

Chemistry 116 - General Chemistry Thermodynamics Practice Problems

Murphy's Law of Thermodynamics: Things get worse under pressure.

- 1) Using the First Law of Thermodynamics, calculate the quantity listed, in joules, for the system of one mole of a gas in a cylinder with movable piston.
The gas heat capacities are: $12.5 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ at constant V and $20.8 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ at constant P.
- The gas absorbs 234 J of heat and is compressed by 534 J of work. $\Delta E = ?$
 - The gas is cooled by removing 106 J of heat and expands doing 242 J of work. $\Delta E = ?$
 - The gas is heated at constant volume from 298 K to 398 K. $\Delta E = ?$
 - The gas is heated at constant pressure from 298 K to 398 K. $q = ?$
 - The gas expands from 0.250 L to 1.00 L against an external pressure of 2.50 atm. $w = ?$
 - The change in internal energy for a constant pressure process was -407 J and the change in enthalpy was -678 J. $w = ?$
- 2) Calculate ΔE , q and w for the following processes of an ideal gas going from State 1 to State 2.

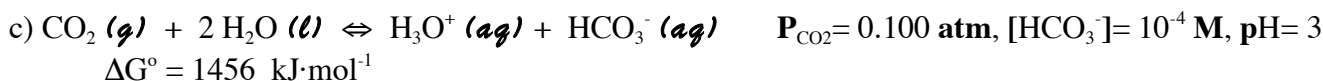
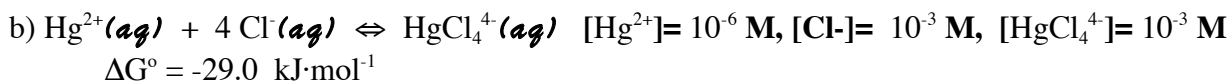
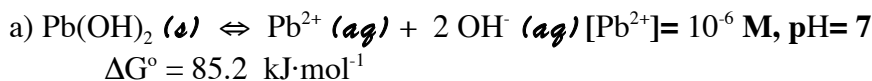
	State 1	State 2
a)	P= 2.50 atm V=8.97 L T= 273.15 K	P= 2.50 atm V=15.5 L T= 473.15 K
b)	P= 2.50 atm V=15.5 L T= 473.15 K	P= 1.45 atm V=15.5 L T= 273.15 K
c)	P= 1.45 atm V=15.5 L T= 273.15 K	P= 2.50 atm V=8.97 L T= 273.15 K

- 3) Calculate the difference in energy between ΔE and ΔH for the following reactions at constant pressure and 25.00 °C.
- $\text{CH}_3\text{CH}_2\text{CH}_3 (g) + 5 \text{O}_2 (g) \rightleftharpoons 3 \text{CO}_2 (g) + 4 \text{H}_2\text{O} (l)$
 - $\text{C}_6\text{H}_{12}\text{O}_6 (s) + 6 \text{O}_2 (g) \rightleftharpoons 6 \text{CO}_2 (g) + 6 \text{H}_2\text{O} (l)$
 - $\text{Mg} (s) + 2 \text{H}^+(aq) \rightleftharpoons \text{Mg}^{2+}(aq) + \text{H}_2 (g)$
- 4) Predict the sign of ΔS for the following processes:
- Dissolving a solute in a solvent to produce a solution.
 - Freezing a liquid.
 - Evaporating a liquid.
 - Condensing vapor.
 - Each of the three reactions in Problem 3.
- 5) Given ΔH° and ΔS° for phase changes below, estimate the melting point or boiling point.
- $\Delta H^\circ_{\text{fusion}} = 13.1 \text{ kJ}\cdot\text{mol}^{-1}$ $\Delta S^\circ_{\text{fusion}} = 7.03 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ (Fe)
 - $\Delta H^\circ_{\text{vap}} = 31.0 \text{ kJ}\cdot\text{mol}^{-1}$ $\Delta S^\circ_{\text{vap}} = 94.6 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ (acetone)

6) For each of the three reactions in Problem 3, calculate ΔG° from ΔH° and ΔS° . Use Table of thermodynamic data listed below. Calculate ΔG° at 0.00 °C, 100.00 °C, and 200.00 °C.

Standard Thermodynamic Data		
substance	ΔH°_f (kJ·mol ⁻¹)	S° (J·mol ⁻¹ ·K ⁻¹)
CH₃CH₂CH₃ (g)	-104	270
C₆H₁₂O₆ (s)	-1268	212
CO₂ (g)	-394	214
O₂ (g)	0	205
H₂ (g)	0	131
H₂O (l)	-286	69.9
Mg (s)	0	32.7
Mg²⁺ (aq)	-467	-138
H⁺ (aq)	0	0

7) Calculate the value of Q and ΔG for the following reactions, given initial concentrations and ΔG° at 298.15 K.



8) Given the following values of ΔG° for reactions, calculate the values of the equilibrium constants for the reactions at 25.00 °C.

- a) $-30.0 \text{ kJ}\cdot\text{mol}^{-1}$
 b) $4.0 \text{ kJ}\cdot\text{mol}^{-1}$
 c) $-13.0 \text{ kJ}\cdot\text{mol}^{-1}$

Answers

1. a) 768 J b) -348 J c) 1250 J d) 2080 J e) -190 J f) 271 J
 2. a) $\Delta E = 2500 \text{ J}$ $q = 4160 \text{ J}$ $w = -1660 \text{ J}$
 b) $\Delta E = -2500 \text{ J}$ $q = -2500 \text{ J}$ $w = 0 \text{ J}$
 c) $\Delta E = 0 \text{ J}$ $q = -1654 \text{ J}$ $w = 1654 \text{ J}$
 3. a) $\Delta E - \Delta H = 7436 \text{ J}$
 b) $\Delta E - \Delta H = 0$
 c) $\Delta E - \Delta H = -2479 \text{ J}$
 4. a) + b) - c) + d) - e) a -, b +, c +
 5. a) 1860 K b) 328 K
 6. a) $\Delta H^\circ = -2222 \text{ kJ}\cdot\text{mol}^{-1}$ $\Delta S^\circ = -373 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ $\Delta G^\circ = -2120, -2083, -2046 \text{ kJ}\cdot\text{mol}^{-1}$
 b) $\Delta H^\circ = -2812 \text{ kJ}\cdot\text{mol}^{-1}$ $\Delta S^\circ = 261 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ $\Delta G^\circ = -2883, -2909, -2935 \text{ kJ}\cdot\text{mol}^{-1}$
 c) $\Delta H^\circ = -467 \text{ kJ}\cdot\text{mol}^{-1}$ $\Delta S^\circ = -39.7 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ $\Delta G^\circ = -456, -452, -448 \text{ kJ}\cdot\text{mol}^{-1}$
 7. a) $-29.0 \text{ kJ}\cdot\text{mol}^{-1}$ b) $56.6 \text{ kJ}\cdot\text{mol}^{-1}$ c) $1422 \text{ kJ}\cdot\text{mol}^{-1}$
 8. a) 1.80×10^5 b) 0.199 c) 190