Heat & temperature

Heat transport

First law of thermodynamics

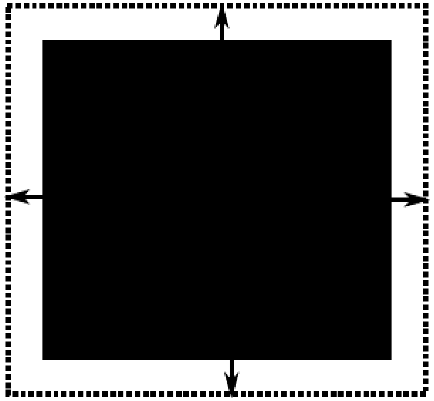
Ideal gases

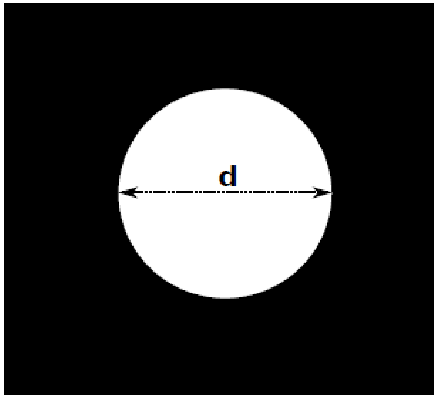
Kinetic gas theory

Introduction to Physics I

For Biologists, Geoscientists, & Pharmaceutical Scientists

Temperature - question





Eine Metallplatte dehnt sich nach dem Erwärmen aus. Die gleiche Metallplatte, mit einem Loch in der Mitte, wird erwärmt. Wie verändert sich der Durchmesser des Lochs?

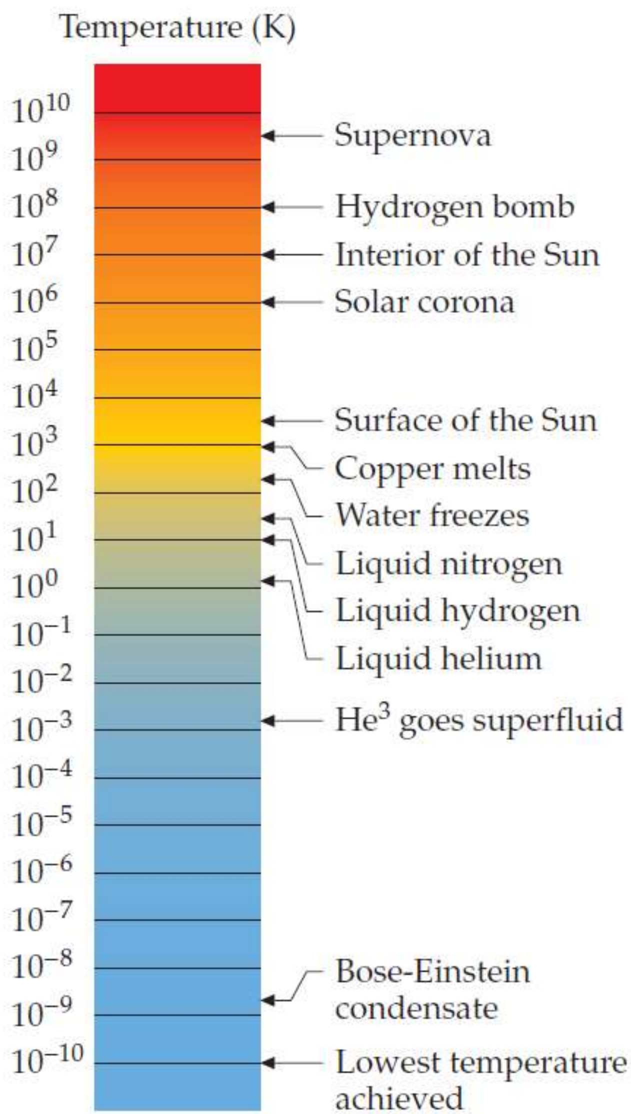
1. Der Durchmesser wird grösser.
2. Der Durchmesser wird kleiner.
3. Der Durchmesser bleibt gleich gross.

Temperature - question

Antwort: 1. Der Durchmesser wird grösser.

Durch die Erwärmung werden die Gitterabstände im Festkörper grösser, und zwar in der ganzen Platte. Ein kleiner Durchmesser, bedeutet kleinere Molekülabstände auf der Innenseite des Lochs, was der Ausdehnung im ganzen Festkörper widersprechen würde.

Table 17-1 **The Temperatures of Various Places and Phenomena**



Kelvin temperature scale

T [K] = T [C] + 273.15 K

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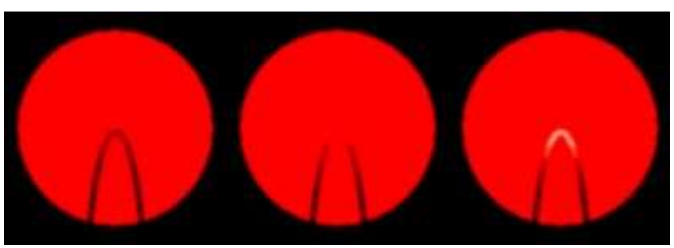
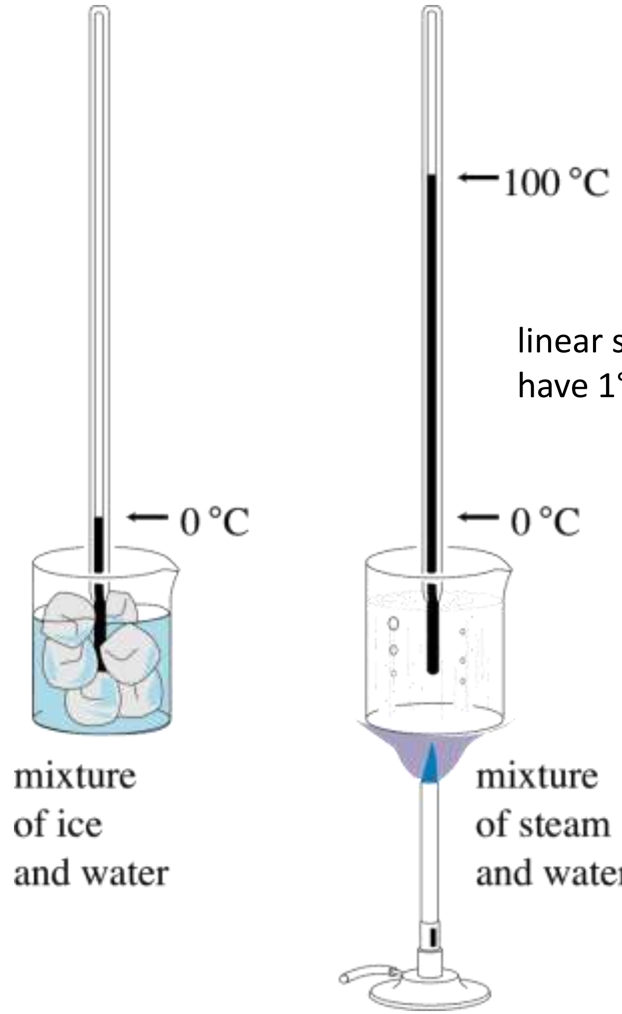
Thermometers examples

Mercury thermometer (Celsius)

Disappearing filament pyrometer

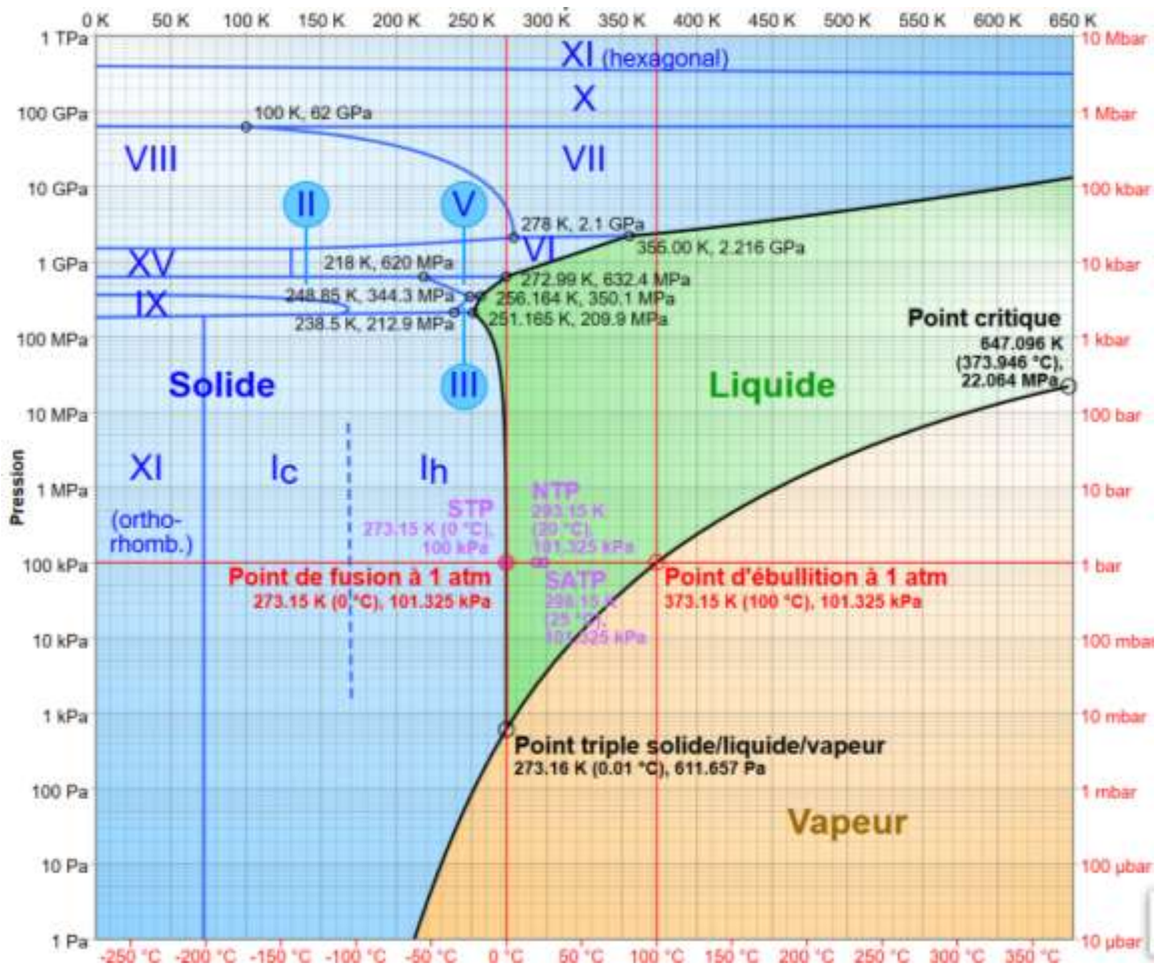




linear subdivision to have 1°C steps

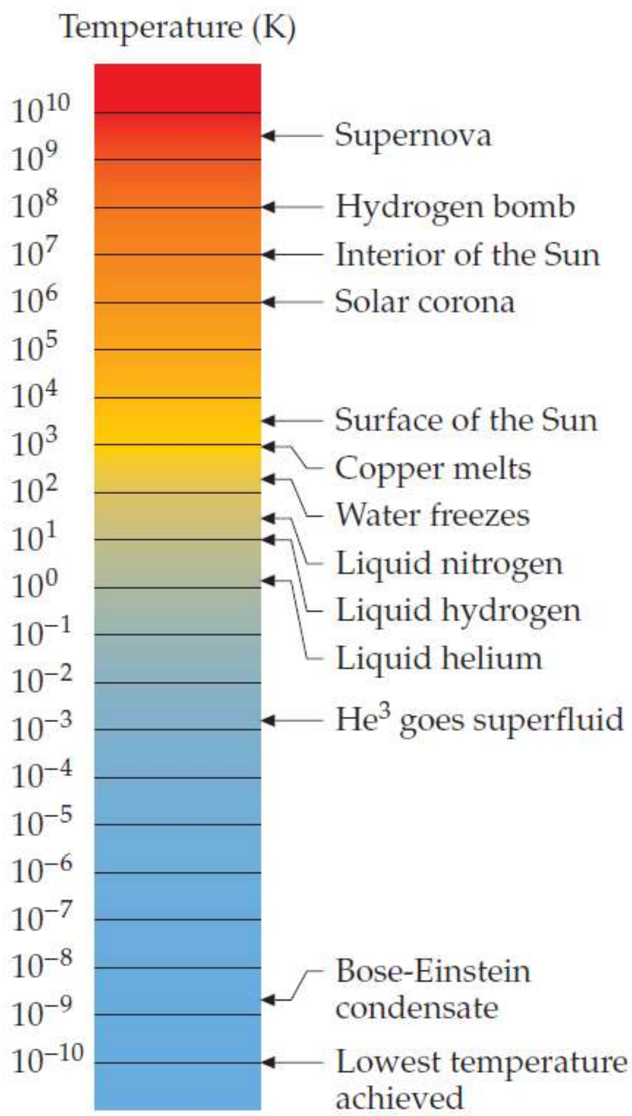
http://www.met.reading.ac.uk/pplato2

triple point of water



Triple Point Data		
Substance	Pressure [kPa]	Temperature [K]
Hydrogen	7.04	13.8
Deuterium	17.1	18.6
Neon	43.2	24.6
Oxygen	0.152	54.4
Nitrogen	12.5	63.2
Ammonia	6.07	195.4
Carbon dioxide	517	216.6
Water	0.611	273.16

Table 17-1 The Temperatures of Various Places and Phenomena



Kelvin temperature scale

T [K] = T [C] + 273.15 K

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Seebeck coefficients

Material	**Seebeck coefficient** ***relative to platinum*** **(μV/K)**
Selenium	900
Tellurium	500
Silicon	440
Germanium	330
Antimony	47
Nichrome	25
Molybdenum	10
Cadmium, tungsten	7.5
Gold, silver, copper	6.5
Rhodium	6.0
Tantalum	4.5
Lead	4.0
Aluminium	3.5
Carbon	3.0
Mercury	0.6
Platinum	0 (definition)
Sodium	-2.0
Potassium	-9.0
Nickel	-15
Constantan	-35
Bismuth	-72

For Platinum (at ~300K)

$S \approx -5\ \mu V/K$

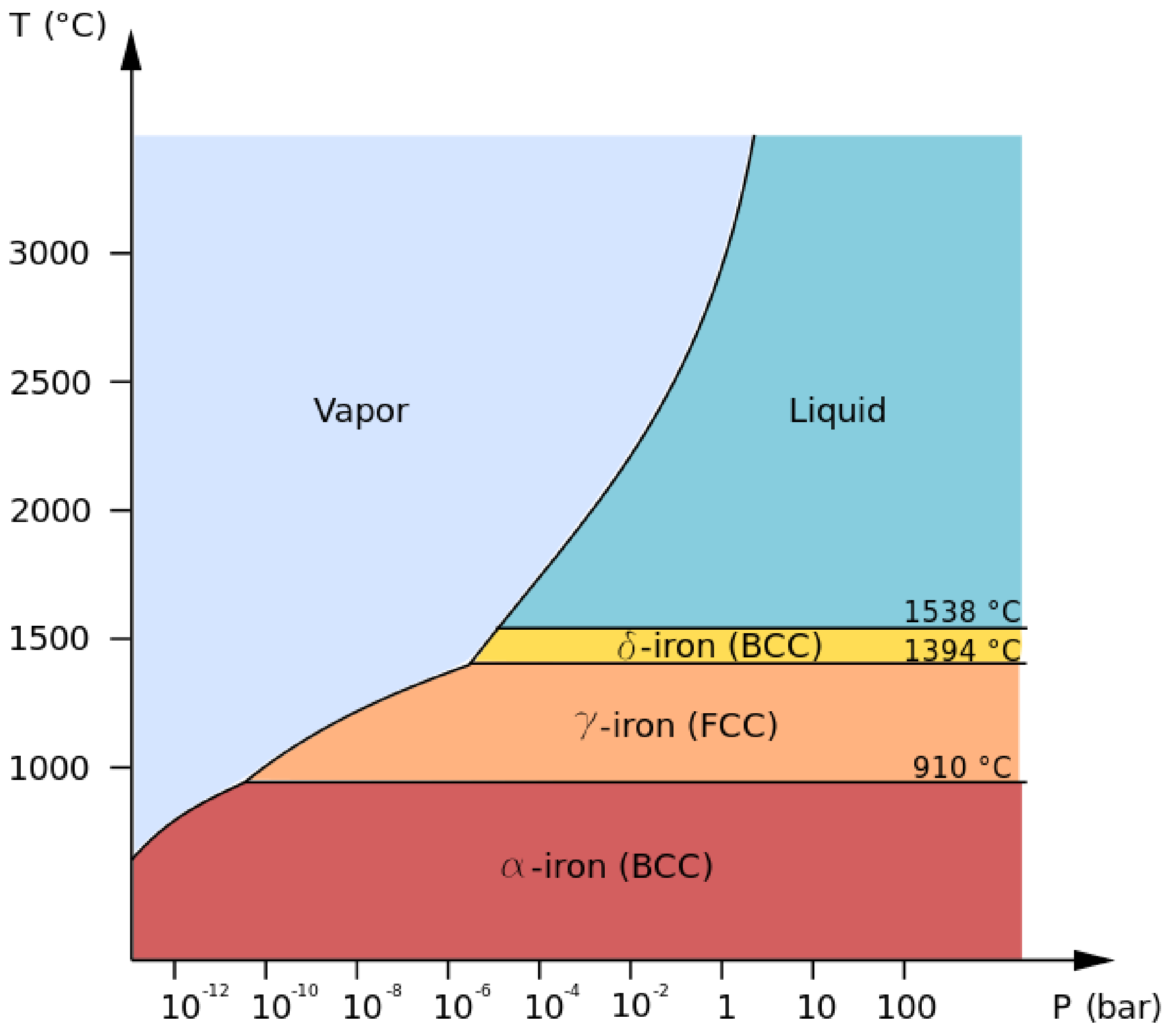
wikipedia

Linear expansion coefficients

Tabelle linearer Ausdehnungskoeffizienten α

fester Stoff	α (K^{-1})
Kupfer	$16.8 \cdot 10^{-6}$
Eisen	$12.2 \cdot 10^{-6}$
Thüringer Glas	$8.5 \cdot 10^{-6}$
Pyrex-Glas	$3.2 \cdot 10^{-6}$
Invar Stahl	$1.5 \cdot 10^{-6}$
Quarzglas	$0.45 \cdot 10^{-6}$
Edelstahl	$16 \cdot 10^{-6}$
Dentalmaterial:	
Zahnsubstanz	$11.4 \cdot 10^{-6}$
Silikatzement	$7.6 \cdot 10^{-6}$
Dentalamalgam	$25.0 \cdot 10^{-6}$
Porzellan	$4.1 \cdot 10^{-6}$
Polymethylmethacrylat	$81.0 \cdot 10^{-6}$

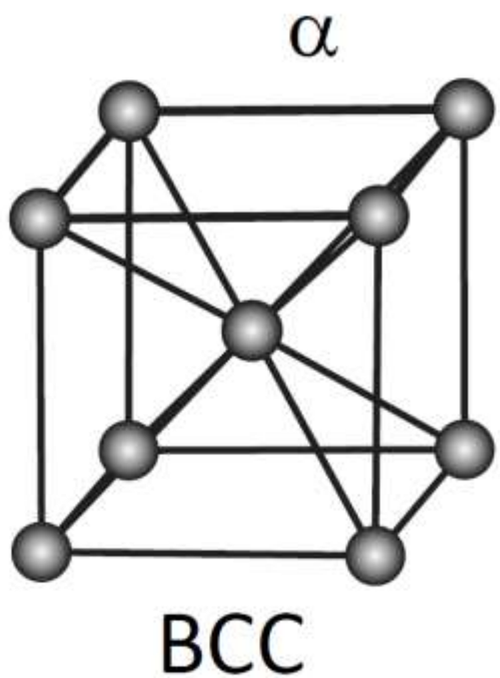
Iron (Fe) wire expansion



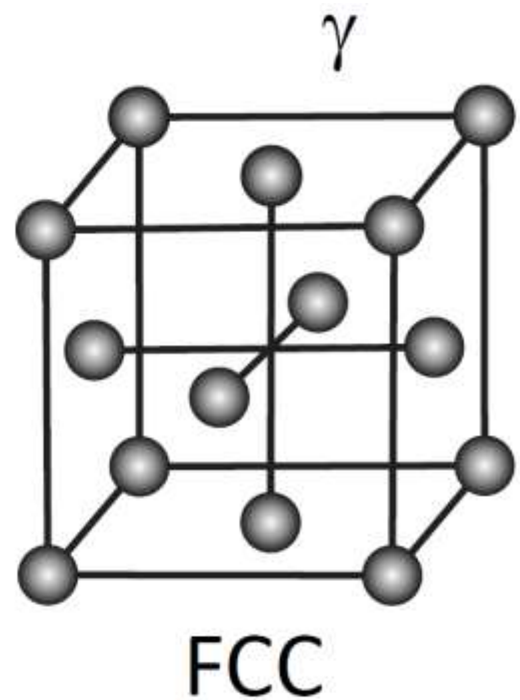
Iron (Fe) wire expansion

two iron allotropes with different lattice structure

912 C



(body centered cubic)



(face centered cubic)

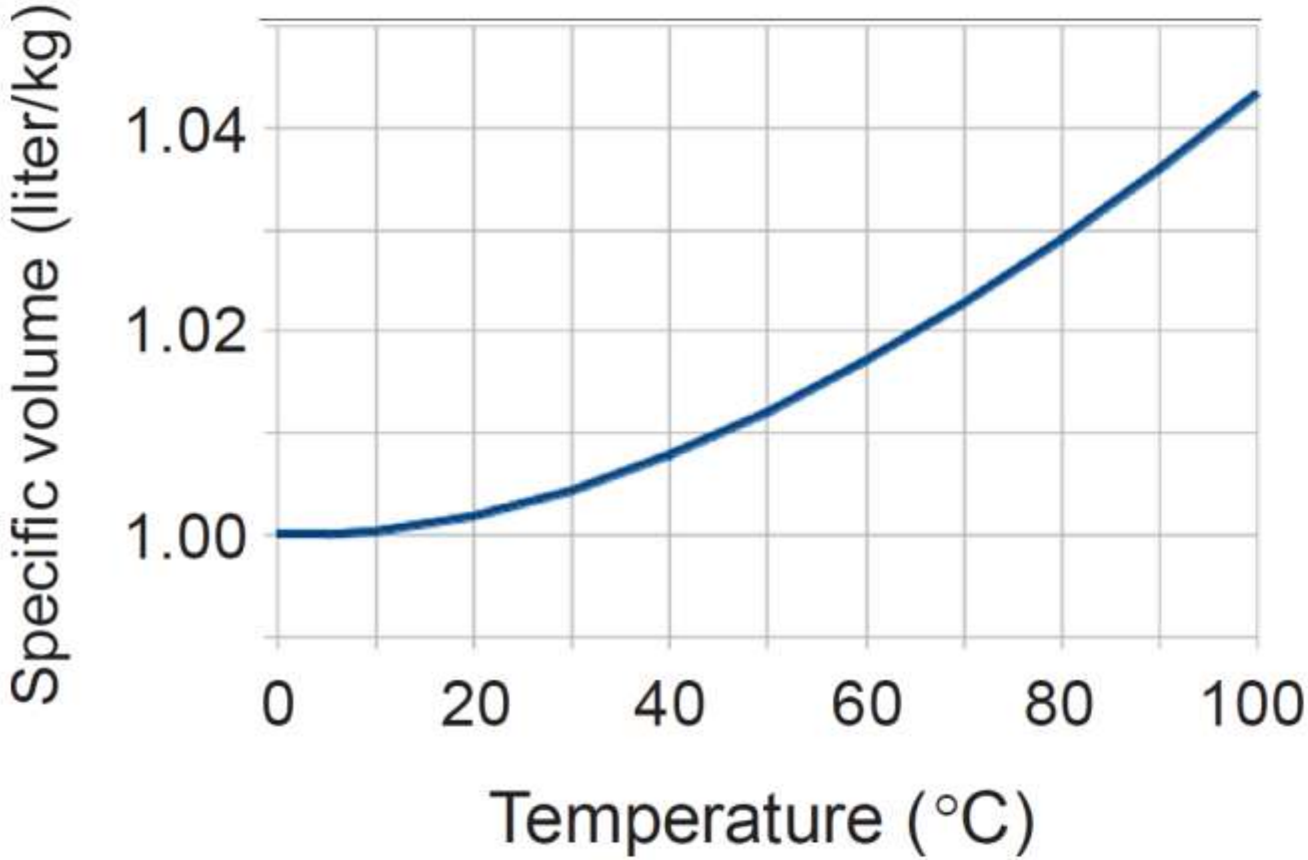
Thermal expansion coefficients

Material	linear (1D) α_l $(10^{-6}K^{-1})$	volumic (3D) α_V $(10^{-6}K^{-1})$
Gasoline	317	950
Ethanol	250	750
PP	150	450
PVC	52	156
Aluminium	23	69
Kapton	20	60
Copper	17	51
Iron	12	36
Steel	11	33
Invar	1.2	3.6
Quartz	0.3	1

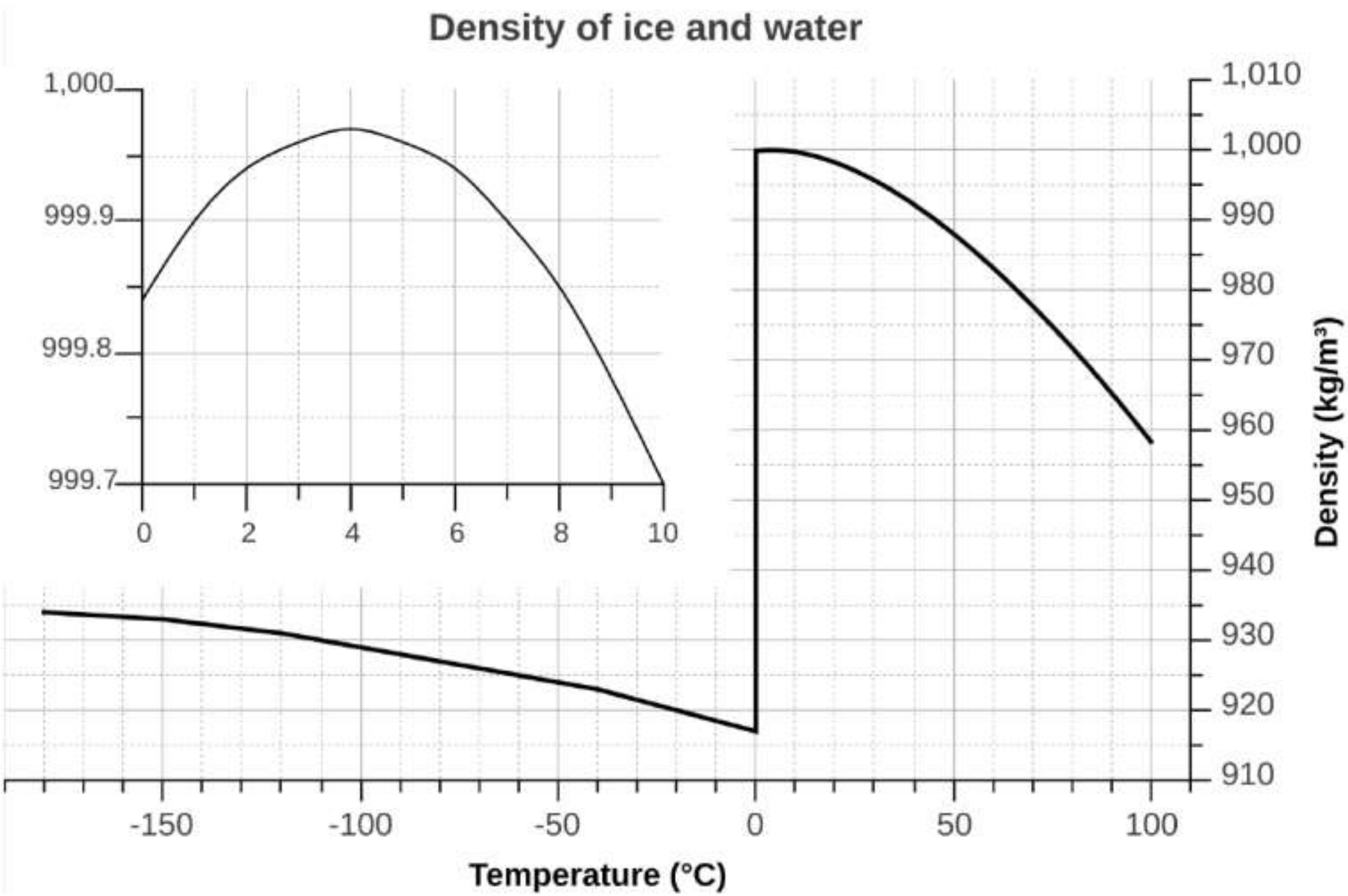
$$\alpha_V = 3\alpha_l$$

Volume expansion

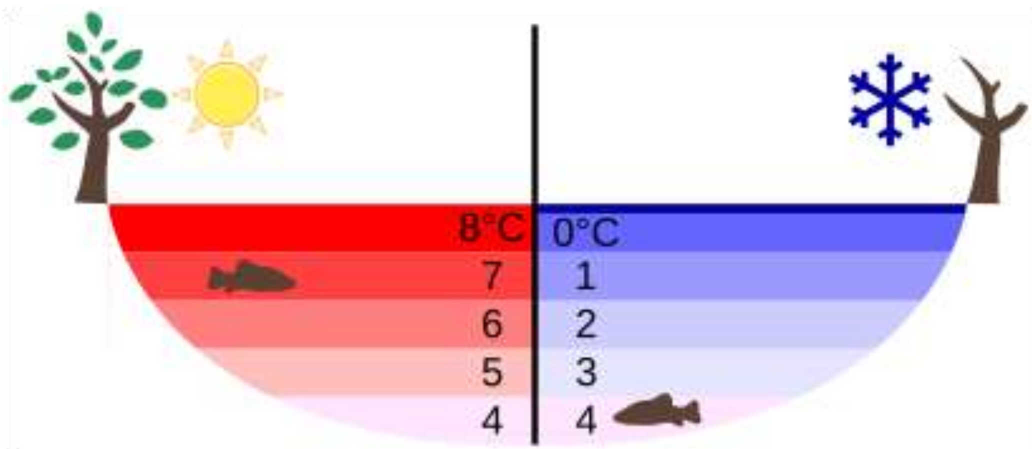
Thermal expansion of water



Thermal expansion of water



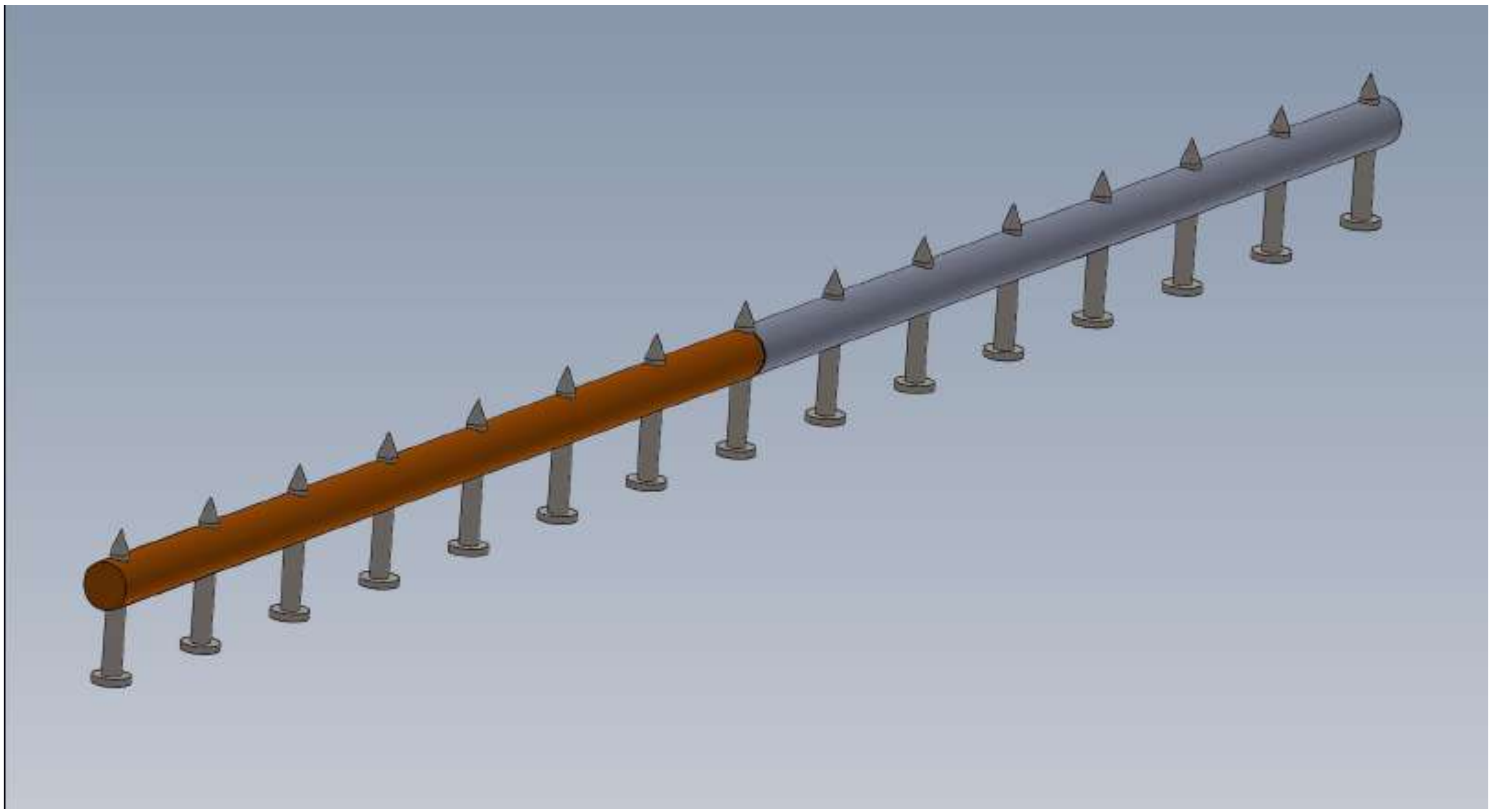
Thermal expansion of water
density of water vs T



Thermal conductivity

Material	Thermal conductivity (W/(m*K))
Diamond*	2300
Copper	390
Lead	35
Stainless steel	15
Granite	3
Ethanol	0.17
Cotton	0.06
Paper	0.01
Glass wool	0.005

Exp. heat transport



Heat capacity

Material	c (J/(K*kg))
Hydrogen	14000
Sea water	3900
Ice	2100
Aluminium	900
Granite	840
Iron	450
Copper	390
Lead	130
Platinum	130

Heat and work

Joule's experiment

FIGURE 18-2 Schematic diagram for Joule's experiment. Insulating walls surround water. As the weights fall at constant speed, they turn a paddle wheel, which does work on the water. If friction is negligible, the work done by the paddle wheel on the water equals the loss of mechanical energy of the weights, which is determined by calculating the loss in the potential energy of the weights.

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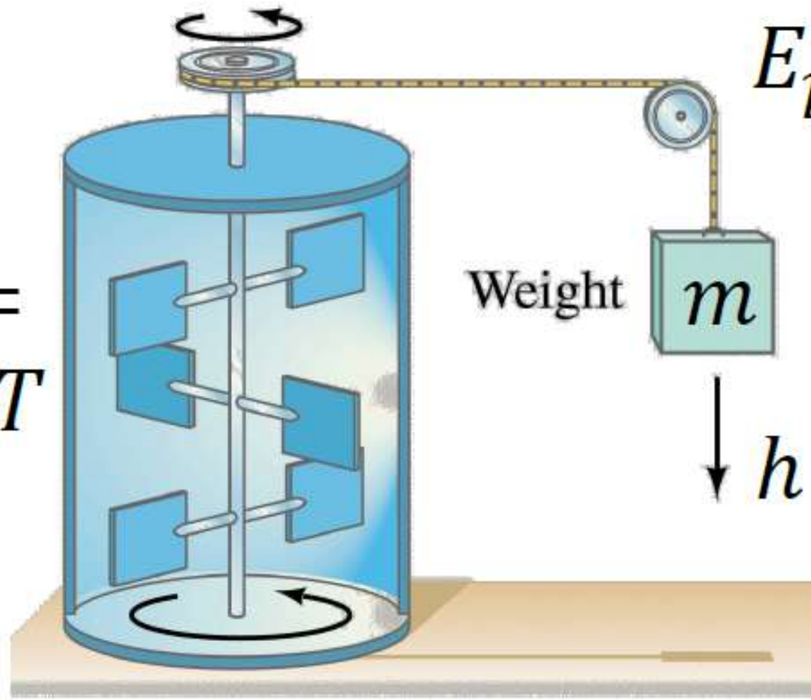
Heat and work

Joule's experiment

$$E_p = mgh$$

$$\Delta Q = m'c\Delta T$$



$$mgh = m'c\Delta T$$

universal gas constant

$PV = nRT$

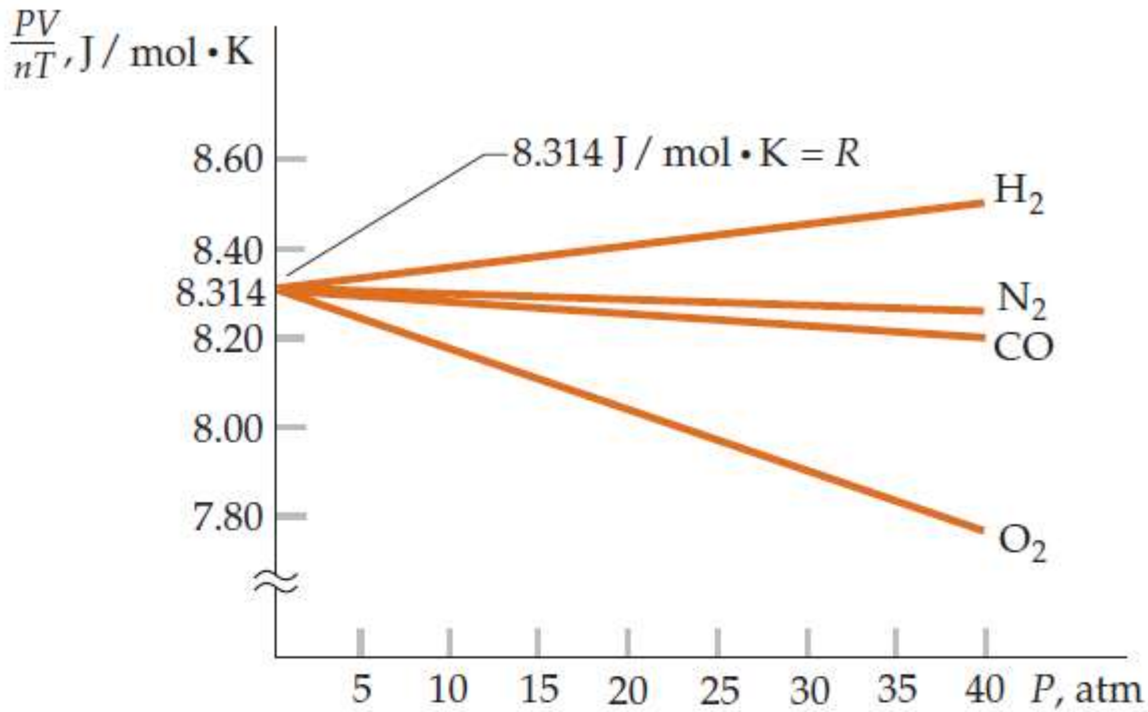


FIGURE 17-8 Plot of PV/nT versus P for real gases. In these plots, varying the amount of gas varies the pressure. The ratio PV/nT approaches the same value, 8.314 J/(mol · K), for all gases as we reduce their densities, and thereby their pressures, of the gases. This value is the universal gas constant R.

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