LULEÅ UNIVERSITY OF TECHNOLOGY
Applied Physics

Course code	F7035T
Examination date Time	2017-08-26 09.00 - 14.00

Examination in: STATISTICAL PHYSICS AND THERMODYNAMICS
Total number of problems: 5

Teacher on duty: Hans Weber — Tel: (49)2088, Room E163
Examiner: Hans Weber — Tel: (49)2088, Room E163

Allowed aids: Fysikalia, Physics Handbook, Beta, calculator, COLLECTION OF FORMULAE

Define notations and motivate assumptions and approximations. Present the solutions so that they are easy to follow. Maximum number of point is 15 p. 7.0 points is required to pass the examination. Grades 3: 7.0, 4: 9.5, 5: 12.0

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1. **Three questions**

   1. What would be the greatest effect on the ideal gas law if there is a slight attractive force between the molecules?
      - A. At low densities, the pressure would be less than that predicted by the ideal gas law.
      - B. At high densities, the pressure would be less than that predicted by the ideal gas law.
      - C. At high densities, the pressure would be greater than that predicted by the ideal gas law.
      - D. At low densities, the pressure would be higher than that predicted by the ideal gas law.
      - E. There is no effect.
   2. Which has higher entropy - a mole of ideal gas at 20 ^{o}C occupying 10 liters or a mole of the same gas at 20 ^{o}C occupying 100 liters?
      - A. The gas in 10 liters
      - B. The gas in 100 liters
      - C. No difference
      - D. The statement contains not enough information.
   3. How much higher entropy does a mole of ideal gas at 20 ^{o}C occupying 100 liters have compared to a mole of gas at 20 ^{o}C occupying 10 liters?

(3p)

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2. **Rotation of a di–atomic molecule**

The kinetic energy of a di–atomic molecule consists of a translational part and a rotational part. The rotational energy $\epsilon(j)$ has quantised levels and for a di–atomic molecule these are given by:

$$\epsilon(j) = j(j+1)\epsilon_0$$

where j is an integer with the following values $j = 0, 1, 2, ...$ The degeneracy $g(j)$ of each level is given by:

$$g(j) = 2j + 1.$$

a) Calculate the partition function for the rotational degrees of freedom $Z_R(\tau)$.

b) Approximate $Z_R(\tau)$ in the limit $\tau >> \epsilon_0$ by an integral and calculate the specific heat C_v in this limit.

c) Approximate $Z_R(\tau)$ in the limit $\tau << \epsilon_0$ by truncating the sum to two terms and calculate the specific heat C_v in this limit.

d) Draw a figure showing the results from b) and c)

(3p)

3. **Binding of O_2 to hemoglobin**

A hemoglobin molecule can bind four O_2 molecules. Assume ϵ is the energy of each bound O_2, relative to O_2 at rest at infinite distance. Let λ denote the absolute activity $e^{\mu/\tau}$ of free O_2 (in solution).

(a) What is the probability that one and only one O_2 is adsorbed on a hemoglobin molecule?

(b) What is the probability that four O_2 are adsorbed on a hemoglobin molecule?

(c) Make a sketch of these probabilities as a function of λ.

(3p)

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4. **The triple point of ammonia**

In the vicinity of the triple point, the vapor pressures of solid and liquid ammonia are respectively given by p_s (in N/m^2) $\ln p_s = 27.923 - 3754/T$ and $\ln p_l = 24.383 - 3063/T$. The temperature T is in Kelvin.

Hint: Assume the the ideal gas law applies to the gas phase. The volume of molecules in the solid phase may be neglected.

a) At what temperature is the triple point?

b) What are the latent heats of sublimation (solid-gas) and of vaporisation (liquid-gas) at the triple point?

c) What is the latent heat of melting (solid-liquid) at the triple point?

(3p)

5. **Pressure and energy of a gas of Photons**

In this problem you are asked to derive an expression for the pressure of a photon gas confined to a cube with the side L.

a) Start by deriving an expression for the energy density $\frac{U}{V}$ (Stefan–Boltzmanns T^4 law). (Hint use the Planck distribution and that the relation between the frequency of the photon ω_n and the mode $n = \sqrt{n_x^2 + n_y^2 + n_z^2}$ is given by $\omega_n = n\pi c/L$.)

b) Derive the expression for the pressure p of the photon gas.
(Hint use the entropy σ.)

c) The energy of a mono atomic gas is given by $pV = \frac{2}{3}U$. Derive the corresponding expression for the photon gas.

(3p)

GOOD LUCK !