Chapter 6. Chemical Calculations: Formula Masses, Moles, and Chemical Equations

Introduction to Inorganic Chemistry
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Online Tests on Following days
March 24, 2017: Test 1 (Chapters 1-3)
April 10, 2017 : Test 2 (Chapters 4-5)
April 28, 2017: Test 3 (Chapters 6,7 &8)
May 12, 2017 : Test 4 (Chapters 9, 10 &11)
May 15, 2017: Make Up Exam: Chapters 1-11)

.

Chapter 6

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Section 6.1

Formula Masses

Atomic Mass of Cu 63.55 amu (g/mol)

Formula Mass of $CaCl_2$ = 110.98 amu (g/mol)
(2 × 35.45) + 40.08

Molecular Mass of H_2O = 18.02 amu (g/mol)
(2 × 12.01.45) + (6 x 1.008)

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Section 6.2

The Mole: A Counting Unit for Chemists

A Mole

- The amount of a substance that contains as many elementary particles (atoms, molecules, or formula units) as there are atoms in exactly 12 grams of pure ^{12}C.
- 1 mole of anything = 6.02×10^{23} units of that thing (Avogadro's number).
- 1 mole C = 6.022×10^{23} C atoms = 12.01 g C

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Section 6.3

The Mass of a Mole

Molar Mass (g/mol)
[molecular or formula mass (weight)]
Mass in grams of one mole of the substance:

Molar Mass of N = 14.01 g/mol

Molar Mass of H_2O = 18.02 g/mol (molecular weight)
(2 × 1.008) + 16.00

Molar Mass of $Ba(NO_3)_2$ = 261.35 g/mol (Formula Weight)
137.33 + (2 × 14.01) + (6 × 16.00)

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Section 6.3

The Mass of a Mole

Exercise

Calculate the mass, in grams, of a 2.5-mole sample of ethane, C_2H_6.

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Section 6.3

The Mass of a Mole

Exercise

Calculate the mass, in grams, of a 2.5-mole sample of ethane, C_2H_6.

Molecular weight of C_2H_6

(2 × 12.01.45) + (6 x 1.008) = **30.068 g/mol C_2H_6**

$$2.5\ \text{mol}\ C_2H_6 \times \left(\frac{30.068\ \text{g}\ C_2H_6}{1\ \text{mol}\ C_2H_6}\right) = 75\ \text{g}\ C_2H_6$$

Section 6.3

The Mass of a Mole

Exercise

Calculate the mass, in grams, of a 2.5-mole sample of ethane, C_2H_6.

$$2.5\ \text{mol}\ C_2H_6 \times \left(\frac{30.068\ \text{g}\ C_2H_6}{1\ \text{mol}\ C_2H_6}\right) = 75\ \text{g}\ C_2H_6$$

75 g C_2H_6

Section 6.3

The Mass of a Mole

Exercise

Calculate the number of moles in 50.0 g of H_2O.

Section 6.3

The Mass of a Mole

Exercise

Calculate the number of moles in 50.0 g of H_2O.

Molecular weight of H_2O

(2 × 1.008) + 16.00 = 18.016 g/mol H_2O

$$50.0\ \text{g}\ H_2O \times \left(\frac{1\ \text{mol}\ H_2O}{18.016\ \text{g}\ H_2O}\right) = 2.78\ \text{mol}\ H_2O$$

Section 6.3

The Mass of a Mole

Exercise

Calculate the number of moles in 50.0 g of H_2O.

Molecular weight of H_2O = 18.016 g/mol

$$50.0\ \text{g}\ H_2O \times \left(\frac{1\ \text{mol}\ H_2O}{18.016\ \text{g}\ H_2O}\right) = 2.78\ \text{mol}\ H_2O$$

2.78 mol H_2O

Section 6.4

Chemical Formulas and the Mole Concept

Chemical Formula – Microscopic View

- The numerical subscripts in a chemical formula give the number of atoms of the various elements present in 1 formula unit of the substance.
  - In one molecule of P_2O_5, two atoms of phosphorus and five atoms of oxygen are present.

Section 6.4

Chemical Formulas and the Mole Concept

Chemical Formula – Macroscopic View (mole)

- Indicates the number of moles of atoms of each element present in one mole of a substance.
  - In one mole of P_2O_5, two moles of phosphorus and five moles of oxygen are present.

Section 6.4

Chemical Formulas and the Mole Concept

Exercise

How many moles of carbon atoms and hydrogen atoms are present in a 2.5-mole sample of ethane, C_2H_6?

Mole to atom conversion factor is used based on number of atoms in the formula

$\frac{2 \text{ mol C}}{1 \text{ mol } C_2H_6}$ $\frac{6 \text{ mol H}}{1 \text{ mol } C_2H_6}$

Then use mole atom conversion get number atoms

$\frac{1 \text{ mol C}}{6.02 \times 10^{23} \text{ C atoms}}$ $\frac{1 \text{ mol H}}{6.02 \times 10^{23} \text{ H atoms}}$

Section 6.4

Chemical Formulas and the Mole Concept

Exercise

How many moles of carbon atoms and hydrogen atoms are present in a 2.5-mole sample of ethane, C_2H_6?

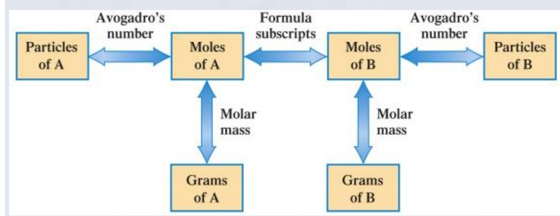
$$2.5 \text{ mol } C_2H_6 \times \left(\frac{2 \text{ mol C}}{1 \text{ mol } C_2H_6}\right) = 5.0 \text{ mol C atoms}$$

$$2.5 \text{ mol } C_2H_6 \times \left(\frac{6 \text{ mol H}}{1 \text{ mol } C_2H_6}\right) = 15 \text{ mol H atoms}$$

Section 6.5

The Mole and Chemical Calculations

Let's Put It All Together!



Section 6.5

The Mole and Chemical Calculations

Concept Check

Which of the following is closest to the average mass of one atom of copper?

a) 63.55 g
b) 52.00 g
c) 58.93 g
d) 65.38 g
e) 1.055×10^{-22} g

$$1 \text{ Cu atom} \times \left(\frac{1 \text{ mol Cu}}{6.02 \times 10^{23} \text{ Cu atoms}}\right) \times \left(\frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}}\right)$$

Section 6.5

The Mole and Chemical Calculations

Concept Check

Which of the following is closest to the average mass of one atom of copper?

a) 63.55 g
b) 52.00 g
c) 58.93 g
d) 65.38 g
e) 1.055×10^{-22} g

$$1 \text{ Cu atom} \times \left(\frac{1 \text{ mol Cu}}{6.02 \times 10^{23} \text{ Cu atoms}}\right) \times \left(\frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}}\right) = 1.055 \times 10^{-22} \text{ g Cu}$$

Section 6.5
The Mole and Chemical Calculations

Concept Check

Calculate the number of copper atoms in a 63.55 g sample of copper.

$$63.55 \text{ g Cu} \times \left(\frac{1 \text{ mol Cu}}{63.55 \text{ g Cu}}\right) \times \left(\frac{6.02 \times 10^{23} \text{ Cu atoms}}{1 \text{ mol Cu}}\right) = 6.02 \times 10^{23} \text{ Cu atoms}$$

Section 6.5
The Mole and Chemical Calculations

Concept Check

Calculate the number of copper atoms in a 63.55 g sample of copper.

6.022×10^{23} Cu atoms

Section 6.5
The Mole and Chemical Calculations

Concept Check

Which of the following 100.0 g samples contains the greatest number of atoms?

a) Magnesium
b) Zinc
c) Silver

Section 6.5
The Mole and Chemical Calculations

Concept Check

Which of the following 100.0 g samples contains the greatest number of atoms?

a) Magnesium
b) Zinc
c) Silver

$$100.0 \text{ g Mg} \times \left(\frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}}\right)\left(\frac{6.02 \times 10^{23} \text{ Mg atoms}}{1 \text{ mol Mg}}\right) = 2.476 \times 10^{24} \text{ Mg atoms}$$

$$100.0 \text{ g Zn} \times \left(\frac{1 \text{ mol Zn}}{65.38 \text{ g Zn}}\right)\left(\frac{6.02 \times 10^{23} \text{ Zn atoms}}{1 \text{ mol Zn}}\right) = 9.208 \times 10^{23} \text{ Zn atoms}$$

$$100.0 \text{ g Ag} \times \left(\frac{1 \text{ mol Ag}}{107.9 \text{ g Ag}}\right)\left(\frac{6.02 \times 10^{23} \text{ Ag atoms}}{1 \text{ mol Ag}}\right) = 5.579 \times 10^{23} \text{ Ag atoms}$$

Section 6.5
The Mole and Chemical Calculations

Exercise

Rank the following according to number of atoms (greatest to least):

a) 107.9 g of silver
b) 70.0 g of zinc
c) 21.0 g of magnesium

a) $107.9 \text{ g Ag} \times \left(\frac{1 \text{ mol Ag}}{107.9 \text{ g Ag}}\right) \times \left(\frac{6.02 \times 10^{23} \text{ Ag atoms}}{1 \text{ mol Ag}}\right) = 6.02 \times 10^{23} \text{ Ag atoms}$

b) $70.0 \text{ g Zn} \times \left(\frac{1 \text{ mol Zn}}{65.38 \text{ g Zn}}\right) \times \left(\frac{6.02 \times 10^{23} \text{ Zn atoms}}{1 \text{ mol Zn}}\right) = 6.44 \times 10^{23} \text{ Zn atoms}$

c) $21.0 \text{ g Mg} \times \left(\frac{1 \text{ mol Mg}}{24.31 \text{ g Mg}}\right) \times \left(\frac{6.02 \times 10^{23} \text{ Mg atoms}}{1 \text{ mol Mg}}\right) = 5.20 \times 10^{23} \text{ Mg atoms}$

Section 6.5
The Mole and Chemical Calculations

Exercise

Rank the following according to number of atoms (greatest to least):

a) 107.9 g of silver
b) 70.0 g of zinc
c) 21.0 g of magnesium

b) a) c)

Section 6.5

The Mole and Chemical Calculations

Exercise

Consider separate 100.0 gram samples of each of the following:

H_2O, N_2O, $C_3H_6O_2$, CO_2

– Rank them from greatest to least number of oxygen atoms.

H_2O = 18.02, N_2O = 46.01 , $C_3H_6O_2$= 74.09, CO_2 = 44.01 g/mol

H_2O = 5.549, N_2O = 2.173 , $C_3H_6O_2$= 1.349, CO_2 = 2.272 mol

O = 5.549, O = 2.173, $C_3H_6O_2$= 2.698, CO_2 = 4.544 mol O

Section 6.5

The Mole and Chemical Calculations

Exercise

Consider separate 100.0 gram samples of each of the following:

H_2O, N_2O, $C_3H_6O_2$, CO_2

– Rank them from greatest to least number of oxygen atoms.

H_2O, CO_2, $C_3H_6O_2$, N_2O

5.549 4.544 2.698 2.173 mol O

Section 6.6

Writing and Balancing Chemical Equations

A Representation of a Chemical Reaction

- A written statement that uses chemical symbols and chemical formulas to describe the changes that occur in a chemical reaction.

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

reactants products

- Reactants are always placed on the left side of the arrow, products are always placed on the right side of the arrow.

Section 6.6

Writing and Balancing Chemical Equations

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

When the equation is balanced.

- All atoms present in the reactants are accounted for in the products.
- 1 mole of ethanol reacts with 3 moles of oxygen to produce 2 moles of carbon dioxide and 3 moles of water.

Section 6.6

Writing and Balancing Chemical Equations

Equation Coefficient

- A number that is placed to the left of a chemical formula in a chemical equation; it changes the amount, but not the identity of the substance.
- The coefficients in the balanced equation have nothing to do with the amount of each reactant that is used/given in the problem.

Section 6.6

Writing and Balancing Chemical Equations

- The balanced equation represents a ratio of reactants and products, not what actually “happens” during a reaction.
- Use the coefficients in the balanced equation to calculate/decide the amount of each reactant that is used, and the amount of each product that is formed.

Section 6.6
Writing and Balancing Chemical Equations

Guidelines for Balancing Chemical Equations

1. Examine the equation and pick one element to balance first.
2. Then pick a second element to balance, and so on.
3. As a final check, count atoms on each side of the equation.

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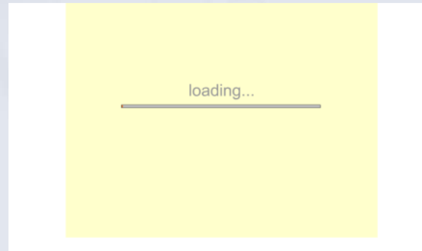
Section 6.6
Writing and Balancing Chemical Equations



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Section 6.6
Writing and Balancing Chemical Equations

Exercise

Which of the following correctly balances the chemical equation given below?

$CaO + C \rightarrow CaC_2 + CO_2$

I. $CaO_2 + 3C \rightarrow CaC_2 + CO_2$
II. $2CaO + 5C \rightarrow 2CaC_2 + CO_2$
III. $CaO + (2.5)C \rightarrow CaC_2 + (0.5)CO_2$
IV. $4CaO + 10C \rightarrow 4CaC_2 + 2CO_2$

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Section 6.6
Writing and Balancing Chemical Equations

Exercise

Which of the following correctly balances the chemical equation given below?

$CaO + C \rightarrow CaC_2 + CO_2$

I. $CaO_2 + 3C \rightarrow CaC_2 + CO_2$
II. $2CaO + 5C \rightarrow 2CaC_2 + CO_2$
III. $CaO + (2.5)C \rightarrow CaC_2 + (0.5)CO_2$
IV. $4CaO + 10C \rightarrow 4CaC_2 + 2CO_2$

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Section 6.6
Writing and Balancing Chemical Equations

Concept Check

Which of the following are true concerning balanced chemical equations? There may be more than one true statement.

I. The number of molecules is conserved.
II. The coefficients tell you how much of each substance you have.
III. Atoms are neither created nor destroyed. The coefficients indicate the mass ratios of the substances used.
IV. The sum of the coefficients on the reactant side equals the sum of the coefficients on the product side.

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Section 6.6
Writing and Balancing Chemical Equations

Concept Check

Which of the following are true concerning balanced chemical equations? There may be more than one true statement.

I. The number of molecules is conserved.
II. The coefficients tell you how much of each substance you have.
III. Atoms are neither created nor destroyed.
IV. The coefficients indicate the mass ratios of the substances used.
V. The sum of the coefficients on the reactant side equals the sum of the coefficients on the product side.

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Section 6.6

Writing and Balancing Chemical Equations

Notice

- The number of atoms of each type of element must be the same on both sides of a balanced equation.
- Subscripts must not be changed to balance an equation.
- A balanced equation tells us the ratio of the number of molecules/units which react and are produced in a chemical reaction.
- Coefficients can be fractions, although they are usually given as lowest integer multiples.

Section 6.7

Chemical Equations and the Mole Concept

Coefficients in a Balanced Chemical Equation

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

- One molecule of C_2H_5OH reacts with three molecules of O_2 to produce two molecules of CO_2 and three molecules of H_2O.
- One mole of C_2H_5OH reacts with three moles of O_2 to produce two moles of CO_2 and three moles of H_2O.

Section 6.7

Chemical Equations and the Mole Concept

Can Be Used to Generate mole Conversion Factors

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

- 1 mole of C_2H_5OH produces 2 moles of CO_2 and 3 moles of H_2O.

$$\left(\frac{1\text{ mol }C_2H_5OH}{2\text{ mol }CO_2}\right) \text{ and } \left(\frac{2\text{ mol }CO_2}{1\text{ mol }C_2H_5OH}\right)$$

$$\left(\frac{1\text{ mol }C_2H_5OH}{3\text{ mol }H_2O}\right) \text{ and } \left(\frac{3\text{ mol }H_2O}{1\text{ mol }C_2H_5OH}\right)$$

Section 6.7

Chemical Equations and the Mole Concept

Can Be Used to Generate Conversion Factors

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

- 1 mole of C_2H_5OH reacts with 3 moles of O_2.

$$\left(\frac{1\text{ mol }C_2H_5OH}{3\text{ mol }O_2}\right) \text{ and } \left(\frac{3\text{ mol }O_2}{1\text{ mol }C_2H_5OH}\right)$$

Section 6.8

Chemical Calculations Using Chemical Equations

Stoichiometric Calculations

- Chemical equations can be used to relate the masses of reacting chemicals.

Section 6.8

Chemical Calculations Using Chemical Equations

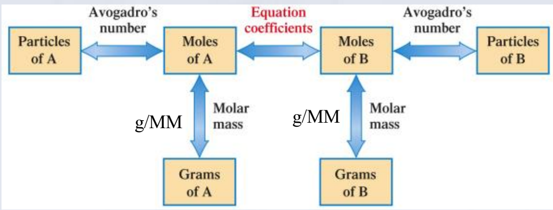
Calculating Masses of Reactants and Products in Reactions

1. Balance the equation for the reaction.
2. Convert the known mass of the reactant or product to moles of that substance.
3. Use the balanced equation to set up the appropriate mole ratios.
4. Use the appropriate mole ratios to calculate the number of moles of desired reactant or product.
5. Convert from moles back to grams if required by the problem.

Section 6.8

Chemical Calculations Using Chemical Equations

Calculating Masses of Reactants and Products in Reactions



Section 6.8

Chemical Calculations Using Chemical Equations

Exercise (Part I)

Methane (CH_4) reacts with the oxygen in the air to produce carbon dioxide and water.

Ammonia (NH_3) reacts with the oxygen in the air to produce nitrogen monoxide and water.

– Write balanced equations for each of these reactions.

Section 6.8

Chemical Calculations Using Chemical Equations

Exercise (Part I)

Methane (CH_4) reacts with the oxygen in the air to produce carbon dioxide and water.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Ammonia (NH_3) reacts with the oxygen in the air to produce nitrogen monoxide and water.

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

– Write balanced equations for each of these reactions.

Section 6.8

Chemical Calculations Using Chemical Equations

Exercise (Part II)

Methane (CH_4) reacts with the oxygen in the air to produce carbon dioxide and water.

Ammonia (NH_3) reacts with the oxygen in the air to produce nitrogen monoxide and water.

– What mass of ammonia would produce the same amount of water as 1.00 g of methane reacting with excess oxygen?

Section 6.8

Chemical Calculations Using Chemical Equations

Let's Think About It

- Where are we going?
  - To find the mass of ammonia that would produce the same amount of water as 1.00 g of methane reacting with excess oxygen.
- How do we get there?
  - We need to know:
    - How much water is produced from 1.00 g of methane and excess oxygen.
    - How much ammonia is needed to produce the amount of water calculated above.

Section 6.8

Chemical Calculations Using Chemical Equations

Exercise (Part II)

$$1 \text{ mol } CH_4 = 2 \text{ mol } H_2O$$

1 g CH_4

$$4 \text{ mol } NH_3 = 6 \text{ mol } H_2O$$

– What mass of ammonia would produce the same amount of water as 1.00 g of methane reacting with excess oxygen? 1.42 g

$$1 \text{ g } CH_4 \times \left(\frac{1 \text{ mol } CH_4}{16.05 \text{ g } CH_4}\right) \times \left(\frac{2 \text{ mol } H_2O}{1 \text{ mol } CH_4}\right) = 1.25 \times 10^{-1} \text{ mol } H_2O$$

$$1.25 \times 10^{-1} \text{ mol } H_2O \times \left(\frac{4 \text{ mol } NH_3}{6 \text{ mol } H_2O}\right) \times \left(\frac{17.04 \text{ g } NH_3}{1 \text{ mol } NH_3}\right) = 1.42 \text{ g } NH_3$$

