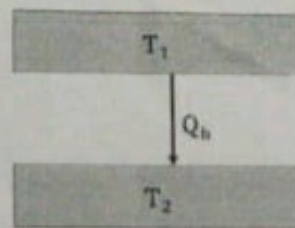


Time: 14.30 - 15.30

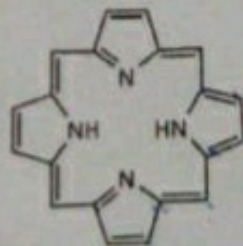
Date: 28/08/2019

Max. Marks = 22.5

1. A Massieu-Planck function (also called entropic thermodynamic potential) which is similar to the Gibbs energy is defined as, $\xi = -\frac{G}{T}$. Obtain an equation for $d\xi$ and from it a Maxwell relation, $\left(\frac{\partial H}{\partial p}\right)_T = V - T\left(\frac{\partial V}{\partial T}\right)_p$. Also, what is the thermodynamic criterion for spontaneity in terms of ξ ? (2.5 M)
2. A coal-oil mixture (COM) is a fuel that can replace heating oil for certain applications. To prevent settling of the coal particles, mixing is required. An open tank contains 5000 kg of COM at 22°C. The COM was stirred for 40 min by a 20 kW paddle mixer. During this operation the temperature of the mixture rose to 27.6°C. The specific heat of the COM is assumed to be constant at 1.4 kJ kg⁻¹ K⁻¹.
 (a) Find the heat interactions of the COM with its surroundings. (3 M)
 (b) What will be the temperature rise (in °C) of the COM if the tank is perfectly insulated? (2 M)
3. Consider a system consisting of two parts, each in equilibrium, but at different temperatures T_1 and T_2 ($T_1 > T_2$), respectively, as shown in the following figure. In process A, the only interaction is the transfer of heat from part 1 to part 2. Is process A reversible? Justify your answer. (2 M)



4. Is the function $\cos ax$ an eigen function of (a) x , (b) d/dx , (c) d^2/dx^2 , (d) fdx . (2 M)
5. A nitrogen molecule is confined in a cubic box of volume 1.00 m³. Assuming that the molecule has an energy equal to $\frac{3}{2}kT$ at $T = 300$ K, what is the value of $n = (n_x^2 + n_y^2 + n_z^2)^{1/2}$ for this molecule? What is the energy separation between the levels n and $n + 1$? What is its de Broglie wavelength? Would it be appropriate to describe this particle as behaving classically? Given, molar mass of $N_2 = 28.01$ g mol⁻¹. (4 M)
6. What is (a) the average value of the linear momentum of a particle in a 1 dimensional box with quantum number n , (b) the average value of p^2 ? (4 M)
 Hint. Use the standard integral $\int \sin^2 ax dx = \frac{x}{2} - \left(\frac{a}{4}\right) \sin 2ax + \text{Constnat}$.
7. Treat the motion of electrons around porphine ring (2), the conjugated macrocycle that forms structural basis of the haem group and the chlorophylls, as particle moving along the perimeter of the ring with a circular radius of 440 pm. Assume that in the ground state of the molecule quantized each state is occupied by two electrons. Calculate the frequency of radiation that can induce a transition between the highest occupied and lowest unoccupied levels. (3 M)



2 Porphine (free base form)

Some useful constants: mass of electron = 9.11×10^{-31} kg, Planck constant $h = 6.6 \times 10^{-34}$ J s, Boltzmann constant $k = 1.38 \times 10^{-23}$ m² kg s⁻² K⁻¹.

$\frac{h^2}{m \lambda^2}$
 $\frac{kg \cdot m^2}{s^2} \times$