Wrocław University of Science and Technology

Physics

JZL1001913C

summer semester

2020/2021

Wednesday, 18:20 - 19:50

Friday, 18:20 - 19:50

virtual room (ZOOM)

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Outline

- *Introduction - Physics rules the world*
- *Motion phenomena - Kinematics*
- *Motion phenomena - Dynamics*
- *Rotational motion*
- *Harmonic motion*
- *Gravitational field*
- *Relativistic phenomena*
- **Basics of Thermodynamics**
- Principles of Thermodynamics
- Kinetic theory of matter
- Electrostatics
- Electric current
- Magnetic field
- Vibrations and electromagnetic waves
- Optics
- Quantum nature of radiation
- Nuclear Physics

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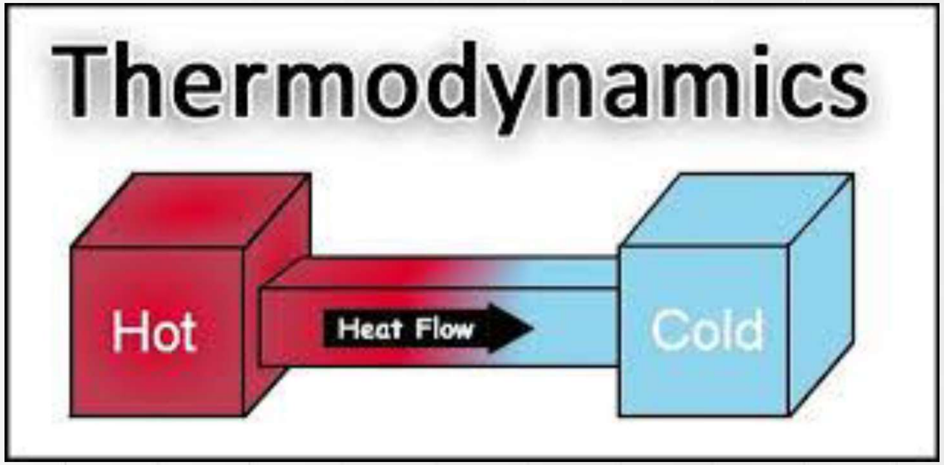
Thermodynamics

Let us break the word **thermodynamics** into two words, **thermo** and **dynamics.** ‘Thermo’ stands for heat while ‘dynamics’ is used in connection with a mechanical motion which involves ‘work’. Therefore, Thermodynamics is the branch of physics that deals with the relationship between heat and other forms of energy.

Specifically, thermodynamics focuses largely on how a heat transfer is related to various energy changes within a physical system undergoing a thermodynamic process. Such processes usually result in work being done by the system and are guided by the laws of thermodynamics.



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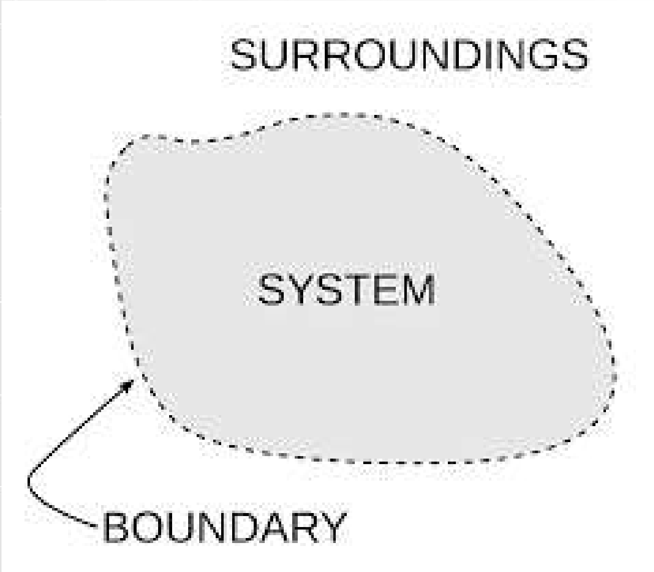
System

In thermodynamics, the system is defined as a definite space or area on which the study of energy transfer and energy conversions is made.

- **Open system:** System in which both mass and energy cross the boundaries of the system.
- **Closed system:** System in which mass does not cross boundaries of the system, though energy may do so.
- **Isolated system:** System in which neither mass nor energy crosses the boundaries of the system.



Boundary

The system and surroundings are separated by a boundary. It may be fixed or movable or imaginary. It will not occupy any volume or mass in space.

Surroundings

Anything outside the system which affects the behavior of the system is known as surroundings.

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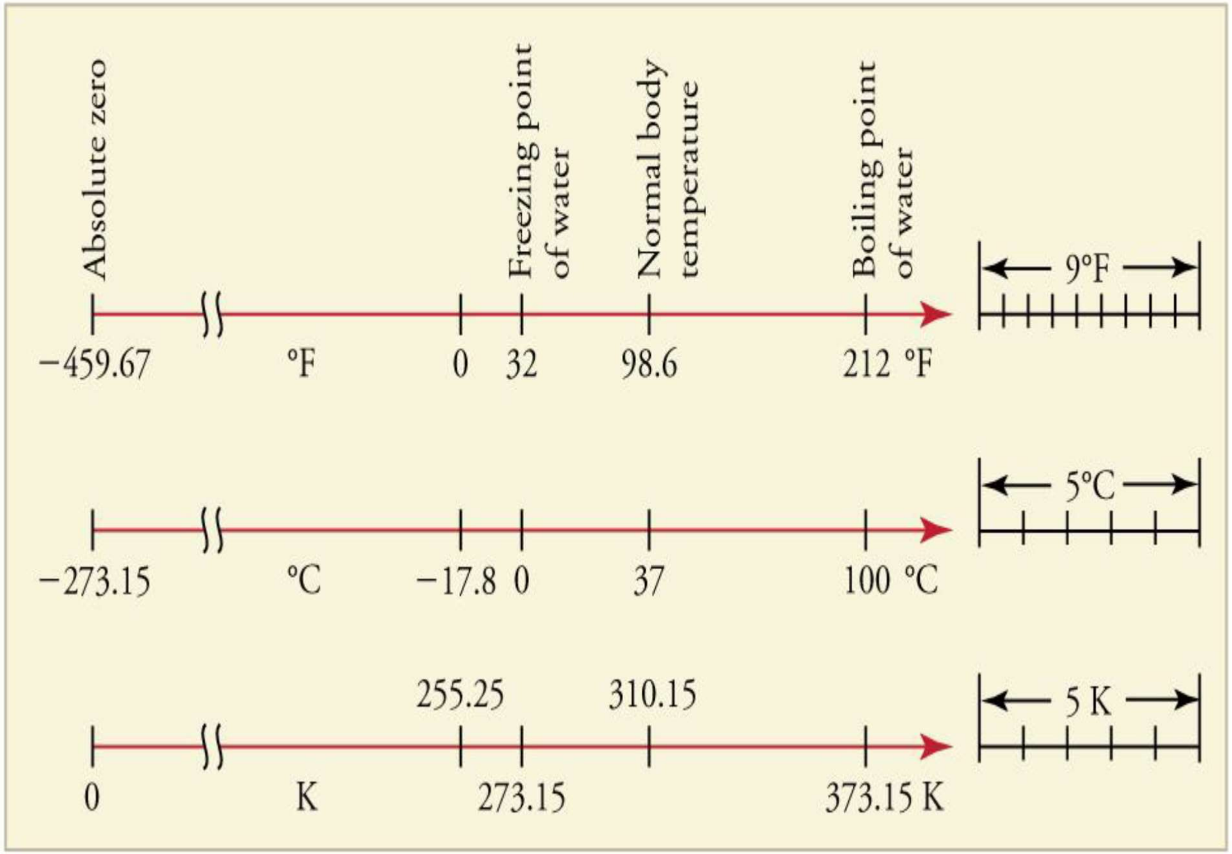
Temperature

The term “Thermodynamics” brings to mind the everyday term temperature. We often use terms like cold, hot, and temperature, but what do these terms actually mean scientifically. You might say that a hot object has a high temperature and a cold object has a low temperature, but what does this really mean. We will start by looking at how everyday temperature scales came about and eventually develop a more scientific definition of temperature.

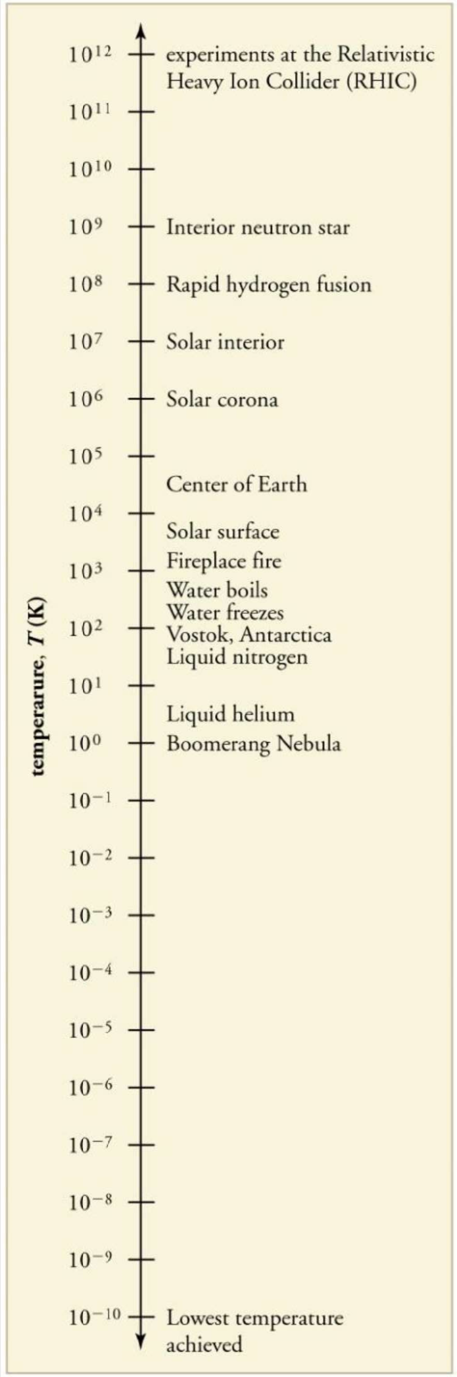
Boiling point of pure water is 100°C

Freezing Point of pure water is 0°C

Temperature Scales



Relationships between the Fahrenheit, Celsius, and Kelvin temperature scales, rounded to the nearest degree.



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Temperature Conversions

To convert from . . .	Use this equation . . .	Also written as . . .
Celsius to Fahrenheit	$T(°\mathrm{F}) = \frac{9}{5}T(°\mathrm{C}) + 32$	$T_{°\mathrm{F}} = \frac{9}{5}T_{°\mathrm{C}} + 32$
Fahrenheit to Celsius	$T(°\mathrm{C}) = \frac{5}{9}(T(°\mathrm{F}) - 32)$	$T_{°\mathrm{C}} = \frac{5}{9}(T_{°\mathrm{F}} - 32)$
Celsius to Kelvin	$T(\mathrm{K}) = T(°\mathrm{C}) + 273.15$	$T_{\mathrm{K}} = T_{°\mathrm{C}} + 273.15$
Kelvin to Celsius	$T(°\mathrm{C}) = T(\mathrm{K}) - 273.15$	$T_{°\mathrm{C}} = T_{\mathrm{K}} - 273.15$
Fahrenheit to Kelvin	$T(\mathrm{K}) = \frac{5}{9}(T(°\mathrm{F}) - 32) + 273.15$	$T_{\mathrm{K}} = \frac{5}{9}(T_{°\mathrm{F}} - 32) + 273.15$
Kelvin to Fahrenheit	$T(°\mathrm{F}) = \frac{9}{5}(T(\mathrm{K}) - 273.15) + 32$	$T_{°\mathrm{F}} = \frac{9}{5}(T_{\mathrm{K}} - 273.15) + 32$

“Room temperature” is generally defined to be 25ºC. What is room temperature in ºF? What is it in K?

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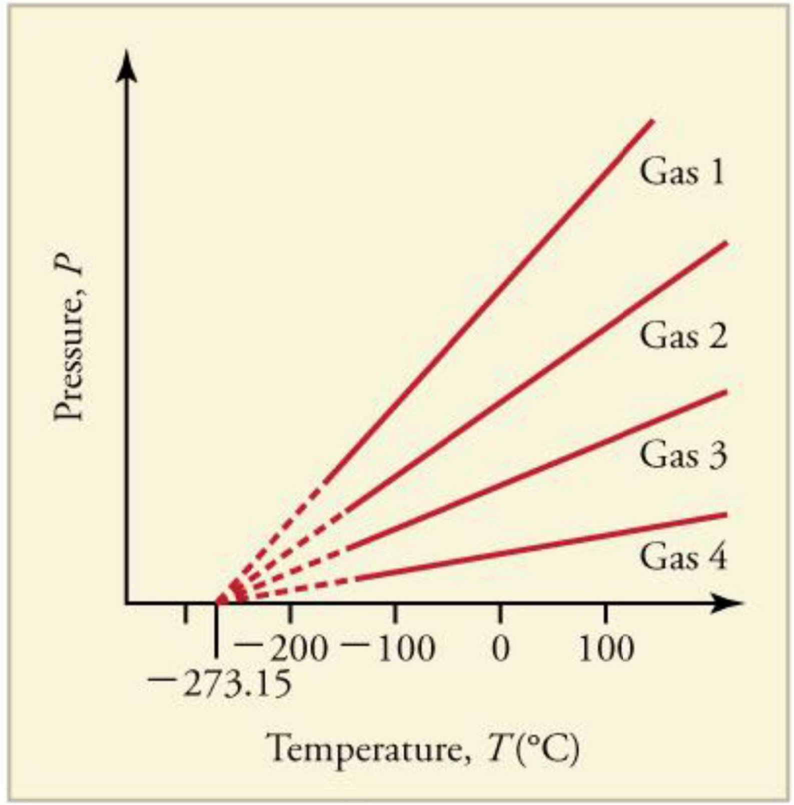
Absolute zero

What is absolute zero? Absolute zero is the temperature at which all molecular motion has ceased. The concept of absolute zero arises from the behavior of gases. Figure shows how the pressure of gases at a constant volume decreases as temperature decreases. Various scientists have noted that the pressures of gases extrapolate to zero at the same temperature, –273.15ºC . This extrapolation implies that there is a lowest temperature. This temperature is called absolute zero. Today we know that most gases first liquefy and then freeze, and it is not actually possible to reach absolute zero. The numerical value of absolute zero temperature is –273.15ºC or 0 K.



Graph of pressure versus temperature for various gases kept at a constant volume.

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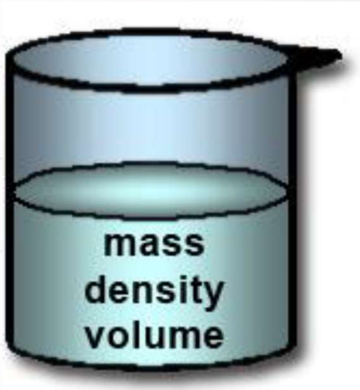
Another important quantities



Mass is a fundamental dimension.

Density has derived dimensions made up of a combination of fundamental dimensions: $\frac{\text{mass}}{\text{length}^3}$

Volume also has cubic fundamental dimension → m^3

Pressure

[noun] (physics) the force applied to a unit area of surface; measured in pascals (SI unit) or in dynes (cgs unit)

$P = F/S$

Thermodynamic Processes

A system undergoes a thermodynamic process when there is some sort of energetic change within the system, generally associated with changes in pressure, volume, internal energy (i.e. temperature), or any sort of heat transfer.

There are several specific types of thermodynamic processes that have special properties:

- **Adiabatic process** - a process with no heat transfer into or out of the system.
- **Isochoric process** - a process with no change in volume, in which case the system does no work.
- **Isobaric process** - a process with no change in pressure.
- **Isothermal process** - a process with no change in temperature

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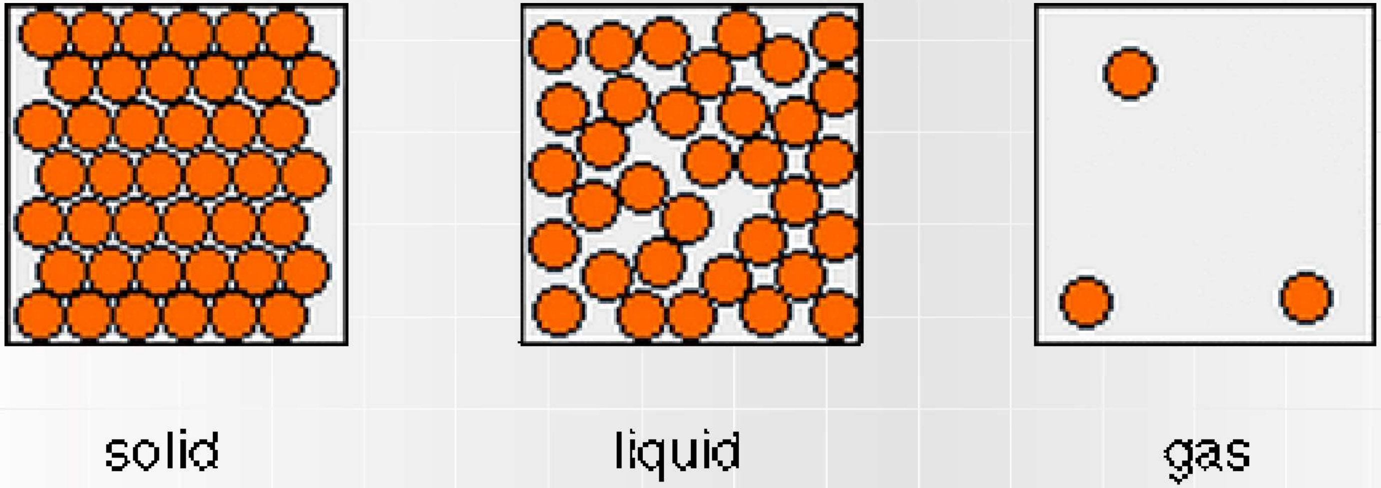
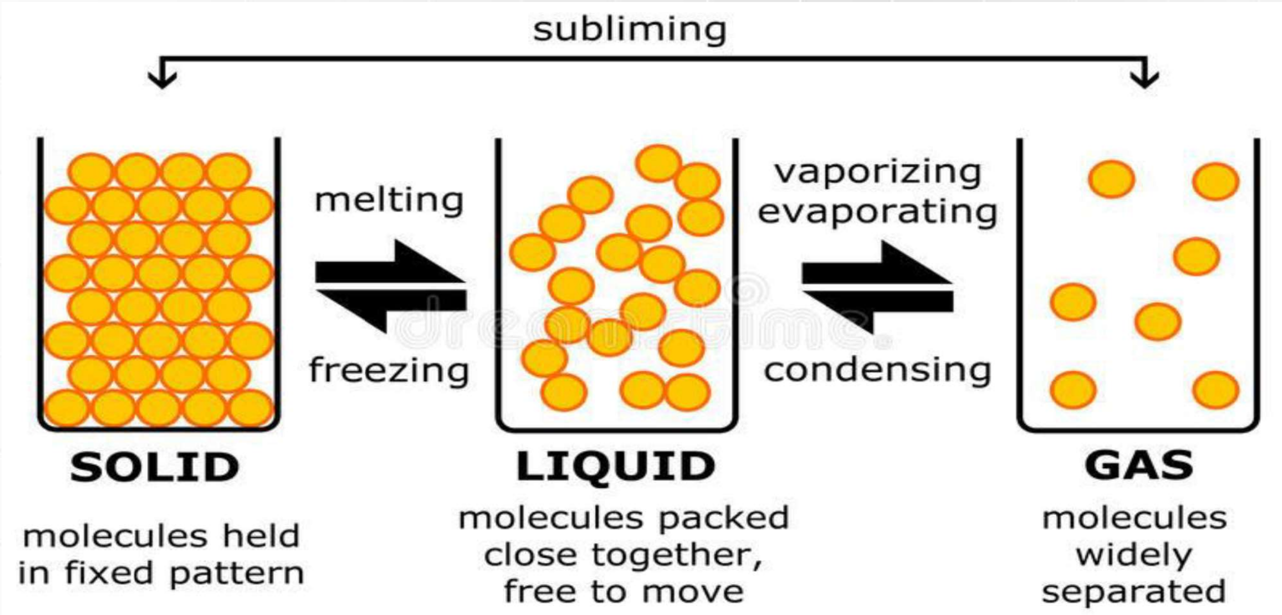
States of Matter

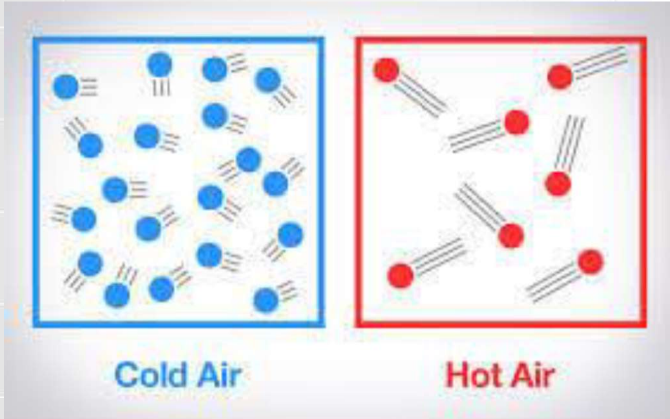


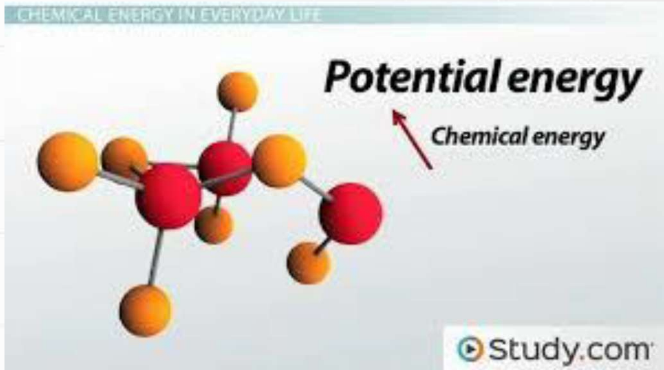
Transition between states of matter



Total internal energy

Although classical thermodynamics deals exclusively with the macroscopic properties of materials—such as temperature, pressure, and volume—thermal energy from the addition of heat can be understood at the microscopic level as an increase in the kinetic energy of motion of the molecules making up a substance.





Additionally, chemical energy is stored in the bonds holding the molecules together, and weaker long-range interactions between the molecules involve yet more energy.

The sum total of all these forms of energy constitutes the total internal energy of the substance in a given thermodynamic state.

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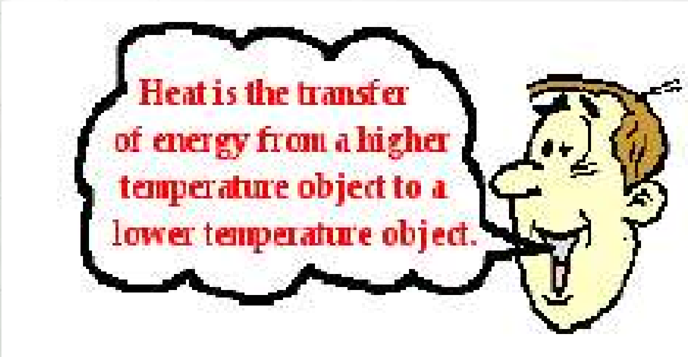
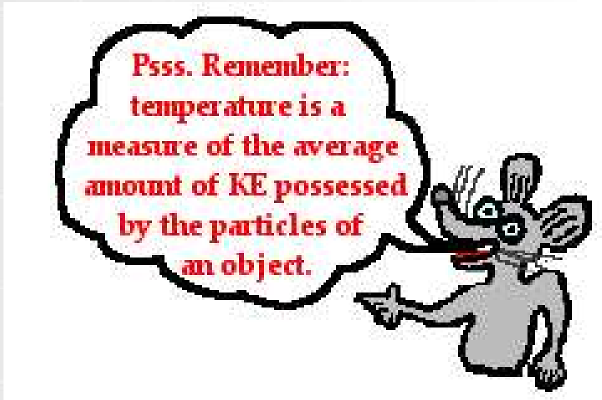
Heat



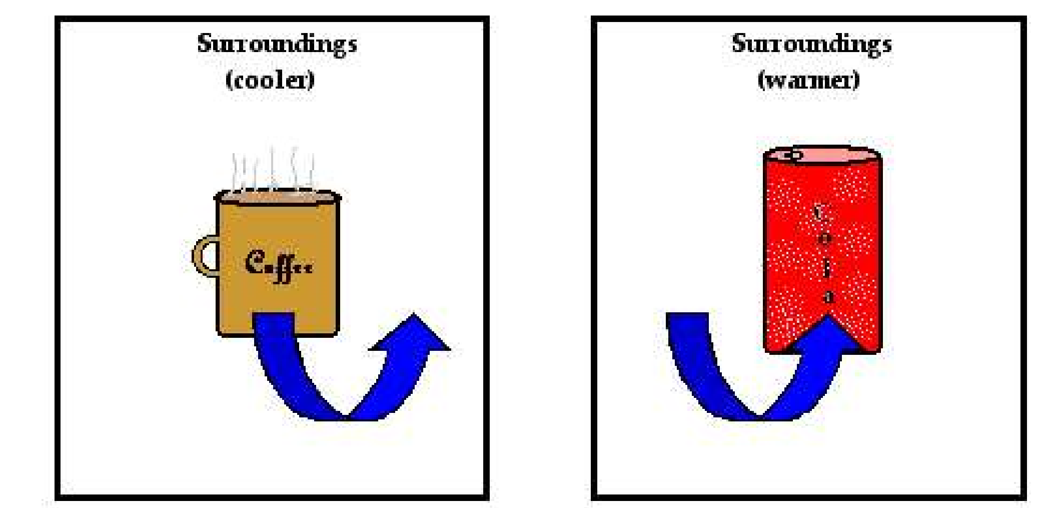
Thermal energy (also called **heat energy**) is produced when a rise in temperature causes atoms and molecules to move faster and collide with each other. The **energy** that comes from the temperature of the heated substance is called **thermal energy**.

Temperature is a measure of the ability of a substance, or more generally of any physical system, to transfer heat energy to another physical system. The higher the temperature of an object is, the greater the tendency of that object to transfer heat. The lower the temperature of an object is, the greater the tendency of that object to be on the receiving end of the heat transfer.



Heat – macroscopic example

On the macroscopic level, we would say that the coffee and the mug are transferring heat to the surroundings. This transfer of heat occurs from the hot coffee and hot mug to the surrounding air. The fact that the coffee lowers its temperature is a sign that the average kinetic energy of its particles is decreasing. The coffee is losing energy. The mug is also lowering its temperature; the average kinetic energy of its particles is also decreasing. The mug is also losing energy. The energy that is lost by the coffee and the mug is being transferred to the colder surroundings. We refer to this transfer of energy from the coffee and the mug to the surrounding air and countertop as heat. In this sense, **heat** is simply the transfer of energy from a hot object to a colder object



Heat is the flow of energy from a high temperature location to a low temperature location.

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Basic Concepts of Heat Transfer

Thermal Contact is when two substances can affect each other's temperature.

Thermal Equilibrium is when two substances in thermal contact no longer transfer heat.

Thermal Expansion takes place when a substance expands in volume as it gains heat. Thermal contraction also exists.

Conduction is when heat flows through a heated solid.

Convection is when heated particles transfer heat to another substance, such as cooking something in boiling water.

Radiation is when heat is transferred through electromagnetic waves, such as from the sun.

Insulation is when a low-conducting material is used to prevent heat transfer.

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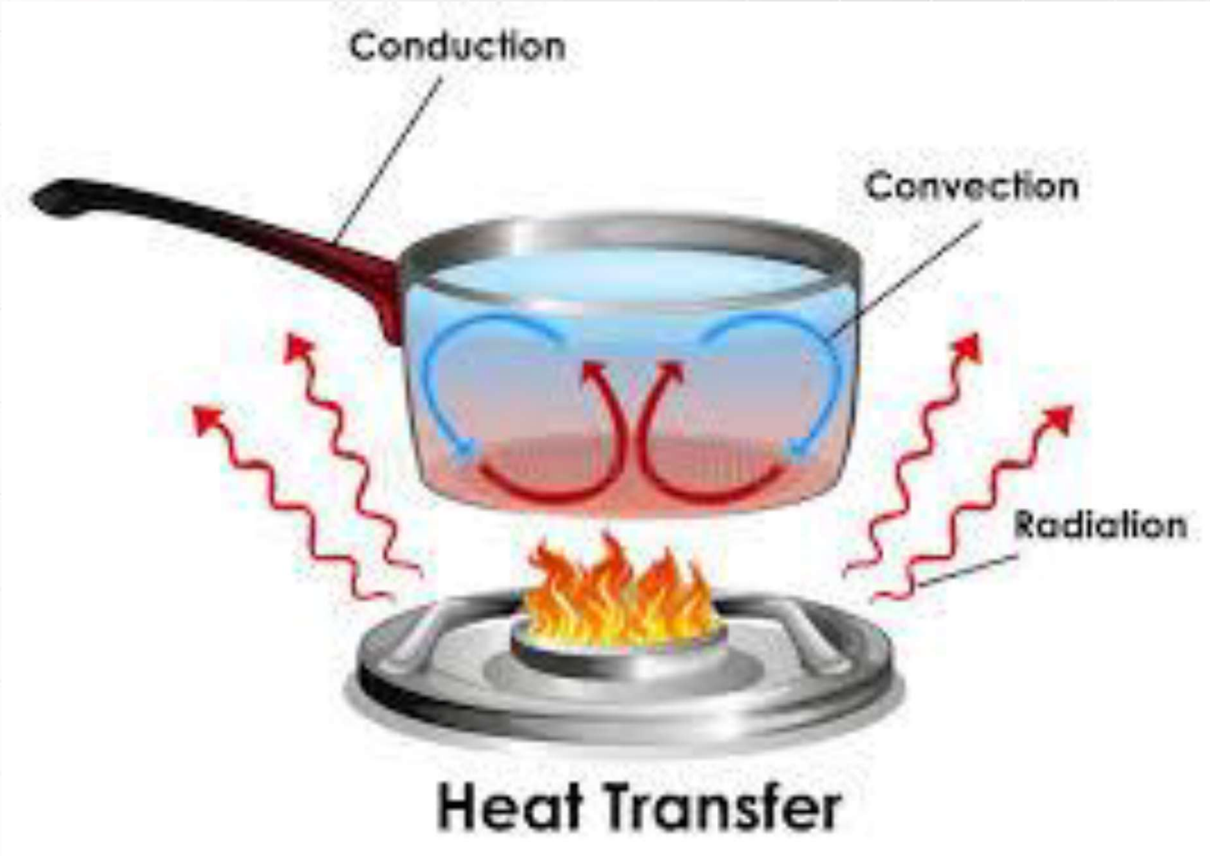
Heat transfer methods



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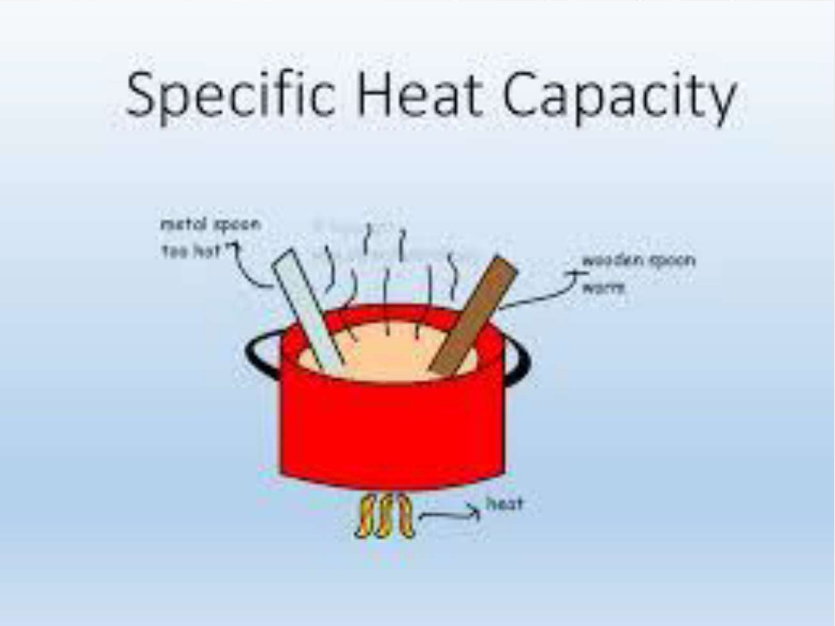
Heat capacity

Suppose that several objects composed of different materials are heated in the same manner. Will the objects warm up at equal rates? The answer: most likely not. Different materials would warm up at different rates because each material has its own specific heat capacity. The **specific heat capacity** refers to the amount of heat required to cause a unit of mass (say a gram or a kilogram) to change its temperature by 1°C. Specific heat capacities of various materials are often listed in textbooks. Standard metric units are Joules/kilogram/Kelvin (J/kg/K).



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Quantity of heat transferred

Specific heat capacities provide a means of mathematically relating the amount of thermal energy gained (or lost) by a sample of any substance to the sample's mass and its resulting temperature change. The relationship between these four quantities is often expressed by the following equation:

$$Q = mc\Delta T$$

m = mass	(kg)
c = specific heat capacity	($J\ kg^{-1}\ {}^{\circ}C^{-1}$)
θ = temperature change	($^{\circ}C$)

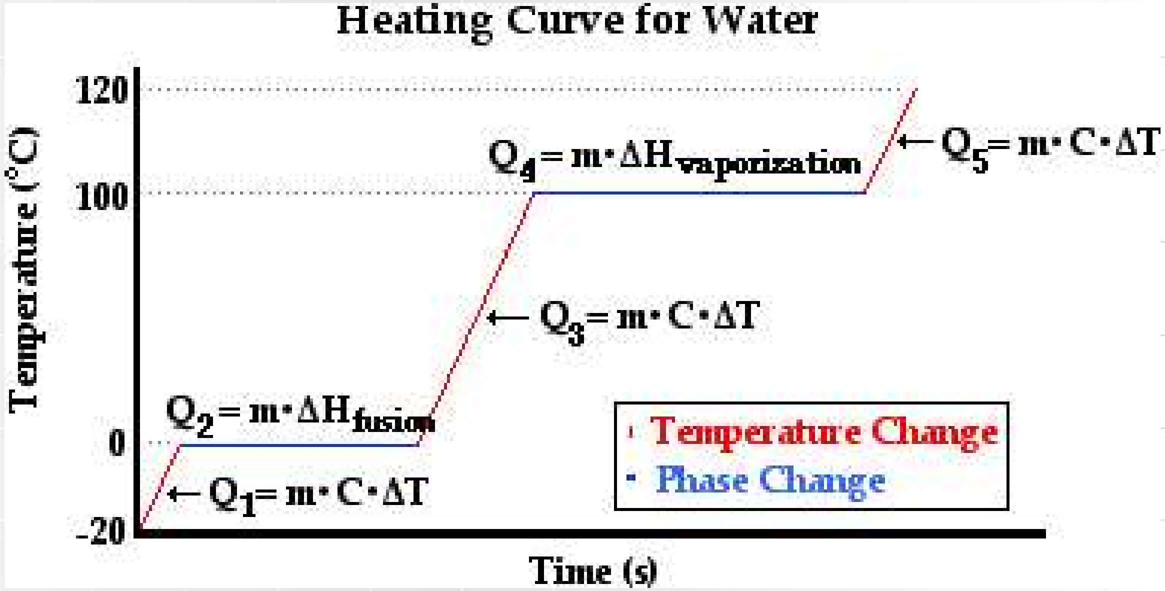
In this case, ΔT is equal to T_{final} - $T_{initial}$.

Example Problem 1

What quantity of heat is required to raise the temperature of 450 grams of water from 15°C to 85°C? The specific heat capacity of water is 4.18 J/g/°C.

Heat of fusion and heat of vaporization

$Q_2 = m \cdot \Delta H_{fusion}$
$Q_4 = m \cdot \Delta H_{vaporization}$



heat of fusion = heat of solidification

heat of vaporization = heat of condensation

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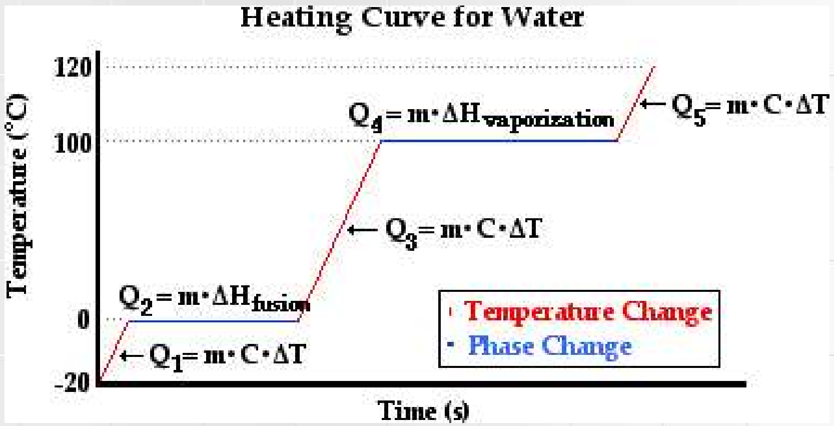
Example Problem 2

So now we will make an effort to calculate the quantity of heat required to change 50.0 grams of water from the solid state at -20.0°C to the gaseous state at 120.0°C. The calculation will require five steps - one step for each section of the graph. While the specific heat capacity of a substance varies with temperature, we will use the following values of specific heat in our calculations:

Solid Water: C=2.00 J/g/°C
Liquid Water: C = 4.18 J/g/°C
Gaseous Water: C = 2.01 J/g/°C

Finally, we will use the previously reported values of ΔH_{fusion} (333 J/g) and $\Delta H_{vaporization}$ (2.23 kJ/g).



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The ideal gas law

The ideal gas law states that

$PV = nRT$,

where P is the absolute pressure of a gas, V is the volume it occupies, n is the number of atoms and molecules in the gas, and T is its absolute temperature. The constant R is called is the ideal gas constant and has the value

$R = 8.314\ J/(mol \cdot K)$.

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Assumptions of the Ideal Gas Law

The ideal gas law is based on a series of assumptions on gas particles.

1. All gas particles are in constant motion and collisions between the gas molecules and the walls of the container cause the pressure of the gas.
2. The particles are so small that their volume is negligible compared with the volume occupied by the gas.
3. The particles don't interact. There are no attractive or repulsive forces between them.
4. The average kinetic energy of the gas particles is proportional to temperature.

The first assumption is true at any temperature above absolute zero.

The fourth assumption is true for small gas molecules

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Thermodynamics

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Pressure P = F/S	Unit 1 Pascal =1N/m^2
Heat capacity **<value depends on materia>**	Unit J/kg/K
Heat $Q = mc\Delta T$	Unit 1 kg * J/kg/K * K = = J
Heat of change $Q = m\Delta T$	Unit 1 kg * J/kg = J

Quantities:
- Temperature
- Pressure
- Heat
- Specific heat capacity
- Heat of fusion/vaporation

The ideal gas law

$$PV = nRT$$

Process	Important point to remember
isothermal	Constant T, $\Delta U = 0$, Q=W
isovolumetric(isochoric)	Constant V, W = 0, ΔU=Q
Isobaric	Constant P,ΔU = Q- (-PΔV)
adiabatic	Nothing is Constant, Q = 0, ΔU= -W

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Additional materials

Lectures:
http://www.thermodynamicsheatengines.com/HeatEnginesVol%201%20Chapter%201%20RS.pdf

Videos:
https://www.khanacademy.org/science/physics/thermodynamics/temp-kinetic-theory-ideal-gas-law/v/thermodynamics-part-1