Summary of chapter 18

Prepared by Dr. A. Mekki

1. If two bodies are in **thermal equilibrium** with each other they must have **the same temperature**.

2. *The Zeroth-law of thermodynamics states that if two bodies A and B are separately in thermal equilibrium with a third body, C, then A and B are in thermal equilibrium with each other when placed in thermal contact.*

3. Change of temperature scale:

$$T_C = T_K - 273$$

$$T_F = 9/5\ T_C + 32$$

$$T_K = 5/9\ T_F + 255$$

Important: $\Delta T_K = \Delta T_C$ and $\Delta T_F = \frac{9}{5}\Delta T_C$

4. When a substance is heated, it generally expands. The change in length, ΔL is related to the change in temperature ΔT and the proportionality constant is called α (coefficient of linear expansion)

5. Expansion of a **solids**

   - In one dimension

The change in length is given by $\Delta L = L_i\ \alpha\ \Delta T$ and

The final length is $L_f = L_i(1 + \alpha \Delta T)$

L_i is the **initial length**, L_f is the **final length**, and α is the **coefficient of linear expansion**

   - In two dimensions

The change in the area is given by $\Delta A = A_i(2\alpha)\Delta T$ and

The final area is $A_f = A_i[1 + (2a)\Delta T]$

- In three dimensions

The change in the volume is $\Delta V = bV_i\Delta T$ and

The final volume is $V_f = V_i(1 + b\Delta T)$

This equation is valid for solids and liquids.

Coefficient of volume expansion $b = 3a$.

6. The heat absorbed or lost by a substance is given by:

(i) If there is a change in temperature and there is no change in the phase

$$Q = mc\Delta T$$

c is the specific heat of the substance and $DT = T_f - T_i$

(ii) If there is a change in phase and the temperature of the system remains the same

$$Q = mL$$

L is called the heat of transformation.

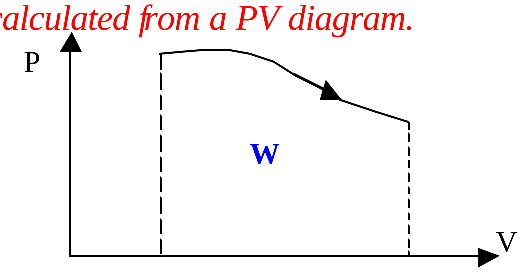
If there is fusion (solid ® liquid), then we use L_f, if there is vaporization (liquid ® gas), then we use L_v.

7. This section is related to gases only

A gas may exchange energy with the surroundings through work.
The work done ***on*** or ***by*** a gas as it expand or contract from Vi to V_f is

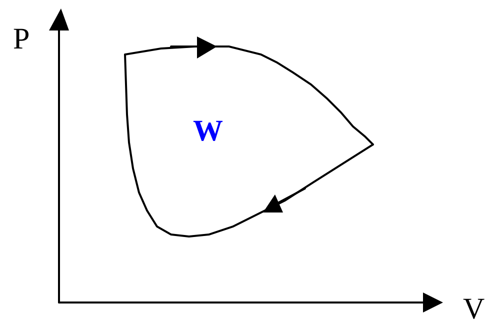
$$W = \int_{Vi}^{Vf} P\, dV$$

The work can also be calculated from a PV diagram.



The work is the area under the process in a PV diagram as shown in the above figure.

For a cyclic process the work is <u>the area enclosed</u> by the cycle.



8. The first law of thermodynamics is the law of ***conservation of energy*** and given by

$$\Delta E_{int} = Q - W$$

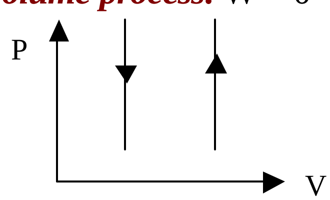
where DE_{int} is the internal energy of the gas.

- ***Q > 0 if the gas absorbs (gains) heat***
- ***Q < 0 if the gas expels (lose) heat***
- ***W > 0 if the gas does work***
- ***W < 0 if external work is done on the gas***

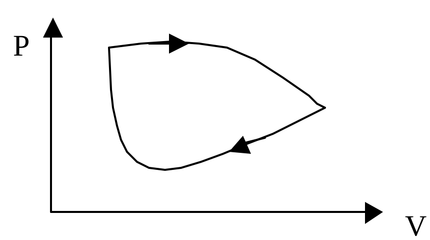
9. Special cases of the first law of thermodynamics

- ***Adiabatic process:*** Q = 0 and $DE_{int} = -W$

- ***Constant volume process:*** W = 0 and $DE_{int} = Q$



- ***Cyclic process:*** $DE_{int} = 0$, Q = W



- ***Free expansion:*** $\Delta E_{int} = Q = W = 0$

10. Heat can be transferred between a system and the environment in three ways; **conduction, convection,** and **radiation**.

   - ***In the case of transfer of heat by conduction, the rate of heat flow is given by:***

$$H = \frac{Q}{t} = kA\frac{T_H - T_C}{L} \qquad \text{(Watts)}$$

k is the thermal conductivity of the material through which heat is conducted.

   - ***Radiation is heat transfer through the emission of electromagnetic energy. The power of the radiating heat source is given by:***

$$P = \sigma \varepsilon A T^4 \qquad \text{(Watts)}$$

$\sigma = 5.6703 \times 10^{-8}$ W/m^{2}K is Stefan-Boltzman constant.
ε is the emissivity of the object and A is its surface area.
T is the temperature in Kelvin.