DUNMAN HIGH SCHOOL

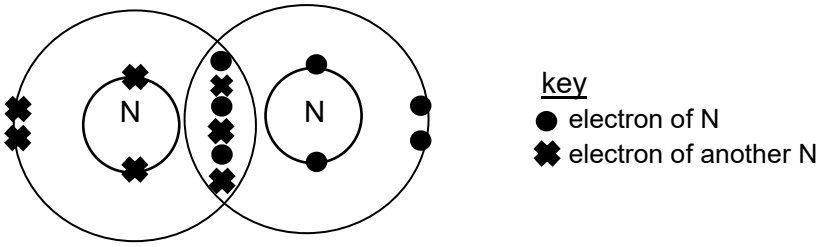
DHP CHEMISTRY WORKSHEET – AMMONIA (HABER PROCESS)

NAME.....…....( ) YEAR ..... DATE.....

Answer the following questions with reference to "Ammonia (Haber Process)" notes.

1 Draw a 'dot-and-cross' diagram to show the bonding in a nitrogen molecule, thus explain why nitrogen is quite unreactive. [3]

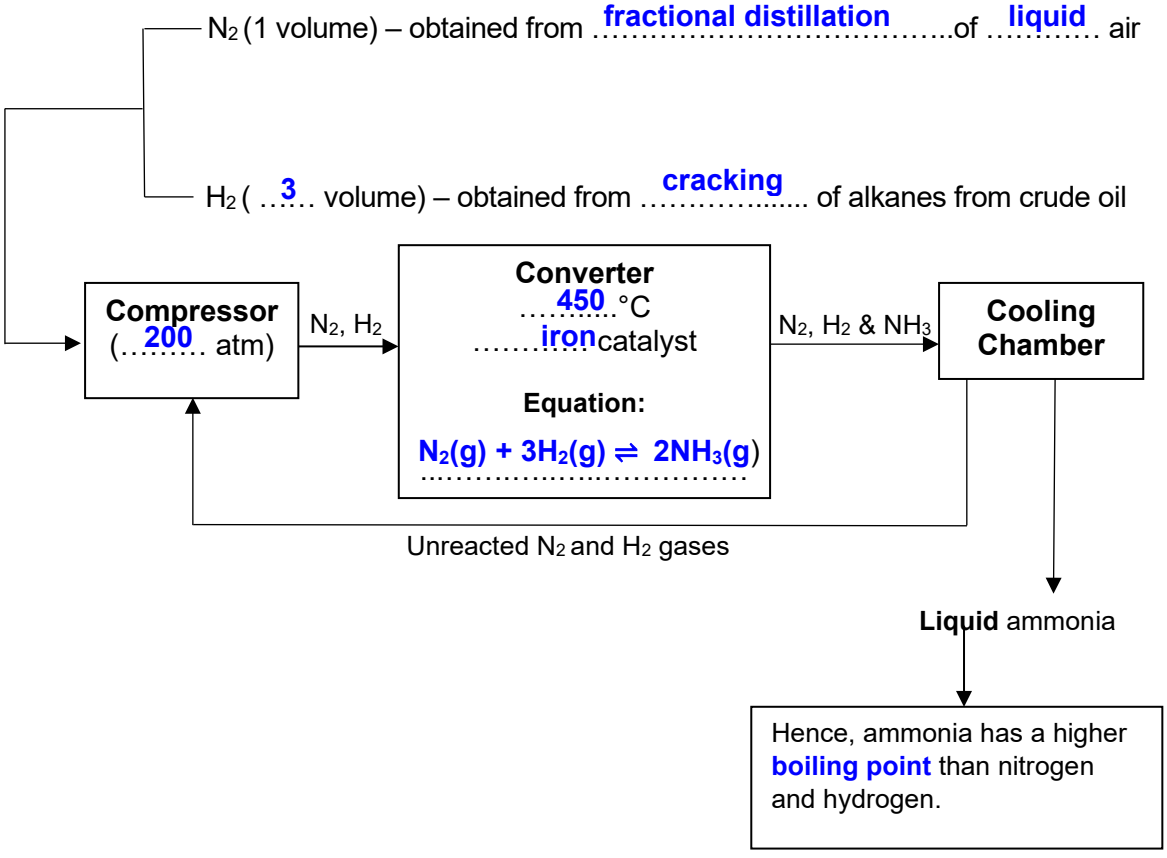
Note: All electrons must be drawn since question did not state "show outer electrons only".



Explanation: **A lot of energy is needed to break the very strong triple covalent bond between the atoms in the molecule before nitrogen can react.** [1]

Bond	Bond energy (kJ/mol)
N-N	167
N=N	418
N≡N	942

2 Complete the flow diagram for the manufacture of ammonia. [7]



3 Suggest two reasons why less energy is needed to maintain the temperature for reaction **C** than for reaction **B** in page C2 of "Ammonia (Haber Process)" notes. [2]

Reaction B: methane reacts with steam to make hydrogen.

$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +210$ kJ

Conditions:
30 atm
nickel oxide catalyst
800°C

Reaction C : nitrogen reacts with hydrogen to make ammonia

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ

Conditions:
200 atm
iron catalyst
450°C

- **The temperature required for reaction C is lower.**
- **Reaction C is exothermic, heat released during the reaction can help to maintain the operating temperature of 450°C.**

4 Using ideas related to stoichiometry and Avogadro's Law, explain why the nitrogen and hydrogen are mixed in a ratio of 1:3 by volume. **($N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$)** [1]

- **From the equation, 1 mole of nitrogen reacts with 3 moles of hydrogen to produce 2 moles of ammonia.**
- **According to Avogadro's Law, 1 volume of nitrogen will react with 3 volumes of hydrogen when the gases are under the same temperature and pressure.**

Some students compared by chemical formula of NH_3. No of atoms of N: No of atoms of H is 1:3. Therefore, volume is 1:3. Why is this wrong?

Another eg. $2CO + O_2 \rightarrow 2CO_2$. Why was CO and O_2 reacted in a 2:1 volume ratio? Is there any way to explain in terms of chemical formula?

Compare by moles of reactants, not of atoms in the chemical formula.

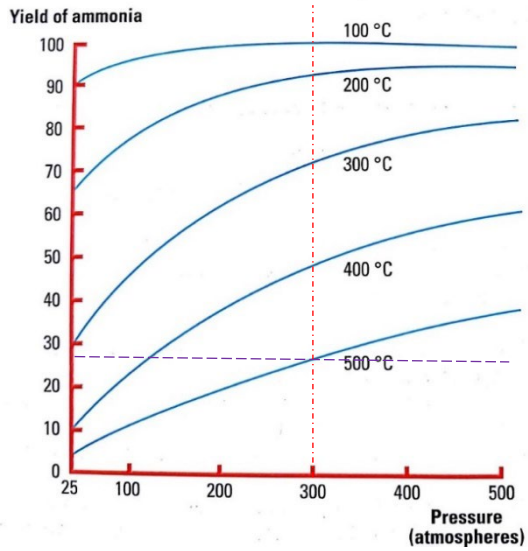
5 Explain why the iron catalyst is finely divided. [1]

A finely divided catalyst has a large surface area, leading to a faster rate of reaction.

6 Give **two** reasons why the unreacted nitrogen and hydrogen are fed back into the converter. [2]

- **To recycle the nitrogen and hydrogen to save cost**
- **To increase the yield of ammonia**

Use **Diagram 1** on page C3 of "Ammonia (Haber Process)" notes to answer questions **7** and **8**.



7 Deduce the effect of the following on the percentage yield of ammonia: [2]

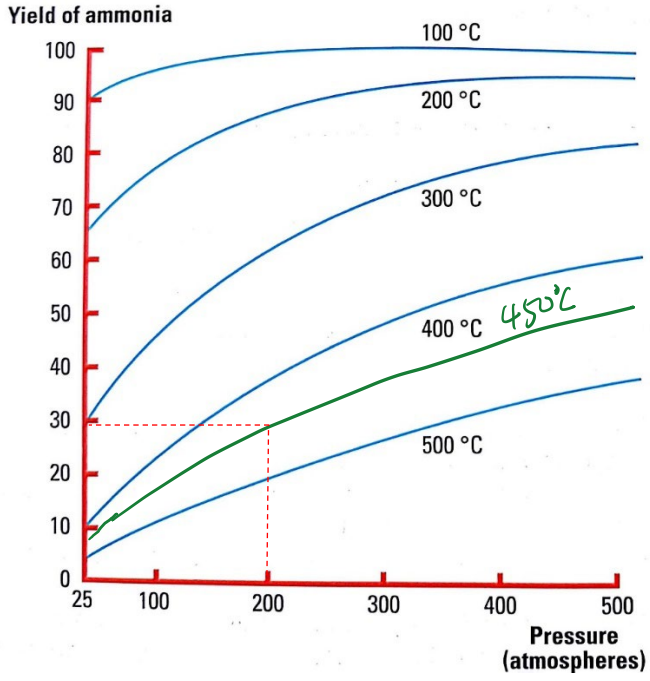
(a) increasing the pressure

The percentage yield of ammonia increases.

(b) increasing the temperature

The percentage yield of ammonia decreases.

8 Estimate the percentage yield of ammonia if the conditions are 200 atm and 450°C. [1]
Any answer from 25% to 31%



9 Suggest one advantage and one disadvantage of using 350°C rather than 450°C in manufacturing ammonia. [2]

Advantage

The percentage yield of ammonia obtained is higher.

[how much you get/ the amount]

Disadvantage

The reaction will be slower.

10 Suggest why the process is not operated at pressures higher than 200 atm. [1]

- **Operating cost will be higher as expensive equipment such as special pump and stronger pipes are needed.**

  OR

- **Risk of explosion will be higher**

7	Deduce the effect of the following on the percentage yield of ammonia:	
	(a)	increasing the pressure
		The percentage yield of ammonia increases.
	(b)	increasing the temperature
		The percentage yield of ammonia decreases.

11 Assuming that an overall of 98% of the nitrogen and hydrogen is converted into ammonia, calculate the volume of hydrogen, measured at r.t.p, required to produce 8.50 tonnes of ammonia. (1 tonne = 1 x 10^6 g) [3]

No. of moles of NH_3 = mass ÷ molar mass
= 8.50 x 10^6 ÷ (14.0 + 3.0)
= 5.00 x 10^5 mol^

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

No. of moles of H_2 = 3/2 x no. of moles of NH_3
= 3/2 x 5.00 x 10^5
= 7.50 x 10^5 mol^ (^both --------- [1])

Volume of H_2 converted to NH_3 = no. of moles of H_2 x molar volume
= 7.50 x 10^5 x 24
= 1.80 x 10^7 dm^3 [1]

Actual volume of H_2 used = 1.80 x 10^7 x $\frac{100\%}{98\%}$
= 1.84 x 10^7 dm^3 (3 s.f.) [1]

12 With reference to reaction **C** on page C2 of "Ammonia (Haber Process)" notes, state the enthalpy change (ΔH) for the reaction, $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$. [1]

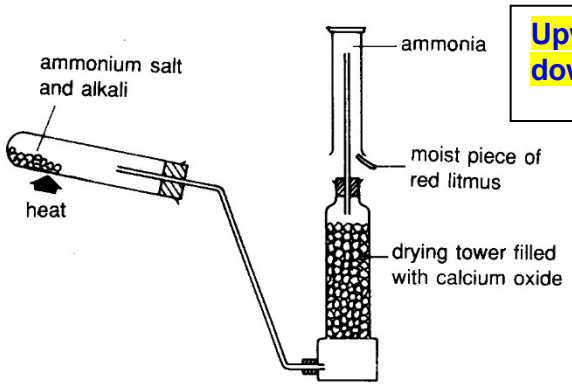
ΔH = + 92 kJ

Reaction C : nitrogen reacts with hydrogen to make ammonia

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ ΔH = -92 kJ

Conditions:
200 atm
Finely divided iron catalyst
450°C

13 In the laboratory, ammonia is usually prepared by heating an ammonium salt with an alkali. The apparatus set up for the preparation is shown below.



Upward delivery of gas or **downward displacement of air**.

Diagram 2

(a) Write the equation for the reaction if ammonium chloride and calcium hydroxide are used to prepare ammonia gas. [1]

$2NH_4Cl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O + 2NH_3$

(b) Why is the test tube containing the reagents tilted downwards? [1]

This prevents condensed water at the mouth of the test tube from running back to the hot part of the test tube and cracking the glass.

(c) Concentrated sulfuric acid (acidic) is a common drying agent, can it be used in place of calcium oxide to dry ammonia gas (alkaline)? Explain your answer. [1]

No. Concentrated sulfuric acid reacts with ammonia.

$H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2SO_4$

(d) Ammonia is less dense than air. Name the method for collecting ammonia as shown in **Diagram 2.** [1]

Upward delivery of gas or **downward displacement of air**.