In the Classroom

Applications and Analogies

Limiting Reactant

An Alternative Analogy

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"The chemical reaction between 4 g of hydrogen and 16 g of oxygen gives 18 g of water. Is this statement true or false?" Among 156 Hungarian secondary school students (aged 17) tested upon finishing their 5-year chemical studies and before starting preparation for university entrance examination in chemistry, 44.2% answered: "False." This shows that one of the most difficult problems in stoichiometric calculations is the identification of the limiting reactant. Although some general chemistry textbooks devote a separate chapter to the idea of the limiting reactant, it is necessary to provide the students various concrete examples and analogies to better explain the identification of a limiting reagent. Some experimental demonstrations were recently published (1, 2), and an excellent cake-making analogy also exists (3). I find that the following simple analogy involving students and the makeup of teams works well in developing the limiting reactant concept.

In my class at secondary school, there are 15 boys and 21 girls. Let's consider the following problem: "Students form teams for a competition. Each team must contain 3 boys and 7 girls. How many teams can be formed in the class?"

Given the number of boys, we find that we can make $15 \div 3 = 5$ teams. However, to form five teams requires $5 \times 7 = 35$ girls, and we don't have that many girls. So, the number of boys cannot determine the number of teams, and if the boys don't, the girls must!

The solution of the problem can be written in "chemical form", too. If we let B and G stand for boys and girls, respectively, the team formula is $B_3G_7$, and the team-making process can be written as follows:

$$3B + 7G = 1B_3G_7$$

We have: $15$ boys $21$ girls

$\downarrow$ $\downarrow$

$3$ boys/1 team $7$ girls/1 team

We get: $5$ teams $3$ teams

Note that this procedure actually gives two species of information: first, the maximum amount of "product" that can be produced (3 teams), and second, the "limiting reagent" (girls).

Following this analogy, the teacher must present a chemical example, too. For example, "How many moles of ammonia can be obtained by the reaction of 5 moles of nitrogen and 9 moles of hydrogen?" The solution is similar to that of the above problem:

$$N_2 + 3H_2 = 2NH_3$$

We have: $5$ mol $N_2$ $9$ mol $H_2$

$\downarrow$ $\downarrow$

$1$ mol $N_2/2$ mol $NH_3$ $3$ mol $H_2/2$ mol $NH_3$

We get: $10$ mol $NH_3$ $6$ mol $N_3$

In developing the limiting reactant concept, the teacher must stress that the analogy relates the number of boys and the number of girls to the number of moles of reactants and not to the number of grams of reactants. If the problem presents the masses (grams) of the reactants, we must convert them to moles before identification of the limiting reagent. This is the case in the chemical problem presented in the introduction of this paper:

$$2H_2 + O_2 = 2H_2O$$

We have: $4$ g $H_2$ $16$ g $O_2$

$\downarrow$ $\downarrow$

$2$ g/mol $32$ g/mol

that is: $2$ mol $H_2$ $0.5$ mol $O_2$

$\downarrow$ $\downarrow$

$2$ mol $H_2/2$ mol $H_2O$ $1$ mol $O_2/2$ mol $H_2O$

We get: $2$ mol $H_2O$ $1$ mol $H_2O$

$\downarrow$ $\downarrow$

$18$ g/mol $18$ g/mol

that is: $18$ g $H_2O$

So, the original statement is true.

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Literature Cited