LULEÅ UNIVERSITY OF TECHNOLOGY
Division of Physics

Course code	F7035T
Examination date Time	2014-05-17 09.00 - 14.00

Examination in: STATISTICAL PHYSICS AND THERMODYNAMICS
Total number of problems: 5
Teacher on duty: Hans Weber — Tel: (49)2088, Room E304
Examiner: Hans Weber — Tel: (49)2088, Room E304

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. **Freezing point of water**

   The latent heat of melting of water is 333.9 J/g. Ice at zero degrees has a density of 0,9168 g/cm^3, whereas liquid water at zero degrees has a density of 0,9998 g/cm^3.

   Determine by how much (amount and direction) the freezing point will change in temperature if the pressure increases from 1.00 atmospheres to 10.0 atmospheres.

   (3p)

2. **Atomic nuclei at low temperatures**

   A crystal consists of N atoms consisting of nuclei with integer spin S. The energy of the nuclei depends on their spin state with respect to an applied field. The possible energy states are given by $0, \epsilon, 2\epsilon, ..., S\epsilon$, where the ground state is not degenerated and the other states all have degeneracy 2.

   The crystal is held at a low temperature. Calculate the contribution to the heat capacity from the spin degrees of freedom of the nucleus in the limit $S\epsilon/\tau >> 1$, ($\tau = k_B T$).

   (3p)

3. **Schottky anomaly**

   A system has two energy levels. The level of higher energy has a two fold degeneracy. The level of lower energy is not degenerated. In a measurement of the heat capacity at constant volume C_v a maximum is found at the temperature $T = 450$K.

   Determine the energy difference (in electron Volts eV) between the two levels. (If you arrive at an equation you cannot solve analytical, solve it graphically or iterate on your pocket calculator)

   (3p)

TURN PAGE!

4. **Gas-solid equilibrium**

In a container of volume V a substance solid phase is in equilibrium with its gas phase. The atoms have a binding energy $-\epsilon_0$ to the solid phase.

Use the following approximations. The substance is mono atomic and for the gas phase the ideal gas applies. Further the gas phase has volume V independent of the amount in the solid phase. Also the entropy of the solid phase is negligible.

Let the total number of atoms be $N = N_s + N_g$ where N_s and N_g are the number of atoms in the solid phase and gas phase.

a) Express the free energy of the system F. (Hint $F = F_s + F_g$.)

b) Minimize F with respect to N_g and derive an expression for N_g.

c) Estimate ϵ_0 for H_2O using the data in the table. Answer in electron volts ! (Assume the ideal gas applies to the gas phase of H_2O. Hint: Note that the range of temperatures is small if you need to make approximations for to the expression of p_g.)

T (^oC)	saturation pressure (kPa)
-2	0.5176
-6	0.3689
-10	0.2602
-14	0.1815
-20	0.1035
-30	0.0381
-40	0.0129

(3p)

5. **Identical particles**

A system consists of two particles. Each particle can be in one of the following three states with the energies: 0, ϵ and 3ϵ. The system is coupled to a heat reservoir of temperature τ.

a) Evaluate an expression for the partition function Z if we consider the particles to be classical (ie we can label the particles as 1 and 2).

b) What will Z if the particles are bosons?

c) What will Z if the particles are fermions?

(3p)

GOOD LUCK !