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Second law of thermodynamics "broken"

By **Matthew Chalmers**

One of the most fundamental rules of physics, the second law of thermodynamics, has for the first time been shown not to hold for microscopic systems.

The demonstration, by chemical physicists in Australia, could place a fundamental limit on miniaturisation, because it suggests that the micro-scale devices envisaged by nanotechnologists will not behave like simple scaled-down versions of their larger counterparts – they could sometimes run backwards.

The second law states that a closed system will remain the same or become more disordered over time, i.e. its entropy will always increase. It is the reason a cup of tea loses heat to its surroundings, rather than being heated by the air around it.

"In a typical room, for example, the air molecules are most likely to be distributed evenly, which is the overall result of their individual random motion", says theoretical physicist Andrew Davies of Glasgow University. "But because of this randomness there is always a probability that suddenly all the air will bunch up in one corner." Thankfully this probability is so small it never happens on human timescales.

To the limit

Physicists knew that at atomic scales over very short periods of time, statistical mechanics is pushed beyond its limit, and the second law does not apply. Put another way, situations that break the second law become much more probable.

broken at micron scale, over time periods of up to two seconds.

Researchers led by Denis Evans at the Australian National University in Canberra measured changes in the entropy of latex beads, each a few micrometres across and suspended in water.

By using a precise laser beam to trap the beads, the team were able to measure the movement of the beads very frequently, and hence repeatedly calculate the entropy of the system at short time intervals.

Running in reverse

They found that the change in entropy was negative over time intervals of a few tenths of a second, revealing nature running in reverse. In this case, the bead was gaining energy from the random motion of the water molecule – the small-scale equivalent of the cup of tea getting hotter. But over time intervals of more than two seconds, on overall positive entropy change was measured and normality restored.

The team say their experiment provides the first evidence that the second law of thermodynamics is violated at appreciable time and length scales.

Their results are also in good agreement with predictions of the "fluctuation theorem", a theory developed at ANU 10 years ago to reconcile the second law with the behaviour of particles at microscopic scales.

"The results imply that the fluctuation theorem has important ramifications for nanotechnology and indeed for how life itself functions", claim the researchers.

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