

- You wish to evaluate changes in the internal energy,  $U$ , as a function of temperature and pressure. Please write a differential equation appropriate for this situation, expressing the result in terms of experimentally measurable parameters. (15%)
- The melting point of gold is 1336K, and the vapor pressure of liquid is given by:  
 $\ln P \text{ (atm)} = 23.716 - 43522 / T - 1.222 \ln T \text{ (K)}$ 
  - Calculate the heat of vaporization of gold at its melting point. (5%)
  - What is the vapor pressure of solid gold at its melting point? (5%)
  - What is the vapor pressure of solid gold at 1200K? What is the heat of fusion of solid gold? (5%)
- The following data have been obtained for A-B solution at a constant temperature. Calculate the activity of B in an A-B solution containing 60 atomic percent B. (25%)

$X_A$	0.09	0.19	0.27	0.37	0.47	0.67	0.78	0.89
$a_A$	0.302	0.532	0.660	0.778	0.820	0.863	0.863	0.906

- Please describe the miscibility gap, spinodal decomposition and nucleation & growth based on the knowledge of Gibbs free energy of an A-B binary solution. How these metallurgical phenomena are distinguished? Assume it is a regular solution. Please make a schematic diagram to illustrate them, and explain how these curves are derived. (25%)
- Consider solution thermodynamics of a water-ethanol mixture (298K, 1atm).
  - Calculate the partial pressure of ethanol in equilibrium with an aqueous solution with  $X_{\text{ethanol}} = 0.001$ . Assume the solution obeys Henry's law over this regime. (5%)
  - Is the deviation from Raoult's law positive or negative for ethanol in aqueous solution? (10%)
  - Determine the value of  $\Delta G^{\circ}_f$  for ethanol in aqueous solution when the standard state is specified in terms of mole fraction instead of molality. (5%)

Symbol used in the table:

l = liquid; g = gaseous; ao = aqueous solution, un-ionized substance, standard state, m = 1 mol/kg

Substance Formula and Description	State	Molar mass g mol <sup>-1</sup>	0 K	298.15 K (25°C) and 0.1 MPa (1 bar)				
			$\Delta_f H^{\circ}$ kJ mol <sup>-1</sup>	$\Delta_f H^{\circ}$	$\Delta_f G^{\circ}$ kJ mol <sup>-1</sup>	$H^{\circ} - H^{\circ}_f$	$S^{\circ}$ J mol <sup>-1</sup> K <sup>-1</sup>	$C_p$
CH <sub>3</sub> OHCOOH in 5 H <sub>2</sub> O in 6 H <sub>2</sub> O in 8 H <sub>2</sub> O in 10 H <sub>2</sub> O in 15 H <sub>2</sub> O		76.0526	—	-652.87	—	—	—	—
		76.0526	—	-652.54	—	—	—	—
		76.0526	—	-652.24	—	—	—	—
		76.0526	—	-652.03	—	—	—	—
		76.0526	—	-651.78	—	—	—	—
CH <sub>3</sub> OHCOOH in 25 H <sub>2</sub> O in 50 H <sub>2</sub> O in 100 H <sub>2</sub> O in 200 H <sub>2</sub> O in 400 H <sub>2</sub> O		76.0526	—	-651.53	—	—	—	—
		76.0526	—	-651.32	—	—	—	—
		76.0526	—	-651.20	—	—	—	—
		76.0526	—	-651.11	—	—	—	—
		76.0526	—	-651.0	—	—	—	—
CH(OH) <sub>2</sub> COOH dihydroxyacetic acid (glyoxylic acid) in 100 H <sub>2</sub> O	cr	92.0520	—	-835.5	—	—	—	—
		92.0520	—	-823.8	—	—	—	—
(HCO <sub>2</sub> H) <sub>2</sub> formic acid dimer	g2	92.0520	—	-816.21	—	—	—	—
CH <sub>3</sub> CH <sub>2</sub> O <sup>-</sup> ethylate	ao	45.0618	—	—	-102.4	—	—	—
C <sub>2</sub> H <sub>5</sub> OH ethanol	l	46.0698	—	-277.69	-174.78	—	160.7	111.46
C <sub>2</sub> H <sub>5</sub> OH in 0.25 H <sub>2</sub> O in 0.5 H <sub>2</sub> O in 1.0 H <sub>2</sub> O	g	46.0698	-217.438	-235.10	-168.49	14.184	282.70	65.44
	ao	46.0698	—	-288.3	-181.64	—	148.5	—
		46.0698	—	-277.977	—	—	—	—
		46.0698	—	-278.140	—	—	—	—
		46.0698	—	-278.600	—	—	—	—