Chemistry 106 - Fundamental 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 $J \cdot mol^{-1} \cdot K^{-1}$ at constant V and 20.8 $J \cdot mol^{-1} \cdot K^{-1}$ at constant P.

a) The gas absorbs 234 J of heat and is compressed by 534 J of work. ΔE = ?
b) The gas is cooled by removing 106 J of heat and expands doing 242 J of work. ΔE = ?
c) The gas is heated at constant volume from 298 K to 398 K. ΔE = ?
d) The gas is heated at constant pressure from 298 K to 398 K. q = ?
e) The gas expands from 0.250 L to 1.00 L against an external pressure of 2.50 atm. w = ?
f) 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) Predict the sign of ΔS for the following processes:

a) Dissolving a solute in a solvent to produce a solution.
b) Freezing a liquid.
c) Evaporating a liquid.
d) Condensing vapor.
e) $C_6H_{12}O_6\,(s) + 6\,O_2\,(g) \Leftrightarrow 6\,CO_2\,(g) + 6\,H_2O\,(l)$
f) $Pb(OH)_2\,(s) \Leftrightarrow Pb^{2+}\,(aq) + 2\,OH^-\,(aq)$

4) Given ΔH° and ΔS° for phase changes below, estimate the melting point or boiling point.

a) ΔH°_{fusion} = 13.1 $kJ \cdot mol^{-1}$ ΔS°_{fusion} = 7.03 $J \cdot mol^{-1} \cdot K^{-1}$ (Fe)
b) ΔH°_{vap} = 31.0 $kJ \cdot mol^{-1}$ ΔS°_{vap} = 94.6 $J \cdot mol^{-1} \cdot K^{-1}$ (acetone)

5) For this reaction: $CH_3CH_2CH_3\,(g) + 5\,O_2\,(g) \Leftrightarrow 3\,CO_2\,(g) + 4\,H_2O\,(l)$

Calculate ΔH° and ΔS°. Use Table of thermodynamic data listed below. Next, calculate ΔG° at 0.00 °C, 100.00 °C, and 200.00 °C.

Standard Thermodynamic Data

substance	$\Delta H°_f$ (kJ·mol^{-1})	S° (J·mol^{-1}·K^{-1})
$CH_3CH_2CH_3\,(g)$	-104	270
$C_6H_{12}O_6\,(s)$	-1268	212
$CO_2\,(g)$	-394	214
$O_2\,(g)$	0	205
$H_2\,(g)$	0	131
$H_2O\,(l)$	-286	69.9
$Mg\,(s)$	0	32.7
$Mg^{2+}(aq)$	-467	-138
$H^+(aq)$	0	0

6) Calculate the value ΔG for the following reactions, given Q and ΔG° at 298.15 K.

a) $Pb(OH)_2\,(s) \Leftrightarrow Pb^{2+}\,(aq) + 2\,OH^-\,(aq)$ $Q = 1.00 \times 10^{-20}$ $\Delta G° = 85.2$ kJ·mol^{-1}

b) $Hg^{2+}(aq) + 4\,Cl^-(aq) \Leftrightarrow HgCl_4^{4-}(aq)$ $Q = 1.00 \times 10^{15}$ $\Delta G° = -29.0$ kJ·mol^{-1}

c) $CO_2\,(g) + 2\,H_2O\,(l) \Leftrightarrow H_3O^+\,(aq) + HCO_3^-\,(aq)$ $Q = 1.00 \times 10^{-6}$ $\Delta G° = 1456$ kJ·mol^{-1}

7) 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 kJ·mol^{-1}

b) 4.0 kJ·mol^{-1}

c) -13.0 kJ·mol^{-1}

Answers

1. a) 768 J b) -348 J c) 1250 J d) 2080 J e) -190 J f) 271 J

2. a) ΔE= 2500 J q= 4160 J w= -1660 J
   b) ΔE= -2500 J q= -2500 J w= 0 J
   c) ΔE= 0 J q= -1654 J w= 1654 J

3. a) + b) - c) + d) - e) + f) +

4. a) 1860 K b) 328 K

5. ΔH° = -2222 kJ·mol^{-1} ΔS° = -373 J·mol^{-1}·K^{-1} ΔG° = -2120, -2083, -2045 kJ·mol^{-1}

6. a) -29.0 kJ·mol^{-1} b) 56.6 kJ·mol^{-1} c) 1422 kJ·mol^{-1}

7. a) 1.80×10^5 b) 0.199 c) 190