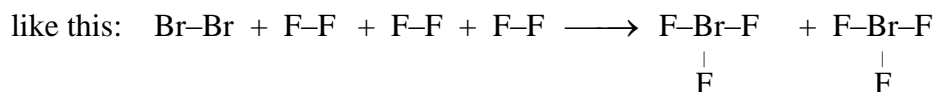


# Stoichiometry

Consider the chemical equation:  $\text{Br}_2(l) + 3 \text{F}_2(g) \longrightarrow 2 \text{BrF}_3(l)$

It is a balanced equation as written. Every atom of bromine (Br) on the reactant side (left side) of the arrow is exactly accounted for on the product side. Likewise the six atoms of fluorine that start out as fluorine gas molecules ( $\text{F}_2$ ) end up in  $\text{BrF}_3$  molecules. We can picture the reaction



So 1 molecule of  $\text{Br}_2$  reacts with 3 molecules of  $\text{F}_2$  to give 2 molecules of  $\text{BrF}_3$ . If this reaction between molecules were run  $6.022 \times 10^{23}$  times, then  $6.022 \times 10^{23}$  molecules (= 1 mole of  $\text{Br}_2$ ) would react with 3 moles of  $\text{F}_2$  and produce 2 moles of  $\text{BrF}_3$ . The reaction could be run any number of times on the molecular level. By this equation every molecule of  $\text{Br}_2$  would react with three molecules of  $\text{F}_2$  to produce 2 molecules of  $\text{BrF}_3$ , or every mole of  $\text{Br}_2$  would react with 3 moles of  $\text{F}_2$  to produce 2 moles of  $\text{BrF}_3$ .

**Problem 1.** Calculate the number of moles of  $\text{BrF}_3$  that can be produced from 5.0 moles of  $\text{Br}_2$  and excess (more than enough to completely react)  $\text{F}_2$ .

We can write the problem this way:  $5.0 \text{ mol Br}_2 = ? \text{ mole BrF}_3$

$$\text{then } 5.0 \text{ mol Br}_2 = 5.0 \text{ mol Br}_2 \times \frac{2 \text{ mol BrF}_3}{1 \text{ mol Br}_2} = 10.0 \text{ mol BrF}_3$$

The conversion factor  $\frac{2 \text{ mol BrF}_3}{1 \text{ mol Br}_2}$  is a valid dimensional analysis conversion factor, because the numerator and denominator are equivalent according to the chemical equation. To have 1 mole of  $\text{Br}_2$  before the reaction is to have 2 moles of  $\text{BrF}_3$  after the reaction.

If the starting quantity is in grams, then it would only require a conversion from grams to moles, and the problem would be solved easily. For example:

**Problem 2.** Determine the number of moles of  $\text{BrF}_3$  that can be produced from 400.0 g of  $\text{Br}_2$  and excess  $\text{F}_2$ .  $400.0 \text{ g Br}_2 = ? \text{ g BrF}_3$

$$400.0 \text{ g Br}_2 = 400.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.8 \text{ g Br}_2} \times \frac{2 \text{ mol BrF}_3}{1 \text{ mol Br}_2} = 5.01 \text{ mol BrF}_3$$

**Problem 3.** Determine the grams of  $\text{BrF}_3$  that can be produced from 75.2 g  $\text{Br}_2$  and excess  $\text{F}_2$

$$75.2 \text{ g Br}_2 = ? \text{ g BrF}_3$$

$$75.2 \text{ g Br}_2 = 75.2 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.8 \text{ g Br}_2} \times \frac{2 \text{ mol BrF}_3}{1 \text{ mol Br}_2} \times \frac{136.9 \text{ g BrF}_3}{1 \text{ mol BrF}_3} = 129. \text{ g BrF}_3$$

This is a fairly standard form for stoichiometry solutions. First convert **grams to moles**, then convert **moles to moles** using coefficients in the equation, then convert **moles to grams**. Notice that the third factor in this solution need not include the 2 moles of  $\text{BrF}_3$ . The 2 moles is accounted for in the mole to moles conversion factor.

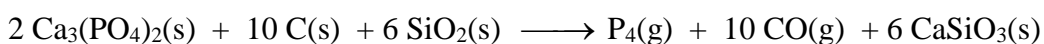
Calculations need not always start from reactants to calculate products. One can calculate reactants starting with products (See Problem 4), or calculate reactants starting from other reactants (See Problem 6), or calculate products starting from other products (See Problem 8).

Problem 4. Calculate the grams of  $F_2$  required in the production of 185.0 g of  $BrF_3$ .

$$185.0 \text{ g } BrF_3 = ? \text{ g } F_2$$

$$185.0 \text{ g } BrF_3 = 185.0 \text{ g } BrF_3 \times \frac{1 \text{ mol } BrF_3}{136.9 \text{ g } BrF_3} \times \frac{3 \text{ mol } F_2}{2 \text{ mol } BrF_3} \times \frac{38.00 \text{ g } F_2}{1 \text{ mol } F_2} = 77.25 \text{ g } F_2$$

Elemental phosphorus is produced industrially from calcium phosphate rock by:



Use this equation to solve the following problems:

Problem 5. Calculate the grams of  $P_4(\text{g})$  that can be formed from  $1.500 \times 10^4$  g of  $\text{Ca}_3(\text{PO}_4)_2$  and excess carbon and silicon dioxide.

Problem 6. Calculate the grams of  $\text{SiO}_2$  needed to react with  $1.500 \times 10^4$  g of  $\text{Ca}_3(\text{PO}_4)_2$ .

Problem 7. Calculate the grams of carbon needed in the production of 500.0 g of phosphorus.

Problem 8. Calculate the grams of  $\text{CaSiO}_3$  that will be produced in the production of 1800.0 g of phosphorus.

Problem 9. Calculate the moles of carbon monoxide gas that will be produced in the reaction of 7000. g of  $\text{Ca}_3(\text{PO}_4)_2$ .

**Answers:**    5. 2996. g  $P_4$                       6. 8716. g  $\text{SiO}_2$                       7. 484.7 g C  
                  8.  $1.013 \times 10^4$  g  $\text{CaSiO}_3$                       9. 112.8 mol CO

## Solutions:

5.  $1.500 \times 10^4$  g of  $\text{Ca}_3(\text{PO}_4)_2 = ?$  g  $\text{P}_4$

$$1.500 \times 10^4 \text{ g of Ca}_3(\text{PO}_4)_2 \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{310.2 \text{ g Ca}_3(\text{PO}_4)_2} \times \frac{1 \text{ mol P}_4}{2 \text{ mol Ca}_3(\text{PO}_4)_2} \times \frac{123.9 \text{ g P}_4}{1 \text{ mol P}_4} = 2996. \text{ g P}_4$$

6.  $1.500 \times 10^4$  g  $\text{Ca}_3(\text{PO}_4)_2 = ?$  g  $\text{SiO}_2$

$$1.500 \times 10^4 \text{ g Ca}_3(\text{PO}_4)_2 \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{310.2 \text{ g Ca}_3(\text{PO}_4)_2} \times \frac{6 \text{ mol SiO}_2}{2 \text{ mol Ca}_3(\text{PO}_4)_2} \times \frac{60.09 \text{ g SiO}_2}{1 \text{ mol SiO}_2} = 8716. \text{ g SiO}_2$$

7. 500.0 g  $\text{P}_4 = ?$  g C

$$500.0 \text{ g P}_4 = 500.0 \text{ g P}_4 \times \frac{1 \text{ mol P}_4}{123.9 \text{ g P}_4} \times \frac{10 \text{ mol C}}{1 \text{ mol P}_4} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 484.7 \text{ g C}$$

8. 1800.0 g  $\text{P}_4 = ?$  g  $\text{CaSiO}_3$

$$1800.0 \text{ g P}_4 = 1800.0 \text{ g P}_4 \times \frac{1 \text{ mol P}_4}{123.90 \text{ g P}_4} \times \frac{6 \text{ mol CaSiO}_3}{1 \text{ mol P}_4} \times \frac{116.16 \text{ g CaSiO}_3}{1 \text{ mol CaSiO}_3} = 10126. \text{ g CaSiO}_3$$

9. 7000. g  $\text{Ca}_3(\text{PO}_4)_2 = ?$  mol CO

$$7000. \text{ g of Ca}_3(\text{PO}_4)_2 = 7000. \text{ g Ca}_3(\text{PO}_4)_2 \times \frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{310.2 \text{ g Ca}_3(\text{PO}_4)_2} \times \frac{10 \text{ mol CO}}{2 \text{ mol Ca}_3(\text{PO}_4)_2} = 112.8 \text{ mol CO}$$