Module 7: Stoichiometry

Topic 4 Content: Limiting and Excess Reactants Presentation Notes

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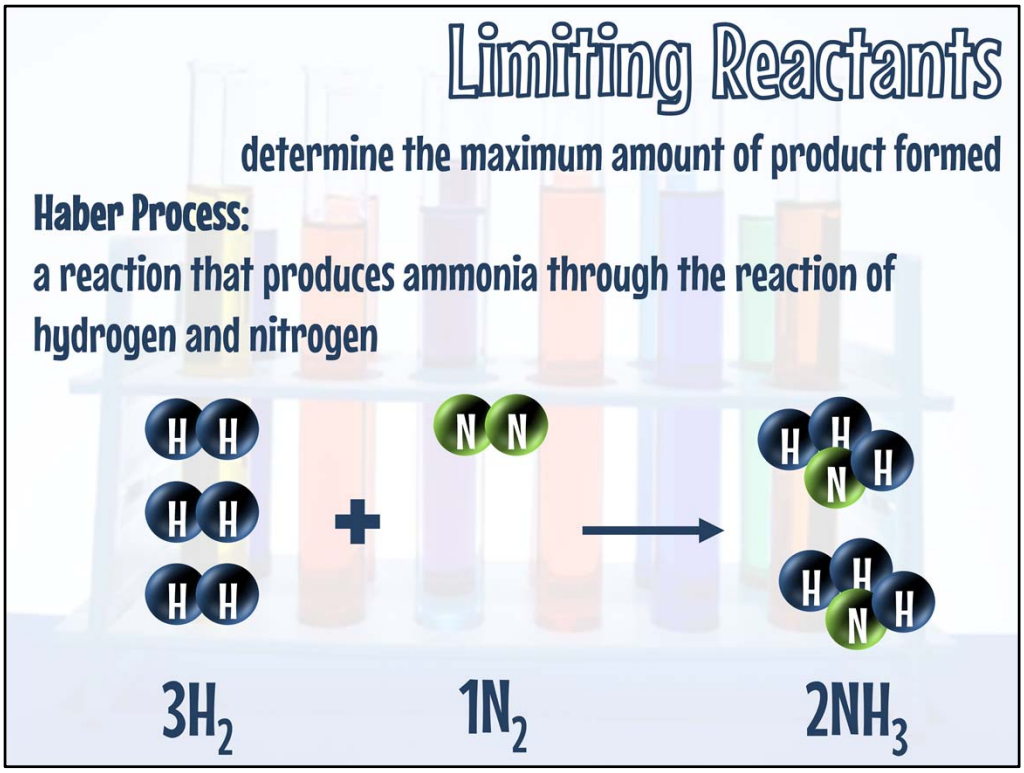

In a chemical reaction, reactants are not always combined in proportions so that each one is completely used up. The limiting reactant determines the maximum amount of product that is formed by the reaction. The Haber process is a great example of a reaction with a limiting reactant. The Haber process is an industrial process for producing ammonia by reacting nitrogen and hydrogen. In this reaction, iron is used as a catalyst. Look at the reaction for ammonia which has 3 moles of hydrogen, or H_2, plus 1 mole of nitrogen gas, or N_2, to yield 2 moles of ammonia, or NH_3. Remember, the mole ratio gives information about the relative amounts of each substance that react. Three moles of hydrogen react with one mole of nitrogen to produce two moles of ammonia.

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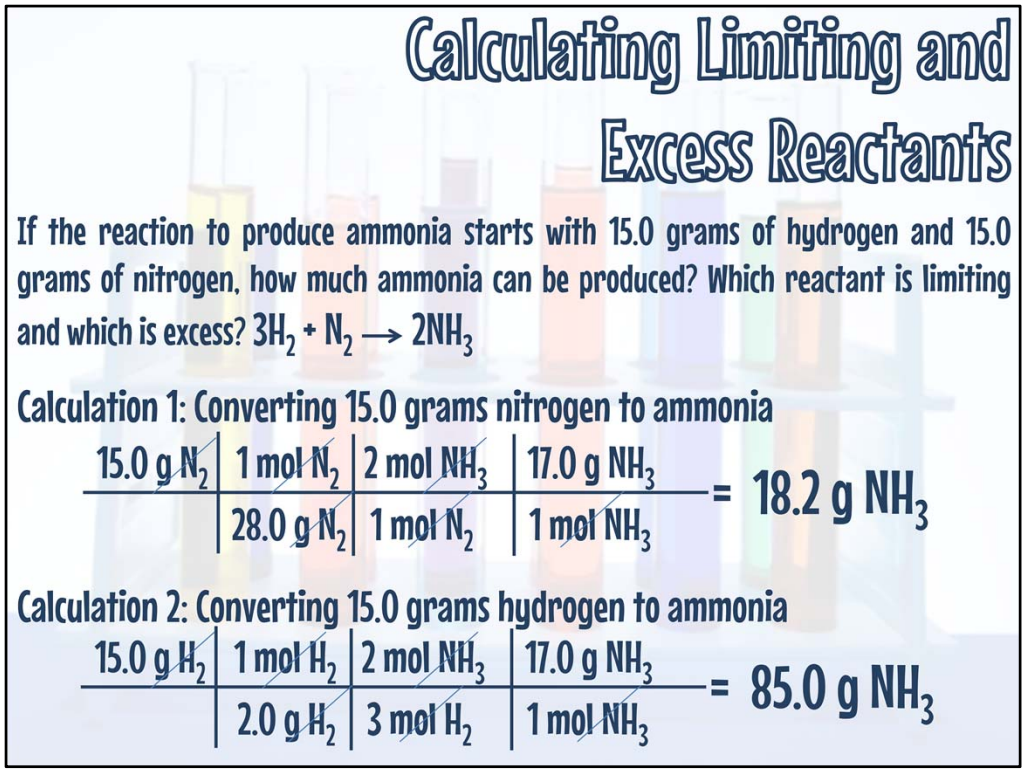

Since ammonia is produced and then sold, chemists will still want to control the reaction. This way, chemists can produce a specific amount of ammonia each reaction. How do chemists accurately predict the amount of ammonia that is produced through the process? Take a moment to look an example problem. If the reaction to produce ammonia starts with 15.0 grams of hydrogen and 15.0 grams of nitrogen, how much ammonia can be produced? Also, which reactant, hydrogen or nitrogen, is limiting, and which is excess? To find these answers, two calculations are needed. The total used of both reactants is 15.0 grams. The first calculation involves the conversion of 15.0 grams of nitrogen to grams of ammonia. The second calculation converts 15.0 grams of hydrogen to grams of ammonia.

In the first calculation, multiply 15.0 grams of nitrogen by 1 mole of N_2 over 28.0 grams of N_2. This will cancel out the unit of "gram N_2". Then, multiply by 2 moles of NH_3 over 1 mole of N_2, which will cancel out the unit of "mole N_2". Finally, multiply by 17.0 grams NH_3 over 1 mole of NH_3. This shows that 15.0 grams of nitrogen in this reaction produces 18.2 grams of NH_3.

For the second calculation, start with 15.0 grams of hydrogen and multiply by 1 mole of H_2 over 2.0 grams of H_2. This will cancel out "grams H_2". Then, multiply by 2 moles of NH_3 over 3 moles of H_2, which cancels out the unit "mole." The last step is to multiply by 17.0 grams of NH_3 over 1 mole of NH_3, which cancels out the unit "mole NH_3." In this reaction, 15.0 grams of nitrogen and hydrogen produce 85.0 grams of NH_3.

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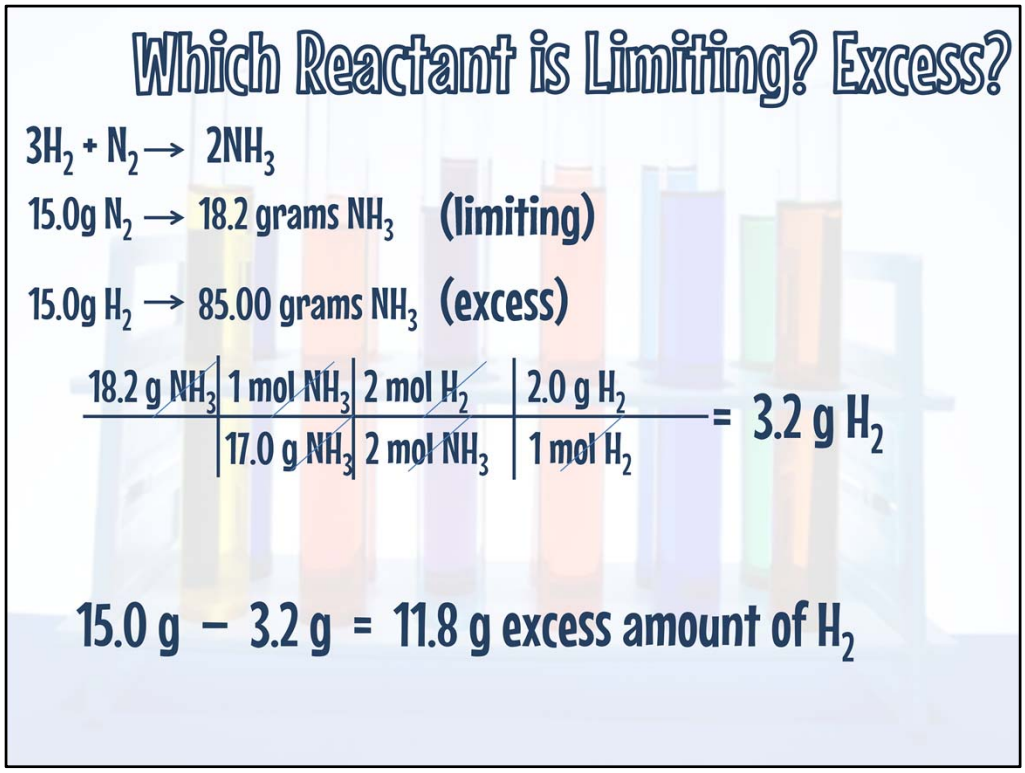

The calculations showed that 15.0 grams of nitrogen yield 18.2 grams of ammonia and 85.0 grams of ammonia is produced from 15.0 grams of hydrogen. After 18.2 grams of ammonia is produced, the reaction stops because there is no more nitrogen to continue. Therefore, nitrogen is the limiting reactant and hydrogen is the excess reactant. One way to calculate how much hydrogen is left over is to convert 18.2 grams of ammonia to grams of hydrogen.

Start with 18.2 grams since this is how much ammonia is produced by the limiting reactant in the reaction, and then multiply by 1 mole of NH_3 over 17.0 grams of NH_3, canceling out the unit "gram NH_3". Next, multiply by 2 moles of H_2 over 2 moles of NH_3 and then multiply by the conversion factor of 2.0 grams of H_2 over 1 mole of H_2. The units "mole NH_3" and "mole H_2" will cancel out. After multiplying and dividing, the equation shows that 18.2 grams of ammonia needs only 3.2 grams hydrogen to produce ammonia.

If only 3.2 grams of hydrogen are needed to use up all of the nitrogen available, the excess amount of hydrogen is determined by subtracting 3.2 grams from 15.0 grams to get 11.8 grams of hydrogen. These grams of hydrogen serve as the excess amount.