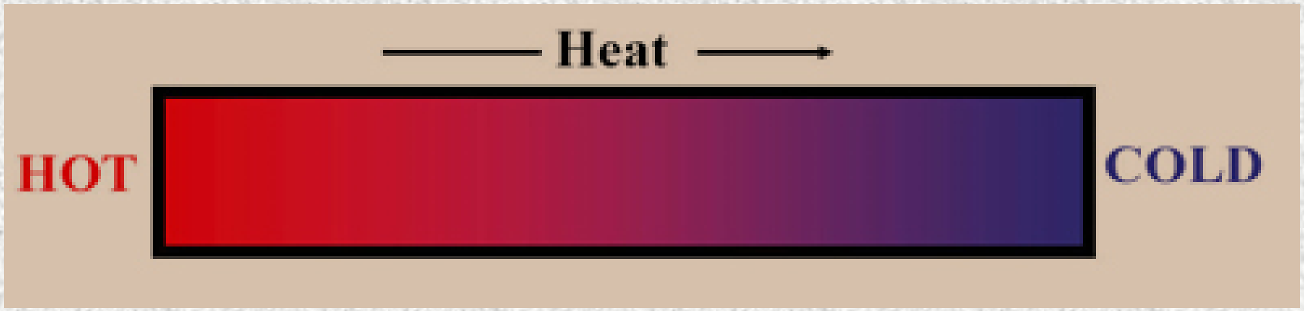
Thermal Properties



Primer Materials For Science Teaching

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Linear Thermal expansion

$L = L_0(1+\alpha\Delta T)$

α - Linear thermal expansion coefficient

Material	α [K^{-1}] $*10^{-5}$
Aluminum	2.4
Brass	2
Copper	1.7
Epoxy	1.8-2.5
Glass (common)	0.8
Quartz, Fused Silica	0.04
Steel	1.2
Zinc	2.6
Diamond	0.1

Heat Capacity

- Specific Heat Capacity – the amount of energy needed to increase 1 kg of material 1 degree

$$c = \frac{1}{m}\frac{dQ}{dT}$$

$$c_{volume} = c \times \rho$$

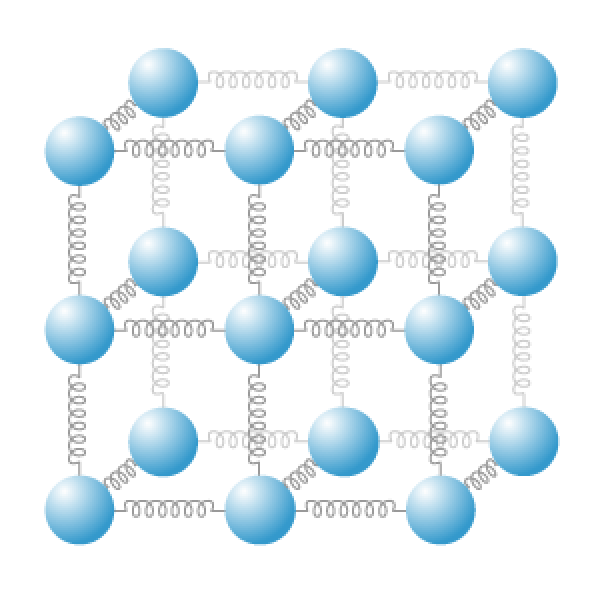
Substance	[J/(Kg*K)]	[J/(cm³ *K)]
Aluminum	930	2.51
Copper	390	2.87
Water, fresh	4179	4.18
iron	444	3.49
gold	129	2.49
zinc	390	2.78
sodium	1230	1.19
Hydrogen	14000	1.25
Diamond	509	1.8

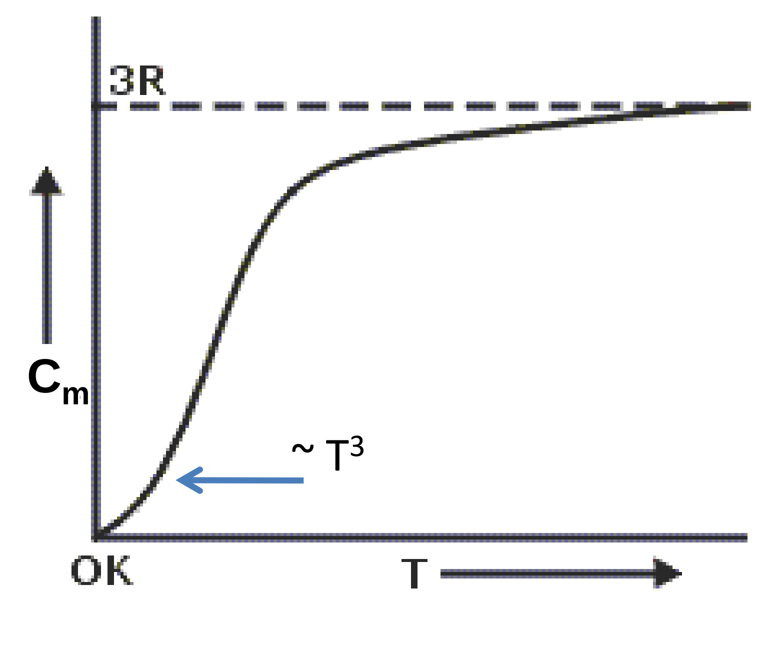
Example

- How much energy one need to invest in order to heat 1 kg of water from 25 ^oC to 60 ^oC?
- C=4179 [J/(Kg*K)]
- $\Delta Q = M*c*\Delta T = 4179*35 = 146KJ$

$$c = \frac{1}{m}\frac{dQ}{dT}$$

Heat Capacity of Solids





Variation of C_m with T

At high temperatures al monoatomic solid crystals have the same heat capacity

$$C_m = 3*R = 24.9\ [J/(mol*K)]$$

Thermal Conductivity

Thermal Conductivity– the ability of a material to transport heat

Material	λ[W/m*K]
Aluminum	250
Copper	390
Brass	130
PVC	0.19
Glass (SiO_2)	1
Alumina	25
Steel	54
Silver	427
Diamond	2000
AlN	170
ZrO_2	3

$$\lambda_{metal} \propto \sigma_{electron}$$

$$\lambda_{insulator} \propto \sqrt{\frac{E}{\rho}}$$

Thermal Diffusivity

Thermal Diffusivity– how fast a material can transfer temperature

$$D = \frac{\lambda}{C_{volume}}$$

Material	D [cm^2/sec]
Aluminum	1
Copper	1.36
PVC	0.0014
Glass (SiO_2)	0.0045
Steel	0.28
Silver	1.73
Diamond	11

Exercise

1. A zinc rod has a length of 1.9 m at 20 ^oC. What should its length be a) on a hot day in Sahara desert (48 ^oC) b) on a cold night in Greenland (-53 ^oC)
2. An engineer is working on a new engine design. One of the moving parts contains 1.6 kg of Al and 0.3 kg of iron and design to operate at 210 ^oC. How much heat is required to raise its temperature from 20 to 210 ^oC
3. Can you think of an a device which can conduct heat in only one direction?

1

- The thermal expansion coefficient of zinc is: $\alpha = 2.6X10^{-5}$ [1/K].
- A) $\Delta T = 28$ → $L=L_0 + L_0\alpha\ \Delta T = 1.9014m$
- B) $\Delta T = -73$ → $L=L_0 - L_0\alpha\ \Delta T = 1.8964m$

2

$$Cv\_Al := 910 \frac{J}{kg \cdot K} \qquad Cv\_Fe := 444 \frac{J}{kg \cdot K}$$

$$M\_Al := 1.6kg \qquad M\_Fe := 0.3kg$$

$$kJ := 1 \cdot 10^3 J$$

$$\Delta T := 190K$$

$$\Delta Q\_Al := M\_Al \cdot Cv\_Al \cdot \Delta T \qquad \Delta Q\_Fe := M\_Fe \cdot Cv\_Fe \cdot \Delta T$$

$$\Delta Q := \Delta Q\_Al + \Delta Q\_Fe$$

$$\Delta Q = 301.948\,kJ$$

3

- Consider put two parts with similar dimensions made from two different materials with different thermal expansion.
- When heat will flow from right to left the red material will expend and will touch the blue one and heat will flow.
- The thermal expansion coefficient of the blue is much smaller than the red. So if heat comes from left to right the blue material will not touch the red and heat will not flow form left to right