Beatty Secondary School
Science Department (Chemistry Unit)
Chemistry 6092

Name: _____ ( ) Date: _____

Class: 4E___

TOPIC: AMMONIA (WORKSHEET 1)

Learning Objectives:

(a) State that some chemical reactions are reversible, e.g. manufacture of ammonia.

(b) Describe the use of nitrogen, from air, and hydrogen, from the cracking of crude oil, in the manufacture of ammonia.

(c) Describe the essential conditions for the manufacture of NH_3 by the Haber process.

(d) Describe the use of ammonia to manufacture nitrogenous fertilisers.

(e) Describe the displacement of ammonia from its salts and explain why adding calcium hydroxide to soil can cause the loss of nitrogen from added nitrogenous fertiliser.

Multiple-Choice Questions

1 The catalyst used in the Haber process is _____.

A copper **B** iron
C hydrogen chloride **D** nickel (**B**)

2 When 1 mol of nitrogen is reacted with 3 mol of hydrogen at 250 atm and 450 °C in the presence of an iron catalyst, less than 2 mol of ammonia is formed.

Which of the following best explains this observation?

A The pressure used was too low.
B The temperature used was too low.
C The nitrogen and hydrogen used in the reaction contained impurities.
D The reaction of nitrogen and hydrogen to form ammonia is reversible. (**D**)

3 Which ion will react with ammonium sulfate to give ammonia gas?

A NH_4^+ **B** OH^-
C H^+ **D** Cl^- (**B**)

4 All ammonium salts on heating with sodium hydroxide produce ammonia gas. From which ammonium salt can the greatest mass of ammonia be obtained?

A 0.5 mol $(NH_4)_3PO_4$ **B** 0.5 mol $(NH_4)_2SO_4$
C 1.0 mol NH_4Cl **D** 1.0 mol NH_4NO_3 (**A**)

5 Which of the following will **not** react with ammonium salts to give ammonia gas?

A limewater **B** potassium hydroxide
C hydrochloric acid **D** sodium hydroxide (**C**)

Use the following information to answer Questions 6 and 7.

The Haber process is used to manufacture ammonia gas. The reaction is exothermic and the chemical equation for the process is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

6 Given that the same volumes of nitrogen and hydrogen was used, what is the effect of increasing the pressure inside the reaction vessel on the rate of production and the **overall** yield of ammonia gas?

	rate	yield
A	decrease	decrease
B	increase	unchanged
C	increase	decrease
D	increase	increase

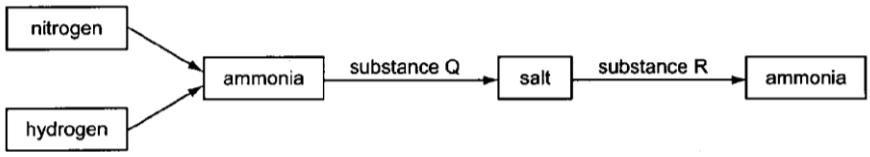
(**B**)

7 Which of the following statements is **not** true of the Haber process?

A The raw material, nitrogen gas, is obtained from the cracking of petroleum.
B Liquid ammonia is the product of the Haber process.
C Nitrogen and hydrogen gases are compressed at 250 atm during the process.
D Unreacted nitrogen and hydrogen are recycled and transferred back into the converter. (**A**)

8 Ammonia is produced by the reaction of the elements hydrogen and nitrogen in the Haber process. One of these elements is obtained from crude oil.

The ammonia formed can be reacted with substance Q to form a salt. Ammonia can be displaced from this salt by reacting with substance R.



Which row correctly shows the element obtained from crude oil and the types of substances corresponding to Q and R?

	element obtained from crude oil	substance Q	substance R
A	hydrogen	acid	base
B	hydrogen	base	acid
C	nitrogen	acid	base
D	nitrogen	base	acid

(**A**)

9 Which of the following statements are true of the Haber process?

1 An increase in pressure increases the speed of reaction.
2 An iron catalyst is used to increase the yield of ammonia.
3 A high temperature of 450 °C is used to increase the yield of ammonia.
4 A relatively low pressure of 250 atm is used because it is costly to maintain a high pressure.

A 1 and 4 **B** 1, 3 and 4
C 2 and 3 **D** 1, 2, 3 and 4 (**A**)

10 Which conditions are ideal for the manufacture of ammonia in the Haber process?

	pressure / atm	temperature / °C	ratio of hydrogen : nitrogen
A	250	450	3 : 1
B	250	450	1 : 3
C	450	250	3 : 1
D	450	250	1 : 3

(**A**)

11 Which fertiliser provides the most nitrogen per mole?

A NH_4NO_3 **B** $NaNO_3$
C $(NH_4)_3PO_4$ **D** $(NH_4)_2SO_4$ (**C**)

12 Hydrazine has the formula, H_2NNH_2. It has similar properties to ammonia. Which property will hydrazine have?

A It dissolves in water to give hydrogen ions.
B It is an ionic compound.
C It reacts with alkalis to form salts.
D It reacts with hydrogen chloride to form a compound with the formula ClH_3NNH_3Cl. (**D**)

13 The fertiliser ammonium nitrate (NH_4NO_3, M_r = 80) is manufactured from ammonia (NH_3, M_r = 17) by a two-stage process.

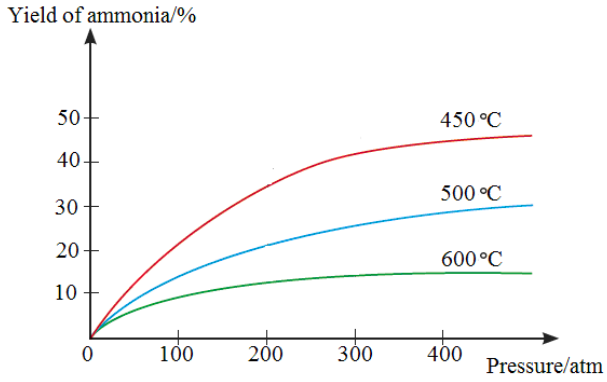
Stage 1 $NH_3 + 2O_2 \rightarrow HNO_3 + H_2O$
Stage 2 $HNO_3 + NH_3 \rightarrow NH_4NO_3$

What is the maximum mass of fertiliser that can be made if only 17 tonnes of ammonia is available?

A 17 tonnes **B** 40 tonnes
C 80 tonnes **D** 97 tonnes (**B**)

Structured Questions

14 Ammonia is produced commercially by the Haber process. The graph shows the percentage yield of ammonia at different pressures and temperatures.



(a) How does pressure affect the yield of ammonia?

The higher the pressure, the higher the percentage yield of ammonia.

(b) How does temperature affect the yield of ammonia?

The higher the temperature, the lower the percentage yield of ammonia.

(c) What happens to the speed of reaction when the temperature is lowered?

The speed of reaction decreases when the temperature is lowered

(d) Why is the temperature used in the Haber process usually around 450 °C and not higher?

A higher temperature greater than 450 °C would lead to a decrease in the percentage yield of ammonia as the products would thermally decompose to form back nitrogen and hydrogen reactants.

(e) Based on the graph, what will be the percentage of ammonia formed at 450 °C and 200 atm?

Around 35.0%

15 The production of ammonia from nitrogen and hydrogen is a reversible reaction.

(a) What do you understand by the term *reversible reaction*?

A reversible reaction is a reaction whereby the reactants, N_2 and H_2, can react to undergo a forward reaction to form the product, NH_3, and the product, NH_3, can dissociate to undergo a backward reaction to form N_2 and H_2 at the same time.

(b) Given that the ΔH = −92 kJ/mol for the production of ammonia, is the decomposition of ammonia to nitrogen and hydrogen an exothermic or endothermic process? Explain your answer.

Endothermic. The enthalpy change for the reverse reaction would have a positive value of +92.0 kJ/mol.

(c) With the aid of an equation, explain why the volume of hydrogen to nitrogen gas used is 3:1.

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2NH_3\,(g)$$

According to the equation, 1 mole of nitrogen requires 3 moles of hydrogen to react together. Since 1 mole of any gas has the same volume at room temperature and pressure. Thus, based on Avogadro's Law, 1 volume of nitrogen requires 3 volumes of hydrogen to react together.

(d) When the mixture of hydrogen, nitrogen and ammonia enters the cooler, the ammonia turns into a liquid, but the other gases do not. What does this tell you about the boiling point of ammonia?

The boiling point of ammonia is higher than hydrogen and nitrogen.

16 Ammonia is used to manufacture nitric acid, by a two-stage process.

Stage 1: the ammonia is converted to nitrogen monoxide.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

Stage 2: the nitrogen monoxide is converted to nitric acid

$$4NO(g) + 2H_2O(g) + 3O_2(g) \rightarrow 4HNO_3(aq)$$

(a) Explain why stage 2 is a redox process.

Oxygen in O_2 is reduced to HNO_3 and nitrogen in NO is oxidised to HNO_3 at the same time.

Oxidation state of O decreases from 0 in O_2 to −2 in HNO_3 while oxidation state of N increases from +2 in NO to +5 in HNO_3.

(b) Determine the percentage yield of nitric acid, if 720 dm^3 of ammonia, at room temperature and pressure produces 10.0 dm^3 of 2.50 mol/dm^3 nitric acid.

% yield = 83.3%

(c) A farmer wants to improve crop yield by adding slaked lime to neutralise his soil that is acidic. However, the soil has previously been fertilised with ammonium nitrate. Explain why this is an **ineffective** method.

Calcium hydroxide (slaked lime) will react with ammonium nitrate to form calcium nitrate salt, water and ammonia gas. As nitrogen is an essential element for plant growth, there will be loss of nitrogen in the form of ammonia to the atmosphere, reduced plant growth. Furthermore, the pH of the soil remains acidic as the slaked lime reacted to form a neutral salt.

17 Nitrogen and hydrogen are mixed in definite proportions before they enter the reactor. The table shows the percentages of each gas in the mixture by volume and by mass.

	nitrogen	hydrogen
percentage by volume	25	75
percentage by mass	82	18

(a) Explain why these percentages by volume are chosen.

According to the equation, 1 mole of nitrogen requires 3 moles of hydrogen to react together to form ammonia. Since 1 mole of any gas has the same volume at room temperature and pressure. Thus, based on Avogadro's Law, 1 volume of nitrogen (25%) requires 3 volumes of hydrogen (75%).

(b) Explain why the percentages of the gases are different when they are measured by volume and when they are measured by mass.

Both gases have different relative molecular masses M_r of N_2 = 28 and M_r of H_2 = 2. Since mass is dependent on the molecular masses, the percentage by mass would be different.

However, since the volume of 1 mole of gas is 24 dm^3, the volume ratio would still be 1:3.

(c) The gases leaving the reactor contain unreacted nitrogen and hydrogen and about 15% ammonia by volume. Unreacted nitrogen and hydrogen are fed back into the reactor in stage 2. Give **two** reasons why the unreacted gases are fed back into the reactor.

1. **This is to conserve nitrogen and hydrogen resources. Thus, they are recycled so that less raw materials need to be processed. This will save cost and energy.**

2. **Only about 10 – 15% of the gases react to form ammonia. Recycling the gases helps to maximise the yield of ammonia.**