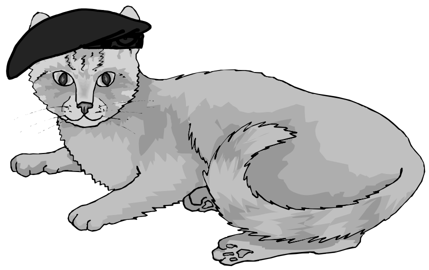
Le Châtelier's principle



The significance of Kc values

- Read 14.6 (560 - 561) do PE5

If Kc is small (0.001 or lower), [products] must be small, thus forward reaction is weak

If Kc is large (1000 or more), [products] must be large, thus forward reaction is strong

If Kc is about 1, then reactants and products are about equal

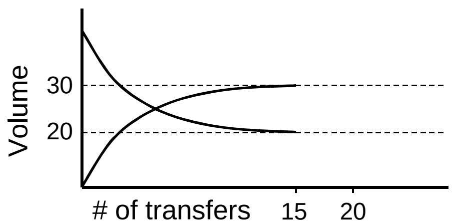
but not exactly since they may be raise to different exponents

Reactants $\leftrightarrow$ Products

$$Kc = \frac{[\text{Products}]}{[\text{Reactants}]}$$

Altering the straw lab

- Recall the lab with large and small straws
- The volumes stopped changing at 30, 20 mL



Q - Predict what will happen when:

5 ml is added to GC2 at 15 transfers, and then

10 ml is removed from GC1 at 20 transfers

Stresses to equilibria

- Changes in reactant or product concentrations is one type of "stress" on an equilibrium
- Other stresses are temperature, and pressure.
- The response of equilibria to these stresses is explained by Le Chatelier's principle:
  If an equilibrium in a system is upset, the system will tend to react in a direction that will reestablish equilibrium
- Thus we have: 1) Equilibrium, 2) Disturbance of equilibrium, 3) Shift to restore equilibrium
- Le Chatelier's principle <u>predicts</u> how an equilibrium will shift (but does not explain why)
- Movie (10 minutes at 1:10) - Le Châtelier

Summary of Le Chatelier's principle

E.g. $N_2 + 3H_2 \leftrightarrow 2\,NH_3 + 92\text{ kJ}$

<u>Amounts of products and reactants</u>: equilibrium shifts to compensate

$\uparrow N_2$	$N_2 + 3H_2 \leftrightarrow 2NH_3 + 92\text{ kJ}$	shift right
$\downarrow H_2$	$N_2 + 3H_2 \leftrightarrow 2NH_3 + 92\text{ kJ}$	shift left

<u>Temperature</u>: equilibrium shifts to compensate:

$\uparrow$ Heat	$N_2 + 3H_2 \leftrightarrow 2NH_3 + 92\text{ kJ}$	shift left

<u>Pressure</u> (due to decreased volume): increase in pressure favors side with fewer molecules

<u>Catalysts</u>: does not influence reaction

Le Châtelier and the equilibrium law

- The response to changes in an equilibrium can be explained via the equilibrium law
- Consider $C_2H_4(g) + H_2O(g) \leftrightarrow C_2H_5OH(g)$

$$Kc = \frac{[C_2H_5OH]}{[C_2H_4][H_2O]},\; 300 = \frac{[0.150]}{[0.0222][0.0225]}$$

← Sample values

- What happens if 1 mol C_2H_5OH is added?
- Now mass action expression = 2300
- Recall Kc does not change (for a given temp)
- To reestablish equilibrium we must reduce 2300 to 300 ($\downarrow$ top, $\uparrow$ bottom = shift left)
- The equilibrium law explains Le chatelier's principle (compensating for stresses)

Pressure and equilibrium

- Pressure will increase if: 1)volume decreases, 2) a (unrelated/inert) gas is added
- Only the first will cause a shift in equilibrium…

$$C_2H_4(g) + H_2O(g) \leftrightarrow C_2H_5OH(g)$$

$$Kc = \frac{[C_2H_5OH]}{[C_2H_4][H_2O]},\; 300 = \frac{[0.150]}{[0.0222][0.0225]}$$

- If volume is reduced, for example, by half, we will have [0.300]/[0.0444][0.0450] = 150
- To get back to 300, we must have a shift to the right (fewest number of particles)
- However, if pressure is increased by adding an unrelated gas [ ]s do not change

Catalysts, Le Châtelier questions

- The last factor to consider is the addition of a catalyst: this does not affect an equilibrium
- A catalyst speeds both forward and reverse reactions (by lowering the activation energy)
- It allows us to get to equilibrium faster, but it does not alter equilibrium concentrations

Q- predict the colour of the "NO_2 tubes" if they are heated and/or cooled (the reaction is endothermic when written as):

N_2O_4 (colourless) $\leftrightarrow$ $2NO_2$ (brown)

Q- 14.24-.27, .29 (p. 589), refer to 14.7 (561-5)

Q-for fig 14.4 (562) what happens if N_2 is added