Name: _____
Date: _____

Haber Process Case Study MINI-ASSIGNMENT

Curriculum Expectation	OVERALL LEVEL
E1. analyse chemical equilibrium processes, and assess their impact on biological, biochemical, and technological systems; FEEDBACK (Teacher Use ONLY): •	

Please write your answers in full sentences.

1. Nitrogen is an essential nutrient for growing plants, as it is a major component of chlorophyll. Approximately 80% of the ammonia (NH_3) produced industrially today is used in agriculture to make nitrogen-based fertilizer.

   Research and briefly describe TWO <u>other</u> industrial uses of ammonia.

   Make sure to include the link(s) to your source(s) with your written answer - no need for formal APA citation this time. **(2 marks)**

2. Watch the SciShow video on Fritz Haber found HERE and answer the following questions:

A. Why must atmospheric nitrogen (N_2) be "fixed" into ammonia (NH_3) before plants can use it? **(1 mark)**

B. Prior to the development of the Haber process, how were industrialized countries sourcing their ammonia-based fertilizers? Was this a sustainable solution to the anticipated global food shortages? **(2 marks)**

C. Write the full <u>balanced</u> equation (including state symbols) for the Haber process. **(2 marks)**

3. Carefully consider the data table below. It shows the percentage yield of NH_3 resulting from various combinations of temperature and pressure.

Pressure (atm)	**NH_3 present at equilibrium (%) at various temperatures**					
	100 °C	***200 °C***	***300 °C***	***400 °C***	***500 °C***	***700 °C***
10	-	50.7	14.7	3.9	1.2	0.2
25	91.7	63.6	27.4	8.7	2.9	-
50	94.5	74.0	39.5	15.3	5.6	1.1
100	96.7	81.7	52.5	25.2	10.6	2.2
200	98.4	89.0	66.7	38.8	18.3	-

400	99.4	94.6	79.7	55.4	31.9	-
1000	-	98.3	92.6	79.8	57.5	12.9

A. Describe the effect of <u>reducing</u> temperature on the percentage yield of NH_3. Does it increase/decrease/stay the same? **(1 mark)**

B. The forward reaction in the Haber Process is exothermic ($\Delta H = -92$ kJ/mol). Explain how the experimental results shown above are in agreement with Le Chatelier's Principle. **(2 marks)**

C. Describe the effect of increasing pressure on the percentage yield of NH_3. Does it increase/decrease/stay the same? Use Le Chatelier's Principle to explain this trend. **(2 marks)**

D. Identify the reaction conditions in the table above that should theoretically produce the highest possible percentage yield of NH_3. **(1 mark)**

4. NH_3 is continuously siphoned away from the reaction mixture as it is produced.

   Use Le Chatelier's Principle to explain why this practice of removing product as it is formed leads to a more efficient production of NH_3. **(2 marks)**

5. Research and thoroughly describe the <u>modern</u> reaction conditions used to maximize the production of NH_3 via the Haber-Bosch Process.

   You must include:
   a) the ratio of N_2 to H_2 gas used in the reaction mixture
   b) the temperature and pressure ranges used throughout the process
   c) the name of one catalyst typically used to speed up the rate of this reaction.

   Make sure to include the link(s) to your source(s) with your written answer - no need for formal APA citation this time. **(3 marks)**

6. In practice, even though optimal reaction conditions are in use, the real-world yield of NH_3 via the Haber-Bosch process is typically <u>under 20%</u>.

A. Suggest a practical reason why the process is not operated at an extremely low temperature. **(1 mark)**

B. Suggest a practical reason why the process is not operated at an extremely high pressure. **(1 mark)**