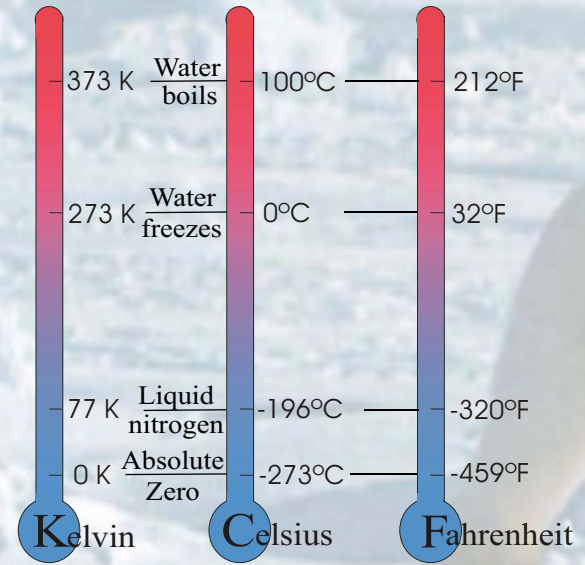


Low Temperatures

Low Temperatures Cryogenics Cold on Earth Cold in Space Superconductivity Superfluidity

Temperature scales

- Temperature scales are defined using fixed points.



- The Kelvin temperature scale has fixed points at the triple point of water, 273.16 K (0.01°C), and absolute zero, 0 K (-273.15°C).

- The absolute temperature T kelvin is related to a temperature t °C by $T = t + 273.15$

How cold?

Some of the lowest temperatures achieved are:

- Liquid helium at 90 K (Lancaster University)
- Copper at 7 K (Lancaster University)
- Rubidium gas atoms at 30 nK (University of Colorado)
- Atomic nuclei in rhodium metal at 100 pK (Helsinki University)

1 mK = 10^{-3} K
 1 K = 10^6 mK
 1 nK = 10^{-9} K
 1 pK = 10^{-12} K

Temperature and thermal energy

The average kinetic energy of atoms in an ideal gas is proportional to the absolute temperature T

$$\left[\frac{1}{2} mv^2 \right]_{\text{average}} = \frac{3}{2} kT$$

where m is the mass of an atom, v is its speed, and $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$ is the Boltzmann constant.

Temperature and the state of a gas

The pressure p of an ideal gas is proportional to the absolute temperature T . For N atoms in a volume V

$$pV = NkT$$

Temperature and heat flow

Heat is energy transferred from one body to another as a result of a temperature difference. Heat flows from high to low temperatures.

Zeroth law of thermodynamics

Objects at the same temperature are in thermal equilibrium, with no net flow of heat between them.

Third law of thermodynamics

Absolute Zero cannot be reached experimentally.

Polar bears are well-adapted to severe cold. Winter temperatures in the arctic often plunge to -50°C.