

Exercise #2

due date: November 5th 2025

a) Read the notes on the virial theorem. Comment the action of repulsive or attractive interactions in the equation of state for imperfect gas.

b) Read the notes on fugacity expansion. In the grandcanonical ensemble calculate the dimensionless ratio $\beta P/\rho$ where $\rho=N/V$ is the number density by performing a fugacity expansion in $z=\exp(\beta\mu)$ up to second order in z and eliminate the fugacity in favor of the average number of particle in order to have an approximation for the equation of state.

Perform the calculation in the case of an interacting classical gas with hard-spheres pair interactions.

Perform the calculation in the case of a quantum perfect gas in the case of Fermi-Dirac and Bose-Einstein statistics.

Compare and comments the two results.

c1) In a two state quantum system (say energy E_0 and E_1) a measure of energy can give with equal probability the two possible value of energy.

- Write the most general state which satisfy the previous constraint and write the associated density matrix.

c2) An ensemble of quantum systems is made by a mixture of state $|0\rangle$ (energy E_0) and $|1\rangle$ (say energy E_1) with equal probability. Write the associated density matrix.

d) Evaluate the average energy as well as the average of the operator

$$X=|0\rangle\langle 1|+|1\rangle\langle 0|$$

in the two cases c1) and c2). Comments the results.

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