Bose-Einstein condensate
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The Bose-Einstein condensate is a phase of matter, in the sense that solid, liquid, gas and plasma are phases of matter. Bose-Einstein condensates form from matter that has been cooled to near absolute zero. They were predicted in the 1920s by Satyendra Nath Bose and Albert Einstein based on Bose's work on rules for deciding when two photons should be counted up as either identical or different; Einstein formalized and generalized these ideas, and the result of their efforts is the so called Bose Einstein statistics. This is the description of the statistics of identical particles that can share a quantum energy level with each other (as opposed to Fermi Dirac statistics, which describe identical particles of which you can only put one in each energy level). One of the results that one can derive from this statistics is the existence of stimulated emission of photons, which is the effect that is used in creating lasers. Einstein also applied the statistics to atoms instead of photons, and discovered that at a certain very low temperature, all of the atoms tend to drop into the lowest accessible energy level.

[caption: Velocity-distribution data that confirm the discovery of a new phase of matter, the Bose-Einstein condensate. The two right-most images, corresponding to lower temperatures, show multiple atoms coalescing into a single macroscopic quantum state.]

The effect can be understood in broad outline by considering the Heisenberg Uncertainty Principle which states, roughly, that it is impossible to know both a particle's velocity and a particle's position simultaneously with certainty. When a group of atoms is cooled to a low enough temperature, however, their velocities become very certain; they must be moving very slowly, or, stated more technically, they must have low quantum energy levels. This causes their positions to "smear out," effectively causing the individual atoms to overlap each other. In a Bose-Einstein condensate, the many overlapping atoms can be considered to be a single super-atom, with all of its constituent atoms sharing a single quantum state.

A Bose-Einstein condensate was not actually created in a lab until June 5, 1995, when Eric Cornell and Carl Wieman used a combination of laser cooling (a technique the invention of which won Steven Chu, Claude Cohen-Tannoudji, and William D. Phillips the 1997 Nobel Prize for Physics) and magnetic evaporative cooling to cool a cloud of approximately 2000 rubidium atoms to one twenty-billionth of a kelvin, the lowest temperature ever achieved at that time. This was cold enough to form a Bose-Einstein condensate; Cornell, Wieman and Wolfgang Ketterle won the 2001 Nobel Prize in Physics for this achievement.

As teams surrounding Rudolf Grimm from the university of Innsbruck, Austria and Deborah S. Jin from the University of Colorado at Boulder, USA were able to show independently in November 2003, Bose-Einstein condensates can also be formed from molecules.

Bose-Einstein condensates are extremely fragile. The slightest interaction with the outside world can be enough to warm them past the condensation threshold, causing them to break back down into individual atoms again; it will likely be some time before any practical applications are developed for them. However, several interesting properties have already been observed in experiments. Bose-Einstein condensates can be made to have an extremely high gradient in the optical densities, resulting in extremely low measured speed of light within it; some condensates have slowed beams of light down to mere meters per second, slower than a human can move on a bicycle. A rotating Bose-Einstein condensate could be used as a model black hole, allowing light to enter but not to escape. Condensates could also be used to "freeze" pulses of light, to be released again when the condensate breaks down. Research in this field is still young and ongoing.

See also

* Superfluid * Supersolid

External links

* Bose-Einstein Condensates at JILA

References

* S. Jochim, M. Bartenstein, A. Altmeyer, G. Hendl, S. Riedl, C. Chin, J. Hecker Denschlag, R. Grimm: Bose-Einstein Condensation of Molecules, Science, November 13, 2003 (10.1126/science.1093280) * Markus Greiner, Cindy A. Regal, Deborah S. Jin: A molecular Bose-Einstein condensate emerges from a Fermi sea, http://xxx.lanl.gov/abs/cond-mat/0311172