Name _____

27-215 Thermodynamics of Materials

Professor D.E. Laughlin **Summer, 2000**

Exam #1

June 23, 2000

Open Book Exam.

(10%) 1. The combined first and second law is often written as:

$$dU - TdS + PdV = 0$$

(a) State all assumptions made in writing this equation this way.

(b) Sometimes the above equation is written as an inequality:

$$dU - TdS + PdV < 0$$

What is assumed here? How is this equation used to understand if a system will change? Explain.

Initials _____

(20%) 2. The work done on a magnetic material when its magnetization (M) is increased by dM is given as:

$$\delta W_M = H\, dM$$

where H is the applied magnetic field.

(a) Write the first law of thermodynamics for a magnetic system including this new work term.

(b) Show that the differential of the Helmholtz free energy for this system is:

$$dA = -PdV - SdT + HdM$$

.

(c) A new free energy is defined as:

$$\Phi \equiv A + PV - HM$$

Use this new free energy to obtain the following Maxwell relationship and determine its sign:

$$\left(\frac{\partial S}{\partial H}\right)_{P,T} =$$

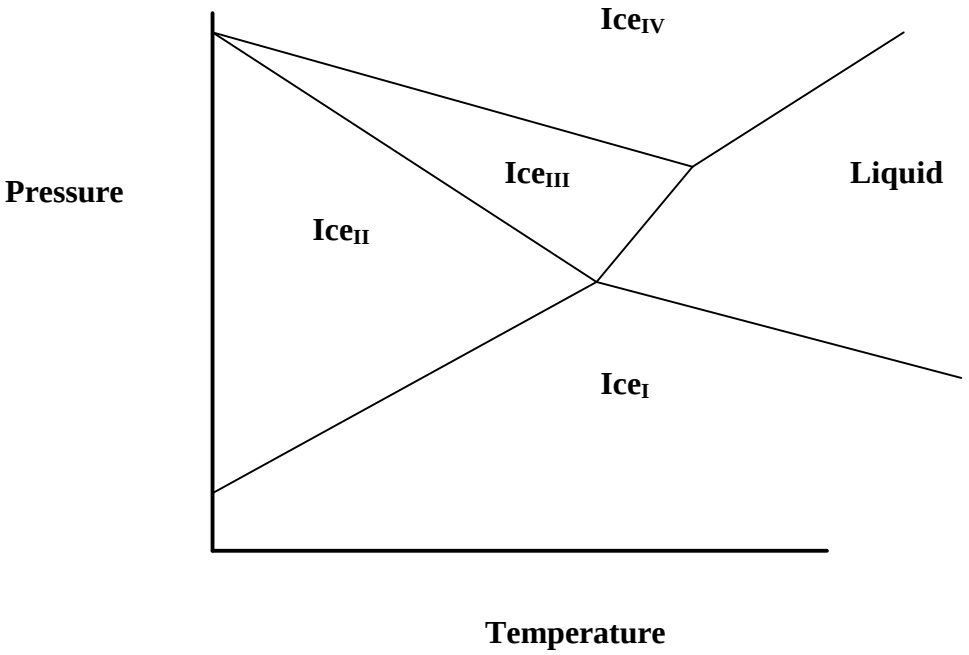
Initials _____

(9%) 3. Which of the following graphs are impossible? Explain in terms of thermodynamic equations.

(i) **(ii)** **(iii)**

Initials _____

(7%) 4. A certain group of researchers from an unnamed University published the following equilibrium P-T phase diagram for ICE at very high pressures. Does it violate any thermodynamic principle(s)? If so which one(s) and where on the diagram?



Initials _____

(25%) 5. Calculate the change in entropy of the system and the environment and the universe when one mole of supercooled water freezes at -20°C and P = 1 atm. The following information is given:

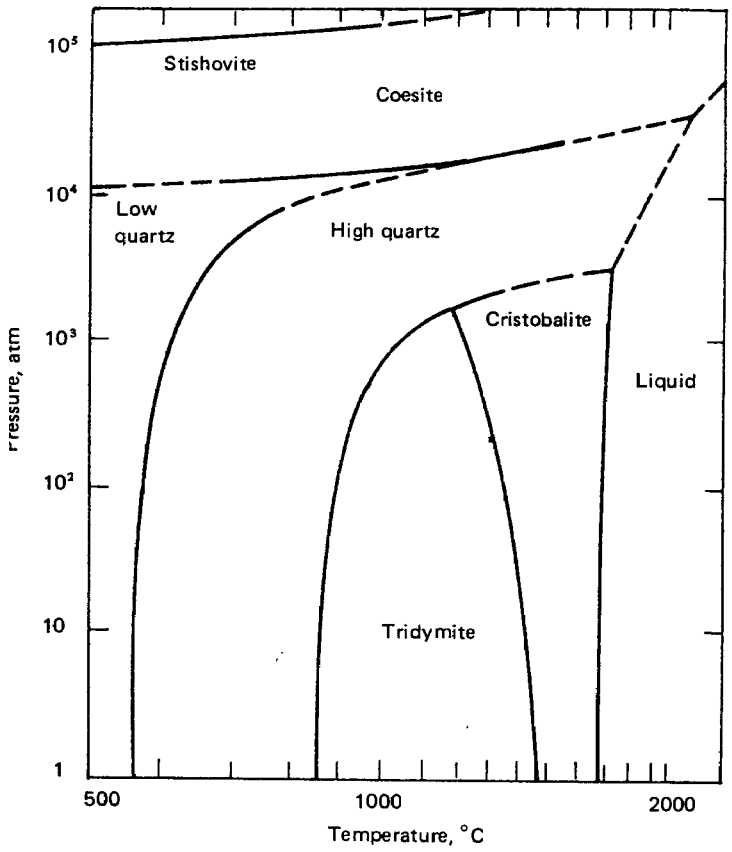
Liquid H_20: $C_p = 18 \frac{cal}{mole\ K}$

Solid H_20: $C_p = 9 \frac{cal}{mole\ K}$

Heat of Fusion at 0°C: $1440 \frac{cal}{mole}$

State all assumptions.

Initials _____



(9%) 6. The Pressure / Temperature Phase Diagram for pure silica (SiO_2) is shown above. The various solid phases have different arrangements of SiO_2 tetrahedra.

(a) Which has the greater density, Tridymite or Cristobalite? Explain.

(b) Which of the named solid phases has the smallest molar volume? Explain.

(c) At some places on the diagram the slope of the P /T curve is infinite (vertical). What does this mean physically?

Initials _____

(10%) 7. An ideal gas undergoes a reversible isobaric process changing from $P_1V_1T_1$ to $P_1V_2T_2$

(a) Derive an expression for the change in internal energy (ΔU) of the gas during this process in terms of the changes in T and V and other thermodynamic variables .

(b) Derive an expression for the change in entropy of the gas during this process in terms of a heat capacity and other thermodynamic variables.

Initials _____

(10%) 8. A system has N_O particles that can exist in either energy level ε_1 or ε_2, where $\varepsilon_2 = 2\,\varepsilon_1$.

(a) Write an expression for the partition function (Z) of this system.

(b) Evaluate the expressions $\frac{n_1}{N_0}$ and $\frac{n_2}{N_0}$ for this system where n_i is the number of particles with energy ε_i.