UNIVERSITY OF MANITOBA
DEPARTMENT OF CHEMISTRY
Chemistry 2290, Winter 2012, G. Schreckenbach

Formula Sheet *(Midterm1)*

> *This formula sheey can be taken
> home after the exam*

Gas Laws (Ideal and Real Gases)

Ideal gas law:

$$PV = nRT$$

Compression factor:

$$Z = \frac{PV_m}{RT}$$

van der Waals equation:

$$\left(P + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

Virial equation of state:

$$Z = \frac{PV_m}{RT} = 1 + \frac{B(T)}{V_m} + \frac{C(T)}{V_m^2} + ...$$

Law of corresponding states

$$\left(P_R + \frac{3}{V_{R,m}^2}\right)\left(V_{R,m} - \frac{1}{3}\right) = \frac{8}{3}RT_R$$

where

$$P_R = \frac{P}{P_C} \; ; \quad V_R = \frac{V}{V_C} \; ; \; T_R = \frac{T}{T_C}$$

First Law of Thermodynamics

First law: $\quad \Delta U = q + w \quad$ *(where q and w are the heat transferred **to** the system and the work done **on** the system, respectively)*

Reversible pV work:

$$w_{rev} = -\int_{V_1}^{V_2} PdV \; ; \qquad \delta w_{rev} = -PdV$$

Enthalpy (definition):

$$H = U + PV$$

Heat capacity at constant volume:

$$C_V = \frac{\delta q_V}{dT} = \left(\frac{\partial U}{\partial T}\right)_V$$

Heat capacity at constant pressure:

$$C_P = \frac{\delta q_P}{dT} = \left(\frac{\partial H}{\partial T}\right)_P$$

For an ideal gas:

$$C_{P,m} = C_{V,m} + R$$

Ideal gas, reversible isothermal process: $\quad \left(\frac{\partial U}{\partial V}\right)_T = 0$, and $w_{rev} = -q_{rev} = nRT \ln\frac{V_1}{V_2}$

Ideal gas, reversible adiabatic process: $\quad P_i V_i^\gamma = P_f V_f^\gamma \quad$ where $\gamma = \frac{C_p}{C_V}$

Second Law of Thermodynamics

Carnot cycle, work and heat: $\quad q_{cycle} = R(T_{hot} - T_{cold})\ln\frac{V_b}{V_a} = -w_{cycle} \quad$ *(per mole of ideal gas)*

Carnot cycle, thermodynamic efficiency: $\varepsilon \equiv \dfrac{-w_{cycle}}{q_{hot}} = 1 - \dfrac{T_{cold}}{T_{hot}}$

Entropy (definition) $\Delta S_{A \to B} = S_B - S_A \equiv \displaystyle\int_A^B \dfrac{\delta q_{rev}}{T}$ or $dS \equiv \dfrac{\delta q_{rev}}{T}$

Second Law of Thermodynamics: $\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings} \geq 0$;

Clausius inequality $dS \geq \dfrac{\delta q}{T}$

Ideal gas, entropy change: $\Delta S = n \displaystyle\int_{T_1}^{T_2} C_{V,m} \dfrac{dT}{T} + nR \ln \dfrac{V_2}{V_1}$

Ideal gas, molar entropy of mixing: $\Delta S_m = -R\left(x_1 \ln x_1 + x_2 \ln x_2\right)$

Entropy of fusion (melting): $\Delta S = \dfrac{q_{fus}}{T_{fus}} = \dfrac{\Delta H_{fus}}{T_{fus}}$ *(similar for other phase transitions)*

Units, Constants

Pressure: $\qquad$ $Pa = kg\ m^{-1}\ s^{-2}$

$\qquad\qquad$ 1 atm = 1.01325 x 10^5 Pa; 1 Torr = 133.322 Pa; 1 bar = 10^5 Pa

Energy: $\qquad$ $J = kg\ m^2\ s^{-2}$;   1 cal = 4.184 J

Temperature: $\qquad$ $T/K = \theta/\,^{o}C + 273.15$

Avogadro's number: $\qquad$ $N_0 = 6.02214 \times 10^{23}\ mol^{-1}$

Ideal gas constant: $\qquad$ $R = 8.3145101\ J\ mol^{-1}\ K^{-1} = 0.0820578\ atm\ L\ K^{-1}\ mol^{-1}$