Equation Sheet

$$M = \frac{n}{V} \qquad M_1 V_1 = M_2 V_2 \qquad c_1 V_1 = c_2 V_2$$

Table 4.1

Simple Rules for Solubility of Salts in Water

1. Most nitrate (NO_3^-) salts are soluble.
2. Most salts of Na^+, K^+, and NH_4^+ are soluble.
3. Most chloride salts are soluble. Notable exceptions are AgCl, $PbCl_2$, and Hg_2Cl_2.
4. Most sulfate salts are soluble. Notable exceptions are $BaSO_4$, $PbSO_4$, and $CaSO_4$.
5. Most hydroxide salts are only slightly soluble. The important soluble hydroxides are NaOH, KOH, and $Ca(OH)_2$ (marginally soluble).
6. Most sulfide (S^{2-}), carbonate (CO_3^{2-}), and phosphate (PO_4^{3-}) salts are only slightly soluble.

$$V = a\left(\frac{1}{p}\right) \qquad V = bT \qquad V = cn$$

$$pV = nRT \qquad P_{\text{total}} = p_1 + p_2 + p_3 + \ldots \qquad V_{\text{total}} = V_1 + V_2 + V_3 + \ldots$$

$$\chi_A = \frac{n_A}{n_{\text{total}}} \qquad \chi_A = \frac{p_A}{p_{\text{total}}} \qquad \mathcal{M}\,(\text{g/mol}) = \frac{dRT}{p}$$

$$p_{\text{air}} = p_{H_2O} + p_{\text{gas}} \qquad \frac{p_1 V_1}{n_1 T_1} = \frac{p_2 V_2}{n_2 T_2}$$

1 atm = 760 mm Hg 1 torr = 1 mm Hg 101.3 kPa = 1 atm

$$PV = \frac{1}{3} N_A m u^2 \qquad 3RT = N_A m u^2 \qquad u_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

$$E_k = \frac{3}{2} RT \qquad \frac{R_A}{R_B} = \frac{(u_{\text{rms}})_A}{(u_{\text{rms}})_B} \qquad \frac{t_A}{t_B} = \sqrt{\frac{M_A}{M_B}}$$

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

$$\mathrm{pH} = -\log[\mathrm{H^+}] \qquad \mathrm{pOH} = -\log[\mathrm{OH^-}] \qquad \mathrm{pH} + \mathrm{pOH} = 14$$

$$\mathrm{pH} = \mathrm{p}K_\mathrm{a} + \log\left(\frac{[\mathrm{A^-}]}{[\mathrm{HA}]}\right) \qquad \mathrm{pOH} = \mathrm{p}K_\mathrm{b} + \log\left(\frac{[\mathrm{BH^+}]}{[\mathrm{B}]}\right)$$

$$K_\mathrm{a}K_\mathrm{b} = K_\mathrm{w} \qquad K_\mathrm{p} = K(RT)^{\Delta n_\mathrm{g}} \qquad \mathrm{p}K_\mathrm{a} + \mathrm{p}K_\mathrm{b} = 14$$

Polyprotic acid titrations

Point in the titration	Major Species	Expression
No base added	H_3A, H_2O	$K_{a_1} = \frac{[H^+][H_2A^-]}{[H_3A]}$
Base added		
Before first equivalence point	H_3A,H_2A^-, H_2O	$K_{a_1} = \frac{[H^+][H_2A^-]}{[H_3A]}$
At the first equivalence point	H_2A^-, H_2O	$\mathrm{pH} = \frac{\mathrm{p}K_{a_1} + \mathrm{p}K_{a_2}}{2}$
Between the first and second equivalence points	H_2A^-, HA^{2-}, H_2O	$K_{a_2} = \frac{[H^+][HA^{2-}]}{[H_2A^-]}$
At the second equivalence point	HA^{2-}, A^{3-}, H_2O	$\mathrm{pH} = \frac{\mathrm{p}K_{a_2} + \mathrm{p}K_{a_3}}{2}$
Between the second and third equivalence points	HA^{2-}, A^{3-}, H_2O	$K_{a_3} = \frac{[H^+][A^{3-}]}{[HA^{2-}]}$
At the third equivalence point	A^{3-}, H_2O	$K_b = \frac{K_w}{K_{a_3}} = \frac{[HA^{2-}][OH^-]}{[A^{3-}]}$
Beyond the third equivalence point	OH^-, A^{3-}, H_2O	pH determined by excess OH^-

Species	$\mathrm{p}K_\mathrm{a}$	$\mathrm{p}K_\mathrm{b}$
HCN	9.11	
$C_6H_5CO_2H$	4.202	
$HC_2H_3O_2$	4.74	
NH_3		4.74
HSO_4^-	0.921	
C_5H_5N		8.75
CH_3NH_2		3.36
HF	3.14	

$$\Delta E = q + w \qquad w = -p_{ex}\Delta V$$

$$\Delta H = q_p \qquad \Delta H = \Delta E + p\Delta V \qquad H = E + pV$$

$$(KE)_{avg} = \frac{3}{2}RT \qquad C_V = \frac{3}{2}R \qquad p\Delta V = nR\Delta T$$

$$C_p = C_V + R \qquad \Delta E = nC_V\Delta T \qquad \Delta H = nC_p\Delta T$$

$$q = nC\Delta T \qquad q = C_{cal}\Delta T \qquad \Delta E = q_V$$

$$\Delta E = 0 \qquad q = -w \qquad \text{(isothermal)}$$

$$w_{rev} = -nRT\ln\left(\frac{V_2}{V_1}\right) \qquad q_{rev} = nRT\ln\left(\frac{V_2}{V_1}\right) \qquad \Delta S = nR\ln\left(\frac{V_2}{V_1}\right)$$

$$\Delta S = \frac{q_{rev}}{T} \qquad \Delta S = nC_p\ln\left(\frac{T_2}{T_1}\right) \qquad \Delta S = nC_V\ln\left(\frac{T_2}{T_1}\right)$$

$$\Delta S_{trs} = \frac{q_{trs}}{T_{trs}} \qquad \Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr} \qquad \Delta S_{surr} = -\frac{\Delta H}{T}$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta_{rxn}H^\circ = \sum \Delta_f H^\circ(\text{products}) - \sum \Delta_f H^\circ(\text{reactants})$$

$$\Delta_{rxn}S^\circ = \sum S_f^\circ(\text{products}) - \sum S_f^\circ(\text{reactants})$$

$$\Delta_{rxn}G^\circ = \sum \Delta_f G^\circ(\text{products}) - \sum \Delta_f G^\circ(\text{reactants})$$

$$G = G^\circ + RT\ln P \qquad \Delta G = \Delta G^\circ + RT\ln Q \qquad \Delta G^\circ = -RT\ln K$$

$$\ln K = -\frac{\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R} \qquad \ln\left(\frac{K_1}{K_2}\right) = -\frac{\Delta H^\circ}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

$$w_{max}^{useful} = \Delta G \qquad q_p = T\Delta S$$

$$\gamma = C_p/C_V \qquad P_1V_1^\gamma = P_2V_2^\gamma \qquad \text{(Adiabatic)}$$

$$P_1V_1 = P_2V_2 \qquad \text{(Isothermal)}$$

$$\mathcal{F} = 96485\,\text{C/mol e}^- \qquad \Delta G^\circ = -n\mathcal{F}\mathcal{E}^\circ \qquad A \times t = \text{charge}$$

$$\mathcal{E}_{cell}^\circ = \mathcal{E}_{(cathode)}^\circ - \mathcal{E}_{(anode)}^\circ \qquad \mathcal{E}_{cell} = \mathcal{E}_{cell}^\circ - \frac{0.0591}{n}\log Q \qquad \mathcal{E}_{cell}^\circ = \frac{0.0591}{n}\ln K$$