Equilibrium: A Dynamic Process

Inspired by Paul Groves

A BLUFFER'S GUIDE

1. aA +bB + . . . ⇌ rR +sS + . . .
Law of Mass Action:

$$K_c = \frac{[R]^r[S]^s \cdots}{[A]^a[B]^b \cdots}$$

and for gases:

$$K_p = \frac{(P_R)^r(P_S)^s}{(P_A)^a(P_B)^b}$$

2. K > 1 Products Favored
K < 1 Reactant Favored

3. Excluded: solids, liquids including water in aqueous solutions.
Why: because their [ ]'s don't change

4. Convert Kc to Kp
$K_p = K_c(RT)^{\Delta n}$
Where Δn =
mol of (g) products – mol of (g) reactants

5. Typical question: Given K_C and the starting concentrations of reactants, find concentrations of products at equilibrium.

Example: K_C for acetic acid = 1.8×10^{-5}.
What is the equilibrium concentration of $[H^+]$ in a 0.100 M solution of the acid?

6. Relationship between modifying a chemical equation and the value of K
- Reverse a rxn = $1/K_{forward}$
- Multiplying by a number "n" = K^n
- Adding rxns = $K_{overall} = K_1 \times K_2 \times \ldots$

7. Le Chatelier's Principle: effect of changes in concentration, pressure and temperature. Equilibrium always "shifts" away from what you add and towards what you remove. "Stress" means too much or too little: chemical, heat, or volume.

8. If NOT at equilibrium (or you don't know if at equilibrium or not): Calculate Q, the reaction quotient.
- Set up the same way as if calculating K
- If K < Q
  - Numerator too large
    Denominator too small
  - Too many products
    Not enough reactants
  - Reverse rxn is favored to reach equilib.
  - "Shift left"
- If K > Q
  - Numerator too small
    Denominator too large
  - Not enough products
    Too many reactants
  - Forward rxn is favored to reach equilib.
  - "Shift right."

9. ICE Box
Example: A ⇌ 2B + C

	A	**B**	**C**
initial	5.0 M	0 M	0 M
change	-x	+2x	+x
equilibrium	5.0-x	2x	x

"C" row follows the stoichiometry of the rxn

10. The 5% rule allows us to approximate
- K must be < 1
- Usually able to be used if K is at least 1000 times smaller than $[\ ]_{initial}$
- x must be ≤ 5% of the $[\ ]_{initial}$
- If 5% rule doesn't work then use quadratic equation *(not often seen on AP Exam)*

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

11. "Perfect Squares" are another way math is sometimes simplified.
$3 \times 10^{-6} = (x)(x) / 0.1$ take √ of both sides and you get $1.73 \times 10^{-3} = x / 0.316$ now solving for x is super easy.

Based on a handout by William Bond, Snohomish HS
Good for solving quadratic, cubic, etc for ICE Tables if no graphing calculator
https://www.mathpapa.com/equation-solver/