# The Equipartition Theorem

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A little known fact is that the Equipartition Theorem was discovered by this cute little donkey.

Every atom in every gas phase molecule has three motional degrees of freedom available to it. This is a result of our living in a three dimensional universe; this is how we have to begin the analysis as it doesn't get more simple than this. The number of degrees of freedom adds together, thus, every molecule has a total of 3N spatial degrees of freedom available to it where N is the number of atoms in the molecule. Now it turns out if every atom in a molecule are moving in the same direction, that's just pure center-of-mass translation; ie. the molecule is banging against the walls. Since again we live in a 3D world, there are three purely translational degrees of freedom (x, y and z). Now for a linear molecule, the atoms may be moving in such a way that they are rotating; there are two ways to do this. For a non-linear molecule, there are three ways to rotate. While not entirely correct, you can think of the three rotations like a forward flip, a sideways somersault, and a pirouette (guys, your going to have to Google search "pirouette"). Thus, there are 3N-5 (for linear molecules) and 3N-6 (for non-linear molecules) degrees of motion left. These must be vibrations. Unfortunately, our terrestrial temperatures are too low to ever hope to vibrationally excite a molecule which is why they do not count towards the molecules internal energy (this is the same thing as saying I cannot "store" heat vibrationally). Let me re-create the chart I made on Friday for completeness:

| Molecule | Degrees of Freedom | U | Terrestrial U |
|---|---|---|---|
| Ar | 3 translational | 3/2 k·T | 3/2 k·T |
| $CO_2$ | 3 translational,<br>2 rotational,<br>3×3-5 = 4 vibrational | 9/2 k·T | 5/2 k·T |
| $CH_4$ | 3 translational,<br>3 rotational,<br>3×5-6 = 9 vibrational | 15/2 k·T | 3 k·T |