# Equilibrium and the Haber process

Edexcel GCSE Chemistry (1CH0) · Foundation and Higher

Show your working where needed. Check the worked answers when you finish.

Name _____ Date _____

## 1. The reactor equation

Nitrogen reacts reversibly with hydrogen to make ammonia. Write a balanced symbol equation that shows the reaction is reversible.

## 2. Readings in a closed container

In a sealed vessel, the amount of ammonia stops changing even though nitrogen and hydrogen remain. Explain why a constant amount of ammonia does not show that the reactions have stopped.

## 3. Running the Haber process

Name the catalyst and give the approximate temperature and pressure used in the Haber process. State a source of the nitrogen.

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### 4. Choosing a fertiliser

A grower uses ammonium nitrate, $NH_4NO_3$, as a source of nitrogen. The crop also needs the other two nutrients in an NPK fertiliser. Name those two elements and explain why ammonium nitrate alone cannot supply them.

### 5. Higher · compressing a gas mixture

$N_2O_4(g) \rightleftharpoons 2NO_2(g)$. The sealed mixture is compressed at constant temperature. Predict what happens to the equilibrium amount of $NO_2$ and explain why.

### 6. Higher · choosing a temperature

Ammonia formation is exothermic. An engineer proposes lowering the reactor temperature. Compare the effects on equilibrium yield and rate. Explain why the factory uses a compromise temperature.

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### 7. Make a fertiliser from ammonia

A factory makes a nitrogen fertiliser by reacting ammonia with nitric acid. Name the fertiliser and describe the type of reaction.

Would replacing nitric acid with sulfuric acid make the same salt? Explain.

### 8. Higher · comparing factory proposals

Proposal A raises pressure at constant temperature. Proposal B adds a more active catalyst at the original temperature and pressure. For a fresh feed, compare the effects on the initial rate and equilibrium yield of ammonia. Give one practical drawback of A.

### 9. Extra challenge · Compare two ways of making a fertiliser

A laboratory needs a few grams of ammonium sulfate crystals. A factory needs a continuous supply of the same fertiliser.

Describe how the laboratory can make the salt from ammonia solution and dilute sulfuric acid. Compare its method with large-scale production, including the source of the starting chemicals.

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# Worked answers

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### 1. The reactor equation

$N_2 + 3H_2 \rightleftharpoons 2NH_3$. The reversible arrow shows that the products can also react to form the reactants.

### 2. Readings in a closed container

At dynamic equilibrium, the forward and reverse reactions continue at equal rates. Ammonia forms at the same rate as it is used up, so its amount stays constant.

### 3. Running the Haber process

Iron is the catalyst. The usual exam values are about 450 °C and 200 atmospheres. Nitrogen is obtained from air.

### 4. Choosing a fertiliser

Phosphorus and potassium. Ammonium nitrate contains nitrogen, hydrogen and oxygen, so it supplies neither phosphorus nor potassium.

### 5. Higher · compressing a gas mixture

The equilibrium amount of $NO_2$ decreases. The position shifts towards $N_2O_4$, with one mole of gas on that side of the equation compared with two moles on the $NO_2$ side. The shift partly opposes the pressure increase.

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# Worked answers

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### 6. Higher · choosing a temperature

Cooling favours the exothermic forward reaction, increasing equilibrium yield. At a lower temperature, fewer collisions have enough energy to react, so ammonia forms more slowly. The compromise gives an acceptable yield in a useful time.

### 7. Make a fertiliser from ammonia

Ammonium nitrate forms in an acid-base neutralisation. The ammonia accepts hydrogen ions to form ammonium ions, which combine with nitrate ions.

Sulfuric acid supplies sulfate ions, so the salt would be ammonium sulfate.

### 8. Higher · comparing factory proposals

A increases the initial rate because gas particles collide more often. It increases equilibrium yield because ammonia formation reduces the number of gas particles. B increases the initial rate and leaves equilibrium yield unchanged.

A requires more energy for compression or equipment designed for higher pressures.

### 9. Extra challenge · Compare two ways of making a fertiliser

Find the proportions that give neutralisation, then mix those amounts without indicator. Concentrate the solution gently and allow crystals to form. Separate and dry them.

Both routes react ammonia with sulfuric acid to make ammonium sulfate. Industrial production uses large-scale equipment and separate stages to make the starting chemicals from raw materials. Ammonia comes from the Haber process. The factory needs supplies and equipment suited to continuous output.

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