Mass Relationships in Chemical Reactions

Chapter 3

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Example 3.3

Zinc (Zn) is a silvery metal that is used in making brass (with copper) and in plating iron to prevent corrosion.

How many grams of Zn are in 0.356 mole of Zn?

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Zinc

Example 3.3 (1)

Strategy

We are trying to solve for grams of zinc.

What conversion factor do we need to convert between moles and grams?

Arrange the appropriate conversion factor so that moles cancel and the unit grams are obtained for your answer.

Example 3.3 (2)

Solution

The conversion factor needed to convert between moles and grams is the molar mass. In the periodic table (see inside front cover) we see the molar mass of Zn is 65.39 g. This can be expressed as

$$1\ \text{mol Zn} = 65.39\ \text{g Zn} 1$$

From this equality, we can write two conversion factors

$$\frac{1\ \text{mol Zn}}{65.39\ \text{g Zn}} \text{ and } \frac{65.39\ \text{g Zn}}{1\ \text{mol Zn}}$$

The conversion factor on the right is the correct one.

Example 3.3 (3)

Moles will cancel, leaving unit of grams for the answer. The number of grams of Zn is

$$0.356 \cancel{\text{ mol Zn}} \times \frac{65.39 \cancel{\text{ g Zn}}}{1 \cancel{\text{ mol Zn}}} = 23.3 \text{ g Zn}$$

Thus, there are 23.3 g of Zn in 0.356 mole of Zn.

Check Does a mass of 23.3 g for 0.356 mole of Zn seem reasonable? What is the mass of 1 mole of Zn?

Example 3.4

Sulfur (S) is a nonmetallic element that is present in coal.

When coal is burned, sulfur is converted to sulfur dioxide and eventually to sulfuric acid that gives rise to the acid rain phenomenon.

How many atoms are in 16.3 g of S?

Example 3.4 (1)

Strategy

The question asks for atoms of sulfur. 9am class 8/23 W

We cannot convert directly from grams to atoms of sulfur.

What unit do we need to convert grams of sulfur to in order to convert to atoms?

What does Avogadro's number represent?

Example 3.4 (2)

Solution

We need two conversions: first from grams to moles and then from moles to number of particles (atoms). The first step is similar to Example 3.2. Because

$$1 \text{ mol S} = 32.07 \text{ g S}$$

the conversion factor is

$$\frac{1 \text{ mol S}}{32.07 \text{ g S}}$$

Avogadro's number is the key to the second step. We have

$$1 \text{ mol} = 6.022 \times 10^{23} \text{ particles (atoms)}$$

Example 3.4 (3)

and the conversion factors are

$$\frac{6.022\times10^{23}\ \text{S atoms}}{1\ \text{mol S}} \text{ and } \frac{1\ \text{mol S}}{6.022\times10^{23}\ \text{S atoms}}$$

The conversion factor on the left is the one we need because it has number of S atoms in the numerator.

We can solve the problem by first calculating the number of moles contained in 16.3 g of S, and then calculating the number of S atoms from the number of moles of S:

$$\text{grams of S} \rightarrow \text{moles of S} \rightarrow \text{number of S atoms}$$

Example 3.4 (4)

We can combine these conversions in one step as follows:

$$16.3\ \cancel{\text{g S}} \times \frac{1\ \cancel{\text{mol S}}}{32.07\ \cancel{\text{g S}}} \times \frac{6.022 \times 10^{23}\ \text{S atoms}}{1\ \cancel{\text{mol S}}} = 3.06 \times 10^{23}\ \text{S atoms}$$

Thus, there are 3.06×10^{23} atoms of S in 16.3 g of S.

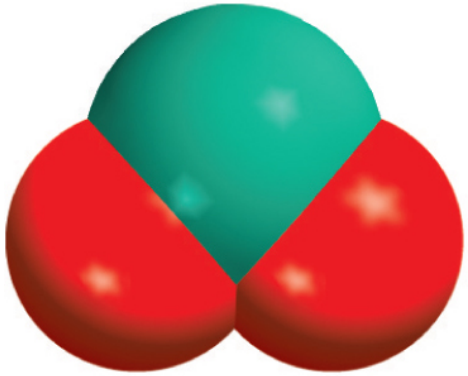
Check

Should 16.3 g of S contain fewer than Avogadro's number of atoms? 10 am class 8/23/17

What mass of S would contain Avogadro's number of atoms?

Molecular Mass

Molecular mass (or molecular weight) is the sum of the atomic masses (in amu) in a molecule.



SO_2

1S	32.07 amu
2O	$+2 \times 16.00$ amu
SO_2	64.07 amu

For any molecule (same #, different unit)

$$\text{molecular mass (amu)} = \text{molar mass (grams)}$$

$$1 \text{ molecule } SO_2 = 64.07 \text{ amu}$$

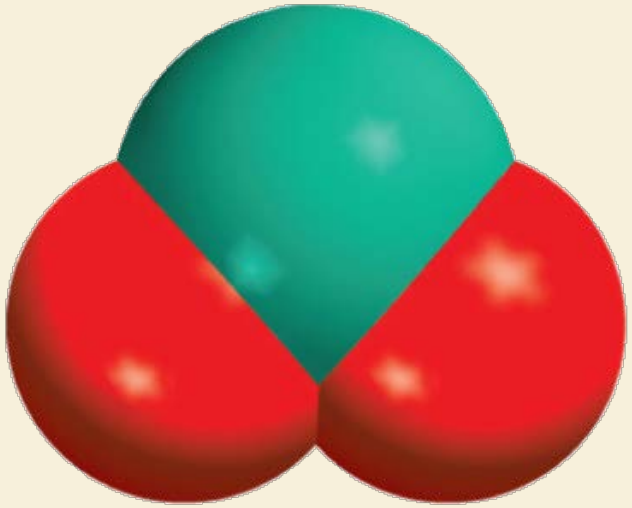
$$1 \text{ mole } SO_2 = 64.07 \text{ g } SO_2$$

Example 3.5

Calculate the molecular masses (in amu) of the following compounds:

(a) sulfur dioxide (SO_2), a gas that is responsible for acid rain

(b) caffeine ($C_8H_{10}N_4O_2$), a stimulant present in tea, coffee, and cola beverages



SO_2

Example 3.5 (1)

Strategy How do atomic masses of different elements combine to give the molecular mass of a compound?

Solution To calculate molecular mass, we need to sum all the atomic masses in the molecule. For each element, we multiply the atomic mass of the element by the number of atoms of that element in the molecule. We find atomic masses in the periodic table (inside front cover).

(a)There are two O atoms and one S atom in SO_2, so that

$$\begin{aligned}\text{molecular mass of } SO_2 &= 32.07\text{amu} + 2(16.00\text{ amu}) \\ &= 64.07\text{ amu}\end{aligned}$$

Example 3.5 (2)

(b) There are eight C atoms, ten H atoms, four N atoms, and two O atoms in caffeine, so the molecular mass of $C_8H_{10}N_4O_2$ is given by

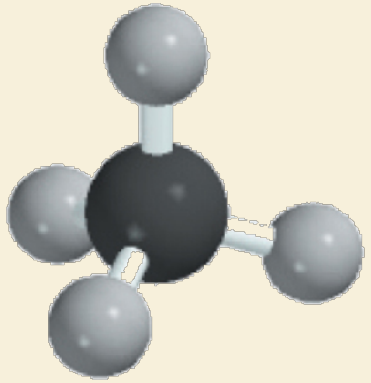
$$8(12.01\ \text{amu}) + 10(1.008\ \text{amu}) + 4(14.01\ \text{amu}) + 2(16.00\ \text{amu})$$

$$= 194.20\ \text{amu}$$

Example 3.6

Methane (CH_4) is the principal component of natural gas.

How many moles of CH_4 are present in 6.07 g of CH_4?



CH_4

Example 3.6 (1)

Strategy

We are given grams of CH_4 and asked to solve for moles of CH_4.

What conversion factor do we need to convert between grams and moles?

Arrange the appropriate conversion factor so that grams cancel and the unit moles are obtained for your answer.

Example 3.6 (2)

Solution

The conversion factor needed to convert between grams and moles is the molar mass. First we need to calculate the molar mass of CH_4, following the procedure in Example 3.5:

$$\begin{aligned}\text{molar mass of } \mathrm{CH_4} &= 12.01\ \mathrm{g} + 4(1.008\ \mathrm{g}) \\ &= 16.04\ \mathrm{g}\end{aligned}$$

Because

$$1\ \mathrm{mol\ CH_4} = 16.04\ \mathrm{g\ CH_4}$$

the conversion factor we need should have grams in the denominator so that the unit g will cancel, leaving the unit mol in the numerator:

$$\frac{1\ \mathrm{mol\ CH_4}}{16.04\ \mathrm{g\ CH_4}}$$

Example 3.6 (3)

We now write,

$$6.07\ \cancel{\text{g CH}_4} \times \frac{1\ \text{mol CH}_4}{16.04\ \cancel{\text{g CH}_4}} = 0.378\ \text{mol CH}_4$$

Thus, there is 0.378 mole of CH_4 in 6.07 g of CH_4. end 9 am & 10 am class 8/25 F

End Exam I

Check

Should 6.07 g of CH_4 equal less than 1 mole of CH_4?

What is the mass of 1 mole of CH_4?