

I Boiling point \rightarrow Intensive

II Entropy \rightarrow extensive

III pH → Intensive

IV density \rightarrow intensive

2. What is the change in internal energy when a gas is compressed from 377 ml to 177 ml under a constant pressure of 1520 torr, while at the same time being cooled by removing 124 J heat ?

[Take : (1 L atm) = 100 J]

$$q = -124 \text{ J}, \quad w = -P(v_2 - v_1) = -\frac{1520}{760} (177 - 377) \text{ atm ml} = 400 \text{ atm ml} \\ = 40 \text{ J}$$

$$\therefore \Delta U = q + w = -124 + 40 = \boxed{-84 \text{ J}}$$

~~3. One mole of an ideal monoatomic gas expanded irreversibly in two stage expansion.~~

A definite
amount

State-1	(8.0 bar, 4.0 litre, 300 K)
State-2	(2.0 bar, 16 litre, 300 K)
State-3	(1.0 bar, 32 litre, 300 K)

Total heat absorbed by the gas in the process is

$$\because T = \text{const} \Rightarrow \Delta U = 0 \quad \because \cancel{\Delta U = Q + W} \Rightarrow Q = -W$$



$$\begin{aligned} W &= W_1 + W_2 = -P_{ext}(V_2 - V_1) - P_{ext}(V_3 - V_2) \\ &= -2(16 - 4) - 1(32 - 16) \\ &= -24 - 16 = -40 \text{ bar L} = -4000 \text{ J.} \end{aligned}$$

$$\therefore Q = -W = \boxed{4000 \text{ J.}}$$

4. An ideal gas undergoes isothermal expansion from A(10 atm, 1L) to B(1 atm, 10 L) either by
(I) Infinite stage expansion or by
(II) First against 5 atm and then against 1 atm isothermally

Calculate $\frac{q_I}{q_{II}}$:

(A) $\frac{1}{13 \times 2.303}$

(B) 13×2.303

(C) $\frac{13}{23.03}$

\checkmark (D) $\frac{23.03}{13}$

I) Infinite stage \Rightarrow rev. isothermal $\Rightarrow \Delta U = 0$ and $Q = -W$

$$\therefore q_I = P_1 V_1 \ln \frac{V_2}{V_1} = 10 \times 1 \ln \frac{10}{1} = 10 \times 2.303 = 23.03 \text{ atm L}$$

$$A(10 \text{ atm}, 1 \text{ L}) \xrightarrow[W_1]{P_{ext}=5 \text{ atm}} (5 \text{ atm}, 2 \text{ L}) \xrightarrow[W_2]{P_{ext}=1 \text{ atm}} B(1 \text{ atm}, 10 \text{ L})$$

$\because P_1 V_1 = P_2 V_2$

$$W = W_1 + W_2 = -5(2-1) - 1(10-2) = -5 - 8 = -13 \text{ atm L}$$

$$\therefore \Delta U = Q + W \quad \therefore \Delta U = 0 \Rightarrow Q = -W$$

$$\therefore q_{II} = -W = 13 \text{ atm L}$$

$$\boxed{\frac{q_I}{q_{II}} = \frac{23.03}{13}}$$

5. One mole of ideal gas is allowed to expand reversibly and adiabatically from a temperature of 27°C . If the work done by the gas in the process is 3 kJ, the final temperature will be equal to ($C_V = 20 \text{ J/K mol}$)

(A) 100 K (B) 450 K ✓ (C) 150 K (D) 400 K

rev adia, $q=0$, $T_i=300K$, $w=-3KJ$

$$\Delta v = w$$

$$\text{or} \quad nC_p (\bar{T}_2 - \bar{T}_1) = -3000$$

$$\sigma, \quad 1 \times 20 (T_2 - 300) = -3000$$

$$0\sigma, \quad T_2 - 300 = -150$$

$$0^\circ, \boxed{T_2 = 150\text{ K}}$$

6. For an adiabatic process, which of the following relation must be correct -

- (A) $\Delta U = 0$ (B) $P\Delta V = 0$ (C) $q = 0$ (D) $q = + W$

7. A system containing ideal gas is expanded under adiabatic process

- (A) Temperature increases (B) Internal energy decreases
(C) Internal energy increases (D) None of these

$$q=0 \Rightarrow \Delta U=W, \text{ for expansion, } W=(-)ve \Rightarrow \Delta U=(-)ve.$$

8. A gas ($C_{v,m} = \frac{5}{2}R$) behaving ideally was allowed to expand reversibly and adiabatically from 1 litre to 32 litre. Its initial temperature was $327^\circ C$. The molar enthalpy change (in J/mole) for the process is :-
- (A) -1125 R (B) - 575 R ~~(C)~~ -1575 R (D) None of these

$$Q=0, \quad V_1 = 1L, \quad V_2 = 32L, \quad T_1 = 600K, \quad \Delta H = ? \quad C_{v,m} = \frac{5}{2}R, \quad \therefore C_{p,m} = C_{v,m} + R$$

$$\therefore \gamma = \frac{C_{p,m}}{C_{v,m}} = \frac{7}{5} \quad = \frac{7}{2}R.$$

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1} \quad (\because \text{Rev. adia})$$

$$\text{or, } T_2 = T_1 \left(\frac{V_1}{V_2} \right)^{\gamma-1} = 600 \left(\frac{1}{32} \right)^{\left(\frac{7}{5}-1\right)} = 600 \left(\frac{1}{32} \right)^{\frac{2}{5}}$$

$$= 600 \left(\frac{1}{2} \right)^2 = 600 \times \frac{1}{4} = 150K.$$

$$\Delta H = n C_{p,m} \Delta T \Rightarrow \frac{\Delta H}{n} = C_{p,m} \Delta T = \frac{7}{2}R(150 - 600) = \frac{7}{2}R \times (-450)$$

$$= \boxed{-1575R}$$

9. Two moles of an ideal gas ($C_v = \frac{5}{2}R$) was compressed adiabatically against constant pressure of 2 atm, which was initially at 350 K and 1 atm pressure. The work involve in the process is equal to -

(A) 250 R (B) 300 R (C) 400 R ✓ (D) 500 R

$$\eta=2, \quad C_V = \frac{5}{2}R, \quad q=0, \quad P_{ext}=2 \text{ atm}, \quad T_i=350K, \quad w=8$$

$$\Delta V = W$$

$$\sigma, \quad n G_m (\tau_2 - \tau_1) = - P_{ext} (v_2 - v_1)$$

$$\text{or, } \frac{n}{2} R(T_2 - T_1) = -P_{ext} \left(\frac{nR T_2}{P_2} - \frac{nR T_1}{P_1} \right) \quad (\text{also, } P_{ext} = P_2)$$

$$00, \quad \frac{5}{2} (T_2 - 350) = -2 \left(\frac{T_2}{2} - \frac{350}{1} \right)$$

$$\text{or, } \frac{5}{2}T_2 - 875 = -T_2 + 700 \Rightarrow 3.5T_2 = 1575 \Rightarrow T_2 = 450\text{K.}$$

$$W = \Delta U = n C_v_m (T_2 - T_1) = 2 \times \frac{5}{2} R (450 - 350) = \boxed{500 R}$$

10. A gas is expanded from volume V_1 to V_2 through three different process :

(a) Reversible adiabatic \Rightarrow Temp decreases

(b) Reversible isothermal \Rightarrow Temp = const

(c) Irreversible adiabatic \Rightarrow Temp decreases but it will be higher than rev. adia .
The correct statements is -

(A) $(T_f)_{\text{Reversible Isothermal}} > (T_f)_{\text{Reversible adiabatic}} > (T_f)_{\text{Irreversible adiabatic}}$

~~(B)~~ $(T_f)_{\text{Reversible Isothermal}} > (T_f)_{\text{Irreversible adiabatic}} > (T_f)_{\text{Reversible adiabatic}}$

(C) $W_{\text{Reversible Isothermal}} > W_{\text{Irreversible adiabatic}} > W_{\text{reversible adiabatic}}$

(D) $(P_f)_{\text{Reversible Isothermal}} > (P_f)_{\text{Reversible adiabatic}} > (P_f)_{\text{Irreversible adiabatic}}$

Whenever expansion occurs adiabatically
its temp decreases.

\because for adiabatic, $Q=0 \Rightarrow \Delta U=W$
for expansion, $W=(-)ve \Rightarrow \Delta U < 0$

or, $nC_v m (T_2 - T_1) < 0$

or, $T_2 < T_1$

\Rightarrow Temp decreases

* final temp of irr. adiabatic
is always $>$ final temp of rev.
adiabatic.

\therefore for expansion & compression both,
with proper sign convention.

$W_{\text{irr}} > W_{\text{rev}}$

or, $\Delta U_{\text{irr}} > \Delta U_{\text{rev}} \quad (\because \Delta U=W \text{ for adiabatic})$

or, $nC_v m (T_{2\text{irr}} - T_1) > nC_v m (T_{2\text{rev}} - T_1)$

or, $T_{2\text{irr}} > T_{2\text{rev}}$.

11. What is the magnitude of work performed by one mole of an ideal gas when its volume increases eight times in irreversible adiabatic expansion if the initial temperature of the gas is 300 K ? C_V for the gas is 1.5 R. ($R = 2 \text{ Cal / mol/K}$)

(A) 900 Cal

(B) 450 Cal

(C) 675 Cal

\checkmark (D) 331.58 Cal

$$|W| = ? \quad n=1, \quad \frac{V_2}{V_1} = 8, \quad \text{Irre adia, } q=0, \quad T_1 = 300 \text{ K}, \quad C_{Vm} = 1.5R.$$

$$\Delta U = W$$

$$\text{or, } n C_{Vm} (T_2 - T_1) = -P_{ext} (V_2 - V_1)$$

$$\text{or, } n \times 1.5R (T_2 - 300) = -P_{ext} V_2 \left(1 - \frac{V_1}{V_2}\right)$$

$$\text{or, } 1.5R (T_2 - 300) = -P_{ext} V_2 \left(1 - \frac{1}{8}\right)$$

$$\text{or, } 1.5 (T_2 - 300) = -\frac{7}{8} T_2$$

$$\text{or, } 1.5 T_2 + \frac{7}{8} T_2 = 450 \Rightarrow \frac{19 T_2}{8} = 450 \Rightarrow T_2 = \frac{450 \times 8}{19} = 189.5 \text{ K.}$$

$$W = \Delta U = n C_{Vm} (T_2 - T_1) = 1 \times 1.5R (189.5 - 300) = -331.58 \text{ Cal.}$$

$$\therefore |W| = \boxed{331.58 \text{ Cal.}}$$

"

$\because P_{ext} = P_2$ and
 $P_2 V_2 = n R T_2$

12. For a process which follows the equation $PV^3 = C$, the work done when one mole of ideal gas was taken from 1 atm to $2\sqrt{2}$ atm starting from initial temperature of 300 K is :-

(A) 300 R

(B) 150 R

(C) 600 R

(D) 900 R

$$PV^3 = \text{const.} \quad n=1, \quad P_1 = 1 \text{ atm}, \quad P_2 = 2\sqrt{2} \text{ atm}, \quad T_1 = 300 \text{ K.} \quad W=?$$

$$\therefore \boxed{x=3/2}$$

$$\therefore P^{1-x} T^x = \text{const}$$

$$\therefore P_1^{1-x} T_1^x = P_2^{1-x} T_2^x$$

$$\text{or, } \left(\frac{T_2}{T_1}\right)^x = \left(\frac{P_1}{P_2}\right)^{1-x} = \left(\frac{P_2}{P_1}\right)^{x-1}$$

$$\text{or, } \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{x-1}{x}}$$

$$\text{or, } T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{x-1}{x}}$$

$$\text{or, } T_2 = 300 \left(\frac{2\sqrt{2}}{1}\right)^{\frac{3-1}{3}}$$

$$\text{or, } T_2 = 300 \left(2^{\frac{3}{2} + \frac{1}{2}}\right) = 600 \text{ K.}$$

$$W = \frac{nR(T_2 - T_1)}{(x-1)} = \frac{1 \times R (600 - 300)}{(3-1)}$$

$$\text{or, } W = \frac{300R}{2} = \boxed{150R}$$

Ans.

13. What is the net work done (w) when 1 mole of monoatomic ideal gas undergoes in a process described by 1, 2, 3, 4 in given V-T graph
Use : $R = 2 \text{ cal/mole K}$

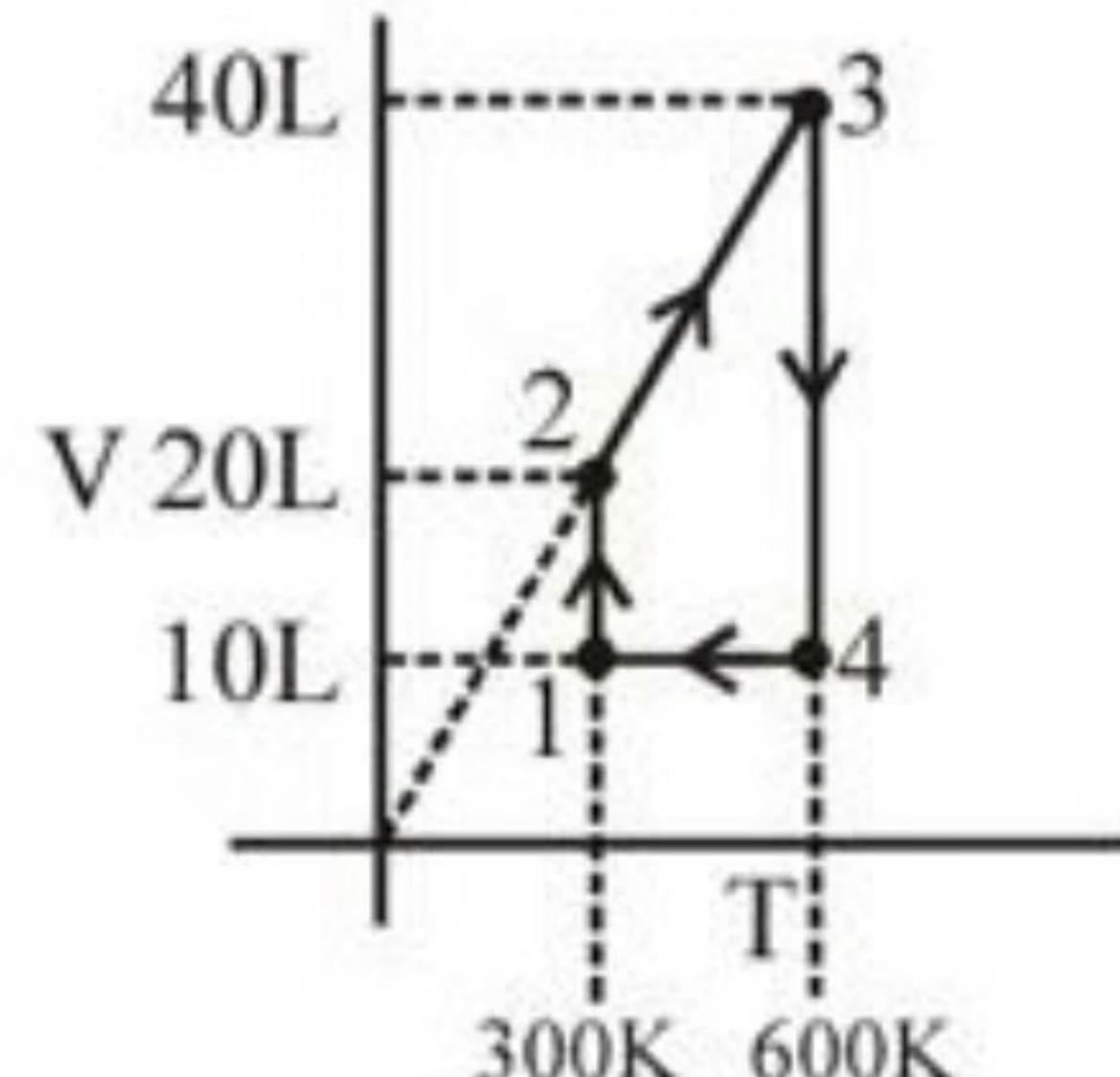
$$\ln 2 = 0.7$$

(A) -600 cal

(B) - 660 cal

\checkmark (C) + 660 cal

(D) + 600 cal



$$1-2 = \text{isothermal} \therefore W_{1-2} = -nRT \ln \frac{V_2}{V_1} = -1 \times 2 \times 300 \ln \frac{20}{10} = -420 \text{ cal.}$$

2-3 : Graph betⁿ V & T, Raising through origin \Rightarrow isobaric.

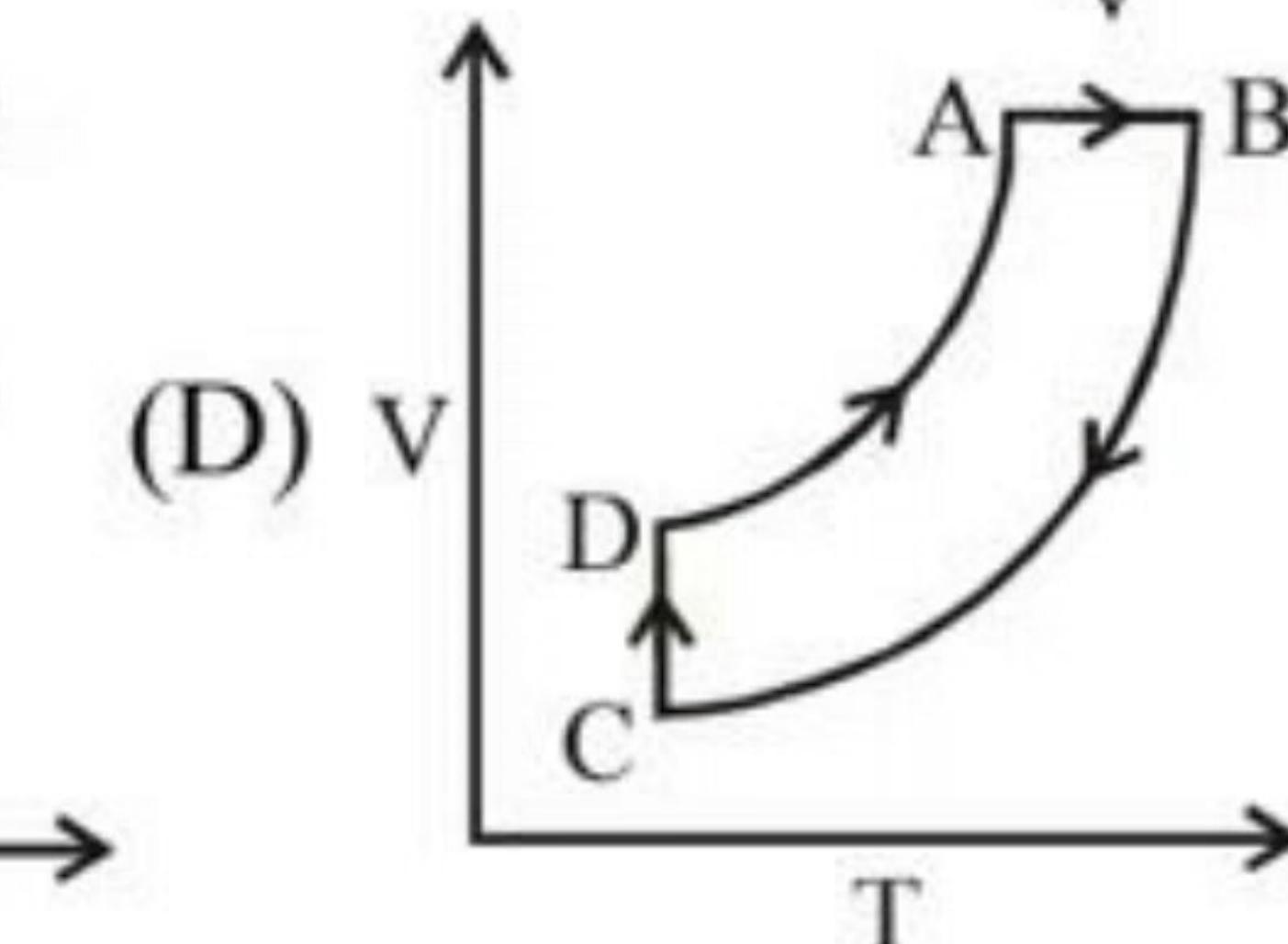
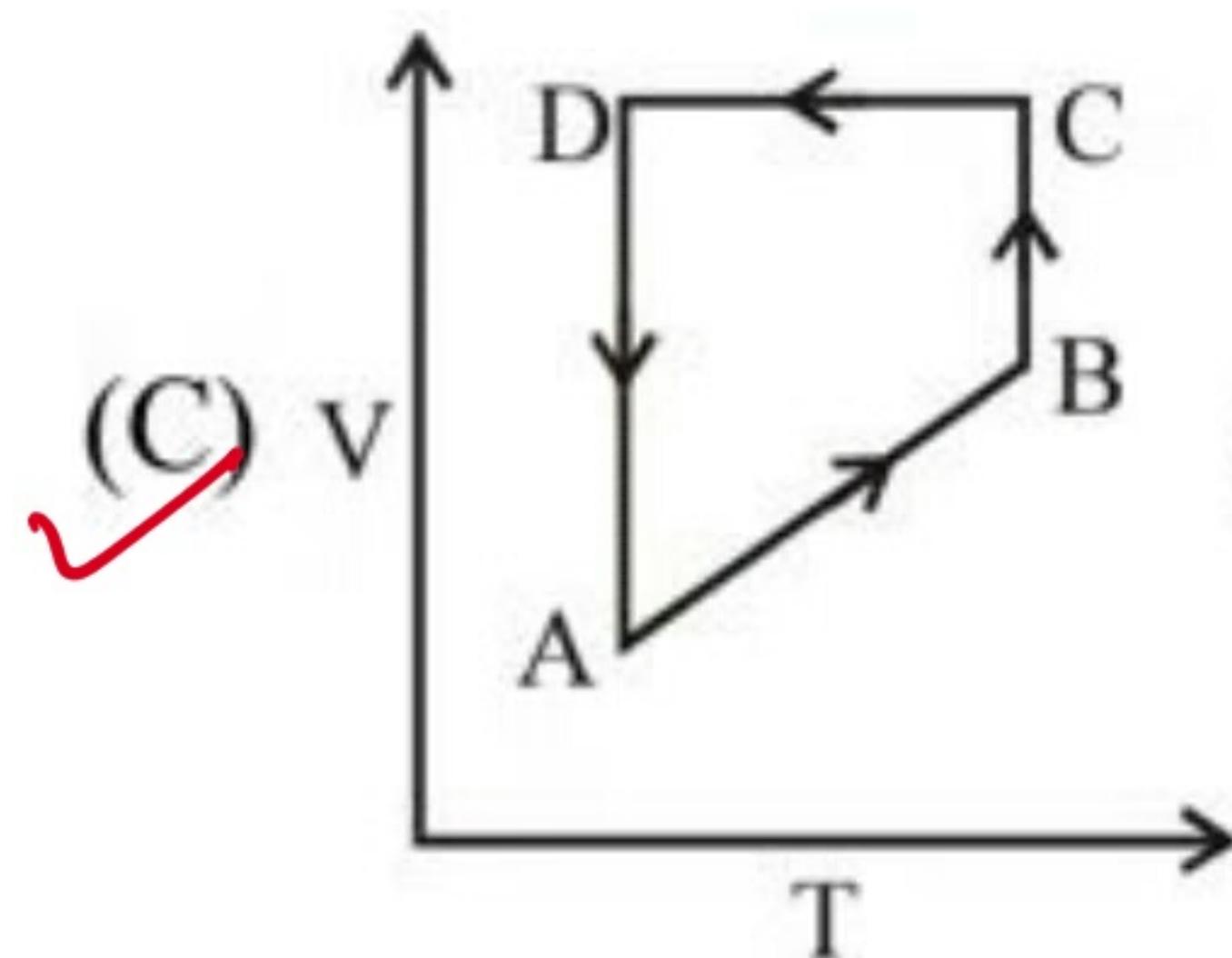
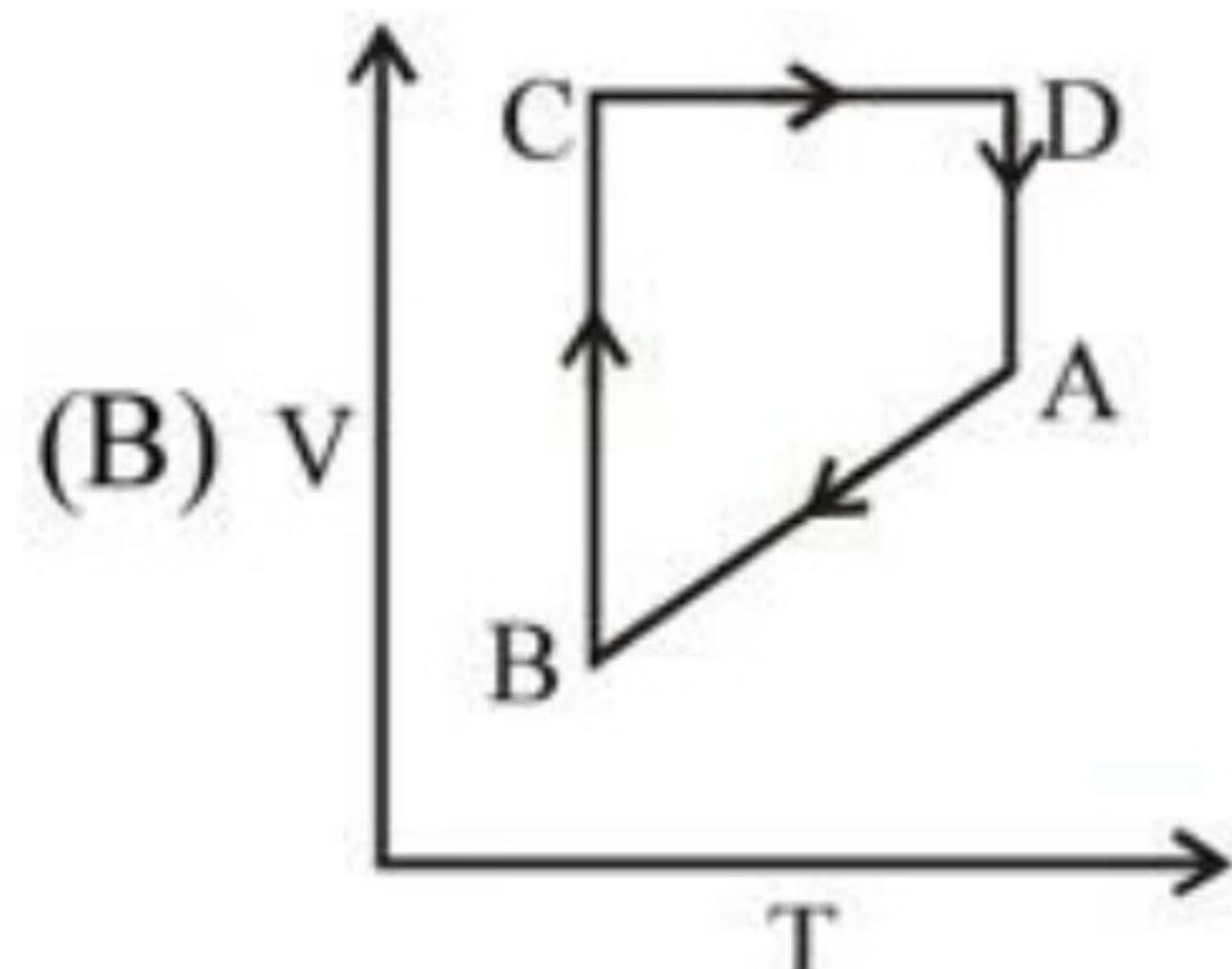
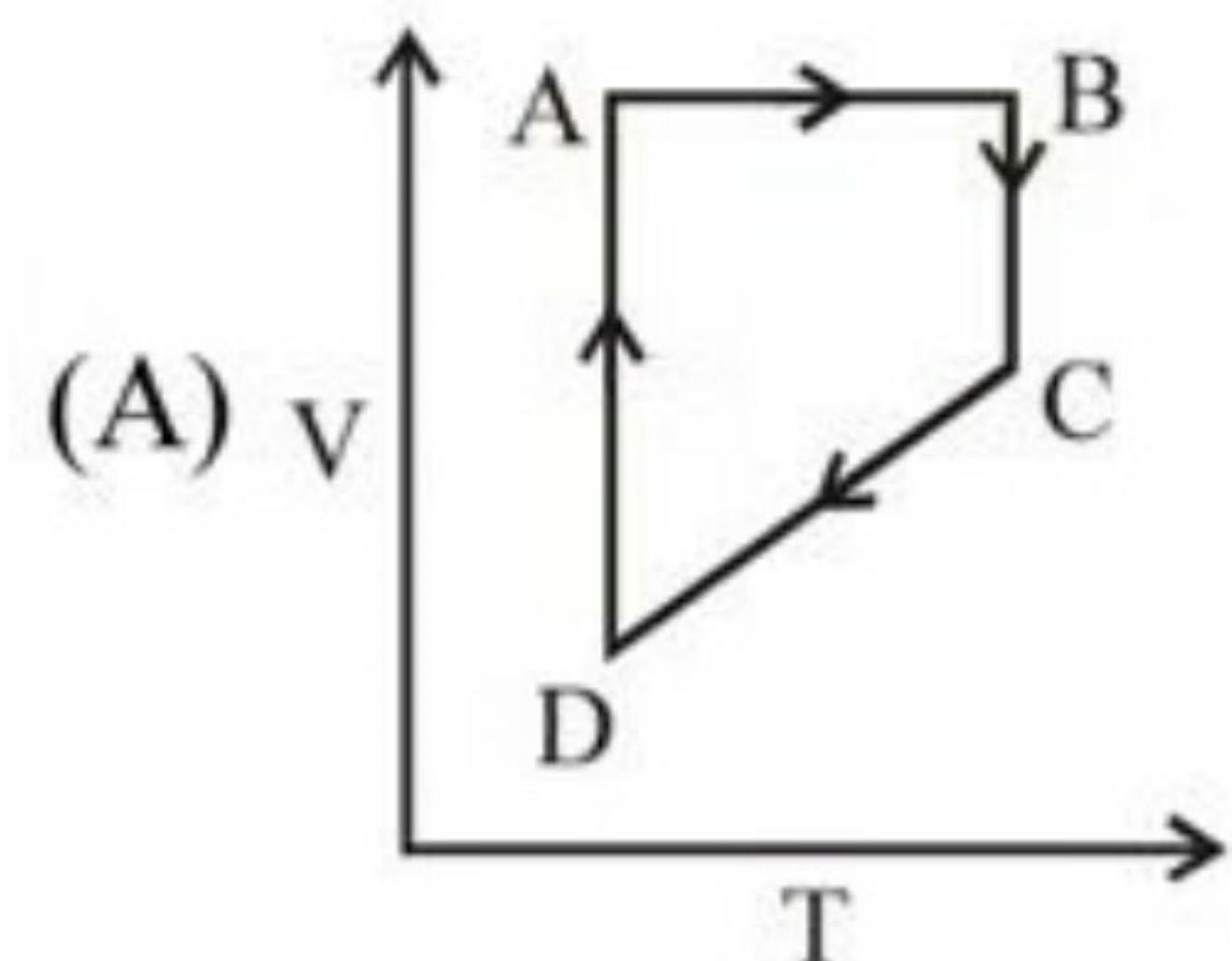
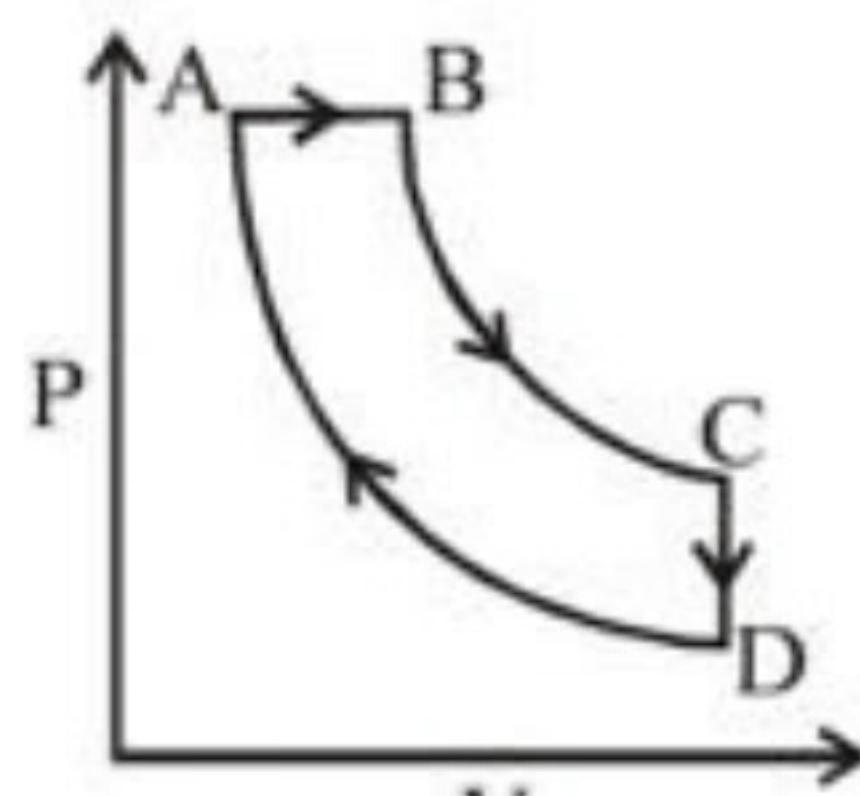
$$W_{2-3} = -nR\Delta T = -1 \times 2 (600 - 300) = -600 \text{ cal.}$$

$$3-4 = \text{isothermal} \therefore W_{3-4} = -nRT \ln \frac{V_4}{V_3} = -1 \times 2 \times 600 \ln \frac{40}{10} = 1680 \text{ cal.}$$

W-1 = isochoric $\Rightarrow W_{4-1} = 0$

$$W_{\text{net}} = W_{1-2} + W_{2-3} + W_{3-4} + W_{4-1} = -420 - 600 + 1680 + 0 = \boxed{660 \text{ cal.}}$$

14. A cyclic process ABCD is shown in PV diagram for an ideal gas. which of the following diagram represents the same process ?



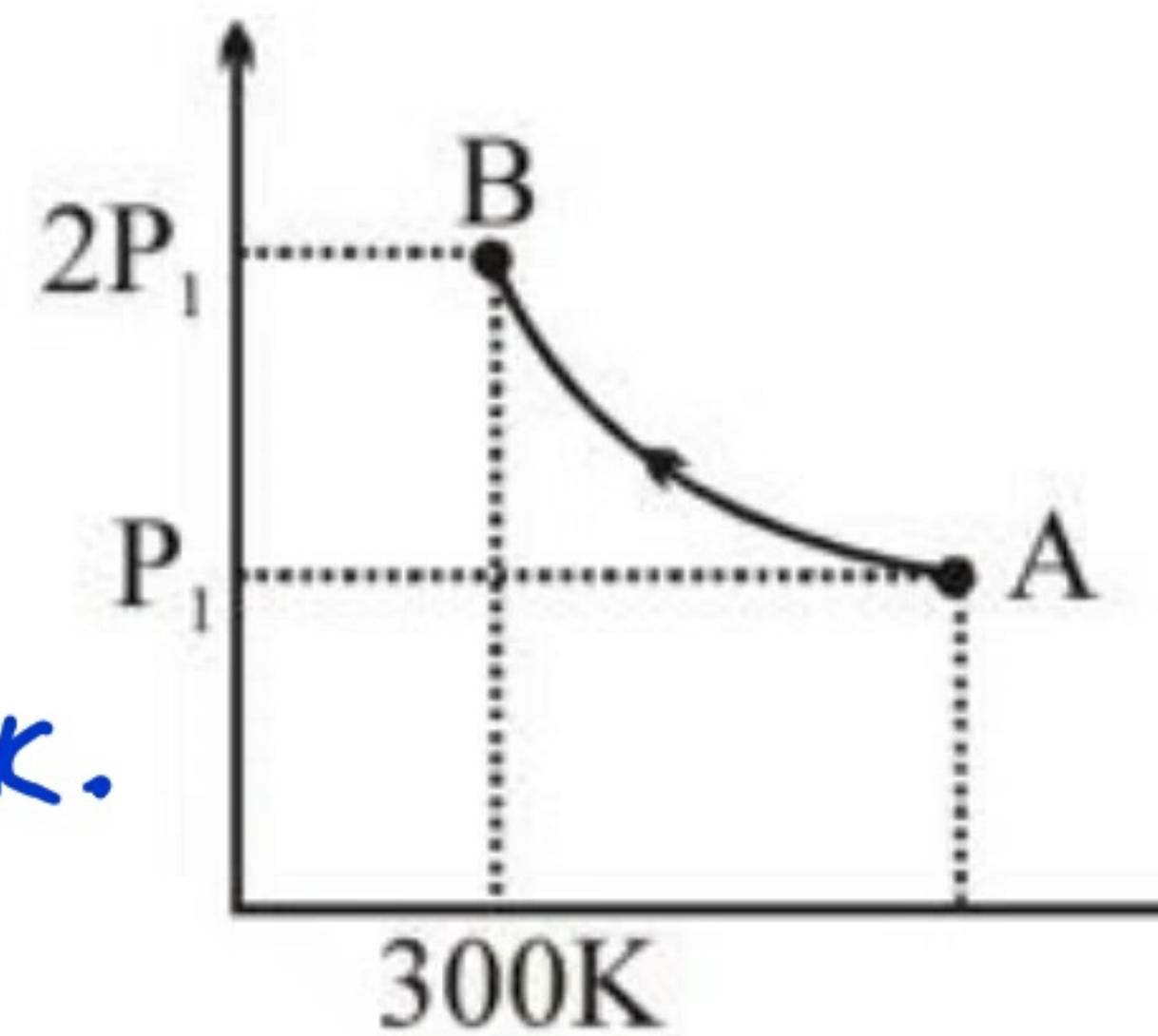
AB = isobaric \Rightarrow in VT diagram it will be a line passing through origin and from A to B volume increases. These two conditions are satisfied only by (C). Therefore 'C' is the correct answer.

15. 2 moles of an ideal monoatomic gas is taken from state A to state B through a process AB in which $P_T = \text{constant}$. The process can be represented on a P-T graph as follows:

$$\therefore P_T = \text{const}$$

$$\Rightarrow P_A T_A = P_B T_B$$

$$\text{or, } T_A = T_B \left(\frac{P_B}{P_A} \right) = 300 \times \frac{2P_1}{P_1} = 600 \text{ K.}$$



Select the incorrect option(s):

- (A) Heat evolved by the gas during process AB = 2100 R
- (B) Heat absorbed by the gas during process AB = 2100 R
- (C) $\Delta U = -900 \text{ R}$
- (D) $W = 1200 \text{ R}$

$\therefore P_T = \text{const} \Rightarrow$ for polytopic process,

$$P^{1-x} T^x = \text{const} \Rightarrow P T^{\frac{x}{1-x}} = \text{const}$$

$$\Rightarrow \frac{x}{1-x} = 1 \Rightarrow 1-x = x \Rightarrow 2x = 0.5$$

$$W_{AB} = \frac{nR(T_B - T_A)}{(x-1)} = \frac{2 \times R(300-600)}{(0.5-1)}$$

$$\text{or, } W_{AB} = +1200R.$$

$$C_m = C_m + \frac{R}{(1-x)}$$

$$= \frac{3}{2} R + \frac{R}{0.5} = \frac{7R}{2}$$

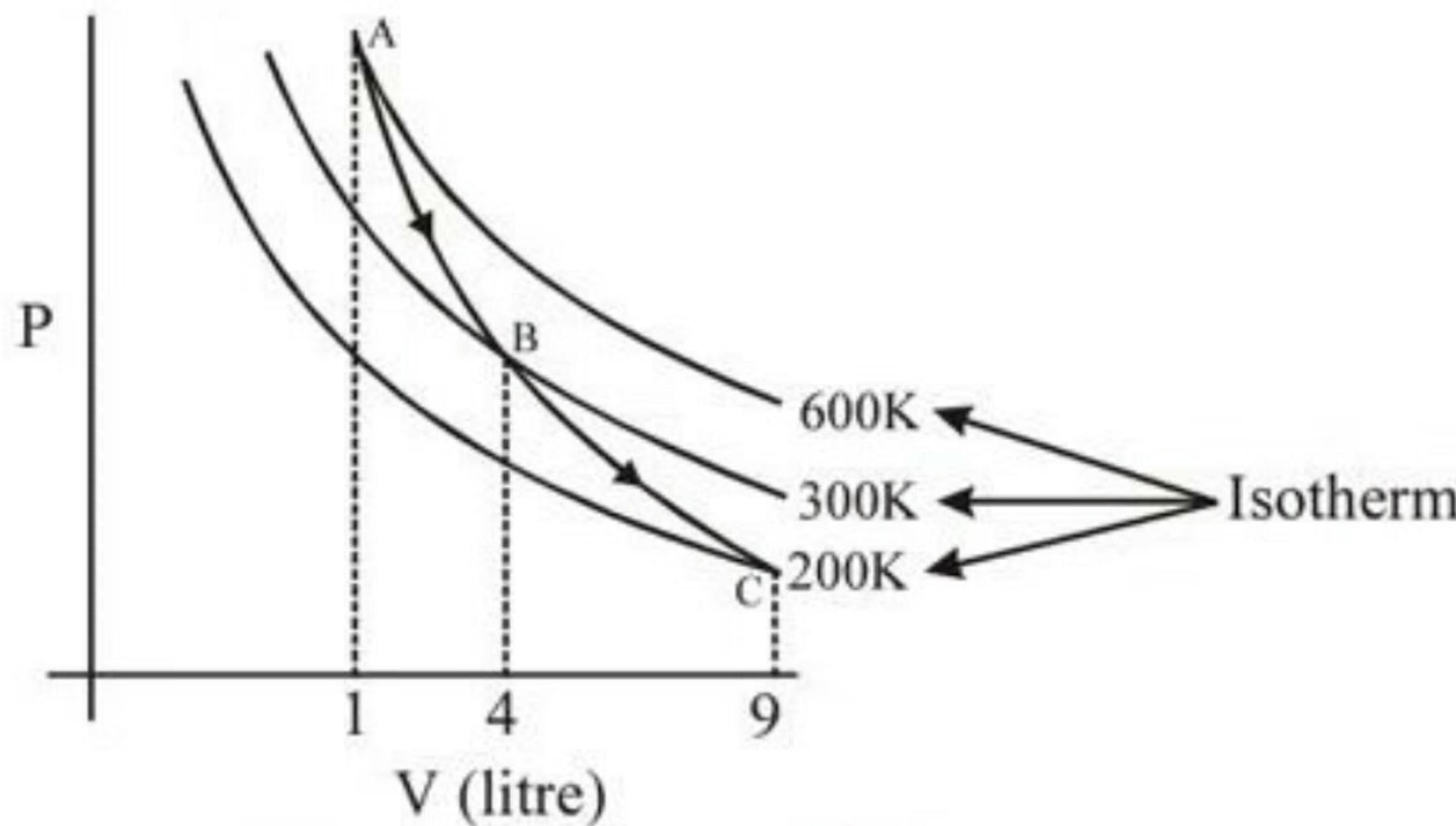
$$Q = nC_m \Delta T = \frac{2 \times 7R \times (300-600)}{2}$$

$$\text{or, } Q = -2100R$$

$$\Delta U = Q + W = -2100R + 1200R$$

$$\text{or, } \Delta U = -900R$$

16. The given figure shows a polytropic process ABC for one mole of an ideal gas. Calculate the polytropic index (x) for the process-



(A) $1/2$

(B) $-1/2$

\checkmark (C) $3/2$

(D) None

$$TV^{x-1} = \text{const}$$

$$\Rightarrow T_A V_A^{x-1} = T_B V_B^{x-1}$$

$$\Rightarrow 600 \times (1)^{x-1} = 300 \times 4^{x-1}$$

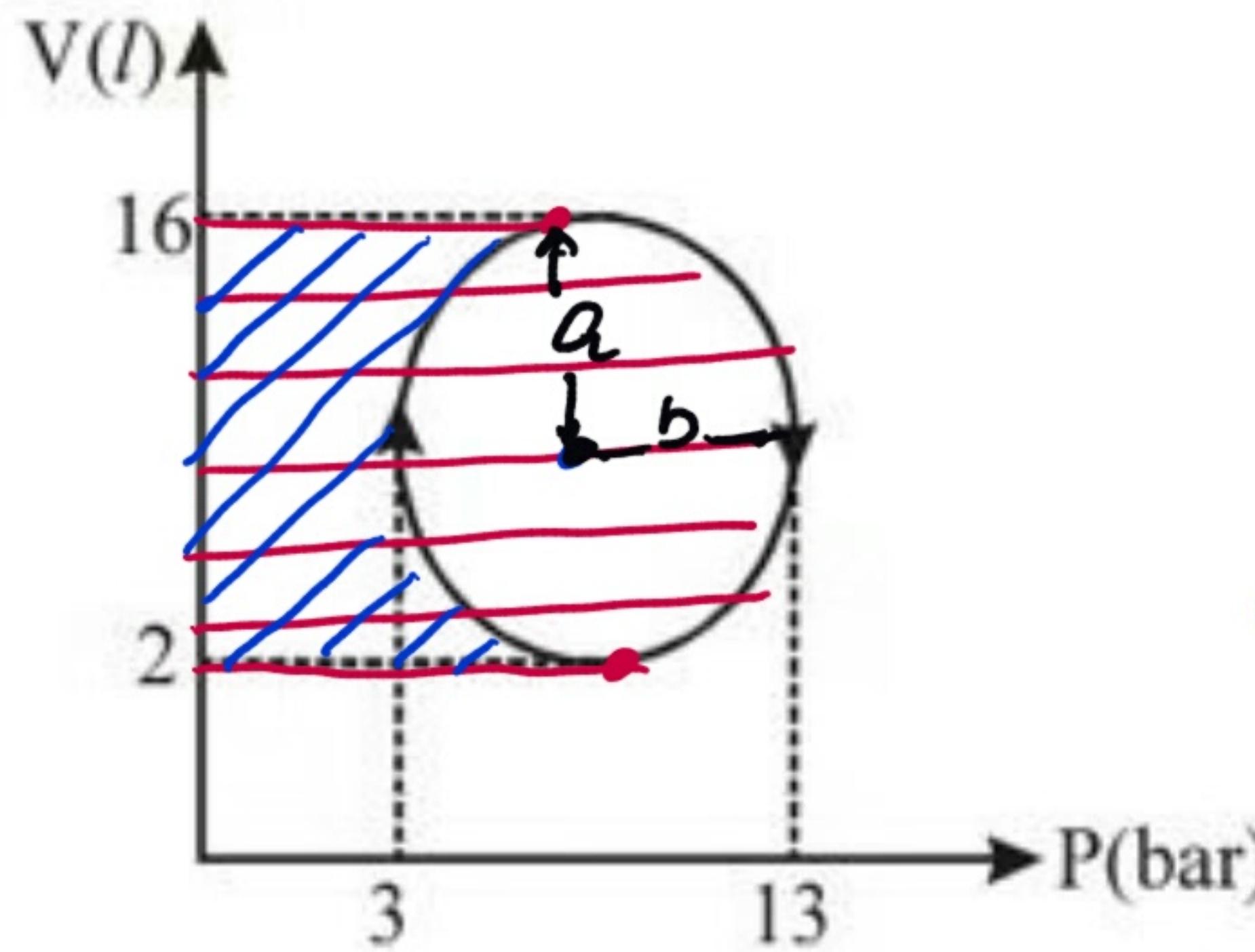
$$\text{or, } 2 = 2^{2(x-1)}$$

$$\text{or, } 2(x-1) = 1$$

$$\text{or, } 2x - 2 = 0.5$$

$$\text{or, } \boxed{x = 1.5}$$

17. Work (in kJ) in the following cyclic process is



Red region = (+)ve work.

Blue region = (-)ve work.

$\therefore W_{\text{net}} = (+)$ ve.

\because Red region > Blue region.

(A) -11

(B) -11000

~~(C)~~ 11

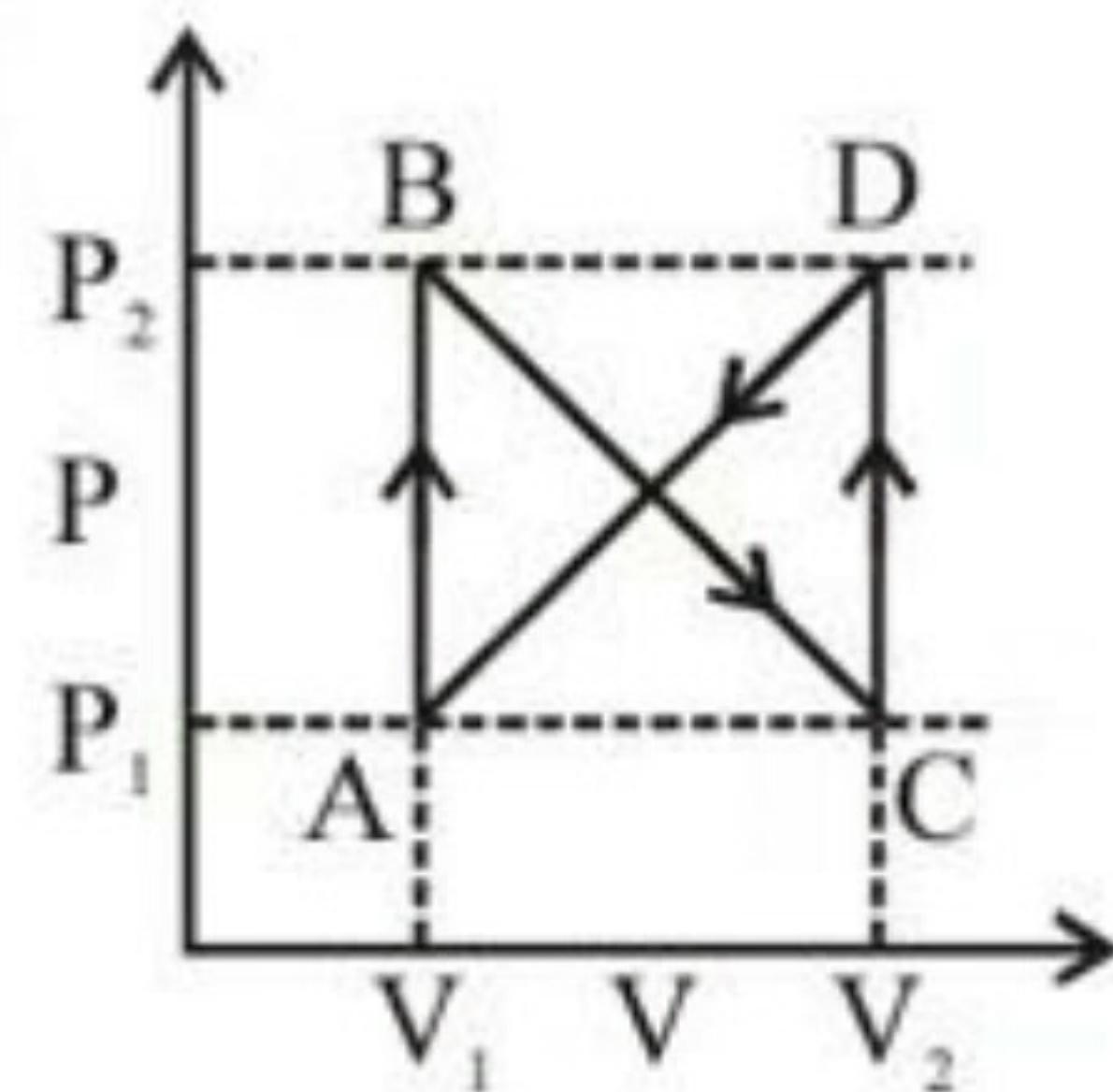
(D) 11000

$$W = \pi ab = \frac{22}{7} \times \left(\frac{16-2}{2}\right) \left(\frac{13-3}{2}\right) = \frac{22}{7} \times 7 \times 5 = 110 \text{ bar L}$$

$$= 110 \times 100 \text{ J} = 11 \text{ kJ}.$$

18. An ideal gas is taken around the cycle ABCDA as shown in figure. The net work done during the cycle is equal to :-

- (A) Zero
- (B) Positive
- (C) Negative
- (D) We cannot predict



$$W_{AB} = 0 \quad (\because V = \text{const})$$

$$W_{BC} = -\frac{1}{2}(P_1 + P_2)(V_2 - V_1) = -(\text{Area of trapezium } BCV_2V_1)$$

$$W_{CD} = 0 \quad (\because V = \text{const})$$

$$W_{DA} = +\frac{1}{2}(P_1 + P_2)(V_2 - V_1) = +(\text{Area of trapezium } DAV_1V_2)$$

$$\therefore W_{\text{net}} = W_{AB} + \cancel{W_{BC}} + \cancel{W_{CD}} + \cancel{W_{DA}} = \boxed{0}$$

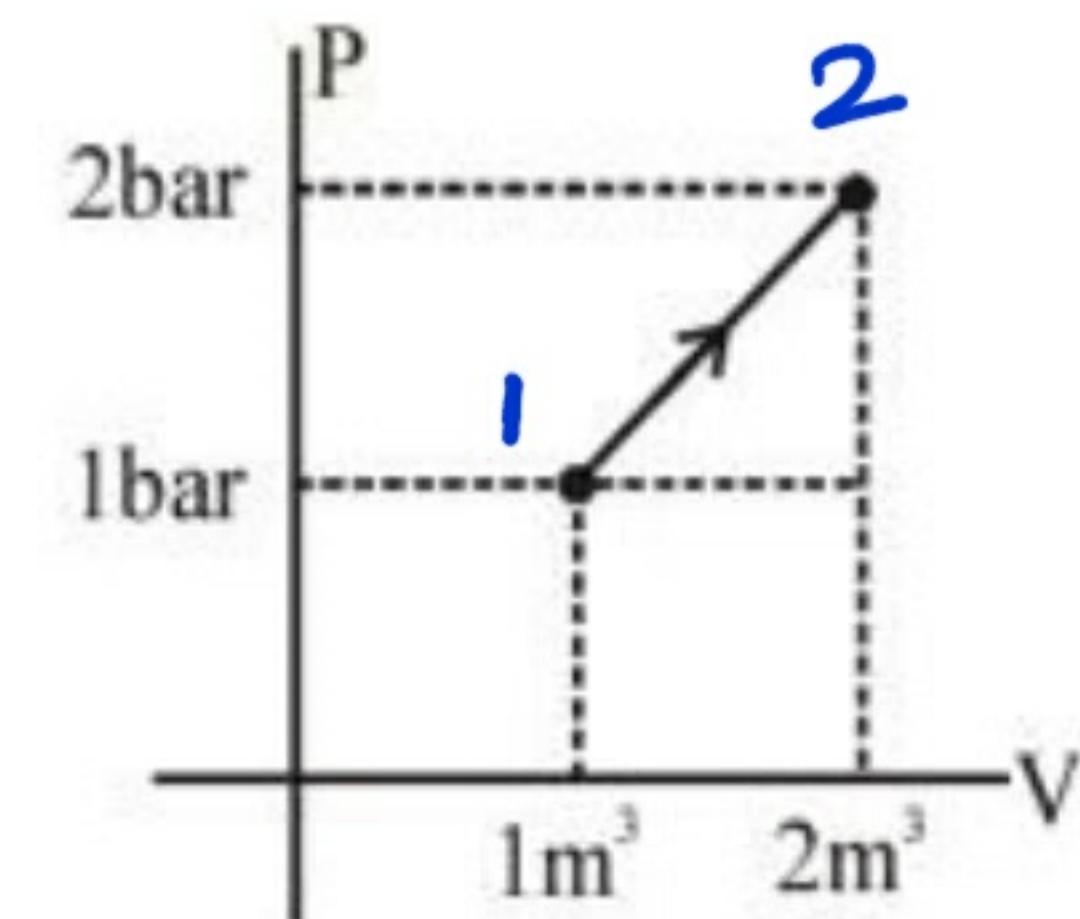
19. What is ΔU for the process described by figure. Heat supplied during the process $q = 200 \text{ kJ}$.

(A) +50 kJ

(B) -50 kJ

(C) -150 kJ

(D) + 150 kJ



$$q = 200 \text{ kJ}, \quad w = w_{1-2} = -\frac{1}{2}(1+2) \times (2-1)$$

$$= -1.5 \text{ bar} \cdot \text{m}^3 = -1.5 \times 10^5 \text{ J}$$

$$= -150 \text{ kJ}.$$

$$\Delta U = q + w$$

$$= 200 - 150 = \boxed{50 \text{ kJ.}}$$

20. A diatomic ideal gas initially at 273 K is given 100 cal heat due to which system did 209 J work, Molar heat capacity (C_m) of gas for the process is [1 cal = 4.18 Joule]

(A) $\frac{3}{2}R$

(B) $\frac{5}{2}R$

(C) $\frac{5}{4}R$

(D) $5R$

$$T_i = 273K, \quad q = 100 \text{ cal}, \quad w = -209 \text{ J}. \quad C_m = ?$$

$$\Delta U = q + w = 100 - \frac{209}{4.18} = 100 - 50 = 50 \text{ Cal.}$$

$$\therefore \Delta U = 50 \text{ Cal}$$

$$n C_m \Delta T = 50$$

$$n \Delta T = \frac{50}{C_m} = \frac{50}{\frac{5}{2}R} = \frac{20}{R}$$

$$q = n C_m \Delta T$$

$$100 = C_m \times \frac{20}{R} \Rightarrow \boxed{C_m = 5R}$$

21. For an ideal monoatomic gas during any process $T = kV$, find out the molar heat capacity of the gas during the process. (Assume vibrational degree of freedom to be active)

✓ (A) $\frac{5}{2}R$

(B) $3R$

(C) $\frac{7}{2}$

(D) $4R$

$\therefore T = kV$

$\propto, \frac{T}{V} = \text{const}$

$\propto, TV^{-1} = \text{const}$

$\Rightarrow x - 1 = -1$

$\propto, x = 0$

$C_m = C_v + \frac{R}{(1-x)}$

$\propto, C_m = \frac{3}{2}R + \frac{R}{1-(0)} = \frac{5R}{2}$

22. An amount Q of heat is added to a monoatomic ideal gas in a process in which the gas performs forms
a work $Q/2$ on its surrounding. The molar heat capacity of gas (in cal/K-mol) for the process is.

(A) $3R$

(B) $5R$

(C) $4R$

(D) $2R$

$$q = Q$$

$$w = -\frac{Q}{2}$$

$$C_m = ?$$

$$\Delta U = q + w$$

$$= Q - \frac{Q}{2}$$

$$\text{or, } \Delta U = \frac{Q}{2}$$

$$\therefore n C_m \Delta T = \frac{Q}{2}$$

$$\text{or, } n \Delta T = \frac{Q}{2 C_m} = \frac{Q}{2 \times \frac{3}{2} R} = \frac{Q}{3R}.$$

$$\therefore q = Q$$

$$\text{or, } n C_m \Delta T = Q$$

$$\text{or, } C_m = \frac{Q}{n \Delta T} = \frac{Q}{(Q/3R)} = \boxed{3R}$$