# Introduction to Physics I

Heat & temperature

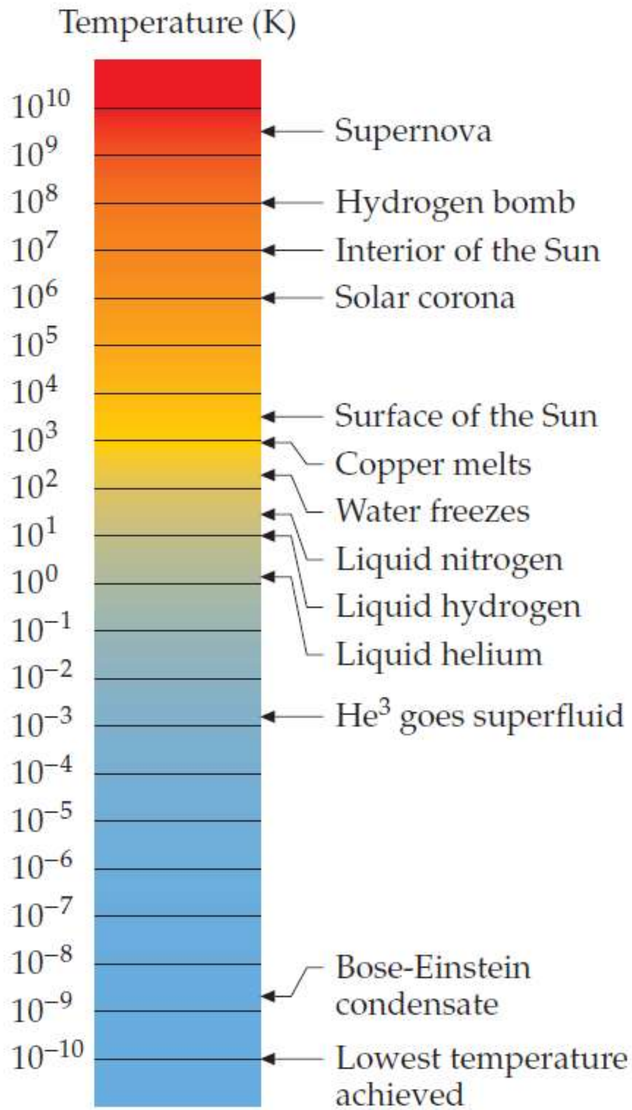
Heat transport

First law of thermodynamics

Ideal gases

Kinetic gas theory

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




Kelvin temperature scale

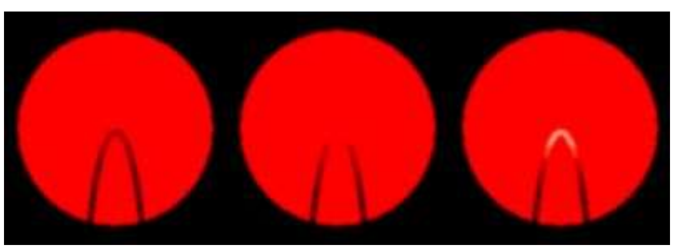
$$T\,[K] = T\,[C] + 273.15\ K$$

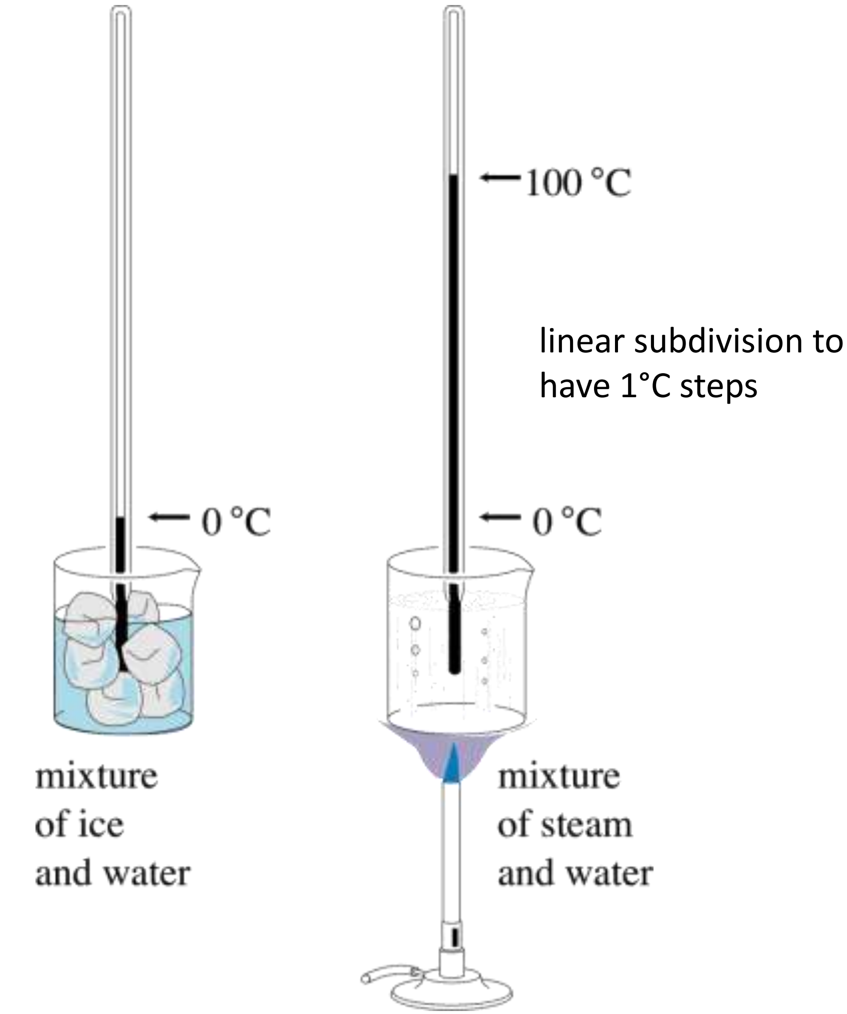
*Tipler*

# Thermometers examples

Mercury thermometer (Celsius)

Disappearing filament pyrometer





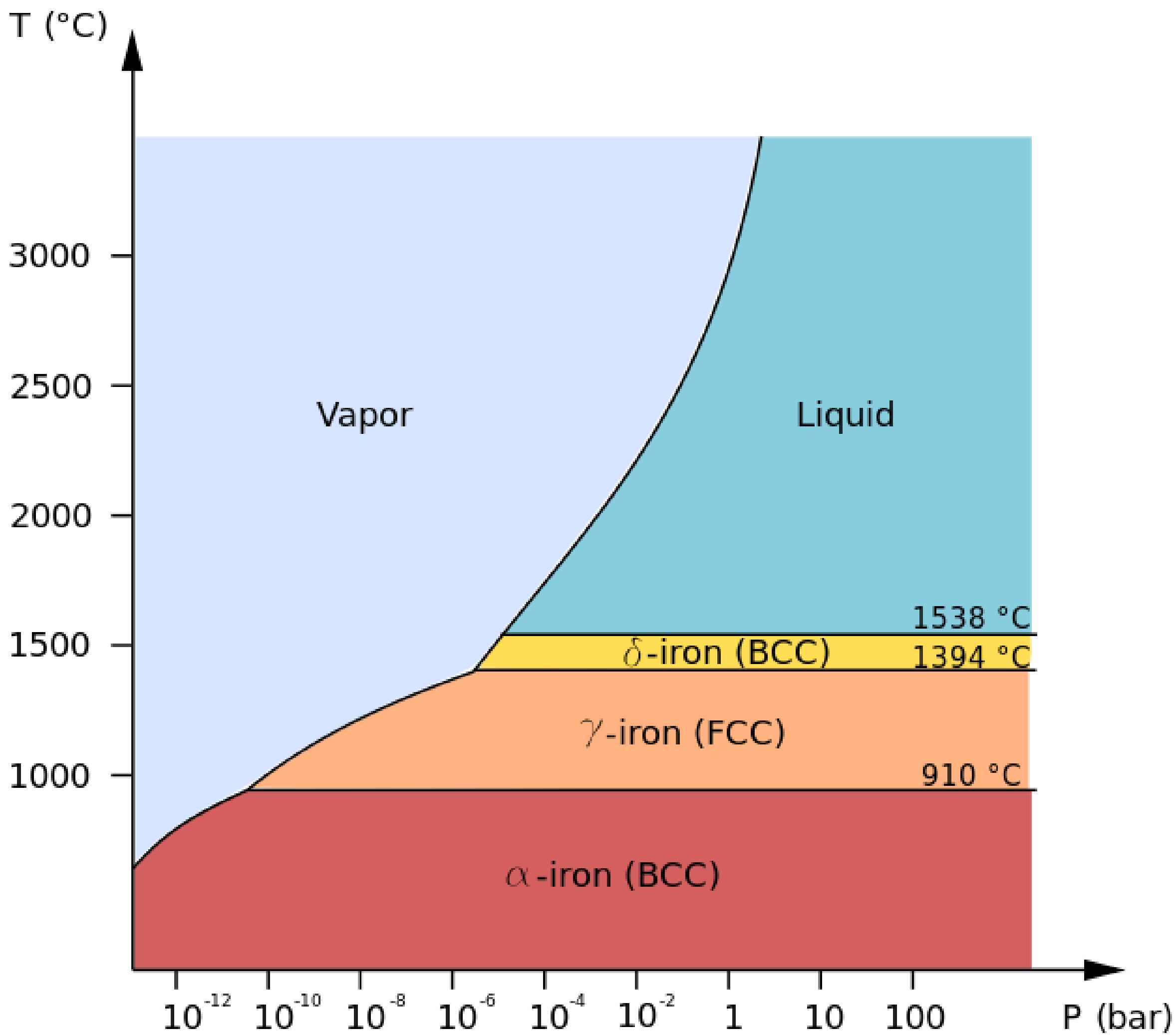

*http://www.met.reading.ac.uk/pplato2*

# Linear expansion coefficients

**Tabelle** linearer Ausdehnungskoeffizienten $\alpha$

| fester Stoff | $\alpha$ ($K^{-1}$) |
|---|---|
| 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 | $81.0 \cdot 10^{-6}$ |

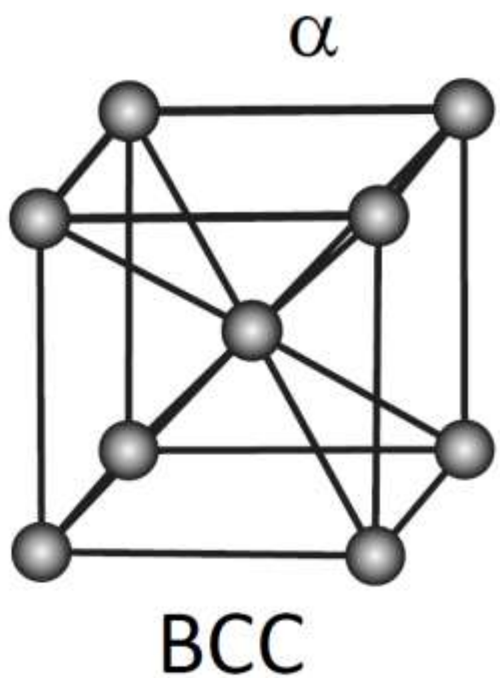
# Iron (Fe) wire expansion



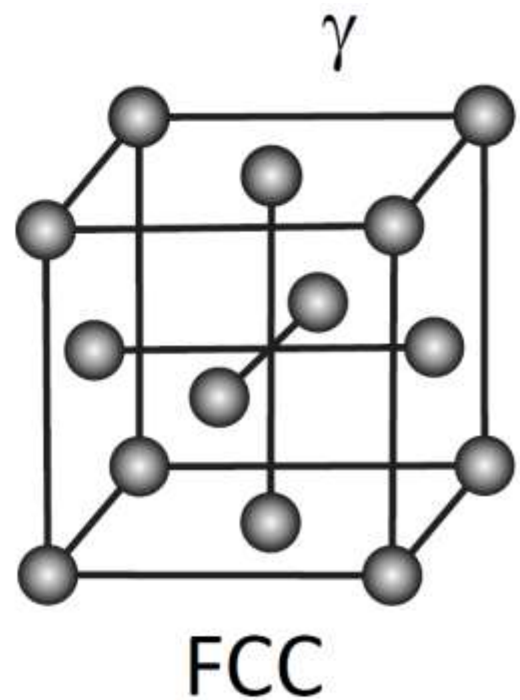
# Iron (Fe) wire expansion

two iron allotropes with different lattice structure

912 C




(body centered cubic)




(face centered cubic)

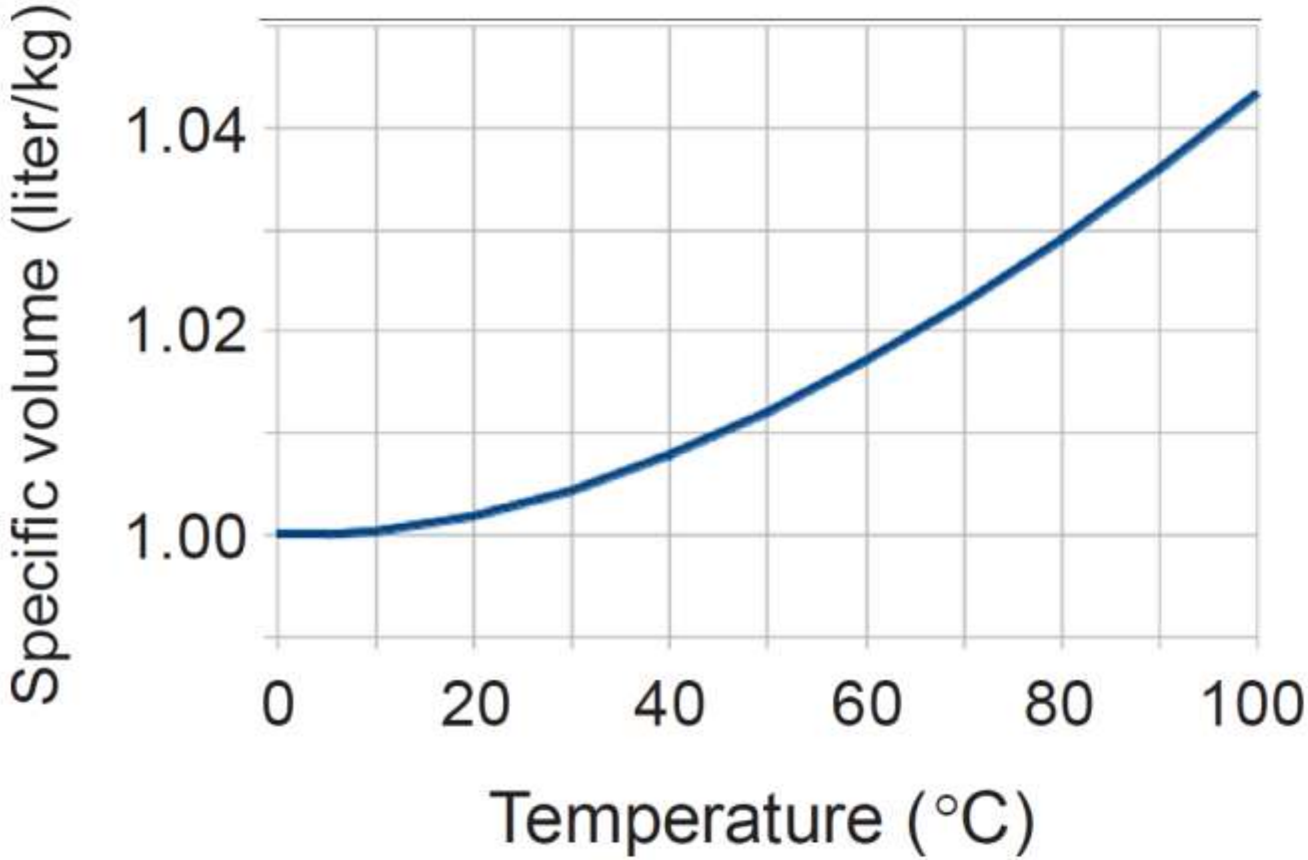
# Thermal expansion coefficients

| Material | linear (1D) $\alpha_l$ $(10^{-6}K^{-1})$ | volumic (3D) $\alpha_V$ $(10^{-6}K^{-1})$ |
|---|---|---|
| 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 |

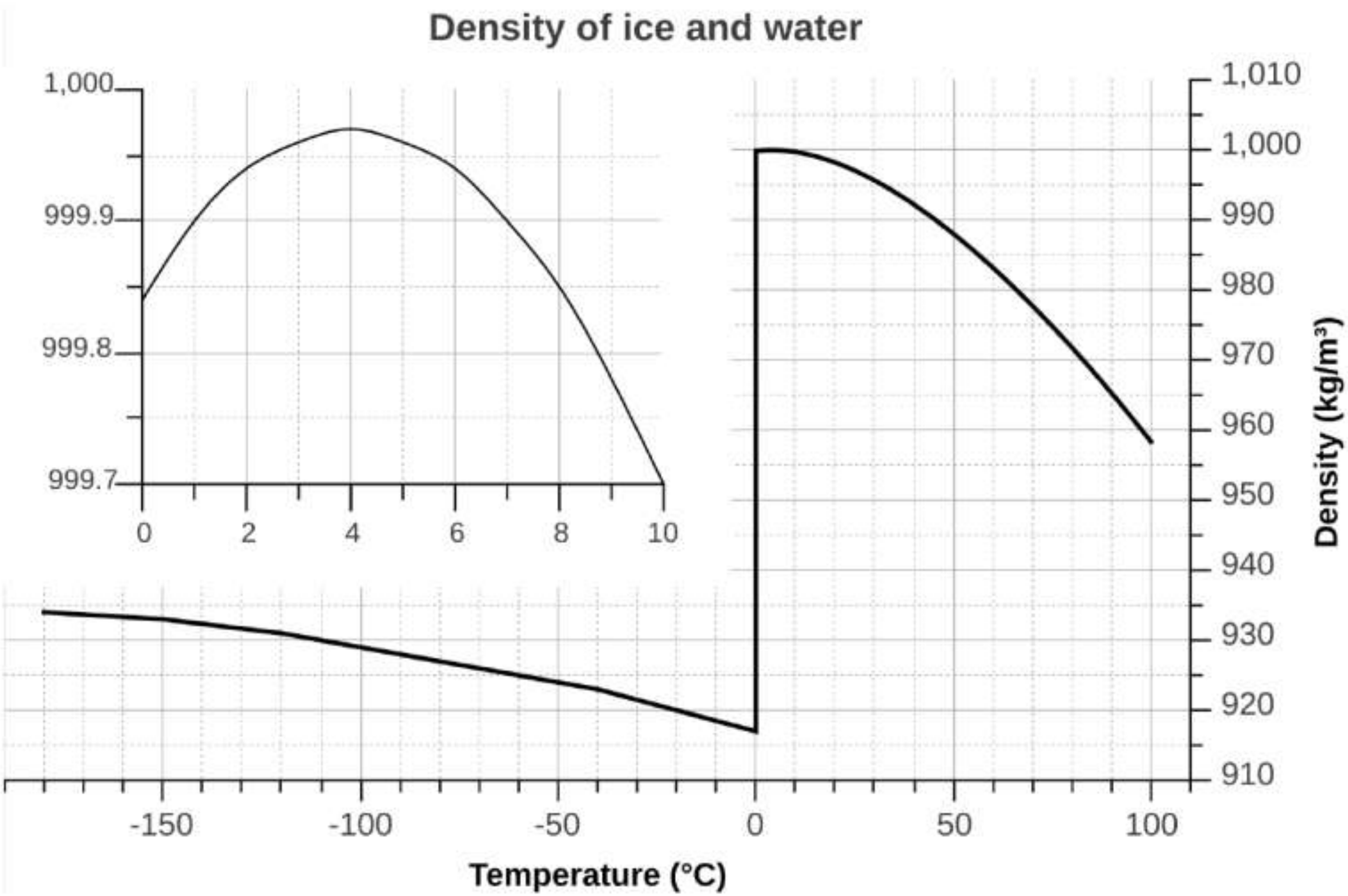
$$\alpha_V = 3\alpha_l$$

# Volume expansion

# Thermal expansion of water

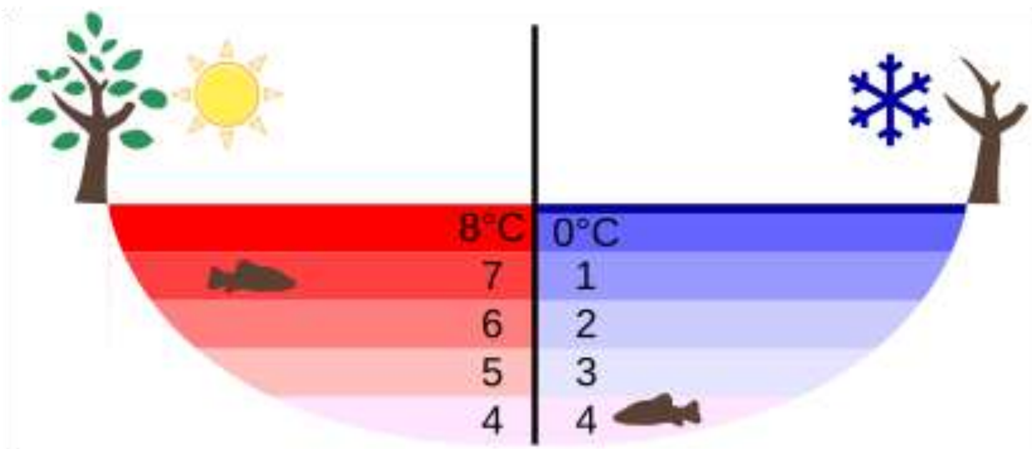


# Thermal expansion of water



# Thermal expansion of water

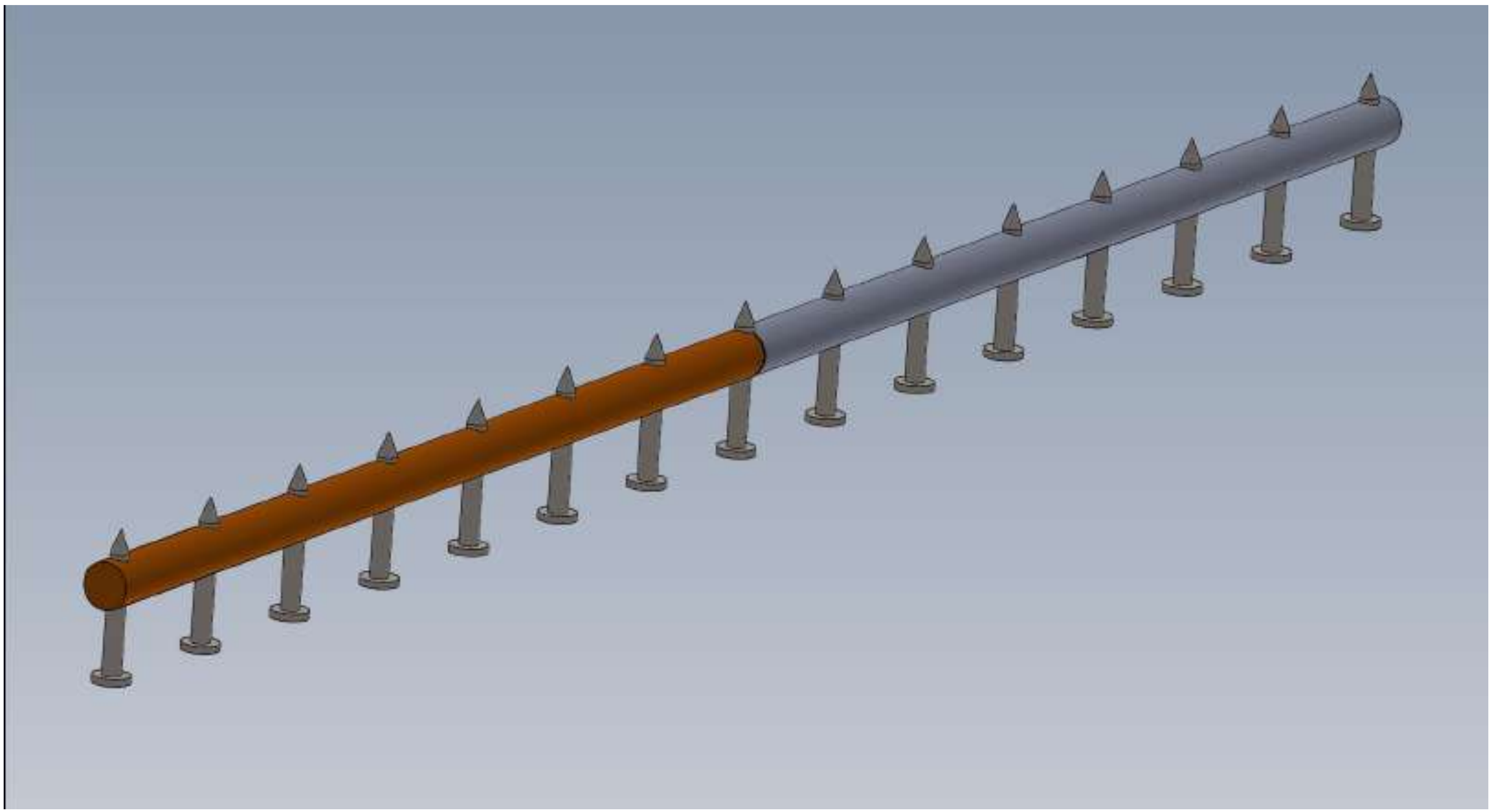
# *density of water vs T*



# 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.

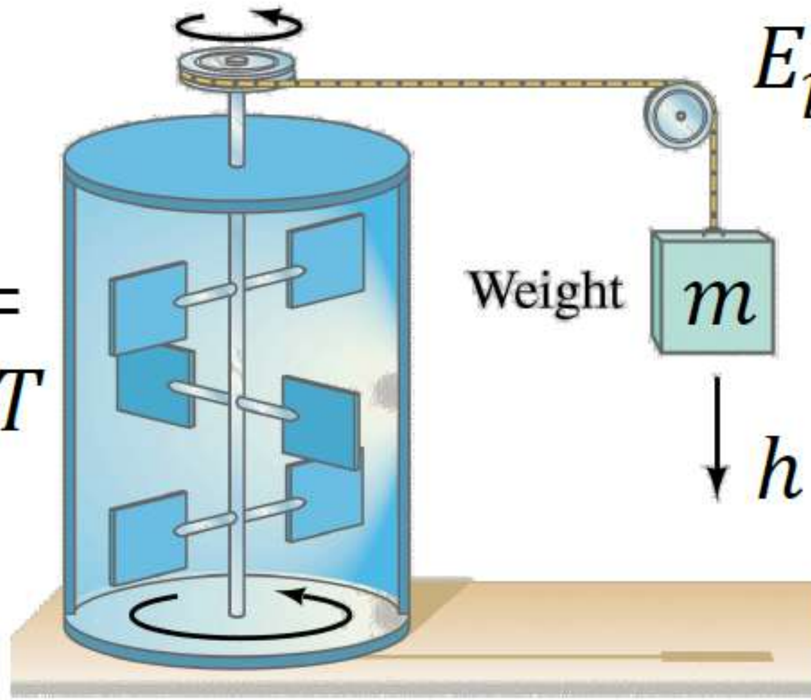
***Tipler***

# Heat and work

**Joule's experiment**

$$E_p = mgh$$

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




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

# universal gas constant

$PV = nRT$

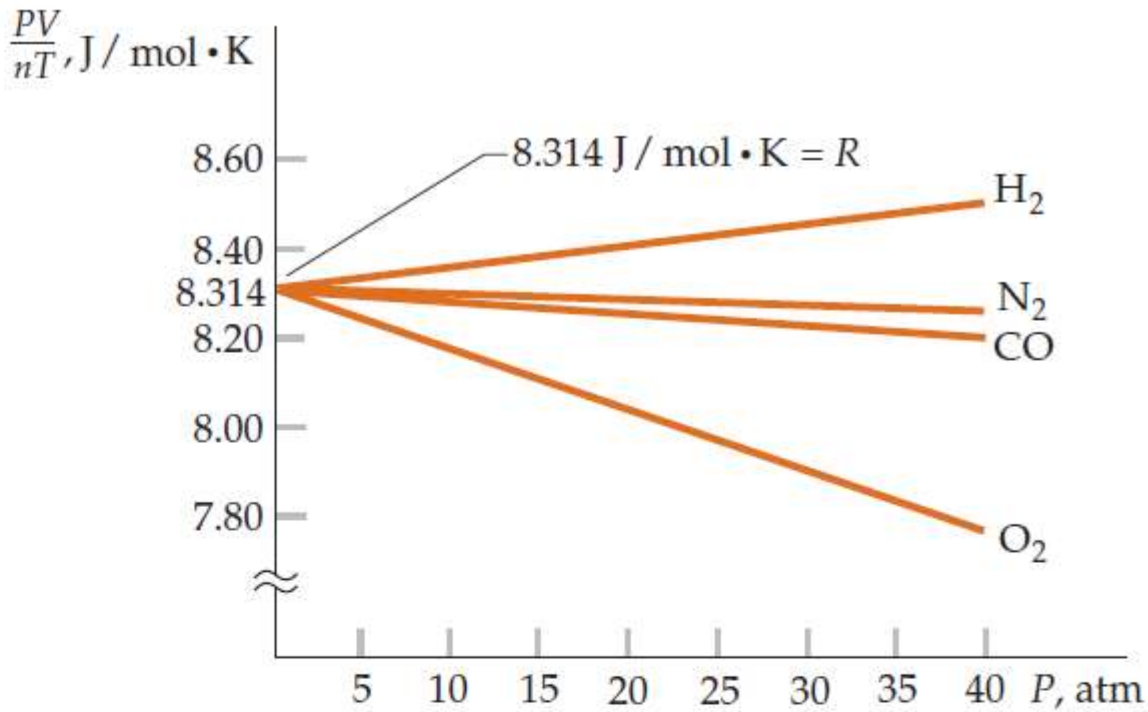
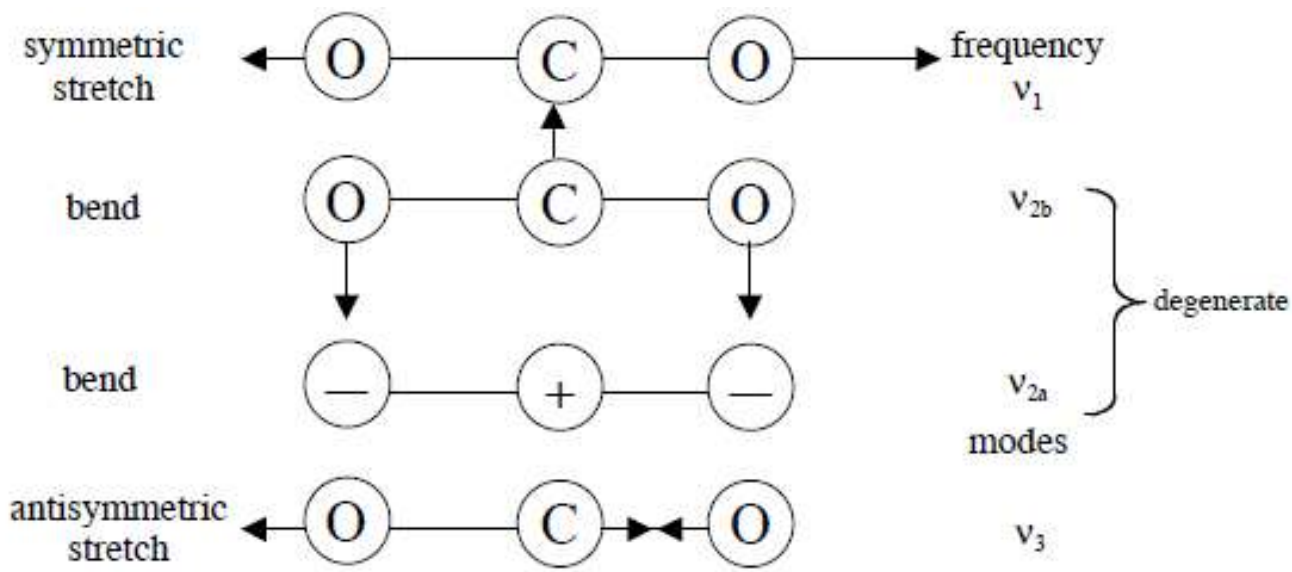



**FIGURE 17-8** Plot of $PV/nT$ versus $P$ for real gases. In these plots, varying the amount of gas varies the pressure. The ratio $PV/nT$ approaches the same value, 8.314 J/(mol · K), for all gases as we reduce their densities, and thereby their pressures, of the gases. This value is the universal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

*Tipler*

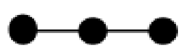
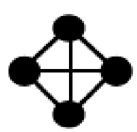
# equipartition theorem
## degrees of freedom

**vibration modes $CO_2$ molecule**



# equipartition theorem

## degrees of freedom

| Gas | | $i = \frac{\text{Atome}}{\text{Molekül}}$ | $f_{trans}$ | $f_{rot}$ | $f_{vibr}$ | $f_{tot}$ (=3i) |
|---|---|---|---|---|---|---|
| He |  | 1 | 3 | 0 | 0 | 3 |
| $H_2$ |  | 2 | 3 | 2 | 1 | 6 |
| $CO_2$ |  | 3 | 3 | 2 | 4 | 9 |
| $NH_3$ |  | 4 | 3 | 3 | 6 | 12 |

*NB: vibration modes contribute kinetic and potential energy to the total internal energy of the gas*