Thermal Conductivity 'k'

- It is a physical property of a material like a density
- k can be determined experimental. However, it can be obtained from tables or charts.
- Units, W/m °C or Btu/ ft^2 h (°F/ft)ΞBtu/ft.h. °F
- In general, k = f(T)

for small ranges of temp., k may be considered constant.

for larger temperature ranges k can be approximated by an equation of the form

$$k = \underbrace{a + b}_{\text{empirical constants}}\, T$$

- For metals
  - k covers a wide range of values

stainless steel	17 W/m. °C
mild steel	45 W/m. °C
copper	380 W/m. °C
silver	415 W/m. °C

Note $k_{metal} \approx$ constant or $\downarrow$ slightly as T $\uparrow$

$k_{alloy} < k_{pure\ metal}$

for other materials see literature or texts

- ***For liquid***
  - the typical value of k for most liquids except water = 0.17 W/m. °C
  - k_{water} = 0.5 to 0.7 W/m. °C
  - note $k_{liq} < k_{solid}$

- ***For gases***

  - $k_{gas} < k_{liq}$
  - for ideal gas $k \propto$ [avg molecular velocity, mean free path, heat capacity]
  - for monatomic gases

$$k = \frac{0.0832}{\sigma^2}\left(\frac{T}{M}\right)^{1/2}$$

where σ is the effective collision diam, Å

M is the molecular weight

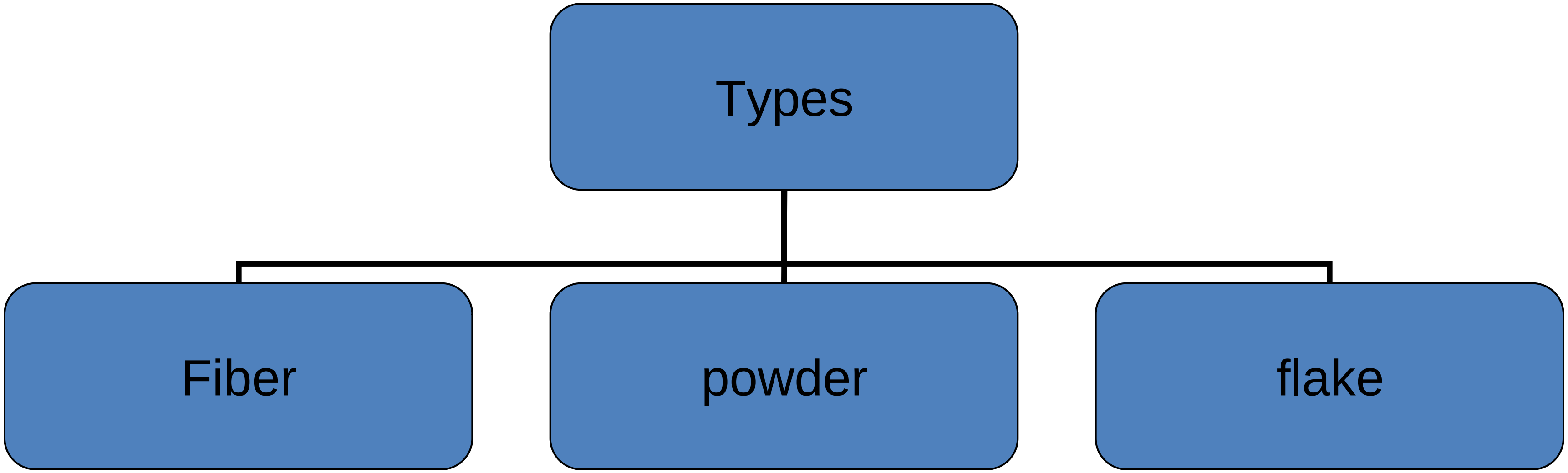
T is tempetature, K

Note solids having low k are used for insulation on pipes, vessels, and buldings.

see texts for typical ranges of k

Insulations

- Insulation consists of materials of low thermal conductivity
- They are used to minimize the heat loss from hot sources.



- In these types the solid material is finely dispersed throughout air space.
- Effective thermal conductivity, k_e is more convenient to characterize these types.
- k_e depends on:

  1. k of solid and k of air gas
  2. surface radiative properties of the solid
  3. nature and volumetric fraction of air or void space.

Other types

- Cellular insulation made of rigid solid material bonding entirely all the surfaces of voids. Examples of such rigid insulation are foamed system (made from plastic and glass material).
- Reflective insulation composed of several layers or thin sheets or foils of highly reflective properties. Sometimes the spaces between layers were evacuated to enhance reflection.

Thermal diffusivity, α

$$\alpha = k / \rho C_p \qquad m^2/s$$

It means the ability of a material to conduct thermal energy relative to its ability to store thermal energy.

Comparison

Materials of large α will respond quickly in thermal environment, while Materials of low α will respond slowly and take long time to reach new equilibrium condition.

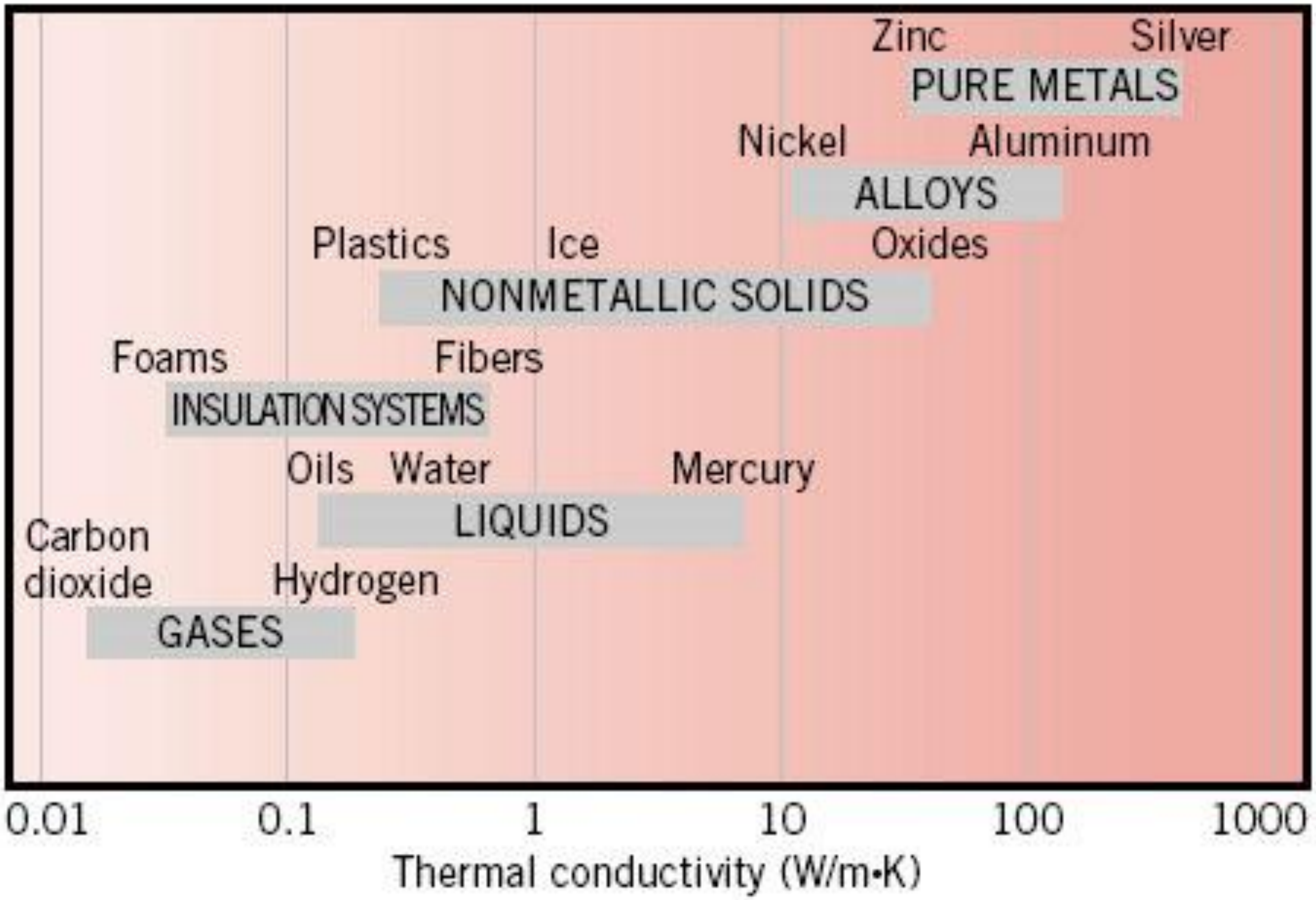


FIGURE 2.4 Range of thermal conductivity for various states of matter at normal temperatures and pressure.

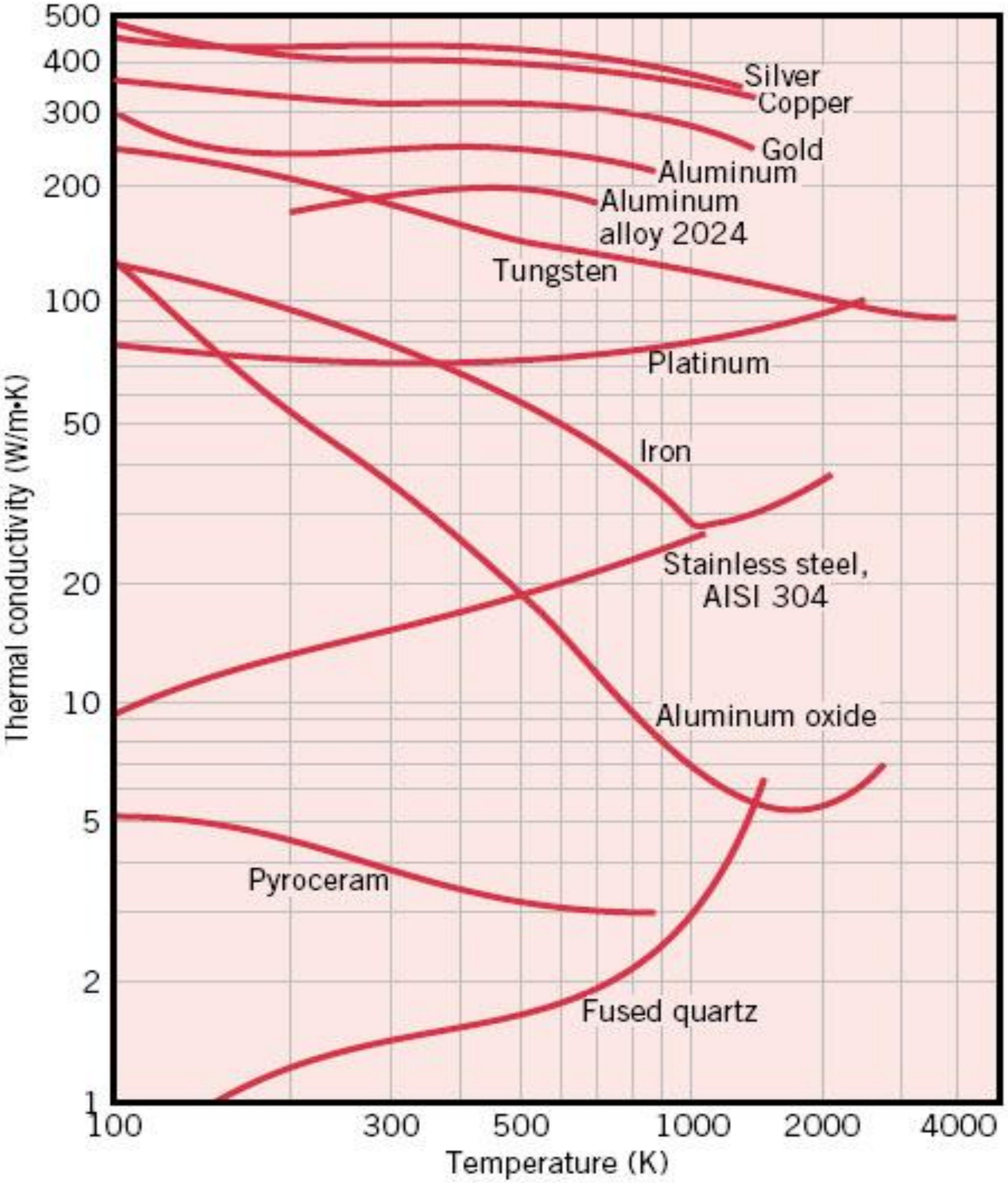


FIGURE 2.5 The temperature dependence of the thermal conductivity of selected solids.

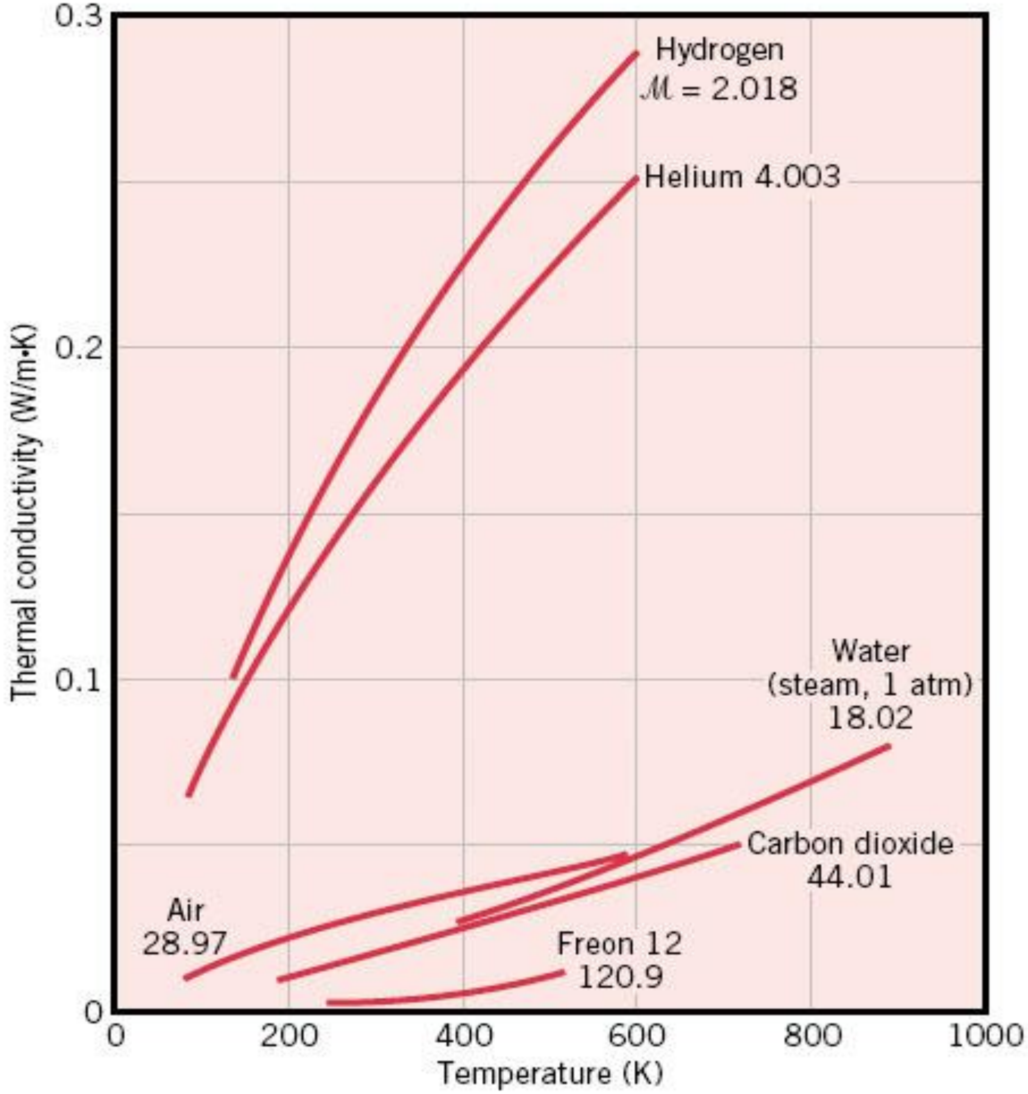


FIGURE 2.8 The temperature dependence of the thermal conductivity of selected gases at normal pressures. Molecular weights ($\mathcal{M}$) of the gases are also shown.

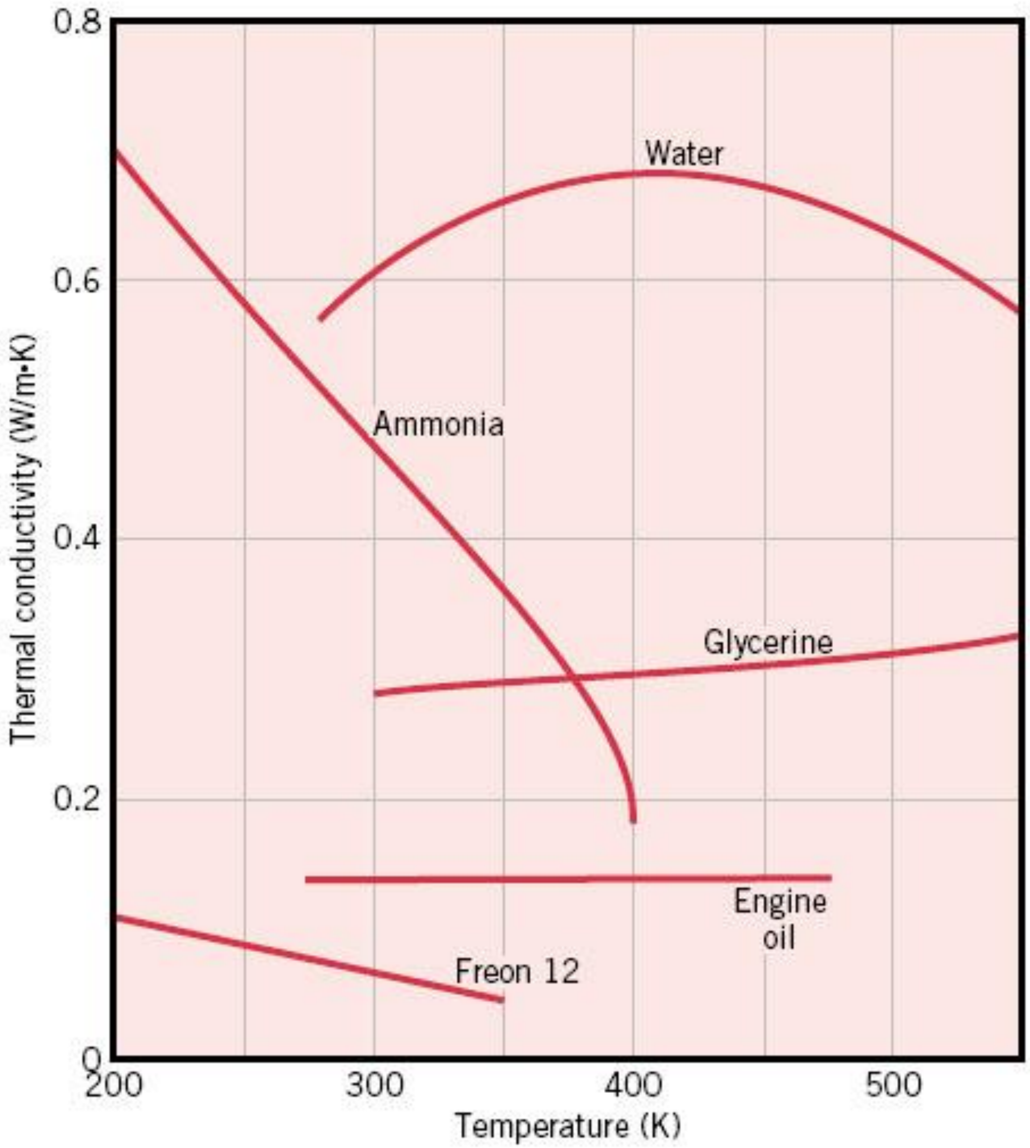


FIGURE 2.9 The temperature dependence of the thermal conductivity of selected nonmetallic liquids under saturated conditions.

Note

Thermo-physical properties of matter:

- Transport properties: k (thermal conductivity/heat transfer), ν (kinematic viscosity/momentum transfer), D (diffusion coefficient/mass transfer)
- Thermodynamic properties, relating to equilibrium state of a system, such as density, ρ and specific heat c_p.
  - the volumetric heat capacity ρc_p (J/m^3.K) measures the ability of a material to store thermal energy.
- *Thermal diffusivity α* is the ratio of the thermal conductivity to the heat capacity:

$$\alpha = \frac{k}{\rho c_p}$$