

The Haber Process

Simulation: edtechsims.com/haber-process

Name: _____ Class: _____ Date: _____



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Part A: The Reaction



A1 Complete the sentences. [6]

The nitrogen used in the Haber process comes from _____ (by fractional distillation of liquid air). The hydrogen comes from _____ or the cracking of hydrocarbons.

The symbol $\rightleftharpoons$ shows that the reaction is _____. In a closed system it reaches _____, where the forward and reverse reactions happen at the _____.

Most of the ammonia made is used to make _____, such as ammonium nitrate and ammonium sulfate.

Part B: Effect of Temperature

On the sim: Click on 'A Microscopic View'. Observe the pressure at 200 atm. Unselect the iron catalyst checkbox. Select different temperatures and record the yields of ammonia.

B1 Complete Table 1. [3]

Temperature / °C	Yield of NH_3 / %	Speed of particles (slow / medium / fast)
350		
450		
550		

Table 1

B2 Describe and explain the effect of increasing the temperature on the yield of ammonia. [2]

.....

.....

B3 Why is a very low temperature, such as 200 °C, not used even though it gives a higher yield? [2]

.....

.....

Part C: Effect of Pressure

On the sim: Click on 'A Microscopic View'. Set the temperature to 450 °C. Unselect the iron catalyst checkbox. Change the pressure and record the yield of ammonia.

C1 Complete Table 2. [4]

Pressure / atm	Yield of NH ₃ / %
100	
200	
300	
400	

Table 2

C2 How many molecules of gas are on each side of the equation? [1]

left side: right side:

C3 Use your answer to C2 to explain the effect of increasing the pressure on the yield. [2]

.....
.....

C4 Suggest two reasons why the pressure is not raised to 1000 atm. [2]

.....
.....

Part D: Effect of the Iron Catalyst

On the sim: Click on 'A Microscopic View'. Set 450 °C and 200 atm. Turn the iron catalyst on and off. Compare the yield and how quickly the particles react.

D1 Complete Table 3. [2]

Iron catalyst	Yield of NH ₃ / %	Rate at which equilibrium is reached
Off		Slower
On		Faster

Table 3

D2 Explain why the catalyst does not change the yield but is still used. [2]

.....
.....

Part E: The Compromise Conditions

E1 Click on 'Plant Manager'. Complete Table 4 with the conditions used in industry and the reason for each. [6]

Condition	Value	Reason
Temperature		
Pressure		
Catalyst		

Table 4

E2 Only about 15% of the nitrogen and hydrogen is converted to ammonia each time the gases pass over the catalyst. Explain how the factory still uses almost all the raw materials. [2]

.....
.....

Part F: Practice Questions

F1 Fig. 1 shows the yield of ammonia at different temperatures and pressures (approximate data).

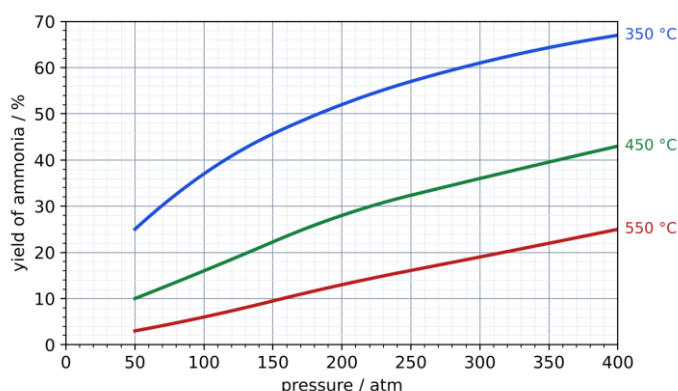


Fig. 1

(a) State the yield of ammonia at 450 °C and 200 atm. [1]

yield = ... %

(b) Use Fig. 1 to describe the effect of temperature on the yield at 300 atm. [2]

.....
.....

(c) Suggest why a plant might choose 450 °C and 200 atm instead of 350 °C and 400 atm, even though the yield is lower. [2]

.....
.....

F2 Calculate the maximum mass of ammonia that can be made from 56 tonnes of nitrogen. (Ar: N = 14, H = 1) [3]

mass = ... tonnes

F3 Describe a test for ammonia gas. [2]

.....

.....

Answer Key: The Haber Process

Part A: The Reaction



A1 Complete the sentences. [6]

The nitrogen used in the Haber process comes from **the air** (by fractional distillation of liquid air).

The hydrogen comes from **natural gas (methane)** or the cracking of hydrocarbons.

The symbol $\rightleftharpoons$ shows that the reaction is **reversible**. In a closed system it reaches **dynamic equilibrium**, where the forward and reverse reactions happen at the **same rate**.

Most of the ammonia made is used to make **fertilisers**, such as ammonium nitrate and ammonium sulfate.

Part B: Effect of Temperature

On the sim: Click on 'A Microscopic View'. Observe the pressure at 200 atm. Unselect the iron catalyst checkbox. Select different temperatures and record the yields of ammonia.

B1 Complete Table 1. [3]

Temperature / °C	Yield of NH ₃ / %	Speed of particles (slow / medium / fast)
350	45.0	Slow
450	28.0	Medium
550	15.0	Fast

Table 1

Yields from the sim; the yield decreases as temperature increases (roughly 50%, 30%, 13% at 200 atm).

B2 Describe and explain the effect of increasing the temperature on the yield of ammonia. [2]

The yield decreases. The forward reaction is exothermic, so a higher temperature favours the reverse (endothermic) reaction and the position of equilibrium shifts to the left.

B3 Why is a very low temperature, such as 200 °C, not used even though it gives a higher yield? [2]

The particles move slowly and collide less often with less energy, so the rate of reaction is too slow; ammonia would be made too slowly to be economical.

Part C: Effect of Pressure

On the sim: Click on 'A Microscopic View'. Set the temperature to 450 °C. Unselect the iron catalyst checkbox. Change the pressure and record the yield of ammonia.

C1 Complete Table 2. [4]

Pressure / atm	Yield of NH ₃ / %
100	14.0
200	28.0
300	38.0
400	43.0

Table 2

Yields from the sim; the yield increases as pressure increases.

C2 How many molecules of gas are on each side of the equation? [1]

Left: 1 + 3 = 4 molecules. Right: 2 molecules.

C3 Use your answer to C2 to explain the effect of increasing the pressure on the yield. [2]

The yield increases. A higher pressure favours the side with fewer gas molecules (the right), so the position of equilibrium shifts to the right and more NH₃ forms.

C4 Suggest two reasons why the pressure is not raised to 1000 atm. [2]

Any two: very expensive to build equipment strong enough; high energy cost to compress the gases; greater safety risk of explosion or leaks.

Part D: Effect of the Iron Catalyst

On the sim: Click on 'A Microscopic View'. Set 450 °C and 200 atm. Turn the iron catalyst on and off. Compare the yield and how quickly the particles react.

D1 Complete Table 3. [2]

Iron catalyst	Yield of NH ₃ / %	Rate at which equilibrium is reached
Off	35.0	Slower
On	35.0	Faster

Table 3

The yield is the same with and without the catalyst (about 28–30% at 450 °C, 200 atm).

D2 Explain why the catalyst does not change the yield but is still used. [2]

A catalyst speeds up the forward and reverse reactions equally, so the position of equilibrium does not change. It makes equilibrium (and ammonia) reached faster, which saves time and money.

Part E: The Compromise Conditions

E1 Click on 'Plant Manager'. Complete Table 4 with the conditions used in industry and the reason for each. [6]

Condition	Value	Reason
Temperature	about 450 °C	Compromise: high enough for a fast rate, low enough for a reasonable yield
Pressure	about 200 atm	Compromise: gives a good yield without very high equipment and energy costs
Catalyst	Iron	Increases the rate of reaction; equilibrium reached faster

Table 4

E2 Only about 15% of the nitrogen and hydrogen is converted to ammonia each time the gases pass over the catalyst. Explain how the factory still uses almost all the raw materials. [2]

The ammonia is removed by cooling it until it liquefies. The unreacted nitrogen and hydrogen are recycled back over the catalyst.

Part F: Practice Questions

F1 Fig. 1 shows the yield of ammonia at different temperatures and pressures (approximate data).

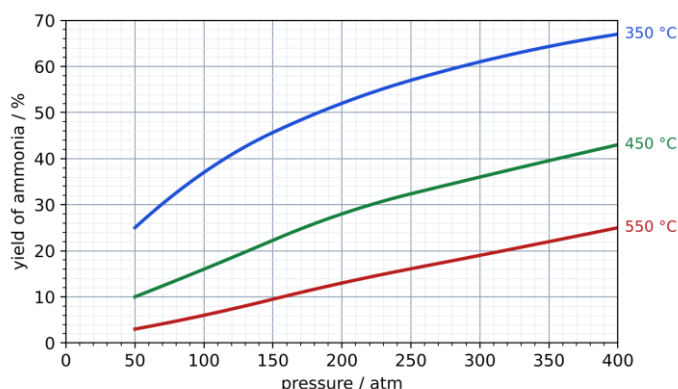


Fig. 1

(a) State the yield of ammonia at 450 °C and 200 atm. [1]
about 28%

(b) Use Fig. 1 to describe the effect of temperature on the yield at 300 atm. [2]
As temperature increases from 350 °C to 550 °C, the yield decreases (from about 61% to about 19%).

(c) Suggest why a plant might choose 450 °C and 200 atm instead of 350 °C and 400 atm, even though the yield is lower. [2]

At 350 °C the rate is slower; 400 atm is more expensive and dangerous. 450 °C and 200 atm give an acceptable yield at a faster rate and lower cost.

F2 Calculate the maximum mass of ammonia that can be made from 56 tonnes of nitrogen. (Ar: N = 14, H = 1) [3]

$$n(\text{N}_2) = 56 \div 28 = 2 \times 10^6 \text{ mol} \rightarrow n(\text{NH}_3) = 4 \times 10^6 \text{ mol}; \text{mass} = 4 \times 17 = 68 \text{ tonnes}$$

F3 Describe a test for ammonia gas. [2]

Place damp red litmus paper at the mouth of the tube; it turns blue.