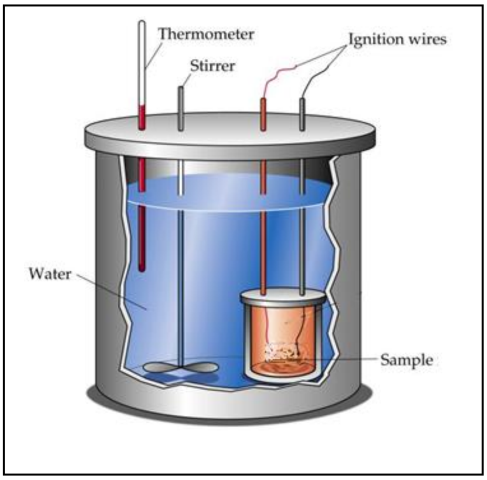
Friday Worksheet **Name: ……………….**

Ammonia production worksheet 2

1) Hydrogen and oxygen gases were mixed in a bomb calorimeter and allowed to react according to the equation below.



$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)\ \Delta H = ?$$

1) The bomb calorimeter contained 25.0 g of water at 20.0°C. At completion of the reaction the final temperature of the water was recorded at 23.0 °C. Once the reaction was complete it was found that 0.126 grams of ammonia was formed.

a) Determine the ΔH for the equation above. Show all working.

Step 1 find the mole of ammonia formed
=> 0.126 / 17.0 = 7.38 X 10^{-3}

Step 2 find the amount of energy given out.
=> E = 4.186 $J.g^{-1}.°C^{-1}$ X mass of water X change in temperature
=> E = 4.186 X 25.0 X 3.00 J
=> E = 314 J

Step 3 find the amount of energy per mol of NH_3 produced
=> E/mol = 314 / 7.30 X 10^{-3} = 43.0 kJ/mol

Step 4 find the ΔH of the equation
=> According to the equation two moles of NH_3 are formed.
=> So 2 X 43.0 kJ = 86.0 kJ/mol
=> ΔH = - 86.0kj/mol

b) The ΔH of the reaction has being determined accurately at a value of -92.0 kJ/mol. Compare your result you obtained in a) above and give a possible explanation for the discrepancy .

The value in a) is less than 92 kJ/mol. One possible reason is that significant heat escaped from the bomb calorimeter without heating the water. Poor insulation may have been a factor.

c) Consider the equation below

$$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)\ \Delta H = -92\ kJ/mol\ \text{-------}\ 1)$$

Will the magnitude of the calculated ΔH (X) of the equation below be less than, equal to or more than the magnitude of the ΔH of equation 1)?

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

It will be greater.

Explain

More energy is required to keep the number of mol of NH_3 in the gas state than in the liquid state. This excess energy is given off as heat since it is not required hence the magnitude of the $\Delta H > 92$ kJ/mol

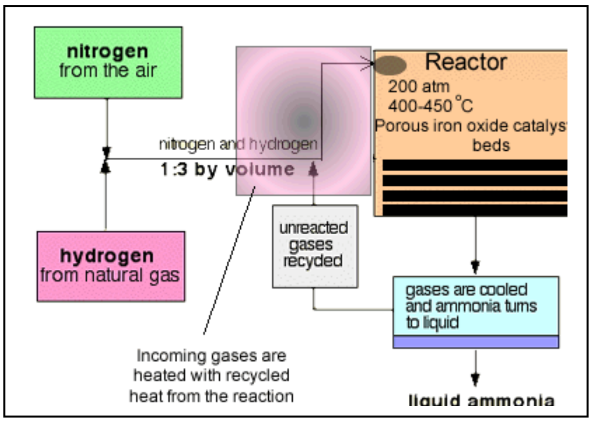
2) 0.200 mol of H_2 gas and 0.350 mol of N_2 gas were placed in another bomb calorimeter at 23.0 ^{o}C. If the volume of the container is 2.31 litres calculate the pressure, in mmHg, exerted by the gasses before any reaction takes place.

Step 1 Find the total mol of gas present
=> 0.200 + 0.350 = 0.550
Step 2 Calculate the pressure
=> PV =nRT
=> P = nRT/V
=> P = 0.550 X 8.31 X 296 / 2.31 = 5860 kPa
Step 3 convert to mmHg
=> 586/101.3 = 5.79 X 760 =4.40 X 10^{3} mmHg

3) A window cleaner contains ammonia. The concentration of ammonia is 10.0 M. What is the concentration of ammonia in %w/v
Step 1 find the mass of ammonia in 1,000 mL
=> mass in one litre = 10.0 X 17.0 = 170.0 grams
Step 2 find the mass of ammonia in 100 mL
=> 17.0 grams
Step 3 w/v%
=> 17.0% w/v

4) Explain, with reference to the structure of the ammonia molecule, why ammonia is highly soluble in water.
Read more

5) Under normal reaction conditions, the Haber process has a yield around 15% with each pass through the reaction chamber. Through different strategies the yield is increased to 98% on average.
a) Aside from temperature and pressure, discuss strategies employed by industrial chemists to achieve such a high yield.
Unreacted gases are recylced
Read more



b) Describe the source of each of the reactants.
Hydrogen is produced from methane gas and nitrogen is sourced from the atmosphere.
c) Why are the reactants added in a $1N_2 : 3H_2$ ratio.
This is the stoichiometric ratio required for the reaction.
d) In one particular country the supply of hydrogen gas is very expensive compared to the supply of nitrogen which is taken straight from the atmosphere. Suggest one way to ensure that most of the expensive reactant is used up.

Instead of adding the reactants in a ratio of $1N_2 : 3H_2$
add excess nitrogen gas to ensure the complete
reaction of the expensive reactant. Keep in mind, the source of both nitrogen and hydrogen are relatively cheap in most industrialised countries.

e) Heating the reactant mixture to temperatures between 400 and 450 ^{o}C can beproblematic as it is very expensive. How is this problem solved.

Heat energy produced from the reaction is used to preheat the reactants before being pumped into the reaction chamber.

6) Nitrogen gas can be converted into nitrogen compounds by bacteria known as nitrogen fixing bacteria. A family of bacteria called Rhizobiaceae convert atmospheric nitrogen into compounds such as NH^+, NO_2^-, NO_3^-.

a) Atmospheric nitrogen is converted to NH_4^+

i. Is this an oxidation, reduction or acid base reaction?

Reduction

N_2(g) nitrogen has an oxidation state of 0 → NH_4^+(aq) nitrogen has an oxidation state of -3

ii. Write the half equation for this reaction.

$N_2(g) \rightarrow 2NH_4^+(aq)$

=>$6e + 8H^+(aq) + N_2(g) \rightarrow 2NH_4^+(aq)$

b) NO_2^- is converted to NO_3^- .

i. Is this an oxidation, reduction or acid base reaction?

Oxidation

NO_2^- (aq) nitrogen has an oxidation state of +3 → NO_3^-(aq) nitrogen has an oxidation state of +5

ii. Write the half equation for this reaction.

$NO_2^-(aq) \rightarrow NO_3^-(aq)$

=>$H_2O\ (l) + NO_2^-(aq) \rightarrow NO_3^-(aq)$

=> $H_2O\ (l) + NO_2^-(aq) \rightarrow NO_3^-(aq) + 2H^+(aq) + 2e$