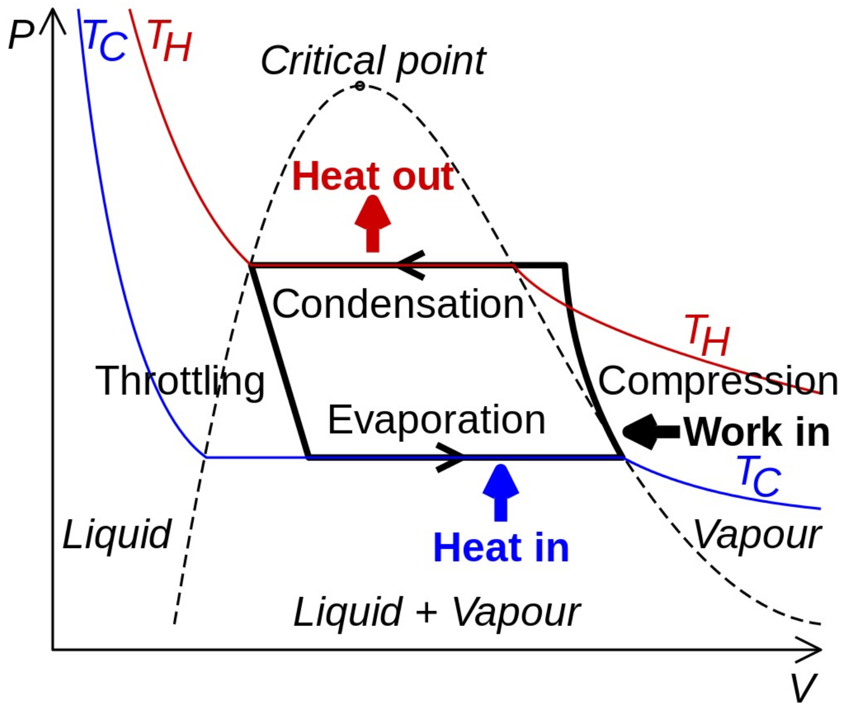
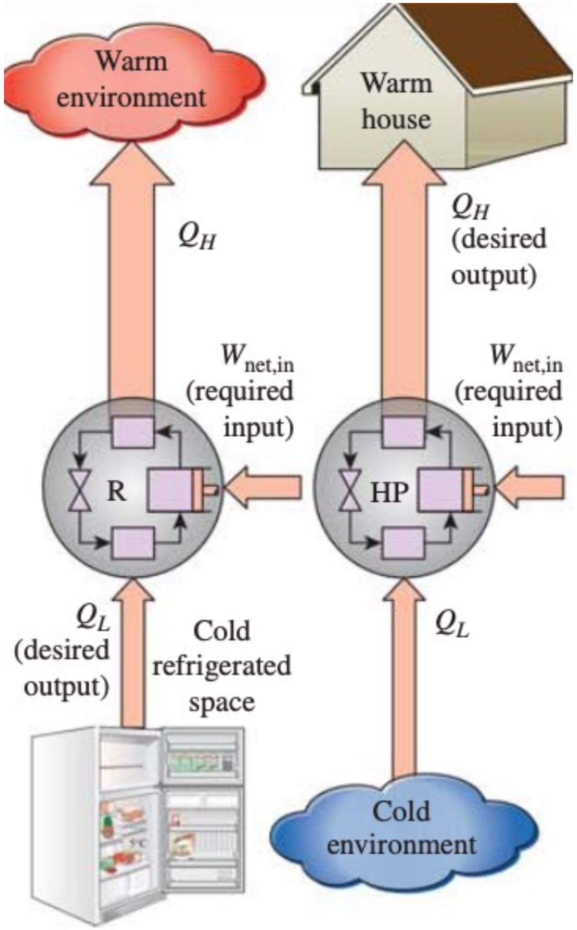
Chemical Engineering Thermodynamics

Lecture 7 Refrigeration Cycles

Xiaofei Xu



Refrigerators and Heat Pumps

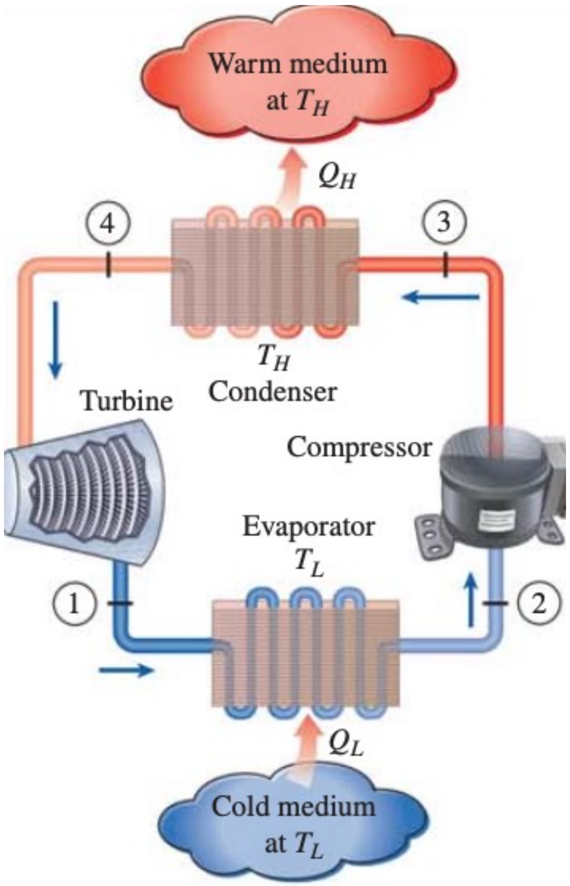


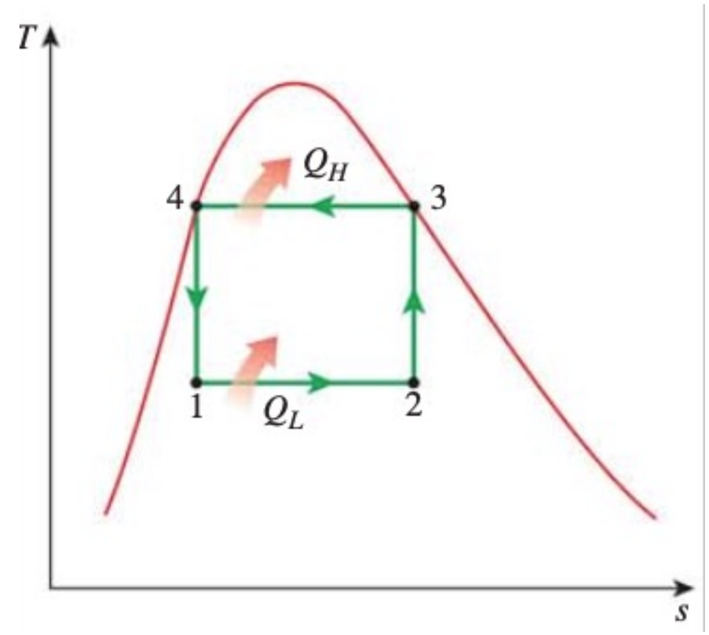
(*a*) Refrigerator (*b*) Heat pump

$$COP_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Cooling effect}}{\text{Work input}} = \frac{Q_L}{W_{net,in}}$$

$$COP_{HP} = \frac{\text{Desired output}}{\text{Required input}} = \frac{\text{Heating effect}}{\text{Work input}} = \frac{Q_H}{W_{net,in}}$$

The Reversed Carnot Cycle





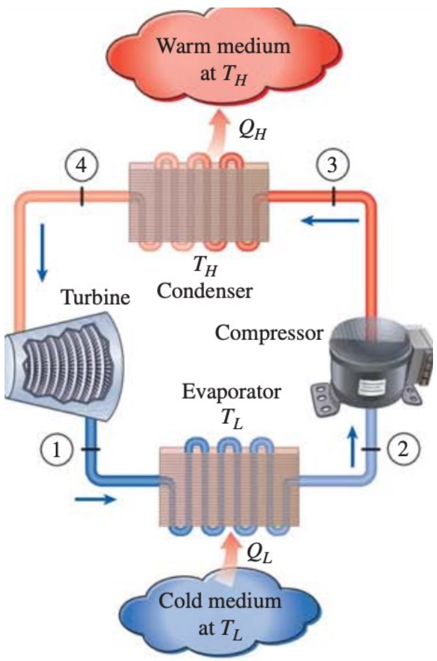
COP of Reversed Carnot Cycle

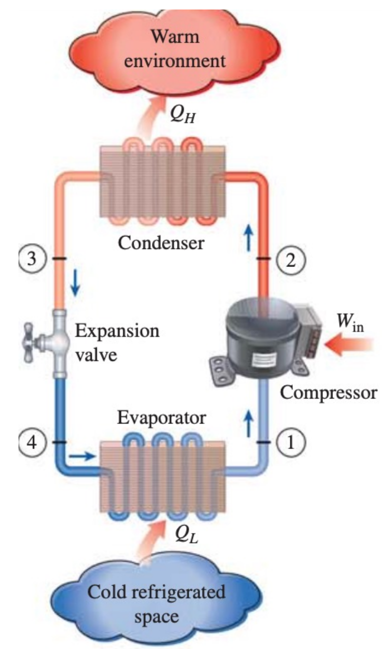
$$\mathrm{COP}_{\mathrm{R,Carnot}} = \frac{1}{\frac{T_H}{T_L} - 1}$$

$$\mathrm{COP}_{\mathrm{HP,Carnot}} = \frac{1}{1 - \frac{T_L}{T_H}}$$

The Ideal Vapor-Compression Refrigeration Cycle

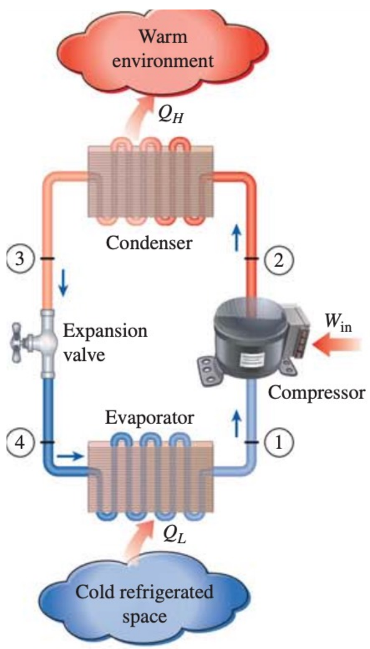
- The most widely used cycle for refrigerators and air-conditioning systems
- Replacing the turbine with a throttling device

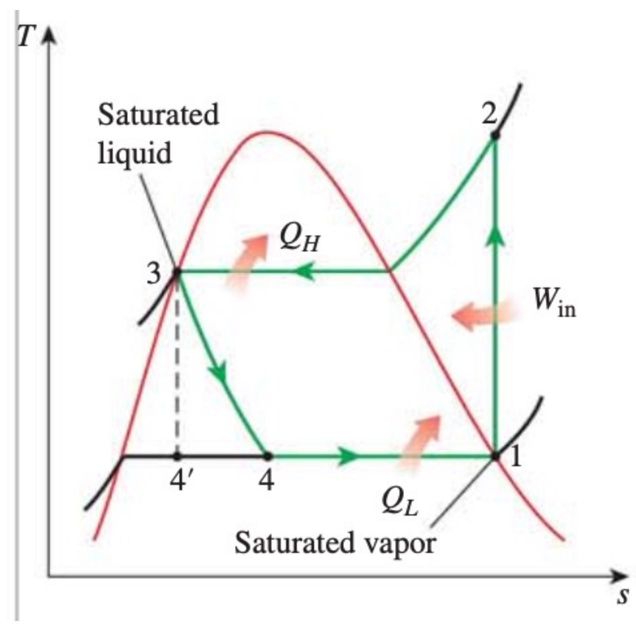




The Ideal Vapor-Compression Refrigeration Cycle

- 1-2: Isentropic compression
- 2-3: Constant-pressure heat rejection in a condenser
- 3-4: Throttling in an expansion device
- 4-1: Constant-pressure heat absorption in an evaporator





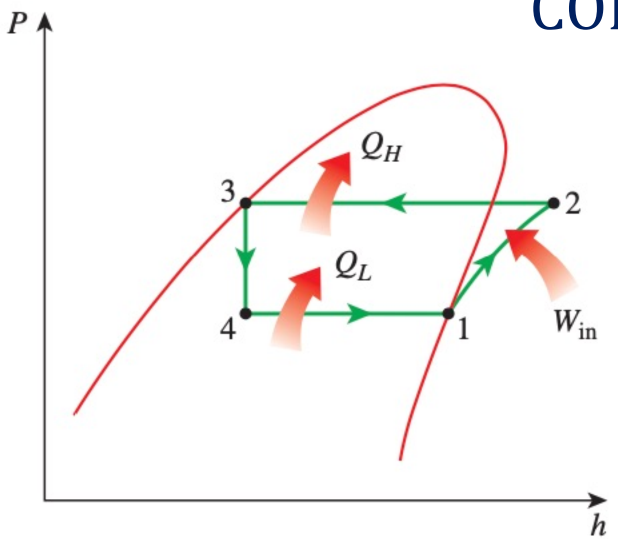
The Ideal Vapor-Compression Refrigeration Cycle

Energy balance

$$(q_{in} - q_{out}) + (w_{in} - w_{out}) = h_{exit} - h_{inlet}$$

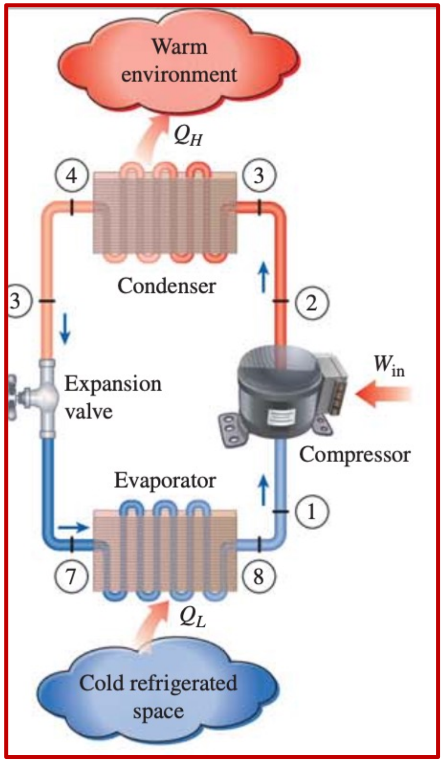
$$\mathrm{COP_R} = \frac{q_L}{w_{\mathrm{net,in}}} = \frac{h_1 - h_4}{h_2 - h_1}$$

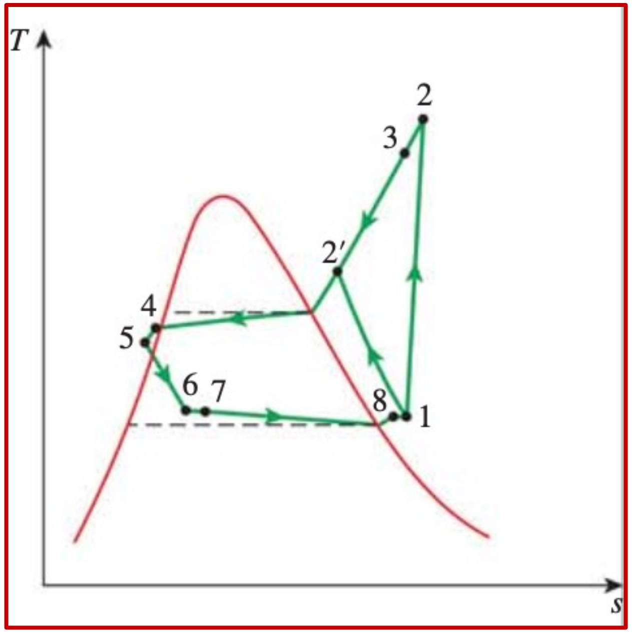
$$\mathrm{COP_{HP}} = \frac{q_H}{w_{\mathrm{net,in}}} = \frac{h_2 - h_3}{h_2 - h_1}$$



Actual Vapor-Compression Refrigeration Cycle

- state 1: slight superheated
- 2





Refrigerator

https://www.youtube.com/watch?v=nVTdukNJdtM

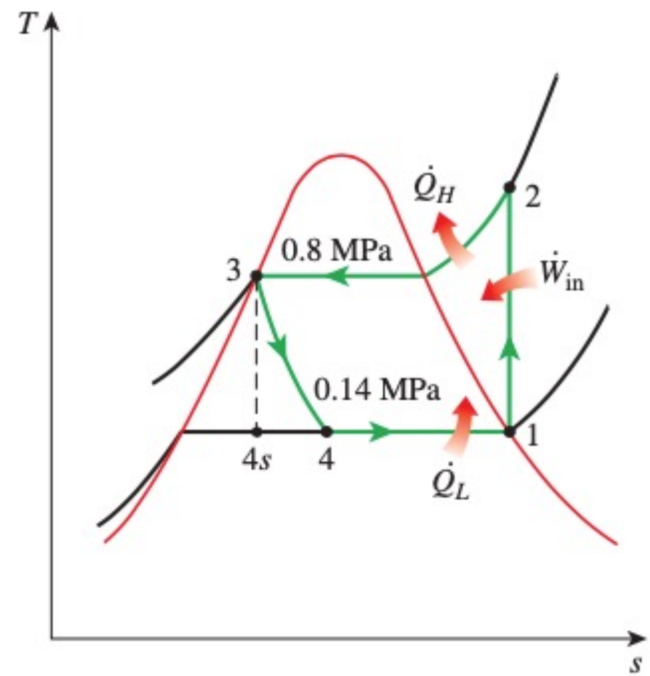
Oliver Evans

1755-1819

1844

Example

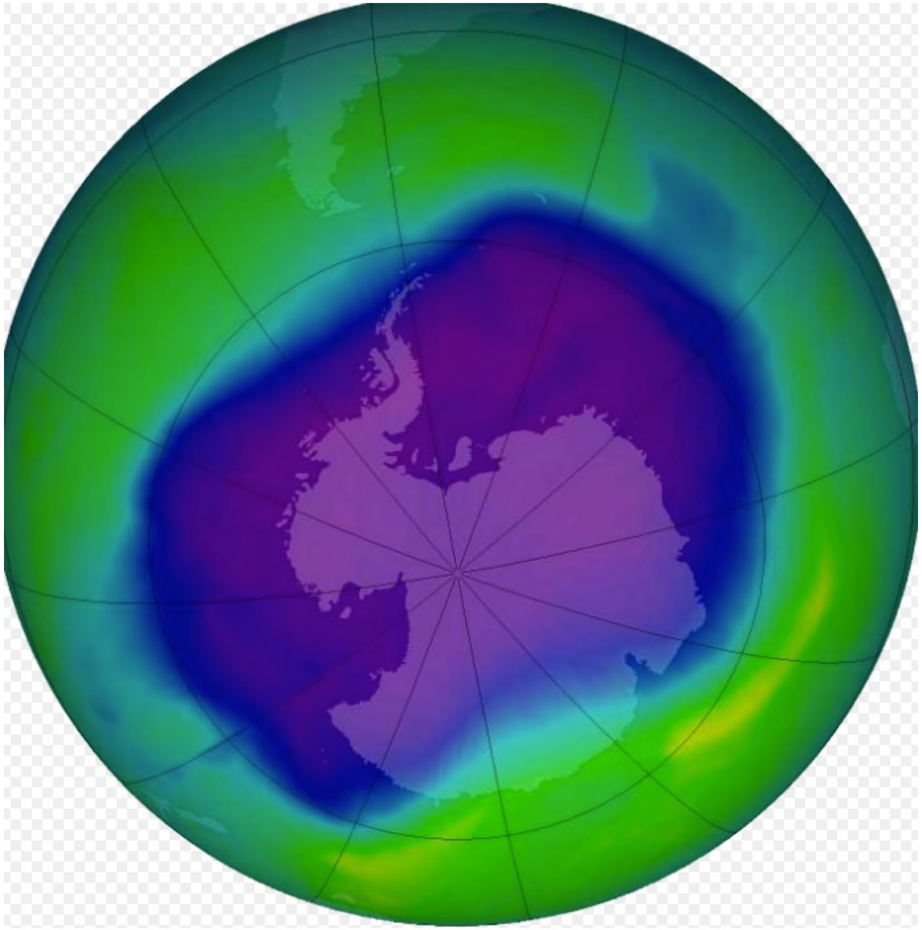
A refrigerator uses refrigerant-134a as the working fluid and operates on an ideal vapor-compression refrigeration cycle between 0.14 and 0.8 MPa. If the mass flow rate of the refrigerant is 0.05 kg/s, determine (*a*) the rate of heat removal from the refrigerated space and the power input to the compressor, (*b*) the rate of heat rejection to the environment, and (*c*) the COP of the refrigerator.



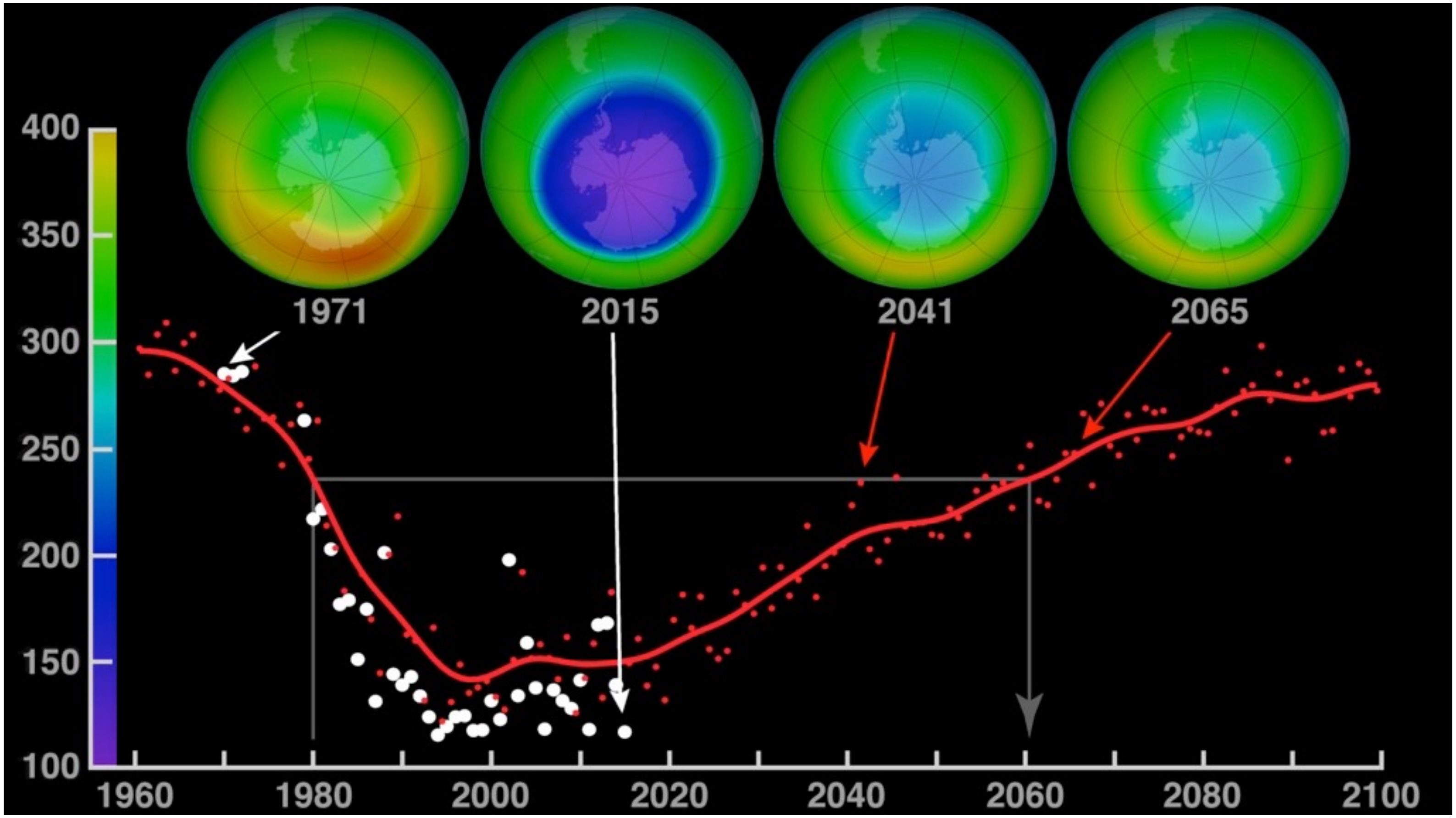
The Choice of Refrigerant

- The COP of Carnot refrigerator is independent of the refrigerant
- Irreversibility
- Toxicity, flammability, cost, corrosion properties, vapor pressure, environmental concerns

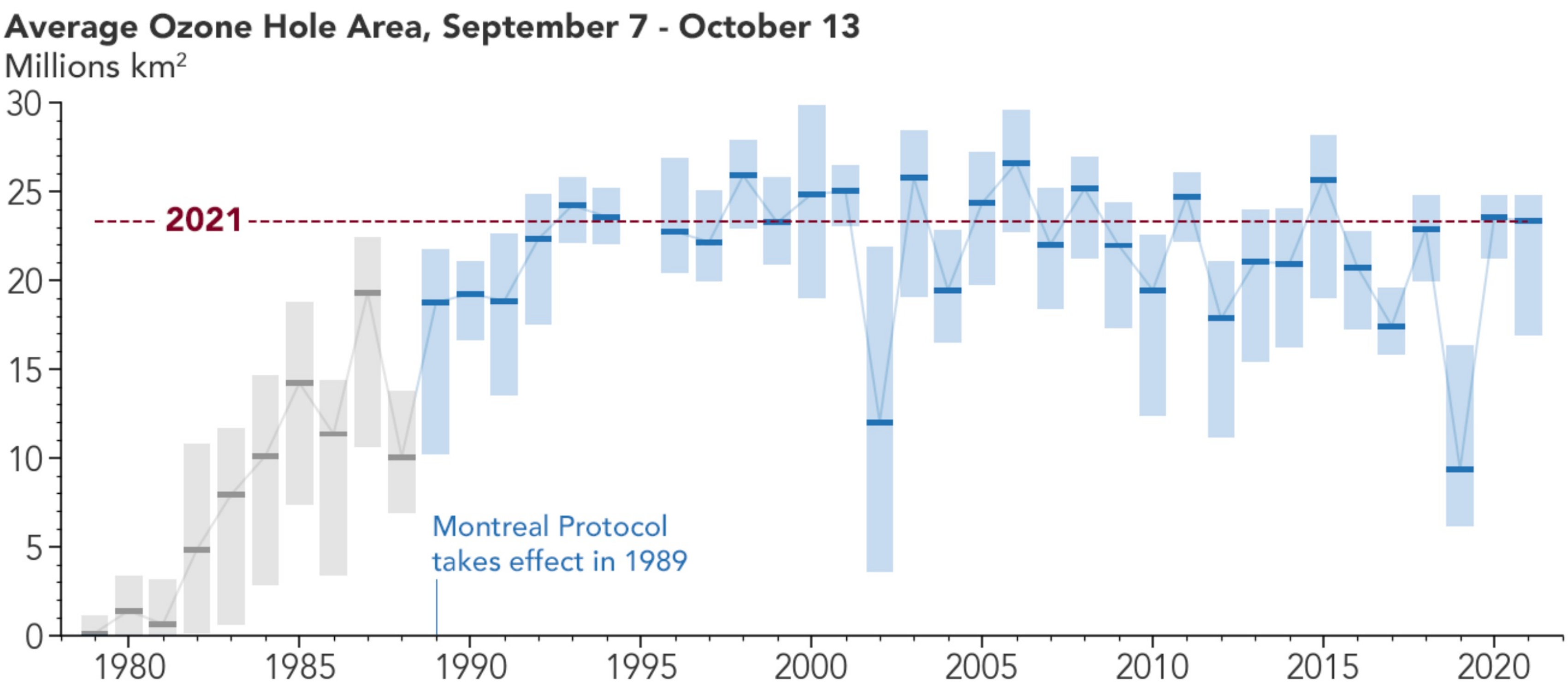
Ozone Depletion



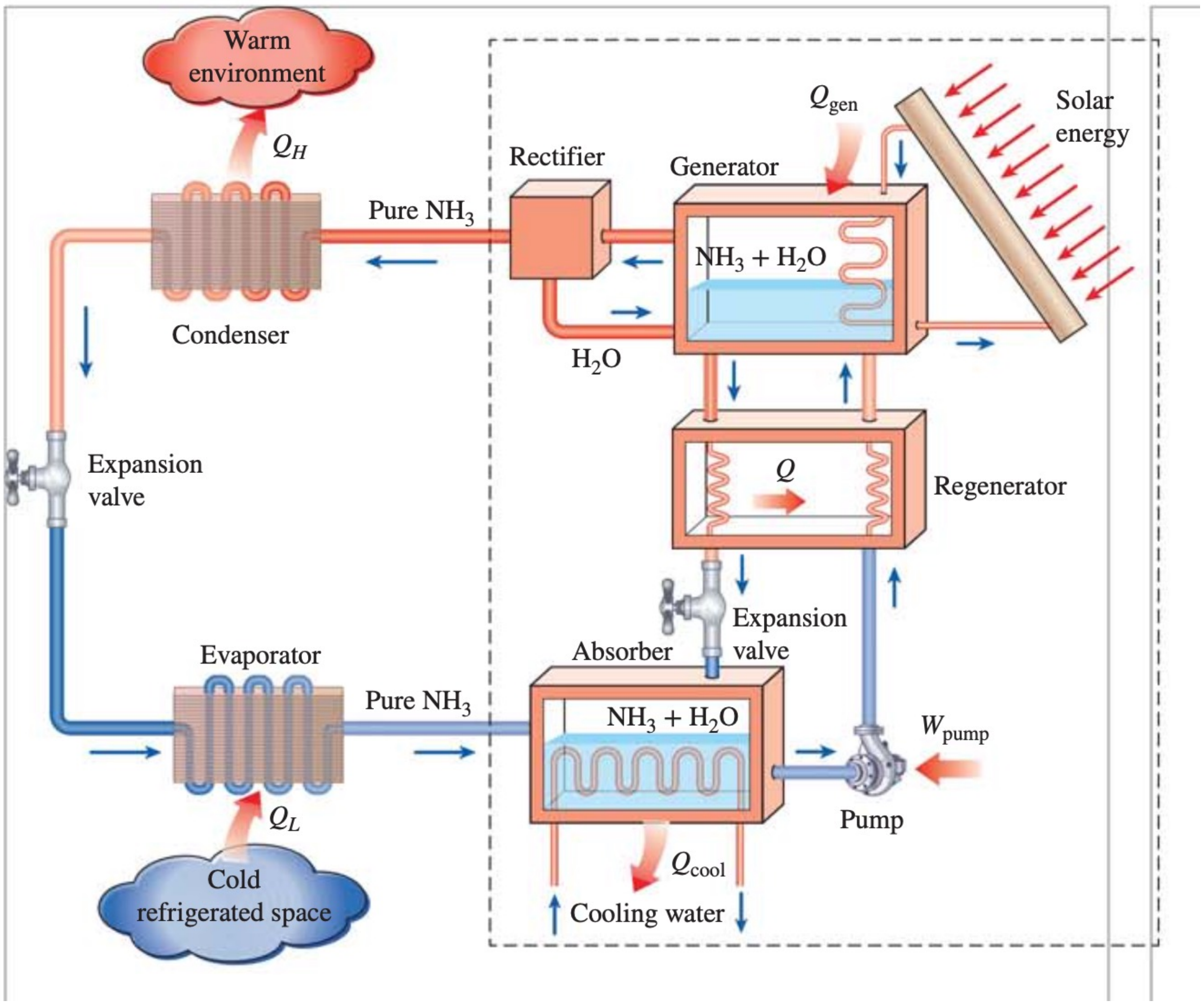
Ozone Depletion



Ozone Depletion



Absorption Refrigerator



Summary Points

- Reversed Carnot cycle
- Ideal vapor-compression refrigeration cycle
- Absorption refrigerator