14-1. In a reversible process the changes in the thermodynamic variables are carried out extremely slowly so that the system is in equilibrium at all intermediate points. One can therefore go both forward and backward. In an irreversible process which is the usual laboratory process the system is in equilibrium in only the initial and the final states. Once the process is carried out there is no way possible to return to the original state. Note that if we wish to represent a system by a point on the P-V diagram, the system must be in equilibrium. Hence the following picture:

14-3 For an adiabatic $PV^r$ constant. However, for a perfect gas

\[ PV = (\text{const}) \ T \]

So \[ PV \ V^{-1} = \text{Const} \]

Yields \[ TV^{-1} = \text{Const} \]


(1) Isotherm at $T_H$, pickup $DQ_H$

\[ DQ_H = R \ T_H \ln \frac{V_B}{V_A} \]

\[ \rightarrow (1) \]

(2) Adiabatic, $DQ = 0$, gas cools to $T_C$

\[ T_C \ V_C^{-1} = T_H \ V_B^{-1} \]

\[ \rightarrow (2) \]

(3) Isotherm at $T_C$, Reject $DQ_C$

\[ DQ_C = R \ T_C \ln \frac{V_B}{V_C} \]

\[ \rightarrow (3) \]

Note: $DQ_C$ is negative.
(4) Adiabatic, $DQ = 0$, gas warms to $T_H$

$$T_H \frac{V_A}{V_A} = T_C \frac{V_D}{V_D}$$

$\rightarrow (4)$

From (1) and (3)

$$\frac{DQ_H}{T_H} + \frac{DQ_C}{T_C} = R \ln \left( \frac{V_B V_D}{V_A V_C} \right)$$

From (3) and (4)

$$\frac{V_B}{V_A} \frac{V_D}{V_C} = 1, \ln 1 = 0$$

So

$$\frac{DQ_H}{T_H} + \frac{DQ_C}{T_C} = 0$$

14-7. $COP = \frac{298}{25} \approx 12$

$Q_H = 12$ K J

We have assumed that the Heat Pump is essentially a Carnot Cycle. Most actual pumps have COP’s around 5 or 6.