Graded Problems: THERMODYNAMICS

4. For each statement below, identify the type of thermodynamic system and process involved.
   To classify a system, **ask yourself**: (1) can matter go in/out of the system? (2) can heat go in/out? (3) can work be done on/by system?
   (Heat and work are equivalent ways of transferring energy.)

   (a) A mole of hydrogen gas is maintained at a constant temperature inside a rigid container impermeable to the gas
   This system of gas is **closed** (no gas can go in/out) and the system cannot be affected by mechanical work. The gas is being maintained at a constant temperature and so the process is **isothermal**. Because the pressure of the gas is dependent only on the number of moles, the volume, and the temperature, the process is also **isobaric** if no other types of gas can pass into the system (the walls are impermeable to the hydrogen gas...).
   Many of you have treated this as an ideal gas, for which the change in internal energy is zero for an isothermal process, i.e., $dU = 0 = q + w$*. Would this make the gas also an adiabatic system? Well, not exactly because heat* is *flowing in and out of the container, but the net heat flows are zero.....*

   (b) A system composed of a bar of nickel fused to a bar of gold is maintained at a constant temperature inside an oven at 0.1 atm pressure; Au and Ni diffuse at the junction between the two bars.
   When the system is the bar, if one assumes that the evaporation of Au and Ni is negligible, the system is **closed**. Otherwise, the system is **open**. The system can do work (it can expand—metals do this when hot!!), and the system is not adiabatic because heat is what keeps the bar at a constant temperature (and it's temperature might decrease as it uses energy to expand). The bar is undergoing an **isobarothermal process**.

   (c) The liquid solvent acetone is mixed with liquid nitrogen in a sealed dewar (a dewar is a container for low-temperature liquids and was named after a British scientist) which is thermally insulated to prevent heat transfer.
   Systems which are insulated (*i.e.*, a thermos) are intrinsically **adiabatic** systems. This system is in fact also closed, and, if one assumes that no work is passed through its walls (*e.g.*, that the dewar is not expanding) this system can also be considered **isolated**. The gas in this dewar is undergoing an **adiabatic process**.

   (d) A beaker of water is warmed in the sun on your porch.
   As the sun radiates heat into the water, the water temperature rises and the water expands and eventually evaporates. Because water vapor is allowed to leave the beaker and other things (atmospheric gases, heat,

and dragonflies) are certainly allowed to enter, this is an **open system** undergoing an **isobaric process** (assuming the altitude of your porch is not changing and ignoring small fluctuations in atmospheric pressure throughout the day).

5. Calculate the total amount of heat absorbed by a mole of neon gas if it undgergoes a reversible expansion from 1L to 4L at a constant temperature of 400K, assuming that neon behaves as an ideal gas and the internal energy of the gas remains constant. What is the entropy change in the gas due to this process?
   The solution is found starting from the first law:

$$dU = dq + dw \tag{1}$$

   If the temperature of the ideal gas remains constant during this process, so too does the internal energy. Thus, $dU = 0$ and we can re-arrange the equation to integrate:

$$dU = 0 \tag{2}$$

$$dq_{rev} = -dw = -(-PdV) \tag{3}$$

$$\int dq_{rev} = q_{rev} = -\int dw = \int_{V_{initial}}^{V_{final}} PdV \tag{4}$$

$$dq_{rev} = \int_{V_{initial}}^{V_{final}} \frac{nRT}{V} dV = nRT\ ln \frac{V_{final}}{V_{initial}} \tag{5}$$

   after invoking the ideal gas law

$$PV = nRT \tag{6}$$

   The entropy change is calculated using the relation between reversible heat transfer and entropy:

$$dS = \frac{dq_{rev}}{T} \tag{7}$$

$$\int dS = \delta S = \int \frac{dq_{rev}}{T} = \int \frac{PdV}{T} = \int \frac{nRT}{TV} dV = \int_{V_{initial}}^{V_{final}} \frac{nR}{V} \tag{8}$$

$$\int dS = nR\ ln \frac{V_{final}}{V_{initial}} \tag{9}$$