- Recap: Lecture 3: 09th January 2014, 0930-1030 hrs.
  - Energy
  - Macroscopic and Microscopic Energy
  - Enthalpy
  - Zeroth law of thermodynamics
  - Temperature scales: Celsius, Fahrenheit and Kelvin scales
  - Ideal gas temperature scale

- *"The unit of thermodynamic temperature T, the kelvin (K), defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water, which is sole defining fixed point of both the ITS-90 and the Kelvin scale."*
- Types of commonly used thermometers:
  - Constant volume gas thermometer , T(P)
  - Constant pressure gas thermometer, T(V)
  - Electric resistance thermometer, T(R)
  - Thermocouple, T(ε)
  - Liquid-in-glass thermometer, T(L)

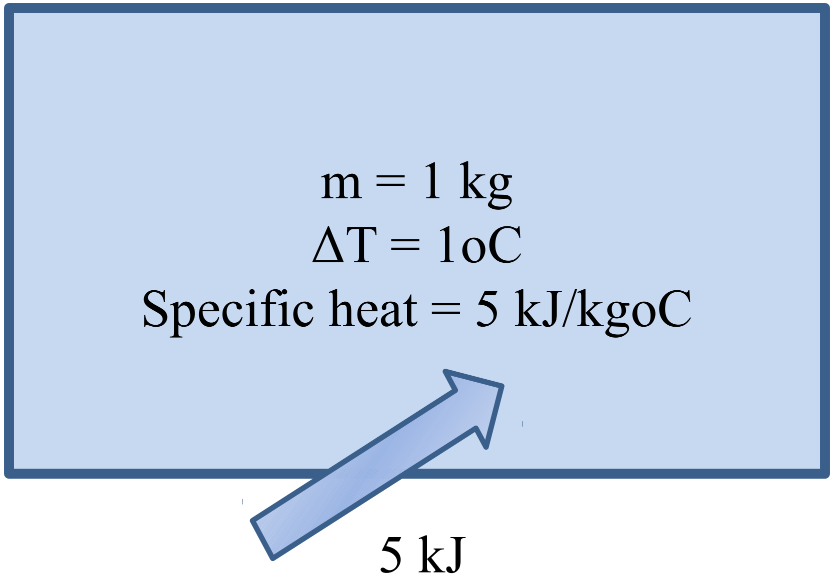
Specific heats

- It takes different amounts of energy to raise the temperature of identical masses of different substances by one degree.
- Therefore, it is desirable to have a property that will enable us to compare the energy storage capabilities of various substances.
- This property is the specific heat.

Specific heats

- Specific heat is defined as the energy required to raise the temperature of a unit mass of a substance by one degree.
- In general, this energy depends on how the process is executed.
- There are two kinds of specific heats: specific heat at constant volume, *cv* and specific heat at constant pressure, *cp*.

Specific heats



Specific heat is the energy required to raise the temperature of a unit mass of a substance by one degree in a specified way.

Specific heat at constant volume and constant pressure

- Specific heats are defined in the following manner.
- Specific heat at constant volume:

$$c_v dT = du \quad \text{at constant volume}$$

$$\text{or, } c_v = \left(\frac{\partial u}{\partial T} \right)_v$$

- Specific heat at constant pressure

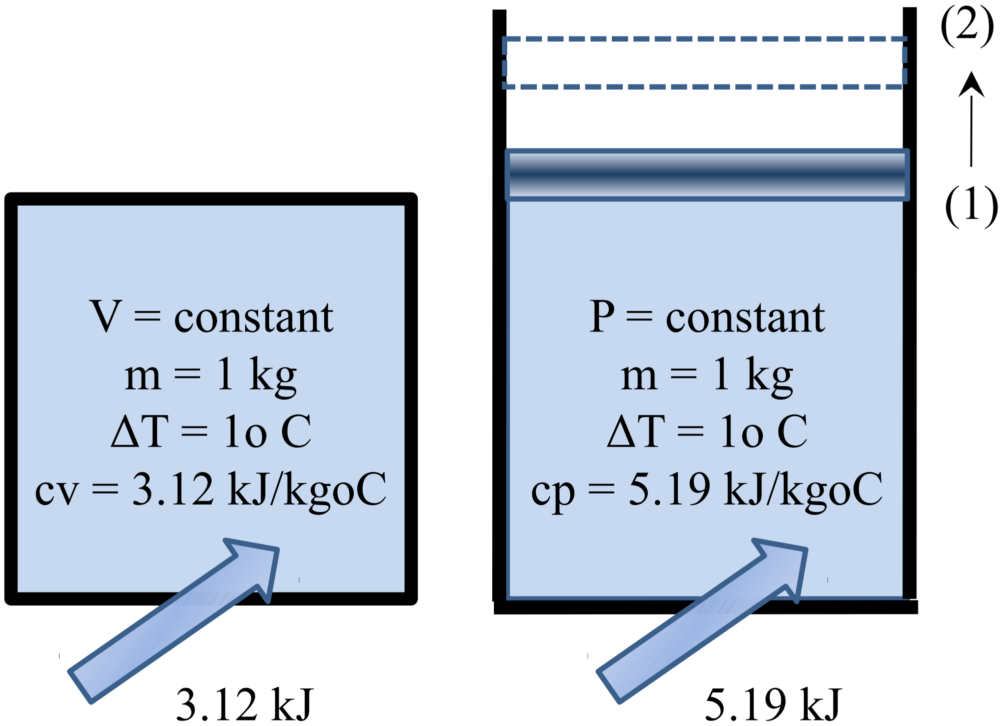
$$c_p dT = dh \quad \text{at constant pressure}$$

$$\text{or, } c_p = \left(\frac{\partial h}{\partial T} \right)_p$$

Specific heats

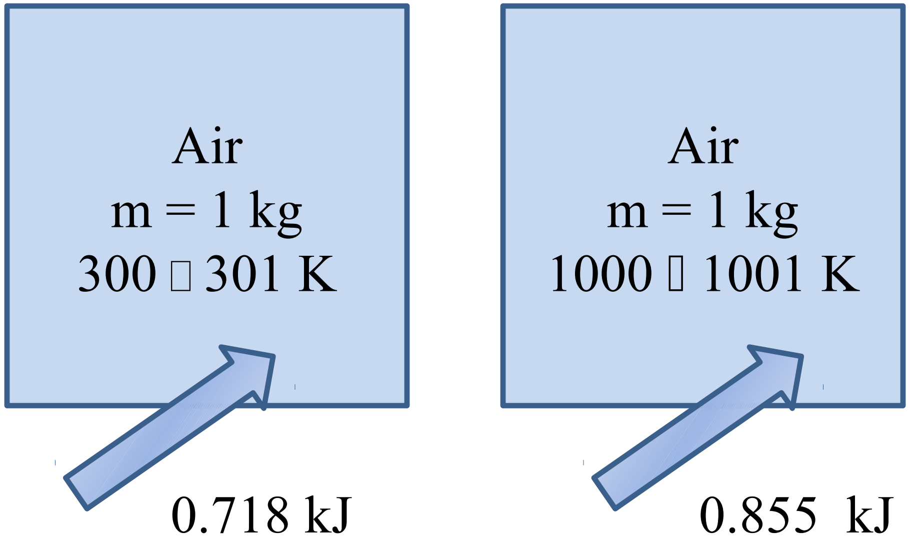
- cp and cv are <u>properties</u> of a system.
- Are valid for any processes
- cp is always > cv
    - Because at constant pressure the system is allowed to expand and the energy for the expansion must also be supplied
- Specific heat of a substance change with temperature.

Specific heats



cp is always > cv

Specific heats



The specific heat of a substance changes with temperature.

NASA Polynomials

The NASA polynomials have the form:
Cp/R = a1 + a2 T + a3 T^2 + a4 T^3 + a5 T^4
H/RT = a1 + a2 T /2 + a3 T^2 /3 + a4 T^3 /4 + a5 T^4 /5 + a6/T
S/R = a1 lnT + a2 T + a3 T^2 /2 + a4 T^3 /3 + a5 T^4 /4 + a7
where a1, a2, a3, a4, a5, a6, and a7 are the numerical coefficients supplied in NASA thermodynamic files.
The first 7 numbers starting on the second line of each species entry (five of the second line and the first two of the third line) are the seven coefficients (a1 through a7, respectively) for the high-temperature range (above 1000 K, the upper boundary is specified on the first line of the species entry).

H(T) = Delta Hf(298) + [H(T) - H(298)] so that, in general, H(T) is not equal to Delta Hf(T) and one needs to have the data for the reference elements to calculate Delta Hf(T).

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H2O L 8/89H 2O 1 G 200.000 3500.000 1000.000
                              1
3.03399249E+00 2.17691804E-03-1.64072518E-07-9.70419870E-11
1.68200992E-14     2
-3.00042971E+04 4.96677010E+00 4.19864056E+00-2.03643410E-03
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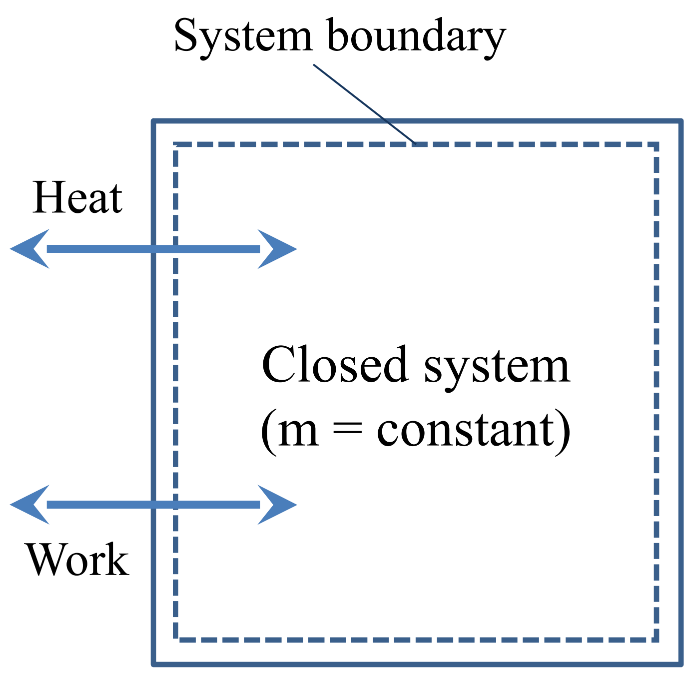
Energy transfer mechanisms

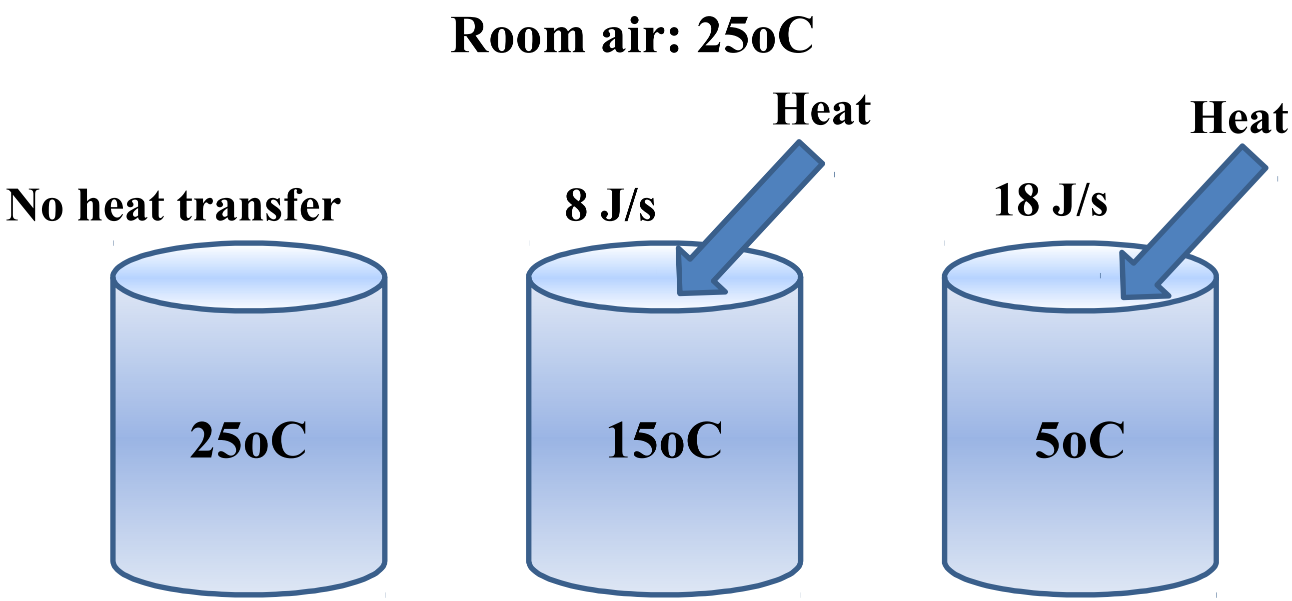


Energy can cross the system boundaries of a closed system: heat and work

Energy transfer by heat

- Heat: the form of energy that is transferred between two systems (or a system and its surroundings) by virtue of a temperature difference.
- Energy interaction is heat only if it takes place by virtue of temperature difference.
- Heat is energy in transition; it is recognised only as it crosses the system boundary.

Energy transfer by heat

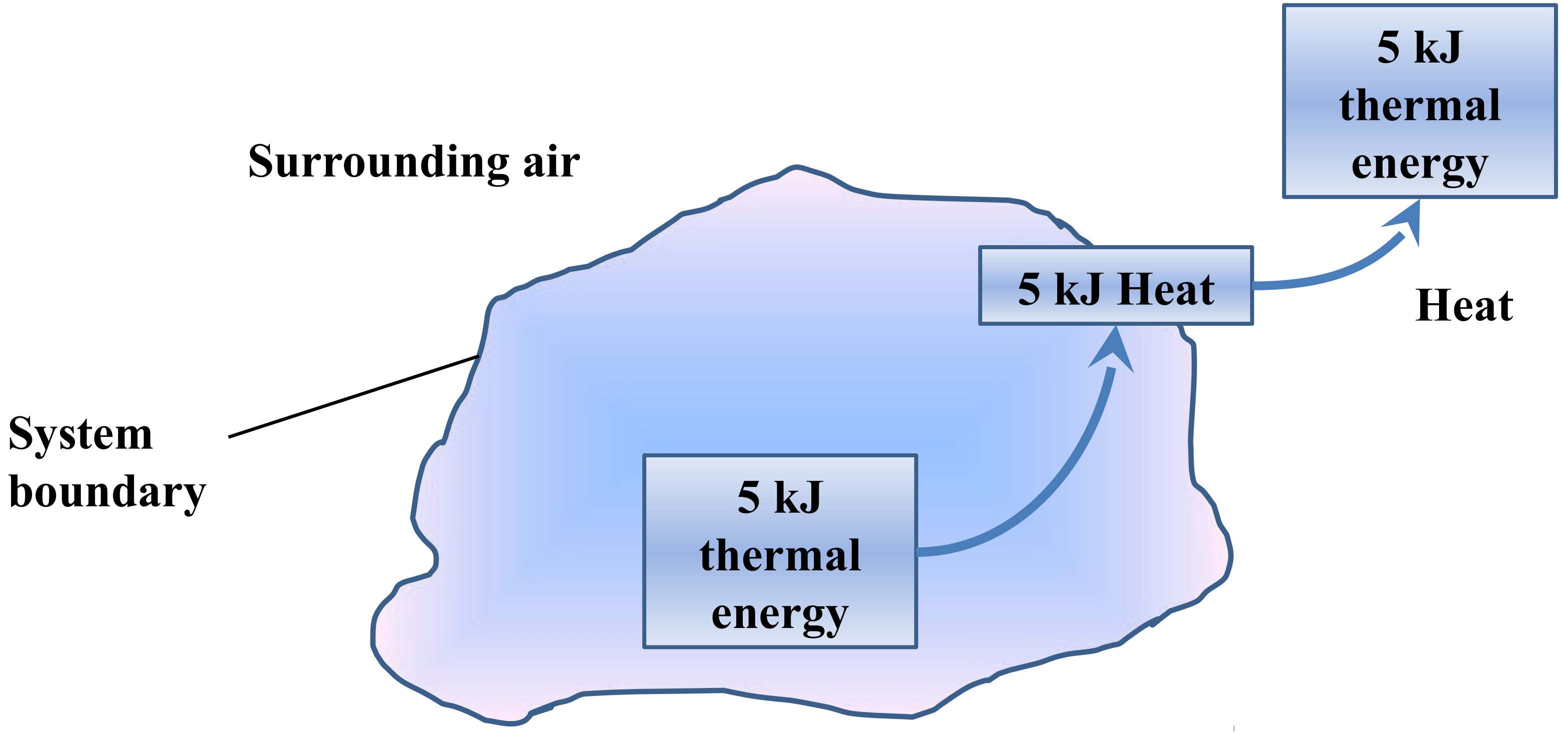


Temperature difference is the driving force for heat transfer. The larger the temperature difference, the higher is the rate of heat transfer.

Energy transfer by heat

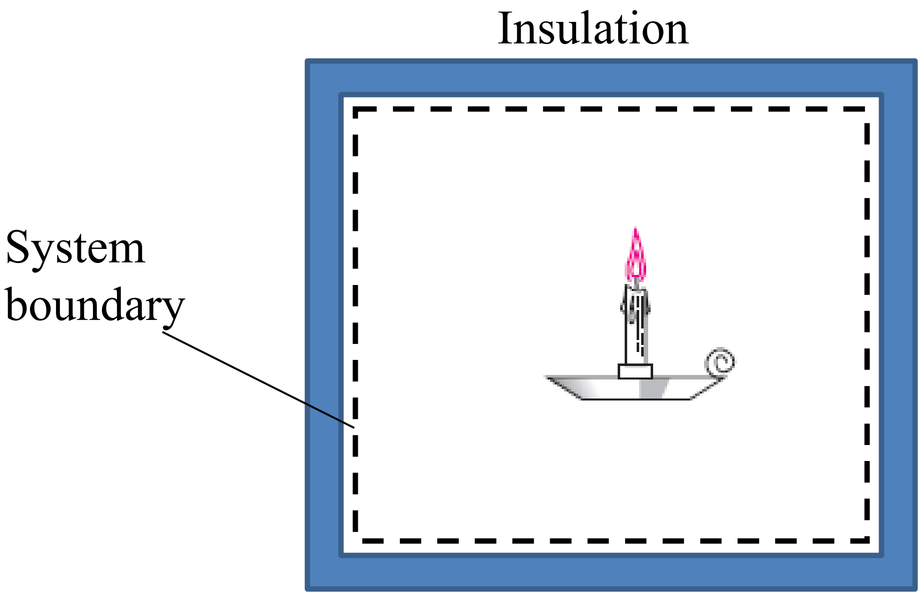
- In thermodynamics, heat refers to heat transfer.
- A process during which there is no heat transfer is called Adiabatic process.
- Heat transfer mechanisms:
  - Conduction
  - Convection
  - Radiation

Energy transfer by heat



Energy is recognized as heat transfer only as it crosses the system boundary.

Energy transfer by heat

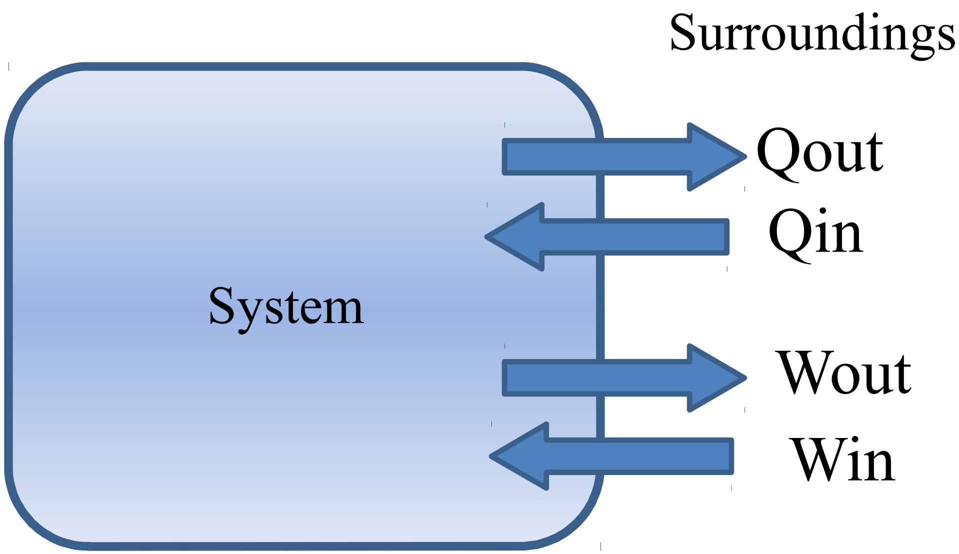


Qn. Is there is any heat transfer during this burning process?
Qn. Is there is any change in the internal energy of the system?

Energy transfer by work

- Any energy interaction of a closed system other than heat is work.
- An energy interaction that is not caused by a temperature difference between a system and its surroundings is work.
- Work is the energy transfer associated with a force acting through a distance.

Sign conventions



- Heat transfer to a system and work done by a system are positive; heat transfer from a system and work done on a system are negative.

Energy transfer by heat and work

- Both heat and work are boundary phenomena.
- Systems possess energy, but not heat or work.
- Both are associated with a process, not a state. Unlike properties, heat or work has no meaning at a state.
- Both are path functions (i.e., their magnitudes depend on the path followed during a process as well as the end states).