Temperature and the Ideal Gas

Temperature: gives us a feeling for how much thermal energy something contains

- Relative quantity
- Need some kind of scale to quantify temperature
- Need an instrument

Thermal Contact: thermal energy can be exchanged

Thermal equilibrium: objects are in thermal contact, but no thermal energy is exchanged

To measure temperature with a thermometer:

- Thermometer must be in thermal contact with system
- Thermometer must come into thermal equilibrium with system
- Thermometer must be much smaller than the system so that very little energy is transferred (system remains at same temperature during the measurement)
- Must use a temperature-dependent physical quantity:
    - Volume of a liquid
    - Length of a solid
    - Pressure of a gas (at constant Volume)
    - Volume of a gas (at constant Pressure)
    - Electric resistance
    - Color of a very hot object

Celcius Temperature scale: based on phases of water

- Ice-water equilibrium point – freezing/melting: 0°C
- Water-steam equilibrium point – boiling: 100°C

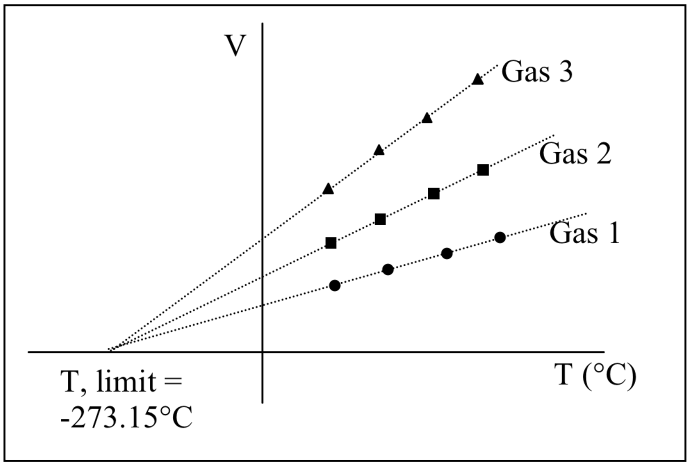
Kelvin – absolute temperature scale

- 0 K = absolute zero ➔ system contains no energy at all

Simulation – gas particles, motion as a function of temperature.

Haven't actually reached absolute zero yet – got close (μK, Bose Einstein Condensation, Eric Cornell, Carl Wieman and Wolfgang Ketterle at MIT were awarded the 2001 Nobel Prize in Physics.)

For ideal gases: Volume (V) ∝ Temperature (T)



Extrapolated to colder temperatures

Each curve intersected at the same point

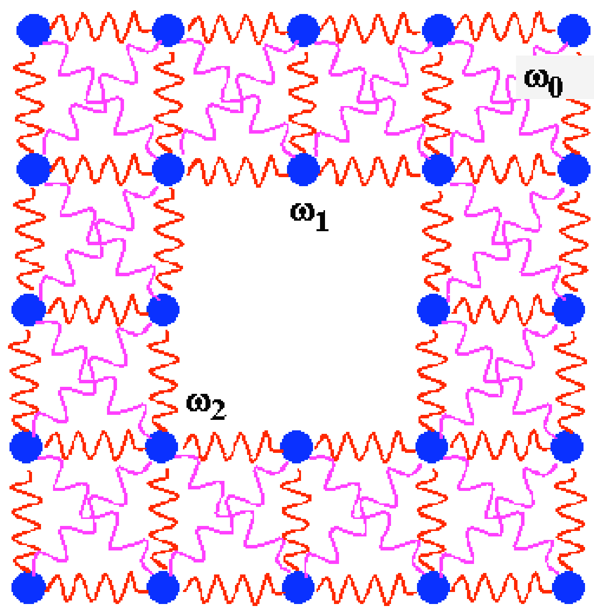
= -273.15°C = 0 K

So, why does the volume increase with increasing temperature?

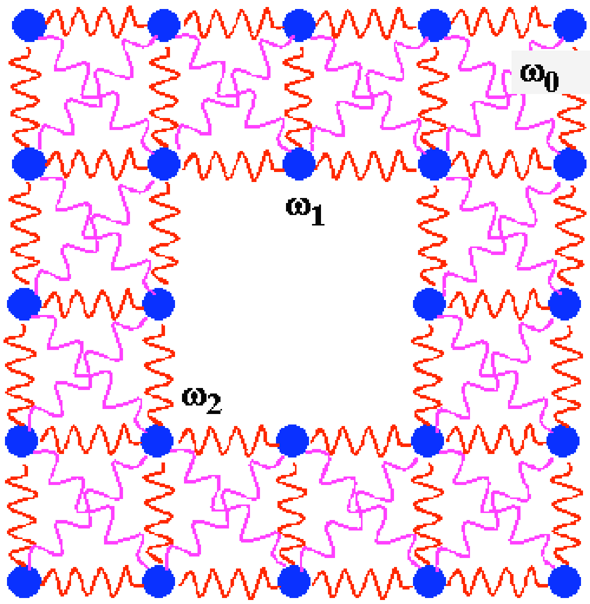
- To increase T, energy must be added to the system
- Increases the internal energy of the system
- Particles in the system move around more (they have more kinetic energy)

Look VERY closely at a solid object:

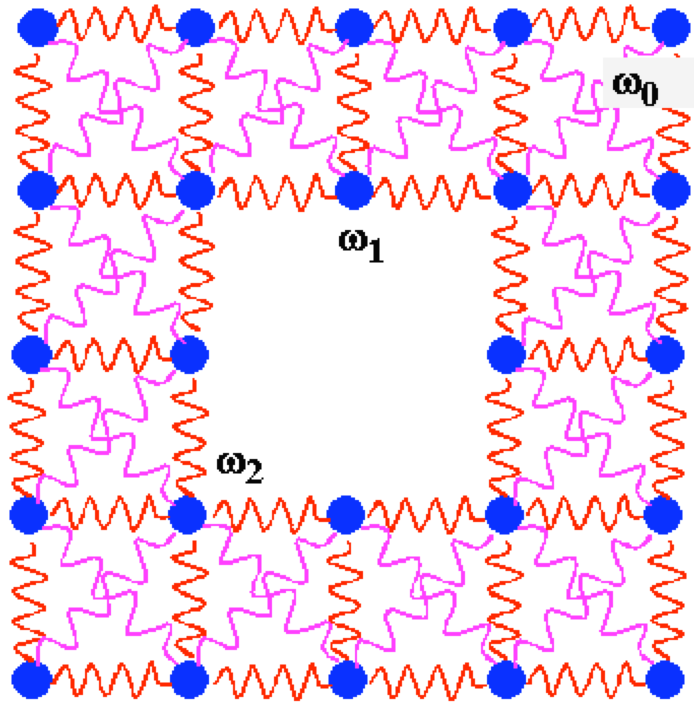
- These atoms (blue circles) have kinetic energy – they are moving around
- Because of the bonds, the atoms vibrate, oscillate back and forth



Lower temperature

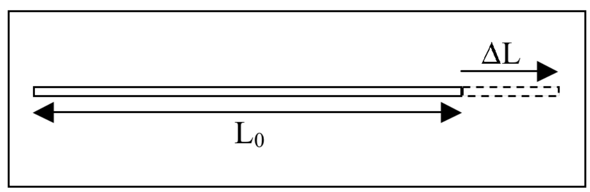


Higher temperature



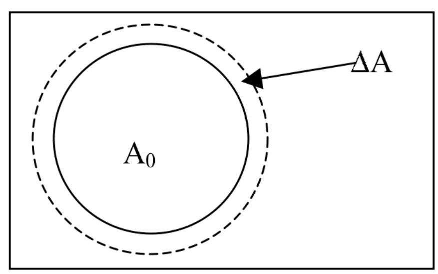
Thermal expansion/contraction:

One dimensional ➔ $\Delta L = \alpha L_0 \Delta T$

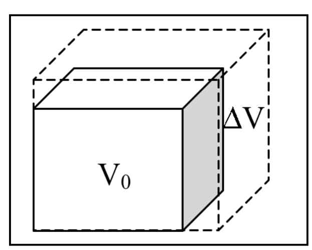


α = thermal expansion coefficient

Two dimensional ➔ $\Delta A = 2\alpha A_0 \Delta T$



Three dimensional ➔ $\Delta V = \underbrace{3\alpha}_{\beta} V_0 \Delta T$



β = volume expansion coefficient

1. There are different ways of measuring temperature depending on what you're measuring the temperature of, and what temperature range you need to measure.

a. Describe two different ways of measuring temperature. What physical properties do they rely on?

b. Give examples of when you might use these methods.

c. Why do you always have to hold the thermometer under your tongue for what seems like hours (but is usually about 30 seconds) when you have your temperature measured?

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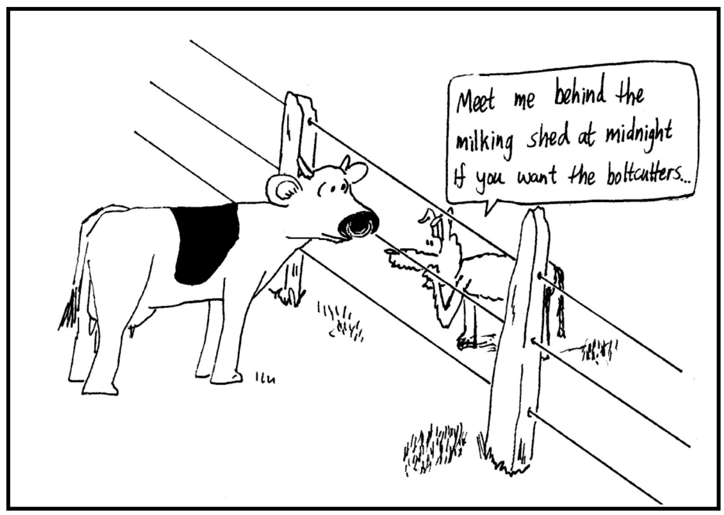
2. A farmer is stringing a wire fence in the middle of the day. He makes it nice and tight so that his cows can't push through it.

a. That night all the wires break. Why?



b. How does running hot water over a jar make the lid easier to get off when both the jar and the lid are being heated?

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3. You fill your gas tank with 15 gallons of gas [full] in the morning when the temperature is 15°C. The car is left in the sun and the temperature in the car rises to 55°C. The coefficient of volume expansion for gas is $\beta = 0.95 \times 10^{-3}\ C^{-1}$.

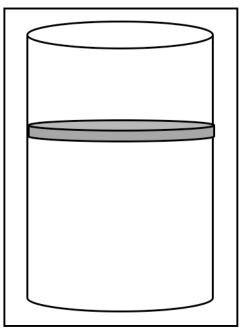
a. How much gas will overflow?

b. If gas is $4.30/gallon, how much money have you wasted?

Ideal gas – what is it?

An ideal gas (or perfect gas) is

- a hypothetical gas consisting of identical particles of zero volume
- with no intermolecular forces
- where the constituent atoms or molecules undergo perfectly elastic collisions with the walls of the container and each other
- in constant random motion.
- Real gases do not behave according to these exact properties, although the approximation is often good enough to describe real gases.



$V \propto T$ at constant P

$P \propto T$ at constant V

$P \propto 1/V$ at constant T

Ideal Gas law (Macroscopic form) ➔ $PV = nRT$

- n = number of moles
- R = 8.31 J/mol•K = universal gas constant

Ideal Gas Law (Microscopic form) ➔ $PV = NkT$

- N = number of atoms/molecules
- $k = 1.38 \times 10^{-23}$ J/K = Boltzmann's constant
- $R = N_A k$
- $N = nN_A$
- $N_A = 6.02 \times 10^{23}$ atoms/mol = Avogadro's number