

# THE EQUATION SHEET

## Constants:

Avogadro's Number ( $N_A$ )	$6.02 \times 10^{23}$
Universal Gas Constant ( $R$ )	8.314 J/mol·K or 0.0821 L·atm/mol·K
Planck's constant ( $h$ )	$6.626 \times 10^{-34}$ J·s
Rydberg Constant ( $R_H$ )	$2.18 \times 10^{-18}$ J
Speed of Light ( $c$ )	$3.00 \times 10^8$ m/s
Charge of an Electron ( $q$ )	$1.602 \times 10^{-19}$
Boltzmann Constant ( $k_B$ )	$1.381 \times 10^{-23}$ J/K
Molar Volume ( $V_{mol}$ )	22.7 L/mol or $2.27 \times 10^{-2}$ m <sup>3</sup> /mol
Mass of Earth	$5.97 \times 10^{24}$ kg
Specific Heat Capacity of Water ( $C$ )	4.18 J/gK or 4.18 kJ/kgK
Ionic Product Constant of Water ( $K_w$ )	$1.00 \times 10^{-14}$ (mol/L) <sup>2</sup> at 298 K (25°C)
Faraday's constant ( $F$ )	96 500 C/mol
STP conditions	273 K and 100 kPa
SATP conditions	298K and 100 kPa

## Basic Equations:

$n = \frac{m}{M_R}$	$n = cV$	$c_1V_1 = c_2V_2$
$n_{gas} = \frac{V}{22.7 \text{ mol/L}}$	$K_{SP} = K_c$ (Aqueous)	
$\% \text{ atom economy} = \frac{\text{molar mass of desired product}}{\text{molar mass of all reactants}} \times 100\%$		
<b>Conversion factors:</b>		
1L atm = 101.3 J	1atm = 760 torr = 760 mm Hg	
1nm = $10^{-9}$ m	0°C = 273 K	
1dm <sup>3</sup> = 1L	1 amu = $1.66 \times 10^{-27}$ kg	

<p><b>Acid-Base Chemistry:</b></p> $pH = -\log[H_3O^+]$ $[H_3O^+] = 10^{-pH}$ $K_w = K_a \times K_b$ $pK_a + pK_b = pK_w$ $pK_a = -\log K_a$ $pK_b = -\log K_b$ $pK_b = 14 - pK_a$ $pH + pOH = 14$ $pOH = -\log[OH^-]$ $[OH^-] = 10^{-pOH}$ $pH_{Buffer} = pK_a - \log\left(\frac{[HA]}{[A^-]}\right)$	<p><b>Thermodynamics:</b></p> $\Delta H_{rxn} = H_P - H_R$ $q = \Delta H \text{ at constant pressure}$ $\Delta H^\circ = \frac{-Q}{\# \text{ mol}}$ $M_{Enthalpy} = \sum(E_k + E_p)$ $E_k = \frac{1}{2}mv^2$ $C = \frac{Q}{\Delta T}$ $Q = mc\Delta T$ $\Delta H_{rxn}^\circ = \sum[\Delta H_{f(P)}^\circ] - \sum[\Delta H_{f(R)}^\circ]$ $\Delta H_{rxn}^\circ = \sum D(\text{broken}) - \sum D(\text{formed})$ $\Delta S = k \ln W = \frac{q}{T} = S_{System} + S_{Surrounding}$ $\Delta S_{rxn}^\circ = \sum S_{(P)}^\circ - \sum S_{(R)}^\circ$ $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ $\Delta G_{rxn}^\circ = \sum \Delta G_{(P)}^\circ - \sum \Delta G_{(R)}^\circ$	<p><b>Chemical Kinetics:</b></p> $\text{Rate}_{Reaction} = \frac{\Delta c}{\Delta t}$ $\text{Order of reaction} = m + n$ $\text{Rate}_{Reaction} = k[A]^m[B]^n$ $E_A = -RT \ln\left(\frac{k}{A}\right)$ $t_{1/2} = \frac{0.693}{k}$ $t_{1/2} = \frac{1}{k[A]_0}$ $k = Ae^{-E_a/RT}$ $[A]_t = -kt + [A]_0$ $\ln[A]_t = -kt + \ln[A]_0$ $\ln \frac{k_1}{k_2} = \frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right)$ $K_C = \frac{[\text{Products}]^n}{[\text{Reactants}]^m}$ $K_P = K_C(RT)^{\Delta n}$ $\Delta G^\circ = -RT \ln K$	<p><b>Quantum Mechanics:</b></p> $\Delta E = \frac{hc}{\lambda}$ $c = \lambda\nu$ $\Delta E = R_H \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$ $E = hf$ $n\lambda = 2d \sin \theta$
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<p><b>Nuclear Chemistry:</b></p> $E = mc^2$ ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\text{He}$ ${}_0^1n \rightarrow {}_1^1H + {}_{-1}^0e$	<p><b>Gas:</b></p> $PV = nRT$ $\frac{\text{Rate}_1}{\text{Rate}_2} = \sqrt{\frac{M_2}{M_1}}$	<p><b>Redox:</b></p> $\text{Charge} = \text{Current} \times \text{Time}$ $E_{cell}^\circ = E_{cathode}^\circ - E_{anode}^\circ$ $\Delta G^\circ = -nFE^\circ$
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## Extras

<p><b>Solubility:</b></p> <table border="1"> <tr> <td>Q<sub>c</sub></td> <td>K<sub>c</sub></td> <td>Q</td> <td>K<sub>sp</sub> (Precipitate)</td> </tr> <tr> <td>&lt;</td> <td>Prod Fav</td> <td>&lt;</td> <td>No</td> </tr> <tr> <td>=</td> <td>EQ</td> <td>=</td> <td>No</td> </tr> <tr> <td>&gt;</td> <td>React Fav</td> <td>&gt;</td> <td>Yes (Super Saturated)</td> </tr> </table>	Q <sub>c</sub>	K <sub>c</sub>	Q	K <sub>sp</sub> (Precipitate)	<	Prod Fav	<	No	=	EQ	=	No	>	React Fav	>	Yes (Super Saturated)	<p><b>Formations:</b></p> <ol style="list-style-type: none"> <li>Acid + Metal = Salt + Hydrogen Gas Ex. <math>2\text{HCl}_{(aq)} + \text{Zn}_{(s)} \rightarrow \text{ZnCl}_{2(s)} + \text{H}_{2(g)}</math></li> <li>Acid + Base = Salt + Water Ex. <math>\text{HCl}_{(aq)} + \text{NaOH}_{(aq)} \rightarrow \text{NaCl}_{(s)} + \text{H}_2\text{O}_{(l)}</math></li> <li>Acid + Metal Carbonate = CO<sub>2</sub> + H<sub>2</sub>O + Salt Ex. <math>\text{CaCO}_{3(s)} + \text{HCl}_{(aq)} \rightarrow \text{H}_2\text{O}_{(l)} + \text{CO}_{2(g)} + \text{CaCl}_{2(s)}</math></li> <li>Metal Oxide + Acid → Salt + Water Ex. <math>\text{MgO}_{(s)} + \text{HCl}_{(aq)} \rightarrow \text{MgCl}_{2(s)} + \text{H}_2\text{O}_{(l)}</math></li> </ol>
Q <sub>c</sub>	K <sub>c</sub>	Q	K <sub>sp</sub> (Precipitate)														
<	Prod Fav	<	No														
=	EQ	=	No														
>	React Fav	>	Yes (Super Saturated)														

## Periodic Table of Electronegativities

<b>H</b> 2.20																	<b>He</b> n.a.
<b>Li</b> 0.98	<b>Be</b> 1.57											<b>B</b> 2.04	<b>C</b> 2.55	<b>N</b> 3.04	<b>O</b> 3.44	<b>F</b> 3.98	<b>Ne</b> n.a.
<b>Na</b> 0.93	<b>Mg</b> 1.31											<b>Al</b> 1.61	<b>Si</b> 1.90	<b>P</b> 2.19	<b>S</b> 2.58	<b>Cl</b> 3.16	<b>Ar</b> n.a.
<b>K</b> 0.82	<b>Ca</b> 1.00	<b>Sc</b> 1.36	<b>Ti</b> 1.54	<b>V</b> 1.63	<b>Cr</b> 1.66	<b>Mn</b> 1.55	<b>Fe</b> 1.83	<b>Co</b> 1.88	<b>Ni</b> 1.91	<b>Cu</b> 1.90	<b>Zn</b> 1.65	<b>Ga</b> 1.81	<b>Ge</b> 2.01	<b>As</b> 2.18	<b>Se</b> 2.55	<b>Br</b> 2.96	<b>Kr</b> 3.00
<b>Rb</b> 0.82	<b>Sr</b> 0.95	<b>Y</b> 1.22	<b>Zr</b> 1.33	<b>Nb</b> 1.60	<b>Mo</b> 2.16	<b>Tc</b> 1.90	<b>Ru</b> 2.20	<b>Rh</b> 2.28	<b>Pd</b> 2.20	<b>Ag</b> 1.93	<b>Cd</b> 1.69	<b>In</b> 1.78	<b>Sn</b> 1.96	<b>Sb</b> 2.05	<b>Te</b> 2.10	<b>I</b> 2.66	<b>Xe</b> 2.60
<b>Cs</b> 0.79	<b>Ba</b> 0.89	<b>La</b> 1.10	<b>Hf</b> 1.30	<b>Ta</b> 1.50	<b>W</b> 2.36	<b>Re</b> 1.90	<b>Os</b> 2.20	<b>Ir</b> 2.20	<b>Pt</b> 2.28	<b>Au</b> 2.54	<b>Hg</b> 2.00	<b>Tl</b> 1.62	<b>Pb</b> 2.33	<b>Bi</b> 2.02	<b>Po</b> 2.00	<b>At</b> 2.20	<b>Rn</b> n.a.
<b>Fr</b> 0.70	<b>Ra</b> 0.89	<b>Ac</b> 1.10	<b>Rf</b> n.a.	<b>Db</b> n.a.	<b>Sg</b> n.a.	<b>Bh</b> n.a.	<b>Hs</b> n.a.	<b>Mt</b> n.a.	<b>Ds</b> n.a.	<b>Rg</b> n.a.	<b>Uub</b> n.a.	—	<b>Uuq</b> n.a.	—	—	—	—

**Polyatomic Ions:**

Acetate	CH <sub>3</sub> COO <sup>-</sup> or C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> <sup>-</sup>	Hydroxide	OH <sup>-</sup>
Aluminate	AlO <sub>2</sub> <sup>-</sup> , Al <sub>2</sub> O <sub>4</sub> <sup>2-</sup>	Hypobromite	BrO <sup>-</sup>
Amide	NH <sub>2</sub> <sup>-</sup>	Hypochlorite	ClO <sup>-</sup>
Ammonium	NH <sub>4</sub> <sup>+</sup>	Hypoiodite	IO <sup>-</sup>
Antimonate	SbO <sub>4</sub> <sup>3-</sup>	Hypophosphite	PO <sub>2</sub> <sup>3-</sup>
Antimonite	SbO <sub>3</sub> <sup>3-</sup>	Hyposulfite	SO <sub>2</sub> <sup>2-</sup>
Arsenate	AsO <sub>4</sub> <sup>3-</sup>	Iodate	IO <sub>3</sub> <sup>-</sup>
Arsenite	AsO <sub>3</sub> <sup>3-</sup>	Iodite	IO <sub>2</sub> <sup>-</sup>
Bicarbonate (hydrogen carbonate)	HCO <sub>3</sub> <sup>-</sup>	Manganate	MnO <sub>4</sub> <sup>2-</sup>
Bromate	BrO <sub>3</sub> <sup>-</sup>	Nitrate	NO <sub>3</sub> <sup>-</sup>
Bromite	BrO <sub>2</sub> <sup>-</sup>	Nitrite	NO <sub>2</sub> <sup>-</sup>
Carbide	C <sub>2</sub> <sup>2-</sup>	Oxalate	C <sub>2</sub> O <sub>4</sub> <sup>2-</sup>
Carbonate	CO <sub>3</sub> <sup>2-</sup>	Ozonide	O <sub>3</sub> <sup>-</sup>
Chlorate	ClO <sub>3</sub> <sup>-</sup>	Perbromate	BrO <sub>4</sub> <sup>-</sup>
Chlorite	ClO <sub>2</sub> <sup>-</sup>	Perchlorate	ClO <sub>4</sub> <sup>-</sup>
Chromate	CrO <sub>4</sub> <sup>2-</sup>	Periodate	IO <sub>4</sub> <sup>-</sup>
Chromite	CrO <sub>2</sub> <sup>-</sup>	Permanganate	MnO <sub>4</sub> <sup>-</sup>
Cyanate	OCN <sup>-</sup>	Peroxide	O <sub>2</sub> <sup>2-</sup>
Cyanide	CN <sup>-</sup>	Phosphate	PO <sub>4</sub> <sup>3-</sup>
Dichromate	Cr <sub>2</sub> O <sub>7</sub> <sup>2-</sup>	Phosphite	PO <sub>3</sub> <sup>3-</sup>
Dihydrogen arsenate	H <sub>2</sub> AsO <sub>4</sub> <sup>-</sup>	Plumbate	PbO <sub>3</sub> <sup>2-</sup>
Dihydrogen phosphate	H <sub>2</sub> PO <sub>4</sub> <sup>-</sup>	Plumbite	PbO <sub>2</sub> <sup>2-</sup>
Dihydrogen phosphite	H <sub>2</sub> PO <sub>3</sub> <sup>-</sup>	Stannate	SnO <sub>3</sub> <sup>2-</sup>
Disulfide	S <sub>2</sub> <sup>2-</sup>	Stannite	SnO <sub>2</sub> <sup>2-</sup>
Ferrate	FeO <sub>4</sub> <sup>2-</sup>	Sulfate	SO <sub>4</sub> <sup>2-</sup>
Hydrogen arsenate	HAsO <sub>4</sub> <sup>2-</sup>	Sulfite	SO <sub>3</sub> <sup>2-</sup>
Hydrogen carbonate (bicarbonate)	HCO <sub>3</sub> <sup>-</sup>	Superoxide	O <sub>2</sub> <sup>-</sup>
Hydrogen phosphate	HPO <sub>4</sub> <sup>2-</sup>	Tartrate	(CH(OH)COO) <sub>2</sub> <sup>2-</sup>
Hydrogen phosphite	HPO <sub>3</sub> <sup>2-</sup>	Tellurate	TeO <sub>4</sub> <sup>2-</sup>
Hydrogen sulfate	HSO <sub>4</sub> <sup>-</sup>	Tellurite	TeO <sub>3</sub> <sup>2-</sup>
Hydrogen sulfite	HSO <sub>3</sub> <sup>-</sup>	Thiocyanate	SCN <sup>-</sup>
Hydronium	H <sub>3</sub> O <sup>+</sup>	Thiosulfate	S <sub>2</sub> O <sub>3</sub> <sup>2-</sup>

**Periodic Table of the Elements**

1 IA 1A																	2 IIA 2A											3 IIIA 3A	4 IVA 4A	5 VA 5A	6 VIA 6A	7 VIIA 7A	8 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
3 Li Lithium 6.941	4 Be Beryllium 9.012																	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948										
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948																
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.833	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 83.94																
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29																
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine 208.98	86 Rn Radon 222.018																
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown																
Lanthanide Series		57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967																	
Actinide Series		89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]																	