

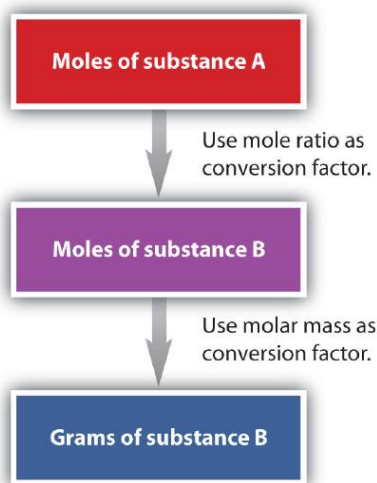
8.4: MAKING MOLECULES- MASS-TO-MASS CONVERSIONS

LEARNING OBJECTIVES

- Convert from mass or moles of one substance to mass or moles of another substance in a chemical reaction.

MOLE TO MASS CONVERSIONS

We have established that a balanced chemical equation is balanced in terms of moles, as well as atoms or molecules. We have used balanced equations to set up ratios, in terms of moles of materials, that we can use as conversion factors to answer stoichiometric questions—such as how many moles of substance A react with so many moles of reactant B. We can extend this technique even further. Recall that we can relate a molar amount to a mass amount using molar mass. We can use that relation to answer stoichiometry questions in terms of the masses of a particular substance, in addition to moles. We do this using the following sequence:



Collectively, these conversions are called mole-mass calculations. Flowchart of mole mass calculations: To convert from moles of substance A to moles of substance B, use the mole ratio conversion factor, and to convert from moles to grams of substance B, use molar mass conversion factor

As an example, consider the balanced chemical equation



If we have 3.59 mol of Fe_2O_3 , how many grams of SO_3 can react with it? Using the mole-mass calculation sequence, we can determine the required mass of SO_3 in two steps. First, we construct the appropriate molar ratio, determined from the balanced chemical equation, to calculate the number of moles of SO_3 needed. Then, using the molar mass of SO_3 as a conversion factor, we determine the mass that this number of moles of SO_3 has.

As usual, we start with the quantity we were given:

$$3.59 \text{ mol } \cancel{\text{Fe}_2\text{O}_3} \times \left(\frac{3 \text{ mol } \text{SO}_3}{1 \text{ mol } \cancel{\text{Fe}_2\text{O}_3}} \right) = 10.77 \text{ mol } \text{SO}_3 \quad (8.4.2)$$

The mol Fe_2O_3 units cancel, leaving mol SO_3 unit. Now, we take this answer and convert it to grams of SO_3 , using the molar mass of SO_3 as the conversion factor:

$$10.77 \cancel{\text{ mol } \text{SO}_3} \times \left(\frac{80.06 \text{ g } \text{SO}_3}{1 \cancel{\text{ mol } \text{SO}_3}} \right) = 862 \text{ g } \text{SO}_3 \quad (8.4.3)$$

Our final answer is expressed to three significant figures. Thus, in a two-step process, we find that 862 g of SO_3 will react with 3.59 mol of Fe_2O_3 . Many problems of this type can be answered in this manner.

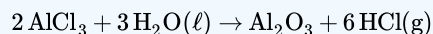
The same two-step problem can also be worked out in a single line, rather than as two separate steps, as follows:

$$3.59 \text{ mol } \cancel{Fe_2O_3} \times \underbrace{\left(\frac{3 \text{ mol } \cancel{SO_3}}{1 \text{ mol } \cancel{Fe_2O_3}} \right)}_{\text{converts to moles of } SO_3} \times \underbrace{\left(\frac{80.06 \text{ g } SO_3}{1 \text{ mol } \cancel{SO_3}} \right)}_{\text{converts to grams of } SO_3} = 862 \text{ g } SO_3$$

We get exactly the same answer when combining all math steps together.

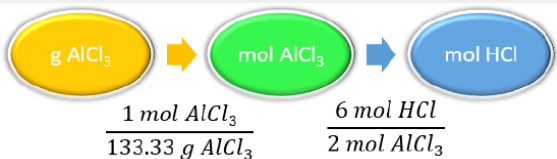
✓ EXAMPLE 8.4.1: GENERATION OF ALUMINUM OXIDE

How many moles of HCl will be produced when 249 g of $AlCl_3$ are reacted according to this chemical equation?



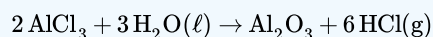
Solution

Solutions to Example 8.5.1

Steps for Problem Solving	Example 8.4.1
Identify the "given" information and what the problem is asking you to "find."	Given: 249 g $AlCl_3$ Find: moles HCl
List other known quantities.	1 mol $AlCl_3$ = 133.33 g $AlCl_3$ 6 mol of HCl to 2 mol $AlCl_3$
Prepare a concept map and use the proper conversion factor.	 <p>Flowchart of needed conversion factors: 1 mole $AlCl_3$ to 133.33 grams $AlCl_3$, and 6 moles HCl to 2 moles $AlCl_3$</p>
Cancel units and calculate.	$249 \text{ g } \cancel{AlCl_3} \times \frac{1 \text{ mol } \cancel{AlCl_3}}{133.33 \text{ g } \cancel{AlCl_3}} \times \frac{6 \text{ mol } HCl}{2 \text{ mol } \cancel{AlCl_3}} = 5.60 \text{ mol } HCl$
Think about your result.	Since 249 g of $AlCl_3$ is less than 266.66 g, the mass for 2 moles of $AlCl_3$ and the relationship is 6 mol of HCl to 2 mol $AlCl_3$, the answer should be less than 6 moles of HCl.

? EXERCISE 8.4.1: GENERATION OF ALUMINUM OXIDE

How many moles of Al_2O_3 will be produced when 23.9 g of H_2O are reacted according to this chemical equation?

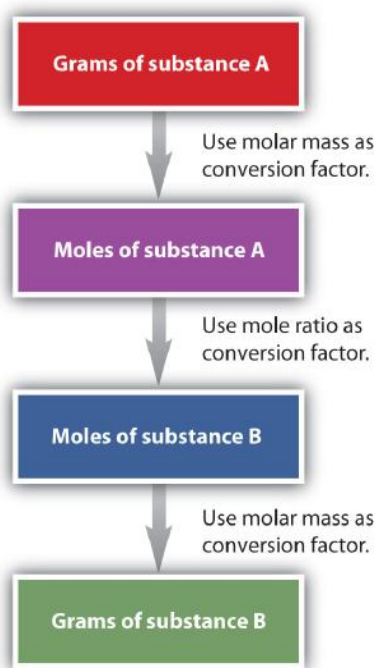


Answer

0.442 mol Al_2O_3

MASS TO MASS CONVERSIONS

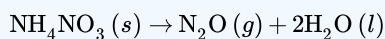
It is a small step from mole-mass calculations to mass-mass calculations. If we start with a known mass of one substance in a chemical reaction (instead of a known number of moles), we can calculate the corresponding masses of other substances in the reaction. The first step in this case is to convert the known mass into moles, using the substance's molar mass as the conversion factor. Then—and only then—we use the balanced chemical equation to construct a conversion factor to convert that quantity to moles of another substance, which in turn can be converted to a corresponding mass. Sequentially, the process is as follows:



This three-part process can be carried out in three discrete steps or combined into a single calculation that contains three conversion factors. The following example illustrates both techniques. Flowchart of mole mass calculations: To convert from grams to moles of substance A, use molar mass conversion factor; To convert from moles of substance A to moles of substance B, use the mole ratio conversion factor, and to convert from moles to grams of substance B, use molar mass conversion factor

✓ EXAMPLE 8.4.2: DECOMPOSITION OF AMMONIUM NITRATE

Ammonium nitrate decomposes to dinitrogen monoxide and water according to the following equation.



In a certain experiment, 45.7 g of ammonium nitrate is decomposed. Find the mass of each of the products formed.

Solutions to Example 8.5.2

Example 8.4.2

Steps for Problem Solving

Identify the "given" information and what the problem is asking you to "find."

Given: 45.7 g NH_4NO_3

Find:

Mass N_2O = ? g

Mass H_2O = ? g

List other known quantities.

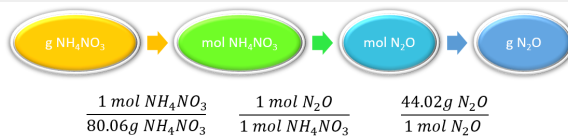
1 mol NH_4NO_3 = 80.06 g

1 mol N_2O = 44.02 g

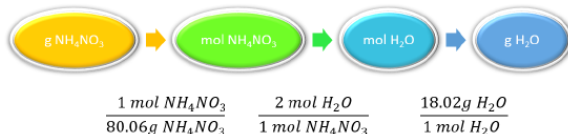
1 mol H_2O = 18.02 g

1 mol NH_4NO_3 to 1 mol N_2O to 2 mol H_2O

Prepare two concept maps and use the proper conversion factor.



Flowchart of conversion factors: 1 mole NH_4NO_3 to 80.06 grams NH_4NO_3 , 1 mole N_2O to 1 mole NH_4NO_3 , 44.02 grams N_2O to 1 mole N_2O



Flowchart of conversion factors: 1 mole NH_4NO_3 to 80.06 grams NH_4NO_3 , 2 moles H_2O to 1 mole NH_4NO_3 , 18.02 grams H_2O to 1 mole H_2O

Cancel units and calculate.

$$45.7 \text{ g } \text{NH}_4\text{NO}_3 \times \frac{1 \text{ mol } \text{NH}_4\text{NO}_3}{80.06 \text{ g } \text{NH}_4\text{NO}_3} \times \frac{1 \text{ mol } \text{N}_2\text{O}}{1 \text{ mol } \text{NH}_4\text{NO}_3} \times \frac{44.02 \text{ g } \text{N}_2\text{O}}{1 \text{ mol } \text{N}_2\text{O}} = 25.1 \text{ g } \text{N}_2\text{O}$$

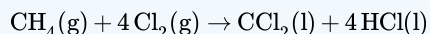
$$45.7 \text{ g } \text{NH}_4\text{NO}_3 \times \frac{1 \text{ mol } \text{NH}_4\text{NO}_3}{80.06 \text{ g } \text{NH}_4\text{NO}_3} \times \frac{2 \text{ mol } \text{H}_2\text{O}}{1 \text{ mol } \text{NH}_4\text{NO}_3} \times \frac{18.02 \text{ g } \text{H}_2\text{O}}{1 \text{ mol } \text{H}_2\text{O}} = 20.6 \text{ g } \text{H}_2\text{O}$$

Think about your result.

The total mass of the two products is equal to the mass of ammonium nitrate which decomposed, demonstrating the law of conservation of mass. Each answer has three significant figures.

? EXERCISE 8.4.2: CARBON TETRACHLORIDE

Methane can react with elemental chlorine to make carbon tetrachloride (CCl_4). The balanced chemical equation is as follows:



How many grams of HCl are produced by the reaction of 100.0 g of CH_4 ?

Answer

908.7g HCl

SUMMARY

- Calculations involving conversions between moles of a substance and the mass of that substance can be done using conversion factors.
- A balanced chemical reaction can be used to determine molar and mass relationships between substances.

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