1. Two allotropes of tin occur near room temperature. The first form of tin is called gray tin and is stable at temperatures below 13.2°C. Gray tin is rather useless, it is brittle and crumbles under stress. At temperatures above 13.2°C, gray tin turns into white tin, the ductile metallic form that has many uses.*  
Densities of gray and white tin are 5.75 g/cm³ and 7.31 g/cm³ respectively.  
Molar heat of the white to gray transition is ΔHᵣ = -2.1 kJ/mol.  
Heat capacities of the two phases are \( c_p^{white} = 26.4 \text{ J/mol K} \) \( c_p^{gray} = 25.8 \text{ J/mol K} \)  
Calculate the pressure which must be applied to tin in order to decrease its white to gray transition temperature by 10°C.

2. Using the information on the gray and white tin provided in the previous problem, performs the following calculations for the phase transformation from Sn (grey, 13.2°C, 1 atm) to Sn (white, 13.2°C, 1 atm)  
(a) Calculate the entropy change for 1 mole of tin  
(b) Calculate the entropy change for the surroundings as well as the total entropy change in the “universe” (tin + surroundings)  
(c) Calculate the difference between the enthalpy of the phase transformation, ΔHᵣ, and the internal energy of the phase transformation, ΔUᵣ.

* In some of the Chemistry and Thermodynamics textbooks, this phase transformation is discussed as one of the causes of the defeat of Napoleon’s troops in the Russian 1812 campaign – as the story goes, the tin buttons on the coats of his troops crumbled to powder as a result of exposure to the cold of a Russian winter, although there is no consensus among historians on this.
3. Using the information on the gray and white tin provided in the previous problem, calculate the change in the molar enthalpy, entropy and Gibbs free energy for a hypothetical transition from gray to white tin at -20°C and pressure of 1 atm. Assume temperature independent heat capacities $c_p = 26.4$ J/K/mol for white tin and $c_p = 25.8$ J/K/mole for gray tin.

Based on the results of your calculations, conclude whether the transition from gray to white Sn would take place spontaneously at 253 K.

4. A piece of chromium is equilibrated at 1900°C. Calculate the number of vacancies that is present in the cubic centimeter of Cr. The energy of vacancy formation for Cr is 2.08 eV, the density is 7.19 g/cm³, and the atomic weight is 51.99 g/mole.
5. (a) Based on the part of a phase diagram given below, list the phases $\alpha$, $\beta$, $\gamma$, $\delta$ in the order of increasing density. Justify your answer using the Clapeyron equation (show your work).

(b) Sketch the Gibbs free energies of all phases as function of temperature at pressure $P_1$ and as function of pressure at temperature $T_1$. Both slopes and curvatures of the lines should be apparent from your plots.