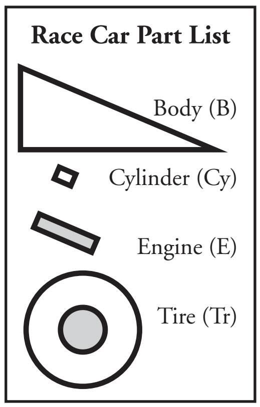
Limiting and Excess Reactants

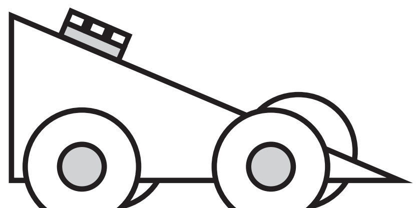
Is there enough of each chemical reactant to make a desired amount of product?

Why?

If a factory runs out of tires while manufacturing cars, production stops. No more cars can be fully built without ordering more tires. A similar thing happens in a chemical reaction. If there are fixed amounts of reactants to work with in a chemical reaction, one of the reactants may be used up first. This prevents the production of more products. In this activity, you will look at several situations where the process or reaction is stopped because one of the required components has been used up.

Model 1 – Assembling a Race Car





Race Car

1. How many of each part are needed to construct 1 complete race car?

   Body (B) Cylinder (Cy) Engine (E) Tire (Tr)

2. How many of each part would be needed to construct 3 complete race cars? Show your work.

   Body (B) Cylinder (Cy) Engine (E) Tire (Tr)

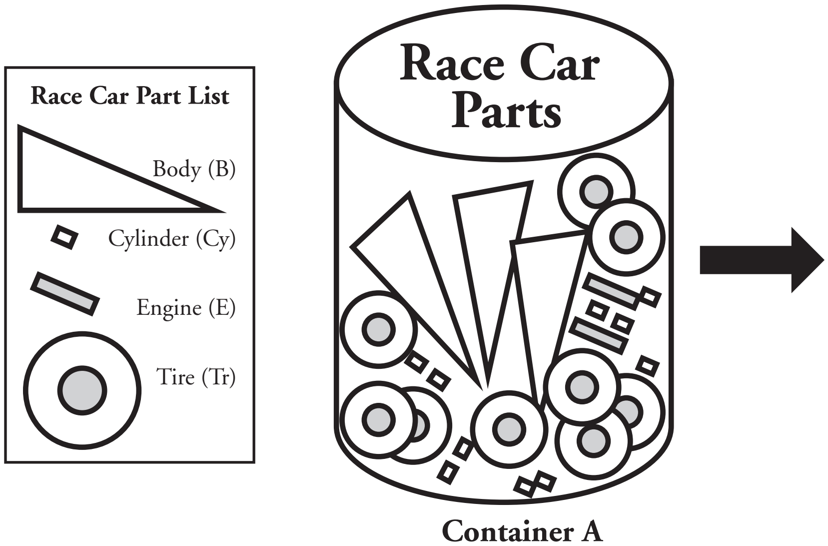
3. Assuming that you have 15 cylinders and an unlimited supply of the remaining parts:

   a. How many complete race cars can you make? Show your work.

   b. How many of each remaining part would be needed to make this number of cars? Show your work.

STOP

Model 2 – Manufacturing Race Cars



4. Count the number of each Race Car Part present in Container A of Model 2.

   Body (B) Cylinder (Cy) Engine (E) Tire (Tr)

5. Complete Model 2 by drawing the maximum number of cars that can be made from the parts in Container A. Show any excess parts remaining also.
6. A student says "I can see that we have three car bodies in Container A, so we should be able to build three complete race cars." Explain why this student is incorrect in this case.
7. Suppose you have a very large number (dozens or hundreds) of tires and bodies, but you only have 5 engines and 12 cylinders.

   a. How many complete cars can you build? Show your work.

   b. Which part (engines or cylinders) limits the number of cars that you can make?

8. Fill in the table below with the maximum number of complete race cars that can be built from each container of parts (A–E), and indicate which part limits the number of cars that can be built. Divide the work evenly among group members. Space is provided below the table for each group member to show their work. Have each group member describe to the group how they determined the maximum number of complete cars for their container. Container A from Model 2 is already completed as an example.

1 B + 3 Cy + 4 Tr + 1 E = 1 car

Container	Bodies	Cylinders	Tires	Engines	Max. Number of Completed Cars	Limiting Part
A	3	10	9	2	2	Engines
B	50	12	50	5		
C	16	16	16	16		
D	4	9	16	6		
E	20	36	40	24		

9. The Zippy Race Car Company builds toy race cars by the thousands. They do not count individual car parts. Instead they measure their parts in "oodles" (a large number of things).

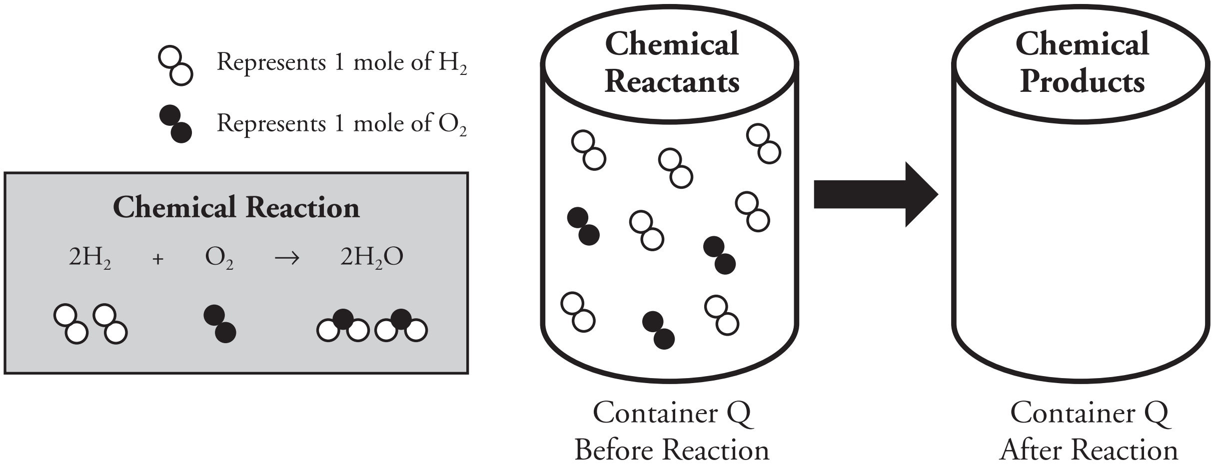
   a. Assuming the inventory in their warehouse below, how many race cars could the Zippy Race Car Company build? Show your work.

Body (B)	Cylinder (Cy)	Engine (E)	Tire (Tr)
4 oodles	5 oodles	8 oodles	8 oodles

   b. Explain why it is not necessary to know the number of parts in an "oodle" to solve the problem in part *a*.

10. Look back at the answers to Questions 8 and 9. Is the component with the smallest number of parts always the one that limits production? Explain your group's reasoning.

Model 3 – Assembling Water Molecules



11. Refer to the chemical reaction in Model 3.

    a. How many moles of water molecules are produced if one mole of oxygen molecules completely reacts?

    b. How many moles of hydrogen molecules are needed to react with one mole of oxygen molecules?

12. Complete Model 3 by drawing the maximum moles of water molecules that could be produced from the reactants shown, and draw any remaining moles of reactants in the container after reaction as well.

    a. Which reactant (oxygen or hydrogen) limited the production of water in Container Q?

    b. Which reactant (oxygen or hydrogen) was present in excess and remained after the production of water was complete?

13. Fill in the table below with the maximum moles of water that can be produced in each container (Q–U). Indicate which reactant limits the quantity of water produced—this is the **limiting reactant**. Also show how much of the other reactant—the **reactant in excess**—will be left over. Divide the work evenly among group members. Space is provided below the table for each group member to show their work. Have each group member describe to the group how they determined the maximum number of moles of water produced and the moles of reactant in excess. Container Q from Model 3 is already completed as an example.

$2H_2 + O_2 \rightarrow 2H_2O$

Container	**Moles of Hydrogen**	**Moles of Oxygen**	**Max. Moles of Water Produced**	**Limiting Reactant**	**Reactant in Excess**
Q	7	3	6	O_2	1 mole H_2
R	8	3			
S	10	5			
T	5	5			
U	8	6			

14. Look back at Questions 12 and 13. Is the reactant with the smaller number of moles always the limiting reactant? Explain your group's reasoning.

15. Below are two examples of mathematical calculations that could be performed to find the limiting reactant for Container U in Question 13.

$8 \text{ mol } H_2 \left(\dfrac{2 \text{ mol } H_2O}{2 \text{ mol } H_2} \right) = 8 \text{ mol } H_2O$ $6 \text{ mol } O_2 \left(\dfrac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} \right) = 12 \text{ mol } H_2O$ Hydrogen makes the lesser amount of product, so it is the limiting reactant.	$8 \text{ mol } H_2 \left(\dfrac{1 \text{ mol } O_2}{2 \text{ mol } H_2} \right) = 4 \text{ mol } O_2$ needed There are 6 moles of O_2 present, which is more than enough, so H_2 must be the limiting reactant.

a. Do both calculations give the same answer to the problem?

b. Which method was used most by your group members in Question 13?

c. Which method seems “easier,” and why?

d. Did your group use any other method(s) of solving this problem that were scientifically and mathematically correct? If so, explain the method.

Extension Questions

16. Consider the synthesis of water as shown in Model 3. A container is filled with 10.0 g of H_2 and 5.0 g of O_2.

    a. Which reactant (hydrogen or oxygen) is the limiting reactant in this case? Show your work. *Hint:* Notice that you are given reactant quantities in mass units here, not moles.

    b. What mass of water can be produced? Show your work.

    c. Which reactant is present in excess, and what mass of that reactant remains after the reaction is complete? Show your work.