UNIVERSITY of GUELPH

CHEM*2820 Fall 2024 Midterm Exam Equation Sheet

Professor L. D. Chen, Department of Chemistry

Constants and Conversions

$$R = 8.3145\ \mathrm{J\cdot mol^{-1}\cdot K^{-1}}, \quad T(\mathrm{K}) = \theta(^\circ\mathrm{C}) + 273.15$$

$$1\ \mathrm{m} = 10\ \mathrm{dm} = 100\ \mathrm{cm}, \quad 1\ \mathrm{atm} = 1.01325\times10^5\ \mathrm{Pa}$$

$$\Delta_\mathrm{f}H^\ominus(\mathrm{SiH_2(g)}) = 274\ \mathrm{kJ\cdot mol^{-1}}$$

$$\Delta_\mathrm{f}H^\ominus(\mathrm{SiH_4(g)}) = 34.3\ \mathrm{kJ\cdot mol^{-1}}$$

$$\Delta_\mathrm{f}H^\ominus(\mathrm{Si_2H_6(g)}) = 80.3\ \mathrm{kJ\cdot mol^{-1}}$$

$$\Delta_\mathrm{fus}H^\ominus(\mathrm{H_2O}) = 6.01\ \mathrm{kJ\cdot mol^{-1}}$$

$$C_{p,\mathrm{m}}(\mathrm{CO_2(g)}) = 37.11\ \mathrm{J\cdot K^{-1}\cdot mol^{-1}}$$

$$C_{p,\mathrm{m}}(\mathrm{H_2O(l)}) = 75.3\ \mathrm{J\cdot K^{-1}\cdot mol^{-1}}$$

$$C_{p,\mathrm{m}}(\mathrm{H_2O(s)}) = 37.6\ \mathrm{J\cdot K^{-1}\cdot mol^{-1}}$$

$$M_\mathrm{H} = 1.008\ \mathrm{g\cdot mol^{-1}}, \quad M_\mathrm{He} = 4.003\ \mathrm{g\cdot mol^{-1}}$$

$$M_\mathrm{C} = 12.011\ \mathrm{g\cdot mol^{-1}}, \quad M_\mathrm{O} = 15.999\ \mathrm{g\cdot mol^{-1}}$$

Mathematical Relations

$$e^x e^y e^z \cdots = e^{x+y+z+\cdots}$$

$$\ln x + \ln y + \cdots = \ln xy\cdots, \quad \ln x - \ln y = \ln\frac{x}{y}$$

$$\mathrm{d}(fg) = f\mathrm{d}g + g\mathrm{d}f, \quad \mathrm{d}\left(\frac{f}{g}\right) = \frac{1}{g}\mathrm{d}f - \frac{f}{g^2}\mathrm{d}g$$

$$\int \frac{1}{x}\mathrm{d}x = \ln x + C$$

$$\int \frac{1}{ax+b}\mathrm{d}x = \frac{1}{a}\ln(ax+b) + C$$

The Properties of Gases

The Perfect Gas

$$pV = nRT \quad \text{or} \quad pV_\mathrm{m} = RT$$

$$p_\mathrm{J} = x_\mathrm{J}p, \quad x_\mathrm{J} = \frac{n_\mathrm{J}}{n}, \quad n = \sum_\mathrm{J} n_\mathrm{J}$$

The Kinetic Model

$$f(v) = 4\pi\left(\frac{M}{2\pi RT}\right)^{3/2} v^2 e^{-Mv^2/2RT}, \quad v_\mathrm{rms} = \left(\frac{3RT}{M}\right)^{1/2}$$

$$v_\mathrm{mean} = \left(\frac{8RT}{\pi M}\right)^{1/2}, \quad v_\mathrm{mp} = \left(\frac{2RT}{M}\right)^{1/2}$$

Real Gases

$$Z = \frac{V_\mathrm{m}}{V_\mathrm{m}^\ominus}, \quad pV_\mathrm{m} = RTZ$$

$$p = \frac{nRT}{V-nb} - a\frac{n^2}{V^2} \quad \text{or} \quad p = \frac{RT}{V_\mathrm{m}-b} - \frac{a}{V_\mathrm{m}^2}$$

The First Law

Internal Energy

$$\mathrm{d}U = \mathrm{d}q + \mathrm{d}w \quad \text{or} \quad \Delta U = q + w$$

$$\mathrm{d}w = -|\mathbf{F}|\mathrm{d}z, \quad w_\mathrm{rev} = -nRT\ln\frac{V_\mathrm{f}}{V_\mathrm{i}}$$

$$\mathrm{d}w = -p_\mathrm{ex}\mathrm{d}V \quad \text{or} \quad w = -p_\mathrm{ex}\Delta V$$

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V, \quad \Delta U = C_V\Delta T, \quad \Delta U = q_V$$

Enthalpy

$$H = U + pV$$

$$C_p = \left(\frac{\partial H}{\partial T}\right)_p, \quad \Delta H = C_p\Delta T, \quad \Delta H = q_p$$

$$C_p - C_V = nR \quad \text{or} \quad C_{p,\mathrm{m}} - C_{V,\mathrm{m}} = R$$

Thermochemistry

$$\Delta_\mathrm{r}H^\ominus = \sum_\text{products}\nu\Delta_\mathrm{f}H^\ominus - \sum_\text{reactants}\nu\Delta_\mathrm{f}H^\ominus$$

$$\Delta_\mathrm{r}C_p^\ominus = \sum_\text{products}\nu C_{p,\mathrm{m}}^\ominus - \sum_\text{reactants}\nu C_{p,\mathrm{m}}^\ominus$$

$$\Delta_\mathrm{r}H^\ominus(T_2) = \Delta_\mathrm{r}H^\ominus(T_1) + \int_{T_1}^{T_2}\Delta_\mathrm{r}C_p^\ominus\,\mathrm{d}T$$

State Functions and Exact Differentials

$$\mathrm{d}U = \left(\frac{\partial U}{\partial V}\right)_T\mathrm{d}V + \left(\frac{\partial U}{\partial T}\right)_V\mathrm{d}T$$

$$\pi_T = \left(\frac{\partial U}{\partial V}\right)_T, \quad \alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$$

$$\left(\frac{\partial U}{\partial T}\right)_p = \alpha\pi_T V + C_V$$

$$\kappa_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T, \quad C_p - C_V = \frac{\alpha^2 TV}{\kappa_T}$$

Adiabatic Changes

$$V_\mathrm{i}T_\mathrm{i}^c = V_\mathrm{f}T_\mathrm{f}^c, \quad c = \frac{C_{V,\mathrm{m}}}{R}$$

$$p_\mathrm{i}V_\mathrm{i}^\gamma = p_\mathrm{f}V_\mathrm{f}^\gamma, \quad \gamma = \frac{C_{p,\mathrm{m}}}{C_{V,\mathrm{m}}}$$

The Second and Third Laws

Entropy

$$\mathrm{d}S = \frac{\mathrm{d}q_\mathrm{rev}}{T}, \quad S = k_\mathrm{B}\ln\Omega$$

$$\Delta S_\mathrm{sur} = \frac{q_\mathrm{sur}}{T_\mathrm{sur}}$$

$$\eta = 1 - \frac{|q_\mathrm{c}|}{|q_\mathrm{h}|}, \quad \eta = 1 - \frac{T_\mathrm{c}}{T_\mathrm{h}}$$

Entropy Changes for Specific Processes

$$\Delta S = nR\ln\frac{V_\mathrm{f}}{V_\mathrm{i}}$$

$$\Delta_\mathrm{trs}S = \frac{\Delta_\mathrm{trs}H}{T_\mathrm{trs}}$$

Measurement of Entropy

$$\Delta_\mathrm{r}S^\ominus = \sum_\text{products}\nu S_\mathrm{m}^\ominus - \sum_\text{reactants}\nu S_\mathrm{m}^\ominus$$

$$\Delta_\mathrm{r}S^\ominus(T_2) = \Delta_\mathrm{r}S^\ominus(T_1) + \int_{T_1}^{T_2}\frac{\Delta_\mathrm{r}C_p^\ominus}{T}\mathrm{d}T$$

Concentrating on the System

$$A = U - TS, \quad G = H - TS$$

$$\Delta_\mathrm{r}G^\ominus = \Delta_\mathrm{r}H^\ominus - T\Delta_\mathrm{r}S^\ominus$$

$$\Delta_\mathrm{r}G^\ominus = \sum_\text{products}\nu\Delta_\mathrm{f}G^\ominus - \sum_\text{reactants}\nu\Delta_\mathrm{f}G^\ominus$$

Combining the First and Second Laws

$$\mathrm{d}U = T\mathrm{d}S - p\mathrm{d}V, \quad \left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial p}{\partial S}\right)_V$$

$$\mathrm{d}H = T\mathrm{d}S + V\mathrm{d}p, \quad \left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p$$

$$\mathrm{d}A = -p\mathrm{d}V - S\mathrm{d}T, \quad \left(\frac{\partial p}{\partial T}\right)_V = \left(\frac{\partial S}{\partial V}\right)_T$$

$$\mathrm{d}G = V\mathrm{d}p - S\mathrm{d}T, \quad \left(\frac{\partial V}{\partial T}\right)_p = -\left(\frac{\partial S}{\partial p}\right)_T$$

$$\left(\frac{\partial G}{\partial p}\right)_T = V, \quad \left(\frac{\partial G}{\partial T}\right)_p = -S$$

$$\left(\frac{\partial(G/T)}{\partial T}\right)_p = -\frac{H}{T^2}$$