Name:

Chemical Equilibrium	**Objectives**
17. Chemical Equilibrium	-explain what is meant by a reversible reaction -explain what is meant by dynamic equilibrium -explain what is meant by chemical equilibrium -state the equilibrium law (K_c only) -write expressions for K_c -state Le Chatelier's principle -use Le Chatelier's principle to predict the effect (if any) on equilibrium position of concentration, pressure, temperature and catalyst -perform a simple experiment to demonstrate the following equilibrium mixture (to demonstrate the effects of both temperature changes and concentration changes on an equilibrium mixture) $Fe^{3+} + CNS^{-} \rightarrow Fe(CNS)^{2+}$ -discuss the Industrial application of Le Chatelier's principle in the Contact process and in the Haber process

Def^n: A **reversible reaction** is one in which both the forward and reverse reactions can occur.

Def^n: A **dynamic reaction** is one in which both the forward and reverse reactions occur simultaneously.

Def^n: **Chemical equilibrium** is when the rate of the forward reaction is equal to the rate of the reverse reaction.

<u>Le Chatelier's Principle:</u>

Def^n: **Le Chatelier's Principle** states that when a stress is applied to system at equilibrium, the system adjusts to oppose the stress.

In other words, if a stress is applied to a reaction at equilibrium (change temperature, concentration or pressure) the system will form more of the reactants/products to "undo" the change we applied.

Effects of Le Chatielier's Principle:

Stress		**LHS**	**RHS**
Concentration	Increase	Favours forward reaction	Favours reverse reaction
	Decrease	Favours reverse reaction	Favours forward reaction
Temperature	Increase	Favours endothermic reaction	
	Decrease	Favours exothermic reaction	
Pressure N.B. Only applied if ALL reactants and products are gaseous.	Increase	Favours side of reaction will the least moles of gas	
	Decrease	Favours side of the reaction with the largest number of moles of gas	
Catalyst		No change, as both forward and reverse reactions are sped up equally	

Industrial Applications of Le Chatelier's Principle:

1. *The Haber Process (Manufacture of Ammonia, NH_3)*

   $\mathbf{3H_2 + N_2 \overset{Fe}{\leftrightharpoons} 2NH_3}$ $\Delta H = -92.4$ kJ mol^{-1} (exothermic in fwd direction)

   Ammonia is used to make fertilisers and cleaning agents.

   By Le Chatelier's Principle, the best way to maximise the yield of ammonia is to use
   1) High Pressure
   2) Low Temperature

   The actual conditions used are:

   1) 200 atm of pressure (too high could be dangerous)
   2) 500^{o}C (even though low temperatures increase yield, they also slow down the rate so it would take too long to produce – 500^{o}C is a compromise between yield and production times.)

2. *The Contact Process (Manufacture of Sulphuric Acid, H_2SO_4)*

   We will focus on one step of this reaction, producing sulphur trioxide, SO_3, from sulphur dioxide, SO_2.

   $\mathbf{2SO_2 + O_2 \overset{V_2O_5}{\leftrightharpoons} 2SO_3}$ $\Delta H = -196$ kJ mol^{-1} (exothermic in fwd direction)

   By Le Chatelier's Principle, the best way to maximise the yield of SO_3 is to use
   1) High Pressure
   2) Low Temperature

   The actual conditions used are:

   1) 1 atm of pressure (cost of high pressure plant is not worth the increase in yield)
   2) 450^{o}C (even though low temperatures increase yield, they also slow down the rate so it would take too long to produce – 450^{o}C is a compromise between yield and production times.)

<u>The Equilibrium Constant (K_c):</u>

K_c is called the **equilibrium constant** and represents the relationship between the concentrations of the reactant and products of a system at equilibrium.

For the reaction: $\mathbf{aA + bB \leftrightharpoons cC + dD}$

the equilibrium constant can be written as:

$$\boxed{\boldsymbol{K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}}}$$

E.g. Write the equilibrium constant expression for the reaction
$H_2 + I_2 \leftrightharpoons 2HI$

Solution:

$$\boldsymbol{K_c = \frac{[HI]^2}{[H_2]^1[I_2]^1}}$$

Notes:

1. Square brackets represent concentration in mol/L.
   They are *essential*, don't use round brackets!
2. Coefficients are written as powers.
3. Products are always in the numerator, reactants in the denominator.
4. K_c is unaffected by concentration, pressure or catalyst changes. Temperature changes WILL change K_c.

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