PhyzExamples: Temperature

Physical Quantities • Symbols • Units • Brief Definitions

Temperature • T • kelvin: K; also °C, °F, R • A measure of the average kinetic energy in the random translational motions of the particles in a body.

Absolute temperature is measured on the Kelvin or Rankine scale.

Relative temperature is measured on the Celsius or Fahrenheit scale.

Boltzmann's Constant • k • 1.38×10^{-23} J/K

Coefficient of Linear Expansion • α • 1/K or 1/°C • A measure of the degree to which the linear dimensions of a body made of a particular substance will change for each increment of change in temperature.

Coefficient of Volume Expansion • β • 1/K or 1/°C • A measure of the degree to which the volumetric dimension of a volume of a particular substance will change for each increment of change in temperature.

Equations

$KE = {}^3/_2 kT$ • *kinetic energy = ³/₂ · Boltzmann's constant · absolute temperature*

$\Delta L = L_0 \alpha \Delta T$ • *change in length = original length · coef. of lin. exp. · change in temp.*

$\Delta V = V_0 \beta \Delta T$ • *change in volume = original vol. · coef. of vol. exp. · change in temp.*

Examples

1. What is the speed of helium atoms at room temperature?

1. $T=293\text{K}$ is room temperature in kelvins

The mass of a helium atom is determined by dividing the molar mass by Avogadro's number.

$m=0.0040026\text{kg}/6.02\text{x}10^{23}$

$m=6.65\text{x}10^{-27}\text{kg}$

$KE = {}^3/_2 kT$

${}^1/_2 mv^2 = {}^3/_2 kT$

$v = \sqrt{(3kT/m)}$

$v = \sqrt{(3 \cdot 1.38\text{x}10^{-23}\text{J/K} \cdot 293\text{K} / 6.65\text{x}10^{-27}\text{kg})}$

<u>v = 1350m/s (>3000mph!)</u>

2. What is the temperature of a helium atom in a collection of atoms cooled to a speed of 7cm/s?

2. $v=0.07\text{m/s} \quad m=6.65\text{x}10^{-27}\text{kg}$

$KE = {}^3/_2 kT$

${}^1/_2 mv^2 = {}^3/_2 kT$

$T = mv^2/3k$

$T = 6.65\text{x}10^{-27}\text{kg} \cdot (0.07\text{m/s})^2 / 3 \cdot 1.38\text{x}10^{-23}\text{J/K}$

<u>T=0.000000787K = 787nK</u>

(such chilly temperatures have been attained in the lab)

3. How much longer does a 100m length of steel pipe get when it warms up by 43°C?

3. $L_0=100\text{m} \quad \alpha=1.2\text{x}10^{-5} 1/°\text{C} \quad \Delta T=43°\text{C}$

$\Delta L = \alpha L_0 \Delta T$

$\Delta L = (1.2\text{x}10^{-5} 1/°\text{C})(100\text{m})(43°\text{C})$

<u>ΔL = 0.052m = 5.2cm</u>

4. The volume of alcohol in a beaker drops from 1000mL to 996.8mL. Assuming no evaporation took place, what was the corresponding change in temperature?

4. $V_0=1000\text{mL} \quad \Delta V=-3.2\text{mL}$ (996.8–1000)

$\beta=7.5\text{x}10^{-4} 1/°\text{C} \quad \Delta T=?$

$\Delta V = \beta V_0 \Delta T$

$\Delta T = \Delta V/\beta V_0$

$\Delta T = -3.2\text{mL}/(7.5\text{x}10^{-4} 1/°\text{C})(1000\text{mL})$

<u>ΔT = –4.3°C</u>