Chemical Equilibria

1. State that some chemical reactions are reversible (manufacture of ammonia)
2. Explain, in terms of the rates of forward and reverse equations, what is meant by a reversible reaction and dynamic equilibrium

Reversible Reactions:

- Chemical reactions that can proceed in two directions: forward and backward
- Reaction from left to right is the forward reaction
- Reaction from right to left is the backward reaction
- Equilibrium: concentration of the reactants and products are constant
    - All reversible reactions will eventually reach an equilibrium
    - State of equilibrium: rate of forward reaction is equal to the rate of backward reaction
    - Note: *this does not mean that the reaction stops when equilibrium is attained (thus the chemical equilibrium is dynamic)*
    - Note: Equilibrium only exists if substances do not escape or enter a reaction container
    - Note: Equilibrium mixture may not be 50% reactant and 50% products: the concentrations of reactions and products remain constant (not half)
    - Note: Equilibrium can be reached from different directions, thus the equilibrium state is independent of the direction from which it is approached
- Reversible reactions can be manipulated to increase the yield of the products
    - Change of concentration, change of temperature, change of pressure

3. State Le Chatelier's Principle and apply it to deduce qualitatively the effects of changes in temperature, concentration or pressure, on a system at equilibrium

Le Chatelier's Principle

- If a system at equilibrium is subjected to a small change, the equilibrium's response is to counteract the change so as to minimize the effect of the change
- Changing concentration:
    - The position of equilibrium will shift to the right when the concentration of a reactant is increased (increasing the concentration of either nitrogen or hydrogen will increase the yield of ammonia in the Haber process/condensation of ammonia into liquid form also shifts position of equilibrium to the right)
- Changing temperature:
    - Lowering the temperature of the reaction is done by removing heat, and the reaction will respond by increasing heat production, to replace the heat removed

	Increase in temperature	Decrease in temperature
Exothermic Reaction	Both the rate of forward and backward reactions increase, but **rate of forward reaction increases less than rate of backward reaction**, thus the position of equilibrium shifts left	Both the rates of forward and backward reactions decrease. **Rate of forward reactions decreases less than backward reaction**, thus position of equilibrium shifts right
Endothermic Reaction	**Rate of forward reaction increases more than backward reaction**, position of equilibrium shifts right	**Rate of forward reaction decreases more than the rate of backward reaction**, thus position of equilibrium shifts left

- Changing pressure:
    - Increasing the pressure of the system will cause the equilibrium to shift to relieve the pressure, thus pressure will decrease if the system contains fewer moles of gas
- Catalyst: increase the speeds of both forward and backward reactions, thus it does not affect the yield of the product

4. Describe the essential conditions for the manufacture of ammonia by Haber process
5. Describe the use of nitrogen, from air, and hydrogen, from cracking oil, in the manufacture of ammonia
    a. 200 atm
    b. 450 degree Celsius
    c. Iron is used as the catalyst to speed up the rate of reaction
    d. Presence of hydrogen from cracking larger hydrocarbons (including oil) and nitrogen from liquefied air (which are the reactants of the reaction)

- Uses of Ammonia:
    - Commercial fertilizers (important to farmers as it increases food production)

6. Describe and explain the conditions used in the Haber process, as an example of the importance of an understanding of chemical equilibrium in the chemical industry: compromise between rate and yield

- Explanation of 450 degrees Celsius
    - The lower the temperature the greater the yield of ammonia (since the production of ammonia is an exothermic reaction with the release of heat energy, thus lowering the temperature favours the forward reaction and shifts the equilibrium to the right to produce more heat, thus increasing ammonia yield)
    - However, low temperature slows the speed of reaction, and the Haber process operates at 450 degrees as the optimum temperature that maximizes the yield of ammonia
- Explanation of 200 atm
    - There is 1 mole of N2 and 3 moles of H2 that forms 2 moles of NH3, and since 1 mole of any gas occupies the same volume (24dm^3), the forward reaction results in a decrease in volume
    - The higher the pressure the greater the yield of ammonia
    - However, very high pressure poses a safety hazard and it becomes less cost-effective to operate at a very high pressure since the cost of maintaining high pressure erodes the profit of producing ammonia, and Haber process operates at 200atm, the optimum pressure that results in an optimum yield of ammonia that maximizes profits