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Exam 1, Editing time: 90 minutes

1 Dogflea experiment by Ehrenfest [4P]

There are two dogs Arko and Bello with a total number $N = 50$ of fleas, which randomly hop from one dog to the other. In the beginning Bello is free from fleas whereas all fleas are on Arko.

a) Sketch the probability distribution (diagram) of the number of fleas for dog Bello

   i) at the very beginning,

   ii) in an intermediate phase,

   iii) and after very long time.

   Mind a proper labelling (coordinate axes, peak heights and scaling)!!!

b) State the partition sum.

c) At which moment the entropy is maximal?
(at the beginning | in the intermediate thermalization phase | in the end)

d) At which moment the probability to find most fleas on ... is maximal

   i) Bello (initially flea-frea)

   ii) Arko (initially full of fleas)?

   (at the beginning | in the intermediate thermalization phase | in the end)

e) What is the probability to find 20 fleas on one of the two dogs after very long time?

f) Sketch the entropy over time.

2 Ideal gas in a box [4P]

Given is an ideal gas with N particles of mass m in a box with volume V at the temperature T in a thermal equilibrium.

Which of the following parameters have to be increased (+), decreased (-) or have not to be changed at all (0) to effect the following changes:

a) The number of total collisions of particles with the wall of the box per time and area unit shall **increase**.

b) The average energy per particle shall **decrease**.

c) The average distance between particles shall **increase**.

d) The average particle velocity in the box shall **increase**.

Zustandsänderung:	V	T	m	N
a) + collisions paricle with wall				
b) – of $\langle E \rangle$ per particle				
c) + $\langle$distance$\rangle$ between particles				
d) + $\langle$velocity$\rangle$				

3 True or false [3P]

Which of the following statements are correct. **Correct the false statements!**

a) The average energy of a single particle in an ideal gas is proportional to the square root of the particle mass (all particles have the same mass).

b) In an ideal gas, particles do not interact (attraction, repulsion).

c) At a given temperature, all particles of the ideal gas have the same kinetic energy.

d) In an ideal gas, the average particle velocity is smaller than the most probable velocity and larger than the square root of the average of the squared velocity. $\sqrt{\langle v^2 \rangle} < \langle v \rangle < v_{\max}$

e) Effusion is a reversible process.

f) Ergodicity of a system is a time independent feature of the system.

g) An ideal gas in a box of volume V with inelastic collisions is an ergodic system for the configuration space consisting of the surface of the energy sphere and the spatial coordinates of the box.

4 Zipperlike chemical compound [4P]

Given is a zipper like chemical compound consisting of $N \gg 1$ bonds (see Fig. 1) which is in contact with a large thermal bath of temperature T. The right hand side of the chemical

Figure 1: Sketch of the zipper–like chemical compound consisting of $N = 18$ bonds, of which seven bonds are open (broken).

compound is fixed to a wall. Each of the N bonds can have two states: open (broken) and closed. All bonds on the left hand side of an open bond are also open (zipper like system). Thus, a configuration with closed bonds on the left side of open bonds are not allowed. The opening (breaking) of a bond costs the energy $\Delta > 0$.

a) Calculate the partition sum. Assume the following: $N \to \infty$.

b) Calculate the internal energy U.

c) Calculate the average number of open bondings.

d) Calculate the heat capacity. (You can combine the exponential terms to a hyperbolic function).

e) Which behaviour does the heat capacity show for high temperatures ($T \gg 1$)?
Which theorem makes statements about the heat capacity at high temperatures? Show whether the behaviour is in agreement with the theorem or not.

f) Which behaviour does the heat capacity show for low temperatures ($T \to 0$)?
Which theorem makes statements about the heat capacity at high temperatures? Show whether the behaviour is in agreement with the theorem or not.

g) Calculate the entropy of the system.