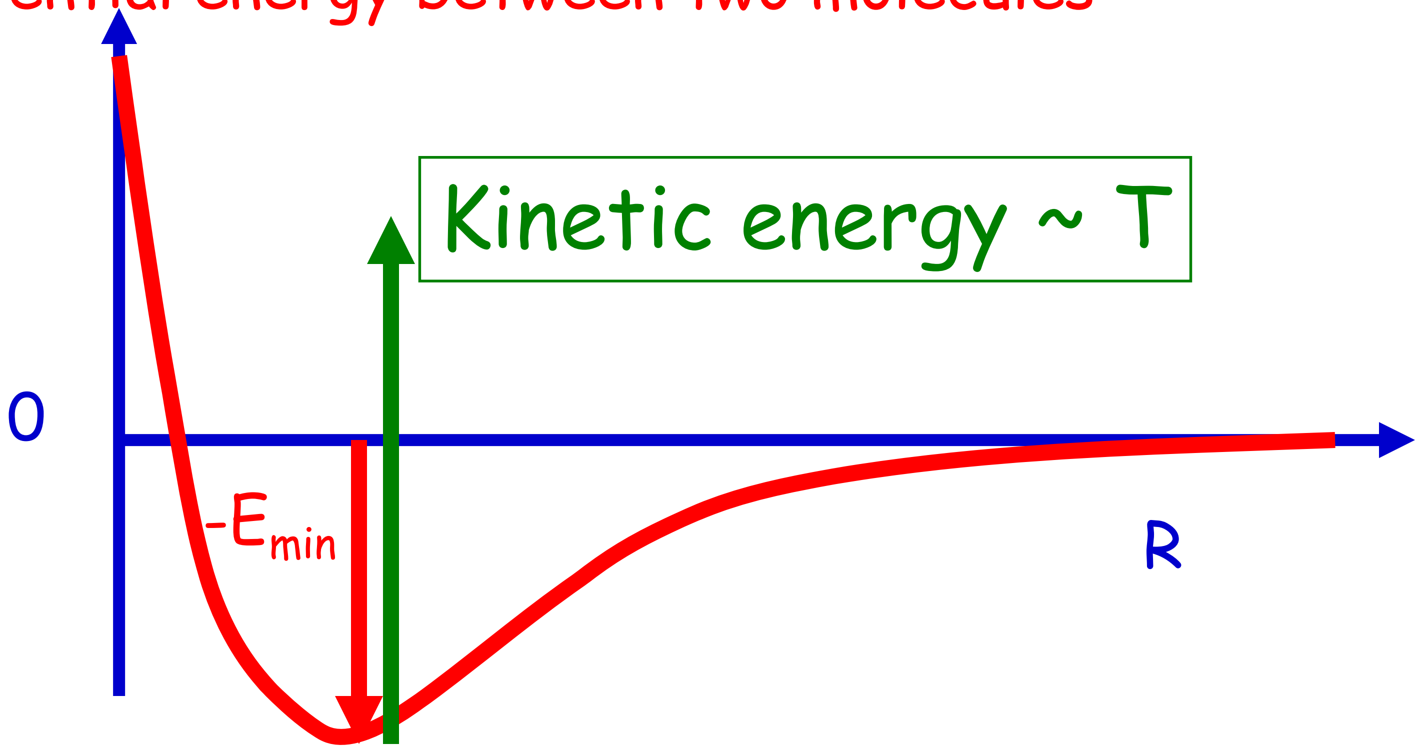
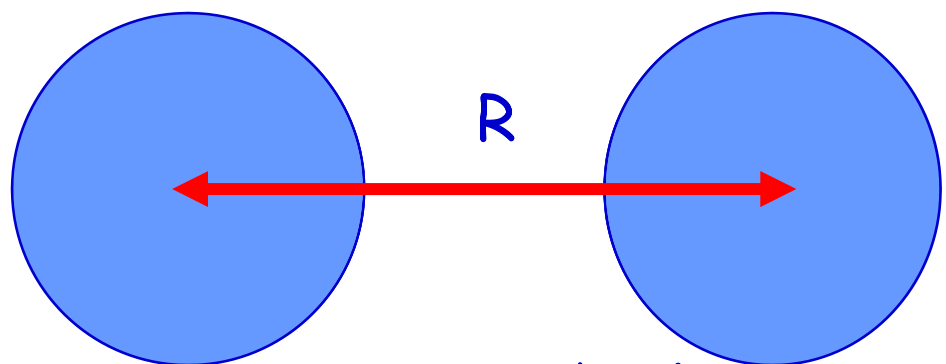
Potential energy between two molecules

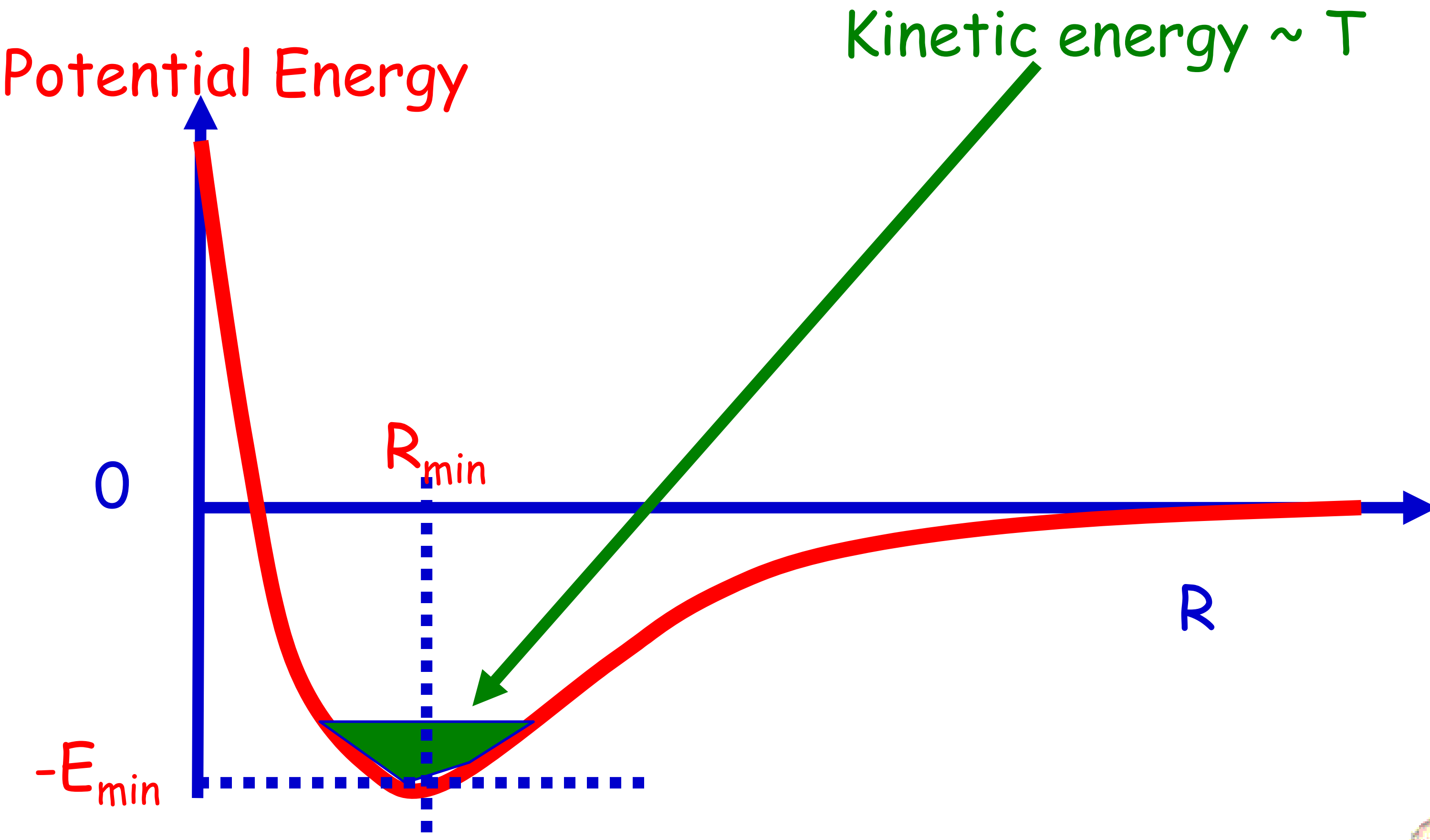


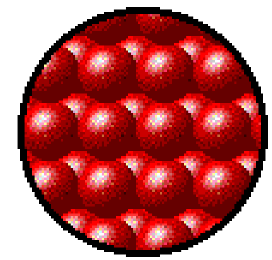
The curve depends on the material, e.g. E_{min} is different for water and iron



2 atom/molecules

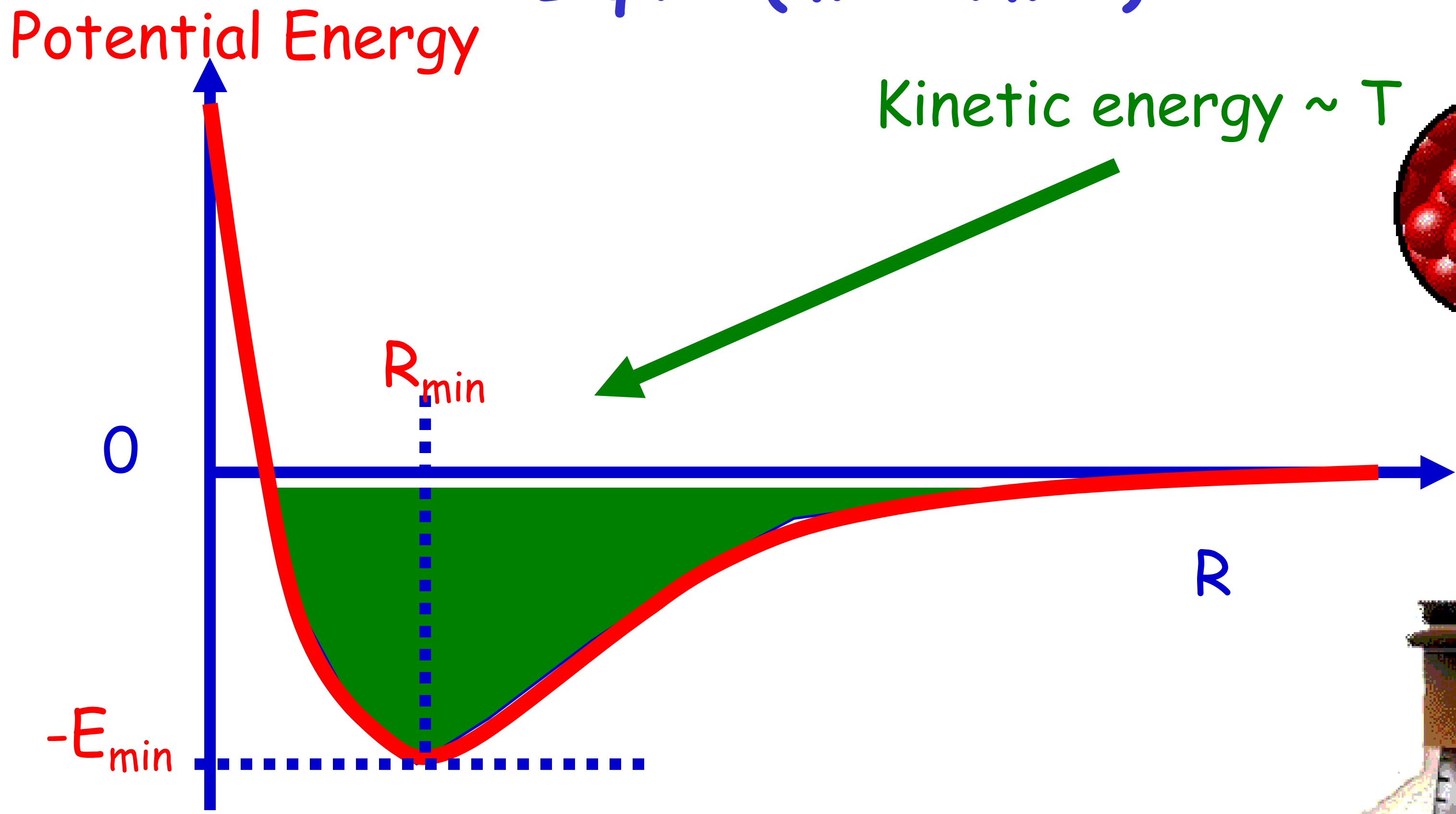
Solid (low T)

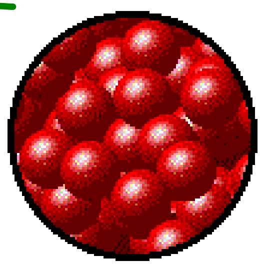




The temperature (and thus kinetic energy) is so small that the atoms/molecules can only oscillate around a fixed position R_{min}

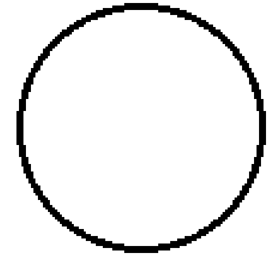
Liquid (medium T)

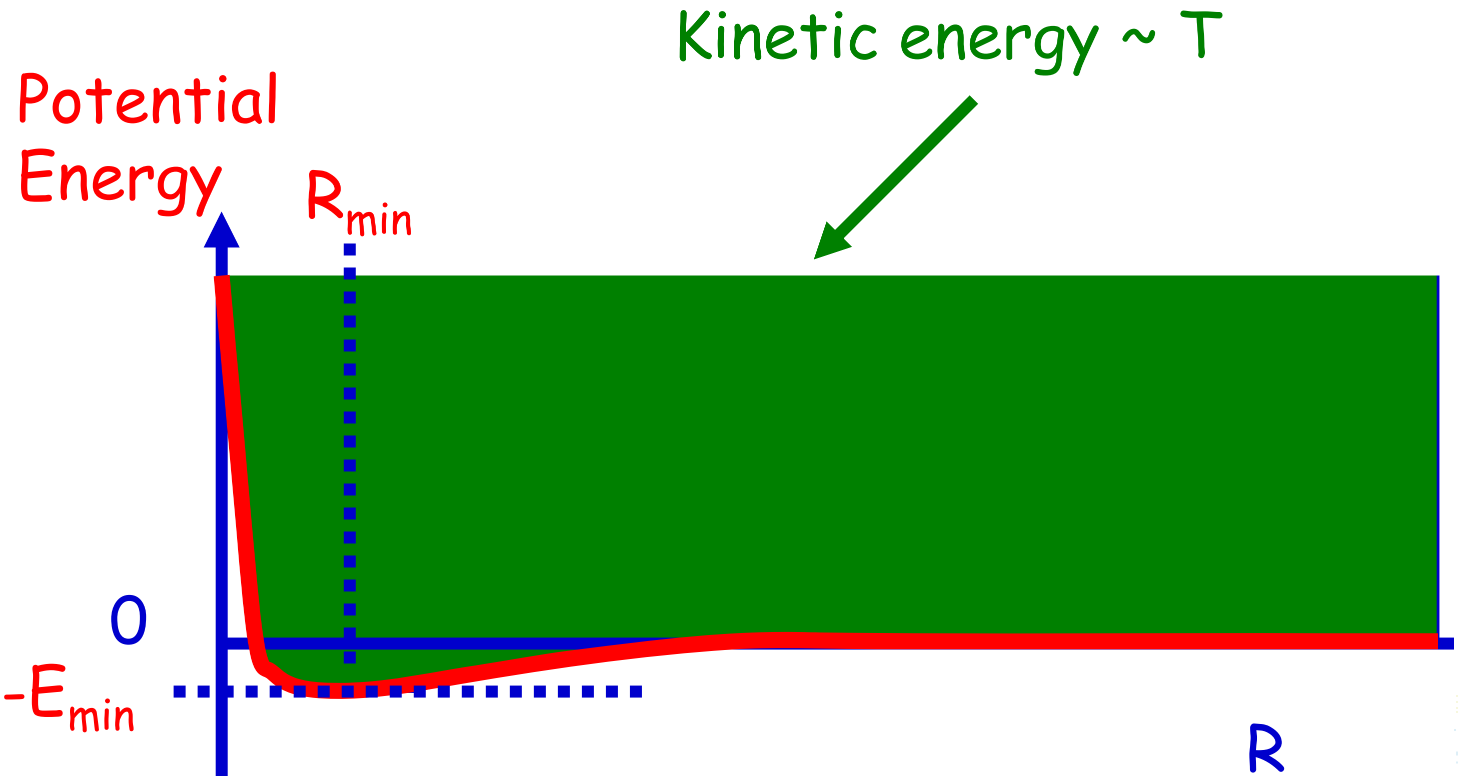




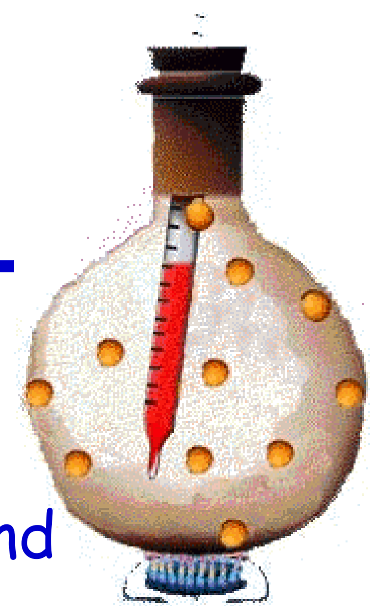
On average, the atoms/molecules like to stick together but sometimes escape and can travel far.

Gas (high T)

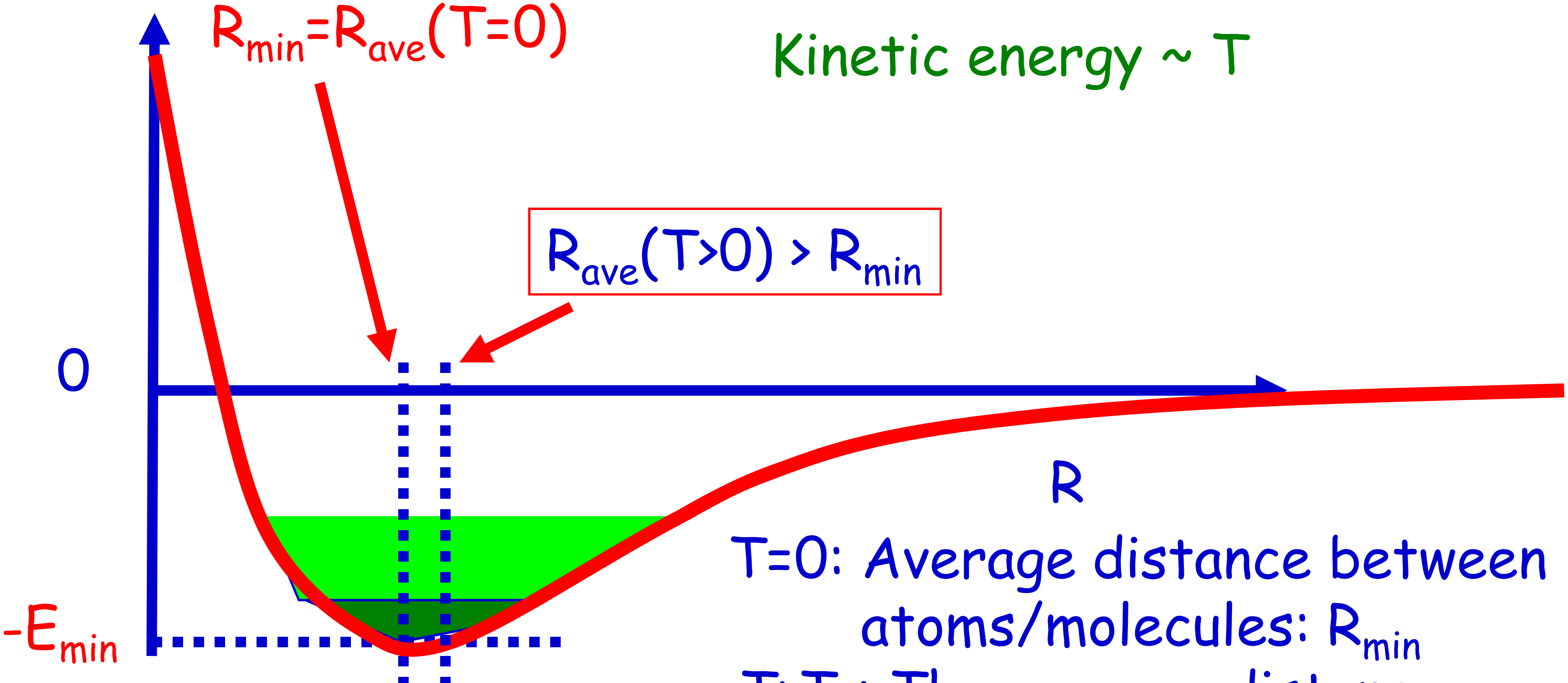




The kinetic energy is much larger than E_{min} and the atoms/molecules move around randomly.



What happens if the temperature of a substance is increased?

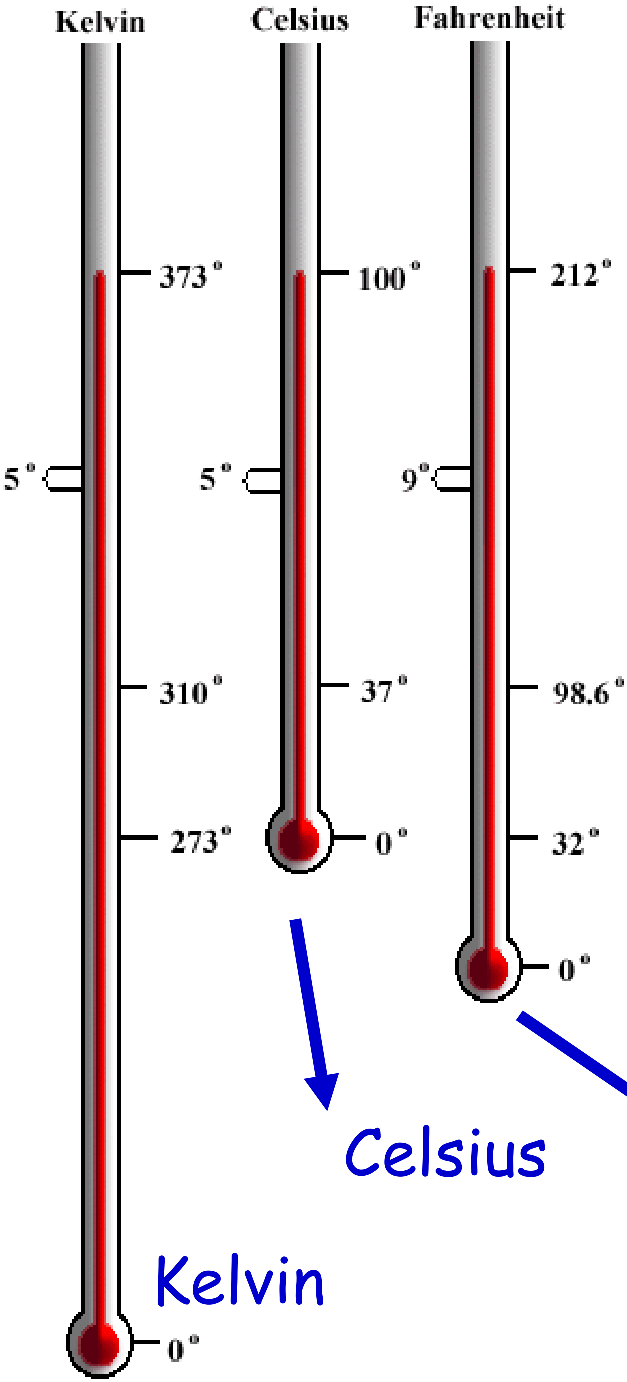


T=0: Average distance between atoms/molecules: R_{min}

$T>T_o$: The average distance between atoms/molecules is larger than R_{min}:

the substance expands

Temperature scales



Fahrenheit

Conversions

$T_{celsius} = T_{kelvin} - 273.$

$T_{fahrenheit} = 9/5 * T_{celcius} + 32$

We will use $T_{kelvin.}$

If $T_{kelvin} = 0$, the atoms/molecules have no kinetic energy and every substance is a solid; it is called the absolute zero-point.

Thermal expansion

length $\Delta L = \alpha L_o \Delta T$

surface $\Delta A = \gamma A_o \Delta T$ $\gamma = 2\alpha$

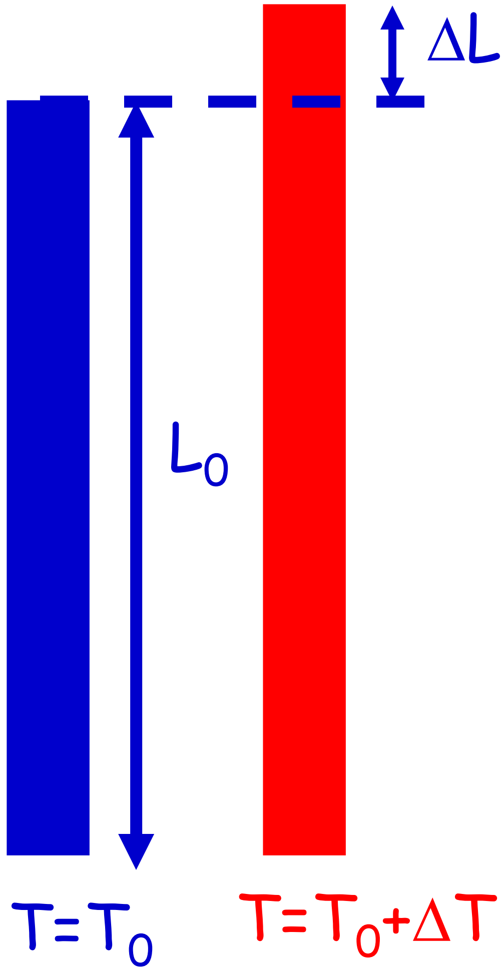
volume $\Delta V = \beta V_o \Delta T$ $\beta = 3\ \alpha$

α: coefficient of linear expansion
different for each material

Some examples:

α=24E-06 /K Aluminum

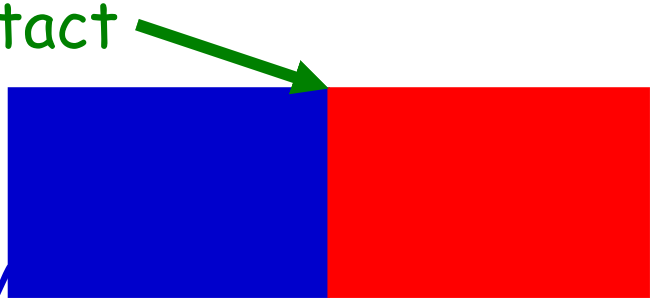
α=1.2E-04 /K Alcohol



Thermal equilibrium

Thermal contact

Low temperature
Low kinetic energy
Particles move slowly



High temperature
High kinetic energy
Particles move fast

Transfer of kinetic energy

Thermal equilibrium: temperature is the same everywhere

Zeroth law of thermodynamics

If objects A and B are both in thermal equilibrium with an object C, than A and B are also in thermal equilibrium.

↓

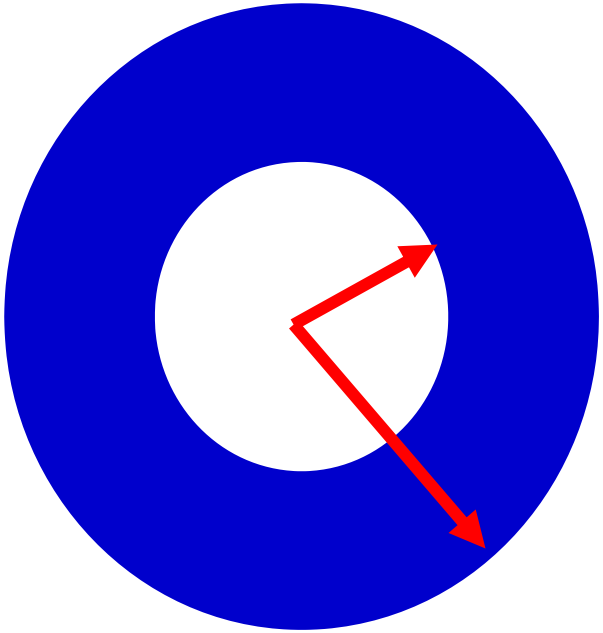
There is no transfer of energy between A, B and C

Thermal expansion: an example

In the early morning ($T=30^o$ F=272.4 K) a person is asked to measure the length of a football field with an aluminum measure and finds 109.600 m. Another person does the same in the afternoon ($T=60^o$ F=289.1 K) using the same ruler and finds 109.566 m. What is the coefficient of linear expansion of the ruler?

$\Delta L=\alpha L_o \Delta T$ so $\alpha = \Delta L/(L_0 \Delta T)$
$\Delta T=16.7$ K $L_0=109.60$ $\Delta L=109.600-109.566=0.034$
So: α=24E-06 /K

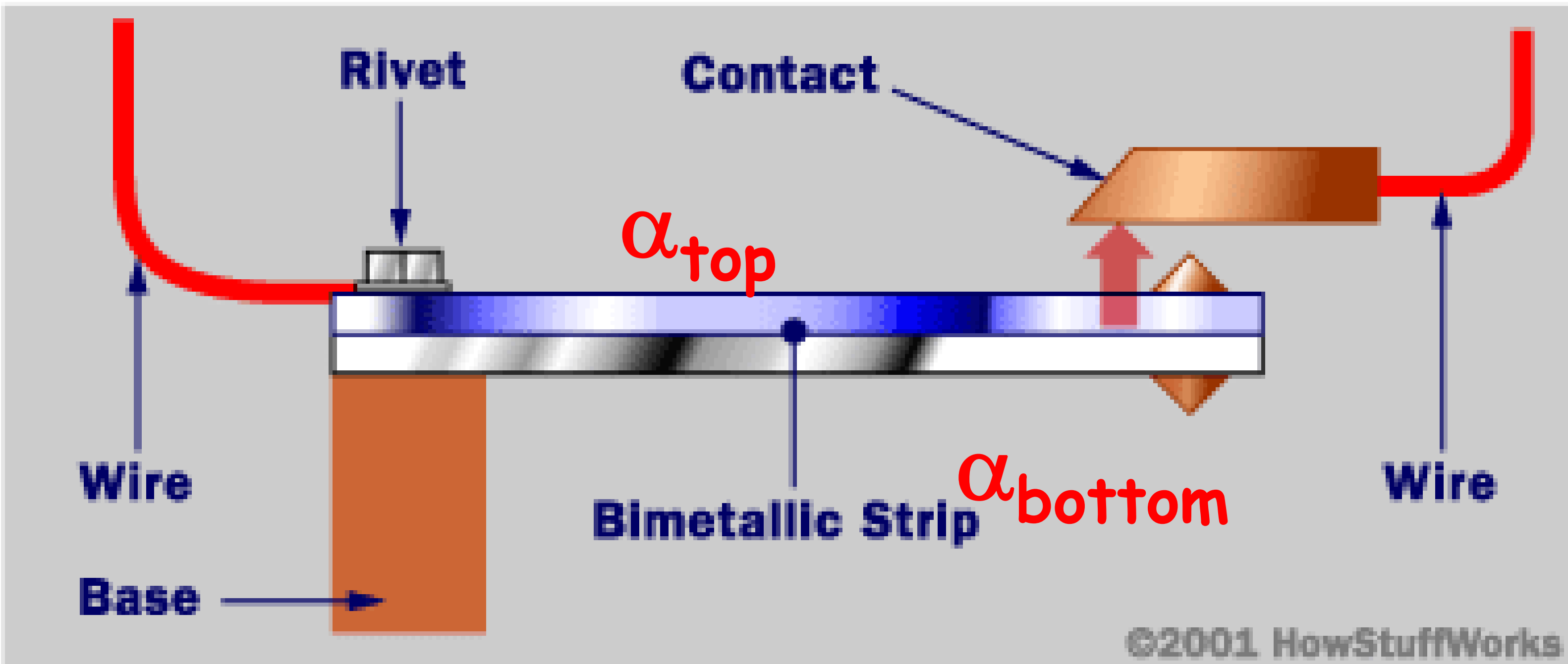
A heated ring



A metal ring is heated. What is true:

a) The inside and outside radii become larger
b) The inside radius becomes larger, the outside radius becomes smaller
c) The inside radius becomes smaller, the outside radius becomes larger
d) The inside and outside radii become smaller

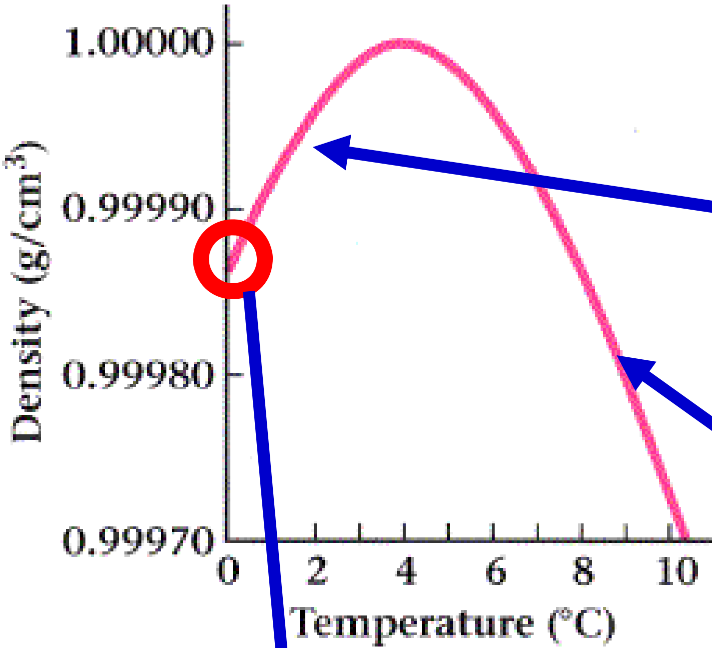
Bimetallic strips



Application: contact in a refrigerator

$\alpha_{top} < \alpha_{bottom}$ if the temperature increases,
The strip curls upward, makes contact and switches on the cooling.

Water: a special case

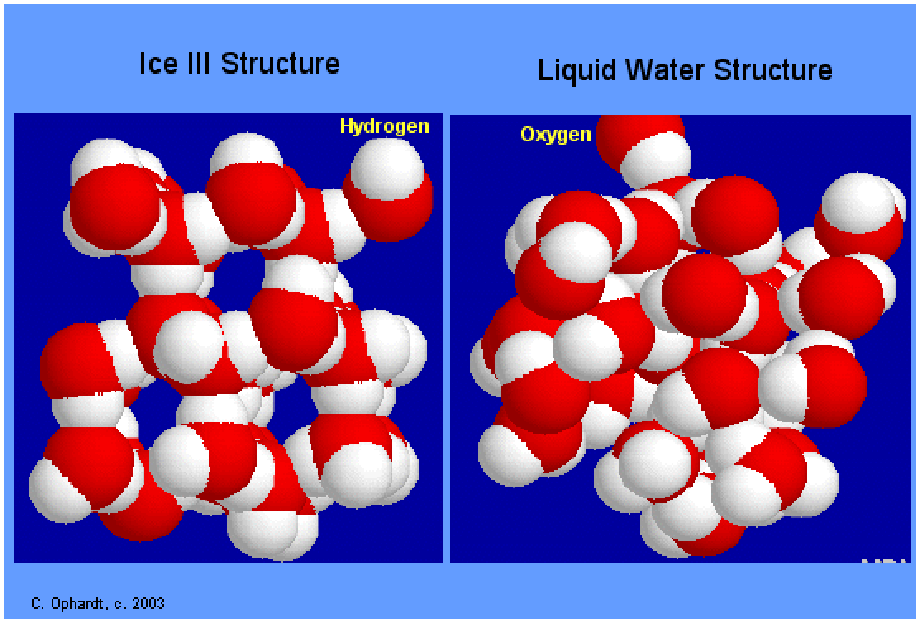


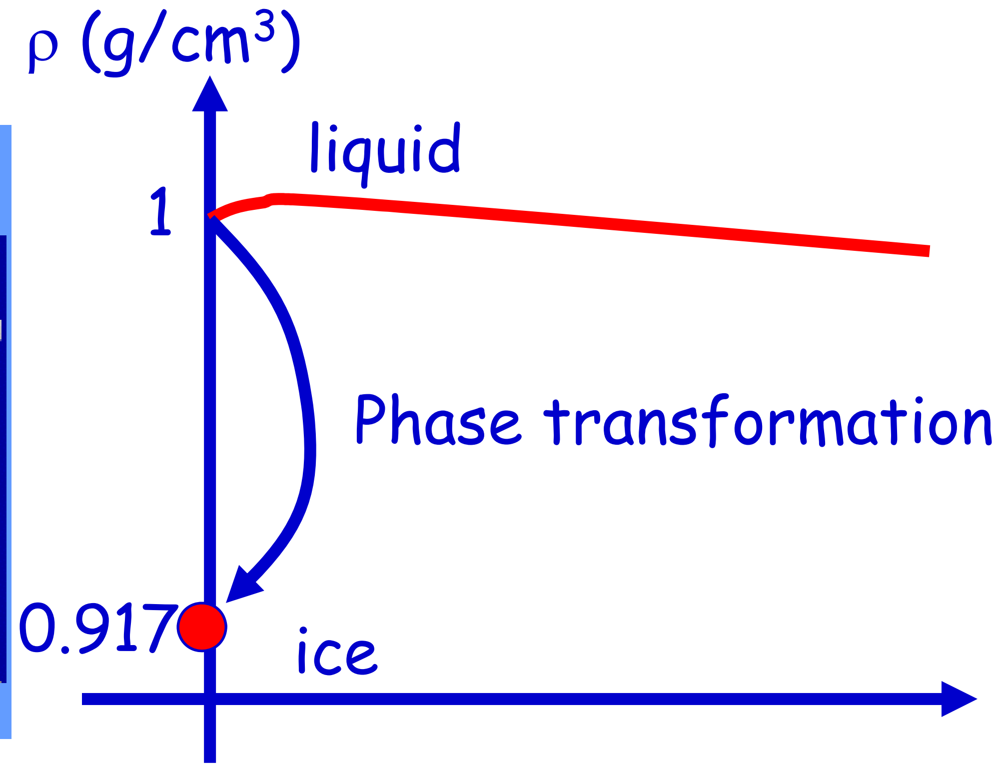
Coef. of expansion is negative: If T drops the volume becomes larger

Coef. of expansion is positive: if T drops the volume becomes smaller

Ice is formed (it floats on water)

Ice





Ice takes a larger volume than water!