**Problem 1.** Consider one mole of non-interacting distinguishable hypothetical particles at a given temperature T. Assume each particle can occupy one of the three energy levels with the following energies: $\varepsilon_0 = 0$; $\varepsilon_1 = 2\varepsilon$; $\varepsilon_2 = 4\varepsilon$. The degeneracy numbers for these energy levels are 1, 3, and 9, respectively. Answer the following questions:

A. Write the expression for the molecular partition function $q$.

B. What are the values of $q$ at $T \rightarrow 0$ and at $T \rightarrow \infty$?

C. You found that at T=200 K all three energy levels are equally populated. Determine the value of $\varepsilon$.

D. Calculate the total energy of the system at this temperature.

E. Calculate the entropy of the system at this temperature.

**Problem 2.** Compare the molecular partition functions of $N_2$ and CO molecules at the same temperature (300 K), volume (V), and pressure. Which molecule has the larger value of the molecular partition function, or perhaps they are equal? Consider the total molecular partition function as a product of the partition functions associated with various types of motions/states that we studied in this course: translational, rotational, vibrational, nuclear spin. For simplicity, ignore the contributions from the electronic states and electron spins. Assume the highest isotopic abundance for the nuclei, i.e. $^{12}C$, $^{14}N$, $^{16}O$, and assume that there is no magnetic field. Some relevant characteristics of these molecules can be found in Table 8.3 of the *Quantum Chemistry and Spectroscopy* textbook.
Compare the partition functions associated with the same type of motion for the two molecules: are they equal or not, and if not – by what factor do they differ? Then combine your results to compare the total partition functions of the molecules.
(*Hints*: think how the partition function associated with each type of motion depends on the physical characteristics of the molecule. You can but don't need to calculate all these individual partition functions for each molecule – it might be simpler to just calculate their ratio between the two molecules.)