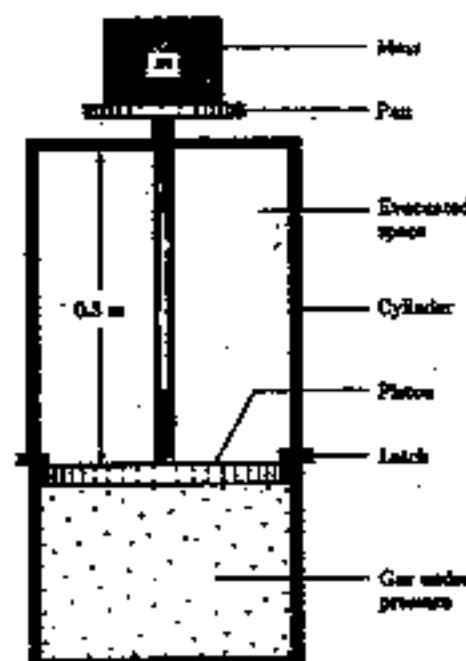


(10 points each)

1. The piston/cylinder arrangement shown in the figure contains nitrogen gas trapped below the piston at a pressure of 7 bar. The piston is held in place by latches. The space above the piston is evacuated. A pan is attached to the piston rod and a mass m of 45 kg is fastened to the pan. The piston, piston rod, and pan together have a mass of 23 kg. The latches holding the piston are released, allowing the piston to rise rapidly until it strikes the top of the cylinder. The distance moved by the piston is 0.5 m. What is the total internal energy change of the gas and the cylinder/piston system?



2. Given that the latent heat of vaporization of water at 100 °C is 2.3 kJ/g. Estimate the latent heat at 300 °C.
3. The enthalpy of a binary liquid solution of species 1 and 2 at fixed T and P is represented by the equation
- $$H = 400 x_1 + 600 x_2 + x_1 x_2 (40 x_1 + 20 x_2)$$
- where x_1 and x_2 are the molar fraction of the species 1 and 2 respectively and H is in J/mol. Determine expressions for the partial molar enthalpy \bar{H}_1 and \bar{H}_2 as functions of x_1 , numerical values for the pure species enthalpies H_1 and H_2 , and numerical values for the partial enthalpies at infinite dilution \bar{H}_1^∞ and \bar{H}_2^∞ .
4. Please explain the following terms using short, precise, clear, and complete descriptions:
- 1) Fugacity
 - 2) Excess properties
 - 3) Gibbs-Duhem equation
 - 4) Activity coefficient
5. Please state the *thermodynamic third law*. Make clear the preconditions required for the observation of this law.

6. Estimate the heat capacities (C_v) of the following elements or compounds at room temperature in terms of the gas constant R (e.g., $2R$, $\frac{3}{2}R$, \dots etc.)

Note: $R=8.314\text{J/mol.K}$ (16%)

- 1) Ar (g)
 - 2) H_2 (g)
 - 3) CO_2 (g)
 - 4) Hg (l)
 - 5) H_2O (l)
 - 6) Al (s)
 - 7) NaCl (s)
 - 8) Al_2O_3 (s)
7. Draw schematic curves of S (entropy), C_v (heat capacity), and H (enthalpy) from 0 to 298K for Hg and H_2 . The melting points of Hg and H_2 are -38.87°C and -259.14°C , respectively, and the boiling points of Hg and H_2 are 356.58°C and -252.87°C , respectively. (12%)
8. Define Gibbs free energy (G), and illustrate the properties and applications of G in thermodynamics. (12%)
9. 1) Write the Nernst equation.
2) Define electromotive force (emf).
3) Give an example to illustrate how emf of an electrolytic cell can be used to measure the activity of an ion in the electrolyte. (10%)