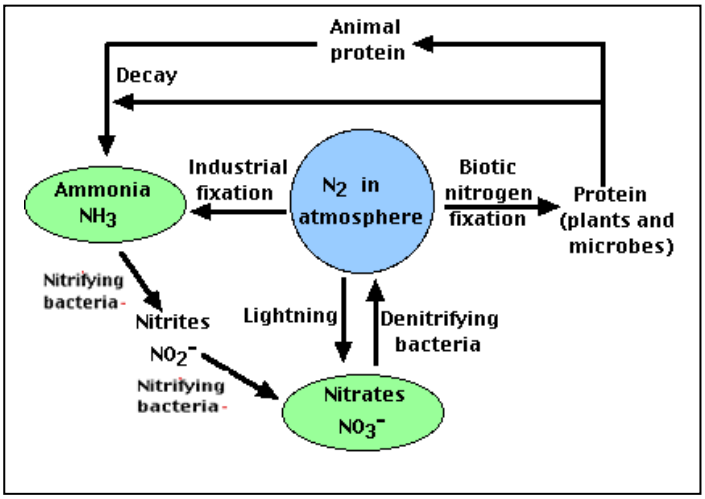
Friday Worksheet **Name: …….**

Ammonia production worksheet 6

1) Nitrogen is essential to life and abundant in the atmosphere but is inaccessible to all organisms. Nitrogen fixation is a process by which nitrogen gas is converted to soluble nitrogenous products, such as ammonium or nitrate ions, that can be used by organisms. Nitrifying bacteria convert ammonia into usable compounds as shown in the diagram below.



a) Give the balanced half equation for the process carried out by nitrifying bacteria in converting ammonia into nitrites

$NH_3(g) + 2H_2O(l) \rightarrow NO_2^-(aq) + 7H^+(aq) + 6e$

b) Give the balanced half equation for the process carried out by denitrifying bacteria in converting nitrates into nitrogen gas.

$10e + 12H^+(aq) + 2NO_3^-(aq) \rightarrow N_2(g) + 6H_2O(l)$

c) NO_2 gas is a pollutant from car exhaust. Nitrogen dioxide undergoes the following reaction to produce dinitrogen tetroxide (N_2O_4). N_2O_4 reacts with liquid water to produce nitric acid according to the equation below.

$3N_2O_4(g) + 2H_2O(l) \rightarrow 4HNO_3(aq) + 2NO(g)$

What type of reaction is this? Give a reason.

Redox reaction. Nitrogen has an oxidation state of +4 in N_2O_4 and is reduced to +2 in NO and oxidised to +5 in HNO_3.

2) The chemical equation for the Haber process is given below

$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$ $\Delta H = -92.3$ kJ/mol

3.00 mol of H_2 gas and 6.00 mol of N_2 gas were placed in a 2.00 L, high pressure reaction vessel and allowed to react. At equilibrium the mixture contained 0.88 mol of NH_3.

a) Calculate the mol of the following at equilibrium.

i. Nitrogen gas = 6.00 - ½ X 0.88 = 5.56

ii. Hydrogen gas = 3.00 – 3/2 X 0.88 = 1.68

b) Calculate the energy produced by this reaction to the right number of significant figures..

Energy produced = (92.3 / 2) X 0.88 = 40.6 kJ

c) Calculate the equilibrium constant at this temperature.

$$\frac{[NH_3]^2}{[N_2][H_2]^3}$$

$=> [0.88/2]^2 / ([5.56/2] [1.68/2]^3 = 0.117 M^{-2}$

d) Calculate the pressure, in atm, exerted on the vessel walls at a temperature of 100.0°C

$PV = nRT$

$=> P = nRT/V$

=> P = (0.88 + 5.56 + 1.62) X 8.31 X 373)/2 = 12591. kPa

=> 12591 /101.325 = 124.3 atm

e) Hydrogen and nitrogen gases were mixed in a bomb calorimeter containing 50.0 mL of water at 22.0 °C. After the reaction, a total amount of 0.340 grams of ammonia was formed. Assuming 55.0% of the energy produced went into directly heating up the water calculate the final temperature of the water.

Step1 calculate the mol of ammonia

=> 0.340 / 17.0 = 0.02

Step 2 Calculate the amount of energy released.

=> 0.02 X 92.3kJ / 2 = 923 J

Step 3 Calculate the amount of energy actually absorbed by the water.

=> 0.550 X 923 = 508J

Step 4 Calculate the ΔT

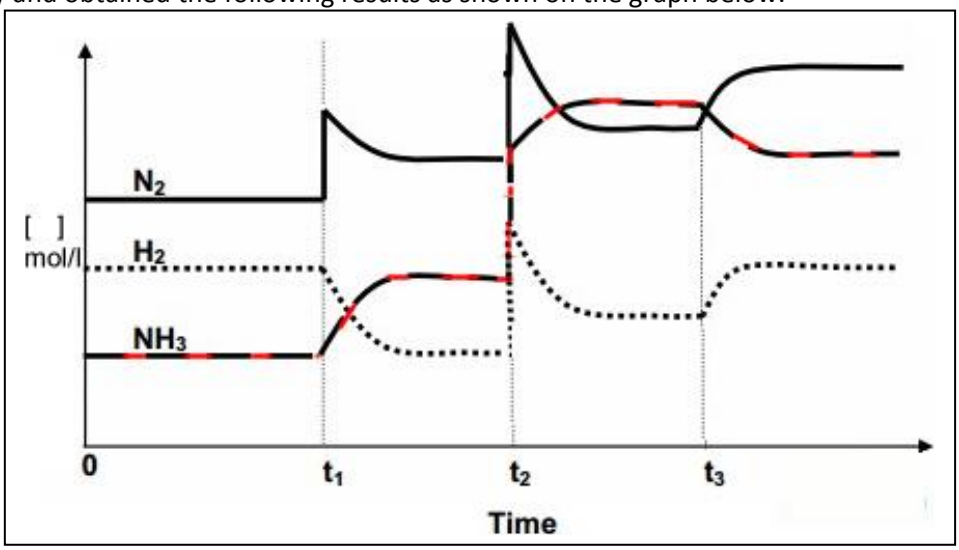
=> 508 = 4.18 X 50.0 X ΔT

=> ΔT = 508 / (4.18 X 50.0) = 2.43

Step 5 calculate the final temperature

=> 22.0 + 2.43 = 24.43 °C

3) The chemical engineer of a large ammonia manufacturing plant was instructed to make adjustments to increase the yield of ammonia. The engineer conducted small scale trials in the laboratory and obtained the following results as shown on the graph below.



a) At time t_1 what is likely to have happened? Explain how this impacted on the yield

Nitrogen gas is added. A single spike for nitrogen gas indicates that only noitrogen gas was added and hence the system shifted to the right to partially undo the change.

b) At time t_2 what is likely to have happened? Explain how this impacted on the yield

Volume was decreased. All concentrations show an increase this is due to a volume decrease.

c) At time t_3 what is likely to have happened? Explain how this impacted on the yield

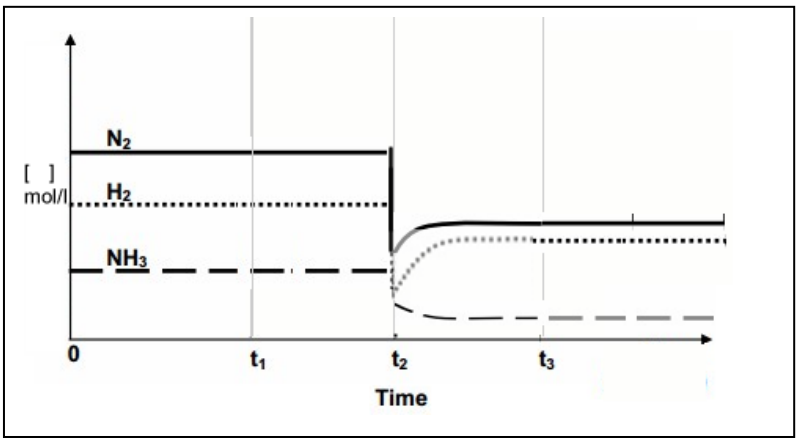
Temperature has increased. The equilibrium has shifted to the left indicating that temperature has been increased thus favouring a shift to the left.

d) Complete the graph on the right if the following changes take place.

t_1 - Pressure is increased through the introduction of helium gas

t_2 - Volume of the reaction chamber is doubled.

t_3 - Catalyst is added



e) Which of the following will cause an increase in the yield? Give reasons for your choice.

i. Heating the gases as they enter the reaction chamber.

Since this is an exothermic reaction heating will only drive the equilibrium position to the left , however the rate of the reaction will increase. Removing the heat given out by the reaction to heat incoming gases, so as to cool the reaction mixture will ultimately increase the yield as the reaction mixture is cools.

ii. Increasing the pressure of the reaction vessel by decreasing its volume.

Since there are fewer particles on the products side the system will shift to the left to try and partially undo the change.

iii. Adding a catalyst.

A catalyst has no impact on the yield and will only increase the rate of the reaction. Once at equilibrium the catalyst increases the forward and reverse reactions equally.

iv. Removing product and recycling the gases.

Removing the product will cause a shift to the right to partially undo the change and hece increase the yield.