Chemical equilibrium occurs when ______________________________________________________________

When does equilibrium occur?

This can be written as: ______________________________________________________________

Complete the graph for the reaction of $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$

At equilibrium, the _________________________ of each reactant and product ____________________________ .

Complete the graph for the reaction of $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$

Do the concentrations of reactant and product have to be equal to each other at equilibrium? ______________

The ratios of substances at equilibrium are __________________________________________________________

Graph for starting with $H_2$ and $N_2$  Fill in the graph for starting with $NH_3$
For the reaction of \( \text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2 \) write the rate laws for the forward and reverse reactions, assuming elementary steps:

If \( \text{rate}_{\text{for}} = \text{rate}_{\text{rev}} \), rearrange the equations, assuming rates are equal at equilibrium.

For a generic reaction of \( a\text{A} + b\text{B} \rightleftharpoons c\text{C} \), write the generic form of the equilibrium constant.

What does the value of \( k \) mean? Write the equilibrium expressions for:

\[
\text{H}_2(g) + \text{Br}_2(g) \rightleftharpoons 2\text{HBr}(g)
\]

\[
\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g)
\]
If $K = 1$, then

$Q$ is the reaction quotient \( \text{same as } K_c \text{ but for ANY conditions } \). section 14.7

Write the equation for $Q$ for the reaction \( 2H^+ + C_2O_4^{2-} \rightleftharpoons H_2C_2O_4 \text{ (all aq)} \)

When does $Q$ equal $K$?

If $K < Q$, then:

If $K > Q$, then:

**Heterogeneous Equilibrium**

The concentration of a solid or liquid \( \). As the # of moles decreases, so does \( \). Solids and liquids do not \( \).

For the following reaction, write the equilibrium expression: \( \text{PbCl}_2(s) \rightleftharpoons \text{Pb}^{2+}(aq) + 2 \text{Cl}^-(aq) \)

**Equilibrium Calculations**

Use Initial, Change, Equilibrium table to help with stoichiometry

It’s important to keep track of initial concentrations, changes, and calculate $K$ only based on equilibrium concentrations.
A closed flask with 1.00 M H₂ and 2.00 M I₂ is heated to 448 °C and allowed to reach equilibrium.
At equilibrium, the concentration of HI is 1.80 M. Calculate K_c at 448 °C.

H₂ + I₂ ⇌ 2HI (gas phase)

Fill in with what we know:

<table>
<thead>
<tr>
<th></th>
<th>[H₂], M</th>
<th>[I₂], M</th>
<th>[HI], M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initially</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At equilibrium</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pressure is related to concentration, so instead of

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

write:

- From the ideal gas law we know that
- This rearranges to
- the relationship between K_c and K_p becomes

where \( \Delta n = (\text{moles of gaseous product}) - (\text{moles of gaseous reactant}) \)

\( T \) in K, \( R = 0.0821 \text{ L*atm/(mol*K)} \)
Practice –
Write equilibrium expression, calculate the value of $K_p$ (500 K), is the reaction at equilibrium product or reactant favored?

$$N_2(g) + 2O_2(g) \rightleftharpoons 2NO_2(g)$$

| Equil Conc. (M) | 0.20 | 0.50 | 0.050 |

Manipulating Equilibrium Constants

The $K$ of one reaction is ________________ for the same reaction written in the ________________

$$K_c = \frac{[NO_2]^2}{[N_2O_4]}$$

$$K_c = \frac{[N_2O_4]}{[NO_2]^2}$$

Le Chatelier’s Principle

How does a system respond to a disturbance?

The answer is given by Le Chatelier’s Principle:

If a system at equilibrium is disturbed by a change in $T$, $P$, or the concentration of one of the components, the concentrations of the system components will shift as to counteract the effect of the disturbance.

-Henri Le Chatelier’s Principle (1888)

Rates are equal at equilibrium. Even if a forward or reverse rate is changed, the rates will become equal once again.

Finish the graph: what happens after $H_2$ is added?

What if ammonia is removed?
Equilibrium concept questions: (tip: writing the equilibrium expression is always a good idea)

For the reaction \( \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{O}(g) \) at equilibrium:

1. What happens to the amount of water vapor present once equilibrium is re-established if the temperature is decreased?

2. What happens to the amount of water vapor present once equilibrium is re-established if more \( \text{H}_2\text{O}(l) \) is added to the system?

For the reaction \( \text{H}_2(g) + \text{CO}(g) \rightleftharpoons \text{C}(s) + \text{H}_2\text{O}(g) \) (\( \Delta H \) is negative) at equilibrium:

3. What happens to the amount of \( \text{H}_2 \) present once equilibrium is re-established if the temperature is increased?

4. What happens to the amount of water vapor present once equilibrium is re-established if \( \text{Fe}(s) \) is added to the system? [\( \text{Fe} \) reacts with \( \text{CO}(g) \) to form \( \text{Fe(CO)}_5 \)]

5. What happens to the amount of \( \text{H}_2\text{O}(g) \) present once equilibrium is re-established if \( \text{CO}(g) \) is added?

6. What happens to the amount of \( \text{C}(s) \) present once equilibrium is re-established if \( \text{CO}(g) \) is added?

7. What happens to the amount of \( \text{H}_2\text{O}(g) \) present once equilibrium is re-established if the volume of the container is increased?

8. What happens to the amount of \( \text{H}_2\text{O}(g) \) present once equilibrium is re-established if the pressure of the system is increased by adding \( \text{Ne}(g) \).

\[
\text{CoCl}_4^{2-}(\text{aq}) + 6 \text{H}_2\text{O}(l) \rightleftharpoons \text{Co(H}_2\text{O})_6^{2+}(\text{aq}) + 4 \text{Cl}^-(\text{aq})
\]