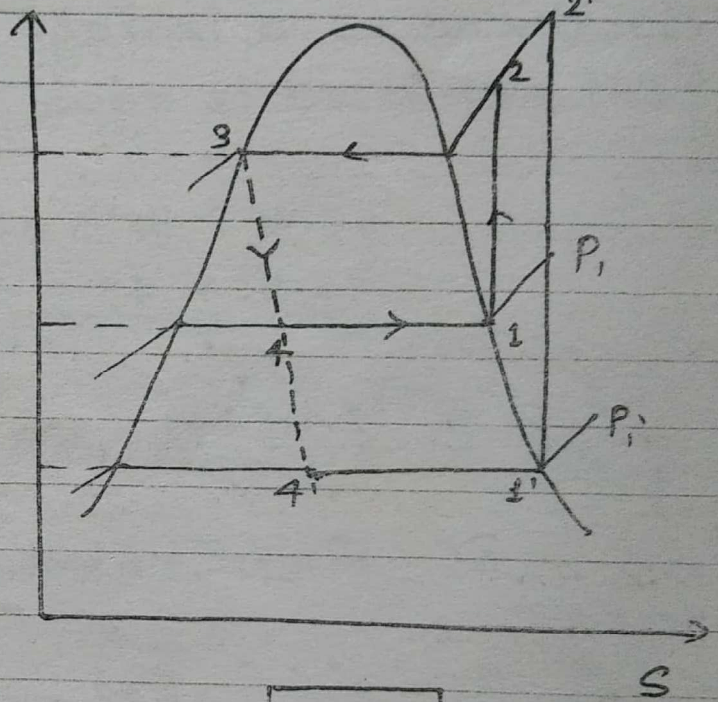
Cascade Refrigeration :- To produce very low temps. the corresponding evaporator pressure will also be low & this results in higher pressure ratios & due to this higher pressure ratio, the volumetric efficiency of compressor decreases & hence to avoid this Cascade Refrigeration system is used.

$$COP = \frac{Q_1}{W_1 + W_2}$$



$$COP_1 = \frac{Q_1}{W_1}$$

$$COP_2 = \frac{Q_2}{W_2}$$

S.T. $COP = \dfrac{COP_1 \times COP_2}{1 + COP_1 + COP_2}$

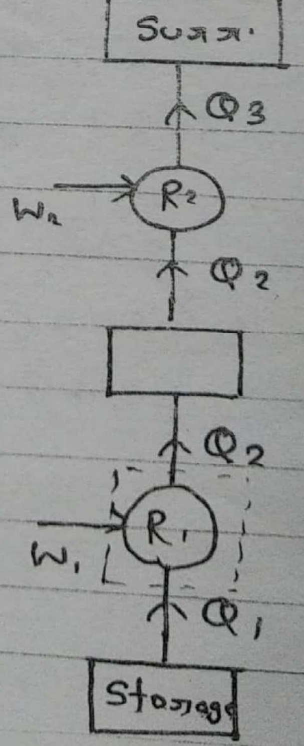
Solⁿ- $W_1 = \dfrac{Q_1}{COP_1}$

$$W_2 = \frac{Q_2}{COP_2}$$

$$COP = \frac{Q_1}{\frac{Q_1}{COP_1} + \frac{Q_2}{COP_2}}$$

$$COP = \frac{Q_1}{\frac{Q_1}{COP_1} + \frac{W_1}{COP_2} + \frac{Q_1}{COP_2}}$$

$$= \frac{Q_1}{\frac{Q_1}{COP_1} + \frac{Q_1}{COP_1 \times COP_2} + \frac{Q_1}{COP_2}}$$



$$W_1 + Q_1 = Q_2$$

$$COP = \frac{Q_1}{Q_1\left\{\frac{1}{COP_1} + \frac{1}{COP_1 \times COP_2} + \frac{1}{COP_2}\right\}}$$

$$COP = \frac{1}{\frac{COP_2 + 1 + COP_2}{COP_1 \times COP_2}}$$

$$* \left\{ COP = \frac{COP_1 \times COP_2}{1 + COP_1 + COP_2} \right\} *$$

Problm- A Cascade Refrigeration system of 100 capacity uses ammonia & CO_2. The evaporatin & condensing temps. of CO_2 are $-40°C$ & $5°C$ respectively & the evaporating temp. of NH_3 is $-7°C$. The power supplied to NH_3 compressor is 96.5 kW, in CO_2 cycle the refrigerant leaves the evaporator as saturated vapour & compressi is isentropic. Calculate mass flow rate of CO_2 refrigerant, COP of refrigeration system. Us the following data for CO_2 refrigerant.

t (°c)	P(bar)	h_f(kJ/kg)	h_g(kJ/kg)	S_f (kJ/kg-k)	S_g(...
-40	10.05	332.7	652.8	3.8531	5.2262
5	39.7	431	649.8	4.2231	5.003

$Cp_{vap.} = 0.85$ kJ/kg-k

Soln- RC = 100 TR

= 100 × 3.5 kW

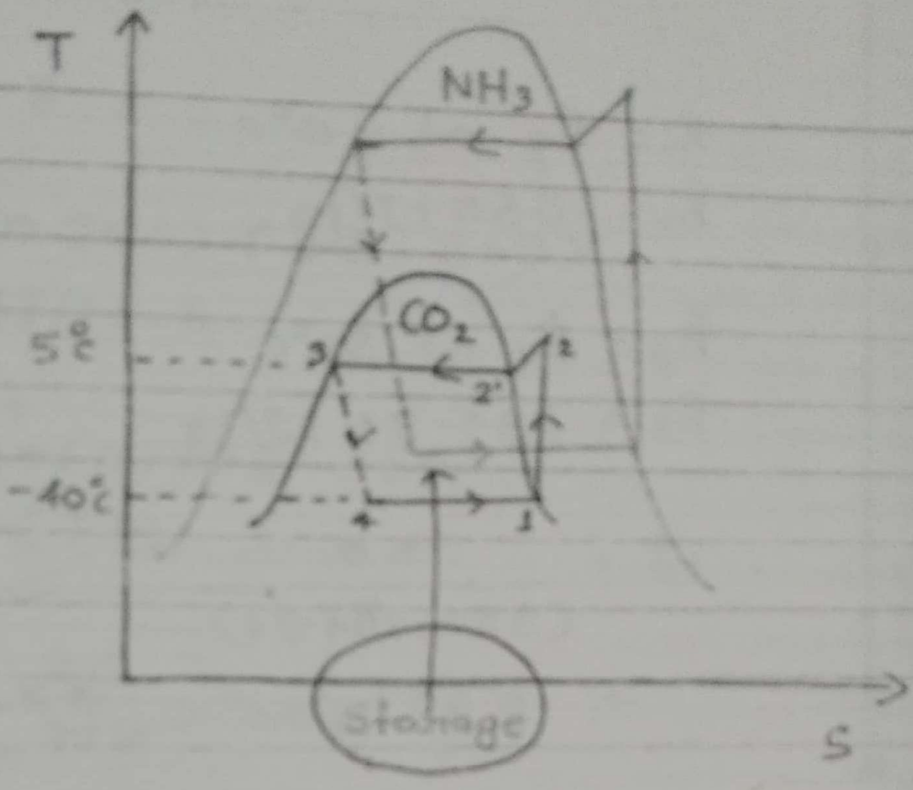
= 350 kW

CO_2 — 5°C, −40°C

$RC = \dot{m}(h_1 - h_3)$

$h_1 = h_g$ at $-40°C$

$h_1 = 652.8$



$$\dot{m} = \frac{RC}{(h_1 - h_3)}$$

$$= \frac{350}{(652.8 - 431)}$$

$$= 1.577\ kg/s$$

$$COP = \frac{RC}{P_{in}} = \frac{RC}{P_{CO_2} + P_{NH_3}}$$

$P_{CO_2} = \dot{m}_{CO_2}(h_2 - h_1)$

$h_1 = 652.8$

$h_2 = h_{2'} + Cp_{vap}(T_2 - T_{2'})$

$h_2 = 649.8 + 0.85(T_2 - 278)$

$S_1 = S_2 = 5.2262$

$S_2 = S_{2'} + Cp_v \ln \frac{T_2}{T_{2'}}$

$$5.2262 = 5.0087 + 0.85 \ln \frac{T_2}{278}$$

$T_2 = 361.18K$

$h_2 = 649.8 + 0.85(361.18 - 278)$

$h_2 = 720.5\ kJ/kg$

$P_{CO_2} = 1.577(720.5 - 652.8)$

$P_{CO_2} = 106.8\ kW$

$$COP = \frac{RC}{P_{CO_2} + P_{NH_3}}$$

$$= \frac{350}{106.8 + 96.5}$$

$= 1.72$ Ans.