Q6.1

Using Table T1, calculate the standard reaction Gibbs functions ($\Delta G^o$) for the following reactions at 298 K.

a. $\text{CH}_3\text{CH}_2\text{OH}(l) + 3 \text{ O}_2(g) \rightarrow 2 \text{ CO}_2(g) + 3 \text{ H}_2\text{O}(l)$

b. $\text{C}_6\text{H}_{12}\text{O}_6(s) + 6 \text{ O}_2 \rightarrow 6 \text{ CO}_2(g) + 6 \text{ H}_2\text{O}(l)$

c. $2 \text{ POCl}_3(l) \rightarrow 2 \text{ PCl}_3(l) + \text{ O}_2(g)$

d. $2 \text{ KBr(s)} + \text{ Cl}_2(g) \rightarrow 2 \text{ KCl(s)} + \text{ Br}_2(l)$

e. $\text{SiH}_4(g) + 2 \text{ Cl}(g) \rightarrow \text{SiCl}_4(l) + 2 \text{ H}_2(g)$

Q6.2

Estimate $\Delta G$ at 1000 K from its value at 298 K for the reaction

\[\text{C(s)} + 2 \text{ H}_2(g) \rightarrow \text{CH}_4(g)\]

with $\Delta G = -50.75\,\text{kJ/mol}$ at 298 K.

Q6.3

The standard Gibbs function for formation ($\Delta G^o_f$) of $\text{PbO}_2(s)$ is -217.4 kJ/mol at 298 K. Assuming $\text{O}_2$ is an ideal gas, find the standard Helmholtz function for formation ($\Delta A^o_f$) for $\text{PbO}_2$ at 298K.

Q6.4

Calculate the entropy change for 1.00 mol of an ideal monatomic gas ($C_V = 3/2\,R$) undergoing an expansion and simultaneous temperature increase from 10.0 L at 298 K to 205.0 L at 455 K.

Q6.5

Consider a gas that obeys the equation of state

\[p = \frac{nRT}{V-nb}\]

a. Find expressions for $\alpha$ and $\kappa_T$ for this gas.

b. Evaluate the difference between $C_p$ and $C_V$ for the gas.
Q6.6
Show that
\[
\left( \frac{\partial C_p}{\partial p} \right)_T = 0
\]
for an ideal gas.

Q6.7
Derive the thermodynamic equation of state
\[
\left( \frac{\partial H}{\partial p} \right)_T = V(1 - T \alpha)
\]

Q6.8
Derive the thermodynamic equation of state
\[
\left( \frac{\partial U}{\partial V} \right)_T = T \frac{\alpha}{\kappa_T} - p
\]

Q6.9
The “Joule Coefficient” is defined by
\[
\mu_J = \left( \frac{\partial T}{\partial V} \right)_U
\]
Show that
\[
\mu_J = \frac{1}{C_V} \left( p - T \alpha \right) \frac{1}{\kappa_T}
\]
and evaluate the expression for an ideal gas.

Q6.10
Derive expressions for the pressure derivatives
\[
\left( \frac{\partial X}{\partial p} \right)_T
\]
where \(X\) is \(U\), \(H\), \(A\), \(G\), and \(S\) at constant temperature in terms of measurable properties. (The derivation of \( \left( \frac{\partial H}{\partial p} \right)_T \) was done in problem Q6.7).
Evaluate the expressions for
• \( \left( \frac{\partial S}{\partial p} \right)_T \)
Q6.11

Derive expressions for the volume derivatives
\[
\left( \frac{\partial X}{\partial V} \right)_T
\]
where \(X\) is \(U\), \(H\), \(A\), \(G\), and \(S\) at constant temperature in terms of measurable properties. (The derivation of \(\left( \frac{\partial U}{\partial V} \right)_T\) was done in problem Q8.8.)

Evaluate the expressions for
\[
\left( \frac{\partial X}{\partial V} \right)_T
\]
for a van der Waals gas.

Q6.12

Evaluate the difference between \(C_p\) and \(C_V\) for a gas that obeys the equation of state
\[
p = \frac{nRT}{V-nb}
\]

Q6.13

The adiabatic compressibility (\(k_S\)) is defined by
\[
k_S = \frac{1}{V} \left( \frac{\partial V}{\partial p} \right)_S
\]
Show that for an ideal gas,
\[
k_S = \frac{1}{p \gamma}
\]