

**Harold's High School Chemistry**  
**2<sup>nd</sup> Semester**  
**Cheat Sheet**  
 5 May 2026

**Chapter 9: Chemists Have Solutions**

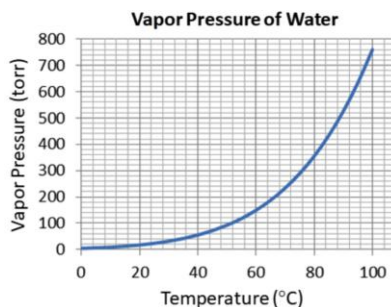
Term	Description	Equation												
<b>Dissolving Compounds</b>	<ul style="list-style-type: none"> <li>When <u>ionic</u> compounds dissolve, they split up into their individual <u>atoms</u>.</li> <li>When polar <u>covalent</u> compounds dissolve, they split up into their individual <u>molecules</u>.</li> </ul>													
<b>Solubility of Solutes</b>	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th style="background-color: #e67e22; color: white;">State</th> <th style="background-color: #e67e22; color: white;">Temperature</th> <th style="background-color: #e67e22; color: white;">Pressure</th> </tr> </thead> <tbody> <tr> <td>Solid</td> <td style="text-align: center;">↑</td> <td style="text-align: center;">-</td> </tr> <tr> <td>Liquid</td> <td style="text-align: center;">-</td> <td style="text-align: center;">-</td> </tr> <tr> <td>Gas</td> <td style="text-align: center;">↓</td> <td style="text-align: center;">↑</td> </tr> </tbody> </table>	State	Temperature	Pressure	Solid	↑	-	Liquid	-	-	Gas	↓	↑	
State	Temperature	Pressure												
Solid	↑	-												
Liquid	-	-												
Gas	↓	↑												
<b>Concentration</b>	The behavior of a chemical often depends on concentration.													
<b>Molarity</b>	$\text{Molarity} = \frac{\text{moles of solute}}{\text{liters of solution}} M$	Liters												
<b>Molality</b>	$\text{Molality} = \frac{\text{moles of solute}}{\text{kilograms of solvent}} m$	Kilograms												
<b>Freezing Point Depression</b>	$\Delta T = -i \cdot K_f \cdot m$	$K_{f_{H_2O}} = 1.86 \text{ } ^\circ\text{C}/m$												
<b>Boiling Point Elevation</b>	$\Delta T = i \cdot K_b \cdot m$	$K_{b_{H_2O}} = 0.512 \text{ } ^\circ\text{C}/m$												

## Chapter 10: It's a Gas!

Term	Equation	Note
Ideal Gas Law	$PV = nRT$	$P = \text{Pressure (atm)}$ $V = \text{Volume (L)}$ $n = \# \text{ Moles of gas}$ Ideal Gas Constant (R): $R = 0.0821 \frac{\text{L atm}}{\text{mole K}}$ $T = \text{Temperature (K)}$
Boyle's Law	$P_1V_1 = P_2V_2$	Assumes $T = \text{constant}$
Charle's Law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	Assumes $P = \text{constant}$
Combined Gas Law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	Since $nR = \text{constant}$
Avagadro's Law	$n = \frac{PV}{RT}$	Same number of molecules or atoms
Volumes of Gases	$V = \frac{nRT}{P}$	Relationship between volumes of those gases
Kelvin (T)	$K = ^\circ C + 273.15$ $0 \text{ K} = \text{Absolute Zero}$	$^\circ F = \left(\frac{9}{5}\right)^\circ C + 32 \quad [32^\circ - 212^\circ]$ $^\circ C = \left(\frac{5}{9}\right)(^\circ F - 32) \quad [0^\circ - 100^\circ]$
Pressure (P)	$P = \frac{F}{A}$	$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$
	$1 \text{ atm} = 760 \text{ torr}$ $1 \text{ torr} = 1 \text{ mmHg}$ $1 \text{ mmHg} = 133.322 \text{ Pa}$ $1 \text{ atm} = 101,325 \text{ Pascals (Pa)}$	Units can be torr, atm, or Pa
Ideal Gas	<ul style="list-style-type: none"> <li>The molecules or atoms that make up the gas occupy <u>no volume</u>.</li> <li>The molecules or atoms that make up the gas are <u>not attracted</u> to each other.</li> <li>The <u>collisions</u> that occur between the molecules or atoms that make up the gas are <u>elastic</u>, which means no energy is lost in such a collision. This is also true for any collisions between the molecules or atoms that make up the gas and the walls of the container in which the gas is held.</li> </ul>	
STP	A gas is at STP if its pressure is 1 atm and its temperature is $0^\circ C$ .	Standard Temperature and Pressure
Dalton's Law	$P_{total} = P_a + P_b + P_c + \dots$	Partial pressures
Mole Fraction	$X_a = \frac{P_a}{P_{total}}$	$X_a = \frac{\text{moles of compound a}}{\text{total moles in the mixture}}$
Vapor Pressure	Boiling point = The temperature at which a liquid's vapor pressure is equal to the external air pressure.	
Extrapolation	Extending a trend in data to situations for which no measurements have been made. Usually linear approximations.	

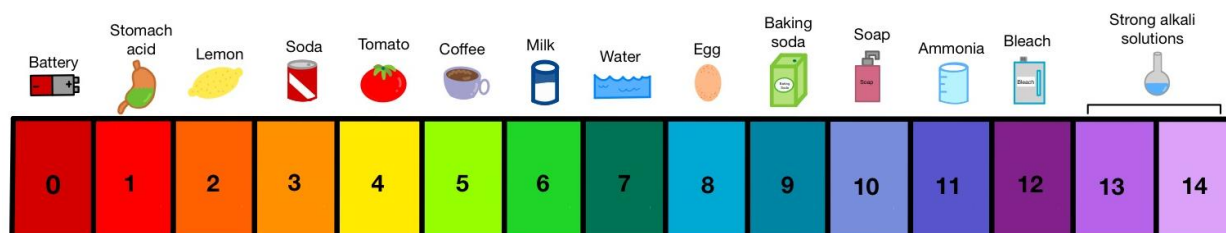
## Vapor Pressure of Water

Temperature (°C)	Vapor Pressure (torr)		Temperature (°C)	Vapor Pressure (torr)
0	4.6		39	52.4
2	5.3		40	55.3
4	6.1		42	61.5
6	7.0		44	68.3
8	8.0		46	75.5
10	9.2		48	83.7
12	10.5		50	92.5
14	12.0		52	102.1
15	12.8		54	112.5
16	13.6		56	123.8
17	14.5		58	136.1
18	15.5		60	149.4
19	16.5		62	163.8
20	17.5		64	179.3
21	18.7		66	196.1
22	19.8		68	214.2
23	21.1		70	233.7
24	22.4		72	254.6
25	23.8		74	277.2
26	25.2		76	301.4
27	26.7		78	327.3
28	28.3		80	355.1
29	30.0		82	384.9
30	31.8		84	416.8
31	33.7		86	450.9
32	35.7		88	487.1
33	37.7		90	525.8
34	39.9		92	567.0
35	42.2		94	610.9
36	44.6		96	657.6
37	47.1		98	707.3
	49.7		100	760.0



## Chapter 11: Some Pretty Basic (and Acidic) Chemicals

Term	Equation / Definition	Note
<b>Acids</b> (Acidic)	A chemical that <u>donates</u> an $H^+$ . Have more $H^+$ ions.	<ol style="list-style-type: none"> <li>Tend to taste <u>sour</u></li> <li>Are covalent electrolytes</li> <li>Turn <u>blue</u> litmus paper <u>red</u></li> </ol>
<b>Bases</b> (Alkaline)	A chemical that <u>accepts</u> an $H^+$ . Have more $OH^-$ ions.	<ol style="list-style-type: none"> <li>Tend to taste <u>bitter</u></li> <li>Tend to feel slippery when mixed with water</li> <li>Turn <u>red</u> litmus paper <u>blue</u></li> </ol>
<b>Litmus</b>	An <u>acid/base</u> indicator that is usually on a strip of paper	
<b>Amphoteric</b> (Amphiprotic)	Capable of reacting as either an <u>acid</u> or a <u>base</u> ( $H_2O$ , metal oxides)	
<b>Covalent Electrolytes</b>	hydrofluoric acid + water $\rightarrow$ fluoride ion + hydronium ion $HF + H_2O \rightarrow F^- + H_3O^+$ <u>acid</u> <u>base</u>	
	ammonium hydroxide (ammonia) + water $\rightarrow$ ammonium ion + hydroxide ion $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ <u>base</u> <u>acid</u>	
<b>Ionic Electrolytes</b>	hydrochloric acid + sodium hydroxide (lye) $\rightarrow$ water + salt $HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq)$ <u>acid</u> <u>base</u> ( $Na^+OH^-$ )   ( $Na^+Cl^-$ )	
<b>Acid/Base Identification Rules</b>	<ul style="list-style-type: none"> <li>Ammonia (<math>NH_3</math>) is a covalent <u>base</u>.</li> <li>If a covalent compound starts with an <math>H</math>, it can usually act like an <u>acid</u>.</li> <li>Ionic compounds that contain the hydroxide ion (<math>OH^-</math>) can act as <u>bases</u>.</li> <li>An <u>acid</u> reacts with an ionic <u>base</u> to make water (<math>H_2O</math>) and salt (<math>NaCl</math>).</li> </ul>	
<b>pH Scale</b>	Potential hydrogen (pH). Amount of hydronium ion ( $H_3O^+$ ) in the solution.	
	<p>pH of 0: highly <u>acidic</u></p> <p>pH of 7: neutral</p> <p>pH of 14: highly <u>alkaline</u></p>	
<b>Polyprotic Acid</b>	An <u>acid</u> that can donate two or more $H^+$ ions. Examples: hydrogen sulfate ( $H_2SO_4$ ), carbonic acid ( $H_2CO_3$ ) $CO_2(g) + H_2O(l) \rightarrow H_2CO_3(aq)$ <u>acid rain</u>	
<b>Titration</b>	The process by which an <u>acid</u> of known concentration is added to a <u>base</u> of unknown concentration (or vice versa) until a neutral pH is reached to determine the unknown concentration.	

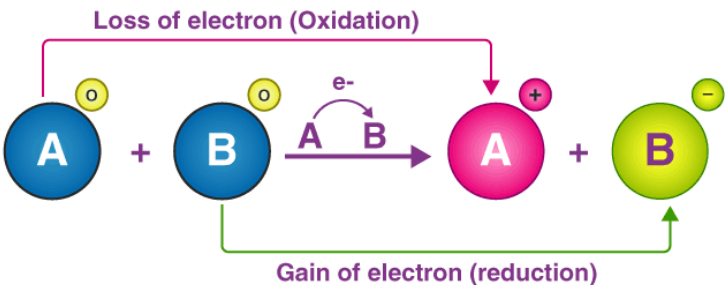
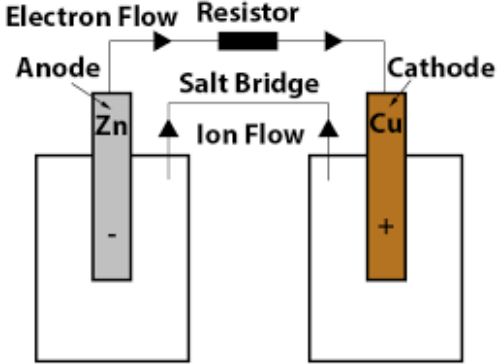


pH of Acids					pH of Bases				
Acid	Name	1 mM	10 mM	100 mM	Base	Name	1 mM	10 mM	100 mM
H <sub>2</sub> SeO <sub>4</sub>	selenic acid	2.74	1.83	1	Ba(OH) <sub>2</sub>	barium hydroxide	11.27	12.22	13.08
H <sub>2</sub> SO <sub>4</sub>	sulfuric acid (oil of vitriol)	2.75	1.87	1	Sr(OH) <sub>2</sub>	strontium hydroxide (caustic alkali)	11.27	12.22	13.09
HI	hydroiodic acid (muriatic acid)	3.01	2.04	1.1	NaOH	sodium hydroxide (lye)	10.98	11.95	12.88
HBr	hydrobromic acid	3.01	2.04	1.1	KOH	potassium hydroxide (caustic potash)	10.98	11.95	12.88
HCl	hydrochloric acid (gastric acid)	3.01	2.04	1.1	Na <sub>2</sub> SiO <sub>3</sub>	sodium metasilicate	11	11.91	12.62
HNO <sub>3</sub>	nitric acid	3.01	2.04	1.1	Ca(OH) <sub>2</sub> (CaO:H <sub>2</sub> O)	calcium hydroxide (lime)	11.27	12.2	12.46
H <sub>3</sub> PO <sub>4</sub>	orthophosphoric acid	3.06	2.26	1.6	Na <sub>3</sub> PO <sub>4</sub>	trisodium phosphate (food additive)	10.95	11.71	12.12
H <sub>3</sub> AsO <sub>4</sub>	arsenic acid	3.08	2.31	1.7	K <sub>2</sub> CO <sub>3</sub>	potassium carbonate (potash or pearl ash)	10.52	11	11.36
H <sub>2</sub> SeO <sub>3</sub>	selenous acid	3.15	2.47	1.9	Na <sub>2</sub> CO <sub>3</sub>	sodium carbonate (soda ash)	10.52	10.97	11.26
H <sub>2</sub> CrO <sub>4</sub>	chromic acid	3.03	2.33	2.1	NH <sub>4</sub> OH (NH <sub>3</sub> :H <sub>2</sub> O)	ammonium hydroxide (Windex)	10.09	10.61	11.12
C <sub>6</sub> H <sub>8</sub> O <sub>7</sub>	citric acid (lemon juice)	3.24	2.62	2.1	Mg(OH) <sub>2</sub> (MgO:H <sub>2</sub> O)	magnesium hydroxide	10.4	10.4	10.4
HF	hydrofluoric acid	3.27	2.65	2.1	CaCO <sub>3</sub>	calcium carbonate (limestone or calcite)	9.91	9.91	9.91
HNO <sub>2</sub>	nitrous acid	3.28	2.67	2.1	Fe(OH) <sub>2</sub>	iron(II) hydroxide (ferrous hydroxide)	9.45	9.45	9.45
HOCN	isocyanic acid	3.35	2.76	2.2	Cd(OH) <sub>2</sub>	cadmium hydroxide	9.36	9.36	9.36
CH <sub>2</sub> O <sub>2</sub>	formic acid, (formic or methanoic acid)	3.47	2.91	2.4	Na <sub>2</sub> B <sub>4</sub> O <sub>7</sub>	sodium borate (Borax)	9.21	9.17	9.05
H <sub>2</sub> Se	hydrogen selenide	3.49	2.93	2.4	Co(OH) <sub>2</sub>	cobalt(II) hydroxide	9.15	9.15	9.15
H <sub>2</sub> MoO <sub>4</sub>	molybdic acid	3.46	2.94	2.4	Zn(OH) <sub>2</sub>	zinc hydroxide	8.88	8.88	8.88
C <sub>3</sub> H <sub>6</sub> O <sub>3</sub>	lactic acid (milk acid)	3.51	2.96	2.4	Ni(OH) <sub>2</sub>	nickel(II) hydroxide	8.37	8.37	8.37
C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	acetic acid (vinegar)	3.91	3.39	2.9	CH <sub>3</sub> COOK	potassium acetate (diuretic salt)	7.87	8.33	8.75
H <sub>2</sub> CO <sub>3</sub>	carbonic acid	4.68	4.18	3.7	CH <sub>3</sub> COONa	sodium acetate (acetic acid)	7.87	8.33	8.75
H <sub>2</sub> S	hydrogen sulfide	4.97	4.47	4	KHCO <sub>3</sub>	potassium hydrogen carbonate	8.27	8.25	8.13
H <sub>3</sub> AsO <sub>3</sub>	arsenious acid	6.07	5.58	5.1	NaHCO <sub>3</sub>	sodium hydrogen carbonate (baking soda)	8.27	8.22	8.02
HCN	hydrocyanic acid	6.11	5.62	5.1	Be(OH) <sub>2</sub>	beryllium hydroxide	7.9	7.9	7.9
H <sub>3</sub> BO <sub>3</sub>	boric acid	6.12	5.62	5.1	Cu(OH) <sub>2</sub>	copper(II) hydroxide	7.69	7.69	7.69
H <sub>4</sub> SiO <sub>4</sub>	silicic acid	6.4	5.91	5.4	Pb(OH) <sub>2</sub>	lead(II) hydroxide	7.54	7.54	7.54
H <sub>4</sub> SiO <sub>4</sub>	silicic acid	6.4	6.26	6.3	Cr(OH) <sub>3</sub>	chromium(III) hydroxide	7.04	7.04	7.04
H <sub>2</sub> O	pure water	7.0	7.0	7.0	Hg(OH) <sub>2</sub>	mercury(II) hydroxide	7.03	7.03	7.03

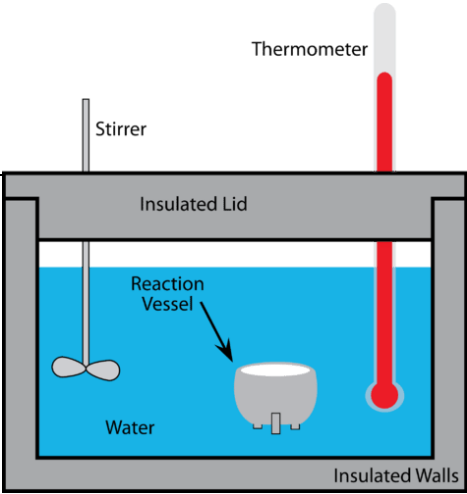
Source: aqion (27 Oct 2024), [pH of Common Acids and Bases, https://www.aqion.de/](https://www.aqion.de/)

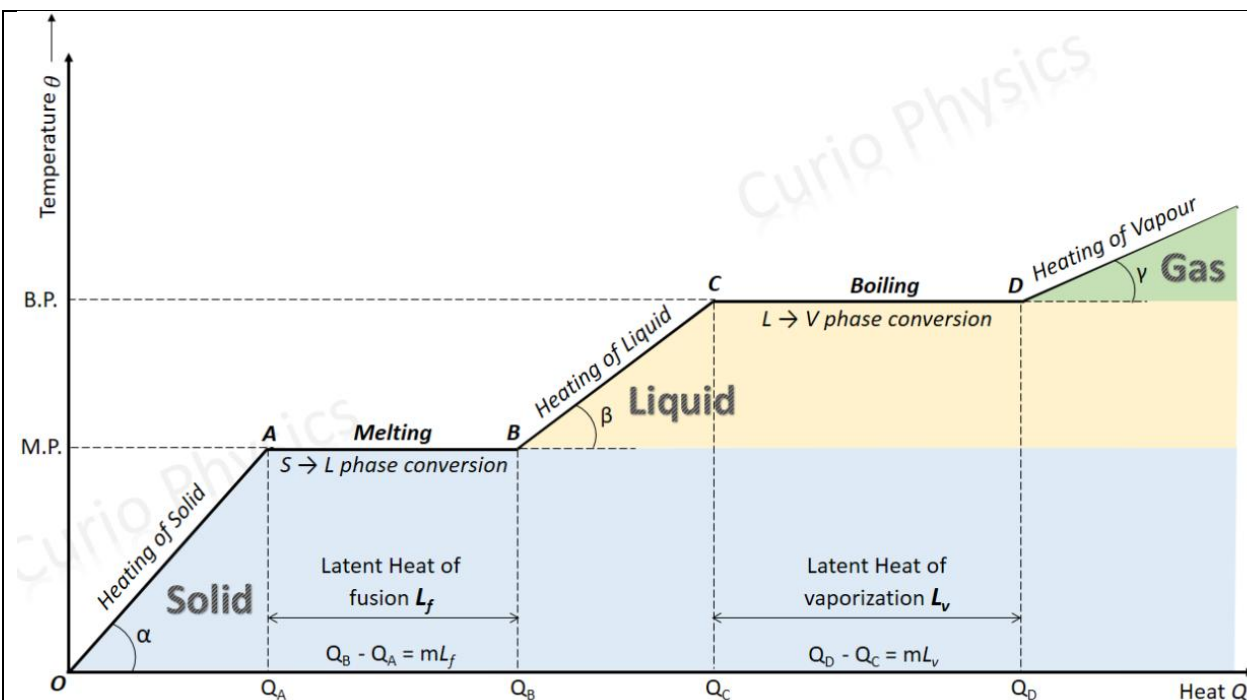
## Chapter 12: Reduction and Oxidation

Term	Description	Equation								
<b>Chemical Reaction Types</b>	<ol style="list-style-type: none"> <li>Synthesis (Formation)</li> <li>Decomposition</li> <li>Single Displacement</li> <li>Double Displacement</li> <li>Combustion</li> <li>Acid-Base</li> <li>Reduction-Oxidation</li> </ol>	<ol style="list-style-type: none"> <li><math>A + B \rightarrow AB</math></li> <li><math>AB \rightarrow A + B</math></li> <li><math>A + BC \rightarrow AC + B</math></li> <li><math>AB + CD \rightarrow AD + CB</math></li> <li><math>C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O + \text{heat (propane)}</math></li> <li><math>HA + BOH \rightarrow BA + H_2O</math></li> <li><math>Fe^0 + O_2^0 \rightarrow Fe_2^{3+} + O_3^{2-}</math></li> </ol>								
<b>Oxidation State</b>	<p>The charge on an ion, or for a molecule, the charge that an atom would have, if the shared electrons in a bond were always given to the more <b>electronegative</b> atom.</p> <p>Atomic No. → <math>\begin{matrix} \text{H} \\ 1 \\ 2.2 \\ \text{H} \\ \text{Symbol} \\ 2.2 \\ \text{Electronegativity} \end{matrix}</math> ← Symbol Electronegativity</p> <p>Low → High</p> <p>Electronegativity decreases as we move right to left from fluorine</p> <p>Electronegativity decreases as we move top to bottom from fluorine</p>	<table border="1"> <thead> <tr> <th colspan="2">Covalent</th> <th colspan="2">Ionic</th> </tr> </thead> <tbody> <tr> <td><math>CF_4 \rightarrow C^{4+} + 4F^-</math></td> <td></td> <td><math>Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}</math></td> <td></td> </tr> </tbody> </table>	Covalent		Ionic		$CF_4 \rightarrow C^{4+} + 4F^-$		$Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}$	
Covalent		Ionic								
$CF_4 \rightarrow C^{4+} + 4F^-$		$Al_2O_3 \rightarrow 2Al^{3+} + 3O^{2-}$								
<b>Oxidation State Rules</b>	<p><u>These rules are <b>always</b> true:</u></p> <ol style="list-style-type: none"> <li>For ions composed of only one atom, the oxidation state is equal to the charge on the ion.</li> <li>For all elements and homonuclear molecules, the oxidation state of each atom is 0.</li> <li>For molecules and polyatomic ions, the sum of the oxidation states must equal the total charge.</li> <li>The oxidation state of F in any compound is 1-.</li> <li>In covalent compounds and polyatomic ions, H has an oxidation state of 1+.</li> </ol> <p><u>These rules are <b>usually</b> true:</u></p> <ol style="list-style-type: none"> <li>In most compounds, O has an oxidation state of 2-.</li> <li>Group 7A elements (especially Cl) usually have an oxidation state of 1-.</li> </ol>									

<p><b>Reduction-Oxidation (Redox)</b></p>	 <p>Reactions that transfer electrons from one set of atoms to another. LEO says GER.</p>													
<p><b>Oxidized</b></p>	<p>Atom <b>loses</b> an electron</p>	<p>“Lose Electrons Oxidation” (LEO)</p>												
<p><b>Reduced</b></p>	<p>Atom <b>gains</b> an electron</p>	<p>“Gain Electrons Reduction” (GER)</p>												
	<table border="1" data-bbox="597 699 1284 1066"> <thead> <tr> <th>Oxidation</th> <th>Reduction</th> </tr> </thead> <tbody> <tr> <td>Complete loss of electrons (ionic reactions)</td> <td>Complete gain of electrons (ionic reactions)</td> </tr> <tr> <td>Shift of electrons away from an atom in a covalent bond</td> <td>Shift of electrons towards an atom in a covalent bond</td> </tr> <tr> <td>Gain of oxygen</td> <td>Loss of oxygen</td> </tr> <tr> <td>Loss of hydrogen by a covalent compound</td> <td>Gain of hydrogen by a covalent compound</td> </tr> <tr> <td>An increase in oxidation number</td> <td>A decrease in oxidation number</td> </tr> </tbody> </table>		Oxidation	Reduction	Complete loss of electrons (ionic reactions)	Complete gain of electrons (ionic reactions)	Shift of electrons away from an atom in a covalent bond	Shift of electrons towards an atom in a covalent bond	Gain of oxygen	Loss of oxygen	Loss of hydrogen by a covalent compound	Gain of hydrogen by a covalent compound	An increase in oxidation number	A decrease in oxidation number
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<p><b>Oxidizing Agent</b></p>	<p>If a reactant is reduced, it is called the <b>oxidizing agent</b>, because it oxidizes another reactant.</p>													
<p><b>Reducing Agent</b></p>	<p>If a reactant is oxidized, it is called the <b>reducing agent</b>, because it reduces another reactant.</p>													
<p><b>Batteries</b></p>	<p>Galvanic Cell (battery)</p> <p>Anode</p> <p>Cathode</p>	<p>A system that uses a redox reaction to produce electrical energy.</p> <p>The <b>negative</b> electrode in a Galvanic cell.</p> <p>The <b>positive</b> electrode in a Galvanic cell.</p>												
														
<p><b>Balancing Charge</b></p>	<p>For a chemical equation to be balanced, the total charge on each side of the equation must be the same.</p>													
<p><b>Electroplating</b></p>	<p>Using reduction (usually powered by electricity) to coat an object with a metal.</p>													
<p><b>Corrosion</b></p>	<p>The chemical deterioration of a substance, usually by oxidation. (rust)</p>													

## Chapter 13: The Heat Is On

Term	Equation	Note
<b>Energy</b>	$E = W + q + K + \Delta U$	The ability to do work. Units are energy are always in Joules ( $J$ ). Conservation of energy ( $E_i = E_f$ ).
<b>Work</b>	$W = Fd$	The application of a force to move an object over a distance.
<b>Heat</b>	$q$	Energy that is exchanged because of a difference in temperature or a phase change.
<b>Kinetic Energy</b>	$K = \frac{1}{2}mv^2$	Energy that is in <u>motion</u> .
<b>Potential Energy</b>	$\Delta U_g = mgh$	Energy that is <u>stored</u> .
<b>calorie</b>	$1 \text{ calorie} = 4.184 J$	The amount of heat required to raise 1 gram of water 1 degree Celsius.
<b>Calorie</b>	1 <u>Food</u> Calorie = 1,000 chemist calories	Big 'C' vs. little 'c'.
<b>Specific Heat Capacity (c)</b>	$c_{H_2O} = 4.184 \frac{J}{g \cdot ^\circ C}$	The amount of heat it takes to raise a <u>specific mass</u> of a substance 1 °C.
<b>Heat Capacity (C)</b>	$q = C \cdot \Delta T$	The amount of heat it takes to raise an <u>entire object</u> 1 °C. Takes the mass of the object into account.
<b>Measuring Heat</b>	$q = m \cdot c \cdot \Delta T$ where: $m = \text{mass}$ $c = \text{specific heat capacity}$ $\Delta T = T_{\text{final}} - T_{\text{initial}}$	
<b>Calorimeter</b>	$-q_{\text{object}} = q_{\text{liquid}} + q_{\text{calorimeter}}$	In a calorimeter experiment, the temperature of the liquid and the calorimeter are always the same. In addition, the <i>final</i> temperature of the liquid, calorimeter, and object are all the same.
<b>Latent Heat</b>	$q = m \cdot L$ where: $L_f$ = Latent heat of fusion $L_v$ = Latent heat of vaporization	The amount of heat absorbed or released by a substance during a <u>phase change</u> .

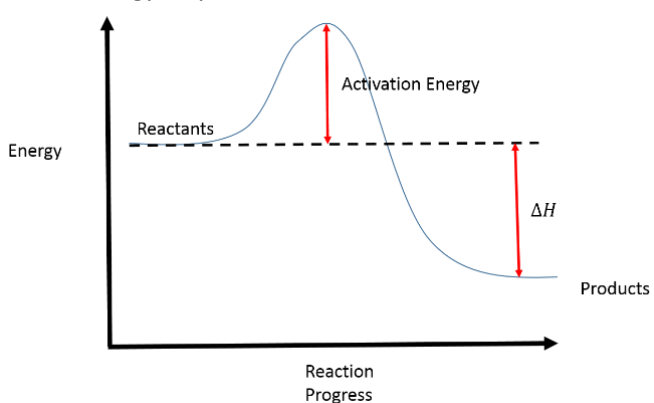


<b>Exothermic Reaction</b>		A chemical reaction that <u>releases</u> energy. e.g., Dilution of sulfuric acid ( $H_2SO_4$ ) in water.
<b>Endothermic Reaction</b>		A chemical reaction that <u>absorbs</u> energy. e.g., Dissolving ammonium nitrate ( $NH_4NO_3$ ) in water.

### Specific Heat Capacities of Different Substances

Substance	Specific Heat J/g°C	Substance	Specific Heat J/g°C
Water (l)	4.184	Nickel (s)	0.440
Water (s)	2.093	Zinc (s)	0.387
Vegetable Oil	2.000	Copper (s)	0.386
Air	1.020	Brass (s)	0.380
Magnesium (s)	1.020	Sand	0.290
Aluminum (s)	0.900	Silver (s)	0.240
Glass	0.840	Tin (s)	0.210
Potassium (s)	0.757	Lead(s)	0.160
Calcium (s)	0.650	Mercury (l)	0.140
Iron (s)	0.444	Gold (s)	0.126

## Chapter 14: Thermodynamics

Term	Description	Equation
<b>Enthalpy (<math>\Delta H</math>)</b>	The <u>energy change</u> that accompanies a chemical or physical change.	
<b>Enthalpy Observations</b>	<ul style="list-style-type: none"> <li>For exothermic reactions, <math>\Delta H</math> is negative (-).</li> <li>For endothermic reactions, <math>\Delta H</math> is positive (+).</li> </ul>	
<b>Enthalpy</b>	$\Delta H = (\text{Energy for breaking bonds}) - (\text{Energy from making bonds})$	
<b>Bond Energy</b>	The energy required to break a mole of a given type of bond.	
<b>State Function</b>	A property that is independent of the path.	
<b>Default Enthalpy</b>	The $\Delta H_f^\circ$ of any element in its natural phase is zero.	
<b>Hess's Law</b>	Chemical reaction: $aA + bB \rightarrow cC + dD$ $\Delta H = \Delta H_{\text{Products}} - \Delta H_{\text{Reactants}}$ $\Delta H = (c \cdot \Delta H_f^\circ(C) + d \cdot \Delta H_f^\circ(D)) - (a \cdot \Delta H_f^\circ(A) + b \cdot \Delta H_f^\circ(B))$	
<b>Activation Energy</b>	The energy required to initiate a chemical reaction. 	
<b>Thermodynamics</b>	The study of the relationships and conversions between different forms of energy. <ul style="list-style-type: none"> <li><u>1<sup>st</sup> Law</u>: Energy cannot be created or destroyed. It can only change form.</li> <li><u>2<sup>nd</sup> Law</u>: The entropy of the universe can never decrease. It must always stay the same or increase.</li> </ul>	

<b>Entropy (<math>\Delta S</math>)</b>	A measure of the amount of thermal energy in a system that is <u>not</u> available to do useful work.  Because work is obtained from ordered molecular motion, entropy is also a measure of the molecular <u>disorder</u> , or randomness, of a system.	
<b>Change in Entropy</b>	$\Delta S_{\text{system}} + \Delta S_{\text{surroundings}} \geq 0$	
<b>Entropy Observations</b>	<ul style="list-style-type: none"> <li>The <u>solid</u> phase is the <u>lowest</u>-entropy phase.</li> <li>The <u>gas</u> phase is the <u>highest</u>-entropy phase.</li> <li>The larger the number of molecules, the higher the entropy.</li> </ul>	
<b>Entropy Reactions</b>	Chemical reaction: $aA + bB \rightarrow cC + dD$ $\Delta S = \Delta S_{\text{Products}} - \Delta S_{\text{Reactants}}$ $\Delta S = (c \cdot S^\circ(C) + d \cdot S^\circ(D)) - (a \cdot S^\circ(A) + b \cdot S^\circ(B))$	

<b>Gibbs Free Energy (<math>\Delta G</math>)</b>	$\Delta G = \Delta H - T \cdot \Delta S$
	<p>a) endothermic reaction      b) exothermic reaction</p>
<b>Efficiency</b>	$\Delta G$ can predict chemical reaction efficiency. $\text{Efficiency} = \frac{\Delta G}{\Delta H} \times 100\%$
<b>Gibbs Observations</b>	<ul style="list-style-type: none"> <li>• When <math>\Delta G</math> is negative (-), the reaction is <u>spontaneous</u>.</li> <li>• When <math>\Delta G</math> is positive (+), the reaction is <u>not spontaneous</u>.</li> <li>• The <math>\Delta G_f^\circ</math> of any element in its natural phase is zero.</li> </ul>
<b>Gibbs Reactions</b>	Chemical reaction: $aA + bB \rightarrow cC + dD$ $\Delta G = \Delta G_{\text{Products}} - \Delta G_{\text{Reactants}}$ $\Delta G = (c \cdot \Delta G_f^\circ(C) + d \cdot \Delta G_f^\circ(D)) - (a \cdot \Delta G_f^\circ(A) + b \cdot \Delta G_f^\circ(B))$

## Bond Energies

Bond	Energy (kJ/mole)	Bond	Energy (kJ/mole)	Bond	Energy (kJ/mole)
H - H	436	C - C	350	F - F	159
H - C	410	C - F	450	Cl - Cl	243
H - O	460	C - Cl	330	S - H	340
H - Cl	432	C - O	350	S - F	310
H - N	390	C - N	300	O - Cl	200
C = C	611	C = O	732	N $\equiv$ N	945
N = O	607	O = O	498	C $\equiv$ O	1072

## Standard Enthalpies of Formation

Compound	$\Delta H_f^\circ$ (kJ/mole)	Compound	$\Delta H_f^\circ$ (kJ/mole)	Compound	$\Delta H_f^\circ$ (kJ/mole)
$CH_4(g)$	-74.9	$C_2H_6O(l)$	-277.7	$H_2O_2(aq)$	-191.2
$C_2H_6(g)$	-84.7	$CO_2(g)$	-393.5	$HCl(g)$	-92.3
$C_6H_6(g)$	82.6	$CO(g)$	-110.5	$HCl(aq)$	-167.2
$C_6H_6(l)$	49.0	$CS_2(g)$	116.9	$NH_3(g)$	-45.9
$CH_4O(g)$	-200.7	$CS_2(l)$	89.7	$NH_3(aq)$	-80.3
$CH_4O(l)$	-238.7	$H_2O(g)$	-241.8	$NH_4Cl(s)$	-314.6
$C_2H_6O(g)$	-235.1	$H_2O(l)$	-285.8	$NaOH(s)$	-425.9

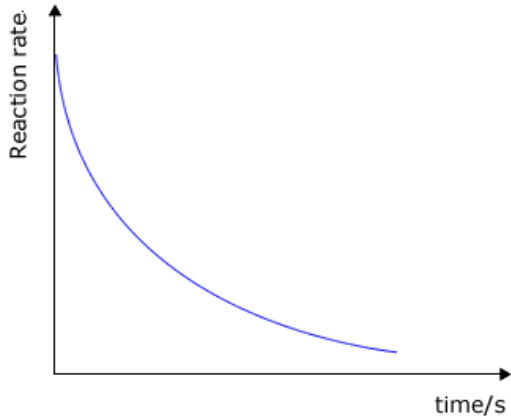
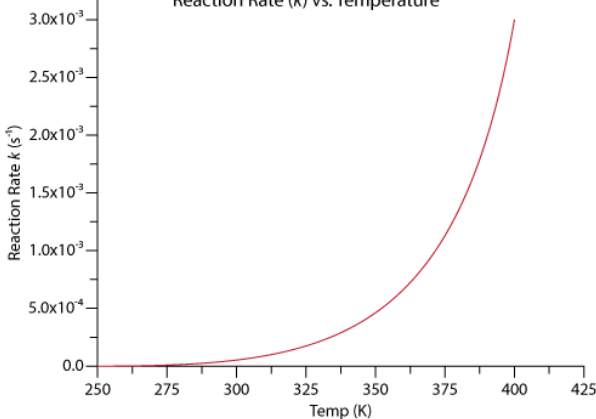
## Absolute Entropies

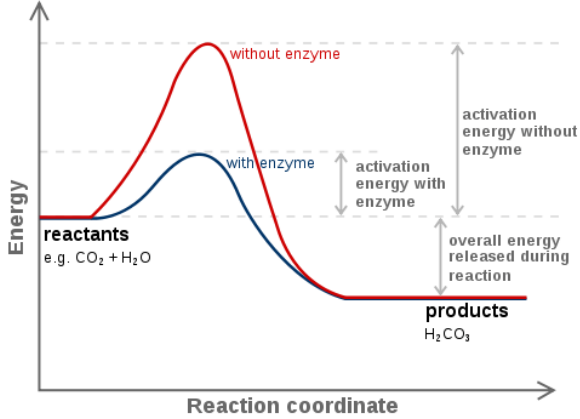

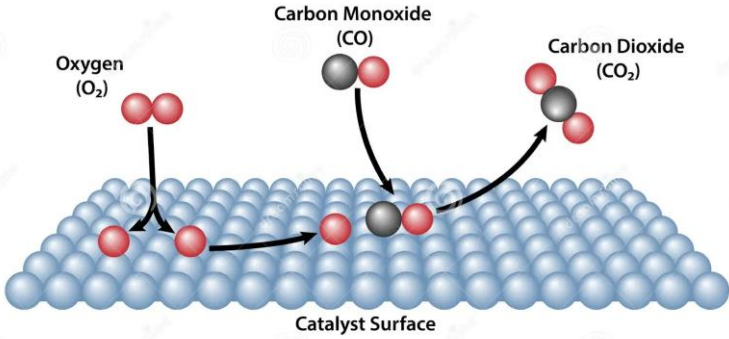
Substance	$S^\circ$ (J/mole·K)	Substance	$S^\circ$ (J/mole·K)	Substance	$S^\circ$ (J/mole·K)
$CH_4(g)$	186.1	$C_2H_6O(l)$	160.7	$H_2O_2(aq)$	143.9
$C_2H_6(g)$	229.5	$CO_2(g)$	213.7	$HCl(g)$	186.8
$C_6H_6(g)$	269.2	$CO(g)$	197.5	$HCl(aq)$	56.5
$C_6H_6(l)$	173.4	$CS_2(g)$	237.9	$NH_3(g)$	192.7
$CH_4O(g)$	239.7	$CS_2(l)$	153.1	$NH_3(aq)$	111.3
$CH_4O(l)$	126.8	$H_2O(g)$	188.7	$NH_4Cl(s)$	94.9
$C_2H_6O(g)$	282.6	$H_2O(l)$	70.0	$NaOH(s)$	64.4
$C(\text{graphite})$	5.7	$H_2(g)$	130.6	$Cl_2(g)$	223.0
$C(g)$	158.0	$O_2(g)$	205.0	$N_2(g)$	191.6

## Standard Gibbs Free Energy of Formation

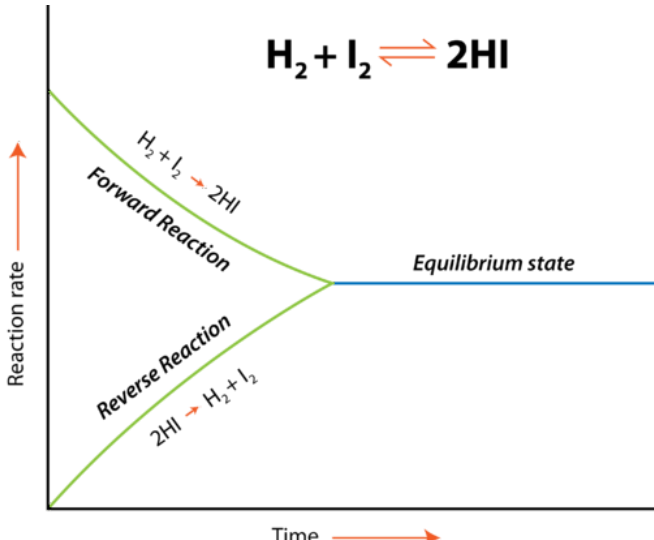
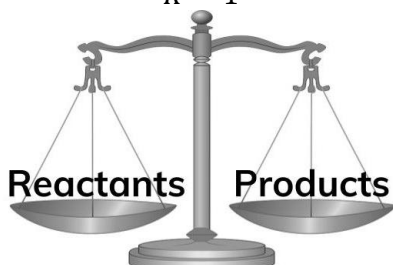
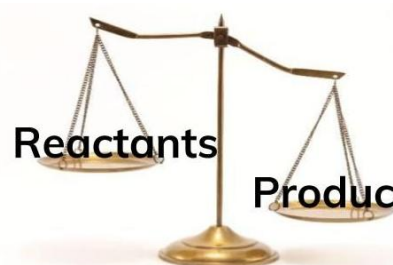
Compound	$\Delta G_f^\circ$ (kJ/mole)	Compound	$\Delta G_f^\circ$ (kJ/mole)	Compound	$\Delta G_f^\circ$ (kJ/mole)
$CH_4(g)$	-50.8	$C_2H_6O(l)$	-174.9	$H_2O_2(aq)$	-134.1
$C_2H_6(g)$	-32.9	$CO_2(g)$	-394.4	$HCl(g)$	-95.3
$C_6H_6(g)$	129.7	$CO(g)$	-137.2	$HCl(aq)$	-131.3
$C_6H_6(l)$	124.4	$CS_2(g)$	66.9	$NH_3(g)$	-16.4
$CH_4O(g)$	-162.0	$CS_2(l)$	65.3	$NH_3(aq)$	-26.6
$CH_4O(l)$	-166.4	$H_2O(g)$	-228.6	$NH_4Cl(s)$	-203.1
$C_2H_6O(g)$	-168.8	$H_2O(l)$	-237.1	$NaOH(s)$	-379.7

## Chapter 15: Kinetics

Term	Equation	Note
<b>Kinetics</b>	The study of chemical reaction rates.	
<b>Rate</b>	$\text{Rate} = \frac{\Delta[\text{C}]}{\Delta t}$ $\text{Rate} = \frac{-\Delta[\text{A}]}{\Delta t}$	Chemical reaction: $A + B \rightarrow C + D$ <i>reactants</i> → <i>products</i> [ ] = "The concentration of"
<b>Reaction Rate Observations</b>	The reaction rate is usually proportional to the: <ul style="list-style-type: none"> <li>• Concentration of reactants</li> <li>• Surface area over which the reaction can occur</li> <li>• Temperature</li> </ul>	
<b>Rate Equation</b>	$\text{Rate} = k[\text{A}]^x[\text{B}]^y$	Chemical reaction: $a\text{A} + b\text{B} \rightarrow c\text{C} + d\text{D}$ $\text{rate} = k \times [\text{A}]^x [\text{B}]^y [\text{C}]^z$ <p> <i>rate constant</i> (points to <math>k</math>)  <i>orders with respect to each reactant</i> (points to <math>x</math> and <math>y</math>)  <i>concentrations of reactants</i> (points to <math>[\text{A}]</math> and <math>[\text{B}]</math>)         </p>
<b>Rate Constant</b>	<ul style="list-style-type: none"> <li>• The units for the rate constant depend on the overall order of the reaction.</li> <li>• The rate constant increases exponentially with increasing temperature.</li> <li>• The rate constant decreases with increasing activation energy.</li> </ul>	
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>Reaction rate vs time/s</p> </div> <div style="text-align: center;">  <p>Reaction Rate (<math>k</math>) vs. Temperature</p> </div> </div>		

<p><b>Catalyst</b></p>	<p>A chemical that increases the rate of a chemical reaction <u>without being used up</u> in the process.</p> <p>i.e., It lowers the activation energy of the reaction by pulling the molecules closer to one another than they would normally be.</p> 
<p><b>Catalase</b></p>	<p>A common enzyme found in nearly all living organisms exposed to oxygen which catalyzes the decomposition of <math>H_2O_2</math> to <math>H_2O</math> and <math>O_2</math>.</p>
<p><b>Heterogeneous Catalyst</b></p>	<p>A catalyst in a phase that is <u>different</u> from that of the reactants. e.g., Catalytic converter (g) + (s).</p>
<p><b>Catalytic Converter</b></p> 	<p>A device attached to the exhaust of a car that speeds up the following reaction:</p> $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ <p>The catalyst is the platinum-coated (<b>solid</b>) mesh that lowers the activation energy.</p>  <p style="text-align: center;"><b>1 Adsorption      2 Reaction      3 Desorption</b></p>
<p><b>Homogeneous Catalyst</b></p>	<p>A catalyst in a phase that is the <u>same</u> as that of the reactants. <math>2O_3(g) \rightarrow 3O_2(g)</math></p>
<p><b>Reaction Mechanism</b></p>	<p>A detailed, step-by-step process that tells you exactly how a reaction occurs.</p> $2O_3(g) \rightarrow 3O_2(g)$ <p>Step 1: <math>NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)</math>  Step 2: <math>O_3(g) \rightarrow O_2(g) + O(g)</math> due to UV light  Step 3: <math>NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)</math></p>

## Chapter 16: Chemical Equilibrium

Term	Description	Equation
Chemical Equilibrium	The state that occurs in a chemical reaction when the rate of the forward reaction equals the rate of the reverse reaction.	
Example	 <p style="text-align: center;"><math>\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}</math></p>	
Equilibrium Constant	$K = \frac{[\text{C}]_{eq}^c [\text{D}]_{eq}^d}{[\text{A}]_{eq}^a [\text{B}]_{eq}^b}$	Chemical reaction: $a\text{A} + b\text{B} \rightarrow c\text{C} + d\text{D}$ <i>reactants</i> $\rightarrow$ <i>products</i>
	The value of the equilibrium constant for a given reaction changes with temperature.	
Interpreting the Constant	<p><b><math>K &lt; 1</math>:</b></p> <ul style="list-style-type: none"> <li>When the equilibrium constant is small, the reaction makes fewer products and has lots of reactants.</li> <li>The smaller it is, the more reactants there are and the fewer products there are at equilibrium.</li> </ul> <p><b><math>K = 1</math>:</b></p> <ul style="list-style-type: none"> <li>When the equilibrium constant is 1, the reaction is balanced between reactants and products.</li> </ul> <p><b><math>K &gt; 1</math>:</b></p> <ul style="list-style-type: none"> <li>When the equilibrium constant is large, the reaction makes lots of products and has few reactants.</li> <li>The larger it is, the more products there are and the fewer reactants there are at equilibrium.</li> </ul>	
	<p style="text-align: center;"><math>K = 1</math></p> 	<p style="text-align: center;"><math>K &gt; 1</math></p> 

<b>Focus on Gas</b>	Do not include <u>solid</u> or <u>liquid</u> reactants or products in the equation for the equilibrium constant.
<b>Interpreting <math>K</math> Results</b>	$K = \frac{[C]_{eq}^c [D]_{eq}^d}{[A]_{eq}^a [B]_{eq}^b}$
	<p>For the above equation:</p> <ul style="list-style-type: none"> <li>• &gt;: If the result is <u>greater than</u> the equilibrium constant, the reaction will shift towards the reactants.</li> <li>• =: If the result is <u>equal</u> to the equilibrium constant, the reaction is at equilibrium.</li> <li>• &lt;: If the result is <u>less than</u> the equilibrium constant, the reaction will shift towards the products.</li> </ul>
<b>Le Chatelier's Principle</b>	When a system at equilibrium is stressed, it will shift in a way that relieves the stress and reestablishes equilibrium.
<b><math>K</math> Shifting: Concentration</b>	<p>A system in equilibrium will:</p> <ul style="list-style-type: none"> <li>• ↑: <u>shift away</u> from the side that experiences an increase in concentration.</li> <li>• ↓: <u>shift towards</u> the side that experiences a decrease in concentration.</li> </ul>
<b><math>K</math> Shifting: Temperature</b>	<ul style="list-style-type: none"> <li>• ↑: When temperature is <u>raised</u>, an equilibrium will shift away from the side that contains energy.</li> <li>• ↓: When temperature is <u>lowered</u>, it will shift towards the side that contains energy.</li> </ul>
<b><math>K</math> Shifting: Pressure</b>	<ul style="list-style-type: none"> <li>• ↑: When pressure is <u>raised</u>, an equilibrium will shift away from the side that has the most gas molecules.</li> <li>• ↓: When pressure is <u>lowered</u>, it will shift towards the side that has the most gas molecules</li> <li>• ↔: If there are <u>no gas</u> molecules, the equilibrium doesn't shift when pressure is changed.</li> </ul>
<b>Acid Ionization Constant (<math>K_a</math>)</b>	The equilibrium constant for the reaction between an <u>acid</u> and water.
<b>Base Ionization Constant (<math>K_b</math>)</b>	The equilibrium constant for the reaction between a <u>base</u> and water.

## Sources

These chapters and content are from the textbook:

- Dr. Jay L. Wile (2015). [Discovering Design with Chemistry](#), 1<sup>st</sup> Edition.