The production of ammonia

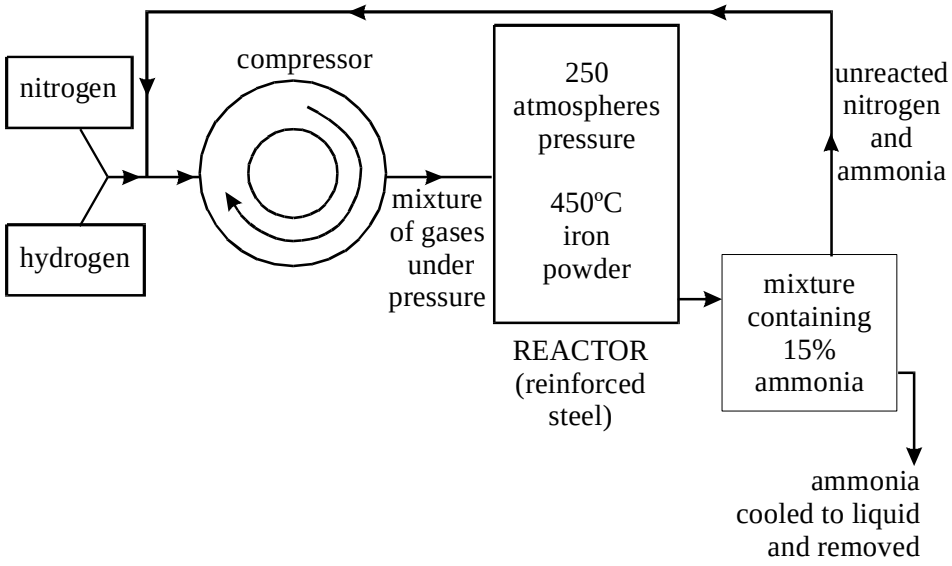
NB q3(b) deleted

1. Ammonia is manufactured from nitrogen and hydrogen. The reaction is shown in the equation below.

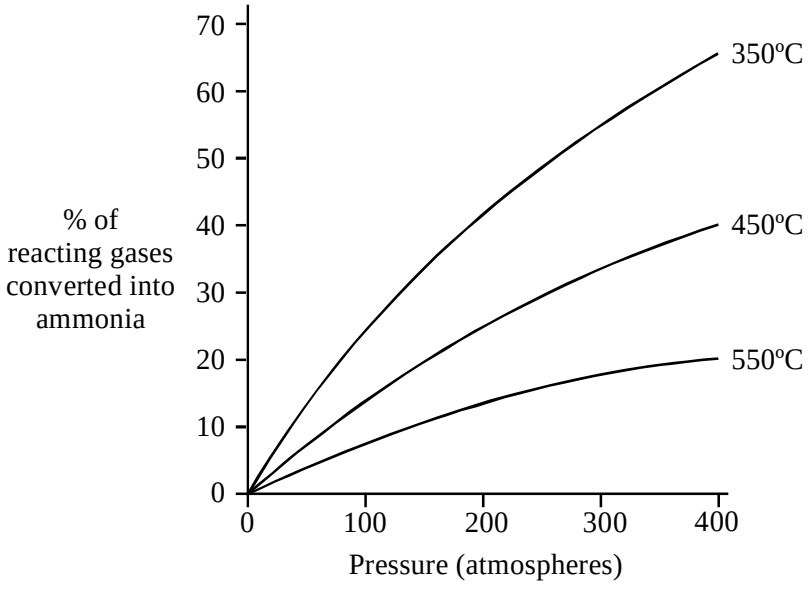
$$\underset{\text{nitrogen}}{N_2} + \underset{\text{hydrogen}}{3H_2} \rightleftharpoons \underset{\text{ammonia}}{2NH_3}$$

exothermic (→) / endothermic (←)

The diagram shows some details of the manufacturing process.



The graph shows the percentage of reacting gases converted into ammonia at different temperatures and pressures.



At room temperature and pressure, the reaction is very slow and only a small percentage of the reacting gases is converted to ammonia.

Use the information on the diagram and graph to:

(a) describe the conditions used in the manufacture of ammonia **to increase the rate of reaction**.

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(4)

(b) describe and explain the conditions used in the manufacture of ammonia **to increase the yield.**

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(7)
(Total 11 marks)

2. Methanol is a fuel that is used in some racing cars instead of petrol.

Methanol can be made from carbon monoxide and hydrogen. The equation for this reaction is shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The forward reaction is exothermic.

(a) A high pressure (between 50 and 100 atmospheres) is used in this process.

Explain why the highest equilibrium yield of methanol is obtained at high pressure.

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(1)

(b) The temperature used in this process is about 250 °C.

It has been stated that, 'the use of this temperature is a compromise between the equilibrium yield of product and the rate of reaction'.

Explain this statement.

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(3)
(Total 4 marks)

3. The reaction of methane with steam is used in industry to make hydrogen.

One of the reactions in this process is represented by this equation.

$$CH_4(g) + H_2O \rightleftharpoons CO(g) + 3H_2(g)$$

The forward reaction is endothermic.

State the conditions of temperature and pressure that would give the maximum yield of hydrogen.

Explain your answers.

(i) Temperature

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(2)

(ii) Pressure

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(2)

(iii) Which one of the following metals is most likely to be a catalyst for this process? Draw a ring around your answer.

aluminium **lead** **magnesium** **nickel** **sodium**

Give a reason for your choice.

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(1)