Units – Go Away

\[ aA + bB \rightleftharpoons cC + dD \]

Reactants ⇌ Products

Use activities, \( a \), is a ratio concentration to a 1M reference or if using pressure to a 1atm reference

\[
K_c = \frac{(a_c)^c (a_d)^d}{(a_a)^a (a_b)^b}
\]

K has no units if concentrations are in activities.

Heterogeneous Equilibrium

More than one phase

\[ \text{CaCO}_3(s) \rightleftharpoons \text{CaO}(s) + \text{CO}_2(g) \]

\[
K_p = \frac{a_{\text{CaO}} \cdot a_{\text{CO}_2}}{a_{\text{CaCO}_3}} = P_{\text{CO}_2}
\]

\[ \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_2\text{O}(g) \]

\[ K_p = P_{\text{H}_2\text{O}} \]

Heterogeneous Equilibrium

More than one phase

\[ \text{H}_2\text{O}(l) + \text{HF(aq)} \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{F}^-(aq) \]

\[
K = \frac{a_{\text{H}_3\text{O}^+} \cdot a_{\text{F}^-}}{a_{\text{H}_2\text{O}} \cdot a_{\text{HF}}} = \frac{([\text{H}_3\text{O}^+]/1\text{M}_{\text{H}_3\text{O}^+}) ([\text{F}^-]/1\text{M}_{\text{F}^-})}{1 \times ([\text{HF}]/1\text{M}_{\text{HF}})}
\]

\[
K = \frac{([\text{H}_3\text{O}^+])([\text{F}^-])}{[\text{HF}]}
\]

K has no units if concentrations are in activities.

2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \quad K = 1.6 \times 10^{-5}

\[
K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} = 1.6 \times 10^{-5}
\]

If you had a initial [NOCl] of 1M what would be the Cl_2 concentration at equilibrium?

Write an algebraic equation for Q assuming you get \( x \) moles of Cl_2.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 2x^3 )</td>
<td>( 2x^3 )</td>
<td>( 4x^3 )</td>
<td>( 4x^3 )</td>
<td>( 4x^3 )</td>
</tr>
<tr>
<td>( [1-x]^2 )</td>
<td>( [1-2x]^2 )</td>
<td>( [1-x]^2 )</td>
<td>( [1-2x]^2 )</td>
<td>( [1-4x]^2 )</td>
</tr>
</tbody>
</table>

2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g) \quad K = 1.6 \times 10^{-5}

\[
K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} = 1.6 \times 10^{-5}
\]

If you had a initial [NOCl] of 1M what would be the Cl_2 concentration at equilibrium?

\[
K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} = 1.6 \times 10^{-5} = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2}
\]

\[
K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} = 1.6 \times 10^{-5}
\]

\[
K_c = \frac{[\text{NO}]^2 [\text{Cl}_2]}{[\text{NOCl}]^2} = 1.6 \times 10^{-5}
\]

x will be small compared to 1 \( x = 1.6 \times 10^{-2} \)

N_2(g) + 3 H_2(g) \rightleftharpoons 2NH_3(g) \quad K = 6.02 \times 10^{2} \text{L}^2/\text{mol}^2

\[
K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} = 6.02 \times 10^{2} = \frac{(2x)^2}{(1-x)(3-3x)^3} = .06 = \frac{2^2 x^2}{3^3 (1-x)^4}
\]

Fourth Order Equation – Are you Crazy?
What is \([N_2]\) at equilibrium?

\[
K_p = \frac{P_{N\text{H}_3}^2}{P_{N_2} \cdot P_{H_2}^3} = \frac{(2x)^2}{(1-x)(3-3x)^3} = 5.5 \times 10^5
\]

\[
K_p = \frac{P_{N\text{H}_3}^2}{P_{N_2} \cdot P_{H_2}^3} = \frac{(2x)^2}{(1-x)(3-3x)^3} = 5.5 \times 10^5
\]

\[
\frac{(2-2x)^2}{(x)(3x)^3} = \frac{4}{27x^4} = 5.5 \times 10^5
\]

\[X = .023 \text{ atm}\]

---

**What is an acid? What is a base?**

**Acid-Base Definitions**

**Arrhenius**
- **Acid** = produces \(H^+\) when dissolved in water
- **Base** = produces \(OH^-\) when dissolved in water

**Bronsted-Lowery Concept**
- **Acid** = a proton donor
- **Base** = a proton acceptor

**Lewis**
- **Acid** = an electron pair acceptor
- **Base** = an electron pair donor

---

**What is nature of \(H_3O^+\)?**

A. Trigonal planar   B. Pyramidal   C. T-shaped

**Which would form the stronger hydrogen bonds?**

A. \(H_2O\)   B. \(H_3O^+\)

**What is the molarity of \(H_3O^+\) in pure water?**

A. \(10^{14}\)   B. \(10^7\)   C. \(1\)   D. \(10^{-7}\)   E. \(10^{-14}\)

**What is the approximate lifetime of a \(H_3O^+\) ion?**

[It “dies” by donating a proton to an \(H_2O\).]

A. 1 hour   B. 1 minute   C. 1 sec   D. \(10^{-3}\) sec
E. \(10^{-6}\) sec   F. \(10^{-9}\) sec   G. \(10^{-12}\) sec   H. \(10^{-15}\) sec
\[ \text{pH} = -\log([H^+]) \]
\[ [H^+] = 2 \times 10^{-5} \text{ M} \quad \text{pH} = -\log(2 \times 10^{-5}) = 4.7 \]

\[ \text{pOH} = -\log([\text{OH}^-]) \]
\[ [\text{OH}^-] = 7 \times 10^{-9} \text{ M} \quad \text{pOH} = -\log(7 \times 10^{-9}) = 8.1 \]

\[ \text{pK}_a = -\log(K_a) \]
For HF \( K_a = 7.2 \times 10^{-4} \) \( \text{pK}_a = -\log(7.2 \times 10^{-4}) = 3.1 \)

\[ \text{p(anything)} = -\log(\text{anything}) \]

---

**If you have $1732.13 in your bank account, how much do you have in p(cents)?**

A. -12.1
B. -5.2
C. -3.2
D. -1.7
E. 1.7
F. 3.2
G. 5.2
H. 12.1

---

### Table 2.2 Values of \( K_a \) for Some Common Monoprotic Acids

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
<th>Value of ( K_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{HSO}_3^- )</td>
<td>Hydrogen sulfite ion</td>
<td>( 1.2 \times 10^{-2} )</td>
</tr>
<tr>
<td>( \text{HCO}_3^- )</td>
<td>Chlorous acid</td>
<td>( 1.2 \times 10^{-5} )</td>
</tr>
<tr>
<td>( \text{HClO}_2 )</td>
<td>Monochloric acid</td>
<td>( 1.35 \times 10^{-3} )</td>
</tr>
<tr>
<td>( \text{HF} )</td>
<td>Hydrofluoric acid</td>
<td>( 7.2 \times 10^{-4} )</td>
</tr>
<tr>
<td>( \text{HNO}_2 )</td>
<td>Nitrous acid</td>
<td>( 4.0 \times 10^{-4} )</td>
</tr>
<tr>
<td>( \text{H}_2\text{CO}_3 )</td>
<td>Acetic acid</td>
<td>( 1.8 \times 10^{-3} )</td>
</tr>
<tr>
<td>( [\text{AlH}_3\text{O}_4]^{3+} )</td>
<td>Hydrazoic acid(III) ion</td>
<td>( 1.4 \times 10^{-3} )</td>
</tr>
<tr>
<td>( \text{HCN} )</td>
<td>Hydrazine</td>
<td>( 3.5 \times 10^{-10} )</td>
</tr>
<tr>
<td>( \text{NH}_3 )</td>
<td>Ammonium</td>
<td>( 5.6 \times 10^{-10} )</td>
</tr>
<tr>
<td>( \text{HOC}_6\text{H}_5 )</td>
<td>Phenol</td>
<td>( 1.6 \times 10^{-10} )</td>
</tr>
</tbody>
</table>

**Note:** Increasing acid strength from top to bottom.

\[ K_a = [H^+]\text{[A}^-\text{]}/[\text{HA}] \]
\[ \text{pK}_a = -\log K_a \text{, so pK}_a \text{ of HF is 3.14 (etc.)} \]