Use the Haber process to synthesize ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2), according to the following balanced chemical equation:

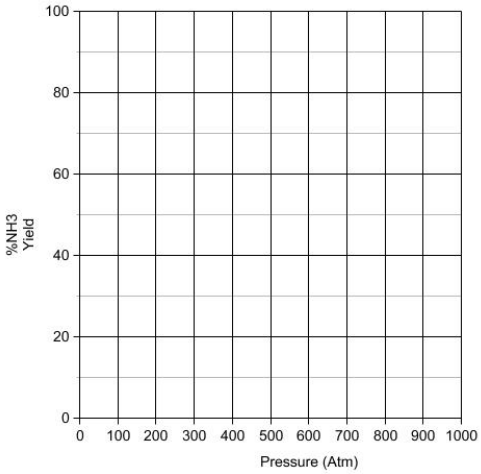
$$N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_{3(g)}$$

As the manager of the plant, your job is to produce the maximum amount of NH_3 for the least amount of money during each 24-hour shift.

You can adjust several independent variables using the Control Panel and analyze the results (including yield, time to equilibrium, and net profit) on the output monitor. You'll want to vary each independent variable to determine how it affects the results.

1) Begin by experimenting with the effect of **Pressure** on the system. Set **Temperature** to 400˚C, then choose a **Pressure.** Now, press the **Run** button. After the 24-hour run, press the **See Results** button to view your data.

Try 3-5 different pressure values, keeping all other variables constant, then graph your results below:



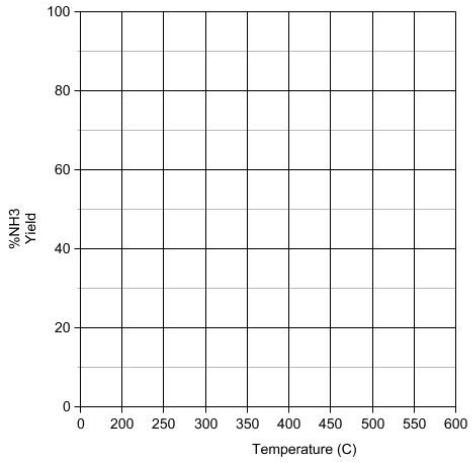
What happens to the NH3 yield when pressure is increased?

What happens to the reaction rate (the time to equilibrate)? Are there pressure settings that prevent the reaction from occurring within the 24-hour run?

Is there a pressure that is too high to run the reaction?

Given just this information, what do you predict is an optimal pressure to maximize efficiency?

2) Using this optimal pressure and keeping all other variables constant, experiment with 3-5 temperature values. Graph your results below:



What happens to the yield when temperature is increased?

What happens to the reaction rate (the time to equilibrate)?

Is there a temperature that is too low to run the reaction in 24 hours?

What is the optimal temperature to maximize **Net Profit**?

3) Experiment with each of the three **Catalysts**. After finding a temperature and pressure that produce the maximum **Net Profit**, do at least one run with each catalyst in turn.

What happens to the yield when the catalysts are changed?

What happens to the reaction rate?

Is it always better to use the highest-grade catalyst? Why or why not?

4) Now experiment with at least two of the other three variables (**Flow Rate**, **Purge**, and **Cooling**) and attempt to maximize your profit.

Write at least one variable that increased **Total Output** but decreased **Net Profit**:

5) After experimenting with different settings, what is the maximum **Net Profit** that you were able to obtain?

At this maximum profit, what are the optimal settings for each of the following variables?

Temperature:

Pressure:

Catalyst:

Flow Rate:

Purge:

Cooling:

Be sure to print out your results and attach the chart to this worksheet.

6) Compare the factors that increase **Total Output** and those that increase **Net Profit**. Are they the same? If you had to leave instructions for another person running the plant, how would you describe the best strategy for maximizing profits?