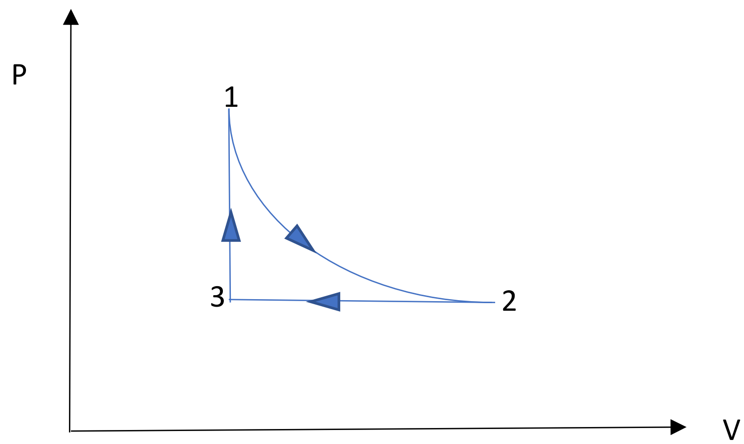
Example 1

2.8 grams of nitrogen gas at 6 atm and 160 ^oC in a frictionless piston-cylinder device undergoes polytropic expansion (n=2.0) due to heating until its volume becomes doubled. Then the gas is compressed at constant pressure to its initial volume followed by another compression at constant volume to its initial state. Calculate the net boundary work done on the gas. Draw the P-V diagram for the process.

Solution:



Number of Nitrogen moles $= \frac{2.8 g}{28\ g/mol}$

$= 0.1\ mol$

Initial volume, V_1 $\quad V_1 = \frac{nRT}{P}$

$V_1 = 6.0 \times 10^{-4} m^3$

Therefore, $\quad V_2 = 2V_1 =$
$12.0 \times 10^{-4} m^3$

For the polytrophic expansion

$$PV^n = constant$$

$$P_1 V_1^n = P_2 V_2^n$$

Hence

$$P_2 = P_1 \frac{V_1^n}{V_2^n}$$

$$P_2 = 1.5\ atm$$

Work done during the expansion process

$$W_{12} = \int_1^2 Pdv$$

For the polytrophic process

$$W_{12} = \frac{P_2V_2 - P_1V_1}{1-n}$$

$$W_{12} = 180\ J$$

Work done during the constant pressure compression process

$$W_{23} = \int_2^3 Pdv$$

$$W_{23} = P_2(V_3 - V_2)$$

$$W_{23} = -90\ J$$

Work done during the constant pressure compression process

$$W_{31} = \int_3^1 Pdv$$

$$W_{31} = 0\ J$$

Therefore, total work done

$$W = W_{12} + W_{23} + W_{31}$$

$$W = 90\ J$$

Note

Adiabatic Processes

In addition to the constant pressure (isobaric), constant volume (isochoric), constant temperature (isothermal) and polytrophic processes there is a special type called Adiabatic process. In an adiabatic process there is **no heat exchange between the system and the surrounding**. For an adiabatic process to happen, the system must be insulated properly.

$$\cancel{Q} - W = \Delta E$$

$$PV^{\Upsilon} = constant$$

$$\gamma = 1.667\ for\ monoatomic\ gases$$

$$\gamma = 1.4\ for\ diatomic\ gases$$

Example 2

During the charging of a storage battery, the current is 20A and the voltage is 12V. The rate of heat transfer from battery is 12W. Determine the net rate of increase in the internal energy of the battery

Solution

Rate of electrical work done on the battery,

$$W_E = VI = -240W\ ('-'sign\ for\ work\ done\ on\ the\ system)$$

Heat transfer from the battery to the surrounding

$$Q = -12W\ ('-'sign\ for\ heat\ transfer\ out\ from\ the\ system)$$

Apply First Law Equation

$$Q - W = \Delta E$$

$$-12W - (-240W) = \Delta E$$

Because this is a closed system,

$$\Delta E = \Delta U = change\ in\ internal\ energy\ of\ the\ system$$

$$\Delta U = 228W$$