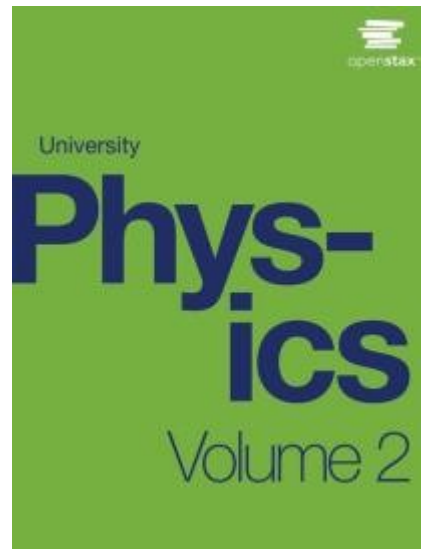


# UNIVERSITY PHYSICS

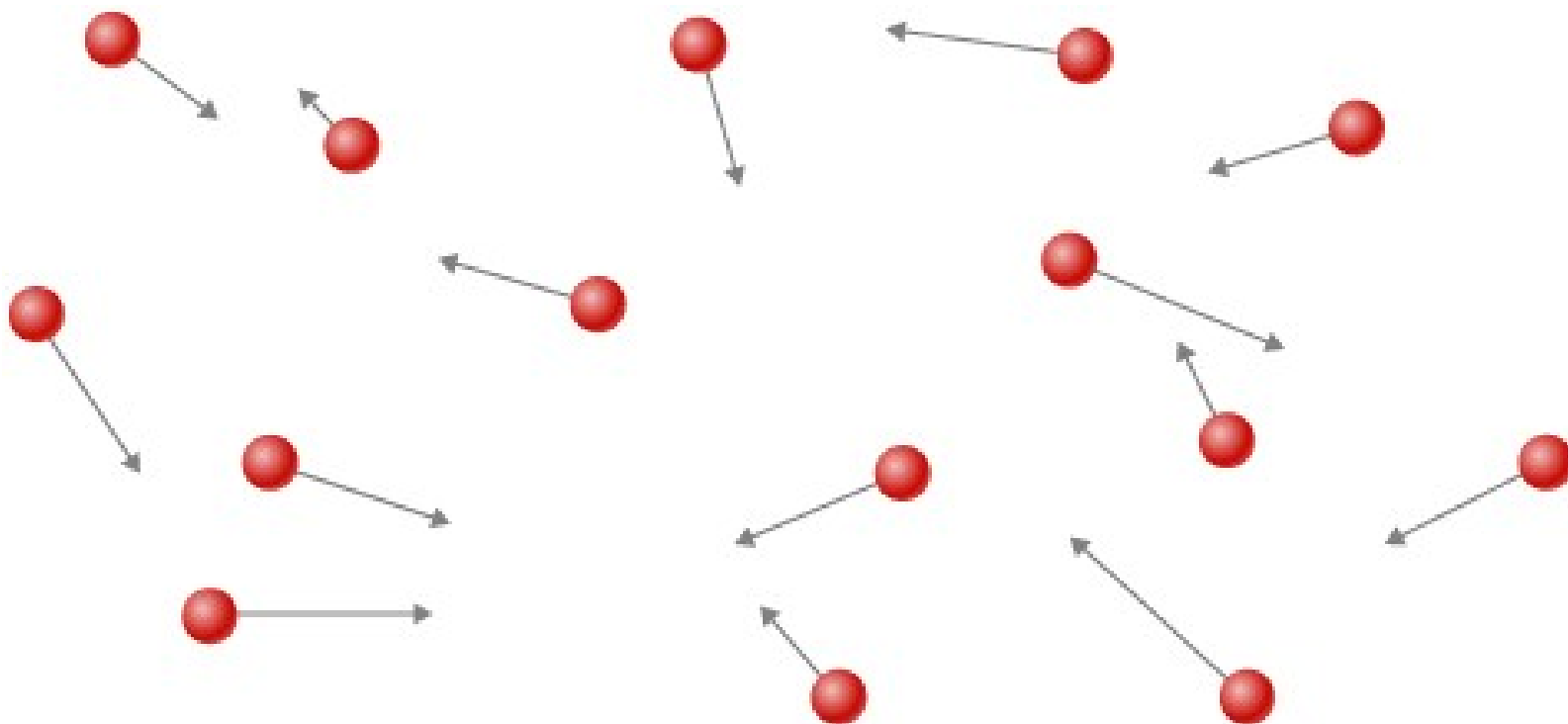
## Chapter 2 THE KINETIC THEORY OF GASES

PowerPoint Image Slideshow



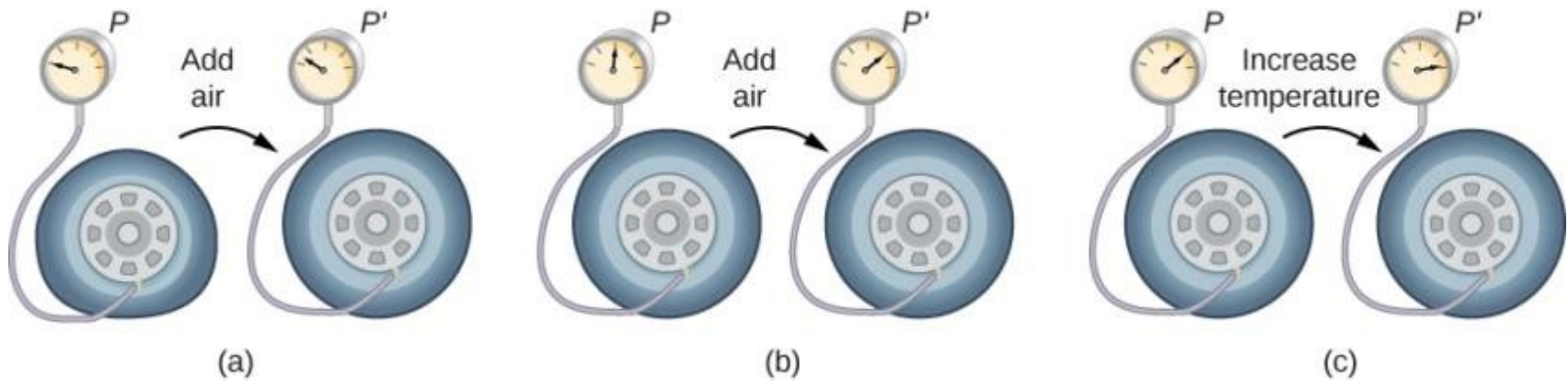
# Introduction

## FIGURE 2.2



Atoms and molecules in a gas are typically widely separated. Because the forces between them are quite weak at these distances, the properties of a gas depend more on the number of atoms per unit volume and on temperature than on the type of atom.

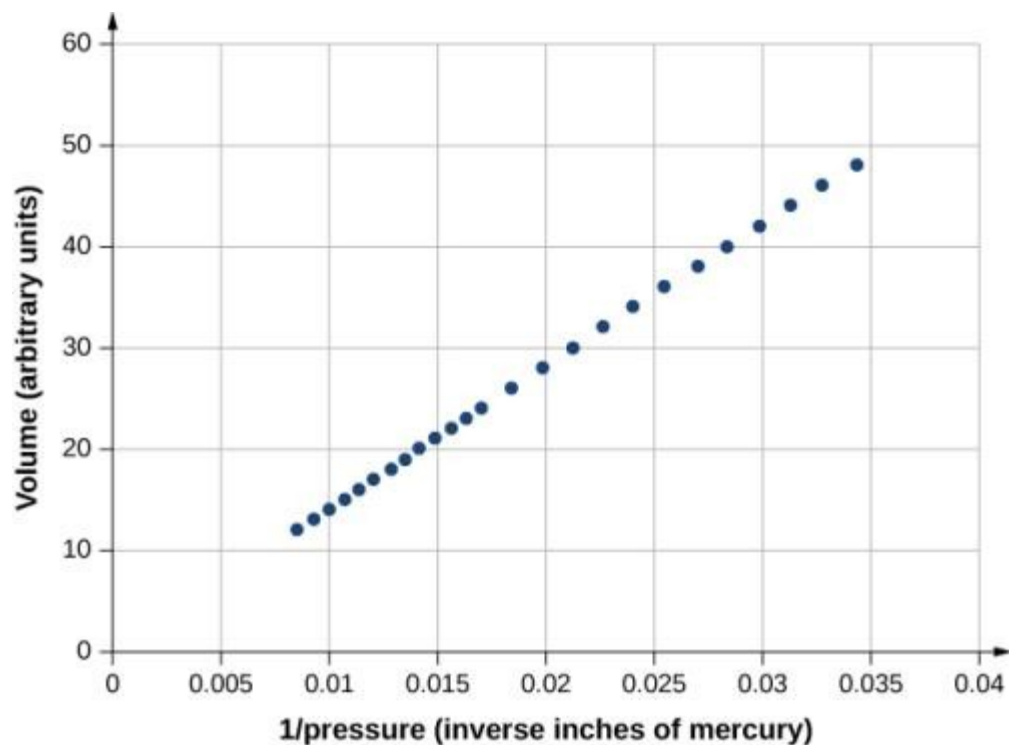
## FIGURE 2.3



- a) When air is pumped into a deflated tire, its volume first increases without much increase in pressure.
- b) When the tire is filled to a certain point, the tire walls resist further expansion, and the pressure increases with more air.
- c) Once the tire is inflated, its pressure increases with temperature.

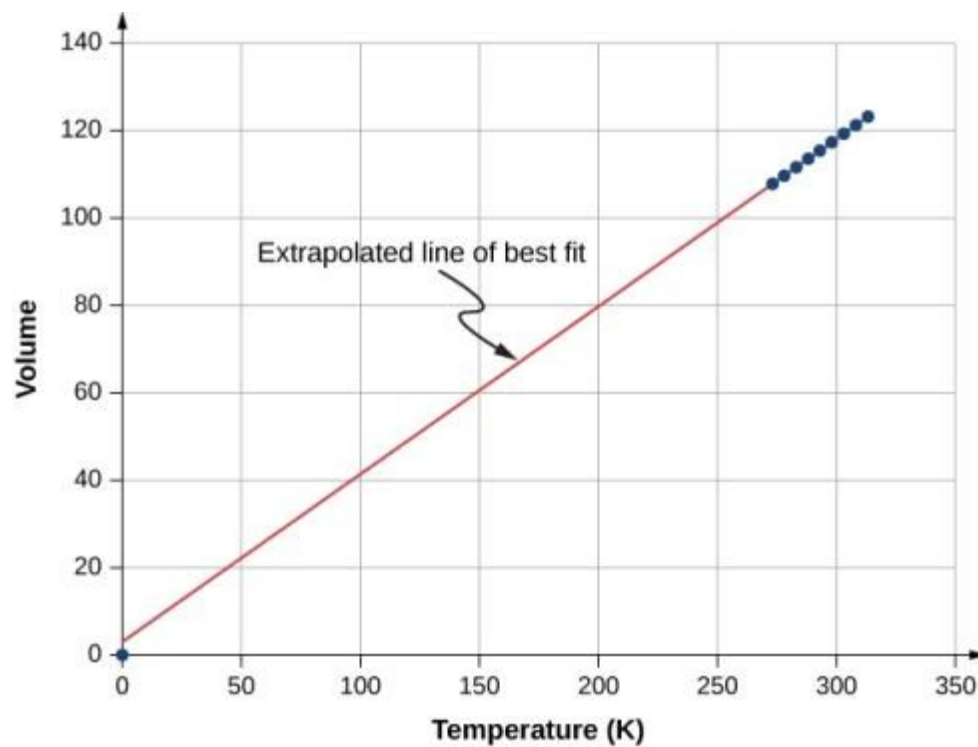
# **Ideal gas law**

## FIGURE 2.4



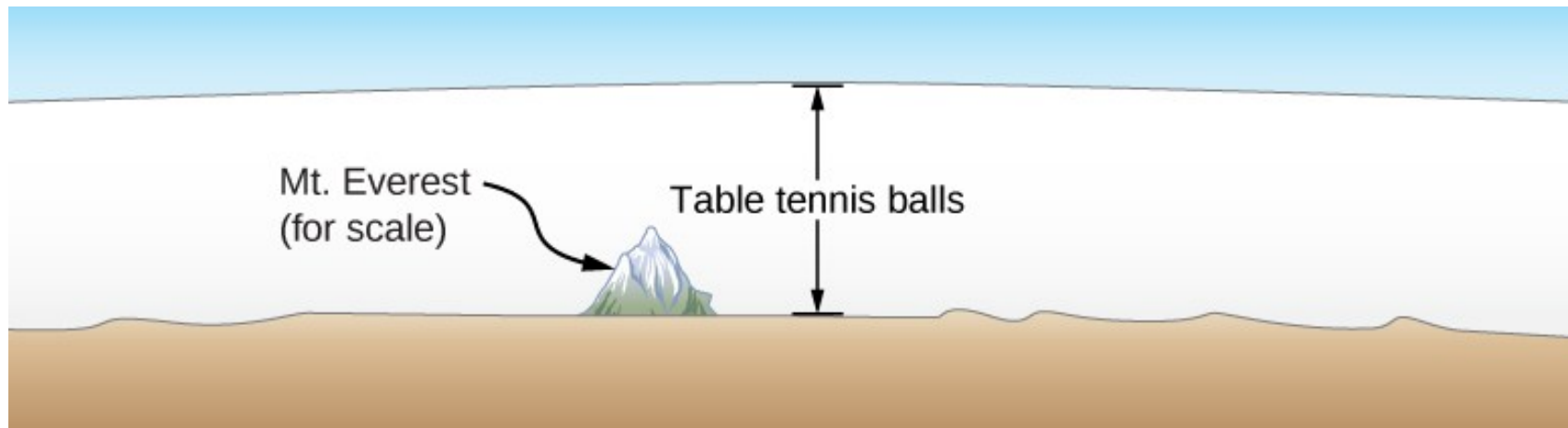
Robert Boyle and his assistant found that volume and pressure are inversely proportional. Here their data are plotted as  $V$  versus  $1/p$ ; the linearity of the graph shows the inverse proportionality. The number shown as the volume is actually the height in inches of air in a cylindrical glass tube. The actual volume was that height multiplied by the cross-sectional area of the tube, which Boyle did not publish. The data are from Boyle's book *A Defence of the Doctrine Touching the Spring and Weight of the Air...*, p. 60.<sup>[1]</sup>

## FIGURE 2.5



Experimental data showing that at constant pressure, volume is approximately proportional to temperature. The best-fit line passes approximately through the origin.<sup>[2]</sup>

## FIGURE 2.6

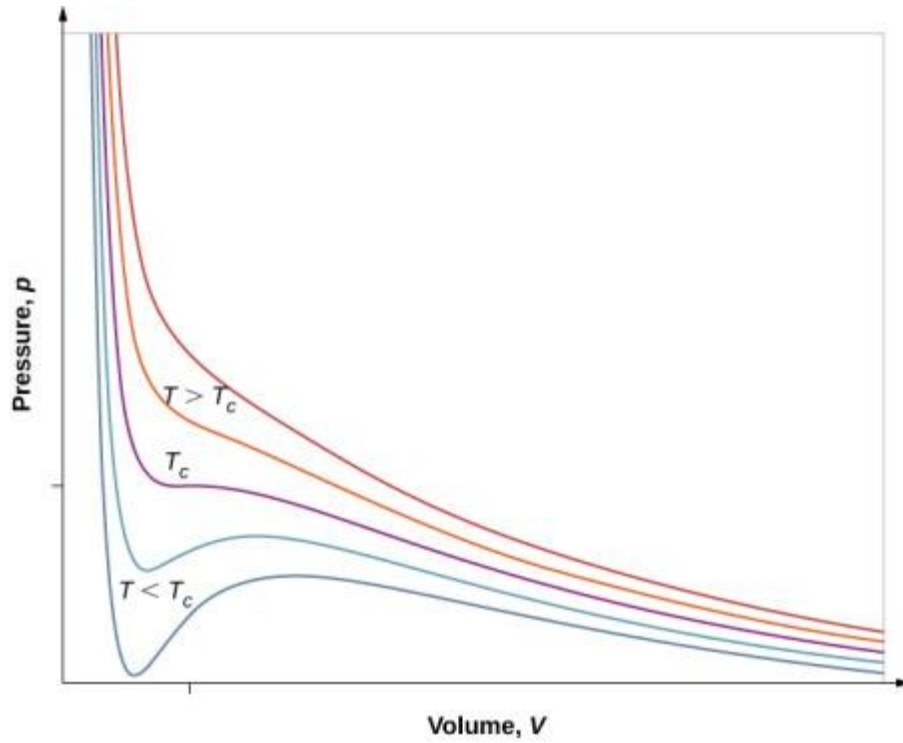


How big is a mole? On a macroscopic level, Avogadro's number of table tennis balls would cover Earth to a depth of about 40 km.



$$PV = nRT$$

# FIGURE 2.7

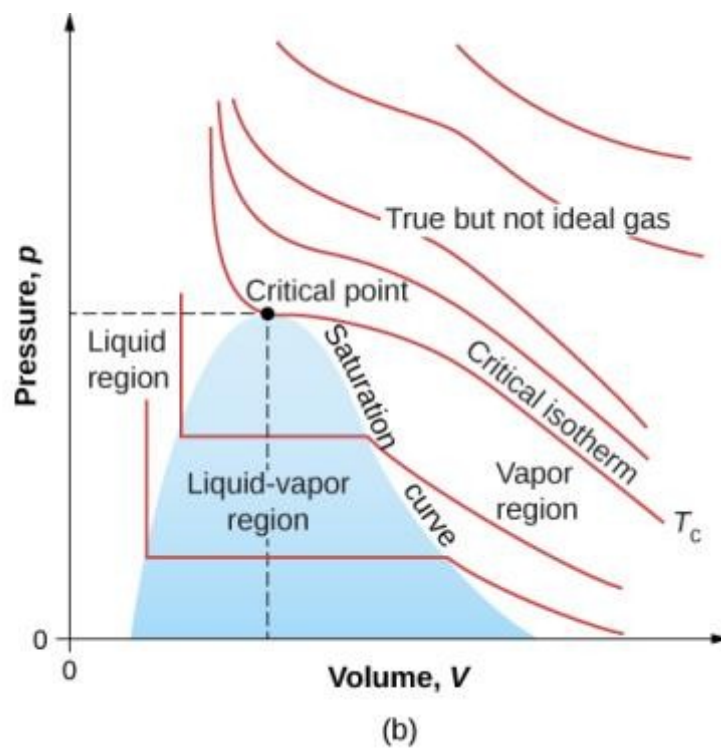
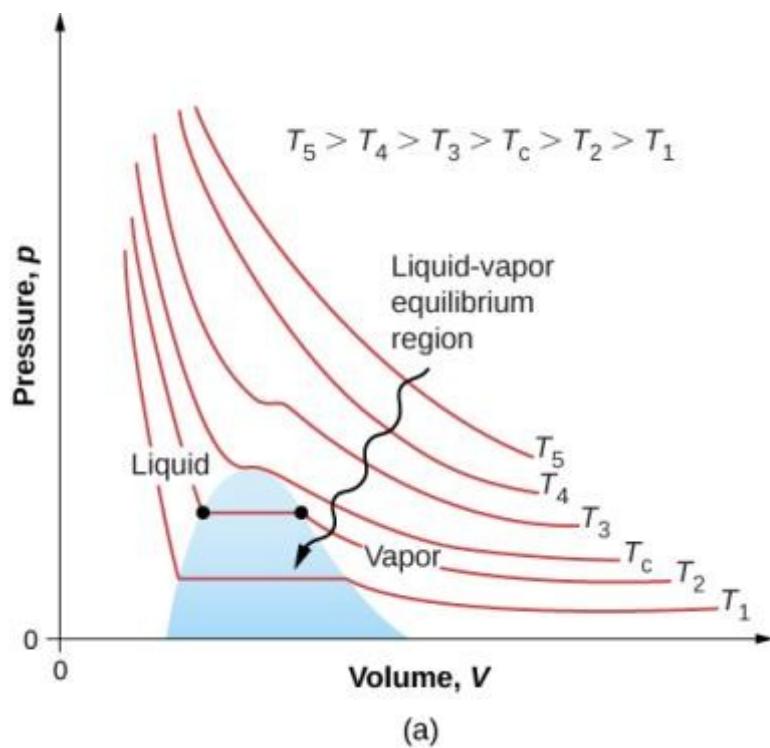


$$P = \frac{RT}{V - b} - \frac{a}{V^2}$$

- P = pressure
- R = universal gas constant
- T = absolute temperature
- V = molar volume
- b = gas constant b
- {a} = gas constant a
- V = molar volume

$pV$  diagram for a Van der Waals gas at various temperatures. The red curves are calculated at temperatures above the critical temperature and the blue curves at temperatures below it. The blue curves have an oscillation in which volume ( $V$ ) increases with increasing pressure ( $p$ ), an impossible situation, so they must be corrected as in **Figure 2.8**. (credit: "Eman"/Wikimedia Commons)

# FIGURE 2.8

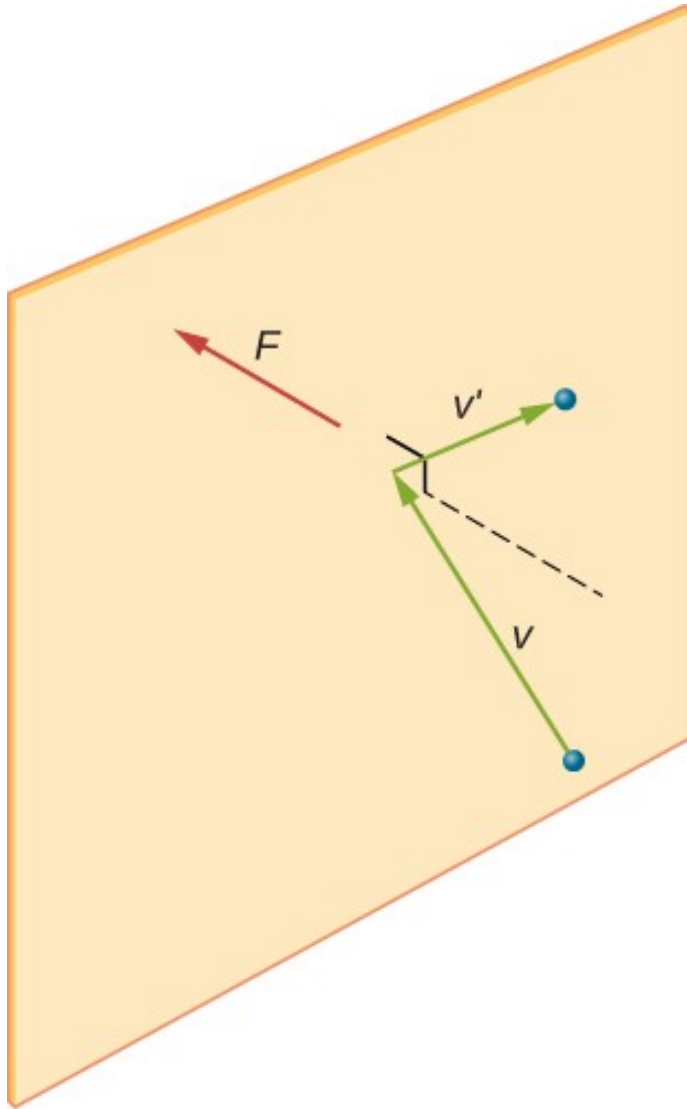


$pV$  diagrams.

- Each curve (isotherm) represents the relationship between  $p$  and  $V$  at a fixed temperature; the upper curves are at higher temperatures. The lower curves are not hyperbolas because the gas is no longer an ideal gas.
- An expanded portion of the  $pV$  diagram for low temperatures, where the phase can change from a gas to a liquid. The term "vapor" refers to the gas phase when it exists at a temperature below the boiling temperature.

**How it works  
microscopically**

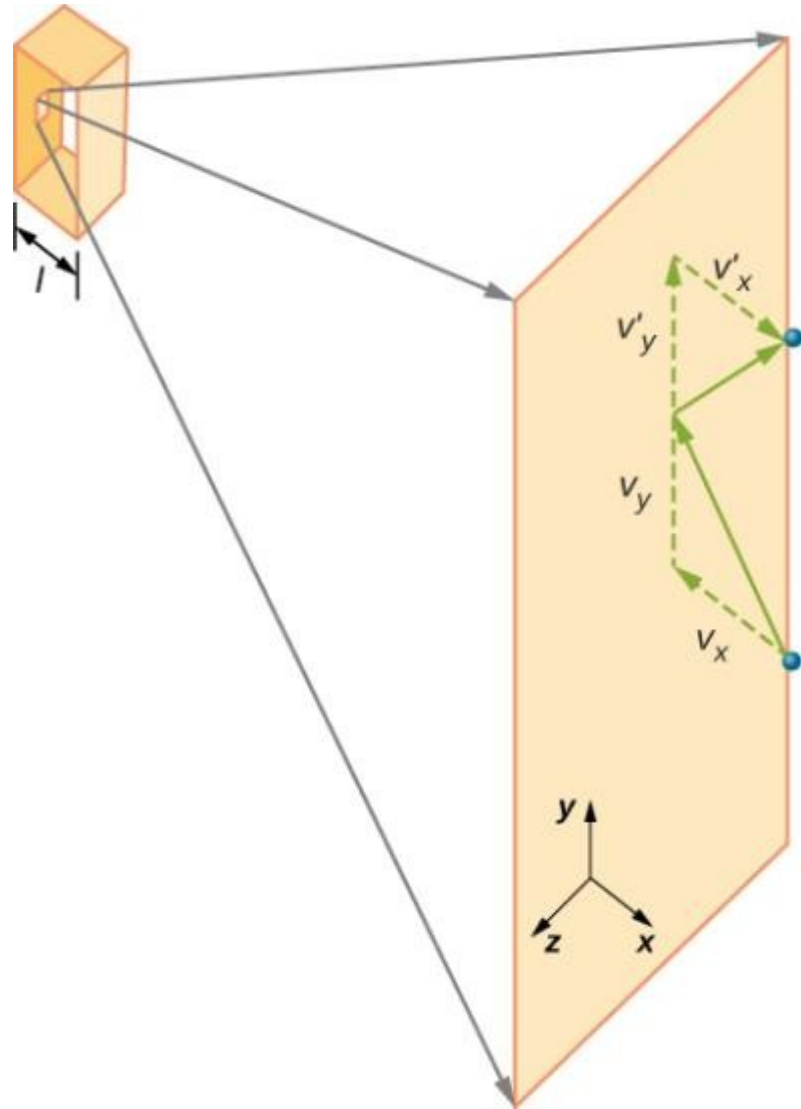
## FIGURE 2.9



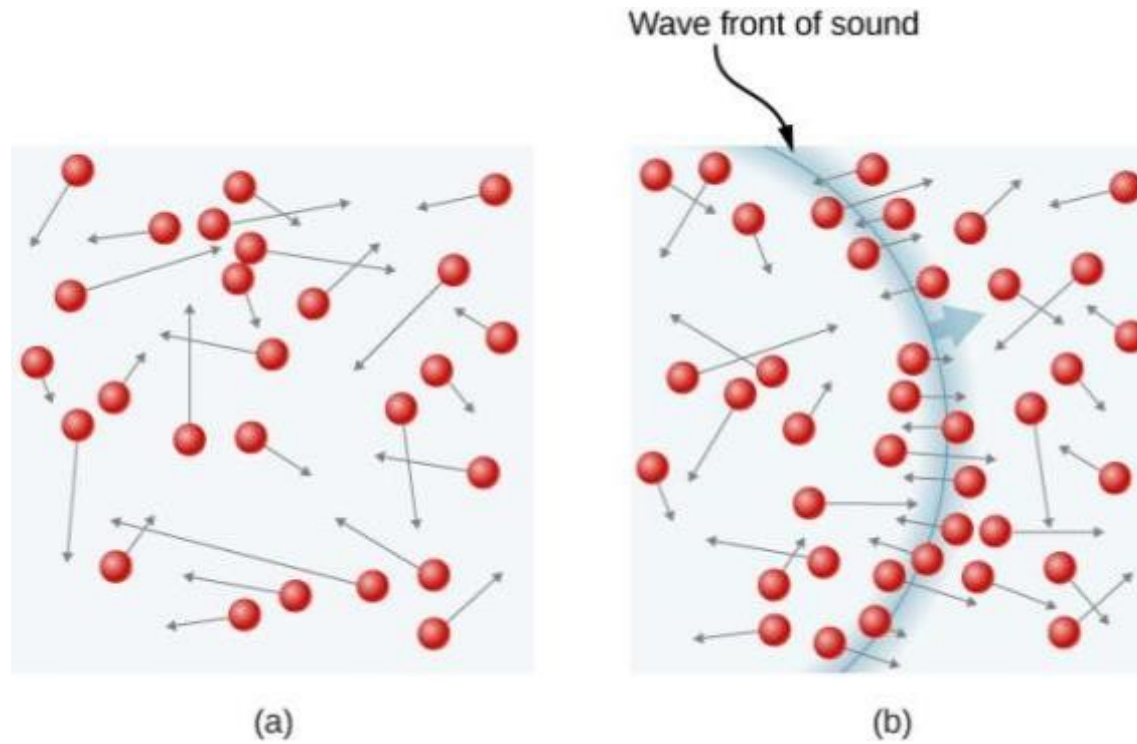
When a molecule collides with a rigid wall, the component of its momentum perpendicular to the wall is reversed. A force is thus exerted on the wall, creating pressure.

Gas in a box exerts an outward pressure on its walls. A molecule colliding with a rigid wall has its velocity and momentum in the  $x$ -direction reversed. This direction is perpendicular to the wall. The components of its velocity momentum in the  $y$ - and  $z$ -directions are not changed, which means there is no force parallel to the wall.

**FIGURE 2.10**



## FIGURE 2.11

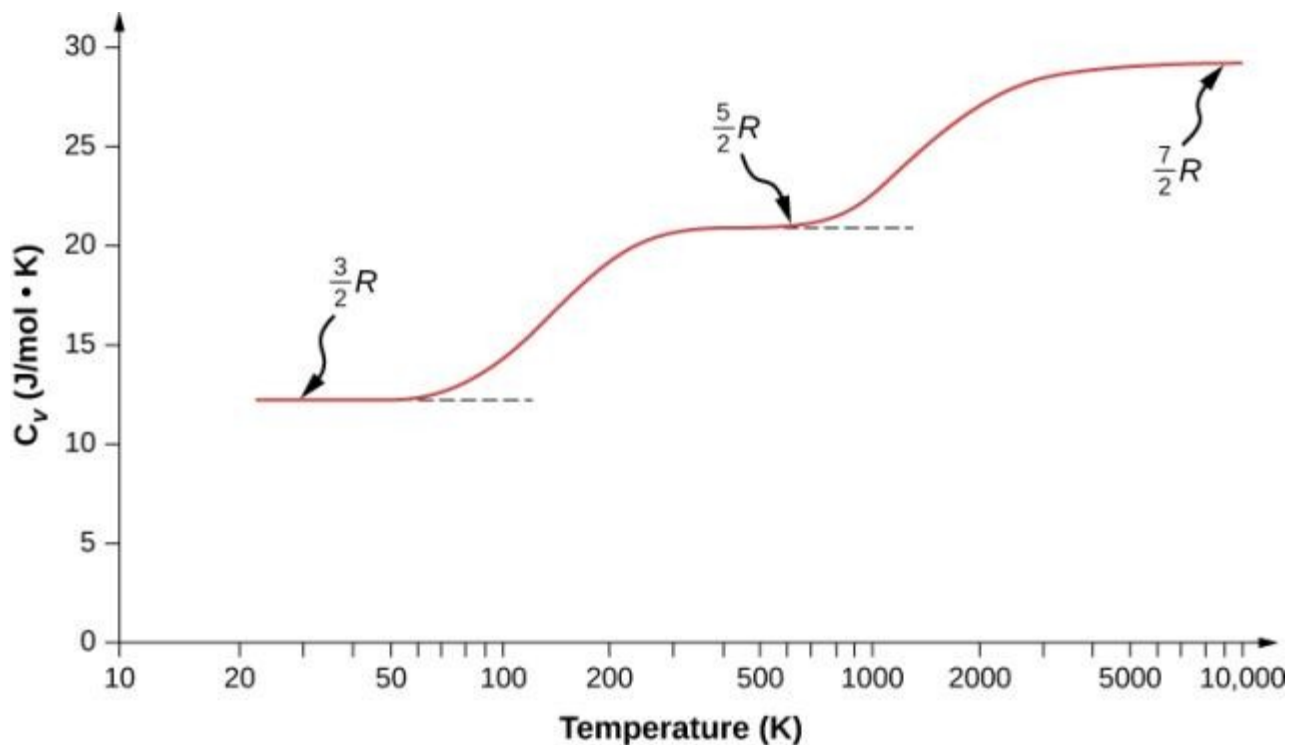


- a) In an ordinary gas, so many molecules move so fast that they collide billions of times every second.
- b) Individual molecules do not move very far in a small amount of time, but disturbances like sound waves are transmitted at speeds related to the molecular speeds.

**Specific heat**

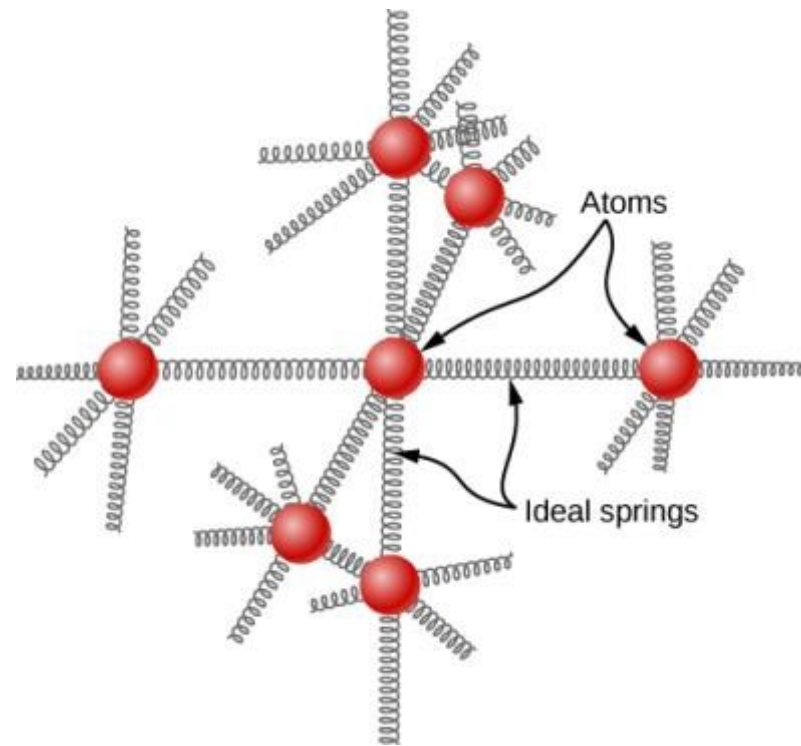


## FIGURE 2.13



The molar heat capacity of hydrogen as a function of temperature (on a logarithmic scale). The three “steps” or “plateaus” show different numbers of degrees of freedom that the typical energies of molecules must achieve to activate. Translational kinetic energy corresponds to three degrees of freedom, rotational to another two, and vibrational to yet another two.

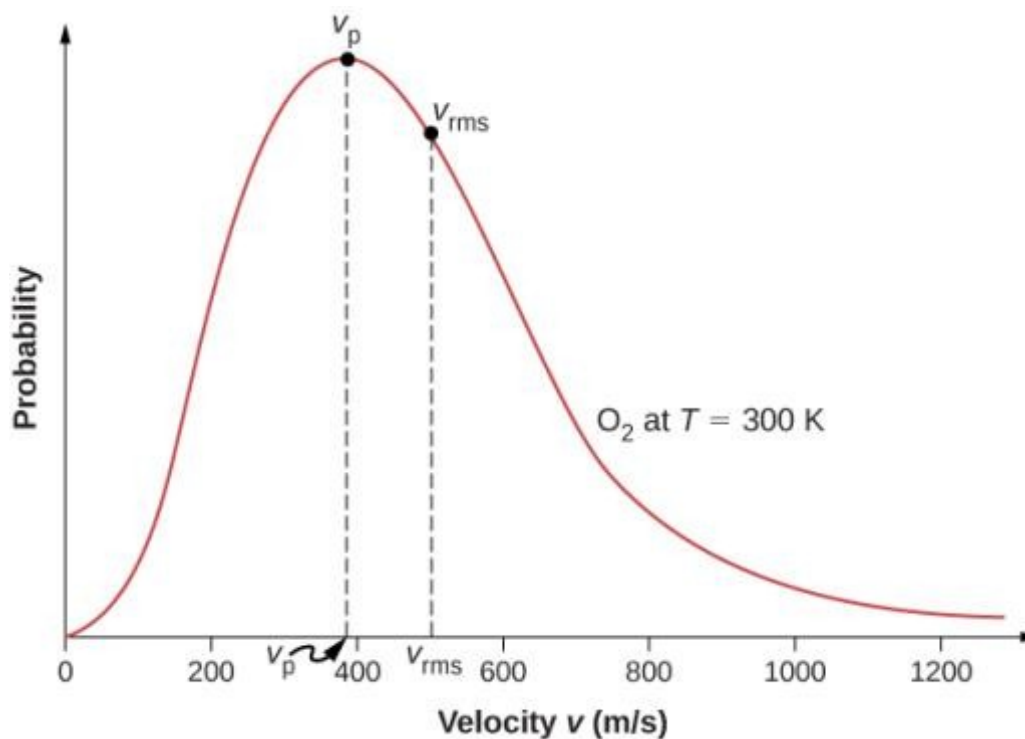
## FIGURE 2.14



In a simple model of a solid element, each atom is attached to others by six springs, two for each possible motion:  $x$ ,  $y$ , and  $z$ . Each of the three motions corresponds to two degrees of freedom, one for kinetic energy and one for potential energy. Thus  $d = 6$ .

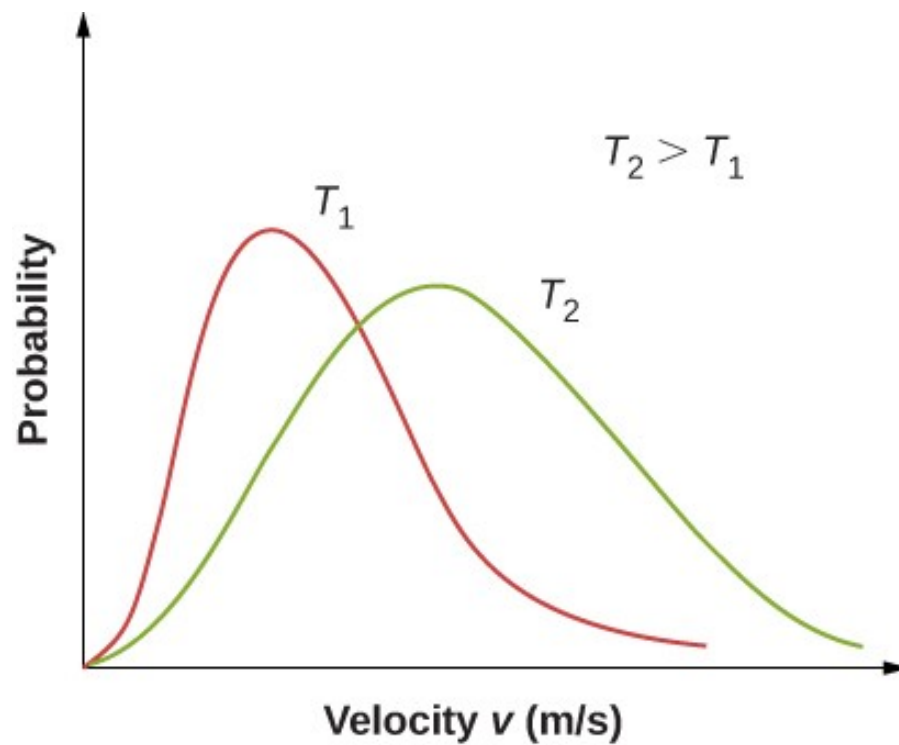
# **Temperature and speed**

## FIGURE 2.15



The Maxwell-Boltzmann distribution of molecular speeds in an ideal gas. The most likely speed  $v_p$  is less than the rms speed  $v_{rms}$ . Although very high speeds are possible, only a tiny fraction of the molecules have speeds that are an order of magnitude greater than  $v_{rms}$ .

## FIGURE 2.16



The Maxwell-Boltzmann distribution is shifted to higher speeds and broadened at higher temperatures.



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