

Chapter 3 Homework Questions

- 3.1** Calculate ΔS (for the system) when the state of 3. moles of a perfect gas at 25 °C and 1. atm is changed to 125 °C and 5. atm.
Note: The constant pressure molar heat capacity of this gas is $C_{p,m} = (5/2)R$,
- 3.2** A sample consisting of 3. moles of a diatomic perfect gas at -73 °C is compressed reversibly and adiabatically until the temperature reaches -23. °C. For this gas, $C_{V,m} = 27.5 \text{ J/mol}\cdot\text{K}$. Calculate q , w , ΔU , ΔH and ΔS for this process.
- 3.3** Calculate the changes in entropy of the system and the surroundings when a 14. g sample of $\text{N}_2(\text{g})$ [$M=28$] at 1. bar and 25 °C doubles its volume in
(a) a reversible isothermal expansion
(b) an irreversible isothermal expansion against $p_{\text{ex}} = 0$.
(c) a reversible adiabatic expansion
- 3.4** The enthalpy of vaporization of chloroform (CHCl_3 , $M=119.4$) is 29.4 kJ/mol at its normal boiling point of 62 °C. For the vaporization of 240. grams of CHCl_3 at its normal boiling point, calculate (a) ΔS of the system and (b) ΔS of the surroundings.
- 3.5** The normal boiling point of ethanol, $\text{C}_2\text{H}_5\text{OH}$ [$M=46$], is 78 °C. The Enthalpy of Vaporization of ethanol is 38.6 kJ/mol.

Calculate q , w , ΔU , ΔH and ΔS when 150 grams of ethanol vapor is condensed to the liquid at 78 °C and 1 bar pressure.
- 3.6** The normal melting point of ethanol, $\text{C}_2\text{H}_5\text{OH}$ [$M=46$], is -114 °C. The Enthalpy of Fusion of ethanol is 9.45 kJ/mol.

Calculate q , w , ΔU , ΔH and ΔS when 150 grams of ethanol liquid crystallizes to the solid at -114 °C and 1 bar pressure.
- 3.7** The normal boiling point of benzene is 80 °C = 353 K. The enthalpy of vaporization of benzene at its normal boiling point is $\Delta_{\text{vap}}H = 35.7 \text{ kJ/mol}$. The constant pressure molar heat capacities of the liquid and vapor are: $C_{p,m}(\text{l}) = 138.7 \text{ J/mol}\cdot\text{K}$ and $C_{p,m}(\text{g}) = 35.1 \text{ J/mol}\cdot\text{K}$

Consider the vaporization of one mole of superheated benzene at 100 oC. Calculate ΔS_{sys} , ΔS_{surr} , and ΔS_{univ} for this process.

- 3.8** The standard molar entropy of $\text{NH}_3(\text{g})$ is $192.45 \text{ J/mol}\cdot\text{K}$ at 25°C . The constant pressure heat capacity is temperature dependent and is given by:

$$C_{p,m} = a + bT + \frac{c}{T^2} \quad a = 29.8 \quad , \quad b = 2.5 \times 10^{-2} \quad , \quad c = -1.6 \times 10^5$$

Calculate the entropy of 3. moles of $\text{NH}_3(\text{g})$ at:

- (a) 100°C
 (b) 500°C
- 3.9** The constant pressure heat capacity of $\text{F}_2(\text{g})$ is temperature dependent and given by:

$$C_{p,m} = a - \frac{b}{T} \quad a = 39.6 \text{ J/mol}\cdot\text{K} \quad \text{and} \quad b = 2.5 \times 10^3 \text{ J/mol}$$

Consider 100 grams of $\text{F}_2(\text{g})$ [$M = 38.$] initially at a pressure of 2. bar and temperature of 600°C . Calculate q , w , ΔU , ΔH , ΔS for each of the following processes.

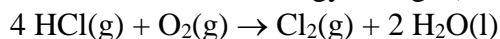
- (a) The gas is cooled to 300°C at constant pressure.
 (b) The gas is cooled to 300°C at constant volume
- 3.10** Use the standard molar entropies (at 298 K) in the table below to calculate the reaction entropies, $\Delta_r S^\circ$, for the following reactions.
- (a) $2 \text{CH}_3\text{CHO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CH}_3\text{COOH}(\text{l})$
 (b) $\text{Hg}(\text{l}) + \text{Cl}_2(\text{g}) \rightarrow \text{HgCl}_2(\text{s})$.

| Compound | S_m° |
|------------------------------------|------------------------------------|
| $\text{CH}_3\text{CHO}(\text{g})$ | $250.3 \text{ J/mol}\cdot\text{K}$ |
| $\text{O}_2(\text{g})$ | 205.1 |
| $\text{CH}_3\text{COOH}(\text{l})$ | 159.8 |
| $\text{Hg}(\text{l})$ | 76.0 |
| $\text{Cl}_2(\text{g})$ | 223.1 |
| $\text{HgCl}_2(\text{s})$ | 146.0 |

- 3.11** Use the standard Gibbs Energies of Formation (at 298 K) in the table below to calculate the reaction entropies, $\Delta_r S^\circ$, for the following reactions.
- (a) $2 \text{CH}_3\text{CHO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CH}_3\text{COOH}(\text{l})$
 (b) $\text{Hg}(\text{l}) + \text{Cl}_2(\text{g}) \rightarrow \text{HgCl}_2(\text{s})$.

| Compound | $\Delta_f G_m^\circ$ |
|------------------------------------|--|
| $\text{CH}_3\text{CHO}(\text{g})$ | -128.9 kJ/mol |
| $\text{CH}_3\text{COOH}(\text{l})$ | -389.9 |
| $\text{HgCl}_2(\text{s})$ | -178.6 |

- 3.12** Use the standard molar entropies and the enthalpies of formation in the table below to calculate the standard Gibbs energy change (at 298 K) for the reaction:



| Compound | S_m° | $\Delta_f H_m^\circ$ |
|---------------------|-------------------------------|--|
| HCl(g) | 186.9 J/mol•K | -92.3 kJ/mol |
| O ₂ (g) | 205.1 | |
| Cl ₂ (g) | 69.9 | |
| H ₂ O(l) | 223.1 | -285.8 |

- 3.13** Consider 70. grams of N₂(g) [M=28] initially at 40 °C and 25 L. The gas is compressed isothermally to a final volume of 500 mL. Calculate ΔG for this process.
- 3.14** The change in the Gibbs Energy for a certain constant pressure process is given by:
 $\Delta G = a + bT^2$, $a = +5620 \text{ J}$, $b = 8.0 \times 10^{-2} \text{ J/K}^2$.
Calculate ΔS for this process at 30 °C (in J/K)
- 3.15** Calculate the change in Gibbs Energy (in J) of 20. moles of liquid benzene (C₆H₆, M = 78 g/mol, d = 0.88 g/mL) when the pressure on the sample is increased from 1.0 atm to 100 atm.
- 3.16** Calculate the change in Gibbs Energy (in J) of 20. moles of H₂(g) when the pressure on the sample is increased from 1.0 atm to 100 atm at 25 °C.
- 3.17** A solid has two crystalline forms, A(s) and B(s). For the transition $A(s) \rightarrow B(s)$, $\Delta G^\circ = +6.0 \text{ kJ/mol}$ (i.e. at 1 bar pressure). The difference in molar volumes of the two forms is
 $V_m(B) - V_m(A) = \Delta V_m = -15 \text{ mL/mol}$.
Calculate the pressure, in bar, at which the two forms will be in equilibrium.