Equilibrium and the Haber process

AQA GCSE Chemistry (8462) · 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. Recovering ammonia

Gas leaving the reactor contains nitrogen, hydrogen and ammonia. Describe how a factory can collect ammonia from this mixture and use the remaining gases to make more product.

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 · Choose reactor conditions (Higher)

A factory compares 400 °C and 250 atm with 450 °C and 200 atm. Predict which combination gives a higher equilibrium yield of ammonia.

Explain why the initial rate cannot be ranked from these changes alone. Suggest one cost or safety check before changing the conditions.

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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. Recovering ammonia

Cool the whole mixture until ammonia condenses. Nitrogen and hydrogen remain gaseous under these conditions and can be returned to the reactor for further reaction.

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 · Choose reactor conditions (Higher)

400 °C and 250 atm gives the higher equilibrium yield. Lower temperature favours the exothermic forward reaction. Higher pressure favours the side with fewer gas molecules.

Lower temperature lowers the initial rate, while higher pressure raises it. Their opposing effects need rate data to rank the two combinations. Check the cost of compression or whether the equipment can safely withstand 250 atm.

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