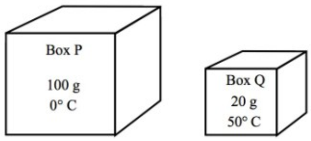
Two containers of the same gas (ideal) have these masses and temperatures:



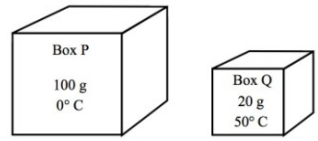
Which gas has atoms with the largest average kinetic energy?

A. P
B. Q
C. Equal
D. Not enough info

$K_{avg} = 3/2\ k_B T$

$E_{th} = NK_{avg} = 3/2\ Nk_B T$

Two containers of the same gas (ideal) have these masses and temperatures:



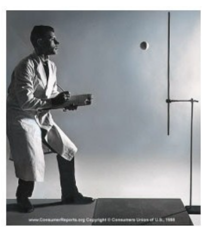
Which container of gas has the largest thermal energy?

A. P
B. Q
C. Equal
D. Not enough info

$K_{avg} = 3/2\ k_B T$

$E_{th} = NK_{avg} = 3/2\ Nk_B T$

Part II/III



- **Conservation Laws**
  - Momentum
  - Energy
  - Mass
- **Macroscopic properties of Matter**
  - Temperature and Pressure
  - Phases of Matter
  - Buoyant Force
  - Fluids

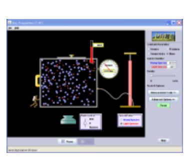
Thermal Properties of Matter

Chapter 12

Temperature

Average Kinetic Energy of particles

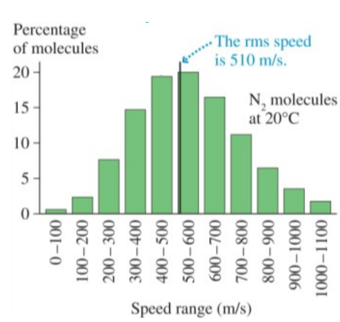
Not all the same speed – average



Speed and Kinetic Energy of Gas Molecules

$$v_{rms} = \sqrt{\frac{3k_B T}{m}}$$

$$k_B = 1.38 \times 10^{-23}\ \text{J/K}$$



Speed and Kinetic Energy of Gas Molecules

$$v_{rms} = \sqrt{\frac{3k_B T}{m}}$$

$k_B = 1.38 \times 10^{-23}$ J/K

What unit does temperature need to be in?

A. Celsius
B. Kelvin
C. Fahrenheit
D. Doesn't matter

Root-mean-square speed

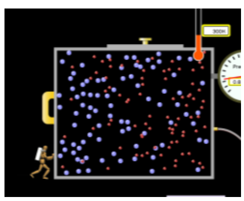
Speed of a typical atom

$K_{avg} = 3/2\ k_B T = ½\ mv^2$

Solve for velocity

$$v_{rms} = \sqrt{\frac{3k_B T}{m}}$$

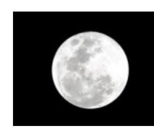
Why are the lighter (red) ones moving faster?



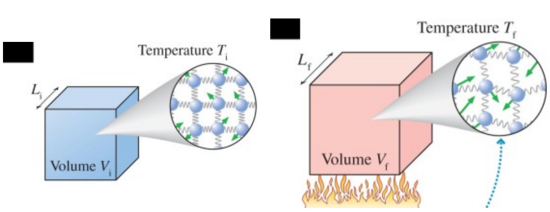
A. They started hotter and will slow down to match blue ones eventually
B. They are lighter so move faster when they have the same Kinetic Energy
C. They were pumped in with the same force so accelerated faster since they are lighter
D. Some other reason

An object moving faster than the earth's escape velocity (about 11 km/s) has enough energy to escape the pull of the earth's gravity. 11 km/s is pretty speedy, but gas atoms move at high speeds. Which one of the following gas molecules would be most likely to be moving at a speed high enough to escape the earth's atmosphere?

A. Carbon dioxide
B. Oxygen
C. Nitrogen
D. Water vapor
E. Hydrogen



Thermal Expansion



$\Delta L = \alpha L_i\, \Delta T$ Linear thermal expansion

$\Delta V = \beta V_i\, \Delta T$ Volume thermal expansion

TABLE 12.3 Coefficients of linear and volume thermal expansion at 20°C

Substance	Linear α (K^{-1})	Volume β (K^{-1})
Aluminum	23×10^{-6}	69×10^{-6}
Glass	9×10^{-6}	27×10^{-6}
Iron or steel	12×10^{-6}	36×10^{-6}
Concrete	12×10^{-6}	36×10^{-6}
Ethyl alcohol		1100×10^{-6}
Water		210×10^{-6}
Air (and other gases)		3400×10^{-6}

What unit does temperature need to be in?

A. Celsius
B. Kelvin
C. Fahrenheit
D. Doesn't matter

In the United States, railroad cars ride on steel rails. Until the mid-1900s, most track consisted of 11.9 m lengths connected with expansion joints that allow for the rails to expand and contract with temperature. If a section of rail is exactly 11.900 m long on a hot, sunny day when it warms up to 50ºC, how long will it be on a cold –10ºC winter morning?

$$\Delta L = \alpha L_i \, \Delta T$$

Linear thermal expansion

An iron ring is tight around a solid aluminum rod. If we wish to loosen the ring to remove it from the rod, we should

A. Increase the temperature of the ring and rod.
B. Decrease the temperature of the ring and rod.
C. Neither will work.

TABLE 12.3 Coefficients of linear and volume thermal expansion at 20°C

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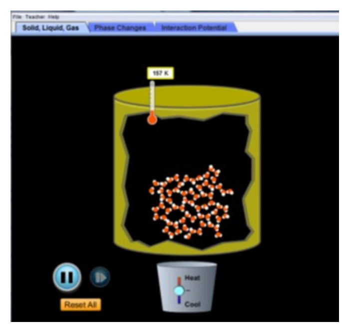
Phases of Matter



Calorimetry

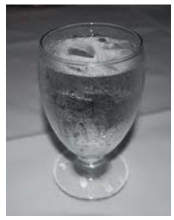
As you add heat (Q) to ice that is at 0ºC it will

A. Melt
B. Temperature will increase
C. Both

You have a mixture of ice and water at atmospheric pressure that has sat for some time.

The temperature of the water could be

A. 0°C
B. Warmer than 0°C
C. Colder than 0°C
D. More than one of the above



20 g of ice at 0°C is added to 100 g of room temp water (20°C).

T_f will be

A. < 0°C
B. 0°C
C. between 0°C and 20°C
D. > 20°C
E. B or C

Specific Heat and Heat of Transformation

Adding heat energy will raise temperature; it may also change phase.

$$Q = Mc\,\Delta T$$

Heat needed to produce a temperature change ΔT for mass M with specific heat c

$$Q = \begin{cases} \pm ML_f & \text{Heat needed to melt/freeze mass } M \\ \pm ML_v & \text{Heat needed to boil/condense mass } M \end{cases}$$

$c_{ice} = 2{,}090$ J/kgK
$c_w = 4{,}186$ J/kgK
$c_s = 2{,}010$ J/kgK

$L_f = 333{,}000$ J/kg
$L_v = 2{,}260{,}000$ J/kg

Can ice (H_2O) be colder than 0°C?

A. Yes
B. No
C. I don't know

Water transformations

Graph Temp versus Heat for 10 g of ice

Ice (-100 °C)

Add steady amount of heat

Steam (200 °C)

Specific Heat and Heat of Transformation

Adding heat energy will raise temperature; it may also change phase.

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