

Solved Problems

MOLECULES AND FORMULA UNITS

- 7.1. Why is the term *molecular mass* inappropriate for NaCl?
- 7.2. Which of the following compounds occur in molecules? (a) C_6H_6 , (b) CH_4O , (c) $C_6H_{12}O_6$, (d) $CoCl_2$, (e) $COCl_2$, (f) NH_4Cl , (g) CO , and (h) $FeCl_2$.
- 7.3. The simplest type of base contains OH^- ions. Which of the following compounds is more apt to be a base, CH_3OH or KOH ?

FORMULA MASSES

- 7.4. The standard for atomic masses is ^{12}C , at exactly 12 amu. What is the standard for formula masses of compounds?
- 7.5. What is the difference between the atomic mass of bromine and the molecular mass of bromine?
- 7.6. What is the formula mass of each of the following? (a) P_4 , (b) Na_2SO_4 , (c) $(NH_4)_2SO_3$, (d) H_2O_2 , (e) Br_2 , (f) H_3PO_3 , (g) $Hg_2(ClO_3)_2$, and (h) $(NH_4)_2HPO_3$.
- Ans.*
- 7.7. What is the mass, in amu, of 1 formula unit of $Al_2(SO_3)_3$?

- 7.8. Calculate the formula mass of each of the following compounds: (a) $NaCl$, (b) NH_4NO_3 , (c) SiF_4 , (d) $Fe(CN)_2$, and (e) KCN .

THE MOLE

- 7.9. How many H atoms are there in 1 molecule of H_2O_2 ? How many moles of H atoms are there in 1 mol of H_2O_2 ?
- 7.10. How many atoms of K are there in 1.00 mol K? What is the mass of 1.00 mol K?
- 7.11. What mass in grams is there in 1.000 mol of $\text{Al}_2(\text{SO}_3)_3$?
- 7.12. (a) Which contains more pieces of fruit, a dozen grapes or a dozen watermelons? Which weighs more?
(b) Which contains more atoms, 1 mol of lithium or 1 mol of lead? Which has a greater mass?

Problems 7.13 through 7.16 are easier to do when both parts are worked together. Note the differences among the parts labeled (a) and also among the parts labeled (b). On examinations, you are likely to be asked only one such problem at a time, so you must read the problems carefully and recognize the difference between similar-sounding problems.

- 7.13. (a) How many socks are there in 10 dozen socks? (b) How many hydrogen atoms are there in 10.0 mol of hydrogen atoms?
- 7.14. (a) How many pairs of socks are there in 10 dozen pairs of socks? (b) How many hydrogen molecules are there in 10.0 mol of hydrogen molecules?
- 7.15. (a) How many pairs of socks can be made with 10 dozen (identical) socks? (b) How many hydrogen molecules can be made with 10.0 mol of hydrogen atoms?

- 7.16. (a) How many socks are there in 10 dozen pairs of socks? (b) How many hydrogen atoms are there in 10.0 mol of hydrogen molecules?
- 7.17. What is the difference between 1 mol of nitrogen atoms and 1 mol of nitrogen molecules?
- 7.18. Show that the ratio of the number of moles of two elements in a compound is equal to the ratio of the number of atoms of the two elements.
- 7.19. How many moles of each substance are there in each of the following masses of substances? (a) 111 g F_2 , (b) 6.50 g Na, (c) 44.1 g NaOH, (d) 0.0330 g NaCl, (e) 1.96 g $(NH_4)_2SO_3$, (f) 7.22 g NaH_2PO_4
- 7.20. In 2.50 mol $Ba(NO_3)_2$, (a) how many moles of barium ions are present? (b) How many moles of nitrate ions are present? (c) How many moles of oxygen atoms are present?
- 7.21. Without doing actual calculations, determine which of the following have masses greater than 1 mg: (a) 1 CO_2 molecule, (b) 1 amu, (c) 6.02×10^{23} H atoms, (d) 1 mol CO_2 , (e) 6.02×10^{23} amu, (f) $\frac{1}{6.02 \times 10^{23}}$ mol H atoms
- 7.22. What is the mass of each of the following? (a) 6.78 mol NaI, (b) 0.447 mol $NaNO_3$, (c) 0.500 mol BaO_2 , (d) 5.44 mol C_8H_{18}

- 7.23. In 0.125 mol NaClO_4 , (a) how many moles of sodium ions are present? (b) how many moles of perchlorate ions are present?
- 7.24. (a) Calculate the formula mass of H_3PO_4 . (b) Calculate the number of grams in 1.00 mol of H_3PO_4 . (c) Calculate the number of grams in 2.00 mol of H_3PO_4 . (d) Calculate the number of grams in 0.222 mol of H_3PO_4 .
- 7.25. (a) Determine the number of moles of ammonia in 27.5 g of ammonia, NH_3 . (b) Determine the number of moles of nitrogen atoms in 27.5 g of ammonia. (c) Determine the number of moles of hydrogen atoms in 27.5 g of ammonia.
- 7.26. How many hydrogen atoms are there in 1.00 mol of methane, CH_4 ?
- 7.27. Determine the number of mercury atoms in 7.11 g of Hg_2Cl_2 .
- 7.28. (a) If 1 dozen pairs of socks weighs 11 oz, how much would the same socks weigh if they were unpaired? (b) What is the mass of 1 mol O_2 ? What is the mass of the same number of oxygen atoms unbonded to one another?
- 7.29. How many molecules are there in 1.00 mol F_2 ? How many atoms are there? What is the mass of 1.00 mol F_2 ?

Ans. There are 6.02×10^{23} molecules in 1.00 mol F_2 (Avogadro's number). Since there are two atoms per molecule, there are

The mass is that of 1.00 mol F_2 or 2.00 mol F:

or

The *mass* is the same, no matter whether we focus on the atoms or molecules. (Compare the mass of 1 dozen pairs of socks rolled together to that of the same socks unpaired. Would the two masses differ? If so, which would be greater? See the prior problem.)

7.30. (a) Create one factor that will change 6.17 g of calcium carbonate to a number of formula units of calcium carbonate. (b) Is it advisable to learn and use such a factor?

7.31. How many moles of Na are there in 7.20 mol Na_2SO_4 ?

7.32. How many moles of water can be made with 1.76 mol H atoms (plus enough O atoms)?

7.33. Make a table showing the number of molecules and the mass of each of the following: (a) 1.00 mol Cl_2 , (b) 2.00 mol Cl_2 , and (c) 0.135 mol Cl_2

Ans.

	Number of Molecules	Mass

7.34. How can you measure the thickness of a sheet of notebook paper with a 10-cm ruler?

7.35. How can you measure the mass of a carbon atom? Compare this problem with the prior problem.

(prior problem), that atoms are too small to count. We can "count" them by combining them with a known number of atoms of another element. For example, to count a number of carbon atoms, combine them with a known number of oxygen atoms to form CO, in which the ratio of atoms of carbon to oxygen is 1 : 1.

- 7.36. What mass of oxygen is combined with 4.13×10^{24} atoms of sulfur in Na_2SO_4 ?
- 7.37. A 106 g sample of an "unknown" element Q reacts with 32.0 g of O_2 . Assuming the atoms of Q react in a 1 : 1 ratio with oxygen *molecules*, calculate the atomic mass of Q.
- 7.38. To form a certain compound, 29.57 g of oxygen reacts with 109.7 g of tin. What is the formula of the compound?
- 7.39. If 29.57 g O_2 were used in Problem 7.38, how would the problem change?
- 7.40. How many P atoms are there in 1.13 mol P_4 ?
- 7.41. How many hydrogen atoms are there in 1.36 mol NH_3 ?

PERCENT COMPOSITION OF COMPOUNDS

- 7.42. A 10.0-g sample of water has a percent composition of 88.8% oxygen and 11.2% hydrogen. (a) What is the percent composition of a 6.67-g sample of water? (b) Calculate the number of grams of oxygen in a 6.67-g sample of water.
- 7.43. Calculate the percent composition of each of the following: (a) C_3H_6 and (b) C_5H_{10} .

The percentages are the same as those in part (a). That result might have been expected. Since the ratio of atoms of carbon to atoms of hydrogen is the same (1 : 2) in both compounds, the ratio of masses also ought to be the same, and their percent by mass ought to be the same. From another viewpoint, this result means that the two compounds cannot be distinguished from each other by their percent compositions alone.

- 7.44. Calculate the percent composition of DDT ($C_{14}H_9Cl_5$).

Ans.

The percent
and multiplying the quotient by 100%:

the mass of the molecule

The percentages add up to . (The answer is correct within the accuracy of the number of significant figures used.)

- 7.45. A forensic scientist analyzes a drug and finds that it contains 80.22% carbon and 9.62% hydrogen. Could the drug be pure tetrahydrocannabinol ($C_{21}H_{30}O_2$)?

Since the percentages are the same, the drug *could* be tetrahydrocannabinol. (It is not proved to be, however. If the percent composition were different, it would be proved *not* to be pure tetrahydrocannabinol.)

- 7.46. A certain mixture of salt (NaCl) and sugar ($C_{12}H_{22}O_{11}$) contains 40.0% chlorine by mass. Calculate the percentage of salt in the mixture.

The percentage of NaCl (in the 100.0 g sample)
distinguish percentage of what in what!

. When using percentages, be careful to

EMPIRICAL FORMULAS

- 7.47. If each of the following mole ratios is obtained in an empirical formula problem, what should it be multiplied by to get an integer ratio? (a) 1.50 : 1, (b) 1.25 : 1, (c) 1.33 : 1, (d) 1.67 : 1, and (e) 1.75 : 1.

- 7.48. Which do we use to calculate the empirical formula of an oxide, the atomic mass of oxygen (16 amu) or the molecular mass of oxygen (32 amu)?
- 7.49. (a) Write a formula for a molecule with 4 phosphorus atoms and 6 oxygen atoms per molecule. (b) What is the empirical formula of this compound?
- 7.50. Which of the formulas in Problem 5.2 obviously are not empirical formulas?
- 7.51. Calculate the empirical formula of a compound consisting of 92.26% C and 7.74% H.

Ans. Assume that _____ of the compound is analyzed. Since the same percentages are present no matter what the sample size, we can consider any size sample we wish, and considering _____ makes the calculations easier. The numbers of grams of the elements are then

The empirical formula (or any formula) must be in the ratio of small integers. Thus, we attempt to get the ratio of moles of carbon to moles of hydrogen into an integer ratio; we divide all the numbers of moles by the smallest number of moles:

- 7.52. Calculate the empirical formula of a compound containing 69.94% Fe and the rest oxygen.

Dividing both of these numbers by the smaller yields

This is still not a whole number ratio, since _____ is much too far from an integer to round. Since _____ is about _____ multiply *both* numbers of moles by _____

We can round when a value is within _____ or _____ of an integer, but not more. This is close enough to an integer ratio, so the empirical formula is _____

- 7.53. Determine the empirical formula of a compound which has a percent composition 23.3% Mg, 30.7% S, and 46.0%, O.

To get integer mole ratios, divide by the smallest,

The mole ratio is: mol to mol to mol, the empirical formula is

- 7.54. Calculate the empirical formula for each of the following compounds: (a) 42.1% Na, 18.9% P, and 39.0% O. (b) 55.0% K and 45.0% O.

MOLECULAR FORMULAS

- 7.55. List five possible molecular formulas for a compound with empirical formula CH_2 .
- 7.56. Explain why we cannot calculate a molecular formula for a compound of phosphorus, potassium, and oxygen.
- 7.57. Which one of the following could possibly be defined as "the ratio of moles of each of the given elements to moles of each of the others"? (a) percent composition by mass, (b) empirical formula, or (c) molecular formula.
- 7.58. A compound consists of 92.26% C and 7.74% H. Its molecular mass is 65.0 amu. (a) Calculate its empirical formula. (b) Calculate its empirical formula mass. (c) Calculate the number of empirical formula units in one molecule. (d) Calculate its molecular formula.
- 7.59. The percent composition of a certain compound is 85.7% C and 14.3% H. Its molecular mass is 70.0 amu. (a) Determine its empirical formula. (b) Determine its molecular formula.

Supplementary Problems

- 7.60. Define or identify each of the following: molecule, ion, formula unit, formula mass, mole, molecular mass, Avogadro's number, percent, empirical formula, molecular formula, molar mass, empirical formula mass, molecular weight.
- 7.61. How is molecular mass related to formula mass?
- 7.62. Does the term *atomic mass* refer to uncombined atoms, atoms bonded in compounds, or both?
- 7.63. A certain fertilizer is advertised to contain 10.5% K_2O . What percentage of the fertilizer is potassium?
- 7.64. A compound consists of 92.26% C and 7.74% H. Its molecular mass is 65.0 amu. Calculate its molecular formula.
- 7.65. (a) Calculate the percent composition of C_3H_6 . (b) Calculate the percent composition of C_4H_8 . (c) Compare the results and explain the reason for these results.
- 7.66. Name and calculate the empirical formula of each of the following compounds.
- | | | | | |
|---------------|----------|----------|---------------|----------|
| (a) 36.77% Fe | 21.10% S | 42.13% O | (d) 71.05% Co | 28.95% O |
| (b) 27.93% Fe | 24.05% S | 48.01% O | (e) 72.7% O | 27.3% C |
| (c) 63.20% Mn | 36.8% O | | (f) 36.0% Al | 64.0% S |

Ans.

- 7.67. What mass of oxygen is contained in 42.8 g $CaCO_3$?

You can also do this problem by using percent composition (Sec. 7.5).

- 7.68. Determine the molecular formula of a compound with molar mass between 105 and 115 g/mol which contains 88.8% C and 11.2% H.

Solved Problems

MOLECULES AND FORMULA UNITS

7.1. Why is the term *molecular mass* inappropriate for NaCl?

Ans. NaCl is an ionic compound; it does not form molecules and so does not have a *molecular mass*. The *formula mass* of a NaCl is 58.5 amu, calculated and used in exactly the same manner as the molecular mass for a molecular compound would be calculated and used.

7.2. Which of the following compounds occur in molecules? (a) C₆H₆, (b) CH₄O, (c) C₆H₁₂O₆, (d) CoCl₂, (e) COCl₂, (f) NH₄Cl, (g) CO, and (h) FeCl₂.

Ans. All but (d), (f), and (h) form molecules; (d), (f), and (h) are ionic.

7.3. The simplest type of base contains OH⁻ ions. Which of the following compounds is more apt to be a base, CH₃OH or KOH?

Ans. KOH is ionic and is a base. CH₃OH is covalently bonded and is not a base.

FORMULA MASSES

7.4. The standard for atomic masses is ¹²C, at exactly 12 amu. What is the standard for formula masses of compounds?

Ans. The same standard, ¹²C, is used for formula masses.

7.5. What is the difference between the atomic mass of bromine and the molecular mass of bromine?

Ans. The atomic mass of bromine is 79.90 amu, as seen in the periodic table or a table of atomic masses. The molecular mass of bromine, corresponding to Br₂, is twice that value, 159.8 amu.

7.6. What is the formula mass of each of the following? (a) P₄, (b) Na₂SO₄, (c) (NH₄)₂SO₃, (d) H₂O₂, (e) Br₂, (f) H₃PO₃, (g) Hg₂(ClO₃)₂, and (h) (NH₄)₂HPO₃.

Ans.

(a) $4 \times 30.97 \text{ amu} = 123.9 \text{ amu}$	(d) 34.0 amu
(b) 2 Na: $2 \times 23.0 \text{ amu} = 46.0 \text{ amu}$	(e) 159.8 amu
S: $1 \times 32.0 \text{ amu} = 32.0 \text{ amu}$	(f) 82.0 amu
4 O: $4 \times 16.0 \text{ amu} = 64.0 \text{ amu}$	(g) 568.1 amu
total = 142.0 amu	(h) 116.0 amu
(c) 116.1 amu	

7.7. What is the mass, in amu, of 1 formula unit of Al₂(SO₃)₃?

Ans. There are 2 aluminum atoms, 3 sulfur atoms, and 9 oxygen atoms in the formula unit.

$$2 \times \text{atomic mass of aluminum} = 54.0 \text{ amu}$$

$$3 \times \text{atomic mass of sulfur} = 96.2 \text{ amu}$$

$$9 \times \text{atomic mass of oxygen} = 144.0 \text{ amu}$$

$$\text{Formula mass} = \text{total} = 294.2 \text{ amu}$$

The formula represents 294.2 amu of aluminum sulfite.

7.8. Calculate the formula mass of each of the following compounds: (a) NaCl, (b) NH₄NO₃, (c) SiF₄, (d) Fe(CN)₂, and (e) KCN.

Ans. (a) 58.44 amu (b) 80.05 amu (c) 104.1 amu (d) 107.9 amu (e) 65.12 amu

THE MOLE

- 7.9. How many H atoms are there in 1 molecule of H_2O_2 ? How many moles of H atoms are there in 1 mol of H_2O_2 ?

Ans. There are two H atoms per molecule of H_2O_2 , and 2 mol H atoms per 1 mol H_2O_2 . The chemical formula provides both these ratios.

- 7.10. How many atoms of K are there in 1.00 mol K? What is the mass of 1.00 mol K?

Ans. There are 6.02×10^{23} atoms in 1.00 mol K (Avogadro's number). There are 39.1 g of K in 1.00 mol K (equal to the atomic mass in grams). This problem requires use of two of the most important conversion factors involving moles. Note which one is used with masses and which one is used with numbers of atoms (or molecules or formula units). With *numbers* of atoms, molecules, or formula units, use Avogadro's number; with *mass*, use the formula mass.

- 7.11. What mass in grams is there in 1.000 mol of $\text{Al}_2(\text{SO}_3)_3$?

Ans. The molar mass has the same value in grams that the formula mass has in amu (Problem 7.7). Thus 1.000 mol represents 294.2 g of aluminum sulfite.

- 7.12. (a) Which contains more pieces of fruit, a dozen grapes or a dozen watermelons? Which weighs more?
(b) Which contains more atoms, 1 mol of lithium or 1 mol of lead? Which has a greater mass?

Ans. (a) Both have the same number of fruits (12), but since each watermelon weighs more than a grape, the dozen watermelons weigh more than the dozen grapes. (b) Both have the same number of atoms (6.02×10^{23}), but since lead has a greater atomic mass (see the periodic table), 1 mol of lead has a greater mass.

Problems 7.13 through 7.16 are easier to do when both parts are worked together. Note the differences among the parts labeled (a) and also among the parts labeled (b). On examinations, you are likely to be asked only one such problem at a time, so you must read the problems carefully and recognize the difference between similar-sounding problems.

- 7.13. (a) How many socks are there in 10 dozen socks? (b) How many hydrogen atoms are there in 10.0 mol of hydrogen atoms?

Ans. (a) $10 \text{ dozen socks} \left(\frac{12 \text{ socks}}{1 \text{ dozen socks}} \right) = 120 \text{ socks}$

(b) $10.0 \text{ mol H} \left(\frac{6.02 \times 10^{23} \text{ H}}{1 \text{ mol H}} \right) = 6.02 \times 10^{24} \text{ H atoms}$

- 7.14. (a) How many pairs of socks are there in 10 dozen pairs of socks? (b) How many hydrogen molecules are there in 10.0 mol of hydrogen molecules?

Ans. (a) $10 \text{ dozen pairs socks} \left(\frac{12 \text{ pair socks}}{1 \text{ dozen pair socks}} \right) = 120 \text{ pairs socks}$

(b) $10.0 \text{ mol H}_2 \left(\frac{6.02 \times 10^{23} \text{ H}_2}{1 \text{ mol H}_2} \right) = 6.02 \times 10^{24} \text{ H}_2 \text{ molecules}$

- 7.15. (a) How many pairs of socks can be made with 10 dozen (identical) socks? (b) How many hydrogen molecules can be made with 10.0 mol of hydrogen atoms?

Ans. (a) $10 \text{ dozen socks} \left(\frac{1 \text{ dozen pairs socks}}{2 \text{ dozen socks}} \right) \left(\frac{12 \text{ pairs socks}}{1 \text{ dozen pairs socks}} \right) = 60 \text{ pairs socks}$
(from definition of a pair) (from definition of a dozen)

(b) $10.0 \text{ mol H} \left(\frac{1 \text{ mol H}_2}{2 \text{ mol H}} \right) \left(\frac{6.02 \times 10^{23} \text{ H}_2}{1 \text{ mol H}_2} \right) = 3.01 \times 10^{24} \text{ H}_2 \text{ molecules}$
(from definition of a molecule) (from definition of a mole)

- 7.16. (a) How many socks are there in 10 dozen pairs of socks? (b) How many hydrogen atoms are there in 10.0 mol of hydrogen molecules?

Ans. (a) 10 dozen pairs socks $\left(\frac{12 \text{ pairs socks}}{1 \text{ dozen pairs socks}}\right)\left(\frac{2 \text{ socks}}{1 \text{ pair socks}}\right) = 240 \text{ socks}$

(b) $10.0 \text{ mol H}_2 \left(\frac{6.02 \times 10^{23} \text{ H}_2}{1 \text{ mol H}_2}\right)\left(\frac{2 \text{ H}}{1 \text{ H}_2}\right) = 1.20 \times 10^{25} \text{ H atoms}$

- 7.17. What is the difference between 1 mol of nitrogen atoms and 1 mol of nitrogen molecules?

Ans. The nitrogen molecules contain two nitrogen atoms each; hence 1 mol of nitrogen molecules contains twice as many atoms as 1 mol of nitrogen atoms. A mole of nitrogen molecules contains 2 mol of bonded N atoms.

- 7.18. Show that the ratio of the number of moles of two elements in a compound is equal to the ratio of the number of atoms of the two elements.

Ans.
$$\frac{x \text{ mol A}}{1 \text{ mol B}} = \frac{x \text{ mol A} \left(\frac{6.02 \times 10^{23} \text{ atoms A}}{1 \text{ mol A}}\right)}{1 \text{ mol B} \left(\frac{6.02 \times 10^{23} \text{ atoms B}}{1 \text{ mol B}}\right)} = \frac{x \text{ atoms A}}{1 \text{ atom B}}$$

- 7.19. How many moles of each substance are there in each of the following masses of substances? (a) 111 g F₂, (b) 6.50 g Na, (c) 44.1 g NaOH, (d) 0.0330 g NaCl, (e) 1.96 g (NH₄)₂SO₃, (f) 7.22 g NaH₂PO₄

Ans. (a) $111 \text{ g F}_2 \left(\frac{1 \text{ mol F}_2}{38.0 \text{ g F}_2}\right) = 2.92 \text{ mol F}_2$

(b) $6.50 \text{ g Na} \left(\frac{1 \text{ mol Na}}{23.0 \text{ g Na}}\right) = 0.283 \text{ mol Na}$

(c) $44.1 \text{ g NaOH} \left(\frac{1 \text{ mol NaOH}}{40.0 \text{ g NaOH}}\right) = 1.10 \text{ mol NaOH}$

(d) $0.0330 \text{ g NaCl} \left(\frac{1 \text{ mol NaCl}}{58.5 \text{ g NaCl}}\right) = 5.64 \times 10^{-4} \text{ mol NaCl}$

(e) $1.96 \text{ g (NH}_4)_2\text{SO}_3 \left(\frac{1 \text{ mol (NH}_4)_2\text{SO}_3}{116 \text{ g (NH}_4)_2\text{SO}_3}\right) = 0.0169 \text{ mol (NH}_4)_2\text{SO}_3$

(f) $7.22 \text{ g NaH}_2\text{PO}_4 \left(\frac{1 \text{ mol NaH}_2\text{PO}_4}{120 \text{ g NaH}_2\text{PO}_4}\right) = 0.0602 \text{ mol NaH}_2\text{PO}_4$

- 7.20. In 2.50 mol Ba(NO₃)₂, (a) how many moles of barium ions are present? (b) How many moles of nitrate ions are present? (c) How many moles of oxygen atoms are present?

Ans. (a) 2.50 mol Ba²⁺ ions

(b) 5.00 mol NO₃⁻ ions

(c) 15.0 mol O atoms

- 7.21. Without doing actual calculations, determine which of the following have masses greater than 1 mg: (a) 1 CO₂ molecule, (b) 1 amu, (c) 6.02 × 10²³ H atoms, (d) 1 mol CO₂, (e) 6.02 × 10²³ amu, (f) $\frac{1}{6.02 \times 10^{23}}$ mol H atoms

Ans. (c), (d), and (e) have masses greater than 1 mg.

- 7.22. What is the mass of each of the following? (a) 6.78 mol NaI, (b) 0.447 mol NaNO₃, (c) 0.500 mol BaO₂, (d) 5.44 mol C₈H₁₈

Ans. (a) $6.78 \text{ mol NaI} \left(\frac{150 \text{ g NaI}}{1 \text{ mol NaI}} \right) = 1020 \text{ g NaI}$
 (b) $0.447 \text{ mol NaNO}_3 \left(\frac{85.0 \text{ g NaNO}_3}{1 \text{ mol NaNO}_3} \right) = 38.0 \text{ g NaNO}_3$
 (c) $0.500 \text{ mol BaO}_2 \left(\frac{169 \text{ g BaO}_2}{1 \text{ mol BaO}_2} \right) = 84.5 \text{ g BaO}_2$
 (d) $5.44 \text{ mol C}_8\text{H}_{18} \left(\frac{114 \text{ g C}_8\text{H}_{18}}{1 \text{ mol C}_8\text{H}_{18}} \right) = 620 \text{ g C}_8\text{H}_{18}$

7.23. In 0.125 mol NaClO_4 , (a) how many moles of sodium ions are present? (b) how many moles of perchlorate ions are present?

Ans. (a) 0.125 mol Na^+ ions (b) 0.125 mol ClO_4^- ions. The subscript 4 refers to the number of O atoms per anion, not to the number of anions.

7.24. (a) Calculate the formula mass of H_3PO_4 . (b) Calculate the number of grams in 1.00 mol of H_3PO_4 . (c) Calculate the number of grams in 2.00 mol of H_3PO_4 . (d) Calculate the number of grams in 0.222 mol of H_3PO_4 .

Ans. (a) 3 H 3.02 amu
 P 30.97 amu
 4 O 64.00 amu
 total 97.99 amu

(b) 97.99 g
 (c) $2.00 \text{ mol} \left(\frac{97.99 \text{ g}}{1 \text{ mol}} \right) = 196 \text{ g}$
 (d) $0.222 \text{ mol} \left(\frac{97.99 \text{ g}}{1 \text{ mol}} \right) = 21.8 \text{ g}$

7.25. (a) Determine the number of moles of ammonia in 27.5 g of ammonia, NH_3 . (b) Determine the number of moles of nitrogen atoms in 27.5 g of ammonia. (c) Determine the number of moles of hydrogen atoms in 27.5 g of ammonia.

Ans. (a) $27.5 \text{ g NH}_3 \left(\frac{1 \text{ mol NH}_3}{17.0 \text{ g NH}_3} \right) = 1.62 \text{ mol NH}_3$
 (b) $1.62 \text{ mol NH}_3 \left(\frac{1 \text{ mol N}}{1 \text{ mol NH}_3} \right) = 1.62 \text{ mol N}$
 (c) $1.62 \text{ mol NH}_3 \left(\frac{3 \text{ mol H}}{1 \text{ mol NH}_3} \right) = 4.86 \text{ mol H}$

7.26. How many hydrogen atoms are there in 1.00 mol of methane, CH_4 ?

Ans. $1 \text{ mol CH}_4 \left(\frac{6.02 \times 10^{23} \text{ CH}_4 \text{ molecules}}{1 \text{ mol CH}_4} \right) \left(\frac{4 \text{ H atoms}}{1 \text{ CH}_4 \text{ molecule}} \right) = 2.41 \times 10^{24} \text{ H atoms}$

7.27. Determine the number of mercury atoms in 7.11 g of Hg_2Cl_2 .

Ans. $7.11 \text{ g Hg}_2\text{Cl}_2 \left(\frac{1 \text{ mol Hg}_2\text{Cl}_2}{472 \text{ g Hg}_2\text{Cl}_2} \right) \left(\frac{2 \text{ mol Hg}}{1 \text{ mol Hg}_2\text{Cl}_2} \right) \left(\frac{6.02 \times 10^{23} \text{ Hg atoms}}{1 \text{ mol Hg}} \right) = 1.81 \times 10^{22} \text{ atoms}$

7.28. (a) If 1 dozen pairs of socks weighs 11 oz, how much would the same socks weigh if they were unpaired? (b) What is the mass of 1 mol O_2 ? What is the mass of the same number of oxygen atoms unbonded to one another?

Ans. (a) The socks would still weigh 11 oz; unpairing them makes no difference in their mass.
 (b) The mass of 1 mol O_2 is 32 g; the mass of 2 mol O is also 32 g. The mass does not depend on whether they are bonded.

7.29. How many molecules are there in 1.00 mol F_2 ? How many atoms are there? What is the mass of 1.00 mol F_2 ?

Ans. There are 6.02×10^{23} molecules in 1.00 mol F_2 (Avogadro's number). Since there are two atoms per molecule, there are

$$6.02 \times 10^{23} \text{ molecules} \left(\frac{2 \text{ atoms}}{1 \text{ molecule}} \right) = 1.20 \times 10^{24} \text{ atoms F in 1.00 mol } F_2$$

The mass is that of 1.00 mol F_2 or 2.00 mol F:

$$1.00 \text{ mol } F_2 \left(\frac{2 \times 19.0 \text{ g } F_2}{1 \text{ mol } F_2} \right) = 38.0 \text{ g } F_2$$

or

$$2.00 \text{ mol F} \left(\frac{19.0 \text{ g F}}{1 \text{ mol F}} \right) = 38.0 \text{ g F}$$

The *mass* is the same, no matter whether we focus on the atoms or molecules. (Compare the mass of 1 dozen pairs of socks rolled together to that of the same socks unpaired. Would the two masses differ? If so, which would be greater? See the prior problem.)

7.30. (a) Create one factor that will change 6.17 g of calcium carbonate to a number of formula units of calcium carbonate. (b) Is it advisable to learn and use such a factor?

Ans. (a)
$$\frac{1 \text{ mol CaCO}_3 \left(\frac{6.02 \times 10^{23} \text{ units CaCO}_3}{1 \text{ mol CaCO}_3} \right)}{100 \text{ g CaCO}_3} = \frac{6.02 \times 10^{23} \text{ units CaCO}_3}{100 \text{ g CaCO}_3}$$

(b) It is possible to use such a conversion factor, but it is advisable while you are learning to use the factors involved with moles to use as few different ones as possible. That way, you have to remember fewer. Also, in each conversion you will change either the unit (mass \rightarrow moles) or the chemical ($CaCO_3 \rightarrow$ O atoms) in a factor, but not both. Many texts do use such combined factors, however.

7.31. How many moles of Na are there in 7.20 mol Na_2SO_4 ?

Ans.
$$7.20 \text{ mol } Na_2SO_4 \left(\frac{2 \text{ mol Na}}{1 \text{ mol } Na_2SO_4} \right) = 14.4 \text{ mol Na}$$

7.32. How many moles of water can be made with 1.76 mol H atoms (plus enough O atoms)?

Ans.
$$1.76 \text{ mol H} \left(\frac{1 \text{ mol H}_2O}{2 \text{ mol H}} \right) = 0.880 \text{ mol H}_2O$$

7.33. Make a table showing the number of molecules and the mass of each of the following: (a) 1.00 mol Cl_2 , (b) 2.00 mol Cl_2 , and (c) 0.135 mol Cl_2

	Number of Molecules	Mass
<i>Ans.</i> (a) 1.00 mol Cl_2	6.02×10^{23}	71.0 g
(b) 2.00 mol Cl_2	1.20×10^{24}	142 g
(c) 0.135 mol Cl_2	8.13×10^{22}	9.59 g

Once you know the mass or number of molecules in 1 mol, you merely have to multiply to get the mass or number of molecules in any other given number of moles. Sometimes the calculation is easy enough to do in your head.

7.34. How can you measure the thickness of a sheet of notebook paper with a 10-cm ruler?

Ans. One way is to measure the combined thickness of many sheets and divide that distance by the number of sheets. For example, if 500 sheets is 5.05 cm thick, then each sheet is $(5.05 \text{ cm})/500 = 0.0101 \text{ cm}$ thick. Note that it is impossible to measure 0.0101 cm with a centimeter ruler, but we did accomplish the same purpose indirectly. (See also the following problem.)

7.35. How can you measure the mass of a carbon atom? Compare this problem with the prior problem.

Ans. We want to measure the mass of a large number of carbon atoms and divide the total mass by the number of atoms. However, we have the additional problem here, compared with counting sheets of paper

(prior problem), that atoms are too small to count. We can “count” them by combining them with a known number of atoms of another element. For example, to count a number of carbon atoms, combine them with a known number of oxygen atoms to form CO, in which the ratio of atoms of carbon to oxygen is 1 : 1.

7.36. What mass of oxygen is combined with 4.13×10^{24} atoms of sulfur in Na_2SO_4 ?

$$\text{Ans.} \quad 4.13 \times 10^{24} \text{ atoms S} \left(\frac{1 \text{ mol S}}{6.02 \times 10^{23} \text{ atoms S}} \right) \left(\frac{4 \text{ mol O}}{1 \text{ mol S}} \right) \left(\frac{16.0 \text{ g O}}{1 \text{ mol O}} \right) = 439 \text{ g O}$$

7.37. A 106 g sample of an “unknown” element Q reacts with 32.0 g of O_2 . Assuming the atoms of Q react in a 1 : 1 ratio with oxygen *molecules*, calculate the atomic mass of Q.

Ans. Since the 106 g of Q reacts with 1.00 mol of O_2 in a 1 : 1 mole ratio, there must be 1.00 mol of Q in 106 g. Therefore, 106 g is 1.00 mol, and the atomic mass of Q is 106 amu.

7.38. To form a certain compound, 29.57 g of oxygen reacts with 109.7 g of tin. What is the formula of the compound?

Ans. The formula is the mole ratio:

$$29.57 \text{ g O atoms} \left(\frac{1 \text{ mol O atoms}}{16.00 \text{ g O}} \right) = 1.848 \text{ mol O atoms}$$

$$109.7 \text{ g Sn atoms} \left(\frac{1 \text{ mol Sn atoms}}{118.7 \text{ g Sn}} \right) = 0.9242 \text{ mol Sn atoms}$$

The mole ratio is 1.848 mol O/0.9242 mol Sn = 2 mol O/1 mol Sn. The formula is SnO_2 .

7.39. If 29.57 g O_2 were used in Problem 7.38, how would the problem change?

Ans. The answer would be the same; 29.57 g of O_2 is 29.57 g of O atoms (bonded in pairs). See Problem 7.28.

7.40. How many P atoms are there in 1.13 mol P_4 ?

$$\text{Ans.} \quad 1.13 \text{ mol P}_4 \left(\frac{6.02 \times 10^{23} \text{ molecules P}_4}{1 \text{ mol P}_4} \right) \left(\frac{4 \text{ atoms P}}{1 \text{ molecule P}_4} \right) = 2.72 \times 10^{24} \text{ P atoms}$$

7.41. How many hydrogen atoms are there in 1.36 mol NH_3 ?

$$\text{Ans.} \quad 1.36 \text{ mol NH}_3 \left(\frac{6.02 \times 10^{23} \text{ molecules NH}_3}{1 \text{ mol NH}_3} \right) \left(\frac{3 \text{ H atoms}}{1 \text{ molecule NH}_3} \right) = 2.46 \times 10^{24} \text{ H atoms}$$

PERCENT COMPOSITION OF COMPOUNDS

7.42. A 10.0-g sample of water has a percent composition of 88.8% oxygen and 11.2% hydrogen. (a) What is the percent composition of a 6.67-g sample of water? (b) Calculate the number of grams of oxygen in a 6.67-g sample of water.

Ans. (a) 88.8% O and 11.2% H. The percent composition does not depend on the sample size.

$$(b) \quad 6.67 \text{ g H}_2\text{O} \left(\frac{88.8 \text{ g O}}{100 \text{ g H}_2\text{O}} \right) = 5.92 \text{ g O}$$

7.43. Calculate the percent composition of each of the following: (a) C_3H_6 and (b) C_5H_{10} .

$$\begin{aligned} \text{Ans.} \quad (a) \quad & \text{C} \quad 3 \times 12.0 = 36.0 \text{ amu} \\ & \text{H} \quad 6 \times 1.0 = 6.0 \text{ amu} \\ & \text{Total} = 42.0 \text{ amu} \end{aligned}$$

The percent carbon is found by dividing the mass of carbon in one molecule by the mass of the molecule and multiplying the quotient by 100%:

$$\% \text{ C} = \left(\frac{36.0 \text{ amu C}}{42.0 \text{ amu total}} \right) \times 100\% = 85.7\% \text{ C} \quad \% \text{ H} = \left(\frac{6.0 \text{ amu H}}{42.0 \text{ amu total}} \right) \times 100\% = 14.3\% \text{ H}$$

The two percentages add up to 100.0%.

$$\begin{array}{rcl}
 (b) & & \\
 & \text{C} & 5 \times 12.0 = 60.0 \text{ amu} \\
 & \text{H} & 10 \times 1.0 = 10.0 \text{ amu} \\
 & & \text{Total} = 70.0 \text{ amu}
 \end{array}$$

$$\% \text{ C} = \frac{60.0 \text{ amu C}}{70.0 \text{ amu total}} \times 100\% = 85.7\% \text{ C} \quad \% \text{ H} = \frac{10.0 \text{ amu H}}{70.0 \text{ amu total}} \times 100\% = 14.3\% \text{ H}$$

The percentages are the same as those in part (a). That result might have been expected. Since the ratio of atoms of carbon to atoms of hydrogen is the same (1 : 2) in both compounds, the ratio of masses also ought to be the same, and their percent by mass ought to be the same. From another viewpoint, this result means that the two compounds cannot be distinguished from each other by their percent compositions alone.

7.44. Calculate the percent composition of DDT ($\text{C}_{14}\text{H}_9\text{Cl}_5$).

$$\begin{array}{rcl}
 \text{Ans.} & & \\
 & \text{C} & 14 \times 12.01 = 168.1 \text{ amu} \\
 & \text{H} & 9 \times 1.008 = 9.07 \text{ amu} \\
 & \text{Cl} & 5 \times 35.45 = 177.2 \text{ amu} \\
 & & \text{Total} = 354.4 \text{ amu}
 \end{array}$$

The percent carbon is found by dividing the mass of carbon in one molecule by the mass of the molecule and multiplying the quotient by 100%:

$$\% \text{ C} = \left(\frac{168.1 \text{ amu C}}{354.4 \text{ amu total}} \right) \times 100\% = 47.43\% \text{ C}$$

$$\% \text{ H} = \left(\frac{9.07 \text{ amu H}}{354.4 \text{ amu total}} \right) \times 100\% = 2.56\% \text{ H}$$

$$\% \text{ Cl} = \left(\frac{177.2 \text{ amu Cl}}{354.4 \text{ amu total}} \right) \times 100\% = 50.00\% \text{ Cl}$$

The percentages add up to 99.99%. (The answer is correct within the accuracy of the number of significant figures used.)

7.45. A forensic scientist analyzes a drug and finds that it contains 80.22% carbon and 9.62% hydrogen. Could the drug be pure tetrahydrocannabinol ($\text{C}_{21}\text{H}_{30}\text{O}_2$)?

$$\begin{array}{rcl}
 \text{Ans.} & 21 \text{ C} & 21 \times 12.01 = 252.2 \text{ amu} \\
 & 30 \text{ H} & 30 \times 1.008 = 30.24 \text{ amu} \\
 & 2 \text{ O} & 2 \times 16.00 = 32.00 \text{ amu} \\
 & \text{Formula mass} & = 314.4 \text{ amu} \\
 & \% \text{ C} = \frac{252.2 \text{ amu}}{314.4 \text{ amu}} \times 100\% & = 80.22\% \text{ C} \quad \% \text{ H} = \frac{30.24 \text{ amu}}{314.4 \text{ amu}} \times 100\% = 9.618\% \text{ H}
 \end{array}$$

Since the percentages are the same, the drug *could* be tetrahydrocannabinol. (It is not proved to be, however. If the percent composition were different, it would be proved *not* to be pure tetrahydrocannabinol.)

7.46. A certain mixture of salt (NaCl) and sugar ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) contains 40.0% chlorine by mass. Calculate the percentage of salt in the mixture.

Ans. In 100.0 g of sample (the size does not make any difference), there is 40.0 g of chlorine and therefore

$$40.0 \text{ g Cl} \left(\frac{58.5 \text{ g NaCl}}{35.5 \text{ g Cl}} \right) = 65.9 \text{ g NaCl}$$

The percentage of NaCl (in the 100.0 g sample) is therefore 65.9%. When using percentages, be careful to distinguish percentage of what in what!

EMPIRICAL FORMULAS

7.47. If each of the following mole ratios is obtained in an empirical formula problem, what should it be multiplied by to get an integer ratio? (a) 1.50 : 1, (b) 1.25 : 1, (c) 1.33 : 1, (d) 1.67 : 1, and (e) 1.75 : 1.

Ans. (a) 2, to get 3 : 2 (b) 4, to get 5 : 4 (c) 3, to get 4 : 3 (d) 3, to get 5 : 3 (e) 4, to get 7 : 4

- 7.48. Which do we use to calculate the empirical formula of an oxide, the atomic mass of oxygen (16 amu) or the molecular mass of oxygen (32 amu)?

Ans. The atomic mass. We are solving for a formula, which is a ratio of atoms. This type of problem has nothing to do with oxygen gas, O₂.

- 7.49. (a) Write a formula for a molecule with 4 phosphorus atoms and 6 oxygen atoms per molecule. (b) What is the empirical formula of this compound?

Ans. (a) P₄O₆ (b) P₂O₃

- 7.50. Which of the formulas in Problem 5.2 obviously are not empirical formulas?

Ans. (a), (d), (e), and (g). The subscripts in (a), (d), (e), and (g) can be divided by a small integer to give a simpler formula, so these cannot be empirical formulas. (They must have at least some covalent bonds.)

- 7.51. Calculate the empirical formula of a compound consisting of 92.26% C and 7.74% H.

Ans. Assume that 100.0 g of the compound is analyzed. Since the same percentages are present no matter what the sample size, we can consider any size sample we wish, and considering 100 g makes the calculations easier. The numbers of grams of the elements are then 92.26 g C and 7.74 g H.

$$92.26 \text{ g C} \left(\frac{1 \text{ mol C}}{12.01 \text{ g C}} \right) = 7.682 \text{ mol C} \quad 7.74 \text{ g H} \left(\frac{1 \text{ mol H}}{1.008 \text{ g H}} \right) = 7.68 \text{ mol H}$$

The empirical formula (or any formula) must be in the ratio of small integers. Thus, we attempt to get the ratio of moles of carbon to moles of hydrogen into an integer ratio; we divide all the numbers of moles by the smallest number of moles:

$$\frac{7.682 \text{ mol C}}{7.68} = 1.00 \text{ mol C} \quad \frac{7.68 \text{ mol H}}{7.68} = 1.00 \text{ mol H}$$

The ratio of moles of C to moles of H is 1 : 1, so the empirical formula is CH.

- 7.52. Calculate the empirical formula of a compound containing 69.94% Fe and the rest oxygen.

Ans. The oxygen must be 30.06%, to total 100.00%.

$$69.94 \text{ g Fe} \left(\frac{1 \text{ mol Fe}}{55.85 \text{ g Fe}} \right) = 1.252 \text{ mol Fe} \quad 30.06 \text{ g O} \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 1.879 \text{ mol O}$$

Dividing both of these numbers by the smaller yields

$$\frac{1.252 \text{ mol Fe}}{1.252} = 1.000 \text{ mol Fe} \quad \frac{1.879 \text{ mol O}}{1.252} = 1.501 \text{ mol O}$$

This is still not a whole number ratio, since 1.501 is much too far from an integer to round. Since 1.501 is about 1½, multiply *both* numbers of moles by 2:

$$2.000 \text{ mol Fe} \quad \text{and} \quad 3.002 \text{ mol O}$$

We can round when a value is within 1% or 2% of an integer, but not more. This is close enough to an integer ratio, so the empirical formula is Fe₂O₃.

- 7.53. Determine the empirical formula of a compound which has a percent composition 23.3% Mg, 30.7% S, and 46.0%, O.

Ans. In a 100-g sample, there are

$$23.3 \text{ g Mg} \left(\frac{1 \text{ mol Mg}}{24.3 \text{ g Mg}} \right) = 0.959 \text{ mol Mg} \quad 46.0 \text{ g O} \left(\frac{1 \text{ mol O}}{16.0 \text{ g O}} \right) = 2.88 \text{ mol O}$$

$$30.7 \text{ g S} \left(\frac{1 \text{ mol S}}{32.0 \text{ g S}} \right) = 0.959 \text{ mol S}$$

To get integer mole ratios, divide by the smallest, 0.956:

$$\frac{0.959 \text{ mol Mg}}{0.959} = 1.00 \text{ mol Mg} \quad \frac{2.88 \text{ mol O}}{0.959} = 3.00 \text{ mol O}$$

$$\frac{0.959 \text{ mol S}}{0.959} = 1.00 \text{ mol S}$$

The mole ratio is 1 mol Mg to 1 mol S to 3 mol O; the empirical formula is MgSO_3 .

- 7.54. Calculate the empirical formula for each of the following compounds: (a) 42.1% Na, 18.9% P, and 39.0% O. (b) 55.0% K and 45.0% O.

Ans. (a) $42.1 \text{ g Na} \left(\frac{1 \text{ mol Na}}{23.0 \text{ g Na}} \right) = 1.83 \text{ mol Na}$ $39.0 \text{ g O} \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 2.44 \text{ mol O}$

$18.9 \text{ g P} \left(\frac{1 \text{ mol P}}{31.0 \text{ g P}} \right) = 0.610 \text{ mol P}$

Dividing by 0.610 yields 3.00 mol Na, 1.00 mol P, 4.00 mol O. The empirical formula is Na_3PO_4 .

(b) $55.0 \text{ g K} \left(\frac{1 \text{ mol K}}{39.1 \text{ g K}} \right) = 1.41 \text{ mol K}$ $45.0 \text{ g O} \left(\frac{1 \text{ mol O}}{16.0 \text{ g O}} \right) = 2.81 \text{ mol O}$

Dividing by 1.41 yields 1.00 mol K and 2.00 mol O. The empirical formula is KO_2 (potassium superoxide).

MOLECULAR FORMULAS

- 7.55. List five possible molecular formulas for a compound with empirical formula CH_2 .

Ans. C_2H_4 , C_3H_6 , C_4H_8 , C_5H_{10} , C_6H_{12} (and any other formula with a C-to-H ratio of 1 : 2).

- 7.56. Explain why we cannot calculate a molecular formula for a compound of phosphorus, potassium, and oxygen.

Ans. The compound is ionic; it does not form molecules.

- 7.57. Which one of the following could possibly be defined as "the ratio of moles of each of the given elements to moles of each of the others"? (a) percent composition by mass, (b) empirical formula, or (c) molecular formula.

Ans. Choice (b). This is a useful definition of empirical formula. The molecular formula gives the ratio of moles of each element to moles of the compound, plus the information given by the empirical formula. The percent composition does not deal with moles, but is a ratio of masses.

- 7.58. A compound consists of 92.26% C and 7.74% H. Its molecular mass is 65.0 amu. (a) Calculate its empirical formula. (b) Calculate its empirical formula mass. (c) Calculate the number of empirical formula units in one molecule. (d) Calculate its molecular formula.

Ans. (a) The empirical formula is calculated to be CH, as presented in problem 7.51.
 (b) The empirical formula mass is 13.0 amu, corresponding to 1 C and 1 H atom.
 (c) There are

$$\frac{65.0 \text{ amu/molecule}}{13.0 \text{ amu/empirical formula unit}} = \frac{5 \text{ empirical formula units}}{1 \text{ molecule}}$$

(d) The molecular formula is $(\text{CH})_5$, or C_5H_5 .

- 7.59. The percent composition of a certain compound is 85.7% C and 14.3% H. Its molecular mass is 70.0 amu. (a) Determine its empirical formula. (b) Determine its molecular formula.

Ans. (a) $85.7 \text{ g C} \left(\frac{1 \text{ mol C}}{12.0 \text{ g C}} \right) = 7.14 \text{ mol C}$ $14.3 \text{ g H} \left(\frac{1 \text{ mol H}}{1.008 \text{ g H}} \right) = 14.2 \text{ mol H}$

The ratio is 1 : 2, and the empirical formula is CH_2 .

(b) The empirical formula mass is 14.0 amu. There are

$$\frac{70.0 \text{ g/mol}}{14.0 \text{ g/mol empirical formula unit}} = \frac{5 \text{ mol empirical formula units}}{1 \text{ mol}}$$

The molecular formula is C_5H_{10} .

Supplementary Problems

7.60. Define or identify each of the following: molecule, ion, formula unit, formula mass, mole, molecular mass, Avogadro's number, percent, empirical formula, molecular formula, molar mass, empirical formula mass, molecular weight.

Ans. See the text.

7.61. How is molecular mass related to formula mass?

Ans. They are the same for compounds which form molecules.

7.62. Does the term *atomic mass* refer to uncombined atoms, atoms bonded in compounds, or both?

Ans. Both

7.63. A certain fertilizer is advertised to contain 10.5% K_2O . What percentage of the fertilizer is potassium?

Ans.
$$\frac{10.5 \text{ g K}_2\text{O} \left(\frac{78.2 \text{ g K}}{94.2 \text{ g K}_2\text{O}} \right)}{100 \text{ g sample}} = 8.72\% \text{ K}$$

7.64. A compound consists of 92.26% C and 7.74% H. Its molecular mass is 65.0 amu. Calculate its molecular formula.

Ans. C_5H_5 . This problem is exactly the same as Problem 7.58. The steps are the same even though they are not specified in the statement of this problem.

7.65. (a) Calculate the percent composition of C_3H_6 . (b) Calculate the percent composition of C_4H_8 . (c) Compare the results and explain the reason for these results.

Ans. (a, b) There is 85.7% C and 14.3% H in each. (c) They are the same because they have the same ratio of moles of elements.

7.66. Name and calculate the empirical formula of each of the following compounds.

- | | | | | |
|---------------|----------|----------|---------------|----------|
| (a) 36.77% Fe | 21.10% S | 42.13% O | (d) 71.05% Co | 28.95% O |
| (b) 27.93% Fe | 24.05% S | 48.01% O | (e) 72.7% O | 27.3% C |
| (c) 63.20% Mn | 36.8% O | | (f) 36.0% Al | 64.0% S |

Ans. (a) FeSO_4 (b) $\text{Fe}_2\text{S}_3\text{O}_{12}$ (c) MnO_2 (d) Co_2O_3 (e) CO_2 (f) Al_2S_3

The names are (a) iron(II) sulfate, (b) iron(III) sulfate [$\text{Fe}_2(\text{SO}_4)_3$], (c) manganese(IV) oxide, (d) cobalt(III) oxide, (e) carbon dioxide, and (f) aluminum sulfide.

7.67. What mass of oxygen is contained in 42.8 g CaCO_3 ?

Ans.
$$42.8 \text{ g CaCO}_3 \left(\frac{1 \text{ mol CaCO}_3}{100 \text{ g CaCO}_3} \right) \left(\frac{3 \text{ mol O}}{1 \text{ mol CaCO}_3} \right) \left(\frac{16.0 \text{ g O}}{1 \text{ mol O}} \right) = 20.5 \text{ g O}$$

You can also do this problem by using percent composition (Sec. 7.5).

7.68. Determine the molecular formula of a compound with molar mass between 105 and 115 g/mol which contains 88.8% C and 11.2% H.

Ans.

$$88.8 \text{ g C} \left(\frac{1 \text{ mol C}}{12.0 \text{ g C}} \right) = 7.40 \text{ mol C} \quad 11.2 \text{ g H} \left(\frac{1 \text{ mol H}}{1.008 \text{ g H}} \right) = 11.1 \text{ mol H}$$

Dividing both numbers of moles by 7.40 yields 1.00 mol C and 1.50 mol H. Multiplying both of these by 2 yields the empirical formula C_2H_3 . The empirical formula mass is thus 27.0 amu. The number of empirical formula units in 1 mol can be calculated by using 110 amu for the molecular mass. The number must be an integer.

$$\frac{110 \text{ amu/molecule}}{27.0 \text{ amu/empirical formula unit}} = \frac{4.07 \text{ empirical formula units}}{1 \text{ molecule}}$$

The answer must be integral—in this case 4. If we had used 105 amu or 115 amu, the answer would still have been closer to the integer 4 than to any other integer. The molecular formula is thus C_8H_{12} .

- 7.69. A compound has a molar mass of 90.0 g/mol and its percent composition is 2.22% H, 26.7% C, and 71.1% O. What is its molecular formula?

Ans. $\text{H}_2\text{C}_2\text{O}_4$

- 7.70. Combine Figures 7-1, 7-2, and 7-3 into one figure. List all the conversions possible using the combined figure.

Ans. The figure is presented as Fig. 7-4. One can convert from mass to moles, moles of component elements, or number of formula units. Additionally, one can convert from number of formula units to moles, to moles of component elements, or to mass; also from moles of component elements to moles of compound, number of formula units of compound, or mass of compound; finally, from moles of compound to number of formula units, mass, or number of moles of component elements.

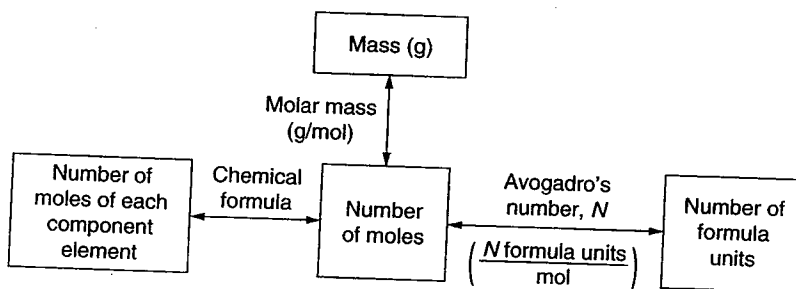


Fig. 7-4. Conversions involving moles

- 7.71. To Fig. 7-4 (Problem 7.70), add a box for the mass of the substance in atomic mass units, and also add the factor labels with which that box can be connected to two others. Add another box to include the number of individual atoms of each element.

Ans. The answer is shown on the factor-label conversion figure, page 348.

- 7.72. (a) Define the unit *millimole* (mmol). (b) How many gold atoms are there in 1 mmol of Au

Ans. (a) $1 \text{ mmol} = 0.001 \text{ mol}$ (b) $6.02 \times 10^{20} \text{ Au atoms}$