*



c. A triatomic molecule of an element

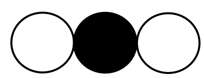


d. A molecule of a compound containing one atom of one element and four atoms of another element

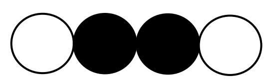


*Note: Each of these structures could be drawn in many different ways.

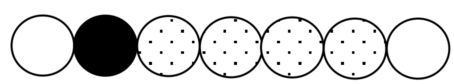
2.2 a. A triatomic molecule of a compound*



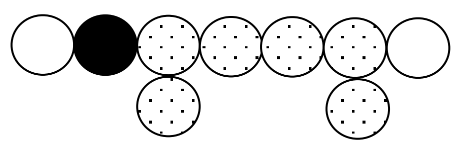
b. A molecule of a compound containing two atoms of one element and two atoms of a second element*



c. A molecule of a compound containing two atoms of one element, one atom of a second element, and four atoms of a third element*



d. A molecule containing two atoms of one element, six atoms of a second element, and one atom of a third element*



*Note: Each of these structures could be drawn in many different ways.

2.3 a. A diatomic molecule of fluorine (two fluorine atoms) — F_2; like Exercise 2.1 a

b. A diatomic molecule of hydrogen chloride (one hydrogen atom and one chlorine atom) — HCl; like Exercise 2.1 b

c. A triatomic molecule of ozone (three oxygen atoms) — O_3; like Exercise 2.1 c*

d. A molecule of methane (one carbon atom and four hydrogen atoms) — CH_4; like Exercise 2.1 d*

*The number and variety of atoms are alike. The actual structures of the molecules are different.

☑2.4 a. A molecule of water (two hydrogen atoms and one oxygen atom) — H_2O; like Exercise 2.2 a*

b. A molecule of hydrogen peroxide (two hydrogen atoms and two oxygen atoms) — H_2O_2; like Exercise 2.2 b*

*The number and variety of atoms are alike. The actual structures of the molecules are different.

	c.	A molecule of sulfuric acid (two hydrogen atoms, one sulfur atom, and four oxygen atoms)	H_2SO_4; like Exercise 2.2 c*
	d.	A molecule of ethyl alcohol (two carbon atoms, six hydrogen atoms, and one oxygen atom)	C_2H_6O; like Exercise 2.2 d*

*The number and variety of atoms are alike. The actual structures of the molecules are different.

2.5	a.	ammonia (NH_3)	1 nitrogen atom; 3 hydrogen atoms
	b.	acetic acid ($C_2H_4O_2$)	2 carbon atoms; 4 hydrogen atoms; 2 oxygen atoms
	c.	boric acid (H_3BO_3)	3 hydrogen atoms; 1 boron atom; 3 oxygen atoms
	d.	ethane (C_2H_6)	2 carbon atoms; 6 hydrogen atoms

2.6	a.	methane (CH_4)	1 carbon atom; 4 hydrogen atoms
	b.	perchloric acid ($HClO_4$)	1 hydrogen atom; 1 chlorine atom; 4 oxygen atoms
	c.	methylamine (CH_5N)	1 carbon atom; 5 hydrogen atoms; 1 nitrogen atom
	d.	propane (C_3H_8)	3 carbon atoms; 8 hydrogen atoms

2.7	a.	H3PO3 (phosphorous acid)	The numbers should be subscripted: H_3PO_3
	b.	$SICl_4$ (silicon tetrachloride)	The elemental symbol for silicon is Si: $SiCl_4$
	c.	SOO (sulfur dioxide)	Only one O should be written and a subscript 2 should be added: SO_2
	d.	2HO (hydrogen peroxide—two hydrogen atoms and two oxygen atoms)	The number 2 should be a subscript after H and after O: H_2O_2

2.8	a.	HSH (hydrogen sulfide)	More than one H is part of the compound; a subscript should be used: H_2S
	b.	$HCLO_2$ (chlorous acid)	The elemental symbol for chlorine is Cl (the second letter of a symbol must be lowercase): $HClO_2$
	c.	$2HN_2$ (hydrazine – two hydrogen atoms and four nitrogen atoms)	The subscripts should reflect the actual number of each type of atom in the compound: H_2N_4
	d.	C2H6 (ethane)	The numbers should be subscripted: C_2H_6

INSIDE THE ATOM (SECTION 2.2)

2.9			**Charge**	**Mass (u)**
	a.	5 protons and 6 neutrons	5	11
	b.	10 protons and 10 neutrons	10	20
	c.	18 protons and 23 neutrons	18	41
	d.	50 protons and 76 neutrons	50	126

☑2.10			**Charge**	**Mass (u)**
	a.	4 protons and 5 neutrons	4	9
	b.	9 protons and 10 neutrons	9	19
	c.	20 protons and 23 neutrons	20	43
	d.	47 protons and 60 neutrons	47	107

2.11 The number of protons and electrons are equal in a neutral atom.

a. 5 electrons b. 10 electrons c. 18 electrons d. 50 electrons

☑2.12 The number of protons and electrons are equal in a neutral atom.

a. 4 electrons b. 9 electrons c. 20 electrons d. 47 electrons

ISOTOPES (SECTION 2.3)

2.13

		Electrons	Protons
a.	sulfur	16	16
b.	As	33	33
c.	element number 24	24	24

2.14

		Electrons	Protons
a.	potassium	19	19
b.	Cd	48	48
c.	element number 51	51	51

2.15

		Protons	Neutrons	Electrons
a.	$^{25}_{12}Mg$	12	13	12
b.	$^{13}_{6}C$	6	7	6
c.	$^{41}_{19}K$	19	22	19

☑2.16

		Protons	Neutrons	Electrons
a.	$^{34}_{16}S$	16	18	16
b.	$^{91}_{40}Zr$	40	51	40
c.	$^{131}_{54}Xe$	54	77	54

2.17 a. cadmium-110 $^{110}_{48}Cd$

b. cobalt-60 $^{60}_{27}Co$

c. uranium-235 $^{235}_{92}U$

2.18 a. silicon-28 $^{28}_{14}Si$

b. argon-40 $^{40}_{18}Ar$

c. strontium-88 $^{88}_{38}Sr$

2.19

		Mass Number	Atomic Number	Symbol
a.	5 protons and 6 neutrons	11	5	$^{11}_{5}B$
b.	10 protons and 10 neutrons	20	10	$^{20}_{10}Ne$
c.	18 protons and 23 neutrons	41	18	$^{41}_{18}Ar$
d.	50 protons and 76 neutrons	126	50	$^{126}_{50}Sn$

2.20

		Mass Number	Atomic Number	Symbol
a.	4 protons and 5 neutrons	9	4	$^{9}_{4}Be$
b.	9 protons and 10 neutrons	19	9	$^{19}_{9}F$
c.	20 protons and 23 neutrons	43	20	$^{43}_{20}Ca$
d.	47 protons and 60 neutrons	107	47	$^{107}_{47}Ag$

2.21 a. contains 18 electrons and 20 neutrons $^{38}_{18}Ar$
b. a calcium atom with a mass number of 40 $^{40}_{20}Ca$
c. an arsenic atom that contains 42 neutrons $^{75}_{33}As$

☑2.22 a. contains 17 electrons and 20 neutrons $^{37}_{17}Cl$
b. a copper atom with a mass number of 65 $^{65}_{29}Cu$
c. a zinc atom that contains 36 neutrons $^{66}_{30}Zn$

RELATIVE MASSES OF ATOMS AND MOLECULES (SECTION 2.4)

2.23 Two element pairs whose average atoms have masses that are within 0.3 u of each other are argon (Ar 39.95 u) and calcium (40.08 u) as well as cobalt (Co 58.93u) and nickel (Ni 58.69u).

2.24 $12\text{ u}\left(\frac{1\text{ atom He}}{4\text{ u He}}\right)=3\text{ atoms He}$

2.25 $28\text{ u}\left(\frac{1\text{ atom Li}}{7\text{ u Li}}\right)=4\text{ atoms Li}$

2.26 $77.1\%\times 52.00\text{ u}=0.771\times 52.00\text{u}=40.1\text{ u}$; Ca; calcium

2.27 In the first 36 elements, the elements with atoms whose average mass is within 0.2 u of being twice the atomic number of the element are:

Atom	Atomic Number	Relative Mass	Ratio
helium (He)	2	4.003	2.002
carbon (C)	6	12.01	2.002
nitrogen (N)	7	14.01	2.001
oxygen (O)	8	16.00	2.000
neon (Ne)	10	20.18	2.018
silicon (Si)	14	28.09	2.006
sulfur (S)	16	32.07	2.004
calcium (Ca)	20	40.08	2.004

2.28 $\frac{1}{2}\times 28.09\text{ u}=14.05\text{ u}$; N; nitrogen

2.29 a. fluorine (F_2) $(2\times 19.00\text{ u})=38.00\text{ u}$
b. carbon disulfide (CS_2) $(1\times 12.01\text{ u})+(2\times 32.07\text{ u})=76.15\text{ u}$
c. sulfurous acid (H_2SO_3) $(2\times 1.008\text{ u})+(1\times 32.07\text{ u})+(3\times 16.00\text{ u})=82.09\text{ u}$
d. ethyl alcohol (C_2H_6O) $(2\times 12.01\text{ u})+(6\times 1.008\text{ u})+(1\times 16.00\text{ u})=46.07\text{ u}$
e. ethane (C_2H_6) $(2\times 12.01\text{ u})+(6\times 1.008\text{ u})=30.07\text{ u}$

2.30 a. sulfur trioxide (SO_3) $(1\times 32.07\text{ u})+(3\times 16.00\text{ u})=80.07\text{ u}$
b. glycerin ($C_3H_8O_3$) $(3\times 12.01\text{ u})+(8\times 1.008\text{ u})+(3\times 16.00)=92.09\text{ u}$

c. sulfuric acid (H_2SO_4) $(2\times1.008\text{ u})+(1\times32.07\text{ u})+(4\times16.00\text{ u})=98.09\text{ u}$

d. nitrogen (N_2) $2\times14.01\text{ u}=28.02\text{ u}$

e. propane (C_3H_8) $(3\times12.01\text{ u})+(8\times1.008\text{ u})=44.09\text{ u}$

2.31 The gas is most likely to be N_2O based on the following calculations:

$$\text{NO}:(1\times14.01\text{ u})+(1\times16.00\text{ u})=30.01\text{ u}$$
$$\text{N}_2\text{O}:(2\times14.01\text{ u})+(1\times16.00\text{ u})=44.02\text{ u}$$
$$\text{NO}_2:(1\times14.01\text{ u})+(2\times16.00\text{ u})=46.01\text{ u}$$

The experimental value for the molecular weight of an oxide of nitrogen was 43.98 u, which is closest to the theoretical value of 44.02 u, which was calculated for N_2O.

☑2.32 The gas is most likely to be ethylene based on the following calculations:

$$\text{acetylene}:(2\times12.01\text{ u})+(2\times1.008\text{ u})=26.04\text{ u}$$
$$\text{ethylene}:(2\times12.01\text{ u})+(4\times1.008\text{ u})=28.05\text{ u}$$
$$\text{ethane}:(2\times12.01\text{ u})+(6\times1.008\text{ u})=30.07\text{ u}$$

The experimental value for the molecular weight of a flammable gas known to contain only carbon and hydrogen is 28.05 u, which is identical to the theoretical value of 28.05 u, which was calculated for ethylene.

2.33 The x in the formula for glycine stands for 5, the number of hydrogen atoms in the chemical formula.

$$(2\times12.01\text{ u})+(\text{x}\times1.008\text{ u})+(1\times14.01\text{ u})+(2\times16.00\text{ u})=75.07\text{ u}$$
$$\text{x}\times1.008\text{ u}+70.03\text{ u}=75.07\text{ u}$$
$$\text{x}\times1.008\text{ u}=5.04\text{ u}$$
$$\text{x}=5$$

2.34 The y in the formula for serine stands for 3, the number of carbon atoms in the chemical formula.

$$(\text{y}\times12.01\text{ u})+(7\times1.008\text{ u})+(1\times14.01\text{ u})+(3\times16.00\text{ u})=105.10\text{ u}$$
$$\text{y}\times12.01\text{ u}+69.07\text{ u}=105.10\text{ u}$$
$$\text{y}\times12.01\text{ u}=36.03\text{ u}$$
$$\text{y}=3$$

ISOTOPES AND ATOMIC WEIGHTS (SECTION 2.5)

2.35 a. The number of neutrons in the nucleus $22.9898-11=11.9898\approx12$ neutrons

b. The mass (in u) of the nucleus (to three significant figures) 23.0 u

2.36 a. The number of neutrons in the nucleus $26.982-13=13.982\approx14$ neutrons

b. The mass (in u) of the nucleus (to three significant figures) 27.0 u

2.37 $7.42\%\times6.0151\text{ u}+92.58\%\times7.0160\text{ u}=$

$0.0742\times6.0151\text{ u}+0.9258\times7.0160\text{ u}=6.94173322\text{ u};6.942\text{ u with SF}$

or

$$\frac{(7.42\times 6.0151\text{ u})+(92.58\times 7.0160\text{ u})}{100}=6.94173322\text{ u; }6.942\text{ u with SF}$$

The atomic weight listed for lithium in the periodic table is 6.941 u. The two values are the very close.

☑2.38 $19.78\%\times 10.0129\text{ u}+80.22\%\times 11.0093\text{ u}=$

$$0.1978\times 10.0129\text{ u}+0.8022\times 11.0093\text{ u}=10.81221208\text{ u; }10.812\text{ u with SF}$$

or

$$\frac{(19.78\times 10.0129\text{ u})+(80.22\times 11.0093\text{ u})}{100}=10.81221208\text{ u; }10.812\text{ u with SF}$$

The atomic weight listed for boron in the periodic table is 10.81 u. The two values are close to one another.

2.39 $92.21\%\times 27.9769\text{ u}+4.70\%\times 28.9765\text{ u}+3.09\%\times 29.9738\text{ u}=$

$$0.9221\times 27.9769\text{ u}+0.0470\times 28.9765\text{ u}+0.0309\times 29.9738\text{ u}=28.08558541\text{ u; }28.09\text{ u with SF}$$

or

$$\frac{(92.21\times 27.9769\text{ u})+(4.70\times 28.9765\text{ u})+(3.09\times 29.9738\text{ u})}{100}=28.08558541\text{ u; }28.09\text{ u with SF}$$

The atomic weight listed for silicon in the periodic table is 28.09 u. The two values are the same.

2.40 $69.09\%\times 62.9298\text{ u}+30.91\%\times 64.9278\text{ u}=$

$$0.6909\times 62.9298\text{ u}+0.3091\times 64.9278\text{ u}=63.5473818\text{ u; }63.55\text{ u with SF}$$

or

$$\frac{(69.09\times 62.9298\text{ u})+(30.91\times 64.9278\text{ u})}{100}=63.5473818\text{ u; }63.55\text{ u with SF}$$

The atomic weight listed for copper in the periodic table is 63.55 u. The two values are the same.

AVOGADRO'S NUMBER: THE MOLE (SECTION 2.6)

2.41

$$3.10\ \cancel{\text{g P}}\left(\frac{6.02\times 10^{23}\text{ atoms P}}{31.0\ \cancel{\text{g P}}}\right)=6.02\times 10^{22}\text{ atoms P}$$

$$6.02\times 10^{22}\ \cancel{\text{atoms S}}\left(\frac{32.1\text{ g S}}{6.02\times 10^{23}\ \cancel{\text{atoms S}}}\right)=3.21\text{ g S}$$

2.42

$$1.60\ \cancel{\text{g O}}\left(\frac{6.02\times 10^{23}\text{ atoms O}}{16.00\ \cancel{\text{g O}}}\right)=6.02\times 10^{22}\text{ atoms O}$$

$$6.02\times 10^{22}\ \cancel{\text{atoms F}}\left(\frac{19.0\text{ g F}}{6.02\times 10^{23}\ \cancel{\text{atoms F}}}\right)=1.90\text{ g F}$$

2.43 a. beryllium

$$1\text{ mol Be atoms}=6.02\times 10^{23}\text{ Be atoms}$$
$$6.02\times 10^{23}\text{ Be atoms}=9.01\text{ g Be}$$
$$1\text{ mol Be atoms}=9.01\text{ g Be}$$

b. lead

$$1 \text{ mol Pb atoms} = 6.02\times10^{23} \text{ Pb atoms}$$
$$6.02\times10^{23} \text{ Pb atoms} = 207 \text{ g Pb}$$
$$1 \text{ mol Pb atoms} = 207 \text{ g Pb}$$

c. sodium

$$1 \text{ mol Na atoms} = 6.02\times10^{23} \text{ Na atoms}$$
$$6.02\times10^{23} \text{ Na atoms} = 23.0 \text{ g Na}$$
$$1 \text{ mol Na atoms} = 23.0 \text{ g Na}$$

2.44 ☑a. silicon

$$1 \text{ mol Si atoms} = 6.02\times10^{23} \text{ Si atoms}$$
$$6.02\times10^{23} \text{ Si atoms} = 28.1 \text{ g Si}$$
$$1 \text{ mol Si atoms} = 28.1 \text{ g Si}$$

☑b. calcium

$$1 \text{ mol Ca atoms} = 6.02\times10^{23} \text{ Ca atoms}$$
$$6.02\times10^{23} \text{ Ca atoms} = 40.1 \text{ g Ca}$$
$$1 \text{ mol Ca atoms} = 40.1 \text{ g Ca}$$

c. argon

$$1 \text{ mol Ar atoms} = 6.02\times10^{23} \text{ Ar atoms}$$
$$6.02\times10^{23} \text{ Ar atoms} = 39.9 \text{ g Ar}$$
$$1 \text{ mol Ar atoms} = 39.9 \text{ g Ar}$$

2.45 a. The number of moles of beryllium atoms in a 25.0-g sample of beryllium

$$1 \text{ mol Be atoms} = 9.01 \text{ g Be}; \ \frac{1 \text{ mol Be atoms}}{9.01 \text{ g Be}}$$
$$25.0 \ \cancel{\text{g Be}} \left(\frac{1 \text{ mol Be atoms}}{9.01 \ \cancel{\text{g Be}}}\right) = 2.77 \text{ mol Be atoms}$$

b. The number of lead atoms in a 1.68-mol sample of lead

$$1 \text{ mol Pb atoms} = 6.02\times10^{23} \text{ Pb atoms}; \ \frac{6.02\times10^{23} \text{ Pb atoms}}{1 \text{ mol Pb atoms}}$$
$$1.68 \ \cancel{\text{mol Pb}} \left(\frac{6.02\times10^{23} \text{ Pb atoms}}{1 \ \cancel{\text{mol Pb atoms}}}\right) = 1.01\times10^{24} \text{ Pb atoms}$$

c. The number of sodium atoms in a 120-g sample of sodium

$$6.02\times10^{23} \text{ Na atoms} = 23.0 \text{ g Na}; \ \frac{6.02\times10^{23} \text{ Na atoms}}{23.0 \text{ g Na}}$$
$$120 \ \cancel{\text{g Na}} \left(\frac{6.02\times10^{23} \text{ Na atoms}}{23.0 \ \cancel{\text{g Na}}}\right) = 3.14\times10^{24} \text{ Na atoms}$$

2.46 ☑a. The number of grams of silicon in 1.25 mol of silicon

$$1 \text{ mol Si atoms} = 28.1 \text{ g Si}; \ \frac{28.1 \text{ g Si}}{1 \text{ mol Si atoms}}$$
$$1.25 \ \cancel{\text{mol Si}} \left(\frac{28.1 \text{ g Si}}{1 \ \cancel{\text{mol Si}}}\right) = 35.1 \text{ g Si}$$

☑b. The mass in grams of one calcium atom

$$6.02\times10^{23} \text{ Ca atoms} = 40.1 \text{ g Ca}; \ \frac{40.1 \text{ g Ca}}{6.02\times10^{23} \text{ Ca atoms}}$$
$$1 \ \cancel{\text{atom Ca}} \left(\frac{40.1 \text{ g Ca}}{6.02\times10^{23} \ \cancel{\text{Ca atoms}}}\right) = 6.66\times10^{-23} \text{ g Ca}$$

(Note: One atom is assumed to be an exact number.)

c. The number of argon atoms in a 20.5-g sample of argon

6.02×10^{23} Ar atoms = 39.9 g Ar; $\dfrac{6.02\times10^{23}\ \text{Ar atoms}}{39.9\ \text{g Ar}}$

$$20.5\ \text{g Ar}\left(\frac{6.02\times10^{23}\ \text{Ar atoms}}{39.9\ \text{g Ar}}\right)=3.09\times10^{23}\ \text{Ar atoms}$$

THE MOLE AND CHEMICAL FORMULAS (SECTION 2.7)

2.47 $(1\times31.0\ \text{u})+(3\times1.01\ \text{u})=34.0\ \text{u};\ 1\ \text{mole } PH_3=34.0\ \text{g } PH_3$

$(1\times32.1\ \text{u})+(2\times16.0\ \text{u})=64.1\ \text{u};\ 1\ \text{mole } SO_2=64.1\ \text{g } SO_2$

$$6.41\ \text{g } SO_2\left(\frac{6.02\times10^{23}\ \text{molecules } SO_2}{64.1\ \text{g } SO_2}\right)=6.02\times10^{22}\ \text{molecules } SO_2$$

$$6.02\times10^{22}\ \text{molecules } PH_3\left(\frac{34.0\ \text{g } PH_3}{6.02\times10^{23}\ \text{molecules } PH_3}\right)=3.40\ \text{g } PH_3$$

2.48 $(1\times10.8\ \text{u})+(3\times19.0\ \text{u})=67.8\ \text{u};\ 1\ \text{mole } BF_3=67.8\ \text{g } BF_3$

$(2\times1.01\ \text{u})+(1\times32.1\ \text{u})=34.1\ \text{u};\ 1\ \text{mole } H_2S=34.1\ \text{g } H_2S$

$$0.34\ \text{g } H_2S\left(\frac{6.02\times10^{23}\ \text{molecules } H_2S}{34.1\ \text{g } H_2S}\right)=6.0\times10^{21}\ \text{molecules } H_2S$$

$$6.0\times10^{21}\ \text{molecules } BF_3\left(\frac{67.8\ \text{g } BF_3}{6.02\times10^{23}\ \text{molecules } BF_3}\right)=0.68\ \text{g } BF_3$$

2.49 a. methane (CH_4)

1. 2 CH_4 molecules contain 2 C atoms and 8 H atoms.
2. 10 CH_4 molecules contain 10 C atoms and 40 H atoms.
3. 100 CH_4 molecules contain 100 C atoms and 400 H atoms.
4. 6.02×10^{23} CH_4 molecules contain 6.02×10^{23} C atoms and 24.08×10^{23} H atoms.
5. 1 mol of CH_4 molecules contains 1 mole of C atoms and 4 moles of H atoms.
6. 16.0 g of methane contains 12.0 g of C and 4.04 g of H.

b. ammonia (NH_3)

1. 2 NH_3 molecules contain 2 N atoms and 6 H atoms.
2. 10 NH_3 molecules contain 10 N atoms and 30 H atoms.
3. 100 NH_3 molecules contain 100 N atoms and 300 H atoms.
4. 6.02×10^{23} NH_3 molecules contain 6.02×10^{23} N atoms and 18.06×10^{23} H atoms.
5. 1 mol of NH_3 molecules contains 1 mole of N atoms and 3 moles of H atoms.
6. 17.0 g of ammonia contains 14.0 g of N and 3.03 g of H.

c. chloroform ($CHCl_3$)

1. 2 $CHCl_3$ molecules contain 2 C atoms, 2 H atoms, and 6 Cl atoms.
2. 10 $CHCl_3$ molecules contain 10 C atoms, 10 H atoms, and 30 Cl atoms.
3. 100 $CHCl_3$ molecules contain 100 C atoms, 100 H atoms, and 300 Cl atoms.
4. 6.02×10^{23} $CHCl_3$ molecules contain 6.02×10^{23} C atoms, 6.02×10^{23} H atoms, and 18.06×10^{23} Cl atoms.
5. 1 mol of $CHCl_3$ molecules contains 1 mole of C atoms, 1 mole of H atoms, and 3 moles Cl atoms.
6. 119 g of chloroform contains 12.0 g of C, 1.01 g of H, and 106 g of Cl.

2.50 a. benzene (C_6H_6)

1. 2 C_6H_6 molecules contain 12 C atoms and 12 H atoms.
2. 10 C_6H_6 molecules contain 60 C atoms and 60 H atoms.
3. 100 C_6H_6 molecules contain 600 C atoms and 600 H atoms.
4. 6.02×10^{23} C_6H_6 molecules contains 36.12×10^{23} C atoms and 36.12×10^{23} H atoms.
5. 1 mol of C_6H_6 molecules contain 6 moles of C atoms and 6 moles of H atoms.
6. 78.1 g of benzene contains 72.0 g of C and 6.1 g of H.

☑b. nitrogen dioxide (NO_2)

1. 2 NO_2 molecules contain 2 N atoms and 4 O atoms.
2. 10 NO_2 molecules contain 10 N atoms and 20 O atoms.
3. 100 NO_2 molecules contain 100 N atoms and 200 O atoms.
4. 6.02×10^{23} NO_2 molecules contain 6.02×10^{23} N atoms and 12.04×10^{23} O atoms.
5. 1 mol of NO_2 molecules contains 1 mole of N atoms and 2 moles of O atoms.
6. 46.0 g of nitrogen dioxide contains 14.0 g of N and 32.0 g of O.

c. hydrogen chloride (HCl)

1. 2 HCl molecules contain 2 H atoms and 2 Cl atoms.
2. 10 HCl molecules contain 10 H atoms and 10 Cl atoms.
3. 100 HCl molecules contain 100 H atoms and 100 Cl atoms.
4. 6.02×10^{23} HCl molecules contain 6.02×10^{23} H atoms and 6.02×10^{23} Cl atoms.
5. 1 mol of HCl molecules contains 1 mole of H atoms and 1 mole Cl atoms.
6. 36.5 g of hydrogen chloride contains 1.01 g of H and 35.5 g of Cl.

2.51 a. **Statement 5.** 1 mol of CH_4 molecules contains 1 mole of C atoms and 4 moles of H atoms.

Factor: $\left(\dfrac{4 \text{ moles H atoms}}{1 \text{ mole } CH_4}\right)$

$$1\ \cancel{\text{mol } CH_4}\left(\frac{4 \text{ moles H atoms}}{1\ \cancel{\text{mole } CH_4}}\right) = 4 \text{ moles H atoms}$$

b. **Statement 6.** 17.0 g of ammonia contains 14.0 g of N and 3.03 g of H.

$$\text{Factor}: \left(\frac{14.0 \text{ g N}}{1 \text{ mole } NH_3}\right)$$

$$1.00 \text{ mole } NH_3 \left(\frac{14.0 \text{ g N}}{1 \text{ mole } NH_3}\right) = 14.0 \text{ g N}$$

c. **Statement 6.** 119 g of chloroform contains 12.0 g of C, 1.01 g of H, and 106 g of Cl.

$$\text{Factor}: \left(\frac{106 \text{ g Cl}}{119 \text{ g } CHCl_3}\right)$$

$$\left(\frac{106 \text{ g Cl}}{119 \text{ g } CHCl_3}\right) \times 100 = 89.1\% \text{ Cl in } CHCl_3$$

2.52 a. **Statement 5.** 1 mol of C_6H_6 molecules contains 6 moles of C atoms and 6 moles of H atoms.

$$\text{Factor}: \left(\frac{6 \text{ moles H atoms}}{1 \text{ mole } C_6H_6}\right)$$

$$0.75 \text{ mol } C_6H_6 \left(\frac{6 \text{ moles H atoms}}{1 \text{ mole } C_6H_6}\right) = 4.5 \text{ moles H atoms}$$

☑b. **Statement 4.** 6.02×10^{23} NO_2 molecules contain 6.02×10^{23} N atoms and 12.04×10^{23} O atoms.

$$\text{Factor}: \left(\frac{12.04 \times 10^{23} \text{ O atoms}}{1 \text{ mole } NO_2}\right)$$

$$0.50 \text{ mole } NO_2 \left(\frac{12.04 \times 10^{23} \text{ O atoms}}{1 \text{ mole } NO_2}\right) = 6.0 \times 10^{23} \text{ O atoms}$$

c. **Statement 6.** 36.5 g of hydrogen chloride contains 1.01 g of H and 35.5 g of Cl.

$$\text{Factor}: \left(\frac{35.5 \text{ g Cl}}{36.5 \text{ g HCl}}\right)$$

$$\frac{35.5 \text{ g Cl}}{36.5 \text{ g HCl}} \times 100 = 97.3\% \text{ Cl in HCl}$$

2.53

$$3 \text{ mole } NO_2 \left(\frac{1 \text{ mole N atoms}}{1 \text{ mole } NO_2}\right)\left(\frac{1 \text{ mole } N_2O_5}{2 \text{ moles N atoms}}\right) = 1.5 \text{ moles } N_2O_5$$

Note: The 3 mol assumed to be an exact number.

2.54

$$0.75 \text{ mole } H_2O \left(\frac{1 \text{ mole O atoms}}{1 \text{ mole } H_2O}\right)\left(\frac{6.02 \times 10^{23} \text{ O atoms}}{1 \text{ mole O atoms}}\right) = 4.515 \times 10^{23} \text{ O atoms}$$

$$4.515 \times 10^{23} \text{ O atoms} \left(\frac{1 \text{ mole O atoms}}{6.02 \times 10^{23} \text{ O atoms}}\right)\left(\frac{1 \text{ mole } C_2H_6O}{1 \text{ mole O atoms}}\right)\left(\frac{46.1 \text{ g } C_2H_6O}{1 \text{ mole } C_2H_6O}\right)$$

$$= 34.575 \text{ g } C_2H_6O \approx 35 \text{ g with SF}$$

2.55 $\frac{14.0 \text{ g N}}{17.0 \text{ g NH}_3}\times 100 = 82.4\%\text{ N in NH}_3$ $\frac{28.0 \text{ g N}}{32.0 \text{ g N}_2\text{H}_4}\times 100 = 87.5\%\text{ N in N}_2\text{H}_4$

2.56 $\frac{4.04 \text{ g H}}{16.0 \text{ g CH}_4}\times 100 = 25.3\%\text{ H in CH}_4$ $\frac{6.06 \text{ g H}}{30.1 \text{ g C}_2\text{H}_6}\times 100 = 20.1\%\text{ H in C}_2\text{H}_6$

2.57 **Statement 4.** 6.02×10^{23} $C_6H_5NO_3$ molecules contain 36.12×10^{23} C atoms, 30.1×10^{23} H atoms, 6.02×10^{23} N atoms, and 18.06×10^{23} O atoms.

Statement 5. 1 mol $C_6H_5NO_3$ molecules contain 6 moles of C atoms, 5 moles of H atoms, 1 mole of N atoms, and 3 moles of O atoms.

Statement 6. 139 g of nitrophenol contains 72.0 g of C, 5.05 g of H, 14.0 g of N, and 48.0 g of O.

a. **Statement 6.** 139 g of nitrophenol contains 72.0 g of C, 5.05 g of H, 14.0 g of N, and 48.0 g of O.

$$\text{Factor}: \left(\frac{14.0 \text{ g N}}{139 \text{ g C}_6\text{H}_5\text{NO}_3}\right)$$

$$70.0 \ \cancel{\text{g C}_6\text{H}_5\text{NO}_3}\left(\frac{14.0 \text{ g N}}{139 \ \cancel{\text{g C}_6\text{H}_5\text{NO}_3}}\right) = 7.05 \text{ g N}$$

b. **Statement 5.** 1 mol $C_6H_5NO_3$ molecules contain 6 moles of C atoms, 5 moles of H atoms, 1 mole of N atoms, and 3 moles of O atoms.

$$\text{Factor}: \left(\frac{3 \text{ moles of O atoms}}{1 \text{ mole C}_6\text{H}_5\text{NO}_3}\right)$$

$$1.50 \ \cancel{\text{moles C}_6\text{H}_5\text{NO}_3}\left(\frac{3 \text{ moles of O atoms}}{1 \ \cancel{\text{mole C}_6\text{H}_5\text{NO}_3}}\right) = 4.50 \text{ moles of O atoms}$$

c. **Statement 4.** 6.02×10^{23} $C_6H_5NO_3$ molecules contain 36.12×10^{23} C atoms, 30.1×10^{23} H atoms, 6.02×10^{23} N atoms, and 18.06×10^{23} O atoms.

$$\text{Factor}: \left(\frac{36.12\times 10^{23} \text{ C atoms}}{6.02\times 10^{23} \text{ C}_6\text{H}_5\text{NO}_3 \text{ molecules}}\right)$$

$$9.00\times 10^{22} \ \cancel{\text{molecules C}_6\text{H}_5\text{NO}_3}\left(\frac{36.12\times 10^{23} \text{ C atoms}}{6.02\times 10^{23} \ \cancel{\text{C}_6\text{H}_5\text{NO}_3 \text{ molecules}}}\right) = 5.4\times 10^{23} \text{ C atoms}$$

2.58 **Statement 4.** 6.02×10^{23} H_3PO_4 molecules contain 18.06×10^{23} H atoms, 6.02×10^{23} P atoms, and 24.08×10^{23} O atoms.

Statement 5. 1 mol H_3PO_4 molecules contains 3 moles of H atoms, 1 mole of P atoms, and 4 moles of O atoms.

Statement 6. 98.0 g of phosphoric acid contains 3.03 g of H, 31.0 g of P, and 64.0 g of O.

a. **Statement 6.** 98.0 g of phosphoric acid contains 3.03 g of H, 31.0 g of P, and 64.0 g of O.

Factor: $\left(\dfrac{3.03\text{ g H}}{98.0\text{ g H}_3\text{PO}_4}\right)$

$$46.8\ \cancel{\text{g H}_3\text{PO}_4}\left(\frac{3.03\text{ g H}}{98.0\ \cancel{\text{g H}_3\text{PO}_4}}\right)=1.45\text{ g H}$$

b. **Statement** 5. 1 mol H_3PO_4 molecules contains 3 moles of H atoms, 1 mole of P atoms, and 4 moles of O atoms.

Factor: $\left(\dfrac{4\text{ moles of O atoms}}{1\text{ mole H}_3\text{PO}_4}\right)$

$$1.25\ \cancel{\text{moles H}_3\text{PO}_4}\left(\frac{4\text{ moles of O atoms}}{1\ \cancel{\text{mole H}_3\text{PO}_4}}\right)=5.00\text{ moles of O atoms}$$

c. **Statement 4.** 6.02×10^{23} H_3PO_4 molecules contain 18.06×10^{23} H atoms, 6.02×10^{23} P atoms, and 24.08×10^{23} O atoms.

Factor: $\left(\dfrac{6.02\times10^{23}\text{ P atoms}}{6.02\times10^{23}\text{ H}_3\text{PO}_4\text{ molecules}}\right)$

$$8.42\times10^{21}\ \cancel{\text{molecules H}_3\text{PO}_4}\left(\frac{6.02\times10^{23}\text{ P atoms}}{6.02\times10^{23}\ \cancel{\text{H}_3\text{PO}_4\text{ molecules}}}\right)=8.42\times10^{21}\text{ P atoms}$$

2.59 Urea (CH_4N_2O) contains the higher mass percentage of nitrogen as shown in the calculation below:

$$\frac{28.0\text{ g N}}{60.0\text{ g CH}_4\text{N}_2\text{O}}\times100=46.7\%\text{ N in CH}_4\text{N}_2\text{O} \qquad \frac{28.0\text{ g N}}{132\text{ g N}_2\text{H}_8\text{SO}_4}\times100=21.2\%\text{ N in N}_2\text{H}_8\text{SO}_4$$

2.60 Magnetite (Fe_3O_4) contains the higher mass percentage of iron as shown in the calculation below:

$$\frac{167\text{ g Fe}}{231\text{ g Fe}_3\text{O}_4}\times100=72.3\%\text{ Fe in Fe}_3\text{O}_4 \qquad \frac{112\text{ g Fe}}{160\text{ g Fe}_2\text{O}_3}\times100=70.0\%\text{ Fe in Fe}_2\text{O}_3$$

2.61 Calcite ($CaCO_3$) contains the higher mass percentage of nitrogen as shown in the calculation below:

$$\frac{40.1\text{ g Ca}}{100\text{ g CaCO}_3}\times100=40.1\%\text{ Ca in CaCO}_3$$

$$\frac{40.1\text{ g Ca}}{184\text{ g CaMgC}_2\text{O}_6}\times100=21.8\%\text{ Ca in CaMgC}_2\text{O}_6$$

ADDITIONAL EXERCISES

2.62 U-238 contains 3 more neutrons in its nucleus than U-235. U-238 and U-235 have the same volume because the extra neutrons in U-238 do not change the size of the electron cloud. U-238 is 3u heavier than U-235 because of the 3 extra neutrons. Density is a ratio of mass to volume; therefore, U-238 is more dense than U-235 because it has a larger mass divided by the same volume.

2.63 $$\frac{1.0\times10^{9}}{6.02\times10^{23}}\times100=1.66\times10^{-13}\%$$

2.64 $$\frac{1.99\times10^{-23}\ \text{g}}{1\ \text{C}-12\ \text{atom}}\left(\frac{1\ \text{C}-12\ \text{atom}}{12\ \text{protons + neutrons}}\right)\left(\frac{14\ \text{protons + neutrons}}{1\ \text{C}-14\ \text{atom}}\right)=\frac{2.32\times10^{-23}\ \text{g}}{1\ \text{C}-14\ \text{atom}}$$

2.65 $D_2O:(2\times2\ \text{u})+(1\times16.00\ \text{u})=20\ \text{u}$

2.66 In Figure 2.2, the electrons are much closer to the nucleus than they would be in a properly scaled drawing. Consequently, the volume of the atom represented in Figure 2.2 is much less than it should be. Density is calculated as a ratio of mass to volume. The mass of this atom has not changed; however, the volume has decreased. Therefore, the atom in Figure 2.2 is much more dense than an atom that is 99.999% empty.

ALLIED HEALTH EXAM CONNECTION

2.67 The symbol K on the periodic table stands for (a) potassium.

2.68 (b) Water is a chemical compound. (a) Blood and (d) air are mixtures, while (c) oxygen is an element.

2.69 (c) Compounds are pure substances that are composed of two or more elements in a fixed proportion. Compounds can be broken down chemically to produce their constituent elements or other compounds.

2.70 $^{34}_{17}Cl$ has (a) 17 protons, 17 neutrons (34-17=17), and 17 electrons (electrons = protons in neutral atom).

2.71 If two atoms are isotopes, they will (c) have the same number of protons, but different numbers of neutrons.

2.72 Copper has (b) 29 protons because the atomic number is the number of protons.

2.73 Atoms are electrically neutral. This means that an atom will contain (c) an equal number of protons and electrons.

2.74 The negative charged particle found within the atom is the (b) electron.

2.75 Two atoms, L and M are isotopes; therefore, they would not have (b) atomic weight in common.

2.76 The major portion of an atom's mass consists of (a) neutrons and protons.

2.77 The mass of an atom is almost entirely contributed by its (a) nucleus.

2.78 (d) $^{33}_{16}S^{2-}$ has 16 protons, 17 neutrons, and 18 electrons.

2.79 An atom with an atomic number of 58 and an atomic mass of 118 has (c) 60 neutrons.

2.80 The mass number of an atom with 60 protons, 60 electrons, and 75 neutrons is (b) 135.

2.81 Avogadro's number is (c) 6.022×10^{23}.

2.82 (c) 1.0 mol NO_2 has the greatest number of atoms (1.8×10^{24} atoms). 1.0 mol N has 6.0×10^{23} atoms, 1.0 g N has 4.3×10^{22} atoms, and 0.5 mol NH_3 has 1.2×10^{24} atoms.

2.83 A sample of 11 grams of CO_2 contains (c) 3.0 grams of carbon.

$$11\ \cancel{g\ CO_2}\left(\frac{12.0\ g\ C}{44.0\ \cancel{g\ CO_2}}\right) = 3.0\ g\ C$$

2.84 The molar mass of calcium oxide, CaO, is (a) 56 g (40 g Ca + 16 g O).

2.85 The mass of 0.200 mol of calcium phosphate is (b) 62.0 g.

$$0.200\ \cancel{mol\ Ca_3(PO_4)_2}\left(\frac{310\ g\ Ca_3(PO_4)_2}{1\ \cancel{mol\ Ca_3(PO_4)_2}}\right) = 62.0\ g\ Ca_3(PO_4)_2$$

2.86 (b) 2.0 moles Al are contained in a 54.0 g sample of Al.

$$54.0\ \cancel{g\ Al}\left(\frac{1\ mole\ Al}{27.0\ \cancel{g\ Al}}\right) = 2.00\ mole\ Al$$

CHEMISTRY FOR THOUGHT

2.87
a. Atoms of different elements contain different numbers of protons.
b. Atoms of different isotopes contain different numbers of neutrons, but the same number of protons.

2.88 Aluminum exists as one isotope; therefore, all atoms have the same number of protons and neutrons as well as the same mass. Nickel exists as several isotopes; therefore, the individual atoms do not have the weighted average atomic mass of 58.69 u.

2.89

$$\frac{2.36\times10^3\ g}{12\ oranges} = 197\frac{g}{orange}$$

None of the oranges in the bowl is likely to have the exact mass calculated as an average. Some oranges will weigh more than the average and some will weigh less.

2.90

$$\frac{dry\ bean\ mass}{jelly\ bean\ mass} = \frac{1}{1.60}$$

$$472\ \cancel{g\ jelly\ beans}\left(\frac{1\ g\ dry\ beans}{1.60\ \cancel{g\ jelly\ beans}}\right) = 295\ g\ dry\ beans$$

$$472\ \cancel{g\ jelly\ beans}\left(\frac{1\ jelly\ bean}{1.18\ \cancel{g\ jelly\ bean}}\right) = 400\ jelly\ beans$$

Each jar contains 400 beans.

2.91

$$1.5\ \cancel{mol\ CS_2}\left(\frac{2\ mol\ S\ atoms}{1\ \cancel{mol\ CS_2}}\right) = 3.0\ mol\ S\ atoms$$

$$0.25 \cancel{\text{mol}}\ \text{S}\left(\frac{6.02\times10^{23}\ \text{CS}_2\ \text{molecules}}{2\ \cancel{\text{mol}}\ \text{S}}\right)=7.5\times10^{22}\ \text{CS}_2\ \text{molecules}$$

2.92 If the atomic mass unit were redefined as being equal to 1/24th the mass of a carbon-12 atom, then the atomic weight of a carbon-12 atom would be 24 u. Changing the definition for an atomic mass unit does not change the relative mass ratio of carbon to magnesium. Magnesium atoms are approximately 2.024 times as heavy as carbon-12 atoms; therefore, the atomic weight of magnesium would be approximately 48.6 u.

2.93 The ratio of the atomic weight of magnesium divided by the atomic weight of hydrogen would not change, even if the atomic mass unit was redefined.

2.94 The value of Avogadro's number would not change even if the atomic mass unit were redefined. Avogadro's number is the number of particles in one mole and has a constant value of 6.022×10^{23}.

EXAM QUESTIONS
MULTIPLE CHOICE

1. Why is CaO the symbol for calcium oxide instead of CAO?
   a. They both can be the symbols for calcium oxide.
   b. They are both incorrect as the symbol should be cao.
   c. A capital letter means a new symbol.
   d. They are both incorrect as the symbol should be CaOx.

   Answer: C

2. What is the meaning of the two in ethyl alcohol, C_2H_5OH?
   a. All alcohol molecules contain two carbon atoms.
   b. There are two carbon atoms per molecule of ethyl alcohol.
   c. Carbon is diatomic.
   d. All of these are correct statements.

   Answer: B

3. The symbols for elements with accepted names:
   a. consist of a single capital letter.
   b. consist of a capital letter and a small letter.
   c. consist of either a single capital letter or a capital letter and a small letter.
   d. no answer is correct

   Answer: C

4. A molecular formula:
   a. is represented using the symbols of the elements in the formula.
   b. is represented using a system of circles that contain different symbols.
   c. cannot be represented conveniently using symbols for the elements.
   d. is represented using words rather than symbols.

   Answer: A

5. Which of the following uses the unit of "u"?
   a. atomic weights of atoms
   b. relative masses of atoms
   c. molecular weights of molecules
   d. more than one response is correct

   Answer: D

6. What is meant by carbon-12?
   a. The carbon atom has a relative mass of approximately 12 grams.
   b. The carbon atom has a relative mass of approximately 12 pounds.
   c. The carbon atom has a relative mass of approximately 12 amu.
   d. The melting point of carbon is 12˚C.

   Answer: C

7. Refer to a periodic table and tell how many helium atoms (He) would be needed to get close to the same mass as an average oxygen atom (O).
   a. six
   b. four
   c. twelve
   d. one-fourth

   Answer: B

8. Determine the molecular weight of hydrogen peroxide, H_2O_2 in u.
   a. 17.01
   b. 18.02
   c. 34.02
   d. 33.01

   Answer: C

9. Using whole numbers, determine the molecular weight of calcium hydroxide, $Ca(OH)_2$.
   a. 56
   b. 57
   c. 58
   d. 74

   Answer: D

10. The average relative mass of an ozone molecule is 48.0 u. An ozone molecule contains only oxygen atoms. What does this molecular weight indicate about the formula of the ozone molecule?
    a. It contains a single oxygen atom.
    b. It contains two oxygen atoms.
    c. It contains three oxygen atoms.
    d. The data tell nothing about the formula of an ozone molecule.

    Answer: C

11. Which of the following pairs are about equal in mass?
    a. proton and electron
    b. electron and neutron
    c. proton and neutron
    d. nucleus and surrounding electron

    Answer: C

12. Which of the following particles is the smallest?
    a. proton
    b. electron
    c. neutron
    d. they are all the same size

    Answer: B

13. How many electrons are in a neutral atom of carbon-13, ^{13}C?
    a. 6
    b. 18
    c. 12
    d. no way to tell

    Answer: A

14. Which of the following carries a negative charge?
   a. a proton
   b. a neutron
   c. an electron
   d. both proton and neutron

   Answer: C

15. Which of the following is located in the nucleus of an atom?
   a. protons
   b. neutrons
   c. electrons
   d. protons and neutrons

   Answer: D

16. Atoms are neutral. How can they have no charge?
   a. equal numbers of protons and neutrons
   b. equal numbers of protons and electrons
   c. equal numbers of neutrons and electrons
   d. any charge has been drained out of the atom

   Answer: B

17. Isotopes differ from each other in what way?
   a. They have different numbers of protons in the nucleus.
   b. They have different numbers of neutrons in the nucleus.
   c. They have different numbers of electrons outside the nucleus.
   d. More than one response is correct

   Answer: B

18. In what way is U-238 different from U-235?
   a. three more electrons
   b. three more protons
   c. three more neutrons
   d. there is no difference

   Answer: C

19. How many protons are found in the nucleus of a boron-11 (B) atom?
   a. 11 b. 6 c. 5 d. 4

   Answer: C

20. How many neutrons are found in the nucleus of a boron-11 (B) atom?
   a. 11 b. 6 c. 5 d. 4

   Answer: B

21. What is the mass number of a carbon-13 (C) atom?
   a. 13 b. 12 c. 6 d. 7

   Answer: A

22. Naturally occurring neon (Ne) has the following isotopic composition (the mass of each isotope is given in parenthesis). Calculate the atomic weight of neon in u from these data.

   neon-20, 90.92% (19.99 u); neon-21, 0.257% (20.99 u); neon-22, 8.82% (21.99 u)

   a. 28.97 b. 37.62 c. 2017 d. 20.17

   Answer: D

23. Naturally occurring lithium (Li) consists of only two isotopes, Li-6 (6.02 u) and Li-7 (7.02 u), where the isotopic masses are given in parentheses. Use the periodic table and determine which isotope is present in the larger percentage in the natural element.
    a. Li-6
    b. Li-7
    c. each is present at 50%
    d. cannot be determined from the information available

    Answer: B

24. What mass of arsenic (As) in grams contains the same number of atoms as 39.95 g of argon (Ar)?
    a. 33.0 b. 74.92 c. 4.16 d. 149.84

    Answer: B

25. Which is greater: the number of Cr atoms in a 26.0 g sample of chromium or the number of Al atoms in a 26.98 g sample of aluminum?
    a. The number of Cr atoms is greater than the number of Al atoms.
    b. The number of Al atoms is greater than the number of Al atoms.
    c. The number of Cr atoms and Al atoms are the same.
    d. The number of Cr atoms and Al atoms cannot be determined from the provided data.

    Answer: B

26. The mass of mercury (Hg), a liquid at room temperature, is 200.6 g/mol. A 200.6 gram sample of mercury is heated until it boils. What is the mass of one mole of mercury vapor (gas)?
    a. less than 200.6 or it would not be a gas
    b. the same as Avogadro's number
    c. the same as when it is a liquid
    d. none of the answers is correct

    Answer: C

27. The formula for dinitrogen monoxide is N_2O. If a sample of the oxide was found to contain 0.0800 g of oxygen, how many grams of nitrogen would it contain?
    a. 0.140 b. 0.280 c. 0.560 d. 0.0700

    Answer: A

28. Avogadro's number of iron (Fe) atoms would weigh
    a. 55.85 g b. 27.95 g c. 6.02×10^{23} g d. 6.02×10^{-23} g

    Answer: A

29. How many atoms are contained in a sample of krypton, Kr, that weighs 8.38 g?
    a. Avogadro's number c. one
    b. one-tenth Avogadro's number d. one-tenth

    Answer: B

30. Which of the following has the largest mass?
    a. 5.0 mol H_2O b. 3.5 mol NH_3 c. 8.0 mol C d. 6.0 mol C_2H_2

    Answer: D

31. How many silicon atoms (Si) are contained in a 12.5 g sample of silicon?
a. 2.68×10^{23} b. 5.83×10^{-22} c. 1.35×10^{24} d. 1.71×10^{21}

Answer: A

32. What is the number of hydrogen atoms in a 18.016 gram sample of water?
a. 2.000 b. 6.022×10^{23} c. 18.02 d. 1.204×10^{24}

Answer: D

33. How many moles of oxygen atoms are in one mole of CO_2?
a. 1 b. 2 c. 6.02×10^{23} d. 12.04×10^{23}

Answer: B

34. How many hydrogen atoms are in 1.00 mole of NH_3?
a. 3.00 b. 6.02×10^{23} c. 12.0×10^{23} d. 18.1×10^{23}

Answer: D

35. How many moles of hydrogen molecules (H_2) contain the same number of hydrogen atoms as two moles of hydrogen peroxide (H_2O_2)?
a. 1 c. 3
b. 2 d. 4

Answer: B

36. Calculate the weight percentage of hydrogen in water, rounded to 3 significant figures.
a. 33.3 b. 66.7 c. 2.00 d. 11.2

Answer: D

37. What is the weight percentage of nitrogen in urea, CN_2H_4O, rounded to 3 significant figures?
a. 46.7 b. 30.4 c. 32.6 d. 16.3

Answer: A

38. How many carbon atoms are contained in 5.50 g of ethane, C_2H_6?
a. 2.75×10^{-22} b. 3.29×10^{24} c. 1.10×10^{23} d. 2.20×10^{23}

Answer: D

39. Which element is approximately 65 percent of sulfuric acid (H_2SO_4) by weight?
a. hydrogen b. sulfur c. oxygen d. any of these

Answer: C

40. How many moles of N_2O contain the same number of nitrogen atoms as 4.60 g of NO_2?
a. 0.500 b. 0.0500 c. 0.100 d. 0.200

Answer: B

41. How many grams of iron (Fe) are contained in 15.8 g of $Fe(OH)_3$?
a. 12.1 b. 8.26 c. 11.8 d. 5.21

Answer: B

42. What is the symbol for bromine?
a. B b. Br c. Be d. none of these

Answer: B

43. What is the weight percent of sulfur in K_2SO_4, rounded to 3 significant figures?
   a. 14.2%   b. 18.4%   c. 54.4%   d. 22.4%

   Answer: B

44. What is the number of moles of water in one liter of water if one gram of water takes up one milliliter of space?
   a. 1   b. 18   c. 55.6   d. 1000

   Answer: C

45. How many neutrons are in an atom that has a mass number of 75 and contains 35 protons?
   a. 40   b. 35   c. 75   d. no way to know

   Answer: A

46. Atoms that have the same atomic number but differ by mass number are called?
   a. protons   b. neutrons   c. isotopes   d. positrons

   Answer: C

47. If you have $3.011x10^{23}$ atoms of carbon, what would you expect their combined mass to be?
   a. 12.01 g   b. 6.005 g   c. 3.003 g   d. 1.000 g

   Answer: B

48. What is wrong with the following molecular formula: SOO (sulfur dioxide)
   a. OSO is the correct form
   b. SO should be So
   c. OO should be written as O2
   d. OO should be written as O_2

   Answer: D

49. Determine the number of electrons and protons in element 43, technetium, Tc.
   a. 43 protons, 43 electrons
   b. 43 protons, 56 electrons
   c. 56 protons, 43 electrons
   d. 99 protons, 43 electrons

   Answer: A

50. Upon which of the following is the system of atomic mass units based?
   a. Assigning C-12 as weighing exactly 12 u and comparing other elements to it.
   b. Measuring the true mass of each subatomic particle.
   c. Comparing the differences in protons and electrons.
   d. Viewing how atoms are affected by electromagnetic fields.

   Answer: A

TRUE-FALSE

1. The symbols for all of the elements are derived from the Latin names.

   Answer: F

2. The symbols for all of the elements always begin with a capital letter.

   Answer: T

3. The first letter of the symbol for each of the elements is the first letter of its English name.

   Answer: F

4. The most accurate way to determine atomic mass is with a mass spectrometer.

   Answer: T

5. H_2O_2 contains equal parts by weight of hydrogen and oxygen.

   Answer: F

6. Electrons do not make an important contribution to the mass of an atom.

   Answer: T

7. The charge of the nucleus depends only on the atomic number.

   Answer: T

8. Isotopes of the same element always have the same number of neutrons.

   Answer: F

9. Isotopes of the same element always have the same atomic number.

   Answer: T

10. Isotopes of the same element always have the same atomic mass.

    Answer: F

11. A mole of copper contains the same number of atoms as a mole of zinc.

    Answer: T

12. One mole of average atoms of an element would have the same mass as a mole of one isotope of the same element.

    Answer: F

13. One mole of silver has the same mass as a mole of gold.

    Answer: F

14. One mole of H_2O contains two moles of hydrogen atoms.

    Answer: T

15. One mole of H_2O contains 2.0 grams of hydrogen.

    Answer: T

16. One mole of O_3 weighs 16 grams.

    Answer: F

17. The pure substance, water, contains both hydrogen molecules and oxygen molecules.

    Answer: F

18. A diet is planned for a trip on a space ship and is lacking in milk, but is rich in turnips and broccoli. Such a diet could provide a sufficient amount of calcium for adults.

    Answer: T

19. Calcium supplements can be taken in 1,000 mg increments.

    Answer: F

20. Protons and neutrons have approximately the same mass.

Answer: T