Introduction to Physics I

Ideal gas law

change of state, adiabatic changes, gas pressure

Kinetic gas theory

- equipartition, degrees of freedom
- mean free path
- Maxwell-Boltzmann distribution
- Brownian motion

Ideal gas examples: adiabatic processes, heat capacity

Real gas law: van der Waals equation

Please note:

No lecture
on Dec. 20

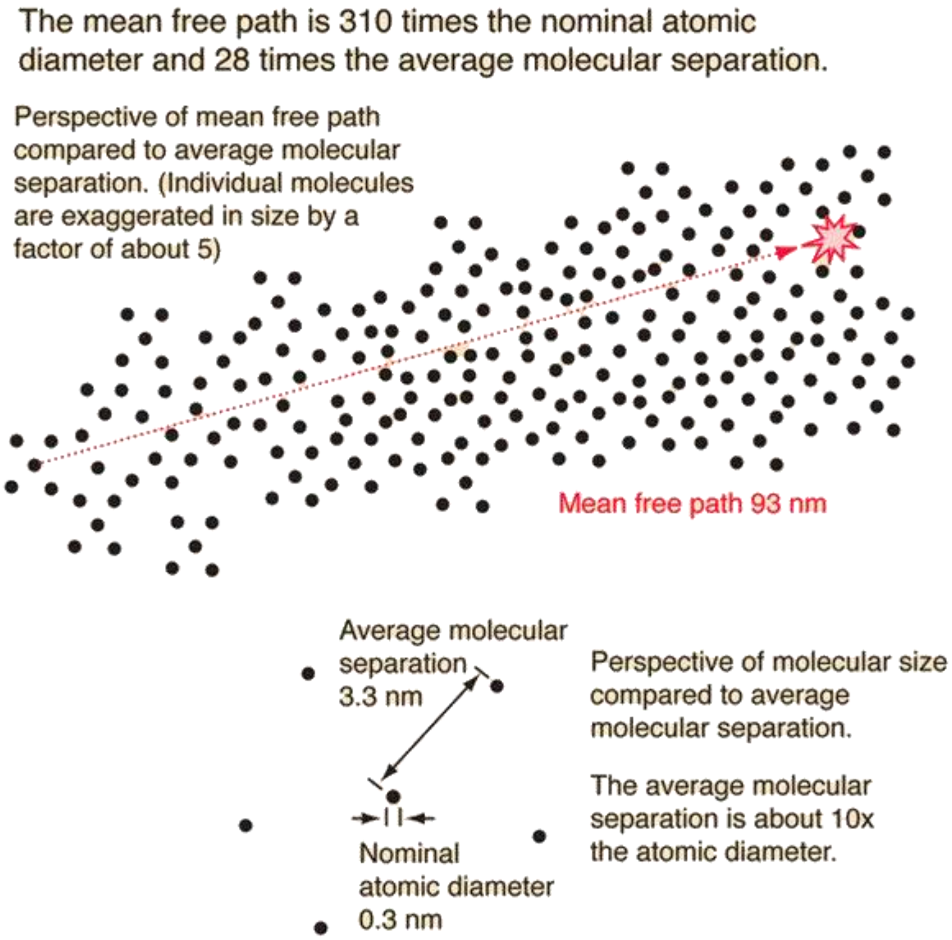
Introduction to Physics I

For Biologists, Geoscientists, & Pharmaceutical Scientists

mean free path, ideal gas at STP

STP
standard pressure
& temperature
P = 100kPa (1bar)
T = 273.15 K (0C)

Atomic diameter
assumed here
0.3nm



The mean free path is 310 times the nominal atomic diameter and 28 times the average molecular separation.

Perspective of mean free path compared to average molecular separation. (Individual molecules are exaggerated in size by a factor of about 5)

Perspective of molecular size compared to average molecular separation.

The average molecular separation is about 10x the atomic diameter.

Hyperphysics

Maxwell-Boltzmann distribution

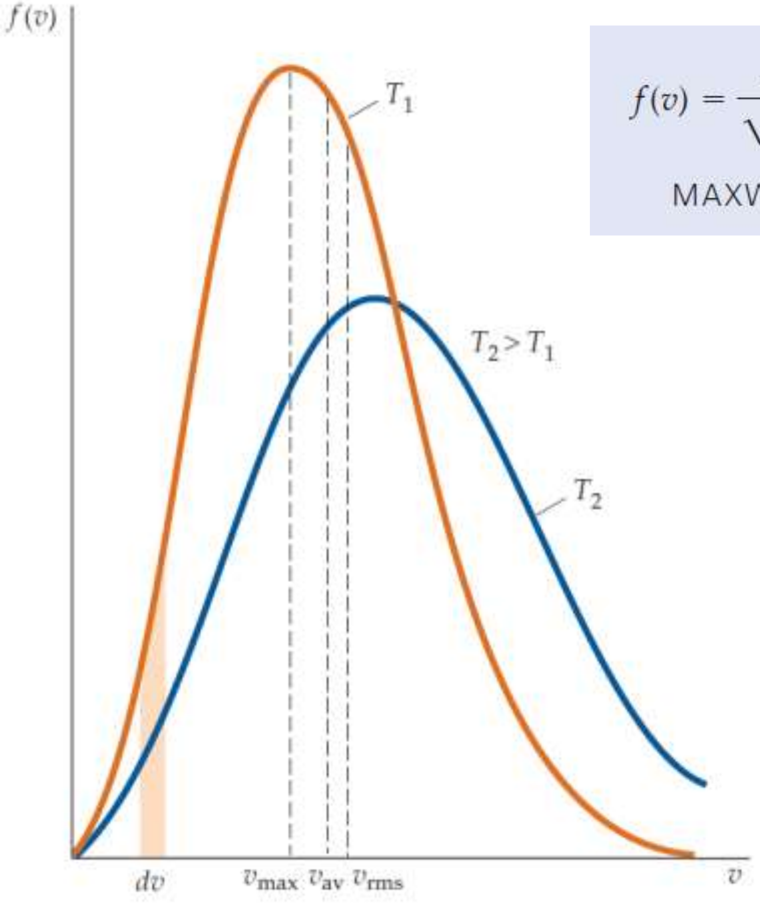


FIGURE 17-17 Distributions of molecular speeds in a gas at two temperatures, T_1 and $T_2 > T_1$. The shaded area $f(v)\,dv$ equals the fraction of the number of molecules having a particular speed in a narrow range of speeds dv. The mean speed v_{av} and the rms speed v_{rms} are both slightly greater than the most probable speed v_{max}.

$$f(v) = \frac{4}{\sqrt{\pi}}\left(\frac{m}{2kT}\right)^{3/2} v^2 e^{-mv^2/(2kT)} \qquad 17\text{-}36$$

MAXWELL–BOLTZMANN SPEED DISTRIBUTION FUNCTION

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adiabatic process

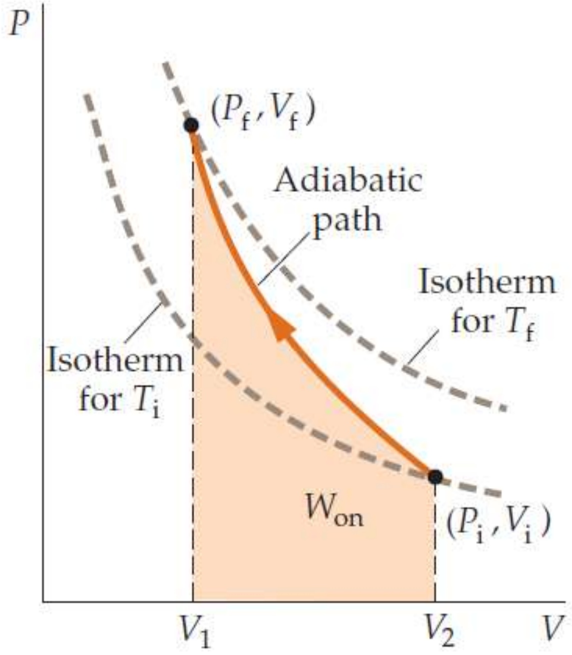

FIGURE 18-20 Quasi-static adiabatic compression of an ideal gas. The dashed lines are the isotherms for the initial and final temperatures. The curve connecting the initial and final states of the adiabatic compression is steeper than the isotherms because the temperature increases during the compression.

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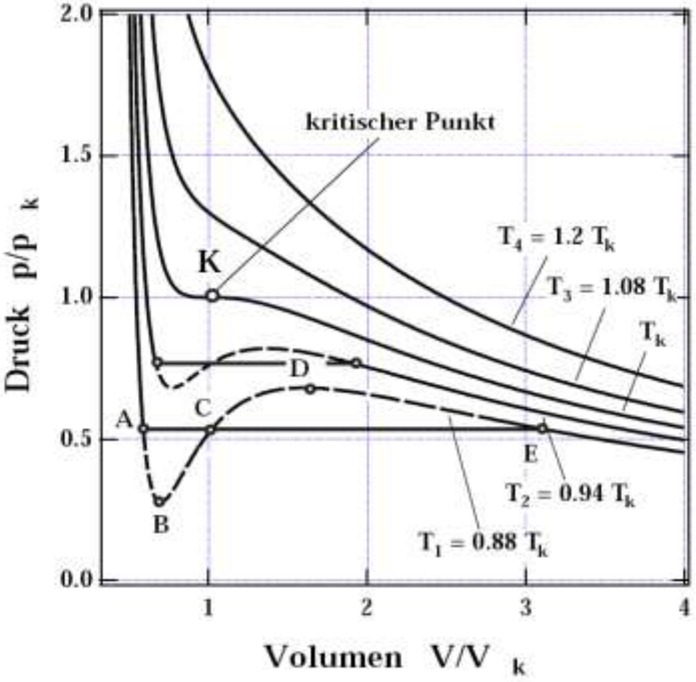
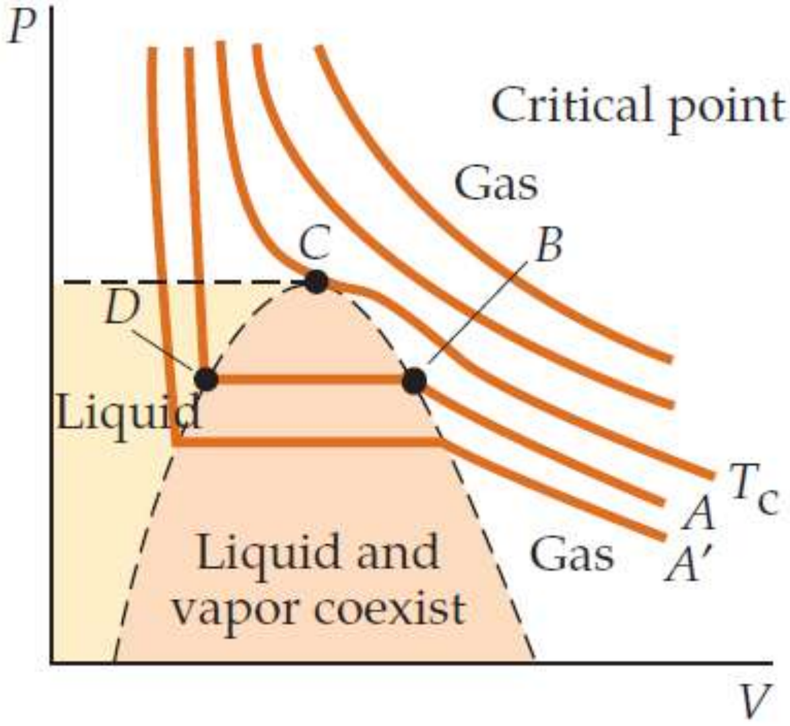
real gas law: van der Waals





$$\left(P + \frac{an^2}{V^2}\right)(V - bn) = nRT$$

FIGURE 20-5 Isotherms on the *PV* diagram for a substance. For temperatures above the critical temperature T_c, the substance remains a gas at all pressures. Except for the region where the liquid and vapor coexist, these curves are described quite well by the van der Waals equation. The pressure for the horizontal portions of the curves in the shaded region is the vapor pressure which is the pressure at which the vapor and liquid are in equilibrium. In the region shaded yellow, to the left of the region shaded pink, the substance is a liquid and is nearly incompressible.

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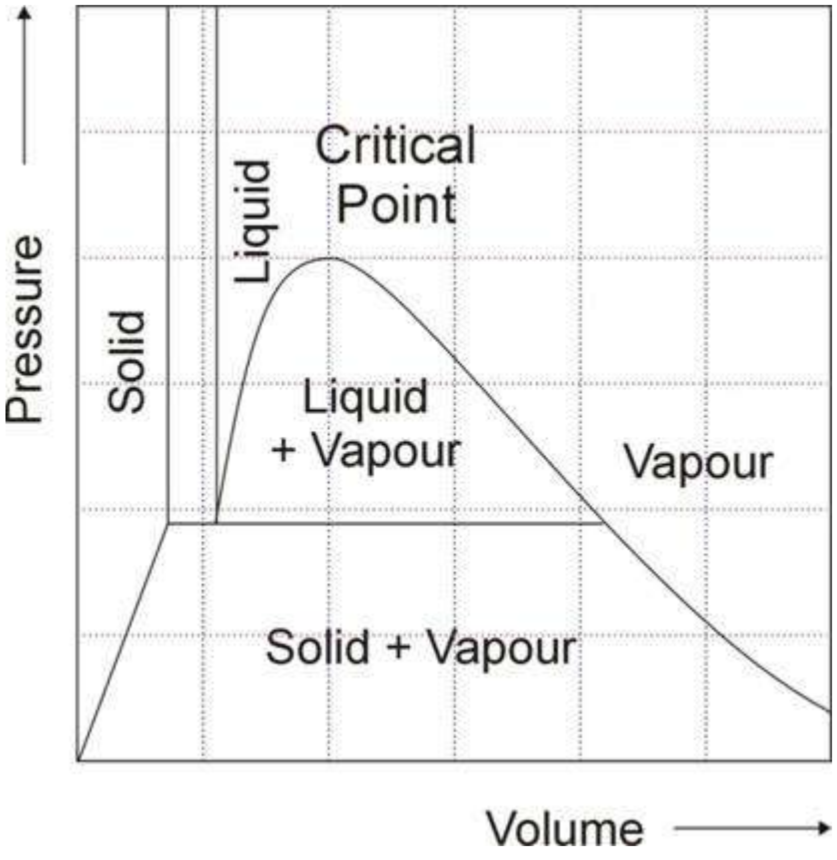
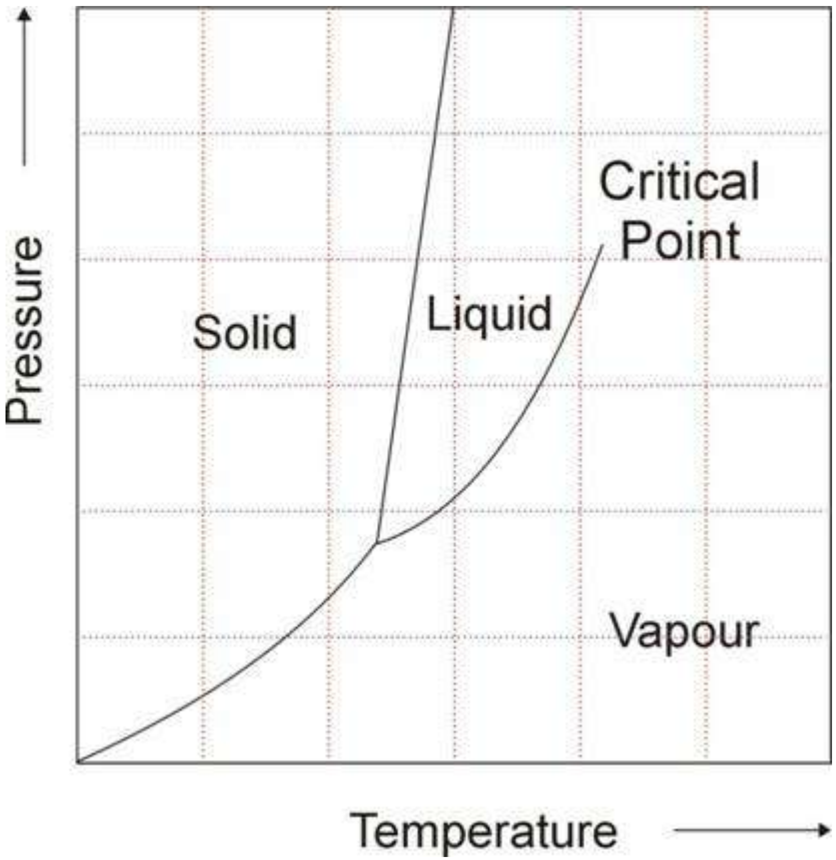
real gas law: van der Waals

PV diagram

PT diagram





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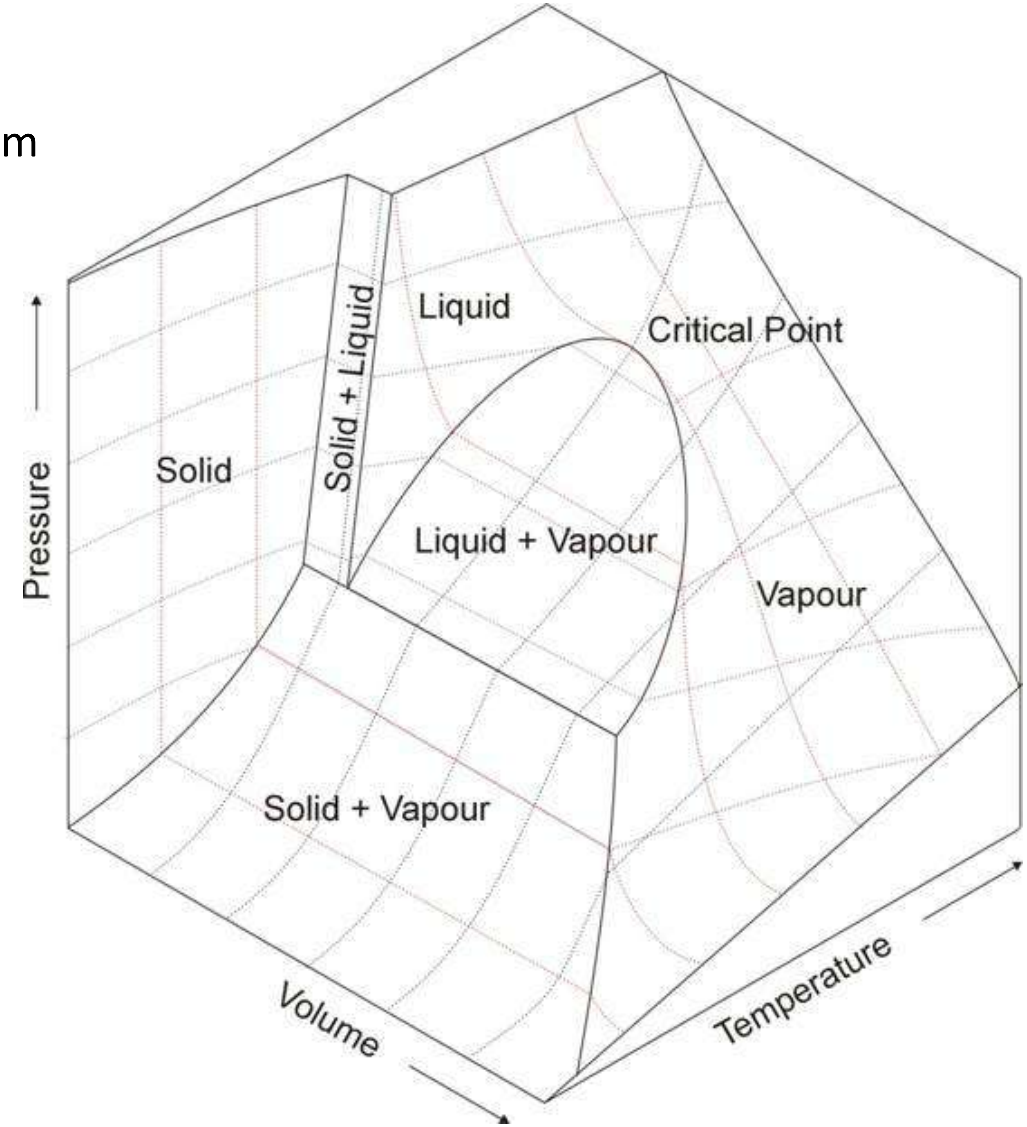
real gas law: van der Waals

PVT phase diagram



real gas law: van der Waals

Cloud forming behind an aircraft as it breaks the sound barrier. As the aircraft moves through the air, an area of low pressure forms behind it. When the pressure of this air parcel falls below the vapor pressure of gaseous water, the water in the air condenses to form the cloud. Different atmospheric conditions cause the phenomenon to occur at different aircraft speeds. *(U.S. Department of Defense/Photo Researchers, Inc.)*

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Introduction to Physics I

Laws of thermodynamics
Carnot cycle
2nd law of thermodynamics
energy balance
heat machines

reversible heat-work transformation
Carnot cycle

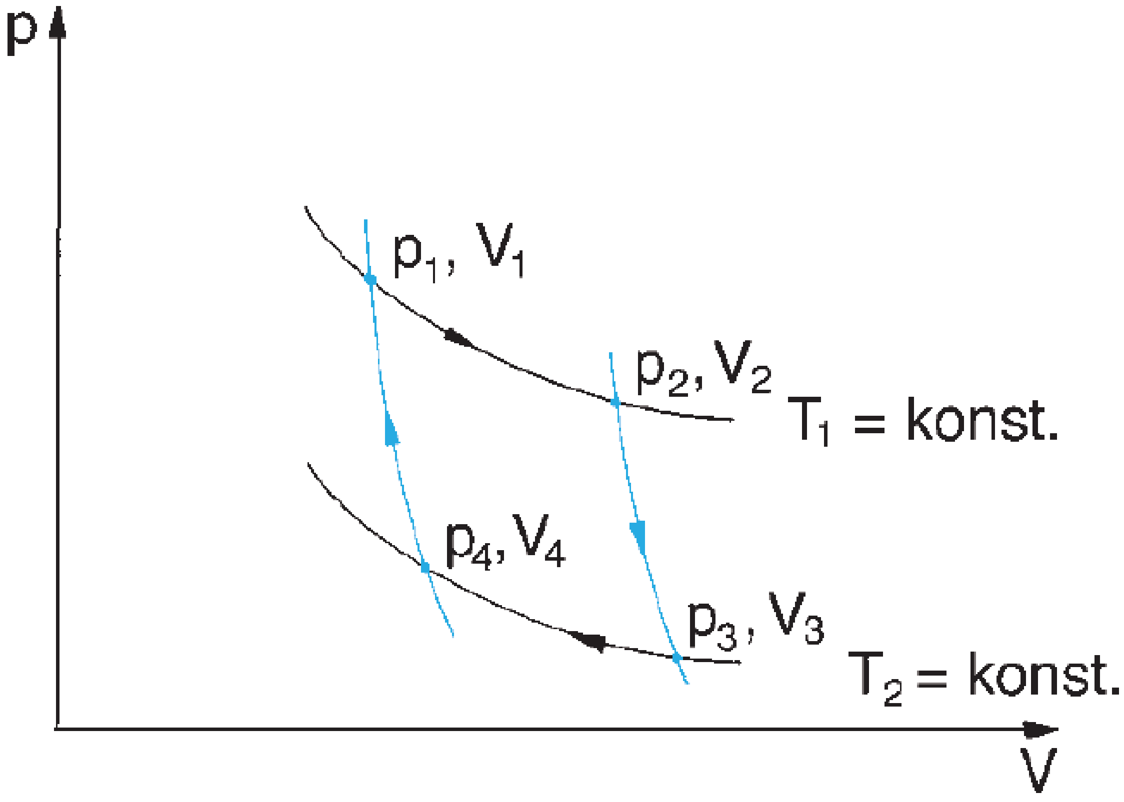
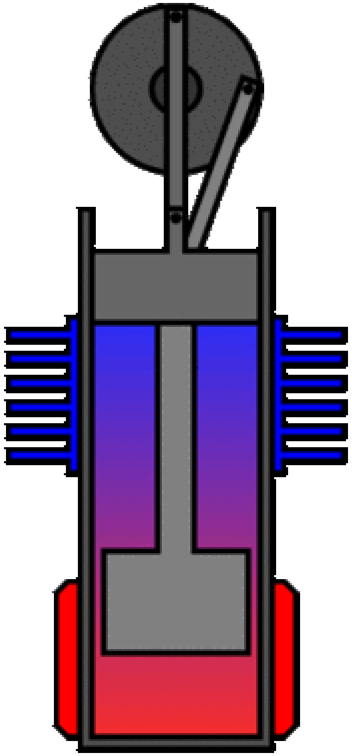
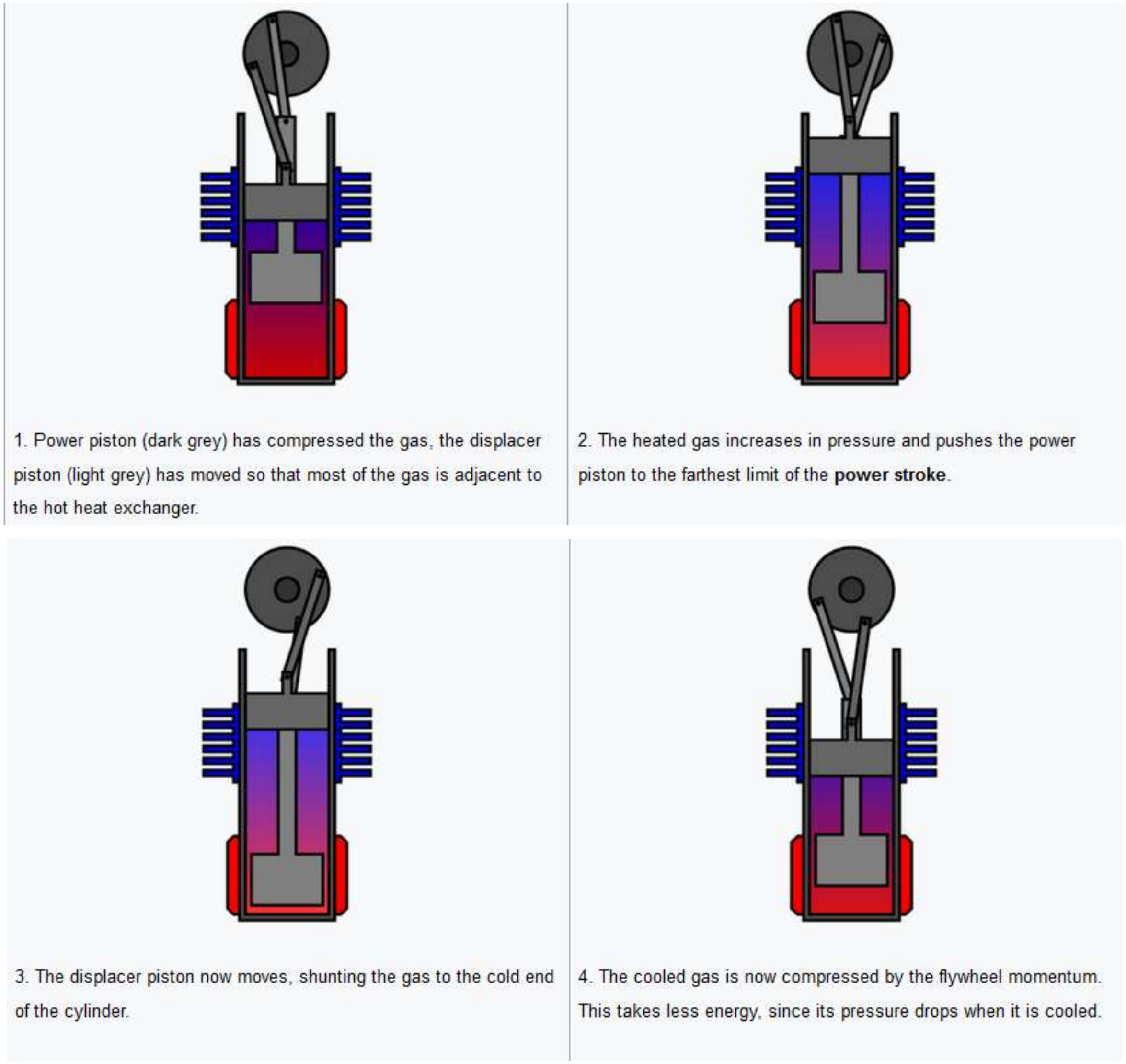


Abb. 12.1 *p*-*V*-Diagramm des Carnot'schen Kreisprozesses.

Trautwein

Stirling engine





1. Power piston (dark grey) has compressed the gas, the displacer piston (light grey) has moved so that most of the gas is adjacent to the hot heat exchanger.

2. The heated gas increases in pressure and pushes the power piston to the farthest limit of the **power stroke**.

3. The displacer piston now moves, shunting the gas to the cold end of the cylinder.

4. The cooled gas is now compressed by the flywheel momentum. This takes less energy, since its pressure drops when it is cooled.

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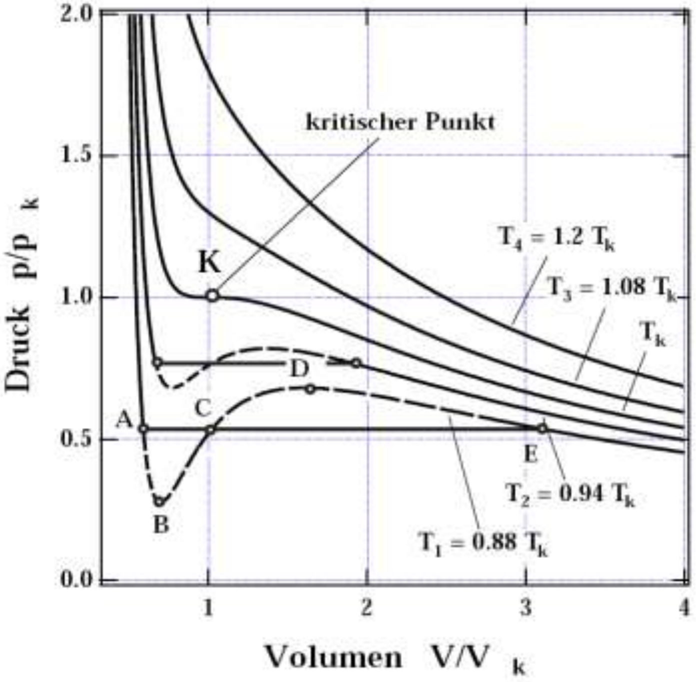
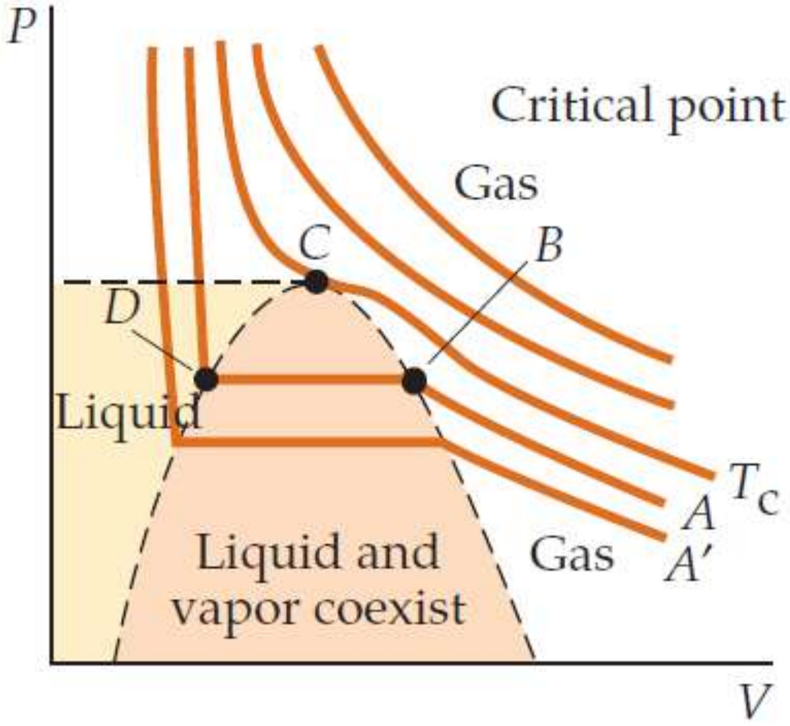
real gas law: van der Waals





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