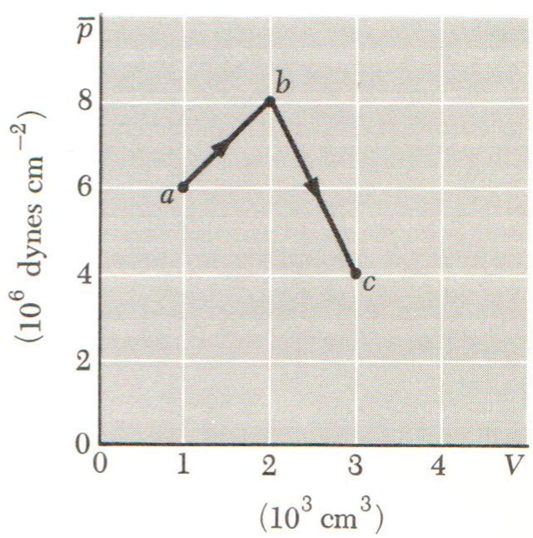
Thermodynamics

Do <u>*two*</u> *of the following three problems, each on a separate sheet (or sheets). Attach each set to a provided cover sheet with your name, subject, and problem number.*

Problem 1

Expansion of an Ideal Gas: An ideal diatomic gas at a moderate absolute temperature T has an internal energy of $U = \frac{5}{2}nRT$, where n is the number of moles of the gas and R is the ideal gas constant. One mole of this gas is taken quasi-statically first from the state a to the state b, and then to state c, along the straight-line paths shown in the pressure-volume figure below.



(a) What is the constant-volume heat capacity of this gas?

(b) What is the work done by the gas in the process $a \to b \to c$?

(c) What is the heat absorbed by the gas in this process?

(d) What is the change in entropy of the gas in this process?

Note: $R = 8.31 \times 10^7$ ergs/mole/K

Problem 2

Gas-liquid equilibrium: A pure substance A is inside a container of volume V maintained at a constant temperature T. The substance is in a gas-liquid equilibrium state; some of the molecules of A are in the gas phase, and some are in the liquid phase, and the two phases are in equilibrium with each other. Now consider these two different transformations of this system:

(a) The volume is reduced from the initial volume V to a final volume V'. The temperature T remains constant. Describe what happens to the gas-liquid equilibrium; will there be an increase in the number of molecules in the gas phase and less in the liquid, or an increase in the liquid and less in the gas, or no change in the relative amounts of gas and liquid? Explain carefully!

(b) Keeping the volume fixed at the original value V, a second pure gas of type B is injected into the container, mixing with the gas A. Three important assumptions:

  (1) There are no chemical reactions between substances A and B.

  (2) Gas B does not dissolve into the liquid phase of A; all molecules of substance B remain in the gas phase.

  (3) You may treat the two gases as being approximately ideal.

  Same question: Describe what happens to the gas-liquid equilibrium of substance A. Explain carefully!

Problem 3

Surface Temperature of the Earth: The Sun radiates with (to a very good approximation) a black-body spectrum corresponding to the temperature of its surface: the peak of the spectrum is at a wavelength of about 500 nm. Assume a simple model where the temperature T_E of the surface of the Earth, also approximated as a black body, is constant everywhere, with the solar radiation reaching the Earth in equilibrium with the radiation emitted by the Earth and the Earth's atmosphere is completely transparent, both to the incoming and to the outgoing radiation. Estimate T_E using the following information:

- The solar radius is 7×10^8 m
- The meter was originally defined as $1/10,000,000$ the distance from the Earth's pole to the equator
- It takes 500 s for sunlight to reach the Earth

and the constants below.

Useful constants:
Wien's displacement constant $b = 2.898\,\text{mm K}$
Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8}\text{W m}^{-2}\text{K}^{-4}$