

## 6.E: Putting the Second Law to Work (Exercises)

### Q6.1

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

- $\text{CH}_3\text{CH}_2\text{OH}(l) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$
- $\text{C}_6\text{H}_{12}\text{O}_6(s) + 6\text{O}_2 \rightarrow 6\text{CO}_2(g) + 6\text{H}_2\text{O}(l)$
- $2\text{POCl}_3(l) \rightarrow 2\text{PCl}_3(l) + \text{O}_2(g)$
- $2\text{KBr}(s) + \text{Cl}_2(g) \rightarrow 2\text{KCl}(s) + \text{Br}_2(l)$
- $\text{SiH}_4(g) + 2\text{Cl}(g) \rightarrow \text{SiCl}_4(l) + 2\text{H}_2(g)$

### Q6.2

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



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

### Q6.3

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

$$p = \frac{nRT}{V - nb} \quad (6.E.2)$$

- Find expressions for  $\alpha$  and  $\kappa_T$  for this gas.
- Evaluate the difference between  $C_p$  and  $C_V$  for the gas.

### Q6.6

Show that

$$\left( \frac{\partial C_p}{\partial p} \right)_T = 0 \quad (6.E.3)$$

for an ideal gas.

### Q6.7

Derive the thermodynamic equation of state

$$\left( \frac{\partial H}{\partial p} \right)_T = V(1 - T\alpha) \quad (6.E.4)$$

### Q6.8

Derive the thermodynamic equation of state

$$\left( \frac{\partial U}{\partial V} \right)_T = T \frac{\alpha}{\kappa_T} - p \quad (6.E.5)$$

### Q6.9

The “Joule Coefficient” is defined by

$$\mu_J = \left( \frac{\partial T}{\partial V} \right)_U \quad (6.E.6)$$

Show that

$$\mu_J = \frac{1}{C_V} \left( p - \frac{T\alpha}{\kappa_T} \right) \quad (6.E.7)$$

and evaluate the expression for an ideal gas.

### Q6.10

Derive expressions for the pressure derivatives

$$\left( \frac{\partial X}{\partial p} \right)_T \quad (6.E.8)$$

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

- $\left( \frac{\partial S}{\partial p} \right)_T$
- $\left( \frac{\partial H}{\partial p} \right)_T$
- $\left( \frac{\partial U}{\partial p} \right)_T$

for a van der Waals gas.

### Q6.11

Derive expressions for the volume derivatives

$$\left( \frac{\partial X}{\partial V} \right)_T \quad (6.E.9)$$

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

- $\left( \frac{\partial X}{\partial V} \right)_T$
- $\left( \frac{\partial X}{\partial V} \right)_T$

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

$$p = \frac{nRT}{V - nb} \quad (6.E.10)$$

## Q6.13

The adiabatic compressibility ( $\kappa_S$ ) is defined by

$$\kappa_S = \frac{1}{V} \left( \frac{\partial V}{\partial p} \right)_S \quad (6.E.11)$$

Show that for an ideal gas,

$$\kappa_S = \frac{1}{p\gamma} \quad (6.E.12)$$

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