PHY294, Winter 2016, QUIZ III.

Answer all questions on the exam paper. Duration: 25 minutes.

Name: the prof. ; **Student #:** _____ ; **Tutorial group:** _____

I. The ammonia molecule, NH_3, has the shape of a tetrahedron. Find the heat capacity of an ideal gas of ammonia molecules, assuming that all degrees of freedom are thermally activated.

3 translational modes : $3 \times \frac{kT}{2}$

3 rotational modes : $3 \times \frac{kT}{2}$

$4 \times 3 - 6 = 6$ vibrational modes : $6 \times 2 \frac{kT}{2}$

(total # d.o.f − translation + rotation)

} avg. energy per particle

$18 \frac{kT}{2} \cdot N$ = energy of gas

$C_V/N = 9k$

2 points

II. Two ideal monatomic gases are placed in thermal contact. One gas has twice the number of particles than the other: $N_1 = N$ and $N_2 = 2N$. The gases occupy volumes V_1 and V_2, respectively, and are thermally isolated from the rest of the world. Let the energy of the first gas be $U_1 = U - x$ and of the second $U_2 = U + x$. What values of x are most likely to occur in thermal equilibrium?

energy per particle should be same

$$\frac{U_1}{N_1} = \frac{U_2}{N_2} \Rightarrow \frac{U-x}{N} = \frac{U+x}{2N} \Rightarrow U+x = 2(U-x)$$

$$U+x = 2U - 2x \rightarrow 3x = U \rightarrow x = \frac{U}{3}$$

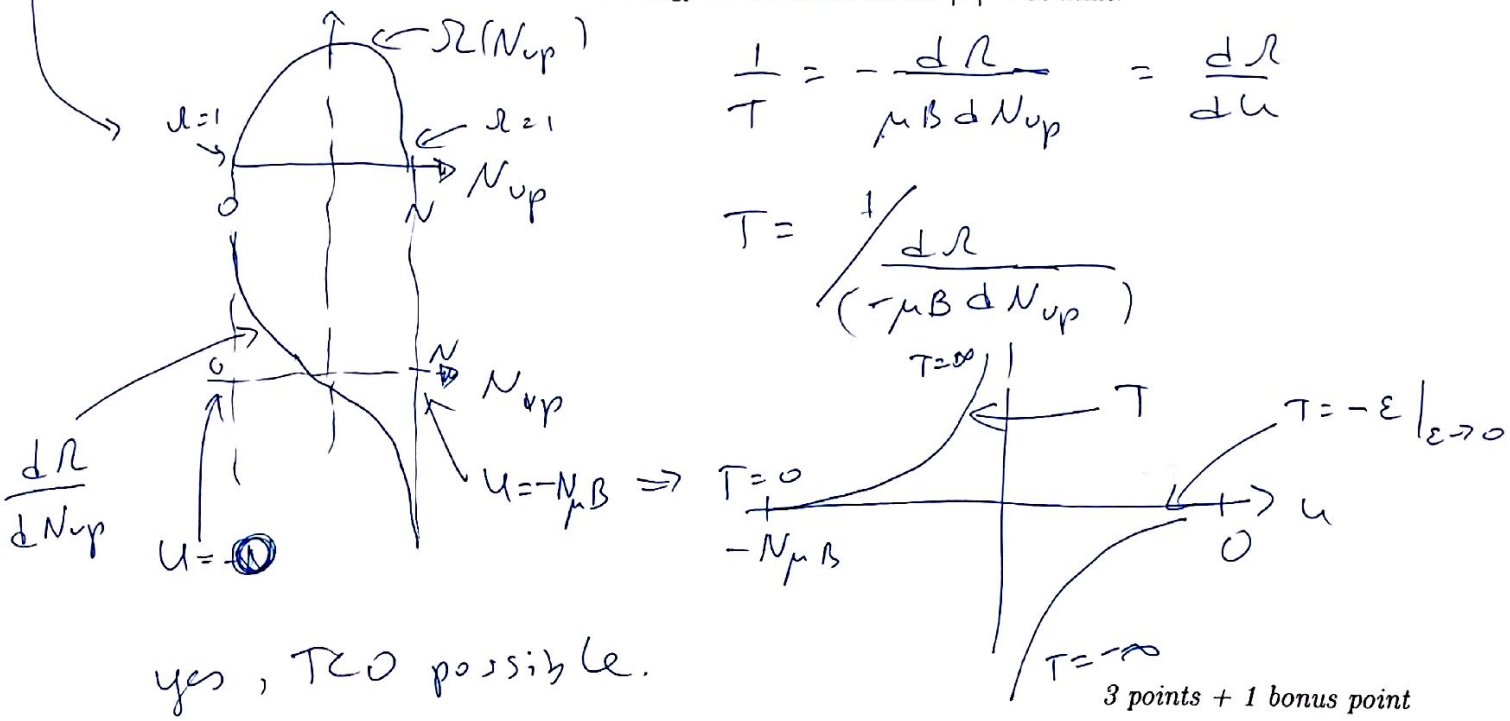
indeed $U_1 = \frac{2}{3}U$ $U_2 = \frac{4}{3}U$ ✓

3 points

Turn over, please →

III. The multiplicity function of a paramagnet of N spins is $\Omega(N, N_{up}) = \binom{N}{N_{up}} = \frac{N!}{N_{up}!(N-N_{up})!}$. *Sketch* the *qualitative behaviour* of Ω as a function of N_{up}.

Next, for a bonus (to be banked for future use, or for fame), defining the "energy" as $U = -N_{up}(\mu B)$, with a fixed external B-field and magnetic moment μ, *sketch* the *qualitative behaviour* of the temperature T of the paramagnet as a function of the energy U. Comment on the $|T| \to \infty$ limit.



3 points + 1 bonus point

IV. An ideal monatomic gas is initially placed in one half of an isolated volume, whose other half is separated by a partition and is empty. What is the work done by the gas as it fills the entire volume after the partition is quickly removed?

no work in free expansion – nothing to push at!

2 points

Total number of points: 2 + 3 + 3 (+1) + 2 = 10 (+1).