Big Idea 6: Dynamic Equilibrium Notes

Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.

Reversible Reactions

\[ \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \]

Characteristics of a System at Equilibrium

The Equilibrium Constant and Equilibrium Expression

Using the “law of mass actions”, we can write equilibrium expressions from the balanced chemical equation:

\[ \text{K}_c \text{ when given molarity} \quad \text{K}_p \text{ when given partial pressures} \]

\[ \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \]

\[ \text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \]
Converting between Kc and Kp

When all species (reactant and product) are gaseous, either Kc (K in terms of concentration) or Kp (K in terms of pressure) can be used. There is a way to convert between Kp and Kc. However, this formula is no longer provided on the AP Exam formula sheet, therefore you will not be expected to perform this conversion. You should, however, be aware of the relationship between Kp and Kc.

\[ Kp = Kc(RT)^{\Delta n} \]

where \( \Delta n = \text{moles (g)}_{\text{product}} - \text{moles (g)}_{\text{reactant}} \)

and \( R = 0.08206 \text{ L-atm/mol·K} \)

Example:

The Equilibrium Constant vs Equilibrium Position

Equilibrium CONSTANT (K)

\[ K > 1 \]

\[ K < 1 \]

Note: when \( K >>> 1 \)

Equilibrium POSITION
Graphs of Equilibrium

Particulate representations

![Particulate representations](image)

0 min  2 min  6 min  8 min
Manipulating $K$

- For the reverse reaction, $K' = 1/K$ of forward reaction
- For a reaction that is multiplied by $n$, $K' = K^n$
- For two reactions which are added, $K' = K_a K_2$

Example:

The Reaction Quotient, $Q$

$Q$ is the reaction quotient (calculated same way as $K$, but for a system not necessarily at equilibrium)

If $K > Q$
  - Not enough products in the P/R ratio
  - Reaction will shift to right (forward reaction occurs to reach equilibrium)

If $K < Q$
  - Too many products in the P/R ratio
  - Reaction will shift to left (reverse reaction occurs to reach equilibrium)

If $Q = K$ system is at equilibrium

Example:
(R)ICE Tables and Calculations Involving K

1. Write the equilibrium expression (must have balanced equation)
2. Make an (R)ICE table:

   R: reaction
   I: initial [ ]
   C: change
   E: equilibrium [ ]

3. Substitute and solve
4. Check

A. **Given an initial set of concentrations and the equilibrium concentration of one reactant or product species, calculate the equilibrium concentrations of the remaining species.**

B. **Given an initial set of concentrations and the value of K, calculate the equilibrium concentrations of all species.**
Disturbing a system at equilibrium

If a system is at equilibrium, and then that equilibrium is “disturbed”, the system will respond in such a way as to return to an equilibrium state. This is known as Le Chatelier’s principle.

| Change in concentration | If a reactant/product is added, system will shift AWAY from added component (attempts to “use up”) to relieve stress (see the 3rd graph above).

If more products are added to a system at equilibrium, Q is now larger than K. Reaction must shift towards reactants to allow K to be reestablished.

If reactant/product is removed, system shifts TOWARDS added component (attempts to “replace”) to relieve stress. |
| Change in pressure | By reducing volume: system responds by decreasing its own volume: it will move in the direction that has the least moles of gas

Watch out for this pitfall:

By adding an inert gas

- Partial pressures of reactants and product are not changed
- Not a part of K
- No effect on equilibrium position |
| Change in temperature | Affects the rates of both the forward and reverse reactions.

- Doesn’t just change the equilibrium position, changes the equilibrium constant.
- The direction of the shift depends on whether it is exo- or endothermic
- For example, for an exothermic reaction:
  - Think of heat as a product
  - Raising temperature pushes toward reactants: Shifts to left. |
| Addition of a catalyst | Another potential pitfall. No change in equilibrium – the system merely reaches equilibrium sooner. |