

Lecture 10 Toward Bose-Einstein condensation P238 10/28/2021

Cooling: Doppler cooling. Optical molasses, Raman-sideband cooling, evaporative cooling. . .

Trapping: Magnetic trap, Optical trap, optical tweezers

How cold do we need to reach to condense atoms?

Bose-Einstein condensation: More than 1 particle in the $|g\rangle$

$$N(E) = N(0) e^{-E/kT}$$

$$N = \sum_i N(E_i) = \int N(E) \rho(E) dE = N(0) \int e^{-E/kT} \rho(E) dE$$

$$\boxed{K_i = 2\pi / (2L/i) = i\pi L} \Rightarrow E_i = \frac{\hbar^2}{2m} \frac{\pi^2}{L^2} (i^2 + j^2 + k^2)$$

Total # of states with energy $< E$

$$N(E) = \frac{1}{8} \frac{4}{3} \pi \left(E \frac{2mL^2}{\hbar^2 \pi^2} \right)^{3/2} = \frac{\pi}{6} \frac{(2m)^{3/2}}{\hbar^3 \pi^3} E^{3/2} V$$

$$\rho(E) = N(E) = \frac{2\pi(2m)^{3/2}}{\hbar^3} E^{1/2} V \quad \text{do Broglie wavelength}$$

$$\Rightarrow N = N(0) \frac{2\pi(2m)^{3/2}}{\hbar^3} V \int E^{1/2} e^{-E/kT} dE = \frac{\pi}{2} (kT)^{3/2}$$

$$\Rightarrow n = N(0) \frac{(2\pi m k T)^{3/2}}{\hbar^3} \Rightarrow n \lambda_{dB}^3 = N(0) > 1 \quad \lambda_{dB} = \frac{\hbar}{\sqrt{2\pi m k T}}$$

$$\Rightarrow N(0) = n \lambda_{dB}^3 = n \frac{\hbar^3}{\sqrt{2\pi m k T}}^3 = N \left(\frac{\hbar}{\Delta x \Delta p_x} \right)^3 > 1 \quad \text{phase-space density}$$

