





### Physical Constants

Standard acceleration of terrestrial gravity	$g = 9.80665 \text{ m s}^{-2}$ (exactly)
Avogadro's number	$N_0 = 6.022137 \times 10^{23}$
Bohr radius	$a_0 = 0.52917725 \text{ \AA} = 5.2917725 \times 10^{-11} \text{ m}$
Boltzmann's constant	$k_B = 1.38066 \times 10^{-23} \text{ J K}^{-1}$
Electron charge	$e = 1.6021773 \times 10^{-19} \text{ C}$
Faraday constant	$\mathcal{F} = 96,485.31 \text{ C mol}^{-1}$
Masses of fundamental particles:	
Electron	$m_e = 9.109390 \times 10^{-31} \text{ kg}$
Proton	$m_p = 1.672623 \times 10^{-27} \text{ kg}$
Neutron	$m_n = 1.674929 \times 10^{-27} \text{ kg}$
Ratio of proton mass to electron mass	$m_p/m_e = 1836.15270$
Permittivity of vacuum	$\epsilon_0 = 8.8541878 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$
Planck's constant	$h = 6.626076 \times 10^{-34} \text{ J s}$
Speed of light in a vacuum	$c = 2.99792458 \times 10^8 \text{ m s}^{-1}$ (exactly)
Universal gas constant	$R = 8.31451 \text{ J mol}^{-1} \text{ K}^{-1}$ $= 0.0820578 \text{ L atm mol}^{-1} \text{ K}^{-1}$

Values are taken from "Quantities, Units and Symbols in Physical Chemistry," International Union of Pure and Applied Chemistry, Blackwell Scientific Publications, 1988.

### Conversion Factors

Standard atmosphere	$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} = 1.01325 \times 10^5 \text{ kg m}^{-1} \text{ s}^{-2}$ (exactly)
Atomic mass unit	$1 \text{ u} = 1.660540 \times 10^{-27} \text{ kg}$ $1 \text{ u} = 1.492419 \times 10^{-10} \text{ J} = 931.4943 \text{ MeV}$ (energy equivalent from $E = mc^2$ )
Calorie	$1 \text{ cal} = 4.184 \text{ J}$ (exactly)
Electron volt	$1 \text{ eV} = 1.6021773 \times 10^{-19} \text{ J} = 96.48531 \text{ kJ mol}^{-1}$
Foot	$1 \text{ ft} = 12 \text{ in} = 0.3048 \text{ m}$ (exactly)
Gallon (U.S.)	$1 \text{ gallon} = 4 \text{ quarts} = 3.78541 \text{ L}$ (exactly)
Liter-atmosphere	$1 \text{ L atm} = 101.325 \text{ J}$ (exactly)
Metric ton	$1 \text{ metric ton} = 1000 \text{ kg}$ (exactly)
Pound	$1 \text{ lb} = 16 \text{ oz} = 0.45359237 \text{ kg}$ (exactly)

Table 8-1

Activity coefficients for aqueous solutions at 25° C

Ion	Ion size ( $\alpha$ , pm)	0.001	0.005	0.01	0.05	0.1
Charge = $\pm 1$						
H <sup>+</sup>	900	0.967	0.933	0.914	0.86	0.83
(C <sub>6</sub> H <sub>5</sub> ) <sub>2</sub> CHCO <sub>2</sub> <sup>-</sup> , (C <sub>3</sub> H <sub>7</sub> ) <sub>4</sub> N <sup>+</sup>	800	0.966	0.931	0.912	0.85	0.82
(O <sub>2</sub> N) <sub>3</sub> C <sub>6</sub> H <sub>2</sub> O <sup>-</sup> , (C <sub>3</sub> H <sub>7</sub> ) <sub>3</sub> NH <sup>+</sup> , CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub> CO <sub>2</sub> <sup>-</sup>	700	0.965	0.930	0.909	0.845	0.81
Li <sup>+</sup> , C <sub>6</sub> H <sub>5</sub> CO <sub>2</sub> <sup>-</sup> , HOC <sub>6</sub> H <sub>4</sub> CO <sub>2</sub> <sup>-</sup> , ClC <sub>6</sub> H <sub>4</sub> CO <sub>2</sub> <sup>-</sup> , C <sub>6</sub> H <sub>5</sub> CH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> , CH <sub>2</sub> =CHCH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> , (CH <sub>3</sub> ) <sub>2</sub> CHCH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> , (CH <sub>3</sub> CH <sub>2</sub> ) <sub>4</sub> N <sup>+</sup> , (C <sub>3</sub> H <sub>7</sub> ) <sub>2</sub> NH <sub>2</sub> <sup>+</sup>	600	0.965	0.929	0.907	0.835	0.80
Cl <sub>2</sub> CHCO <sub>2</sub> <sup>-</sup> , Cl <sub>3</sub> CCO <sub>2</sub> <sup>-</sup> , (CH <sub>3</sub> CH <sub>2</sub> ) <sub>3</sub> NH <sup>+</sup> , (C <sub>3</sub> H <sub>7</sub> )NH <sub>3</sub> <sup>+</sup>	500	0.964	0.928	0.904	0.83	0.79
Na <sup>+</sup> , CdCl <sup>+</sup> , ClO <sub>2</sub> <sup>-</sup> , IO <sub>3</sub> <sup>-</sup> , HCO <sub>3</sub> <sup>-</sup> , H <sub>2</sub> PO <sub>4</sub> <sup>-</sup> , HSO <sub>3</sub> <sup>-</sup> , H <sub>2</sub> AsO <sub>4</sub> <sup>-</sup> , Co(NH <sub>3</sub> ) <sub>4</sub> (NO <sub>2</sub> ) <sub>2</sub> <sup>+</sup> , CH <sub>3</sub> CO <sub>2</sub> <sup>-</sup> , ClCH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> , (CH <sub>3</sub> ) <sub>4</sub> N <sup>+</sup> , (CH <sub>3</sub> CH <sub>2</sub> ) <sub>2</sub> NH <sub>2</sub> <sup>+</sup> , H <sub>2</sub> NCH <sub>2</sub> CO <sub>2</sub> <sup>-</sup>	450	0.964	0.928	0.902	0.82	0.775
<sup>+</sup> H <sub>3</sub> NCH <sub>2</sub> CO <sub>2</sub> H, (CH <sub>3</sub> ) <sub>3</sub> NH <sup>+</sup> , CH <sub>3</sub> CH <sub>2</sub> NH <sub>3</sub> <sup>+</sup>	400	0.964	0.927	0.901	0.815	0.77
OH <sup>-</sup> , F <sup>-</sup> , SCN <sup>-</sup> , OCN <sup>-</sup> , HS <sup>-</sup> , ClO <sub>3</sub> <sup>-</sup> , ClO <sub>4</sub> <sup>-</sup> , BrO <sub>3</sub> <sup>-</sup> , IO <sub>4</sub> <sup>-</sup> , MnO <sub>4</sub> <sup>-</sup> , HCO <sub>2</sub> <sup>-</sup> , H <sub>2</sub> citrate <sup>-</sup> , CH <sub>3</sub> NH <sub>3</sub> <sup>+</sup> , (CH <sub>3</sub> ) <sub>2</sub> NH <sub>2</sub> <sup>+</sup>	350	0.964	0.926	0.900	0.81	0.76
K <sup>+</sup> , Cl <sup>-</sup> , Br <sup>-</sup> , I <sup>-</sup> , CN <sup>-</sup> , NO <sub>2</sub> <sup>-</sup> , NO <sub>3</sub> <sup>-</sup>	300	0.964	0.925	0.899	0.805	0.755
Rb <sup>+</sup> , Cs <sup>+</sup> , NH <sub>4</sub> <sup>+</sup> , Tl <sup>+</sup> , Ag <sup>+</sup>	250	0.964	0.924	0.898	0.80	0.75
Charge = $\pm 2$						
Mg <sup>2+</sup> , Be <sup>2+</sup>	800	0.872	0.755	0.69	0.52	0.45
CH <sub>2</sub> (CH <sub>2</sub> CH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub> , (CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub>	700	0.872	0.755	0.685	0.50	0.425
Ca <sup>2+</sup> , Cu <sup>2+</sup> , Zn <sup>2+</sup> , Sn <sup>2+</sup> , Mn <sup>2+</sup> , Fe <sup>2+</sup> , Ni <sup>2+</sup> , Co <sup>2+</sup> , C <sub>6</sub> H <sub>4</sub> (CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub> , H <sub>2</sub> C(CH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub> , (CH <sub>2</sub> CH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub>	600	0.870	0.749	0.675	0.485	0.405
Sr <sup>2+</sup> , Ba <sup>2+</sup> , Cd <sup>2+</sup> , Hg <sup>2+</sup> , S <sup>2-</sup> , S <sub>2</sub> O <sub>4</sub> <sup>2-</sup> , WO <sub>4</sub> <sup>2-</sup> , H <sub>2</sub> C(CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub> , (CH <sub>2</sub> CO <sub>2</sub> <sup>-</sup> ) <sub>2</sub> , (CHOHCO <sub>2</sub> <sup>-</sup> ) <sub>2</sub>	500	0.868	0.744	0.67	0.465	0.38
Pb <sup>2+</sup> , CO <sub>3</sub> <sup>2-</sup> , SO <sub>3</sub> <sup>2-</sup> , MoO <sub>4</sub> <sup>2-</sup> , Co(NH <sub>3</sub> ) <sub>5</sub> Cl <sup>2+</sup> , Fe(CN) <sub>5</sub> NO <sup>2-</sup> , C <sub>2</sub> O <sub>4</sub> <sup>2-</sup> , Hcitrate <sup>2-</sup>	450	0.867	0.742	0.665	0.455	0.37
Hg <sub>2</sub> <sup>2+</sup> , SO <sub>4</sub> <sup>2-</sup> , S <sub>2</sub> O <sub>3</sub> <sup>2-</sup> , S <sub>2</sub> O <sub>6</sub> <sup>2-</sup> , S <sub>2</sub> O <sub>8</sub> <sup>2-</sup> , SeO <sub>4</sub> <sup>2-</sup> , CrO <sub>4</sub> <sup>2-</sup> , HPO <sub>4</sub> <sup>2-</sup>	400	0.867	0.740	0.660	0.445	0.355
Charge = $\pm 3$						
Al <sup>3+</sup> , Fe <sup>3+</sup> , Cr <sup>3+</sup> , Sc <sup>3+</sup> , Y <sup>3+</sup> , In <sup>3+</sup> , lanthanides <sup>a</sup>	900	0.738	0.54	0.445	0.245	0.18
citrate <sup>3-</sup>	500	0.728	0.51	0.405	0.18	0.115
PO <sub>4</sub> <sup>3-</sup> , Fe(CN) <sub>6</sub> <sup>3-</sup> , Cr(NH <sub>3</sub> ) <sub>6</sub> <sup>3+</sup> , Co(NH <sub>3</sub> ) <sub>6</sub> <sup>3+</sup> , Co(NH <sub>3</sub> ) <sub>5</sub> H <sub>2</sub> O <sup>3+</sup>	400	0.725	0.505	0.395	0.16	0.095
Charge = $\pm 4$						
Th <sup>4+</sup> , Zr <sup>4+</sup> , Ce <sup>4+</sup> , Sn <sup>4+</sup>	1 100	0.588	0.35	0.255	0.10	0.065
Fe(CN) <sub>6</sub> <sup>4-</sup>	500	0.57	0.31	0.20	0.048	0.021

a. Lanthanides are elements 57-71 in the periodic table.  
SOURCE: J. Kielland, *J. Am. Chem. Soc.* 1937, 59, 1675.

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