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CHEM 3410: Physical Chemistry I — Fall 2009

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Lecture 15: Chemical potential of an ideal gas

References

1. Levine, *Physical Chemistry*, Sections 4.6–4.8, 6.1–6.2

Key Concepts

- For a single component system consisting of an ideal gas, we were able to arrive at an expression for the chemical potential by integrating our expression for dG for a single component system at constant temperature ($d\overline{G} = \overline{V}dP$) between some reference pressure P° and the pressure of interest P:

$$\mu(T,P) = \mu^\circ(T) + RT\ln\frac{P}{P^\circ}$$

  where $\mu^\circ(T)$ is the chemical potential of the pure gas in the reference state (usually $P = 1$ bar)

- We can now arrive at expressions for related quantities such as S, since we know that $-\overline{S} = \left(\frac{\partial \overline{G}}{\partial T}\right)_{P,n} = \left(\frac{\partial \mu}{\partial T}\right)_{P,n}$ (where the bar above the quantity means per mole, or the molar entropy).

- For an ideal gas in a mixture, we have to account for the actual amount of each gas in the system using the mole fraction and/or partial pressure. These two quantities are related. For component A, if we denote the partial pressures as P_A and the mole fraction as X_A, then we can write the following:

$$P_A = X_A P_{TOTAL}$$

- By doing some more integrating from a starting state of the pure gas at the reference pressure, to the partial pressure of the gas in the mixture, we arrived at the following expression for the chemical potential of a gas (i) in a mixture of gases:

$$\mu_i^{mixture}(T,P) = \mu_i^{pure}(T,P) + RT\ln X_A$$

  item The mixing of ideal gases is completely driven by entropy. There is no interaction between gas atoms/molecules in an ideal gas, therefore $\Delta H_{mix} = 0$. Going from the unmixed to mixed state results in an increase in entropy ($\Delta S_{mix} > 0$) meaning that $\Delta G_{mix} < 0$ ($\Delta G = \Delta H - T\Delta S$).

- Based on our expression for the chemical potential of an ideal gas in a mixture, we were able to arrive at an expression for the free energy of mixing of ideal gases. In general for a system of i gases and then for a two-compoennt system (A & B) we wrote:

$$\Delta\overline{G}_{mix} = RT\sum X_i \ln X_i$$

$$\Delta\overline{G}_{mix} = RT(X_A\ln X_A + X_B\ln X_B)$$

Related Exercises in Levine

Exercises: 4.40, 6.1