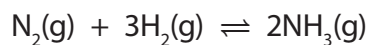


- 1 When nitrogen and hydrogen react to form ammonia, the reaction can reach a dynamic equilibrium.



- (a) Explain what is meant by a **dynamic equilibrium**.

(2)

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- (b) In industry, the reaction between nitrogen and hydrogen is affected by the conditions used.

- (i) The pressure used is 250 atmospheres.
Explain how the use of a higher pressure would affect the equilibrium yield of ammonia.

(2)

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- (ii) The reaction between nitrogen and hydrogen to form ammonia is exothermic.
The temperature used is 450°C.

Explain how the use of a lower temperature would affect the equilibrium yield of ammonia.

(2)

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(iii) Even at 450°C, the reaction is very slow.

State what is used in industry to overcome this problem.

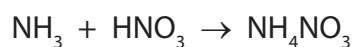
(1)

(c) (i) Calculate the minimum volume of hydrogen required to completely convert 1000 dm³ of nitrogen into ammonia.

(1)

volume of hydrogen = dm³

(ii) Ammonia is reacted with excess nitric acid, HNO₃, to make ammonium nitrate, NH₄NO₃.



Calculate the mass of ammonium nitrate produced by the complete reaction of 34 g of ammonia.

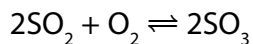
(Relative atomic masses H = 1.0, N = 14, O = 16)

(3)

mass of ammonium nitrate produced = g

(Total for Question 1 = 11 marks)

2 Sulfur trioxide is produced by reacting sulfur dioxide with oxygen.



- (a) (i) This reaction takes place in industry at 1–2 atm pressure and can reach a dynamic equilibrium.

Explain the effect on the rate of attainment of equilibrium, if the process is carried out at a pressure higher than 1–2 atm.

(3)

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- (ii) What volume of oxygen, in cm^3 , would react completely with 500 cm^3 sulfur dioxide?

(1)

- A 500
- B 500
- C 500
- D 500

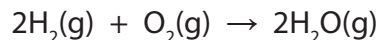
- (b) When there are alternative methods of producing a product, the final pathway is chosen by considering atom economy, cost of energy, yield of product and rates of reactions.

State another factor that should also be considered.

(1)

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3 (a) Hydrogen reacts with oxygen to form water vapour.



If 200 cm³ of hydrogen react completely with 100 cm³ of oxygen, what is the maximum volume of water vapour formed, if all volumes are measured at the same temperature and pressure?

Put a cross (☒) in the box to show your answer.

(1)

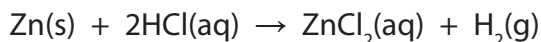
A 100 cm³

B 200 cm³

C 300 cm³

D 400 cm³

(b) Zinc reacts with dilute hydrochloric acid to form zinc chloride and hydrogen.



Calculate the maximum volume of hydrogen formed, at room temperature and pressure, when 13.0 g of zinc reacts completely with excess hydrochloric acid.
(relative atomic mass: Zn = 65.0,
1 mol of any gas occupies 24 dm³ at room temperature and pressure)

(2)

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volume of hydrogen = dm³

(c) In industry, ammonia is produced by the Haber process.



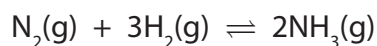
(i) What is the source of the hydrogen used in the Haber process?

Put a cross (☒) in the box to show your answer.

(1)

- A** air
- B** reaction of zinc with dilute sulfuric acid
- C** electrolysis of water
- D** natural gas

(ii) When nitrogen reacts with hydrogen, the amount of ammonia gradually increases until it becomes constant.



Explain why the amount of ammonia remains constant.

(2)

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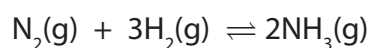
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4 (a) Propene is a gaseous hydrocarbon.

Draw the structure of a molecule of propene, showing all bonds.

(2)

(b) Nitrogen reacts with hydrogen to form ammonia.



(i) Calculate the minimum volume of nitrogen, in dm^3 , required to react completely with 1000 dm^3 of hydrogen.

All volumes are measured at the same temperature and pressure.

Put a cross (☒) in the box next to your answer.

(1)

A 333 dm^3

B 1000 dm^3

C 3000 dm^3

D 4666 dm^3

(ii) The minimum volumes of nitrogen and hydrogen that must react completely to form 5000 dm^3 of ammonia are calculated.

These volumes are mixed and left, under appropriate conditions, until the reaction reaches equilibrium.

Explain which gas or gases will be present when equilibrium is reached.

(2)

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(iii) The Haber process is carried out under a pressure of about 200 atm.

Explain the effect on the **equilibrium yield** of ammonia, if the process is carried out at a pressure higher than 200 atm.

(2)

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(iv) Explain the effect on the **rate of attainment of equilibrium**, if the process is carried out at a pressure higher than 200 atm.

(3)

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(Total for Question 4 = 10 marks)