

Chapter 3

Work

Work. The term work refers to an inter change of energy between a system and its surroundings. When the hot gases in the cylinders of an automobile engine push against the moving pistons, work is done by the gases. When air is forced into a bicycle tire by a pump, work is done on the air. The work may be mechanical, as above, or it may be electrical, magnetic, or any other types.

$$W = \int F \cos \theta ds \quad \text{-----} \quad (1)$$

in most cases of practical interest the work is associated with a change in volume.

Suppose that we have a system of arbitrary shape as in Fig. 1, acted upon by an external hydrostatic pressure P_e , and that the original boundary of the system, shown by full lines, is displaced out ward against the external pressure to a new position show by dotted lines.

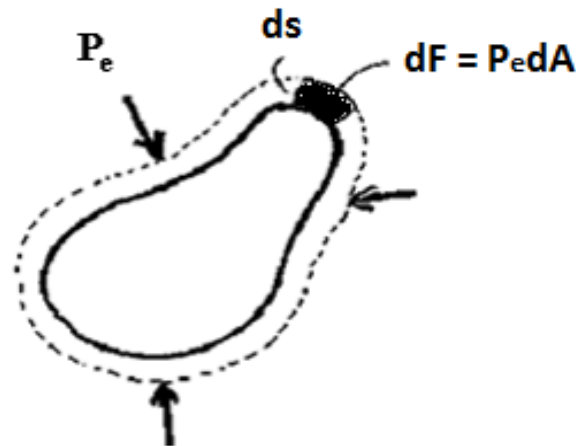


Fig. - 1-

The external force df exerted against a portion of the surface of (dA) is

$$dF = P_e dA \quad \text{-----} \quad (2)$$

And if this portion moves out a distance (ds) the work done against the external force is:

$$dW = dF ds = P_e dA ds \quad \text{-----} \quad (3)$$

$$dW = P_e A ds \quad \text{-----} \quad (4) \quad A = \text{total area of the surface}$$

$$dV = A ds \quad \text{-----} \quad (5) \quad \text{the increase in volume of the system}$$

$$dW = P_e dV \quad \text{-----} \quad (6) \quad \text{external work}$$

Where dv is the change in volume of the system p_e external pressure,

W expressed in joules p_e in ($\frac{N}{m^2}$), dV in m^3 . P_e external pressure = p internal pressure if the process is reversible and in equilibrium at all instants.

$$dW = PdV \quad \text{-----} \quad (7)$$

The work dW is (+ tive) when work is done by a system and the volume of the system increases, and dV is positive. When work is done on a system, the volume decrease, and dV and dW are (- ive), negative.

($\frac{dW}{n} = \frac{PdV}{n}$) when the work is divided through by the mass (m) or the number of moles (n) of a system

The work done per unit mol. $dw = PdV$ ----- (8)

Any reversible process can be represented by a line in the P - v plane. The (dw) done in a small (specific) volume change (dv) is represented graphically by the area of a narrow vertical strip (Fig. 2). The total work (w) done in the finite increase in volume from state a to state b.

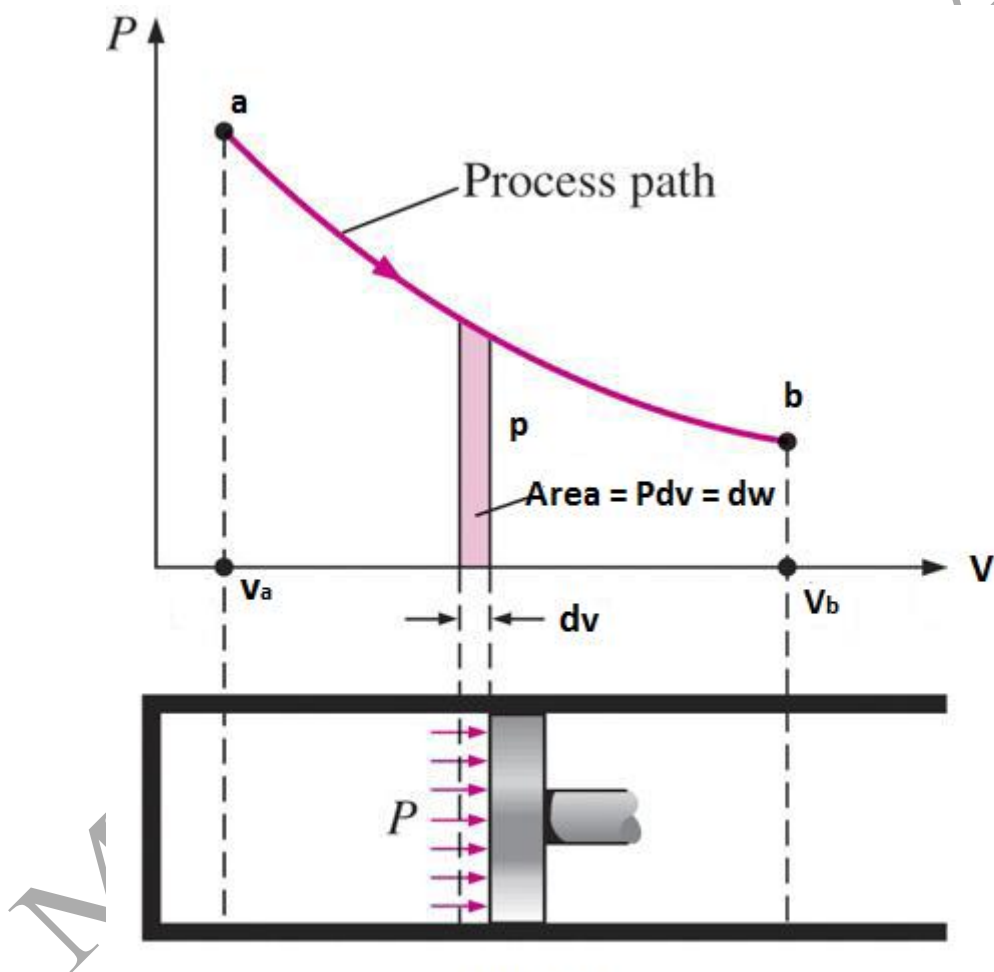


Fig. - 2-
Area represents work in a p-v diagram

$$w = \int_{V_a}^{V_b} Pdv \quad \text{-----} \quad (9)$$

(w +ive) if the process from a to b, (w -ive) if the process in the opposite direction (from b to a) and the work is done is done on the system, Fig. (3- a, b, c)

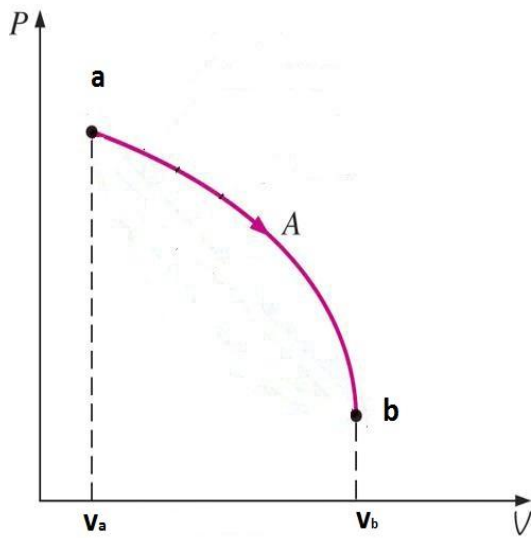


Fig. 3 – a
The work done by the system

$$w = \int_{V_a}^{V_b} Pdv$$

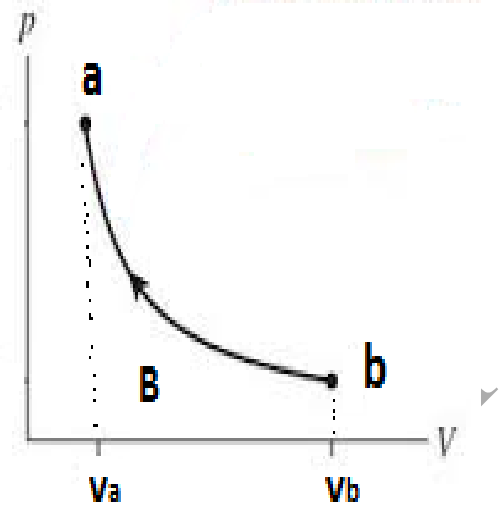


Fig. 3 – b
The work done on the system

$$w = \int_{V_b}^{V_a} Pdv$$

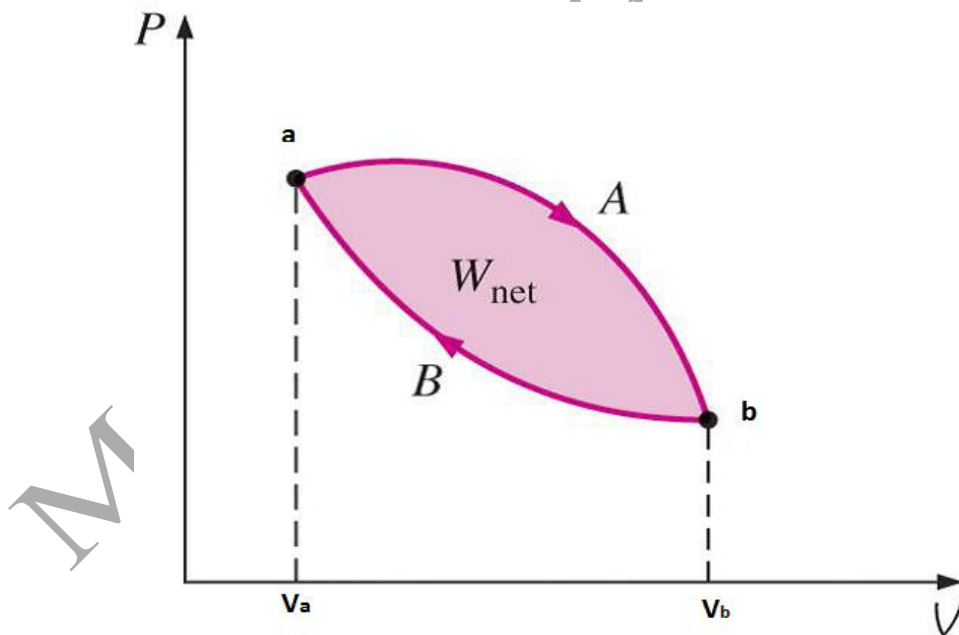


Fig. 3 – c

The net work done by the system

We next evaluate ($\int pdv$) for a number of processes.

1/ The work done in any isometric process is obviously zero, since in such a process

$$v = \text{constant}, dv = 0, w = 0, \text{ fig. 4}$$

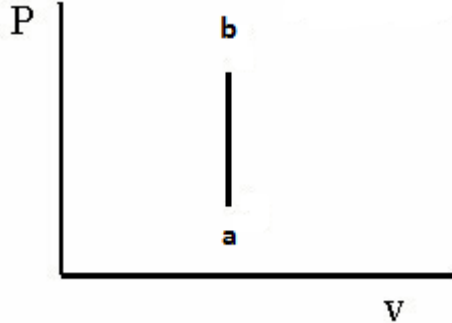


Fig. 4

2/ In an isobaric process the pressure is constant and the work is

$$w = P \int_{v_a}^{v_b} dv = P(v_b - v_a) \quad \text{-----} \quad (10)$$

Which evidently is the area of the shaded rectangle in Fig. 5

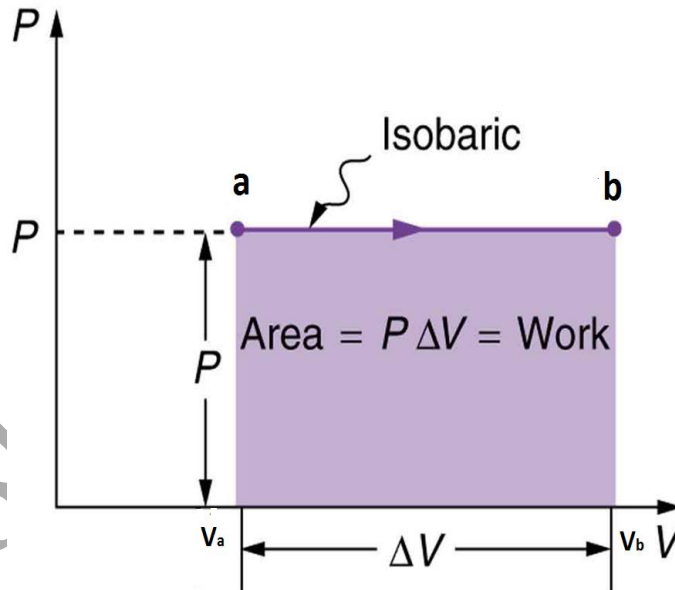


Fig. 5

3/ Consider next an isothermal process, carried out at the constant temperature **T**. If the system is an ideal gas

$$P = \frac{RT}{v} \quad \text{-----} \quad (11)$$

$$w_T = \int_{v_a}^{v_b} \frac{RT}{v} dv = RT \ln \frac{v_b}{v_a} \quad \text{-----} \quad (12)$$

(w_T) is represent by the shaded area in Fig.6, and This equation can be put in a number of different forms

$$P_a v_a = P_b v_b = RT, \quad \frac{v_b}{v_a} = \frac{P_a}{P_b}$$

$$w_T = P_a v_a = \ln \frac{v_b}{v_a} = RT \ln \frac{P_a}{P_b} \quad \text{-----} \quad (13)$$

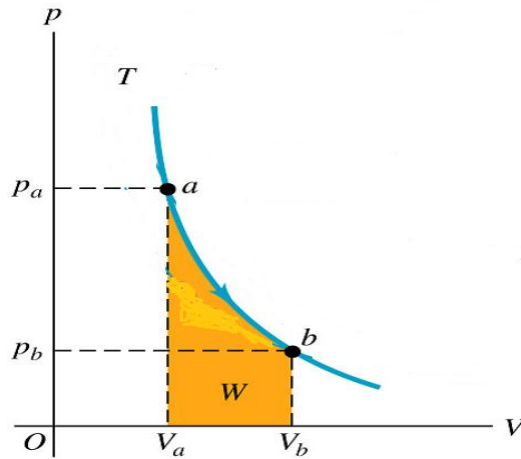


Fig. 6

Work depends on the path

Obviously, there are an infinite number of different processes by which a system can be taken from a given initial state to a final state.

Three possible processes connecting states a and b are show in Fig. 7 The work done by the system is greatest along the path acb, least along path adb, and has some intermediate value along the third path.

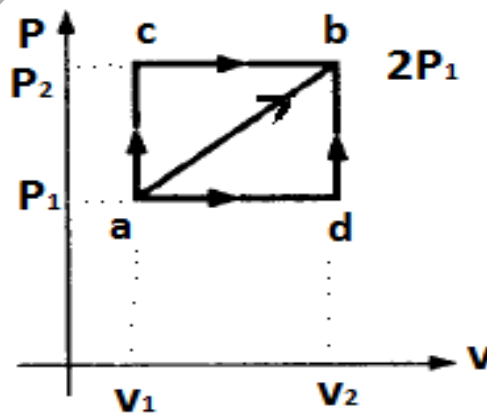


Fig. 7

$$w_{path(a \rightarrow c \rightarrow b)} = \int P dV + \int_{V_1}^{2V_1} P_2 dV = 0 + 2P_1(2V_1 - V_1) = 2P_1V_1 \quad \text{-----} \quad (14)$$

$$w_{path(a \rightarrow d \rightarrow b)} = \int_{V_1}^{2V_1} P_1 dV + \int P dV = P_1(2V_1 - V_1) = P_1V_1 \quad \text{-----} \quad (15)$$

$$w_{path(a \rightarrow b)} = \frac{2P_1V_1 + P_1V_1}{2} = \frac{3}{2}P_1V_1 \quad \text{-----} \quad (16)$$

Partial derivatives

In a system consisting of a fluid under pressure in a cylinder provided with a movable piston, one can change the V by any arbitrary amount dv and the same time change the T by any arbitrary amount dT . When this has been done, the P will be found to have changed by just such an amount dp that the new values of P , V and T also satisfy the equation of state.

The general form of the equation of state is

$$F(P, v, T) = 0 \quad \text{-----} \quad (17)$$

Or, if it is solved in turn for each of the state variables,

$$P = f_1(v, T), \quad v = f_2(T, P), \quad T = f_3(P, v) \quad \text{-----} \quad (18)$$

$$P = f(v, T), \quad dP = \left(\frac{\partial P}{\partial v}\right) dv + \left(\frac{\partial P}{\partial T}\right) dT \quad \text{-----} \quad (19) \quad \text{in mathematics}$$

$$dP = \left(\frac{\partial P}{\partial v}\right)_T dv + \left(\frac{\partial P}{\partial T}\right)_v dT \quad \text{-----} \quad (20) \quad \text{in thermodynamics}$$

$$v = f(T, P), \quad dv = \left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial v}{\partial P}\right)_T dP \quad \text{-----} \quad (21)$$

Let us now eliminate dv between the latter two equations (20 and 21) and collect coefficients of dp and dT .

$$dP = \left(\frac{\partial P}{\partial v}\right)_T \left[\left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial v}{\partial P}\right)_T dP \right] + \left(\frac{\partial P}{\partial T}\right)_v dT \quad \text{-----} \quad (22)$$

$$dP - \left(\frac{\partial P}{\partial v}\right)_T \left(\frac{\partial v}{\partial P}\right)_T dP = \left(\frac{\partial P}{\partial v}\right)_T \left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial P}{\partial T}\right)_v dT$$

$$\left[1 - \left(\frac{\partial P}{\partial v}\right)_T \left(\frac{\partial v}{\partial P}\right)_T \right] dP = \left[\left(\frac{\partial P}{\partial v}\right)_T \left(\frac{\partial v}{\partial T}\right)_P + \left(\frac{\partial P}{\partial T}\right)_v \right] dT$$

But the changes dp and dT are independent, that is, we can assign any value to dT and any other value to dp . Suppose we let $dT = 0$, $dp \neq 0$
Then to satisfy the equation above we must have

$$\left[1 - \left(\frac{\partial P}{\partial v} \right)_T \left(\frac{\partial v}{\partial P} \right)_T \right] = 0,$$

$$\left(\frac{\partial P}{\partial v} \right)_T = \frac{1}{\left(\frac{\partial v}{\partial P} \right)_T} \quad \text{-----} \quad (23)$$

Similarly since we can set $dP = 0$, $dT \neq 0$, it must be true that

$$\left(\frac{\partial P}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_P + \left(\frac{\partial P}{\partial T} \right)_v = 0 \quad \text{-----} \quad (24)$$

By combining Eqs.23 and 24, the latter may be put in the more symmetrical cyclical form (cyclic relation).

$$\left(\frac{\partial P}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_P \left(\frac{\partial T}{\partial P} \right)_v = -1 \quad \text{-----} \quad (25)$$

Eqs. 23 and 25 are readily verified for an ideal gas

$$Pv = RT, \quad P = \frac{RT}{v}, \quad v = \frac{RT}{P}, \quad T = \frac{Pv}{R}$$

$$\left(\frac{\partial P}{\partial v} \right)_T = -\frac{RT}{v^2}, \quad \left(\frac{\partial v}{\partial T} \right)_P = \frac{R}{P}, \quad \left(\frac{\partial T}{\partial P} \right)_v = \frac{v}{R} \quad \text{and}$$

$$\left(\frac{\partial P}{\partial v} \right)_T \left(\frac{\partial v}{\partial T} \right)_P \left(\frac{\partial T}{\partial P} \right)_v = -\frac{RT}{v^2} \times \frac{R}{P} \times \frac{v}{R} = -\frac{RT}{Pv} = -1 \quad \text{in agreement with eq. 25}$$

Coefficient of expansion and compressibility

Even if the equation of state of a substance is not known or cannot be expressed in any simple analytic form, the partial derivatives $\left(\frac{\partial v}{\partial T} \right)_P$ and

$\left(\frac{\partial v}{\partial P}\right)_T$ can be found from tabulated properties of materials, namely, the coefficient of cubical expansion β and the compressibility K .

$$\bar{\beta} = \frac{V_2 - V_1}{V_1(T_2 - T_1)} = \frac{\Delta V}{V_1 \Delta T} \quad \text{-----} \quad (26)$$

Where V_2 and V_1 are the volume of a specimen of the material at temperatures T_2 and T_1 .

$\bar{\beta}$ is the mean fractioned increase in volume, per degree rise in temperature. The true coefficient of volume expansion β .

$$\beta = \lim_{\Delta T \rightarrow 0} \left(\frac{\Delta V}{V_1 \Delta T} \right) = \frac{1}{V} X \frac{dV}{dT} \quad \text{-----} \quad (27)$$

The mks units of β are (deg.⁻¹). However, the volume of an object depends upon pressure as well as upon temperature and it is implied in the definition above that the pressure is to be kept constant.

$$\beta = \frac{1}{V} X \frac{(dV)_P}{(dT)_P} \quad \text{-----} \quad (28)$$

The ratio of a small change in V to a small change in T , both at constant P , is the same thing as the partial derivative of V with respect to T at constant P . Hence

$$\frac{(dV)_P}{(dT)_P} = \left(\frac{\partial V}{\partial T}\right)_P \quad \text{and} \quad \underline{\beta = \frac{1}{V} \left(\frac{\partial V}{\partial T}\right)_P} \quad \text{-----} \quad (29)$$

Or in terms of specific volumes,

$$\beta = \frac{1}{v} \left(\frac{\partial v}{\partial T}\right)_P \quad \text{-----} \quad (30) \quad \underline{\beta v = \left(\frac{\partial v}{\partial T}\right)_P} \quad \text{-----} \quad (30)$$

It follows from eq. (30) that the β of ideal gases

$$Pv = RT, \quad v = \frac{RT}{P}$$

$$\left(\frac{\partial v}{\partial T}\right)_P = \frac{R}{P}, \quad \therefore \beta = \frac{1}{v} X \frac{R}{P} = \frac{R}{RT}, \quad \underline{\therefore \beta = \frac{1}{T}} \quad \text{-----} \quad (31)$$

The van der Waals equation is a cubic in v but can be solved explicitly for P . Hence in computing β it is simplest to use eqs. 23 and 25 and write

$$\left(\frac{\partial v}{\partial T}\right)_P = -\frac{\left(\frac{\partial P}{\partial T}\right)_v}{\left(\frac{\partial P}{\partial v}\right)_T} \quad \text{then, since} \quad P = \frac{RT}{v-b} - \frac{a}{v^2}$$

We have $\left(\frac{\partial P}{\partial T}\right)_v = \frac{R}{v-b}$, $\left(\frac{\partial P}{\partial v}\right)_T = -\frac{RT}{(v-b)^2} + \frac{2a}{v^3}$

$$\beta = \frac{1}{v} \left(\frac{\partial v}{\partial T}\right)_P = -\frac{\frac{R}{(v-b)}}{v \left[-\frac{RT}{(v-b)^2} + \frac{2a}{v^3} \right]}$$

$$\beta = \frac{-1}{v} \times \frac{\frac{R}{(v-b)}}{-\frac{RTv^3 + 2a(v-b)^2}{v^3(v-b)^2}} = \frac{Rv^2(v-b)}{RTv^3 - 2a(v-b)^2}$$

$$\beta = \frac{Rv^2(v-b)}{RTv^3 - 2a(v-b)^2} \quad \text{-----} \quad (32) \quad \text{for van der Waals gas}$$

The mean compressibility of a material \bar{K} is defined by the eq.

$$\bar{K} = -\frac{V_2 - V_1}{V_1(P_2 - P_1)} = -\frac{\Delta V}{V_1 \Delta P} \quad \text{-----} \quad (33)$$

Where V_2 and V_1 are the volume at pressures P_2 and P_1 .

The true compressibility \bar{K} is the limiting value of the expression above when the changes in pressure and volume become infinitesimal.

$$K = \lim_{\Delta P \rightarrow 0} \left(-\frac{\Delta V}{V_1 \Delta P} \right) = -\frac{1}{V} \times \frac{dV}{dP}$$

The (-ive) sign is included in the definition of K because an increase in P always results in a decrease in volume.

Thus if dp is (+ive), dv is (-ive) and K is a (+ive) quantity.

The mks unite of K are (n/m^2).

If the T is constant, the corresponding value of K is called the isothermal compressibility and the derivative becomes the partial of V with respect to P at constant T .

$$K = -\frac{1}{V} X \left(\frac{dV}{dP} \right)_T = -\frac{1}{V} \left(\frac{\partial V}{\partial P} \right)_T \quad \underline{K = -\frac{1}{V} \left(\frac{\partial V}{\partial P} \right)_T} \quad \text{-----} \quad (4)$$

Or in terms of specific volumes.

$$K = -\frac{1}{v} \left(\frac{\partial v}{\partial P} \right)_T \quad \text{-----} \quad (35) \quad \underline{Kv = -\left(\frac{\partial v}{\partial P} \right)_T} \quad \text{-----} \quad (35)$$

From eq(35) the K for an ideal gas is $Pv = RT, \quad v = \frac{RT}{P}$

$$\therefore \left(\frac{\partial v}{\partial P} \right)_T = -\frac{RT}{P^2}, \quad K = -\frac{1}{v} X -\frac{RT}{P^2} = \frac{RT}{Pv} X \frac{1}{P}$$

$$\therefore \underline{K = \frac{1}{P}} \quad \text{-----} \quad (36)$$

For van der Waals gas is $\left(P + \frac{a}{v^2} \right) (v - b) = RT,$

$$P = \frac{RT}{v - b} - \frac{a}{v^2} \quad \text{-----} \quad (a)$$

$$K = -\frac{1}{v} \left(\frac{\partial v}{\partial P} \right)_T = -\frac{1}{v} X \frac{1}{\left(\frac{\partial P}{\partial v} \right)_T} \quad \text{-----} \quad (b)$$

$$\therefore \left(\frac{\partial P}{\partial v} \right)_T = -\frac{RT}{(v - b)^2} + \frac{2a}{v^3} = \frac{-RTv^3 + 2a(v - b)^2}{v^3(v - b)^2} \quad \text{-----} \quad (c)$$

$$\therefore K = -\frac{1}{v} X \frac{1}{\frac{-RTv^3 + 2a(v - b)^2}{v^3(v - b)^2}} = \frac{v^2(v - b)^2}{RTv^3 - 2a(v - b)^2}$$

$$\therefore \underline{K = \frac{v^2(v - b)^2}{RTv^3 - 2a(v - b)^2}} \quad \text{-----} \quad (37)$$

The K of solids and liquids must be determined experimentally.

The work done in terms of β and K

Let $v = f(T, P)$, so $dv = \left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial v}{\partial P}\right)_T dP$

$dw = pdv = P \left[\left(\frac{\partial v}{\partial T}\right)_P dT + \left(\frac{\partial v}{\partial P}\right)_T dP \right] = P[\beta v dT - K v dP]$

$dw = P v [\beta dT - K dP]$ ----- (38)

For an ideal gas, this reduces to

$dw = pdv = \frac{Pv}{T} dT - \frac{Pv}{P} dP, \quad pdv = R dT - v dP$

A relation which could have been written down at once from the equation of state, since

$pdv + v dP = R dT$ ----- (39)

The work depends on the path

As an example , suppose that a solid or liquid is taken from state 1 to state 2 in Fig.8 first along path 1→3→2 and then along path 1→2, where for the latter path,

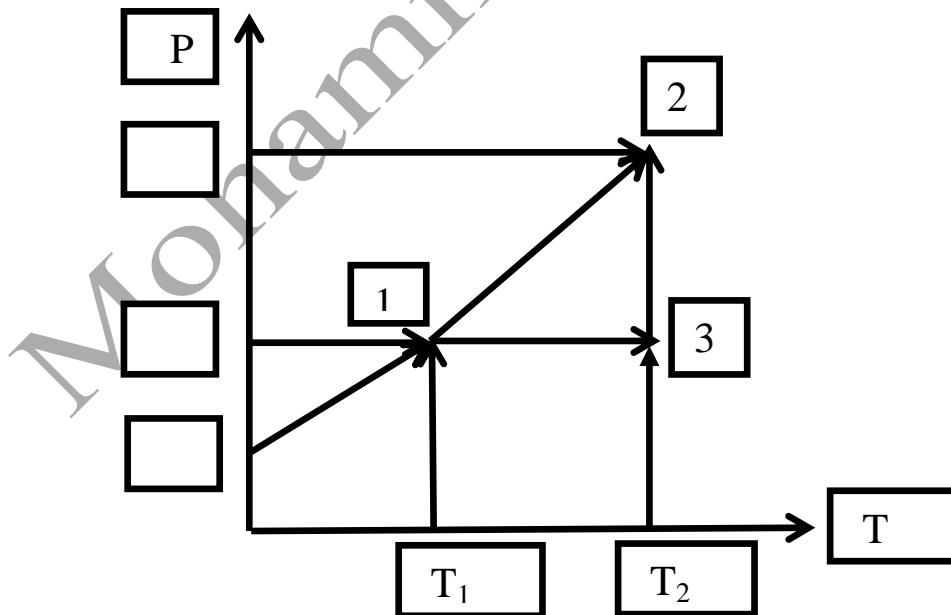


Fig. 8

$$P = P_o + aT$$

Along path 1→3, $P = P_1 = \text{constant}$, $dp = 0$ and

$$w \approx \int P v [\beta dT - K dP], \quad dp = 0$$

$$w_{1 \rightarrow 3} \approx P_1 v \beta \int_{T_1}^{T_2} dT \approx P_1 v \beta (T_2 - T_1) \quad \text{-----} \quad (40)$$

This is the general expression for the work done in any isobaric process by a system having the properties assumed above.

Along path 3→2, $T = \text{const.}$, $dT = 0$ and

$$w = \int P v [\beta dT - K dP], \quad dT = 0$$

$$w_{3 \rightarrow 2} = -K v \int_{P_1}^{P_2} P dP \approx \frac{K v}{2} (P_1^2 - P_2^2), \quad \text{-----} \quad (41)$$

This is the general expression for the work done in any isothermal process by a system having the properties assumed.

The total work along the path $w_{1 \rightarrow 3 \rightarrow 2}$ is

$$w_{1 \rightarrow 3 \rightarrow 2} = w_{1 \rightarrow 3} + w_{3 \rightarrow 2} \approx \beta v P_1 (T_2 - T_1) - \frac{K v}{2} (P_1^2 - P_2^2) \quad \text{-----} \quad (42)$$

Along the direct path 1→2,

$$w_{1 \rightarrow 2} \approx v \beta \int_{T_1}^{T_2} (P_o + aT) dT - v K \int_{P_1}^{P_2} P dP$$

$$w_{1 \rightarrow 2} \approx v \beta P_o (T_2 - T_1) + \frac{a v \beta}{2} (T_2^2 - T_1^2) - \frac{v K}{2} (P_2^2 - P_1^2)$$

Expressing the constants P_o and a in terms of P_1 , P_2 , T_1 and T_2

$$w_{1 \rightarrow 2} \approx \nu\beta \left[P_o(T_2 - T_1) + \frac{a}{2}(T_2 - T_1)(T_2 + T_1) \right] - \frac{\nu K}{2}(P_2^2 - P_1^2)$$

$$w_{1 \rightarrow 2} \approx \nu\beta(T_2 - T_1) \left[P_o + \frac{a}{2}(T_2 + T_1) \right] - \frac{\nu K}{2}(P_2^2 - P_1^2) \quad \text{----- (a)}$$

$$P = P_o + aT, \quad P_1 = P_o + aT_1, \quad P_2 = P_o + aT_2,$$

$$P_1 + P_2 = 2P_o + a(T_2 + T_1), \quad \frac{P_1 + P_2}{2} = P_o + \frac{a}{2}(T_2 + T_1) \quad \text{----- (b)}$$

from eqs. a & b

$$w_{1 \rightarrow 2} \approx \nu\beta \frac{P_1 + P_2}{2}(T_2 - T_1) - \frac{\nu K}{2}(P_2^2 - P_1^2) \quad \text{----- (43)}$$

From eqs. 42 and 43, dw is not an exact differential and that the work depends on the path and not merely on the end points.

From eqs. 24 and 25

$$\left(\frac{\partial P}{\partial \nu} \right)_T \left(\frac{\partial \nu}{\partial T} \right)_P \left(\frac{\partial T}{\partial P} \right)_\nu = -1, \quad \left(\frac{\partial P}{\partial T} \right)_\nu = - \frac{\left(\frac{\partial \nu}{\partial T} \right)_P}{\left(\frac{\partial \nu}{\partial P} \right)_T}$$

From the definition of β and K

$$\left(\frac{\partial P}{\partial T} \right)_\nu = - \frac{\nu\beta}{-\nu K} = \frac{\beta}{K} \quad \text{----- (44)}$$

Then for a solid or a liquid, and to the degree of approximation to which the ratio $\frac{\beta}{K}$ can be considered constant, the increase in pressure ($P_2 - P_1$), when the temperature is increased from T_1 to T_2 and the volume is kept constant, is

$$P_2 - P_1 \approx \frac{\beta}{K}(T_2 - T_1) \quad \text{----- (45)}$$

Questions

Q.(1) Steam at a constant (absolute) pressure of (20atm.) is admitted to the cylinder of a steam engine. The length of the stroke is (60 Cm) and the diameter of the cylinder (20 Cm). How much in joules is done by the steam per stroke?

Q.(2) 1 kgm of water, when converted to steam at atmospheric pressure, occupies a volume of (1.67 m³). Compute the work done against atmospheric pressure.

Q.(3) 5 kgm. of oxygen occupy a volume of (10 m³) at a temperature of (300 K). Find the work necessary to decrease the volume to (5 m³), a// at constant pressure, b// at constant temperature. c// what is the temperature at the end of process a?. d// what is the pressure at the end of process b?. e// show both process in a p-v diagram.

Q.(4) An ideal gas originally at a temperature T_1 and pressure P_1 expands reversibly against a piston to a volume equal to twice its original volume. The temperature of the gas is varied during the expansion as that at each instant the relation $P = KV$ is satisfied, where K is a constant. a// Draw a diagram of the process in the P-V plane. b// Find the work done by the gas, in terms of n , R , T_1 and P_1 .

Q.(5) An ideal gas at an initial pressure P_1 and volume V_1 is heated at constant volume until the pressure is doubled, allowed to expand isothermally until the pressure drops to its original value, and then compressed at constant pressure until the volume returns to its initial value. a// Sketch the process in the P-V plane. b// Compute the net work done in the process, if ($n = 2$ kgm.-moles, $P_1 = 2$ atm. and $V_1 = 4\text{m}^3$).

Q.(6) a// Derive the general expression for the work done per mole by a van der Waals gas in expanding reversibly and at a constant temperature T from a specific volume v_1 to a specific volume v_2 . b// Using the constants ($a = 580 \text{ n-m}^4 / (\text{kgm-mole})^2$, $b = 0.0319 \text{ m}^3/\text{kgm.-mole}$). Find the work done when 2 moles of steam expand from a volume of (30 m³) to a volume of (60 m³) at a temperature of (100°C). C// Find the work done by an ideal gas in the same expansion.

Q.(7) The Clausius equation of state is $P(v-b) = RT$
a// Compute the coefficient of cubical expansion, and the compressibility, for a substance obeying this equation. b// Show that if ($a = 0$), the

corresponding quantities for a van der Waals gas reduce to the expressions derived in (a).

Q.(8) The Dieterici equation of state is $P(v-b)e^{\frac{a}{vRT}} = RT$, where (a & b) are constants, different for different gases. a// Making use of the cyclic relation, eq. 25 , find the coefficient of cubical expansion of a substance obeying this equation. b// At high temperatures and large specific volumes, all gases approximate ideal gases. verify that for large values of T & v, the Dieterici equation and the expression for β derived in a// , both go over into the corresponding equations for an ideal gas.

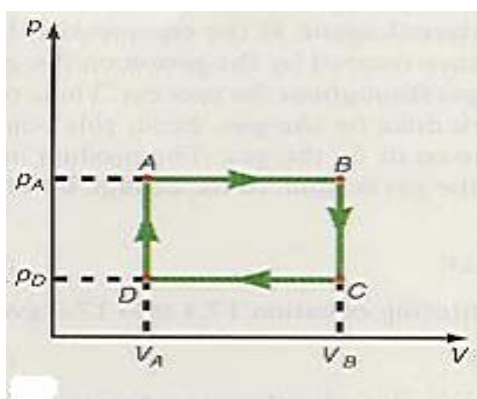
Q.(9) Express the coefficient of cubical expansion and the compressibility, in terms of the density (ρ) and its partial derivatives.

Q.(10) A cylinder provided with a piston contains (1m^3) of a fluid at a pressure of (1 atm.) and a temperature of (300 K). The pressure is increased reversibly to (100 atm.) and the temperature is kept constant. Find the work done on the system, a// if the fluid is an ideal gas, b// if it is a liquid of compressibility [$5 \times 10^{-10} \text{ (n/m}^2\text{)}^{-1}$], about equal to that of water. C// Find the change in volume of each fluid.

Q.(11) A fluid in a cylinder is at a pressure of ($700 \times 10^3 \text{ n/m}^2$). It is expanded at constant pressure from a volume of (0.28 m^3) to a volume of (1.68 m^3). Determine the work done.

Q.(12) One K mole of a gas at (27°C) expands isothermally until its volume is doubled. Find the work done.

Q.(13) Work done in a thermodynamic cycle. One mole of an ideal gas goes through the thermodynamic cycle shown in fig. if ($P_A = 2 \times 10^4 \text{ pa}$, $P_D = 1 \times 10^4 \text{ pa}$, $V_A = 0.25 \text{ m}^3$, and $V_B = 0.5 \text{ m}^3$), find the work done along the path, a// AB, b// BC, C// CD, d// DA, and e// ABCDA.



Q.(14) The volume of a glass beaker is (200 Cm^3) which was filled with mercury at the temperature of (20° C). How much the mercury is spilled, when the temperature of the system is raised to (100° C)?. The coefficient of cubical expansion for glass is $1.2 \times 10^{-5}/^\circ\text{C}$, The coefficient of cubical expansion for Hg is $18.1 \times 10^{-5}/^\circ\text{C}$,

Q.(15) At constant temperature, increase the pressure from Zero to (1000 atm.) on (10 gm) of Cu. Determine the work done if the density of Cu is ($8.93 \text{ gm}/\text{Cm}^3$), and coefficient of compressibility is ($0.716 \times 10^{-6} \text{ atm.}^{-1}$).

Q.(16) Determine the work done at vaporization (100gm) of C_6H_6 at the pressure of (1 atm.), and the boiling point of it is (80.2° C). (molecular weight of C_6H_6 is 78).

Q.(17) Find the work done for one mole of an ideal gas at constant pressure P, where is expanded by rising the temperature of one degree.

Q.(18) Find the work done for (75 kgm.) of water when it is compressed from (140 Kpa) to (7.5 Mpa) at constant temperature (40°C). If the specific volume of water at the temperature (40°C), and the initial pressure was ($1.0078 \text{ Cm}^3/\text{gm}$) and at the final pressure was ($1.0045 \text{ Cm}^3/\text{gm}$)