Evaluation

(e) The percentage yield was less than 100%. One possible source of experimental error is impurities in the copper(II) chloride dihydrate salt, which means there was less copper in the reactant that could be collected as a product. Also, the aluminum metal broke into many small pieces as the reaction occurred. Some copper could have stuck to the aluminum, and when the aluminum was removed it resulted in some of the copper also being removed.

A percentage yield greater than 100% may occur if some unreacted aluminum metal inadvertently remains mixed with the copper residue. The mass of copper will appear to be higher than it actually is, and the percentage yield of copper may be calculated to be higher than 100%.

(f) The reaction was allowed to continue until all visible bubbling ceased. That signalled the end of the reaction.

(g) You would have to reduce the amount of aluminum used and/or increase the amount of copper(II) chloride dihydrate used. Aluminum would be the limiting reagent if the aluminum disappeared before the solution lost its characteristic blue colour.

2.14 CASE STUDY: THE HABER PROCESS

CASE STUDY 2.14 QUESTIONS

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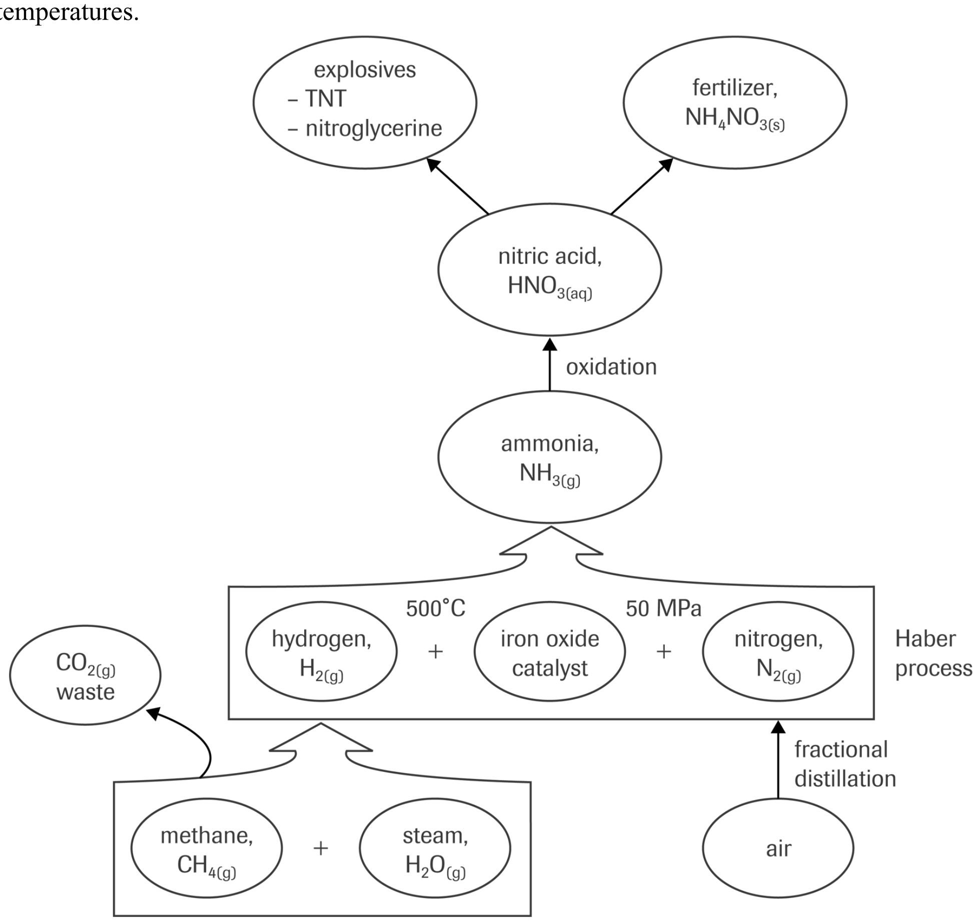
Understanding Concepts

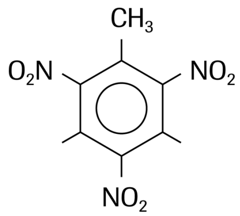
1. Four factors that could affect the production of ammonia in the Haber process include the type of container (open or closed), effect of a catalyst, temperature, and pressure.
2. The reaction is too slow to be economical at low temperatures.
3. Iron oxide is used as a catalyst in the Haber process. Iron oxide speeds up the reaction, even at moderate temperatures.
4.



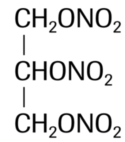
Making Connections

5. (a) The most common types of explosives that are produced with nitric acid are TNT, nitroglycerine, and gun cotton.

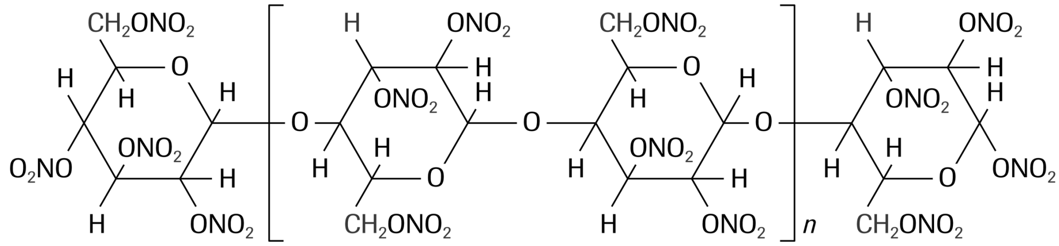
(b)



TNT



nitroglycerine



gun cotton

(c) Gun cotton (nitrocellulose) is a highly explosive nitrated cellulose made by soaking cotton (cellulose) in nitric acid and sulfuric acid. Gun cotton is used to make smokeless gunpowder.

6. (a) Student answers will vary. One suggestion is to use a temperature of 500°C and a pressure of 50 MPa.

(b) The conditions suggested in part (a) would be expensive to produce. Fuel will be necessary to maintain the temperature of a reaction vessel at 500°C, and lots of electricity would be needed to run the compressors that maintain the reaction vessel pressure at 50 MPa.

(c) The company may invest in renewable energy technologies such as solar panels and/or wind generators to produce the heat and electricity required to run the plant.

7. (a) Possible sources of these gases are (for nitrogen) extraction from the atmosphere, and (for hydrogen) hydrolysis of water.

(b) Hydrogen is produced by reacting methane with steam to produce carbon dioxide and hydrogen. Nitrogen is obtained by the fractional distillation of air. Fractional distillation is a process by which the components in a chemical mixture are separated according to their different boiling points. Vapours from a boiling solution are passed along a cooled column. The temperature of the column gradually decreases along its length. Components with a higher boiling point condense on the column and return to the solution; components with a lower boiling points pass through the column, are condensed, and are collected in a suitable collecting vessel.

8. (a) Nitrogen-fixing bacteria such as *Rhizobium* live in nodules found in the roots of plants such as soybean and alfalfa. There, they absorb nitrogen gas from the atmosphere and, through a series of reactions, convert the nitrogen into ammonia.

(b) Human activities contribute more to the global supply of fixed nitrogen each year than natural processes do. Humans generate about 210 million tonnes of fixed nitrogen per year, while natural processes contribute only about 140 million tonnes per year.

(c) Student answers will vary. Most of the fixed nitrogen produced by humans is used as fertilizer. Nitrogen fertilizers are absorbed by plants, and help crops grow, but there is a limit to the quantity of fertilizer that plants can absorb and use. Beyond this level, fertilizers accumulate and pollute the environment, reducing the quality of air and water, and disrupting the health of terrestrial and aquatic ecosystems. On land, nitrogen saturation can disrupt soil chemistry, leading to loss of important soil nutrients like calcium, magnesium, and potassium. Excess nitrogen can also affect the number and kind of species found in an ecosystem. Researchers in the Britain and the United States have found that adding nitrogen fertilizer to grasslands causes a few grass species to dominate, while others disappear.