

## 6.E: Quantities in Chemical Reactions (Exercise)

### 6.1: The Mole

#### Concept Review Exercise

1. What is a mole?

#### Answer

1. A mole is  $6.022 \times 10^{23}$  things.

#### Exercises

1. How many dozens are in 1 mol? Express your answer in proper scientific notation.
2. A gross is a dozen dozen, or 144 things. How many gross are in 1 mol? Express your answer in proper scientific notation.
3. How many moles of each type of atom are in 1.0 mol of  $\text{C}_6\text{H}_{12}\text{O}_6$ ?
4. How many moles of each type of atom are in 1.0 mol of  $\text{K}_2\text{Cr}_2\text{O}_7$ ?
5. How many moles of each type of atom are in 2.58 mol of  $\text{Na}_2\text{SO}_4$ ?
6. How many moles of each type of atom are in 0.683 mol of  $\text{C}_{34}\text{H}_{32}\text{FeN}_4\text{O}_4$ ? (This is the formula of heme, a component of hemoglobin.)
7. How many molecules are in 16.8 mol of  $\text{H}_2\text{O}$ ?
8. How many formula units are in 0.778 mol of iron(III) nitrate?
9. A sample of gold contains  $7.02 \times 10^{24}$  atoms. How many moles of gold is this?
10. A flask of mercury contains  $3.77 \times 10^{22}$  atoms. How many moles of mercury are in the flask?
11. An intravenous solution of normal saline may contain 1.72 mol of sodium chloride ( $\text{NaCl}$ ). How many sodium and chlorine atoms are present in the solution?
12. A lethal dose of arsenic is  $1.00 \times 10^{21}$  atoms. How many moles of arsenic is this?

#### Answers

1.  $5.018 \times 10^{22}$  dozens
2.  $4.18 \times 10^{21}$  grosses
3. 6.0 mol of C atoms, 12.0 mol of H atoms, and 6.0 mol of O atoms
4. 2.0 mol of K atoms, 2.0 mol of Cr atoms, and 7.0 mol of O atoms
5. 5.16 mol of Na atoms, 2.58 mol of S atoms, and 10.32 mol of O atoms
6. 23.2 mol of C atoms, 21.9 mol of H atoms, 0.683 mol of Fe, 2.73 mol of N and 2.73 mol of O atoms
7.  $1.012 \times 10^{25}$  molecules
8.  $4.69 \times 10^{23}$  formula units
9. 11.7 mol
10. 0.0626 mol
11.  $1.04 \times 10^{24}$  Na atoms and  $1.04 \times 10^{24}$  Cl atoms
12. 0.00166 mol

### 6.2: Atomic and Molar Masses

#### Concept Review Exercises

1. How are molar masses of the elements determined?
2. How are molar masses of compounds determined?

## Answers

1. Molar masses of the elements are the same numeric value as the masses of a single atom in atomic mass units but in units of grams instead.
2. Molar masses of compounds are calculated by adding the molar masses of their atoms.

## Exercises

1. What is the molar mass of Si? What is the molar mass of U?
2. What is the molar mass of Mn? What is the molar mass of Mg?
3. What is the molar mass of  $\text{FeCl}_2$ ? What is the molar mass of  $\text{FeCl}_3$ ?
4. What is the molar mass of  $\text{C}_6\text{H}_6$ ? What is the molar mass of  $\text{C}_6\text{H}_5\text{CH}_3$ ?
5. What is the molar mass of  $(\text{NH}_4)_2\text{S}$ ? What is the molar mass of  $\text{Ca}(\text{OH})_2$ ?
6. What is the molar mass of  $(\text{NH}_4)_3\text{PO}_4$ ? What is the molar mass of  $\text{Sr}(\text{HCO}_3)_2$ ?
7. Aspirin ( $\text{C}_9\text{H}_8\text{O}_4$ ) is an analgesic (painkiller) and antipyretic (fever reducer). What is the molar mass of aspirin?
8. Ibuprofen ( $\text{C}_{13}\text{H}_{18}\text{O}_2$ ) is an analgesic (painkiller). What is the molar mass of ibuprofen?
9. Morphine ( $\text{C}_{17}\text{H}_{19}\text{NO}_3$ ) is a narcotic painkiller. What is the mass of 1 mol of morphine?
10. Heroin ( $\text{C}_{21}\text{H}_{23}\text{NO}_5$ ) is a narcotic drug that is a derivative of morphine. What is the mass of 1 mol of heroin?

## Answers

1. 28.09 g/mol; 238.0 g/mol
2. 54.94 g/mol; 24.31 g/mol
3. 126.75 g/mol; 162.20 g/mol
4. 78.12 g/mol; 92.15 g/mol
5. 68.16 g/mol; 74.10 g/mol
6. 149.12 g/mol; 209.64 g/mol
7. 180.17 g/mol
8. 206.31 g/mol
9. 285.37 g
10. 369.45 g

## 6.3: Mole-Mass Conversions

### Concept Review Exercises

1. What relationship is needed to perform mole-mass conversions?
2. What information determines which conversion factor is used in a mole-mass conversion?

## Answers

1. The atomic or molar mass is needed for a mole-mass conversion.
2. The unit of the initial quantity determines which conversion factor is used.

## Exercises

1. What is the mass of 8.603 mol of Fe metal?
2. What is the mass of 0.552 mol of Ag metal?
3. What is the mass of  $6.24 \times 10^4$  mol of  $\text{Cl}_2$  gas?
4. What is the mass of 0.661 mol of  $\text{O}_2$  gas?
5. What is the mass of 20.77 mol of  $\text{CaCO}_3$ ?
6. What is the mass of  $9.02 \times 10^{-3}$  mol of the hormone epinephrine ( $\text{C}_9\text{H}_{13}\text{NO}_3$ )?
7. How many moles are present in 977.4 g of  $\text{NaHCO}_3$ ?
8. How many moles of erythromycin ( $\text{C}_{37}\text{H}_{67}\text{NO}_{13}$ ), a widely used antibiotic, are in  $1.00 \times 10^3$  g of the substance?

9. Cortisone ( $\text{C}_{21}\text{H}_{28}\text{O}_5$ ) is a synthetic steroid that is used as an anti-inflammatory drug. How many moles of cortisone are present in one 10.0 mg tablet?
10. Recent research suggests that the daily ingestion of 85 mg of aspirin (also known as acetylsalicylic acid,  $\text{C}_9\text{H}_8\text{O}_4$ ) will reduce a person's risk of heart disease. How many moles of aspirin is that?

### Answers

1. 480.5 g
2. 59.6 g
3.  $4.42 \times 10^6$  g
4. 21.2 g
5. 2,079 g
6. 1.65 g
7. 11.63 mol
8. 1.36 mol
9.  $2.77 \times 10^{-5}$  mol
10.  $4.7 \times 10^{-4}$  mol

## 6.4: Mole-Mole Relationships in Chemical Reactions

### Concept Review Exercise

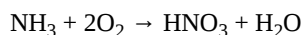
1. How do we relate molar amounts of substances in chemical reactions?

### Answer

1. Amounts of substances in chemical reactions are related by their coefficients in the balanced chemical equation.

### Exercises

1. List the molar ratios you can derive from this balanced chemical equation:



2. List the molar ratios you can derive from this balanced chemical equation



3. Given the following balanced chemical equation,



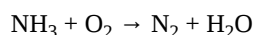
how many moles of NaCl can be formed if 3.77 mol of NaOH were to react?

4. Given the following balanced chemical equation,

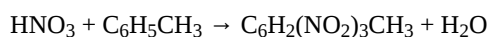


how many moles of  $\text{H}_2\text{O}$  can be formed if 0.0652 mol of  $\text{C}_5\text{H}_{12}$  were to react?

5. Balance the following unbalanced equation and determine how many moles of  $\text{H}_2\text{O}$  are produced when 1.65 mol of  $\text{NH}_3$  react.



6. Trinitrotoluene [ $\text{C}_6\text{H}_2(\text{NO}_2)_3\text{CH}_3$ ], also known as TNT, is formed by reacting nitric acid ( $\text{HNO}_3$ ) with toluene ( $\text{C}_6\text{H}_5\text{CH}_3$ ):



Balance the equation and determine how many moles of TNT are produced when 4.903 mol of  $\text{HNO}_3$  react.

7. Chemical reactions are balanced in terms of molecules and in terms of moles. Are they balanced in terms of dozens? Defend your answer.
8. Explain how a chemical reaction balanced in terms of moles satisfies the law of conservation of matter.

## Answers

- 1 mol  $\text{NH}_3$ ; 2 mol  $\text{O}_2$ ; 1 mol  $\text{HNO}_3$ ; 1 mol  $\text{H}_2\text{O}$
- 2 mol  $\text{C}_2\text{H}_2$ ; 5 mol  $\text{O}_2$ ; 4 mol  $\text{CO}_2$ ; 2 mol  $\text{H}_2\text{O}$
- 3.14 mol
- 0.3912 mol
- $4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O}$ ; 2.48 mol
- $3\text{HNO}_3 + \text{C}_6\text{H}_5\text{CH}_3 \rightarrow \text{C}_6\text{H}_2(\text{NO}_2)_3\text{CH}_3 + 3\text{H}_2\text{O}$ ; 1.634 mol
- Yes, they are still balanced.
- A chemical reaction, balanced in terms of moles, contains the same number of atoms of each element, before and after the reaction. This means that all the atoms and its masses are conserved.

## 6.5: Mole-Mass and Mass-Mass Problems

### Concept Review Exercises

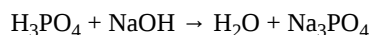
- What is the general sequence of conversions for a mole-mass calculation?
- What is the general sequence of conversions for a mass-mass calculation?

## Answers

- mol first substance  $\rightarrow$  mol second substance  $\rightarrow$  mass second substance
- mass first substance  $\rightarrow$  mol first substance  $\rightarrow$  mol second substance  $\rightarrow$  mass second substance

### Exercises

- Given the following unbalanced chemical equation,



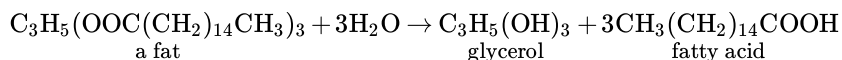
what mass of  $\text{H}_2\text{O}$  is produced by the reaction of 2.35 mol of  $\text{H}_3\text{PO}_4$ ?

- Given the following unbalanced chemical equation,



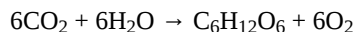
what mass of  $\text{HBr}$  is produced if 0.884 mol of  $\text{C}_2\text{H}_6$  is reacted?

- Certain fats are used to make soap, the first step being to react the fat with water to make glycerol (also known as glycerin) and compounds called fatty acids. One example is as follows:



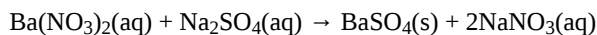
How many moles of glycerol can be made from the reaction of 1,000.0 g of  $\text{C}_3\text{H}_5(\text{OOC}(\text{CH}_2)_{14}\text{CH}_3)_3$ ?

- Photosynthesis in plants leads to the general overall reaction for producing glucose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ):



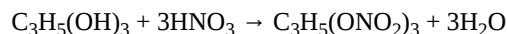
How many moles of glucose can be made from the reaction of 544 g of  $\text{CO}_2$ ?

- Precipitation reactions, in which a solid (called a precipitate) is a product, are commonly used to remove certain ions from solution. One such reaction is as follows:



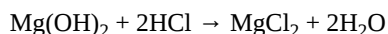
How many grams of  $\text{Na}_2\text{SO}_4$  are needed to precipitate all the barium ions produced by 43.9 g of  $\text{Ba}(\text{NO}_3)_2$ ?

- Nitroglycerin [ $\text{C}_3\text{H}_5(\text{ONO}_2)_3$ ] is made by reacting nitric acid ( $\text{HNO}_3$ ) with glycerol [ $\text{C}_3\text{H}_5(\text{OH})_3$ ] according to this reaction:



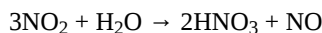
If 87.4 g of  $\text{HNO}_3$  are reacted with excess glycerol, what mass of nitroglycerin can be made?

7. Antacids are bases that neutralize acids in the digestive tract. Magnesium hydroxide  $[\text{Mg}(\text{OH})_2]$  is one such antacid. It reacts with hydrochloric acid in the stomach according to the following reaction:



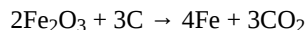
How many grams of HCl can a 200 mg dose of  $\text{Mg}(\text{OH})_2$  neutralize?

8. Acid rain is caused by the reaction of nonmetal oxides with water in the atmosphere. One such reaction involves nitrogen dioxide ( $\text{NO}_2$ ) and produces nitric acid ( $\text{HNO}_3$ ):



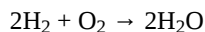
If  $1.82 \times 10^{13}$  g of  $\text{NO}_2$  enter the atmosphere every year due to human activities, potentially how many grams of  $\text{HNO}_3$  can be produced annually?

9. A simplified version of the processing of iron ore into iron metal is as follows:



How many grams of C are needed to produce  $1.00 \times 10^9$  g of Fe?

10. The SS *Hindenburg* contained about  $5.33 \times 10^5$  g of  $\text{H}_2$  gas when it burned at Lakehurst, New Jersey, in 1937. The chemical reaction is as follows:



How many grams of  $\text{H}_2\text{O}$  were produced?

## Answers

1. 127 g
2. 143 g
3. 1.238 mol
4. 2.06 mol
5. 23.9 g
6. 105 g
7. 0.250 g
8.  $1.66 \times 10^{13}$  g
9.  $1.61 \times 10^8$  g
10.  $4.75 \times 10^6$  g

## Additional Exercises

1. If the average male has a body mass of 70 kg, of which 60% is water, how many moles of water are in an average male?
2. If the average female is 60.0 kg and contains 0.00174% iron, how many moles of iron are in an average female?
3. How many moles of each element are present in 2.67 mol of each compound?
  - a. HCl
  - b.  $\text{H}_2\text{SO}_4$
  - c.  $\text{Al}(\text{NO}_3)_3$
  - d.  $\text{Ga}_2(\text{SO}_4)_3$
4. How many moles of each element are present in 0.00445 mol of each compound?
  - a. HCl
  - b.  $\text{H}_2\text{SO}_4$
  - c.  $\text{Al}_2(\text{CO}_3)_3$
  - d.  $\text{Ga}_2(\text{SO}_4)_3$
5. What is the mass of one hydrogen atom in grams? What is the mass of one oxygen atom in grams? Do these masses have a 1:16 ratio, as expected?

6. What is the mass of one sodium atom in grams?
7. If  $6.63 \times 10^{-6}$  mol of a compound has a mass of 2.151 mg, what is the molar mass of the compound?
8. Hemoglobin (molar mass is approximately 64,000 g/mol) is the major component of red blood cells that transports oxygen and carbon dioxide in the body. How many moles are in 0.034 g of hemoglobin?

## Answers

1. 2,330 mol
2. 0.0187 mol
3.
  - a. 2.67 mol of H and 2.67 mol of Cl
  - b. 5.34 mol of H, 2.67 mol of S, and 10.68 mol of O
  - c. 2.67 mol of Al, 8.01 mol of N, and 24.03 mol of O
  - d. 5.34 mol of Ga, 8.01 mol of S, and 32.04 mol of O
4.
  - a. 0.00445 mol of H and 0.00445 mol of Cl
  - b. 0.00890 mol of H, 0.00445 mol of S, and 0.0178 mol of O
  - c. 0.00890 mol of Al, 0.0134 mol of C, and 0.0401 mol of O
  - d. 0.00890 mol of Ga, 0.0134 mol of S, and 0.0534 mol of O
5.  $H = 1.68 \times 10^{-24}$  g and  $O = 2.66 \times 10^{-23}$  g; yes, they are in a 1:16 ratio.
6.  $3.819 \times 10^{-23}$  g
7. 324 g/mol
8.  $5.3 \times 10^{-7}$  mol

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