

Kvikfræði gass - kinetic theory of gases

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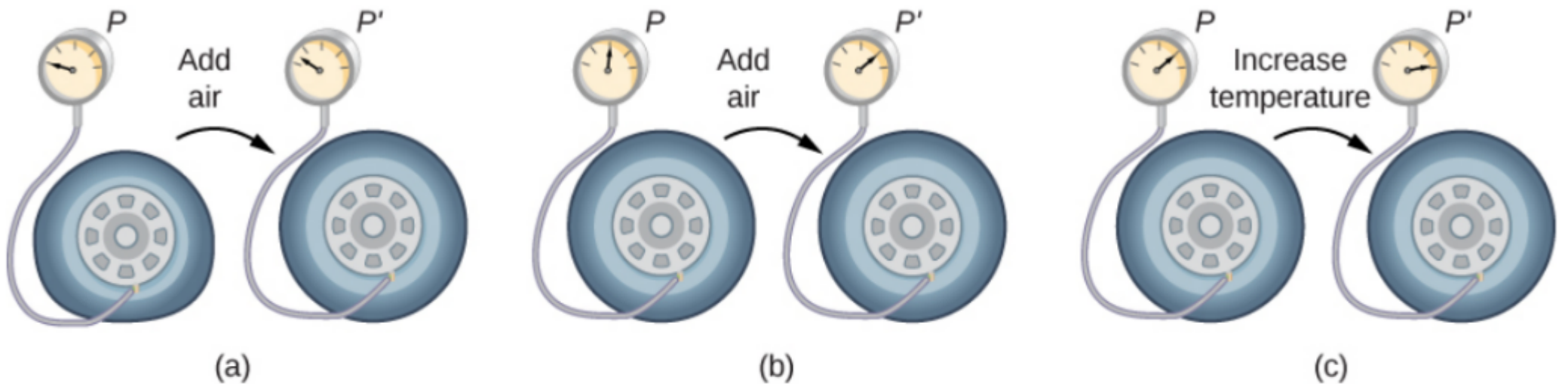


Figure 2.3 (a) When air is pumped into a deflated tire, its volume first increases without much increase in pressure. (b) When the tire is filled to a certain point, the tire walls resist further expansion, and the pressure increases with more air. (c) Once the tire is inflated, its pressure increases with temperature.

Eitt mól $6,022 \times 10^{23}$ atóm eða sameindir --> fjöleindafraði - safneðlisfraði
 Skoðum sígilda lýsingu

Rúmmál - þrýstingur, Robert Boyle

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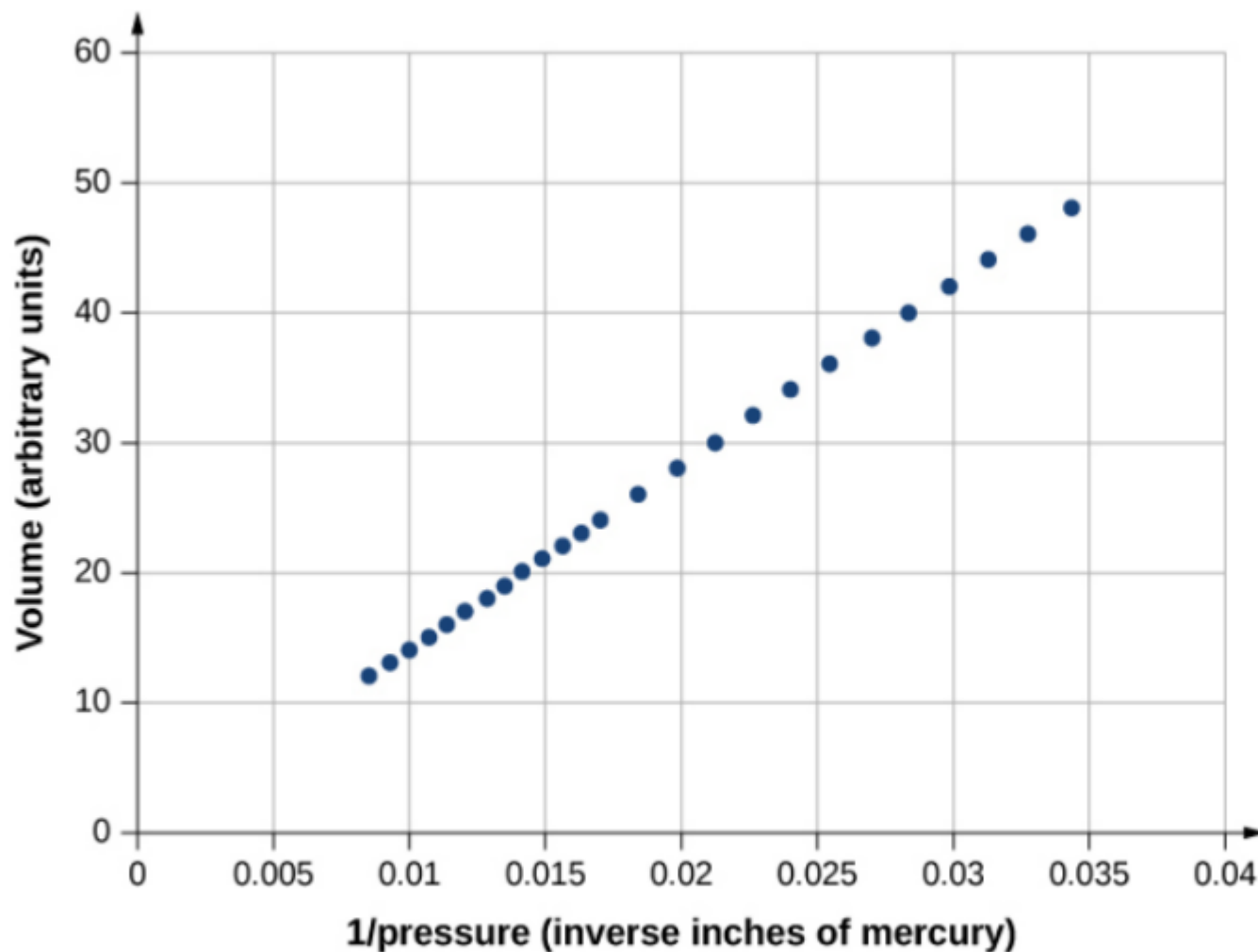
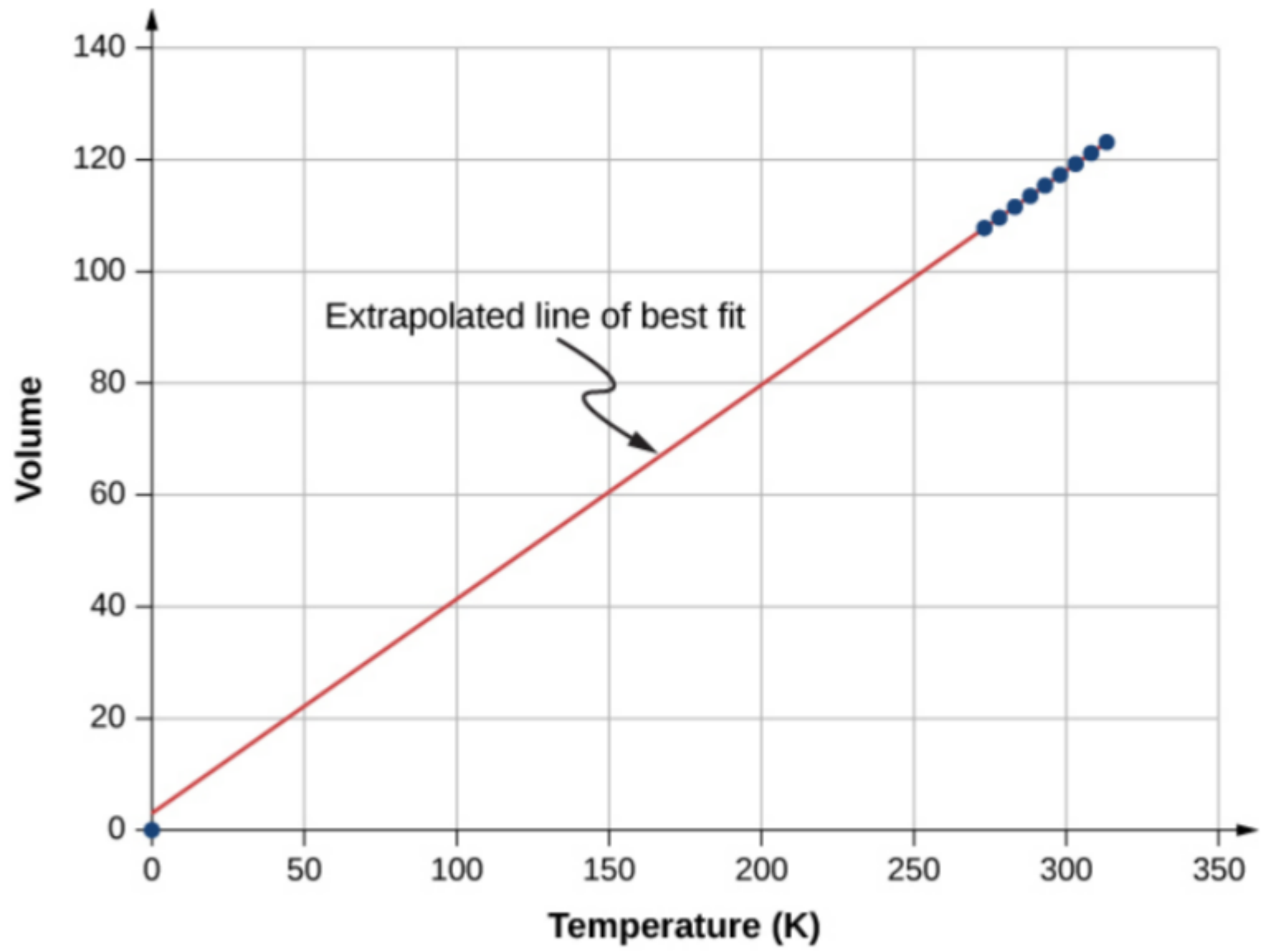


Figure 2.4 Robert Boyle and his assistant found that volume and pressure are inversely proportional. Here their data are plotted as V versus $1/p$; the linearity of the graph shows the inverse proportionality. The number shown as the volume is actually the height in inches of air in a cylindrical glass 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. 60.¹



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Rúmmálið virðist hverfa við $T = 0$, (leiddi til upphafs Kelvin-kvarðans)

Ideal Gas Law

The ideal gas law states that

$$pV = Nk_B T,$$

Ástandsjafna

2.1

where p is the absolute pressure of a gas, V is the volume it occupies, N is the number of molecules in the gas, and T is its absolute temperature.

The constant k_B is called the **Boltzmann constant** in honor of the Austrian physicist Ludwig Boltzmann (1844–1906) and has the value

$$k_B = 1.38 \times 10^{-23} \text{ J/K.}$$

$$\rightarrow \frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

Upphafsmáður
safneðlisfræði

Mól og tala Avogadrosar

$$N_A = 6,02 \cdot 10^{23} \text{ 1/mol}$$

$$N = N_A n, \quad n: \text{ fjöldi móla}$$

$$m_s = n M$$

efnismassi

massi eins móls

$$M = N_A m, \quad m: \text{ massi sameindar}$$

$$pV = Nk_B T = \frac{N}{N_A} (N_A k_B) T$$

Note that $n = N/N_A$ is the number of moles. We define the **universal gas constant** as $R = N_A k_B$, and obtain the ideal gas law in terms of moles.

Ideal Gas Law (in terms of moles)

In terms of number of moles n , the ideal gas law is written as

$$pV = nRT.$$

Ástandsjafna

2.3

In SI units,

$$R = N_A k_B = (6.02 \times 10^{23} \text{ mol}^{-1}) \left(1.38 \times 10^{-23} \frac{\text{J}}{\text{K}} \right) = 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}}$$

In other units,

$$R = 1.99 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

You can use whichever value of R is most convenient for a particular problem.

Ástandsjafrna Johannes van der Waals

Leiðrétting vegna veiks aðdráttarkrafts milli sameinda og endanlegs rúmmáls þeirra

$$\left[p + a \left(\frac{n}{V} \right)^2 \right] (V - nb) = nRT$$

Greinilegir eiginleikar gass,
sem ekki er kjörgas

(ekki punkt eindir - sameindirnar
víxlverkast)

Virial expansion -
eflisliðun

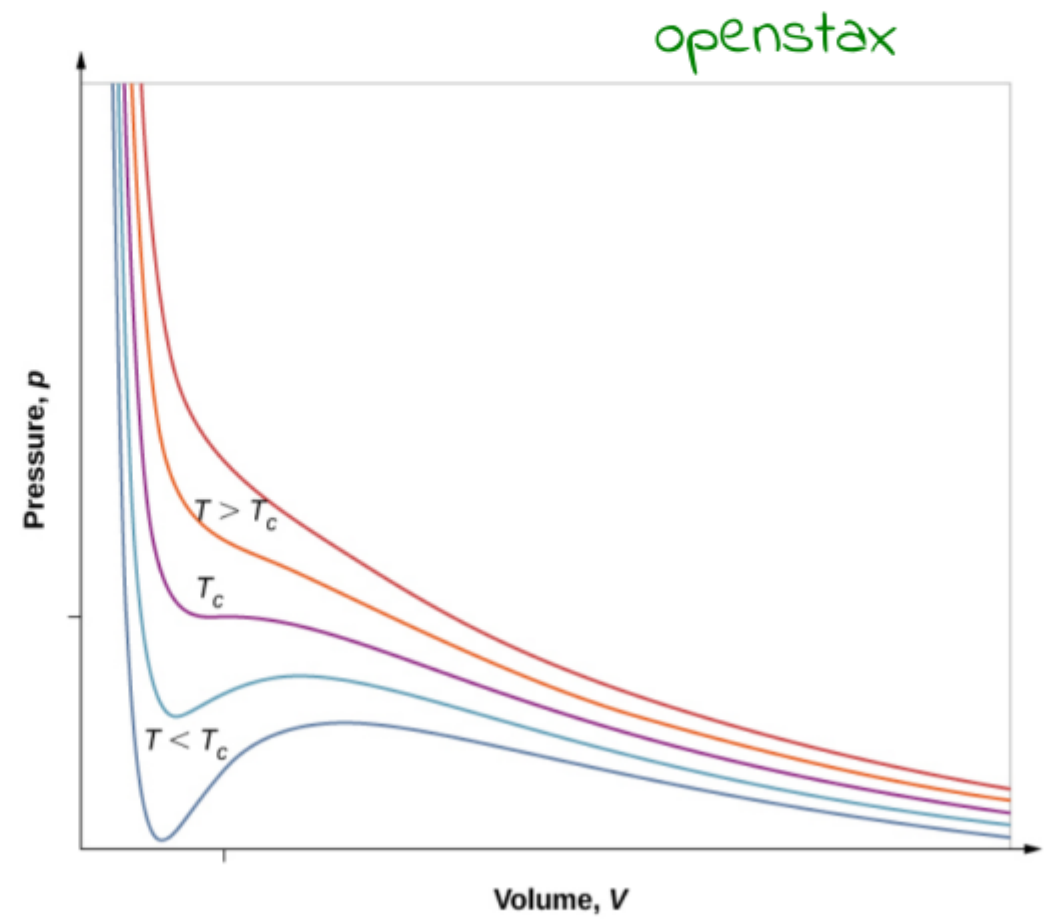


Figure 2.7 pV diagram for a Van der Waals gas at various temperatures. The red curves are calculated at temperatures above the critical temperature and the blue curves at temperatures below it. The blue curves have an oscillation in which volume (V) increases with increasing pressure (P), an impossible situation, so they must be corrected as in Figure 2.8. (credit: "Eman"/Wikimedia Commons)

Jafnhitaferlar

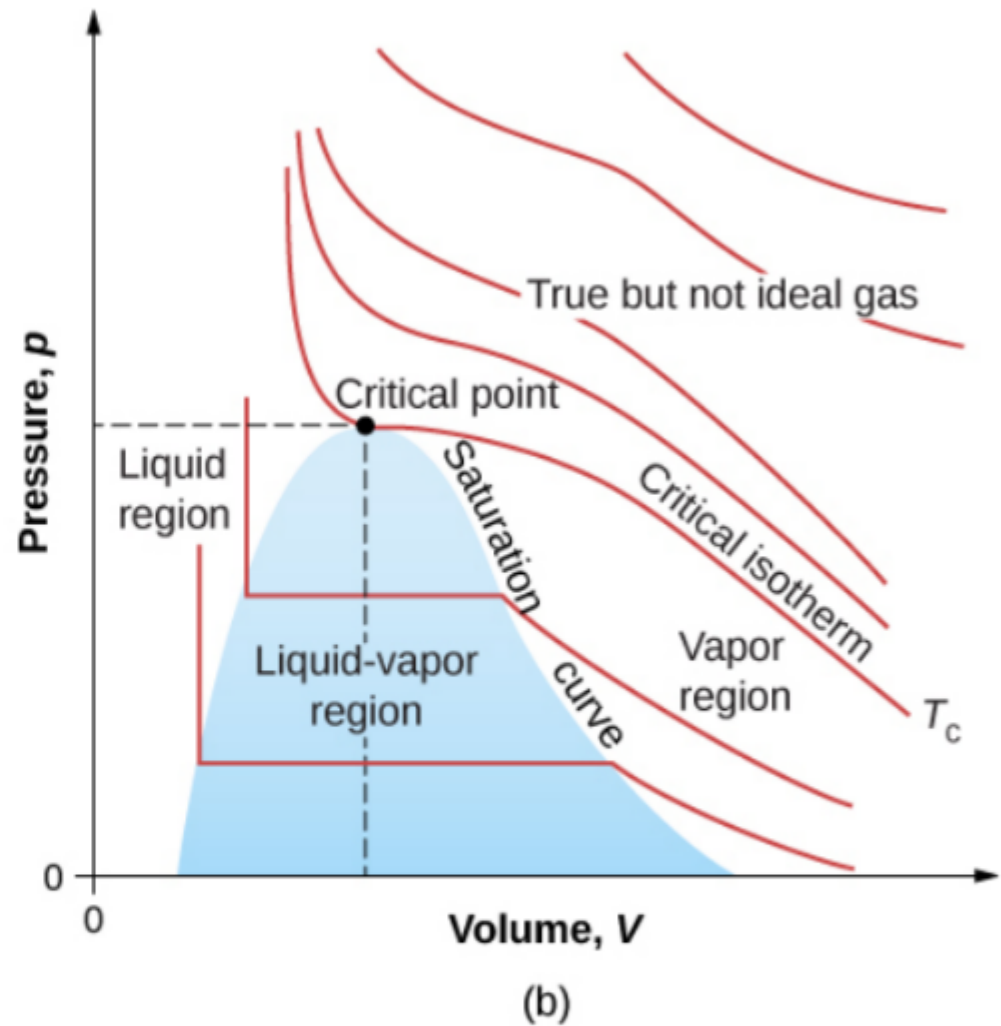
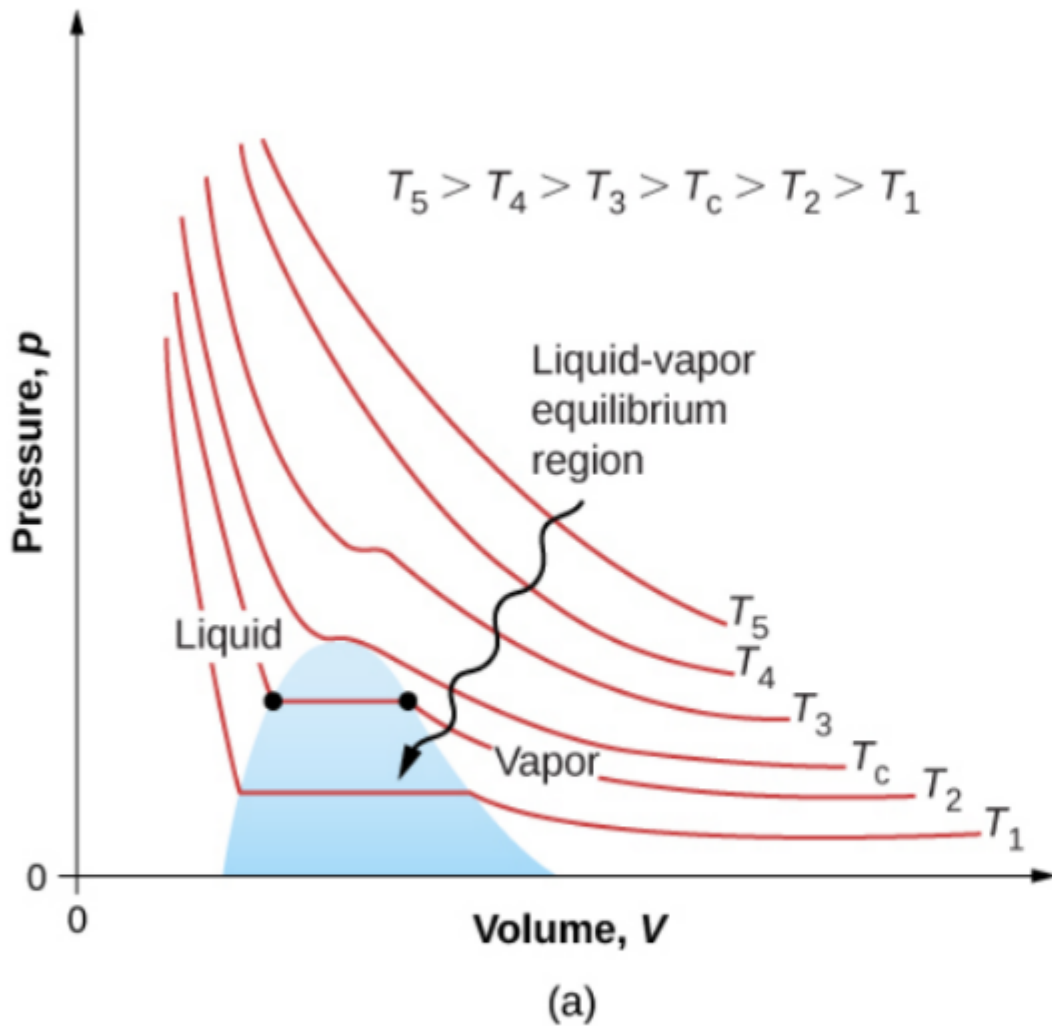
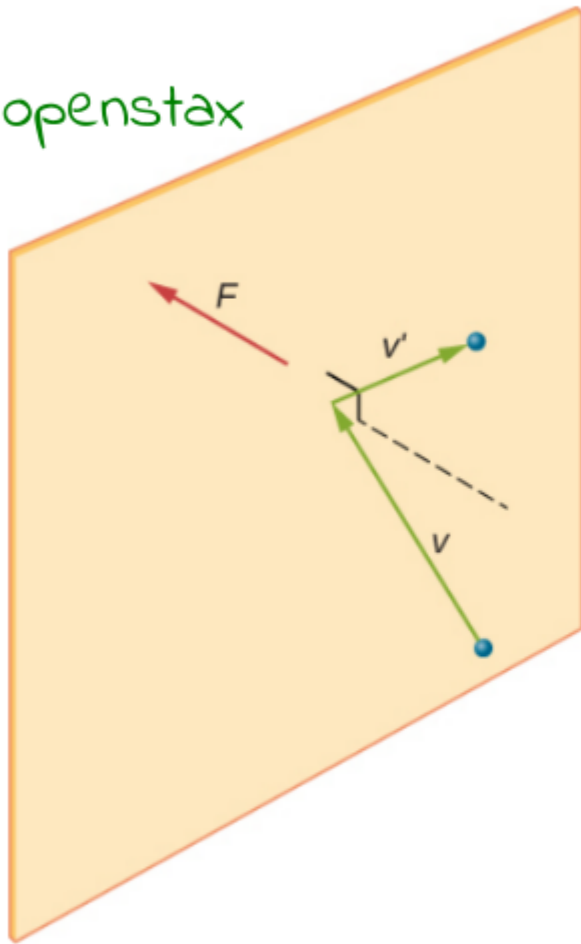


Figure 2.8 pV diagrams. (a) Each curve (isotherm) represents the relationship between p and V at a fixed temperature; the upper curves are at higher temperatures. The lower curves are not hyperbolas because the gas is no longer an ideal gas. (b) An expanded portion of the pV diagram for low temperatures, 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.

Kvikfræði gass

8

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1. Mikill fjöldi sameinda, N_A
2. Lögmál Newtons
3. Mjög smáar sameindir
4. Fjarandi árekstrar
5. Markgildissetning tölfræðinnar

brýstingur á vegg vegna fjarandi árekstra

$$\Delta m v = +m v_x - (-m v_x) = 2m v_x$$

$$F_i = \frac{\Delta p_i}{\Delta t} = \frac{2m v_{ix}}{\Delta t} \leftarrow \begin{array}{l} \text{meðaltími milli} \\ \text{árekstra} \end{array}$$

$$= \frac{2m v_{ix}}{2l / v_{ix}} = \frac{m v_i^2}{l}$$

$$F = \sum_{i=1}^N F_i = \frac{m}{l} \sum_{i=1}^N v_{ix}^2 = N \frac{m}{l} \left[\frac{1}{N} \sum_{i=1}^N v_{ix}^2 \right] = N \frac{m}{l} \langle v_x^2 \rangle$$


l : hláengd kassa

$$\langle v^2 \rangle = \langle v_x^2 \rangle + \langle v_y^2 \rangle + \langle v_z^2 \rangle = 3 \langle v_x^2 \rangle$$

einsátta 

$$\rightarrow F = \frac{Nm \langle v^2 \rangle}{3l}, \quad P = \frac{F}{A} = N \frac{m \langle v^2 \rangle}{3Al} = \frac{Nm \langle v^2 \rangle}{3V}$$

$$\rightarrow PV = \frac{1}{3} Nm \langle v^2 \rangle, \quad \text{en líka } PV = Nk_B T$$

 ástandsjafrnan

Average Kinetic Energy per Molecule

The average kinetic energy of a molecule is directly proportional to its absolute temperature:

$$\bar{K} = \frac{1}{2} m \bar{v}^2 = \frac{3}{2} k_B T.$$

2.6

$$\rightarrow \text{innri orka kjörgass: } E_{\text{tot}}(T) = N \langle K \rangle = \frac{3}{2} nRT$$

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RMS Speed of a Molecule

The root-mean-square (rms) speed of a molecule, or the square root of the average of the square of the speed $\overline{v^2}$, is

$$v_{\text{rms}} = \sqrt{\overline{v^2}} = \sqrt{\frac{3k_B T}{m}}$$

2.8

T. d. N_2 \vec{v} $20^\circ C \rightarrow v_{\text{rms}} \approx 511 \text{ m/s}$
Wave front of sound

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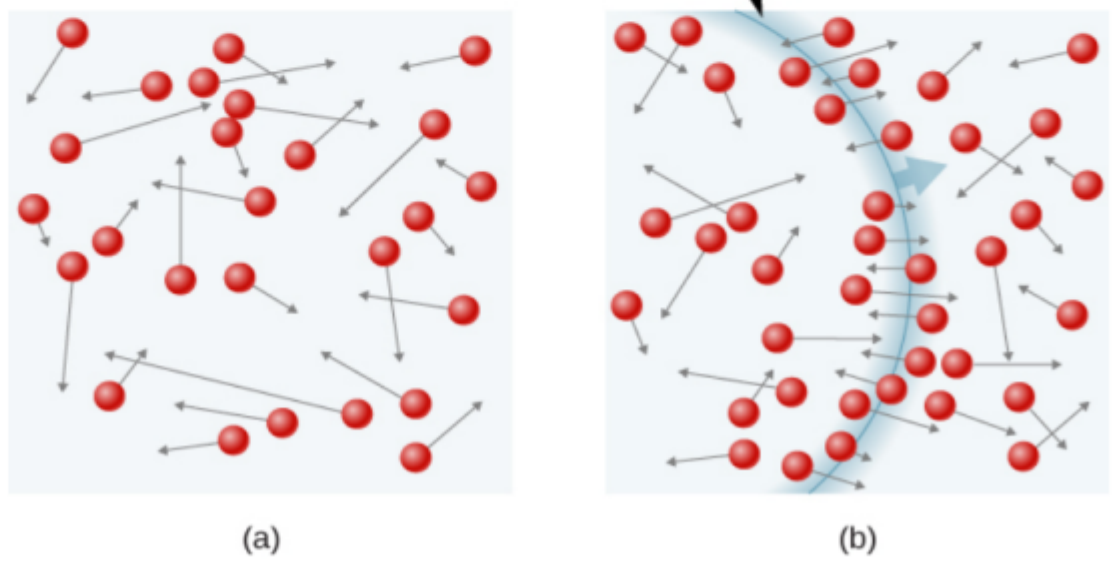


Figure 2.11 (a) In an ordinary gas, so many molecules move so fast that they collide billions of times every second. (b) Individual molecules do not move very far in a small amount of time, but disturbances like sound waves are transmitted at speeds related to the molecular speeds.

Hlutþrýstingur

- Partial pressure is the pressure a gas would create if it existed alone
- Dalton's law states that the total pressure is the sum of the partial pressures of all of the gases present
- For any two gases (labeled 1 and 2) in equilibrium in a container

$$\frac{P_1}{n_1} = \frac{P_2}{n_2}$$

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- vapor pressure is the partial pressure of a vapor at which it is in equilibrium with the liquid (or solid, in the case of sublimation) phase of the same substance

Hlutþrýstingur vatns í lofti er alltaf lægri en gufuþrýstingur þess

Rakastig

T (°C)	Vapor Pressure (Pa)
0	610.5
3	757.9
5	872.3
8	1073
10	1228
13	1497
15	1705
18	2063
20	2338
23	2809
25	3167
30	4243
35	5623
40	7376

$$R.H. = \frac{\text{Partial pressure of water vapor at } T}{\text{Vapor pressure of water at } T} \times 100\%$$

Meðalspölur - mean free path er 

Meðalspölur er meðal vegalengd milli árekstra sameinda

$$\lambda = \frac{V}{4\sqrt{2} \pi r^2 N} = \frac{k_B T}{4\sqrt{2} \pi r^2 p}$$

Meðaltími (meðalævi)

$$\tau = \frac{k_B T}{4\sqrt{2} \pi r^2 v_{rms}}$$

r: árekstraversnið

Table 2.2 Vapor Pressure of Water at Various Temperatures

varmarýmd og jafnskipting orku

varmarýmd einsatóma kjörgass á mól við fast rúmmál

$$C_V = \frac{1}{n} \left(\frac{\Delta Q}{\Delta T} \right)_V$$



$$C_V = \frac{3}{2} R$$

$$\Delta Q = \Delta \bar{E}_{\text{int}} = \frac{3}{2} n R \Delta T$$

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Equipartition Theorem

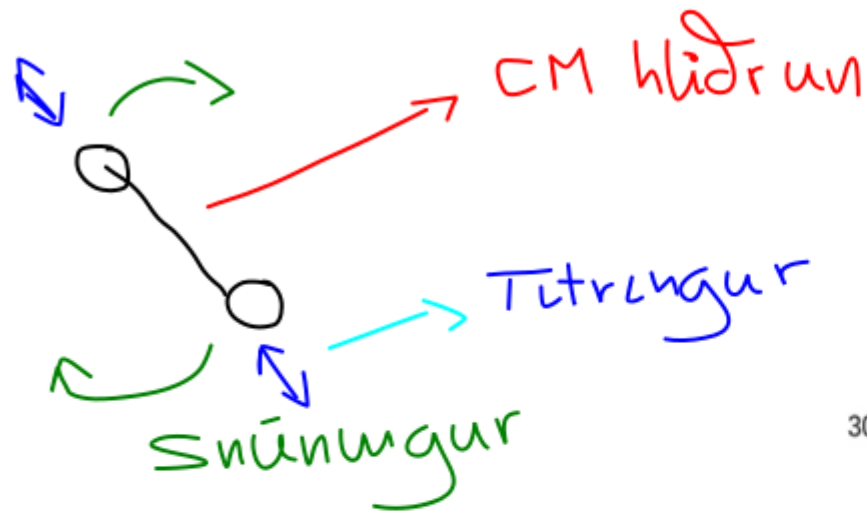
The energy of a thermodynamic system in equilibrium is partitioned equally among its degrees of freedom. Accordingly, the molar heat capacity of an ideal gas is proportional to its number of degrees of freedom, d :

$$C_V = \frac{d}{2} R.$$

2.14

Einatóma gas: $d = 3$

Frelsisgráður H_2



Það þarf vissa innri orku til þess að mismunandi frelsisgráður örvist eða vakni (skammtafræði)

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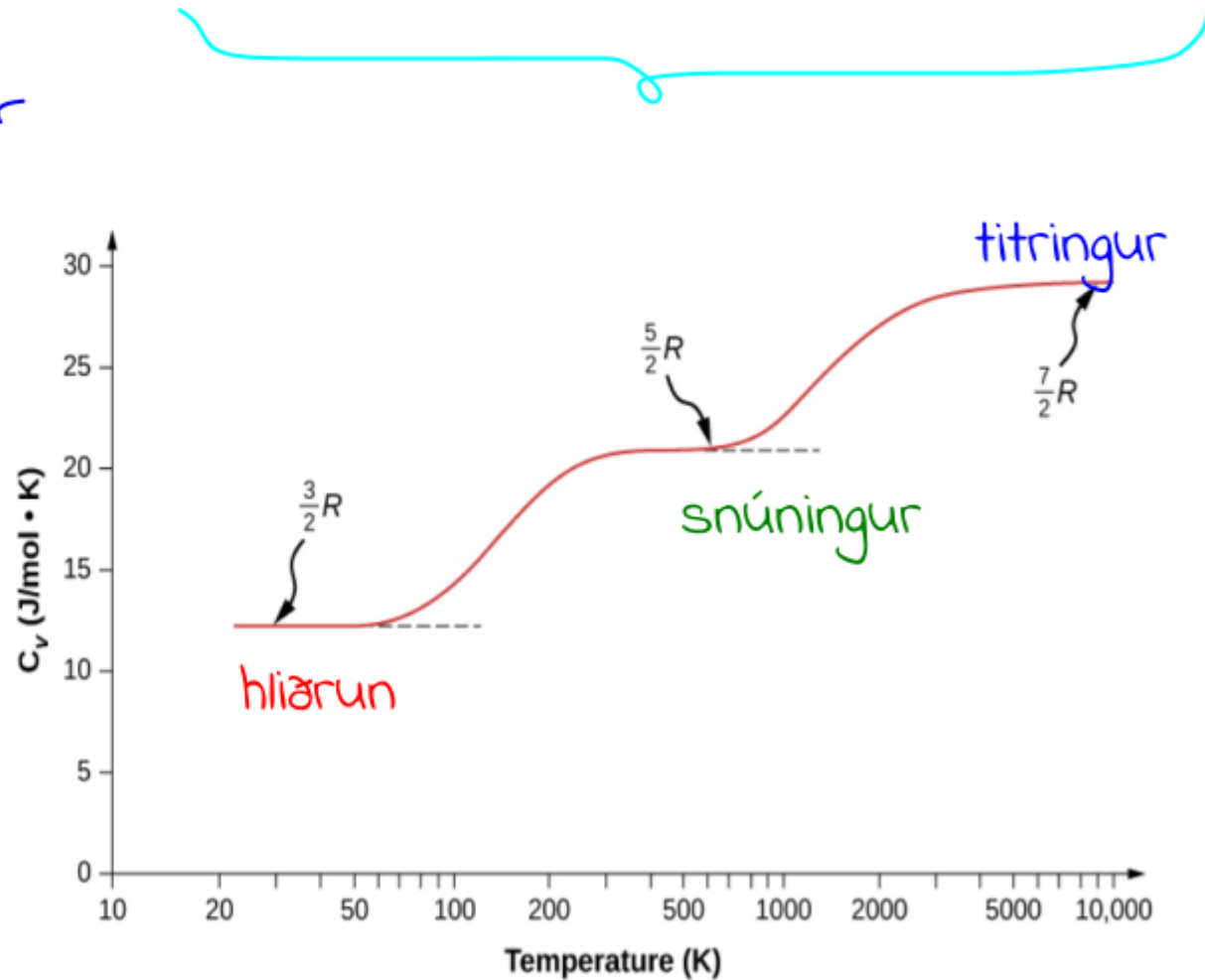


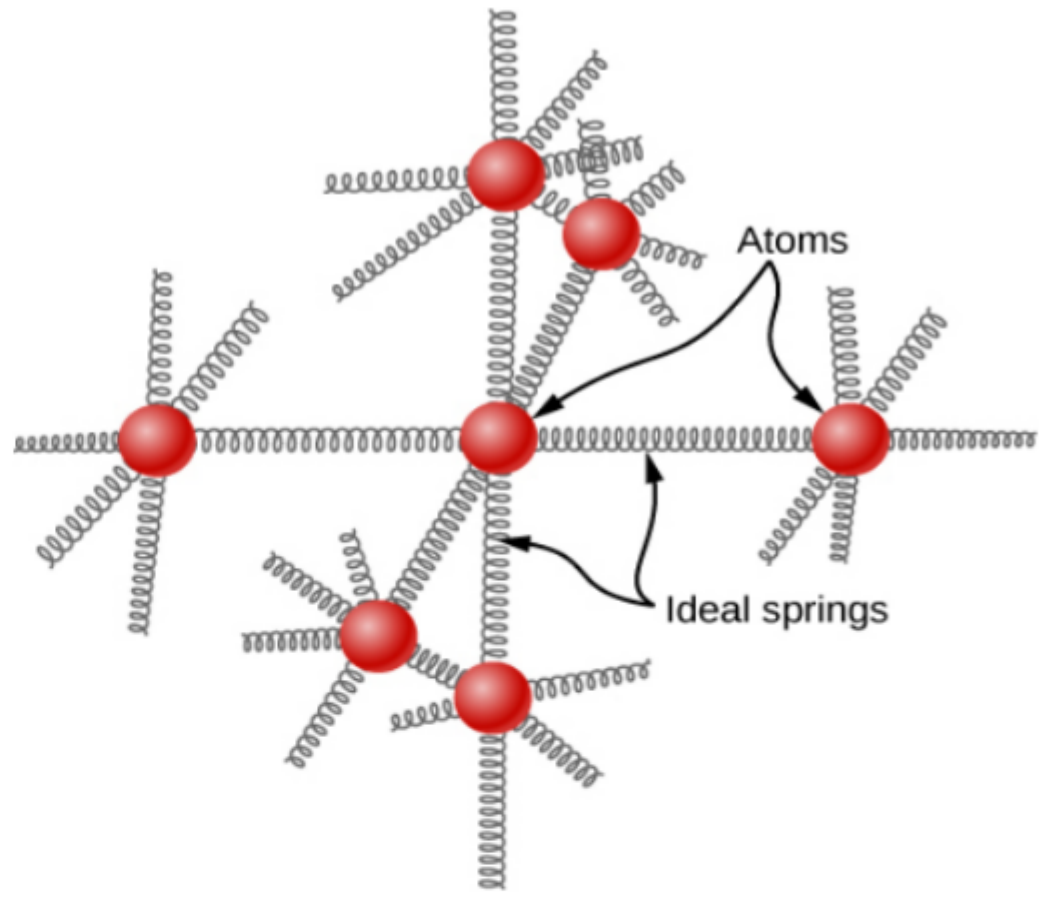
Figure 2.13 The molar heat capacity of hydrogen as a function of temperature (on a logarithmic scale). The three “steps” or “plateaus” show different numbers of degrees of freedom that the typical energies of molecules must achieve to activate. Translational kinetic energy corresponds to three degrees of freedom, rotational to another two, and vibrational to yet another two.

Fast efni

Í einföldu kristölluðu föstu efni þegar allir hjóðeindahættir eru virkaðir við nógu hátt T fæst

$$d = 6$$

$$\rightarrow C = 3R$$



Hraðadreifing Maxwells og Boltzmanns fyrir kjörgas

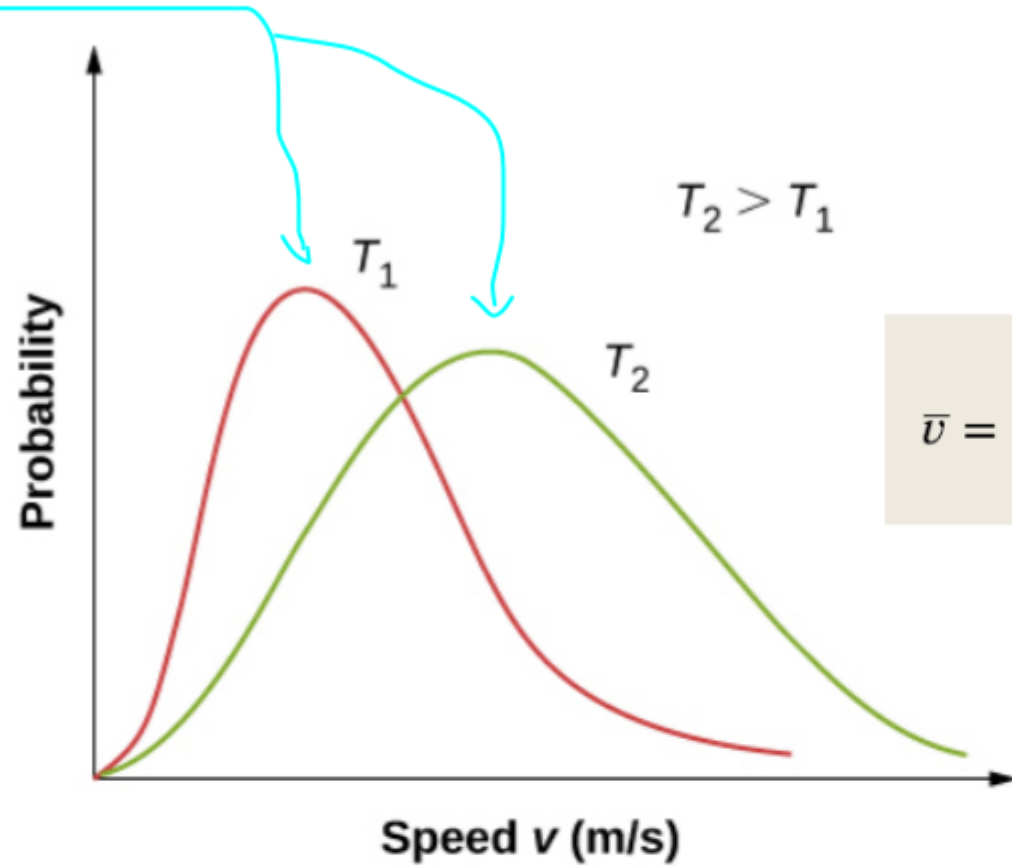
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Maxwell-Boltzmann Distribution of Speeds

The distribution function for speeds of particles in an ideal gas at temperature T is

$$f(v) = \frac{4}{\sqrt{\pi}} \left(\frac{m}{2k_B T} \right)^{3/2} v^2 e^{-mv^2/(2k_B T)}$$

2.15



$$\bar{v} = \int_0^{\infty} v f(v) dv = \sqrt{\frac{8}{\pi} \frac{k_B T}{m}} = \sqrt{\frac{8}{\pi} \frac{RT}{M}}$$

meðalhraðinn

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

$$v_p = \sqrt{\frac{2k_B T}{m}} = \sqrt{\frac{2RT}{M}}$$

líklegasti hraðinn