Researchers at Washington University in St. Louis determined the methods by which students acquire concepts as key predictors in their success in chemistry courses. A more abstract based concept building approach is suggested to leverage for greater overall performance and interpretation of chemistry concepts. The following demonstrates the approach from an abstract learning perspective vs. exemplary learning perspective.

The following question depicts the basic attributes of calculating limit reagent and theoretical yield:

\[
\text{CO(g)} + 2 \text{H}_2(\text{g}) \rightarrow \text{CH}_3\text{OH(l)}
\]

Starting with 12.0 g H\text{\textsubscript{2}} and 74.5 g CO,

What mass of methanol can be obtained (in theory)?

\[
\frac{12.0 \text{ g H}_2}{2.016 \text{ g/mol H}_2} = 5.952 \text{ mol H}_2 \quad \text{PRESENT initially}
\]

\[
\frac{74.5 \text{ g CO}}{28.0 \text{ g/mol CO}} = 2.661 \text{ mol CO} \quad \text{PRESENT initially}
\]

Determine which of the reactants is the limiting reagent.

2.661 mol CO reacted \times \frac{1 \text{ mol CH}_3\text{OH made}}{1 \text{ mol CO reacted}} \times \frac{32.04 \text{ g}}{1 \text{ mol CH}_3\text{OH}} = 85.258 \text{ g CH}_3\text{OH}

Use the limiting reagent to calculate the product theoretical yield.

85.3 g CH\text{\textsubscript{3}}OH
In contrast, solving the next problem requires similar skills but requires one step further in abstract thinking, which is outlined in the box on the right:

A reaction container holds 5.77 g of P₄ and 5.77 g of O₂. The following reaction occurs: \( \text{P}_4 + \text{O}_2 \rightarrow \text{P}_4\text{O}_6 \). If enough oxygen is available then the \( \text{P}_4\text{O}_6 \) reacts further: \( \text{P}_4\text{O}_6 + \text{O}_2 \rightarrow \text{P}_4\text{O}_{10} \).

a. What is the limiting reagent for the formation of \( \text{P}_4\text{O}_{10} \)?

Step 1: Data given
- Mass of P₄ = 5.77 grams
- Mass of O₂ = 5.77 grams

Molar mass of P₄ = 123.90 g/mol
Molar mass O₂ = 32.0 g/mol

Step 2: The balanced equation
\( \text{P}_4 + 3\text{O}_2 \rightarrow \text{P}_4\text{O}_6 \)

Things needed to be determined:
- Which is the limiting reagent to form \( \text{P}_4\text{O}_6 \)
- Is there enough O₂ to further the cascade into the next reaction for \( \text{P}_4\text{O}_{10} \) reaction
- Which limits the \( \text{P}_4\text{O}_{10} \) reaction \( \text{P}_4\text{O}_6 \) or O₂?

Always make sure reaction is balanced.
Step 3: Calculate moles of P4
Moles P4 = mass P4 / molar mass P4
Moles P4 = 5.77 grams / 123.90 g/mol
Moles P4 = 0.0466 moles

Step 4: Calculate moles O2
Moles O2 = mass O2 / molar mass O2
Moles O2 = 5.77 grams / 32.0 g/mol
Moles O2 = 0.1803 moles

Determine the L.R. using standard procedure

At Step 5 this point some abstract thinking skills are needed that are not used in the previous example problem.

Step 5: Calculate limiting reactant
P4 is the limiting reactant in this reaction. It will completely be consumed (0.0466 moles). O2 is in excess, there will react 3*0.0466 = 0.1398 moles
There will remain 0.1803 - 0.1398 = 0.0405 moles O2

If one were to go by Example of the first problem above in green, it would not be clear the need to use the balance equation to stoichiometrically know how much O2 has reacted and now left to react with P4O6 in order to form P410.
Step 6: Calculate the amount of P₄O₁₀
For 1 mol P₄ we'll have 1 mol P₄O₁₀
For 0.0466 moles P₄ we'll have 0.0466 moles P₄O₁₀

Step 7: The balanced equation
P₄O₆ + 2O₂ → P₄O₁₀
We have 0.0466 moles P₄O₆ and 0.0405 moles O₂

Step 8: Calculate the limiting reactant
For 1 mol P₄O₆ we need 2 moles O₂ to produce 1 mol P₄O₁₀
O₂ is the limiting reactant. It will completely be consumed (0.0405 moles)

b. What mass of P₄O₁₀ is produced?
P₄O₆ is in excess. There will react 0.0405/2 = 0.02025 moles P₄O₁₀
This is 0.02635 * 219.88 g/mol = 5.79 grams P₄O₁₀