5.E: The Mole Concept (Exercises)

5.1-5.5: Avogadro's Number, Molar Mass and the Mole

Conceptual Problems

Please be sure you are familiar with the topics discussed in Essential Skills 2 before proceeding to the Conceptual Problems.

1. Describe the relationship between an atomic mass unit and a gram.
2. Is it correct to say that ethanol has a formula mass of 46? Why or why not?
3. If 2 mol of sodium reacts completely with 1 mol of chlorine to produce sodium chloride, does this mean that 2 g of sodium reacts completely with 1 g of chlorine to give the same product? Explain your answer.
4. Construct a flowchart to show how you would calculate the number of moles of silicon in a 37.0 g sample of orthoclase ($KAlSi_3O_8$), a mineral used in the manufacture of porcelain.
5. Construct a flowchart to show how you would calculate the number of moles of nitrogen in a 22.4 g sample of nitroglycerin that contains 18.5% nitrogen by mass.

Numerical Problems

Please be sure you are familiar with the topics discussed in Essential Skills 2 before proceeding to the Numerical Problems.

1. Derive an expression that relates the number of molecules in a sample of a substance to its mass and molecular mass.

2. Calculate the molecular mass or formula mass of each compound.

a. KCl (potassium chloride)
b. NaCN (sodium cyanide)
c. H_2S (hydrogen sulfide)
d. NaN_3 (sodium azide)
e. H_2CO_3 (carbonic acid)
f. K_2O (potassium oxide)
g. $Al(NO_3)_3$ (aluminum nitrate)
h. $Cu(ClO_4)_2$ [copper(II) perchlorate]

3. Calculate the molecular mass or formula mass of each compound.

a. V_2O_4 (vanadium(IV) oxide)
b. $CaSiO_3$ (calcium silicate)
c. BiOCl (bismuth oxychloride)
d. CH_3COOH (acetic acid)
e. Ag_2SO_4 (silver sulfate)
f. Na_2CO_3 (sodium carbonate)
g. $(CH_3)_2CHOH$ (isopropyl alcohol)

8. Calculate the number of molecules or formula units in 5.00×10^2 g of each substance. (Remember that a basic unit of a molecular compound is called a "molecule", while it is called a "Formula Unit" for an ionic compound.)

a. CaO (lime)

b. $CaCO_3$(chalk)

c. $C_{12}H_{22}O_{11}$ [sucrose (cane sugar)]

d. NaOCl (bleach)

e. CO_2 (dry ice)

9. Calculate the mass in grams of each sample.

a. 0.520 mol of N_2O_4

b. 1.63 mol of $C_6H_4Br_2$

c. 4.62 mol of $(NH_4)_2SO_3$

10. Give the number of molecules or formula units in each sample.

a. 1.30×10^{-2} mol of SCl_2

b. 1.03 mol of N_2O_5

c. 0.265 mol of $Ag_2Cr_2O_7$

11. Give the number of moles in each sample.

a. 9.58×10^{26} molecules of Cl_2

b. 3.62×10^{27} formula units of KCl

c. 6.94×10^{28} formula units of $Fe(OH)_2$

12. Solutions of iodine are used as antiseptics and disinfectants. How many iodine atoms correspond to 11.0 g of molecular iodine (I_2)?

13. What is the total number of atoms in each sample?

a. 0.431 mol of Li

b. 2.783 mol of methanol (CH_3OH)

c. 0.0361 mol of $CoCO_3$

d. 1.002 mol of $SeBr_2O$

14. What is the total number of atoms in each sample?

a. 0.980 mol of Na

b. 2.35 mol of O_2

c. 1.83 mol of Ag_2S

d. 1.23 mol of propane (C_3H_8)

15. What is the total number of atoms in each sample?

a. 2.48 g of HBr

b. 4.77 g of CS_2

c. 1.89 g of NaOH

d. 1.46 g of SrC_2O_4

16. Decide whether each statement is true or false and explain your reasoning.

a. There are more molecules in 0.5 mol of Cl_2than in 0.5 mol of H_2.
b. One mole of H_2 has 6.022×10^{23} hydrogen atoms.
c. The molecular mass of H_2O is 18.0 amu.
d. The formula mass of benzene is 78 amu.

17. Complete the following table.

Substance	Mass (g)	Number of Moles	Number of Molecules or Formula Units	Number of Atoms or Ions
$MgCl_2$	37.62	a.	b.	c.
$AgNO_3$	d.	2.84	e.	f.
NH_4Cl	g.	h.	8.93×10^{25}	i.
K_2S	j	k.	l.	7.69×10^{26}
H_2SO_4	m.	1.29	n.	o.

Substance	Mass (g)	Number of Moles	Number of Molecules or Formula Units	Number of Atoms or Ions
C_6H_{14}	11.84	p.	q.	r.
$HClO_3$	s.	t.	2.45×10^{26}	u.

18. Give the formula mass or the molecular mass of each substance.

a. $PbClF$
b. $Cu_2P_2O_7$
c. $BiONO_3$
d. Tl_2SeO_4

19. Give the formula mass or the molecular mass of each substance.

a. $MoCl_5$
b. B_2O_3
c. UO_2CO_3
d. $NH_4UO_2AsO_4$

Conceptual Answers

1. While both are units of mass, a gram is Avogadro's number of atomic mass units so you would multiply the number of amu by 6.022x10^23 to find total number of grams
2. The correct way to state formula mass of ethanol is to show the units of mass which is amu.
3. No because moles and weight operate on different set of standards meaning that they're not equal to each other. This means that moles of different compounds contain different weights. For example, 2 moles of Na = 2 x 22.989 g = 45.98g while 1 mole of Cl = 1 x 35.453 g = 35.453 g Cl. This makes the sodium react completely with chlorine. 2g of sodium would react with = (35.453/45.978) x 2 = 1.542 g Cl
4. Construct a flowchart to show how you would calculate the number of moles of silicon in a 37.0 g sample of orthoclase ($KAlSi_3O_8$), a mineral used in the manufacture of porcelain

$$\frac{given\ mass}{molar\ mass\ of\ KAlSi3O8} x \frac{(3\ moles\ of\ Si)}{(1\ mole\ of\ KAlSi3O8)} = \frac{37\ mol}{278\ mol} x \frac{(3\ moles\ of\ Si)}{(1\ mole\ of\ KAlSi3O8)} =$$

1. . $0.4\ moles$

5. Construct a flowchart to show how you would calculate the number of moles of nitrogen in a 22.4 g sample of nitroglycerin that contains 18.5% nitrogen by mass.

$$\frac{given\ mass\ of\ nitroglycerin}{molar\ mass\ of\ nitroglcerin} x \frac{(3\ moles\ of\ Si)}{(1\ mole\ of\ KAlSi3O8)} = \frac{22.4\ g}{227.0\ g/mol} = 0.099\ mole \rightarrow$$

1. $$\frac{4.14\ (mass\ of\ nitrogen)}{14\ (molar\ atomic\ mass\ of\ nitrogen)} = 0.296\ moles$$

6. The information required to determine the mass of the solute would be the molarity of the solution because once that is achieved, volume of the solution and molar mass of the solute can be used to calculate the total mass. A derivatization that achieves this goes as: Molarity = moles of solute / volume of solution in liter -> Moles = molarity x volume in liter -> Mass= moles x molar mass.

Numerical Answers

1. Derive an expression that relates the number of molecules in a sample of a substance to its mass and molecular mass.

$$1\ mole = 6.022x10^{23} mol = NA\ (Avogadro's\ Number)$$

$$mole = \frac{mass}{molecular\ mass}$$

$$Number\ of\ molecules = moles\ x\ NA \rightarrow \frac{mass}{molecular\ mass} xNA$$

2. Calculate the molecular mass or formula mass of each compound.

a. 74.55 amu

b. 49.01 amu
c. 34.08 amu
d. 65.01 amu
e. 62.02 amu
f. 94.20 amu
g. 213.00 amu
h. 262.45 amu

3. Calculate the molecular mass or formula mass of each compound.

a. 165.88 amu
b. 116.16 amu
c. 260.43 amu
d. 60.05 amu
e. 311.80 amu
f. 105.99 amu
g. 60.10 amu

4. Calculate the molar mass of each compound.

a. 153.82 g/mol

b. 80.06 g/mol

c. 92.01 g/mol

d. 70.13 g/mol

e. 74.12 g/mol

5. Calculate the molar mass of each compound.

a. 92.45 g/mol

b. 135.04 g/mol

c. 44.01 g/mol

d. 40.06 g/mol

6. For each compound, write the condensed formula, name the compound, and give its molar mass.

a. $C_5H_{10}O_2$, Valeric Acid, 102.13 g/mol

b. H_3PO_3, Phosphorous acid, 82 g/mol

7. For each compound, write the condensed formula, name the compound, and give its molar mass.

a. $C_2H_5NH_2$, Ethylamine, 45.08 g/mol

b. HIO_3, Iodic acid, 175.91 g/mol

8. Calculate the number of moles in 5.00×10^2 g of each substance. How many molecules or formula units are present in each sample?

a. 5.37×10^{24} molecules

b. 3.01×10^{24} formula units

c. 8.80×10^{23} molecules

d. 4.04×10^{24} formula units

e. 6.84×10^{24} molecules

9. Calculate the mass in grams of each sample.

a. 47.9 grams

b. 384 grams

c. 537 grams

10. Give the number of molecules or formula units in each sample.

a. 7.83×10^{21} molecules

b. 6.20×10^{23} molecules

c. 1.60×10^{23} molecules

11. Give the number of moles in each sample.

a. 1590 moles

b. 6010 moles

c. 1.15×10^{5} moles or 115000 moles

12. Solutions of iodine are used as antiseptics and disinfectants. How many iodine atoms correspond to 11.0 g of molecular iodine (I_2)?

2.61×10^{22} molecules

13. What is the total number of atoms in each sample?

a. 2.60×10^{23} atoms

b. 1.006×10^{25} atoms

c. 1.09×10^{23} atoms

d. 2.41×10^{24} atoms

14. What is the total number of atoms in each sample?

a. 5.9×10^{23} atoms

b. 2.8×10^{24} atoms

c. 3.31×10^{24} atoms

d. 8.15×10^{24} atoms

15. What is the total number of atoms in each sample?

a. 3.69×10^{22} atoms

b. 1.13×10^{23} atoms

c. 8.54×10^{22} atoms

d. 3.50×10^{23} atoms

16.

a. False, the number of molecules in 0.5 mol Cl2 are the same amount of molecules in H2

b. False, the number of molecules in H2 is 2 x (6.022 x10^23) H atoms

c. True, 2 H (1.01 amu) + 1 O (16.01) = 18.0 amu

d. True, C6H6 -> 12(6) + 1(6) = 78 amu

17. Complete the following table

a. 0.39

b. 2.36x10^23

c. 7.08x10^23

d. 482.8

e. 1.71x10^24

f. 8.55x10^24

g. 7932.7

h. 148.3

i. 5.36x10^26

j. 46938.5

k. 425.7

l. 1276.98

m. 126.5

n. 7.77x10^23

o. 5.44x10^24

p. 0.14

q. 8.27x10^22

r. 1.65x10^24

s. 34358

t. 406.8

u. 1.23x10^2

18. Give the formula mass or the molecular mass of each substance.

a. 261.67 amu
b. 301.04 amu
c. 286.98 amu
d. 551.73 amu

19. Give the formula mass or the molecular mass of each substance.

a. 273.21 amu
b. 69.62 amu
c. 330.04 amu
d. 426.99 amu

5.6-5.9: Percent Composition, Empirical Formula, and Molecular Formula

Conceptual Problems

1. What is the relationship between an empirical formula and a molecular formula
2. Construct a flowchart showing how you would determine the empirical formula of a compound from its percent composition.

Numerical Problems

1. What is the mass percentage of water in each hydrate?

a. $H_3AsO_4 \cdot 5H_2O$

b. $NH_4NiCl_3 \cdot 6H_2O$

c. $Al(NO_3)_3 \cdot 9H_2O$

2. What is the mass percentage of water in each hydrate?

a. $CaSO_4 \cdot 2H_2O$

b. $Fe(NO_3)_3 \cdot 9H_2O$

c. $(NH_4)_3ZrOH(CO_3)_3 \cdot 2H_2O$

3. Which of the following has the greatest mass percentage of oxygen—$KMnO_4$, $K_2Cr_2O_7$, or Fe_2O_3?

4. Which of the following has the greatest mass percentage of oxygen—$ThOCl_2$, $MgCO_3$, or NO_2Cl?

5. Calculate the percent composition of the element shown in bold in each compound.

   a. Sb**Br**$_3$

   b. **As**$_2$I$_4$

   c. Al**P**O$_4$

   d. **C**$_6$H$_{10}$O

6. Calculate the percent composition of the element shown in bold in each compound.

   a. H**Br**O$_3$

   b **Cs**ReO$_4$

   c. **C**$_3$H$_8$O

   d. Fe**S**O$_4$

7. A sample of a chromium compound has a molar mass of 151.99 g/mol. Elemental analysis of the compound shows that it contains 68.43% chromium and 31.57% oxygen. What is the identity of the compound?

8. The percentages of iron and oxygen in the three most common binary compounds of iron and oxygen are given in the following table. Write the empirical formulas of these three compounds.

Compound	% Iron	% Oxygen	Empirical Formula
1	69.9	30.1	
2	77.7	22.3	
3	72.4	27.6	

9. What is the mass percentage of water in each hydrate?

   a. LiCl·H$_2$O

   b. MgSO$_4$·7H$_2$O

   c. Sr(NO$_3$)$_2$·4H$_2$O

10. What is the mass percentage of water in each hydrate?

   a. CaHPO$_4$·2H$_2$O

   b. FeCl$_2$·4H$_2$O

   c. Mg(NO$_3$)$_2$·4H$_2$O

11. Two hydrates were weighed, heated to drive off the waters of hydration, and then cooled. The residues were then reweighed. Based on the following results, what are the formulas of the hydrates?

Compound	Initial Mass (g)	Mass after Cooling (g)
NiSO$_4$·xH$_2$O	2.08	1.22
CoCl$_2$·xH$_2$O	1.62	0.88

12. Which contains the greatest mass percentage of sulfur—FeS_2, $Na_2S_2O_4$, or Na_2S?

13. Given equal masses of each, which contains the greatest mass percentage of sulfur—$NaHSO_4$ or K_2SO_4?

14. Calculate the mass percentage of oxygen in each polyatomic ion.

   a. bicarbonate

   b. chromate

c. acetate

d. sulfite

15. Calculate the mass percentage of oxygen in each polyatomic ion.

a. oxalate

b. nitrite

c. dihydrogen phosphate

d. thiocyanate

16. The empirical formula of garnet, a gemstone, is $Fe_3Al_2Si_3O_{12}$. An analysis of a sample of garnet gave a value of 13.8% for the mass percentage of silicon. Is this consistent with the empirical formula?

17. A compound has the empirical formula C_2H_4O, and its formula mass is 88 g. What is its molecular formula?

18. Mirex is an insecticide that contains 22.01% carbon and 77.99% chlorine. It has a molecular mass of 545.59 g. What is its empirical formula? What is its molecular formula?

27. Calculate the formula mass or the molecular mass of each compound.

a. $MoCl_5$

b. B_2O_3

c. bromobenzene

d. cyclohexene

e. phosphoric acid

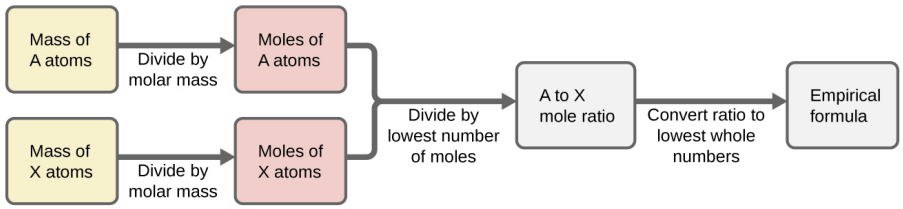
f. ethylamine

Conceptual Answers

1) What is the relationship between an empirical formula and a molecular formula

- An empirical formula refers to the simplest ratio of elements that is obtained from a chemical formula while a molecular formula is calculated to show the actual formula of a molecular compound.

2) Construct a flowchart showing how you would determine the empirical formula of a compound from its percent composition.



Numerical Answers

a. What is the formula mass of each species?

a. 53.49146 amu

b. 49.0072 amu

c. 58.3197 amu

d. 310.177 amu

e. 73.891 amu

f. 81.07 amu

b. What is the molecular or formula mass of each compound?

a.158.034 amu

b. 142.04 amu

c. 27.0253 amu

d. 97.181 amu

e. 124.1 amu

f. 65.99 amu

1. To two decimal places, the percentages are:

   a. 5.97%

   b. 37.12%

   c. 43.22%

2. Percentage of Oxygen in each hydrates are:

   a. 20.93%

   b. 40.13%

   c. 9.52%

3. % oxygen: $KMnO_4$, 40.50%; $K_2Cr_2O_7$, 38.07%; Fe_2O_3, 30.06%

4. % oxygen: ThOCl2, 5.02%; MgCO3, 56.93%; NO2Cl, 39.28%

5. To two decimal places, the percentages are:

   a. 66.32% Br

   b. 22.79% As

   c. 25.40% P

   d. 73.43% C

6.

   a. 61.98% Br

   b. 34.69% Cs

   c. 59.96% C

   d. 21.11% S

7. Cr_2O_3.

8. Empirical Formulas

   1. Fe_2O_3
   2. Fe_4O_4
   3. Fe_6O_8

9. To two decimal places, the percentages are:

   a. 29.82%

   b. 51.16%

   c. 25.40%

10. What is the mass percentage of water in each hydrate?

    a. 20.94%

    b. 36.25%

    c. 32.70%

11. $NiSO_4 \cdot 6H_2O$ and $CoCl_2 \cdot 6H_2O$

12. FeS_2

13. $NaHSO_4$

14. Calculate the mass percentage of oxygen in each polyatomic ion.

    a. 78.66%

    b. 55.17%

    c. 54.19%

    d. 59.95%

15.

    a. 72.71%

    b. 69.55%

    c. 65.99%

    d. 0%

16. The empirical formula of garnet, a gemstone, is $Fe_3Al_2Si_3O_{12}$. An analysis of a sample of garnet gave a value of 13.8% for the mass percentage of silicon. Is this consistent with the empirical formula?

No, the calculated mass percentage of silicon in garnet is 16.93%

17. $C_4H_8O_2$

18.

Empirical Formula: $C_{10}Cl_{12}$

Molecular Formula: $C_{10}Cl_{12}$

19. How many moles of CO_2 and H_2O will be produced by combustion analysis of 0.010 mol of styrene?

Moles of CO2: 0.08 mol CO_2

Moles of H2O: 0.04 mol H_2O

20. How many moles of CO_2, H_2O, and N_2 will be produced by combustion analysis of 0.0080 mol of aniline?

Mole of CO2: 0.048 mol CO_2

Mole of H2O: 0.028 mol H_2O

Mole of N2: 0.004 mol N_2

21. How many moles of CO_2, H_2O, and N_2 will be produced by combustion analysis of 0.0074 mol of aspartame?

Mole of CO2: 0.104 mol CO_2

Mole of H2O: 0.666 mol H_2O

Mole of N2: 0.0074 mol N_2

22. How many moles of CO_2, H_2O, N_2, and SO_2 will be produced by combustion analysis of 0.0060 mol of penicillin G?

Mole of CO2: 0.096 mol CO_2

Mole of H2O: 0.054 mol H_2O

Mole of N2: 0.060 mol N_2

Mole of SO2: 0.060 mol SO_2

23.

    a. 27.6 mg C and 1.98 mg H

    b. 5.2 mg O

c. 15%

d. C_7H_6O

e. C_7H_6O

24. Salicylic acid is used to make aspirin. It contains only carbon, oxygen, and hydrogen. Combustion of a 43.5 mg sample of this compound produced 97.1 mg of CO_2 and 17.0 mg of H_2O.

a. What is the mass of oxygen in the sample?

70.4mg

b. What is the mass percentage of oxygen in the sample?

61.70%

c. What is the empirical formula of salicylic acid?

$C_7H_6O_3$

d. The molar mass of salicylic acid is 138.12 g/mol. What is its molecular formula?

$C_7H_6O_3$

25. hydrocyanic acid, HCN

26. Calculate the formula mass or the molecular mass of each compound.

a. 130.1849 amu

b. 60.1 amu

c. 158.034 amu

d. 323.4 amu

e. 82.07 amu

f. 106.17 amu

27. To two decimal places, the values are:

a. 273.23 amu

b. 69.62 amu

c. 157.01 amu

d. 82.14 amu

e. 98.00 amu

f. 45.08 amu

28. Cyclobutene

29. Urea
