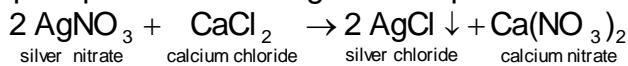


Limiting Reagent Problems

When we mix chemicals together and they react, they recombine their atoms according to the formula equation of the reaction, and they do so in fixed ratios. It's likely that we will add more of one reagent than the ratio calls for, and so we will run out of the other reagent before we've used everything up. The reagent that we run out of first is called the **limiting reagent**, because it limits how long the reaction will go on. We say that the other reagent(s) are **in excess**. There will be some of these reagents left over when the reaction has run its course.

To find the limiting reagent, we must compare the molar amounts of reagents to the mole-to-mole ratio given by the formula equation.

Example 1: A solution containing 17.7 g of AgNO₃ is added to a solution containing 7.53 g of CaCl₂. AgCl precipitates according to the equation:



Determine the mass of silver chloride that precipitates, and the mass and identity of the reagent in excess.

Solution: [1] Convert both reacting quantities to moles, since we're dealing with a reaction.

$$\text{silver nitrate: } 17.7 \text{ g AgNO}_3 \times \frac{1 \text{ mol AgNO}_3}{169.88 \text{ g AgNO}_3} = 0.104 \text{ mol AgNO}_3$$

$$\text{calcium chloride: } 7.53 \text{ g CaCl}_2 \times \frac{1 \text{ mol CaCl}_2}{110.98 \text{ g CaCl}_2} = 0.0679 \text{ mol CaCl}_2$$

[2] Divide the molar amounts of each reagent by that reagent's coefficient in the equation. The lowest answer is the limiting reagent.

$$\text{silver nitrate: } 0.104 \text{ mol} \div 2 = 0.0520 \text{ mol}$$

$$\text{calcium chloride: } 0.0679 \text{ mol} \div 1 = 0.0679 \text{ mol}$$

Silver nitrate is the limiting reagent.

Let's stop for a moment and look at what that means in this problem. Silver nitrate reacts with calcium chloride in a ratio of 2 : 1. We would expect 0.104 mol of AgNO₃ to react completely with 0.0520 mol of CaCl₂, since that's also a 2 : 1 ratio. We would expect 0.0679 mol of CaCl₂ to react with twice that much AgNO₃, 0.136 mol, but we don't have that much. We will run out of silver nitrate before we've used up all our calcium chloride.



[3] Calculate the amounts of any products and reagents involved in the reaction that the question asks for. We'll use conversion fractions and the coefficients in the formula to do this, basing our calculations on the limiting reagent.

$$\text{calcium chloride: } 0.104 \text{ mol AgNO}_3 \times \frac{1 \text{ mol CaCl}_2}{2 \text{ mol AgNO}_3} = 0.0520 \text{ mol CaCl}_2$$

$$\text{silver chloride: } 0.104 \text{ mol AgNO}_3 \times \frac{2 \text{ mol AgCl}}{2 \text{ mol AgNO}_3} = 0.104 \text{ mol AgCl}$$

So 0.104 mol AgCl is precipitated, and 0.0520 mol CaCl₂ is reacted.

[4] Determine the mass of the remaining excess reagent. Since 0.0520 mol of CaCl₂ is used up, and we started with 0.0679 mol of CaCl₂, there is 0.0159 mol of CaCl₂ remaining. We need to convert this to grams.

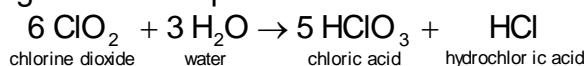
$$0.0159 \text{ mol CaCl}_2 \times \frac{110.98 \text{ g CaCl}_2}{1 \text{ mol CaCl}_2} = 1.76 \text{ g CaCl}_2$$

[5] Determine the mass of the precipitate.

$$0.104 \text{ mol AgCl} \times \frac{143.32 \text{ g AgCl}}{1 \text{ mol AgCl}} = 14.9 \text{ g AgCl}$$

EXERCISES

A. Consider the following balanced equation:



4.25 g of chlorine dioxide and 0.853 g of water are reacted.

- 1) How many moles of ClO₂ are available for reaction?

- 2) How many moles of H₂O are available for reaction?

- 3) Which is the limiting reagent?

- 4) Which is the excess agent?

- 5) How many moles of the excess reagent were actually consumed in the reaction?



6) How many moles of the excess reagent remain after the reaction has finished?

7) How many grams of the excess reagent remain?

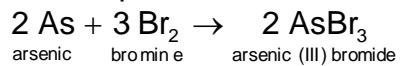
8) How many moles of HClO_3 are produced?

9) How many grams of HClO_3 are produced?

10) How many moles of HCl are produced?

11) How many grams of HCl are produced?

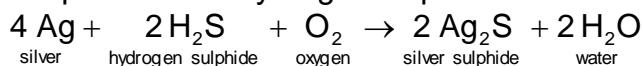
B. Consider the following balanced equation:



1) How many grams of arsenic (III) bromide can be produced when 55.3 g of arsenic is mixed with 125 g of bromine?

2) What is the mass and identity of the reagent in excess?

C. Silver tarnishes in the presence of hydrogen sulphide:



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Silver sulphide is responsible for the black colour. Hydrogen sulphide is released into the air during the decomposition of organic matter.

- 1) How many grams of Ag_2S could be obtained from a mixture of 0.750 g Ag, 0.155 g H_2S and 0.900 g O_2 ?
 - 2) Which is the limiting reagent, and which are the excess reagents? How many grams of the excess reagents remain in excess?
 - 3) How many grams of water are produced in the reaction?

SOLUTIONS

- A. (1) 0.0630 mol (2) 0.0474 mol (3) chlorine dioxide (4) water (5) 0.0315 mol
(6) 0.0159 mol (7) 0.286 g H₂O (8) 0.0525 mol (9) 4.43 g HClO₃ (10) 0.0105 mol
(11) 0.383 g HCl

B. (1) 164 g AsBr₃ (2) 16.2 g of arsenic

C. (1) 0.861 g (2) silver is the limiting reagent; 0.0366 g H₂S and 0.844 g O₂
(3) 0.0626 g

