

## 1.1: What is Statistical Mechanics About?

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Statistical mechanics treats matter in bulk. While most branches of physics. . . classical mechanics, atomic physics, quantum mechanics, nuclear physics. . . deal with one or two or a few dozen particles, statistical mechanics deals with, typically, about a mole of particles at one time. A mole is  $6.02 \times 10^{23}$ , considerably larger than a few dozen. Let's compare this to a number often considered large, namely the U.S. national debt. This debt is (2014) about 18 trillion dollars, so the national debt is about thirty trillionth of a mole of dollars.<sup>1</sup> Even so, a mole of water molecules occupies only 18 ml or about half a fluid ounce. . . it's just a sip.

The huge number of particles present in the systems studied by statistical mechanics means that the traditional questions of physics are impossible to answer. For example, the traditional question of classical mechanics is the time-development problem: Given the positions and velocities of all the particles now, find out what they will be at some future time. This problem has not been completely solved for three gravitating bodies. . . clearly we will get nowhere asking the same question for  $6.02 \times 10^{23}$  bodies! But in fact, a solution of the time-development problem for a mole of water molecules would be useless even if it could be obtained. Who cares where each molecule is located? No experiment will ever be able to find out. To make progress, we have to ask different questions, question like "How does the pressure change with volume?", "How does the temperature change upon adding particles?", "What is the mean distance between atoms?", or "What is the probability for finding two atoms separated by a given distance?". Thus the challenge of statistical mechanics is two-fold: first find the questions, and only then find the answers.

<sup>1</sup> In contrast, the Milky Way galaxy contains about 0.3 or 0.6 trillionth of a mole of stars. The entire universe probably contains fewer than a mole of stars.

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