

Sept. 15, 2015, 7:55-8:55 AM

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Name

KEY

Last,

First

100 points in 8 questions on 4 pages including Tables 2.3 and A.5

For full credit show all work and put correct units on final answers. Note: information that is not needed may be present in some problems.

- (14 pts) 1. If a system composed of *unknown* material goes from state 1 to state 2 such that:

$$P_1 = 3 \text{ bar}, V_1 = 50 \text{ L}, \text{ and } T_1 = 300 \text{ K}$$

$$P_2 = 6 \text{ bar}, V_2 = 10 \text{ L}, \text{ and } T_2 = 300 \text{ K}$$

heat absorbed by the system = 20 kJ; work done by the system = 30 kJ
 i.e. heat flows into syst. i.e., work come out of system

Find ΔU , ΔH , q , w , and ΔS using the First Law of Thermodynamics, and definitions of q and w used by our text book. If insufficient information is given to find some of these, please indicate what is missing.

$$\Delta U = q + w$$

$$\Delta H = \Delta U + \Delta PV$$

$$= \Delta U + (P_2 V_2 - P_1 V_1)$$

$$= \Delta U + (6 \cdot 10 - 3 \cdot 50) \text{ L bar} \times \frac{100 \text{ J}}{\text{L bar}} \times \frac{10^{-3} \text{ kJ}}{\text{J}}$$

$$= -10 \text{ kJ} - 9 \text{ kJ}$$

$$q \quad +20 \text{ kJ}$$

$$w \quad -30 \text{ kJ}$$

$$\Delta U \quad -10 \text{ kJ}$$

$$\Delta H \quad -19 \text{ kJ}$$

$$\Delta S \quad ?$$

ΔS cannot be known because the process was not stated to be reversible

$$\Delta S = \frac{q_{\text{rev}}}{T}$$

- (8 pts) 2. State the 2nd Law of thermodynamics in words and with an equation.

The entropy of the Universe increases during all real (natural) processes.

$$\Delta S + \Delta S_{\text{surr}} > 0$$

- (16pts) 3. (a) Consider the **isothermal reversible compression** of 2 moles of **ideal gas** from $V_1 = 25 \text{ L}$ to $V_2 = 10 \text{ L}$ at 300 K . $C_v = 20 \text{ J mol}^{-1} \text{ K}^{-1}$ and $C_p = 29 \text{ J mol}^{-1} \text{ K}^{-1}$. Calculate q , w , ΔU , ΔH , ΔS , and ΔS_{surr} for this process. If there is not enough information to calculate any of the properties, indicate what is missing for these.

$$w = -nRT \ln \frac{V_2}{V_1} = 4571 \text{ J}$$

$0.083145 \frac{\text{J}}{\text{mol K}}$

$$q = -w$$

$$q = q_{\text{rev}}$$

$$\Delta S = \frac{q_{\text{rev}}}{T} = \frac{-4571}{300} = -15.2 \frac{\text{J}}{\text{K}}$$

$$\Delta S_{\text{surr}} = -q/T$$

$$q \quad -4571 \text{ J}$$

$$w \quad +4571 \text{ J}$$

$$\Delta U \quad 0$$

$$\Delta H \quad 0$$

$$\Delta S \quad -15.2 \text{ J/K}$$

$$\Delta S_{\text{surr}} \quad +15.2$$

- (16 pts) 4. In the cylinder of a diesel engine, the fuel + air mixture is ignited solely by the temperature rise caused by **adiabatic** compression. (It is adiabatic because there is not time for heat to conduct out of the cylinder during the compression.) Calculate q , w , ΔU , ΔH , ΔS , and ΔS_{surr} for 3 moles of an **ideal** diatomic gas ($C_{v,m} = 5/2 R$) if its **temperature increases by 1000 K** during the compression, assuming the compression is done with p_{ex} much larger than p (irreversible). If there is not enough information to calculate any of the properties, indicate what is missing for these.

$$q = 0 \quad (\text{adiabatic})$$

$$w = \Delta U = n C_{v,m} \Delta T \quad \text{for any ideal gas process}$$

$$= (3 \text{ mol}) \left(\frac{5}{2} \cdot 8.3145 \frac{\text{J}}{\text{K mol}} \right) (1000 \text{ K})$$

$$\Delta H = n C_{p,m} \Delta T = \Delta U + \Delta PV$$

$$= \Delta U + n R \Delta T$$

$$= 62359 + 24944 =$$

$$\Delta S_{\text{surr}} = -q/T = 0$$

ΔS can't be found: NO q_{rev}

$$q \quad 0$$

$$w \quad 62359 \text{ J}$$

$$\Delta U \quad 62359 \text{ J}$$

$$\Delta H \quad 87303 \text{ J}$$

$$\Delta S \quad ?$$

$$\Delta S_{\text{surr}} \quad 0$$

(12 pts) 5. If the partial pressure of O_2 gas is 0.2 bar and that of N_2 gas is 0.8 bar in a closed container at $T=300\text{ K}$, what is molar concentration of the O_2 ?

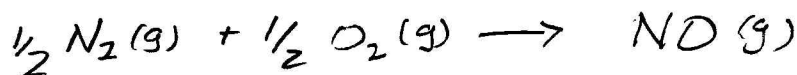
$$P_{O_2} = \frac{n_{O_2}}{V} RT = [O_2] RT$$

$$[O_2] = \frac{P_{O_2}}{RT} = \frac{0.2 \text{ bar}}{0.083145 \frac{\text{L bar}}{\text{mol K}} \cdot 300 \text{ K}} = \boxed{0.008 \text{ M}}$$

(12 pts) 6. Describe the phenomenon of boiling, including the essential relation of temperature, vapor pressure, and pressure applied to the liquid.

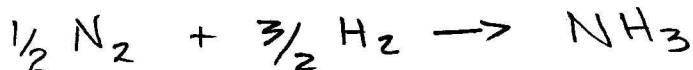
Boiling is evaporation of liquid into bubbles.
This can happen only if the temperature is high enough that the vapor pressure is equal to or greater than the applied pressure.

(10 pts) 7. Write the balanced chemical reaction whose $\Delta_r H^\circ = \Delta_f H^\circ$ for $NO(g)$ at room temperature.



Stable elements
are gases at
room temp.

(12 pts) 8. Using the Bond Dissociation table below, estimate the heat of formation of $NH_3(g)$.



$$\frac{1}{2} D_{N \equiv N} + \frac{3}{2} D_{H-H} - 3 D_{N-H}$$

$$= \frac{1}{2} (945.4) + \frac{3}{2} (436) - 3 (383) = \boxed{-22.3 \frac{\text{kJ}}{\text{mol}}}$$

TABLE A.5 Inorganic Compounds* (cont.)

	$\Delta_f H^\circ$ (kJ mol ⁻¹)	S° (J K ⁻¹ mol ⁻¹)	$\Delta_f G^\circ$ (kJ mol ⁻¹)
HCO ₃ ⁻ (aq)	-691.99	91.2	-586.77
CO ₃ ²⁻ (aq)	-677.14	-56.9	-527.81
Fe(s)	0	27.28	0
Fe ₂ O ₃ (s)	-824.2	87.40	-742.2
H ₂ (g)	0	130.79	0
H ₂ O(g)	-241.82	188.93	-228.73
H ₂ O(l)	-285.83	69.91	-237.13
H ⁺ (aq)	0	0	0
OH ⁻ (aq)	-229.99	-10.75	-157.244
H ₂ O ₂ (aq)	-191.17	143.9	-134.03
H ₂ S(g)	-20.63	205.90	-33.56
H ₂ SO ₄ (g)	-735.13	298.8	-653.37
N ₂ (g)	0	191.72	0
NH ₃ (g)	-46.11	192.56	-16.78
NH ₃ (aq)	-80.29	111.3	-26.50
NH ₄ ⁺ (aq)	-132.51	113.4	-79.31
NO(g)	-90.25	210.87	-86.55
NO ₂ (g)	33.18	240.17	51.47
NO ₃ ⁻ (aq)	-205.0	146.40	-108.74
Na ⁺ (aq)	-240.12	59.0	-261.90
NaOH(s)	-411.15	72.15	-384.14
NaCl(aq)	-407.27	115.5	-393.13
NaOH(s)	-425.61	64.46	-379.49
O ₂ (g)	0	205.25	0
O ₃ (g)	142.7	239.04	163.4
S(rhombic)	0	31.80	0
SO ₂ (g)	-296.83	248.33	-300.19
SO ₃ (g)	-395.72	256.87	-371.22

* Standard thermodynamic values at 25°C (298.15 K) and 1 bar pressure. Values for ions refer to an aqueous solution at unit activity on the molarity scale. Standard enthalpy of formation, $\Delta_f H^\circ$, third-law entropies, S° , and standard Gibbs free energy of formation, $\Delta_f G^\circ$, are given.

† The standard state for all ions and for species labeled (aq) is that of a solute on the molarity scale.

(Data from *The NBS Tables of Thermodynamic Properties*, D. D. Wagman et al., eds., *J. Phys. Chem. Ref. Data*, 11, Suppl. 2 (1982), corrected to 1 bar pressure.)

Table 2.3 Bond
Dissociation Energies

Bond	D (kJ mol ⁻¹)
C—C	359
C=C	611
C≡C	827
C—H	411
C—N	303
C—O	361
C=O	709
C—S	294
N—H	383
O—H	452
S—H	359
H—H	436.0
N≡N	945.4
O=O	498.3
C (graphite)	716.7
S (rhombic sulf)	277.0