Chem101: General Chemistry
Chapter 2: Atoms and Molecules

. ANSWERS AND SOLUTIONS TO ODD-NUMBERED PROBLEMS:

nbols and Formulas (Section 2.1)

Draw a "formula" for each of the following molecules using circular symbols of your choice to represent atoms.

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.

SOLUTION:

a) 
b) 
c) 
d) 

Write formulas for the following molecules using elemental symbols from Table 2.1 and subscripts. Compare these formulas to those of Exercise 2.1.

a) A diatomic molecule of fluorine gas.
b) A diatomic molecule of hydrogen chloride (one hydrogen atom and one chlorine atom).
c) A triatomic molecule of ozone (a molecular form of the element oxygen).
d) A molecule of methane (one carbon atom and four hydrogen atoms).

SOLUTION:

a) F_2 b) HCl c) O_3 d) CH_4

Determine the number of each type of atom in molecules represented by the following formulas:

a) sulfur trioxide (SO_3) b) nitric acid (HNO_3) c) ammonia (NH_3) d) propane (C_3H_8)

SOLUTION:

a) 1 sulfur, 3 oxygen
b) 1 hydrogen, 1 nitrogen, 3 oxygen
c) 1 nitrogen, 3 hydrogen
d) 3 carbon, 8 hydrogen

2.7 Tell what is wrong with each of the following molecular formulas and write the correct formula.

a) H3PO3 (phosphorous acid)
b) $SICl_4$ (silicon tetrachloride)
c) SOO (sulfur dioxide)
d) 2HO (Hydrogen peroxide-two hydrogen atoms and two oxyge atoms)

SOLUTION:

a) Numerals should be subscripts (H_3PO_3).
b) The symbol for silicon is Si ($SiCl_4$).
c) Combine oxygens using a subscript (SO_2)
d) Use subscripts, not coefficients, for number of atoms (H_2O_2)

Inside the Atom (Section 2.2)

2.9 Determine the charge and mass (in u) of nuclei made up of the following particles:

a) 2 protons and 2 neutrons
b) 4 protons and 5 neutrons
c) 5 protons and 4 neutrons

SOLUTION:

a) charge = 2+; mass = about 4 u
b) charge = 4+; mass = about 9 u
c) charge = 5+; mass = about 9 u

2.11 Determine the number of electrons that would have to be associated with each nucleus described in Exercise 2.9 to produce a neutral atom.

SOLUTION:

a) 2
b) 4
c) 5

Isotopes (Section 2.3)

2.13 Determine the number of electrons and protons contained in an atom of the following elements:

a) sulfur
b) As
c) element number 24

SOLUTION:

a) 16 electrons, 16 protons
b) 33 electrons, 33 protons
c) 24 electrons, 24 protons

2.15 Determine the number of protons, number of neutrons, and number of electrons in atoms of the following isotopes:

a) $^{7}_{3}Li$
b) $^{22}_{10}Ne$
c) $^{44}_{20}Ca$

SOLUTION:

a) 3 protons, 4 neutrons, 3 electrons
b) 10 protons, 12 neutrons, 10 electrons
c) 20 protons, 24 neutrons, 20 electrons

2.17 Write symbols like those given in Exercise 2.15 and 2.16 for the following isotopes:

a) cadmium-110
b) cobalt-60
c) uranium-235

SOLUTION:

a) $^{110}_{48}Cd$
b) $^{60}_{27}Co$
c) $^{235}_{92}U$

Determine the mass number and atomic number for atoms containing the nuclei described in Exercise 2.9. Write symbols for each atom like those given in Exercise 2.15 and 2.16.

SOLUTION:

a) atomic number = 2, mass number = 4; $^{4}_{2}He$
b) atomic number = 4, mass number = 9; $^{9}_{4}Be$
c) atomic number = 5, mass number = 9; $^{9}_{5}B$

Write isotope symbols for atoms with the following characteristics.

a) contains 15 electrons and 16 neutrons
b) A radon atom with a mass number of 211
c) An oxygen atom that contains 10 neutrons

SOLUTION:

a) $^{31}_{15}P$ b) $^{211}_{86}Rn$ c) $^{18}_{8}O$

ive Masses of Atoms and Molecules (Section 2.4)

Write the symbols and names for the two elements whose average atoms have masses that are within 0.3 u of each other. Do not look beyond element number 83.

SOLUTION:

There are two cases:

(1) Ar, argon, u = 39.95 and Ca, calcium, u = 40.08 (2) Co, cobalt, u = 58.93 and Ni, nickel, u = 58.69

What is the symbol and name for the element whose average atoms have a mass very close to three times the mass of an average beryllium atom?

SOLUTION:

Since Be = 9 u, the other element would be 3 x 9 u or about 27 u. Al, aluminum, is close to 27 u.

What is the symbol and name of the element whose average atoms have a mass that is closest to twice the element's atomic number?

SOLUTION:

Several elements have an average mass which is about twice the atomic number.

Atom	Atomic Number	Relative Mass	Ratio
He	2	4.003	2.0015
C	6	12.01	2.0017
N	7	14.01	2.0014
O	8	16.00	2.000
Ne	10	20.18	2.018
Ca	20	40.08	2.004

The O, oxygen, has the ratio closest to 2.

Determine the molecular weights of the following in u:

a) oxygen (O_2) b) carbon monoxide (CO) c) chloric acid ($HClO_3$)
d) glycerine ($C_3H_8O_3$) e) sulfur dioxide (SO_2)

SOLUTION:

a) 2 x 16.00 u = 32.00 u
b) (1 x 12.01 u) + (1 x 16.00 u) = 28.01 u
c) (1 x 1.008 u) + (1 x 35.45 u) + (3 x 16.00) = 84.458 (round to 2 decimal places) = 84.46 u
d) (3 x 12.01 u) + (8 x 1.008 u) + (3 x 16.00) = 92.094 (round to 2 decimal places) = 92.09 u
e) (1 x 32.06 u) + (2 x 16.00 u) = 64.06 u

2.31 The molecular weight is determined for a gas that is known to be an oxide of nitrogen. The value obtained experimentally was 43.98 u. Which of the following is most likely to be the formula of the gas? NO, N_2O, NO_2

SOLUTION:

The molecular weights for the three gases are:

$NO = 14.01 + 16.00 = 30.01$ u

$N_2O = (2 \times 14.01) + 16.00 = 44.02$ u

$NO_2 = 14.01 + (2 \times 16.00) = 46.01$ u

The gas is N_2O.

2.33 Glycine, an amino acid found in proteins, has a molecular weight of 75.07 u and a formula represented as $C_2H_xNO_2$. What number does x stand for in the formula?

SOLUTION:

The 2 carbon, 1 nitrogen, and 2 oxygen have a combined mass of (2 x 12.01 u) + 14.01 u + (2 x 16.00 u) = 70.03
This is 5 u away from the molecular weight of glycine. Since each hydrogen has a mass of 1.0 u, 5 hydrogen atoms be needed. x = 5

Isotopes and Atomic Weights (Section 2.5)

2.35 Naturally occurring beryllium contains only a single isotope. Determine the following for the naturally occurring ato of beryllium:

a) The number of neutrons in the nucleus.
b) The mass (in u) of the nucleus (to three significant figures).

SOLUTION:

a) Five. Since beryllium has only one naturally occurring isotope, the mass number equals the atomic mass rounded whole number. If the mass number is 9, there are 4 protons and 5 neutrons.
b) 9.012 u. Look up the atomic mass value in the periodic table.

2.37 Calculate the atomic weight of lithium on the basis of the following percentage composition and atomic weights of th naturally occurring isotopes. Compare the calculated value to the atomic weight listed for lithium in the periodic tabl lithium-6 = 7.42 % (6.0151 u), lithium-7 = 92.58 % (7.0160 u)

SOLUTION:

Atomic weight = 7.42 % of 6.0151 u + 92.58 % of 7.0160 u =
(0.0742 x 6.0151) + (0.9258 x 7.0160) = 0.446 + 6.495 = 6.941 u

Actual weight from periodic table = 6.941 u

2.39 Calculate the atomic weight of silicon on the basis of the following percentage composition and atomic weights of the naturally occurring isotopes. Compare the calculated value to the atomic weight listed for silicon in the periodic table silicon-28 = 92.21 % (27.9769 u), silicon-29 = 4.70 % (28.9765 u), silicon-30 = 3.09 % (29.9738 u)

SOLUTION:

Atomic weight = 92.21 % of 27.9769 u + 4.70 % of 28.9765 u + 3.09 % of 29.9738 u
= (0.9221 x 27.9769) + (0.0470 x 28.9765) + (0.0309 x 29.9738)
= 28.086 (round to hundredths) = 28.09 u

Actual weight from periodic table = 28.09 u

gadro's Number: The Mole (Section 2.6)

Refer to the periodic table and determine how many grams of phosphorus contains the same number of atoms as 0.12 g of carbon.

SOLUTION:

If the ratio of the grams of phosphorus to the grams of carbon is the same as the ratio of the atomic weights, the mass of P atoms equals the mass of the C times the ratio of the atomic weights.

$$\text{g P} = 0.12 \text{ g C} \times \frac{30.97 \text{ u P}}{12.01 \text{ u C}} = 0.30944 \text{ (round to 2 sig figs)} = 0.31 \text{ g P}$$

Write three relationships (equalities) similar to those in Example 2.7 for each of the following elements:
a) potassium b) magnesium c) tin

SOLUTION:

a) 1 mol K atoms = 6.02×10^{23} K atoms
6.02×10^{23} K atoms = 39.10 g K
1 mol K atoms = 39.10 g K
b) 1 mol Mg atoms = 6.02×10^{23} Mg atoms
6.02×10^{23} Mg atoms = 24.31 g Mg
1 mol Mg atoms = 24.31 g Mg
c) 1 mol Sn atoms = 6.02×10^{23} Sn atoms
6.02×10^{23} Sn atoms = 118.7 g Sn
1 mol Sn atoms = 118.7 g Sn

5 Use a factor derived from the relationships in Exercise 2.43 and the factor-unit method to determine the following:
a) The number of moles of potassium atoms in a 50.0 g sample of potassium.
b) The number of magnesium atoms in a 1.82 mol sample of magnesium.
c) The number of tin atoms in a 200 g sample of tin.

SOLUTION:

a) $50.0 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 1.2788 \text{ (round to 3 sig figs)} = 1.28 \text{ mol K}$

b) $1.82 \text{ mol Mg} \times \frac{24.31 \text{ g Mg}}{1 \text{ mol Mg}} = 44.2442 \text{ (round to 3 sig figs)} = 44.2 \text{ g Mg}$

c) $200 \text{ g Sn} \times \frac{6.02 \times 10^{23} \text{ Sn atoms}}{118.7 \text{ g Sn}} = 1.01 \times 10^{24} \text{ Sn atoms}$

e Mole and Chemical Formulas (Section 2.7)

7 For each formula given below, write statements equivalent to Statements 1-6 (see Section 2.7):
a) methane (CH_4) b) ammonia (NH_3) c) chloroform ($CHCl_3$)

SOLUTION:

a) 2 CH_4 molecules contain 2 C atoms and 8 H atoms
10 CH_4 molecules contain 10 C atoms and 40 H atoms
100 CH_4 molecules contain 100 C atoms and 400 H atoms
6.02×10^{23} CH_4 molecules contain 6.02×10^{23} C atoms and 24.08×10^{23} H atoms
1 mol CH_4 molecules contains 1 mol C atoms and 4 mol H atoms
16.0 g CH_4 molecules contain 12.01 g C and 4.03 g H

b) 2 NH_3 molecules contain 2 N atoms and 6 H atoms
10 NH_3 molecules contain 10 N atoms and 30 H atoms
100 NH_3 molecules contain 100 N atoms and 300 H atoms
6.02×10^{23} NH_3 molecules contain 6.02×10^{23} N atoms and 18.06×10^{23} H atoms
1 mol NH_3 molecules contains 1 mol N atoms and 3 mol H atoms
17.03 g NH_3 molecules contain 14.01 g N and 3.02 g H

c) 2 $CHCl_3$ molecules contain 2 C atoms, 2 H atoms, and 6 Cl atoms
10 $CHCl_3$ molecules contain 10 C atoms, 10 H atoms, and 30 Cl atoms
100 $CHCl_3$ molecules contain 100 C atoms, 100 H atoms, and 300 Cl atoms
6.02×10^{23} $CHCl_3$ molecules contain 6.02×10^{23} C atoms, 6.02×10^{23} H atoms, and 6.02×10^{23} Cl atoms
1 mol $CHCl_3$ molecules contains 1 mol C atoms, 1 mol H atoms, and 3 mol Cl atoms
119.37 g $CHCl_3$ molecules contain 12.01 g C, 1.01 g H, and 106.35 g Cl

2.49 Answer the following questions based on information contained in the statements you wrote for Exercise 2.47.
a) How many moles of hydrogen atoms are contained in 1 mol of CH_4 molecules?
b) How many grams of nitrogen are contained in 1.00 mol of NH_3?
c) What is the mass percentage of chlorine in $CHCl_3$?

SOLUTION:

a) 4 mol H atoms

b) 14.01 g N

c) $$\frac{106.35 \text{ g Cl}}{119.37 \text{ g } CHCl_3} \times 100 = 89.09 \text{ \% Cl}$$

2.51 How many moles of $C_4H_{10}O$ contain the same number of carbon atoms as 1 mol of $C_2H_3O_2F$?

SOLUTION:

1 mol of C_2H_3OF contains 2 mol C atoms

$$2 \text{ ~~mol C atoms~~} \times \frac{1 \text{ mol } C_4H_{10}O}{4 \text{ ~~mol C atoms~~}} = 0.50 \text{ mol } C_4H_{10}O$$

2.53 Determine the mass percentage of nitrogen in N_2O and NO_2.

SOLUTION:

N_2O: 44.0 g N_2O contains 28.0 g N and 16.0 g O.

$$\% \text{ N} = \frac{28.0 \text{ g N}}{44.0 \text{ g } N_2O} \times 100 = 63.6 \text{ \% N}$$

NO_2: 46.0 g NO_2 contains 14.0 g N and 32.0 g O.

$$\% \text{ N} = \frac{14.0 \text{ g N}}{46.0 \text{ g } NO_2} \times 100 = 30.43 \text{ \% N}$$

2.55 Any of the statements based on a mole of substance (Statements 4-6) can be used to obtain factors for problem solving the factor-unit method. Write statements equivalent to 4, 5, and 6 for nitrophenol ($C_6H_5NO_3$). Use a single factor obtained from the statements to solve each of the following. A different factor will be needed in each case.

a. How many grams of nitrogen is contained in 70.0 g of $C_6H_5NO_3$?
b. How many moles of oxygen atoms are contained in 1.50 mol of $C_6H_5NO_3$?
c. How many atoms of carbon are contained in 9.00×10^{22} molecules of $C_6H_5NO_3$?

SOLUTION:
6.02×10^{23} $C_6H_5NO_3$ molecules contain 36.12×10^{23} C atoms, 30.10×10^{23} H atoms, 6.02×10^{23} N atoms, and 18.06×10^{23} O atoms.
1 mol $C_6H_5NO_3$ molecule contains 6 mol C atoms, 5 mol H atoms, 1 mol N atoms, and 3 mol O atoms.
163.0 g $C_6H_5NO_3$ contain 96.0 g C, 5.0 g H, 14.0 g N, and 48.0 g O.

a) $70.0 \text{ g } C_6H_5NO_3 \times \dfrac{14.0 \text{ g N}}{163.0 \text{ g } C_6H_5NO_3} = 6.01 \text{ g N}$

b) $1.50 \text{ mol } C_6H_5NO_3 \times \dfrac{3 \text{ mol O}}{1 \text{ mol } C_6H_5NO_3} = 4.50 \text{ mol O}$

c) $9.00 \times 10^{22} \text{ } C_6H_5NO_3 \text{ molecules} \times \dfrac{36.12 \times 10^{23} \text{ C atoms}}{6.02 \times 10^{23} \text{ } C_6H_5NO_3 \text{ molecules}} = 5.40 \times 10^{23} \text{ C atoms}$

.57 Urea (CH_4N_2O) and ammonium sulfate ($N_2H_8SO_4$) are both used as agricultural fertilizers. Which one contains the higher mass percentage of nitrogen?

SOLUTION:
Urea: 60.0 g CH_4N_2O contains 28.0 g N.

$$\% \text{ N} = \frac{28.0 \text{ g N}}{60.0 \text{ g } CH_4N_2O} \times 100 = 46.7 \% \text{ N}$$

Ammonium Sulfate: 132.1 g $N_2H_8SO_4$ contains 28.0 g N

$$\% \text{ N} = \frac{28.0 \text{ g N}}{132.1 \text{ g } N_2H_8SO_4} \times 100 = 21.2 \% \text{ N}$$

The urea has a higher % N by mass.

2.59 Both calcite ($CaCO_3$) and dolomite ($CaMgC_2O_6$) are used as dietary calcium supplements. Calculate the mass percent of calcium in each mineral.

SOLUTION:
Calcite: 100.1 g $CaCO_3$ contain 40.1 g Ca

$$\% \text{ Ca} = \frac{40.1 \text{ g Ca}}{100.1 \text{ g } CaCO_3} \times 100 = 40.1 \% \text{ Ca}$$

Dolomite: 184.4 g $CaMgC_2O_6$ contain 40.1 g Ca

$$\% \text{ Ca} = \frac{40.1 \text{ g Ca}}{184.4 \text{ g } CaMgC_2O_6} \times 100 = 21.7 \% \text{ Ca}$$