Temperature and Heat
8.1

Temperature
Heat
Heat capacity
Phase change
  heat of fusion
  heat of vaporization

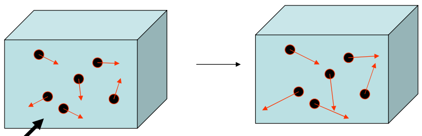
Heat and Temperature

- Heat is a quantity of thermal energy.
- The amount of heat depends on the size of the object
- Temperature is the measure of the "strength" or "pressure" of thermal energy.
- The Temperature level does not depend on the size of the object

Heat flows into the object and raises the temperature

Microscopic and Macroscopic description of heat

- Thermodynamics- Macroscopic description or heat and temperature
- Statistical Mechanics- Microscopic description in terms of microscopic properties i.e. molecular mass, velocities averaged over many particles.



Thermal Energy

- Thermal energy is in some sense a form of mechanical energy spread over a large number of particles.
- But there are some important differences between mechanical energy of a ball and the microscopic thermal energy of atoms.
- Mechanical energy can be converted into thermal energy with 100% efficiency. Thermal energy cannot be converted into mechanical energy with 100% efficiency.

Thermal equilibrium

- Two objects in thermal contact until no changes occur are in thermal equilibrium and have the same Temperature.
- If an object A is in thermal equilibrium with an object B and object B is in thermal equilibrium with object C then A and C are in thermodynamic equilibrium with each other.

Measuring Temperature

- Thermometers - Use conveniently measured property of matter that depends on temperature.
  - Volume, voltage, resistance

mercury thermometer

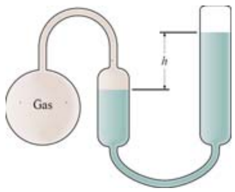
(volume)

thermocouple
(voltage)

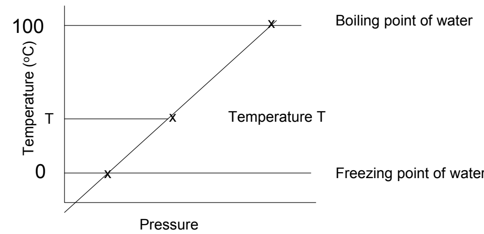
thermistor
(resistance)

Gas Thermometer

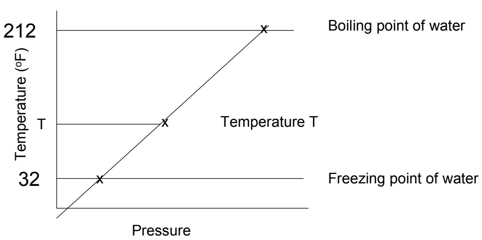
Gas thermometer – Fundamental definition of temperature in terms of the pressure of a ideal gas.



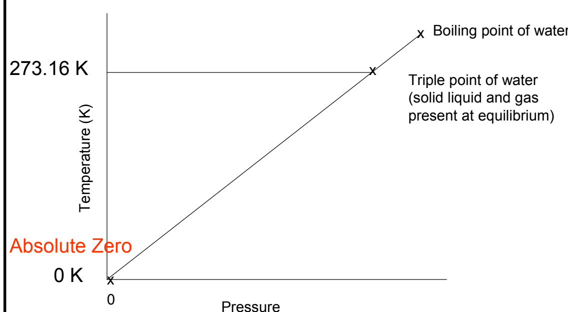
Celsius Temperature scale



Fahrenheit Temperature scale



Kelvin scale



Temperature scale conversion

Celsius to Kelvin

$$T_K = T_C + 273.16$$

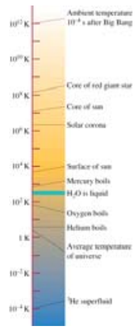
Celsius to Fahrenheit

$$T_F = \frac{9}{5}T_C + 32$$

Question

A swine flu patient has a temperature of 40º C. Find his temperature in Kelvin and Celsius.

Temperature of physical processes



Nuclear fusion Temperature
Deuterium-Tritium

Room Temperature

Heat and temperature

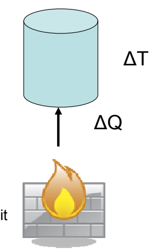
Heat , Q is thermal energy needed to raise the temperature of an object.

Units of Heat

Joules Heat has units of energy, Joules

Calories (cal)
One calorie is the heat required to raise the temperature of one gram of water 1 degree C.

1cal= 4.184 J



British Thermal Units
BTU. On BTU is the heat required to raise the temperature of one pound of water on degree Fahrenheit

1BTU =1055 J

Heat Capacity and specific heat

Heat capacity- C – ratio of heat input to temperature rise in heating an object.

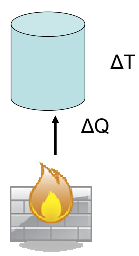
$$\Delta Q = C\Delta T$$

the heat capacity depends on the size of the object.

Specific Heat –c- Heat capacity divided by the mass

$$\Delta Q = mc\Delta T$$

the specific heat is independent of the size of the object but only depends on the material out of which the object is made.



Specific heats

Substance	SI J/kgK	cal/g^{o}C
Aluminum	900	0.215
Copper	386	0.0923
Iron	447	0.107
glass	753	0.18
Water	4184	1.00
Ice(-10^{o}C)	2050	0.49
Wood	1400	0.33

Question

The energy content of food is given in kilocalories C. A glass of beer has a energy content of 150 C. If this beer is drunk by a 75 kg UCSD student during the Sun God festival what would be the temperature rise assuming all the energy was converted to heat and the student's heat capacity was that of water.

Question

You want to heat up your coffee (240 ml) of coffee in a microwave oven. If 1000 W of power is absorbed by the coffee how long does it take to raise the temperature from 20^o C to the boiling point. Ignore the heat capacity of the cup.

Heat to raise the temperature

$$\Delta Q = mc\Delta T$$

Heat output from the oven

$$\Delta Q = P\Delta t$$

$$\Delta t = \frac{mc\Delta T}{P} = \frac{(0.24kg)(4184J/kg^oC)(100-20^oC)}{1000J/s} = 80s$$

Phase change

Heat can provide thermal energy to change the phase of a material. The energy is required to break interactions between atoms.

- Fusion – Change from solid to liquid
- Vaporization – Change from liquid to gas
- Sublimation- Change from solid to gas.

Heat of transformation

- Latent heat of fusion (solid to liquid)

$$Q = L_f m$$

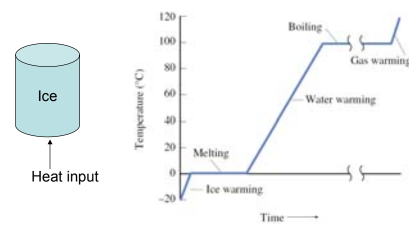
- Latent heat of vaporization (liquid to gas)

$$Q = L_v m$$

Latent Heat of transformation

Substance	L_f (kJ/kg)	L_v (kJ/kg)
Water	334	2257
Alcohol	109	879
Copper	205	4726
Mercury	11.3	296

Phase change in water



At the melting temperature and boiling temperature, two phases are In equilibrium and the heat does not cause a change in temperature. The relative amounts of the two phases changes.

Question

A 200 g mass of ice at 0° C is in a microwave oven with 1000 W of power. Assume all the power goes into heating the ice. How long will it take to melt? How long will it take to go from the melting point to the boiling point? How long will it take to evaporate completely?

Melting $$\Delta t = \frac{Q}{p} = \frac{mL_f}{p} = \frac{(0.2)334x10^3}{1000} = 66s$$

Temperature rise $$\Delta t = \frac{Q}{p} = \frac{mc\Delta T}{p} = \frac{(0.2)(4184)(100)}{1000} = 84s$$

Evaporation $$\Delta t = \frac{mL_f}{p} = \frac{0.2(2257x10^3)}{1000} = 450s$$

Question

A 250 ml cup of coffee is at 80°C. What amount of ice would have to be added to bring the coffee to 5°C assuming no heat flows out of the cup