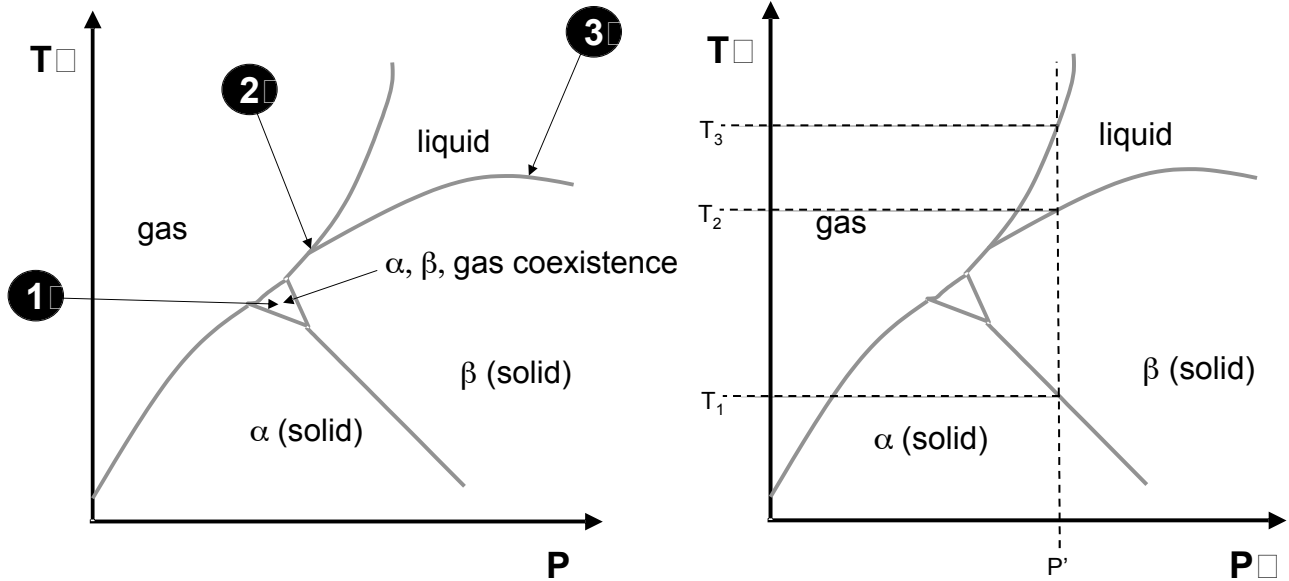

BONDING

1. In order to get used to a representation in spherical coordinates, calculate the volume of the Earth's atmosphere (use as radius of the Earth 6,400 kilometers, and for the thickness of the atmosphere 10 kilometers) (spherical coordinates are discussed in Appendix B-2, Eq. B-26 of the Mortimer)
2. Determine which of the following operators are linear, and which are Hermitian:
 - x
 - $[x, p_x]$
 - $i \frac{d^2}{dx^2}$
3. Calculate the commutator between L_x and p_y .
4. With the help of the Mortimer textbook, summarize the steps that allow us to obtain spherical harmonics as solutions of the eigenvalue equation for the expectation values of the square of the angular momentum (Mortimer 16.1, and Appendix F.3).

THERMODYNAMICS

1. **single-component phase diagrams.** Shown below is a hypothetical phase diagram for a single-component closed system. Answer the following questions about this diagram:
 - a. Apply the phase rule to each of the marked locations 1, 2, and 3, and determine whether those points on the diagram correctly mark stable equilibria.
 - b. Is the molar volume change of transformation $\Delta \bar{V}_{\alpha \rightarrow \text{gas}}$ for the transformation of solid α to the gas phase positive or negative?
 - c. For the fixed pressure P' , draw a qualitative plot of the Gibbs free energy of this material for each phase as a function of temperature over the range shown.



2. **Free energy behavior of solutions.** Shown on the following page is a diagram of free energies for a two-component A-B system at a fixed temperature of 500 K and fixed pressure of 1 atm. This system exists in 3 different phases- liquid, and two solid phases α and β . Two copies of the diagram are provided to sketch on. Use this diagram to answer the questions below:

- a. Using the top copy of the free energy diagram, draw common tangents that identify composition regions of two-phase equilibrium at this temperature and pressure. Draw a 'composition bar' at the bottom of the diagram as in lecture, and denote which phases are present as a function of composition.
- b. At the composition marked X' on the diagram, the system is in equilibrium with 2 phases in coexistence.
 - i. What two phases are present?
 - ii. What are the phase fractions, in terms of parameters given on the diagram?
 - iii. What is the composition of each phase that is present?
- c. On the lower copy of the phase diagram, draw constructions or mark points as necessary to identify the following quantities for a system with composition X' :
 - i. The chemical potential of A in each phase, and B in each phase present.
 - ii. The standard state chemical potential of A and B in each phase present.

