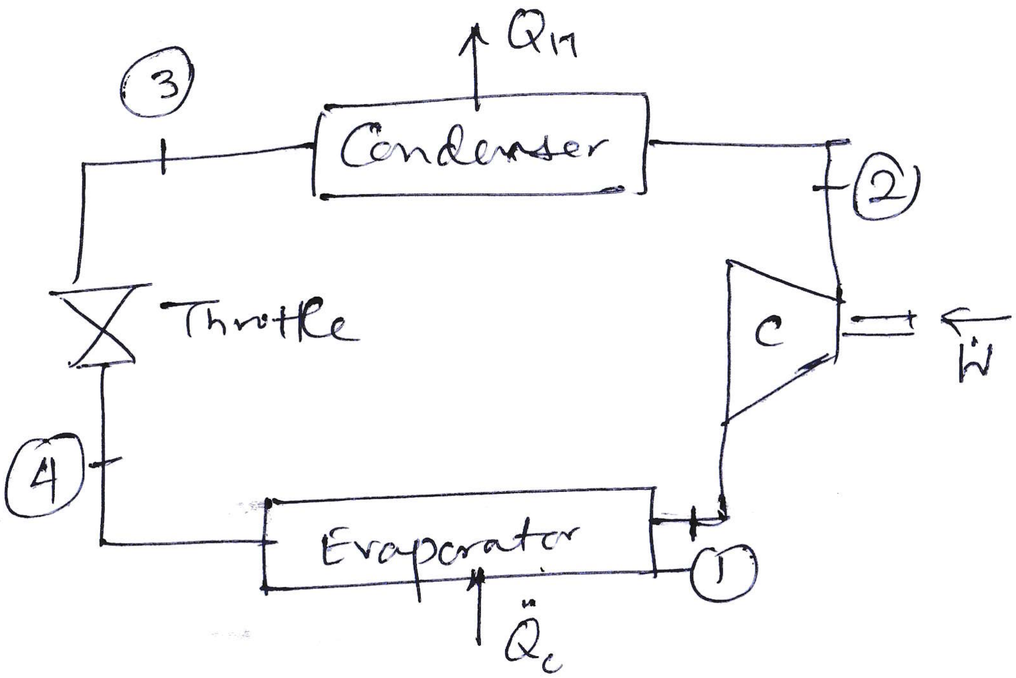
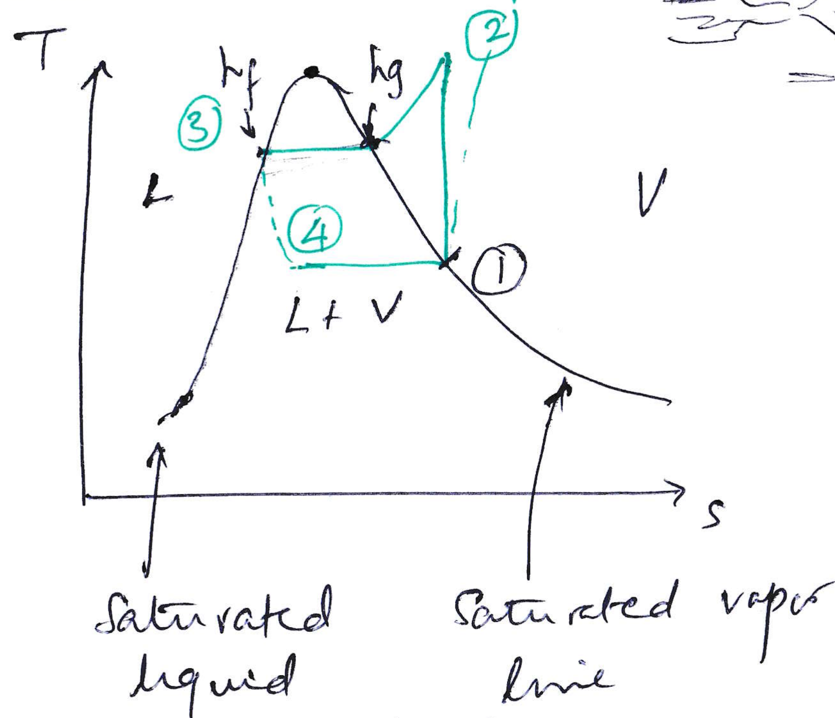
Vapor Compression Refrigeration cycle





$1 \to 2$: Isentropic compression $w = h_2 - h_1$

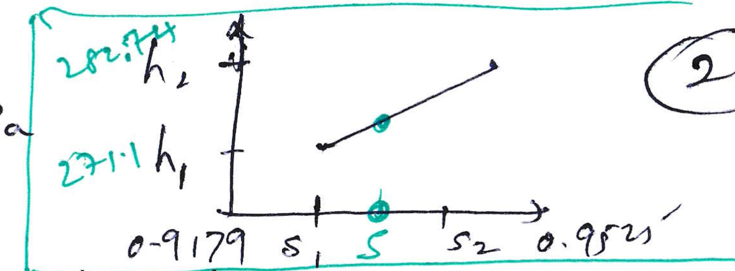
$2 \to 3$: Constant pressure heat rejection $q_h = h_2 - h_3$

$3 \to 4$ Constant enthalpy $h_3 = h_4$

$4 \to 1$ Constant pressure heat addition. $q_c = h_1 - h_4$

1 bar = 100 kPa

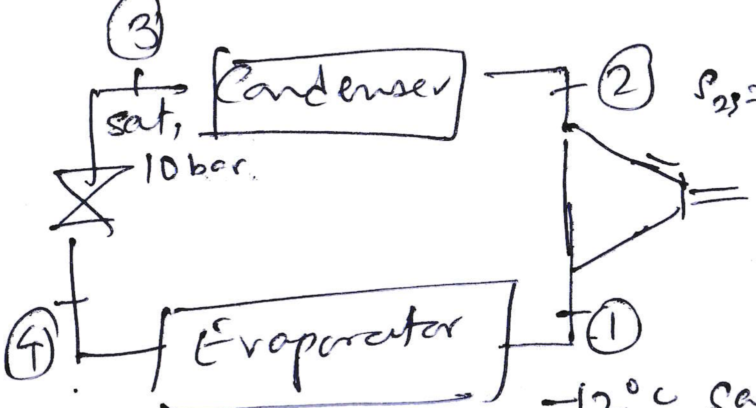
10 bar = 1000 kPa = 1 MPa



R-134a is used as refrigerant for a 2 ton refrigeration system. Saturated vapor leaves the evaporator at -12C. Saturated liquid exits the condenser at 10 bar. The isentropic efficiency of the compressor is 90%. Determine 1) the mass of refrigerant 2) Power required to run the compressor 3) Coefficient of performance 4) Entropy generated in the compressor.

$\dot{Q}_c = 2 \text{ tons} = 7 \text{ kW}$

1 ton of refrigeration $\equiv 3.5$ kW



$s_{2s} = 0.93911$ kJ/kg K

-12°C, sat

$h_1 = 243.3$ kJ/kg

$s = 0.93911$ kJ/kg K

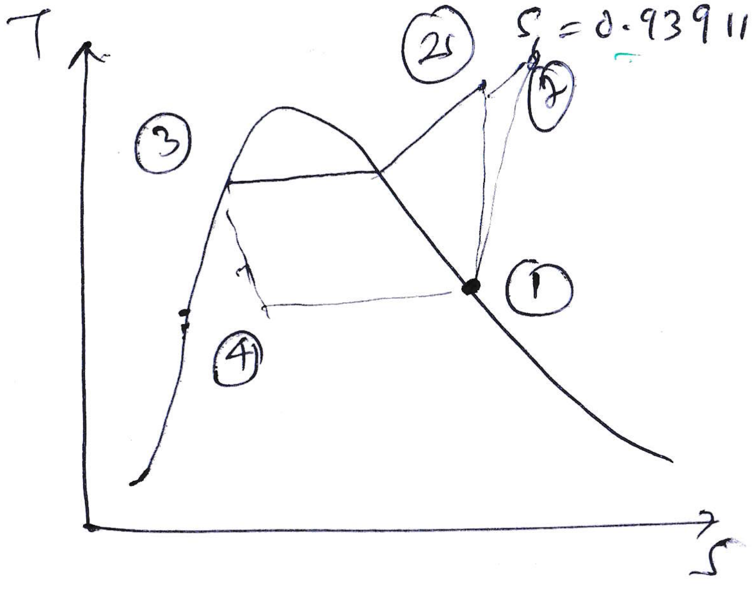
State 2 : $h_{2s} = \left(\dfrac{0.93911 - 0.9179}{\cancel{0.93911}\ 0.9525 - 0.9179}\right)\left(282.74 - 271.71\right) + 271.71$

$= 278.47$ kJ/kg

$\eta = \dfrac{h_{2s} - h_1}{h_2 - h_1} \Rightarrow 0.9 = \dfrac{278.47 - 243.3}{h_2 - 243.3}$

$\Rightarrow h_2 = 282.4$ kJ/kg

$s_2 \simeq 0.9525$ kJ/kg K



State 3 $p = 10$ bar, sat $h_3 = 107.32$ kJ/kg K

$s_3 = 0.39189$

State 4 $h_4 = h_3 = 107.32$ kJ/kg K;

At -12°.

At $-12°C$, $h_f = 35.92$ kJ/kg $h_g = 243.3$ kJ/kg.

Liquid   Vapor

$h_f = 35.92$ $h = 107.32$ $h_g = 243.3$ kJ/kg

Let x denote the quantity of vapor
(x = condition, quality)

$$h_4 = (1-x)h_f + x\,h_g \Rightarrow x = \frac{h - h_f}{h_g - h_f} = \frac{107.32 - 35.92}{243.3 - 35.92} = 0.344$$

$$s_4 = (1-x)s_f + x\,s_g \Rightarrow s_4 = (1-0.344)\,0.14504 + (0.344)(0.93911)$$
$$= 0.4182 \text{ kJ/kg K}$$

1) $\dot{Q}_c = \dot{m}(h_1 - h_4) \Rightarrow 7\text{ kW} = \dot{m}(243.3 - 107.32) \Rightarrow \boxed{\dot{m} = 0.0515 \text{ kg/s}}$

(2) $\dot{W} = \dot{m}(h_2 - h_1) = (0.0515)(282.4 - 243.3) = \boxed{2.013 \text{ kW}}$

(3) $COP = \dfrac{\dot{Q}_c}{\dot{W}} = \dfrac{7}{2.013} = 3.48$

(4) $\Delta\dot{S}_{compressor} = \dot{m}(s_2 - s_1) = (0.0515)(0.9525 - 0.93911)$
$= 6.9 \times 10^{-4}$ kW/K

$\Delta\dot{S}_{throttle} = \dot{m}(s_4 - s_3) = (0.0515)(0.4182 - 0.39189) = 1.35 \times 10^{-3}$ kW/K.