Eingengin ferli - irreversible processes, jafngengin ferli - reversible processes

$\Delta W = 0$

Kjörgas, $V \to 2V$, $pV = nRT \to p = p_0/2$, $\Delta E_{int} = 0$, $\Delta Q = 0$

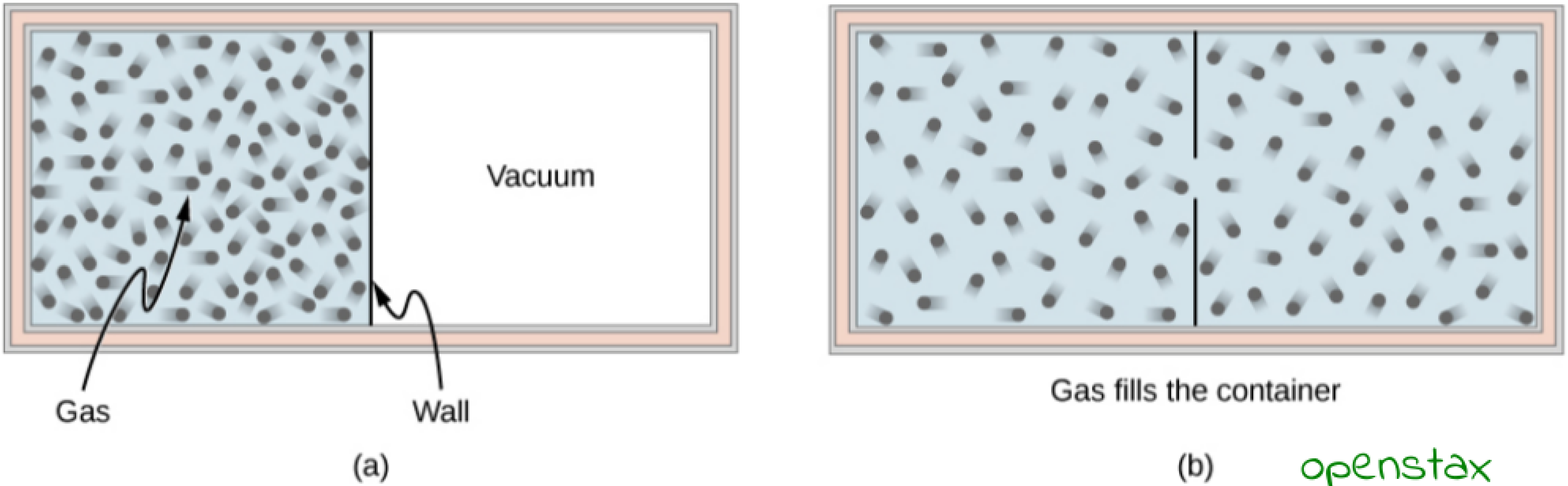

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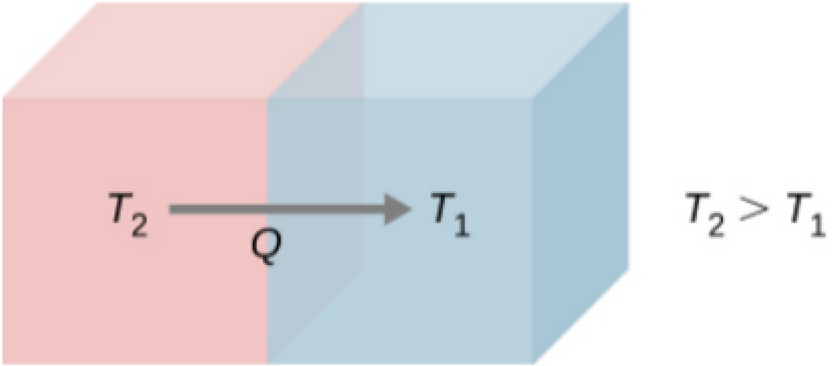
Figure 4.2 A gas expanding from half of a container to the entire container (a) before and (b) after the wall in the middle is removed.

Eingengt ferli, "ólíklegt" er að kerfið komist sjálfkrafa í upphafsástandið (vissulega er hægt að koma því með vinnu í upphafsástandið)



Spontaneous heat flow from an object at higher temperature T_2 to another at lower temperature T_1

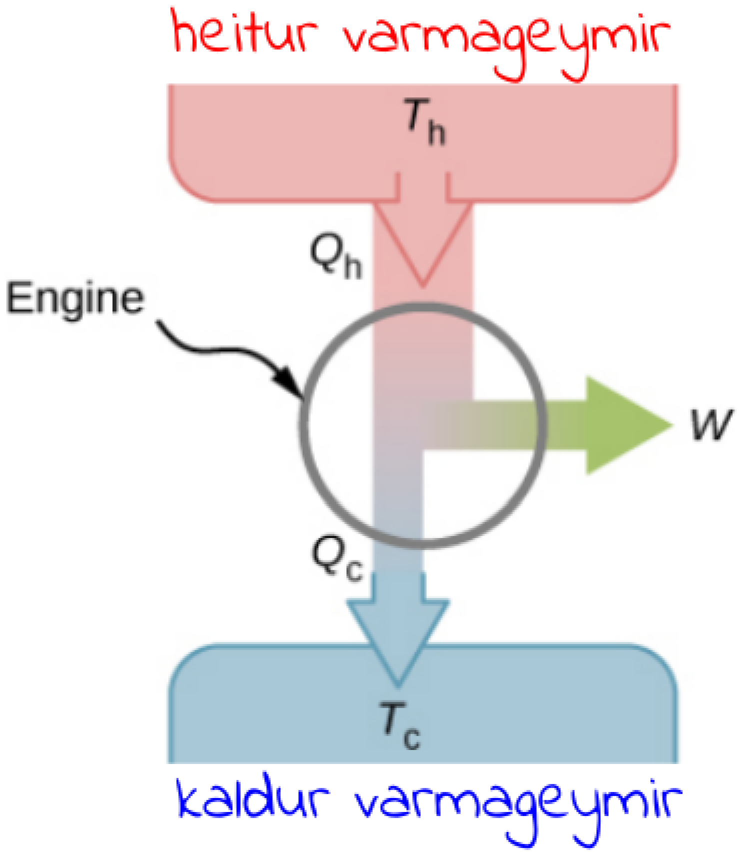
Second Law of Thermodynamics (Clausius statement)

Heat never flows spontaneously from a colder object to a hotter object.

Reynslulögmál - tilraunaniðurstaða

Safneðlisfræði: ákaflega ákaflega ákaflega ólíklegt miðað við aldur alheimsins

Varmavélar



Einn hringur: $\Delta E_{int} = 0$

$$\boxed{W = Q - \Delta E_{int}} = (Q_h - Q_c) - 0$$

$$\boxed{= Q_h - Q_c}$$

Nýttni - efficiency: $\boxed{e = \frac{W}{Q_h} = 1 - \frac{Q_c}{Q_h}}$

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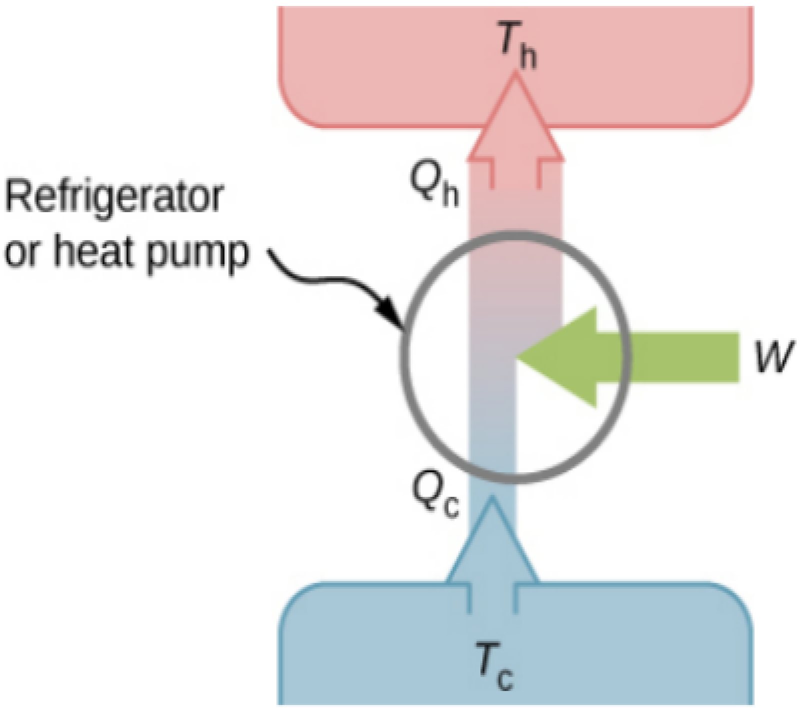
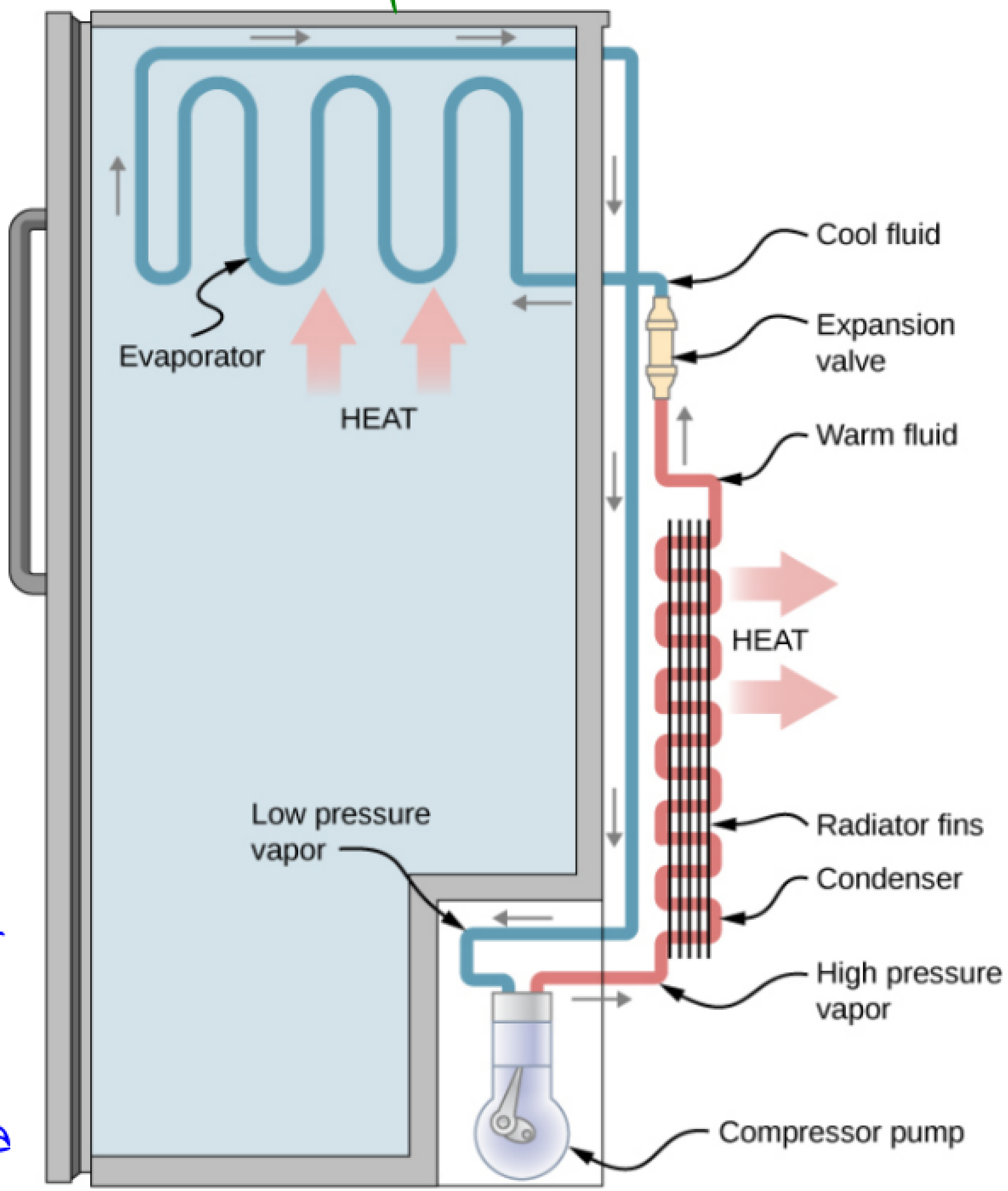
Kælivélar





Afkastageta

$$K_R = \frac{Q_c}{W} = \frac{Q_c}{Q_h - Q_c}$$ kælir

$$K_P = \frac{Q_h}{W} = \frac{Q_h}{Q_h - Q_c}$$ dæla

2. lögmálið á öðrum ham

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Second Law of Thermodynamics (Kelvin statement)

It is impossible to convert the heat from a single source into work without any other effect.

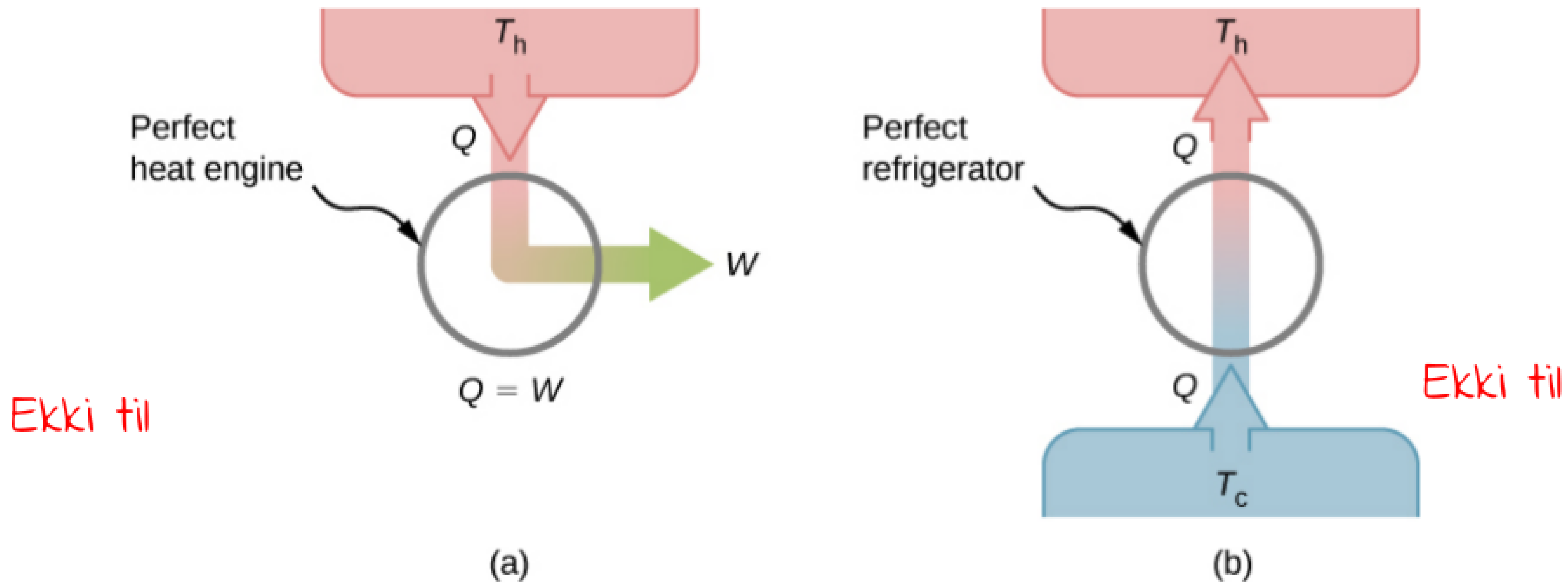

Figure 4.8 (a) A "perfect heat engine" converts all input heat into work. (b) A "perfect refrigerator" transports heat from a cold reservoir to a hot reservoir without work input. Neither of these devices is achievable in reality.

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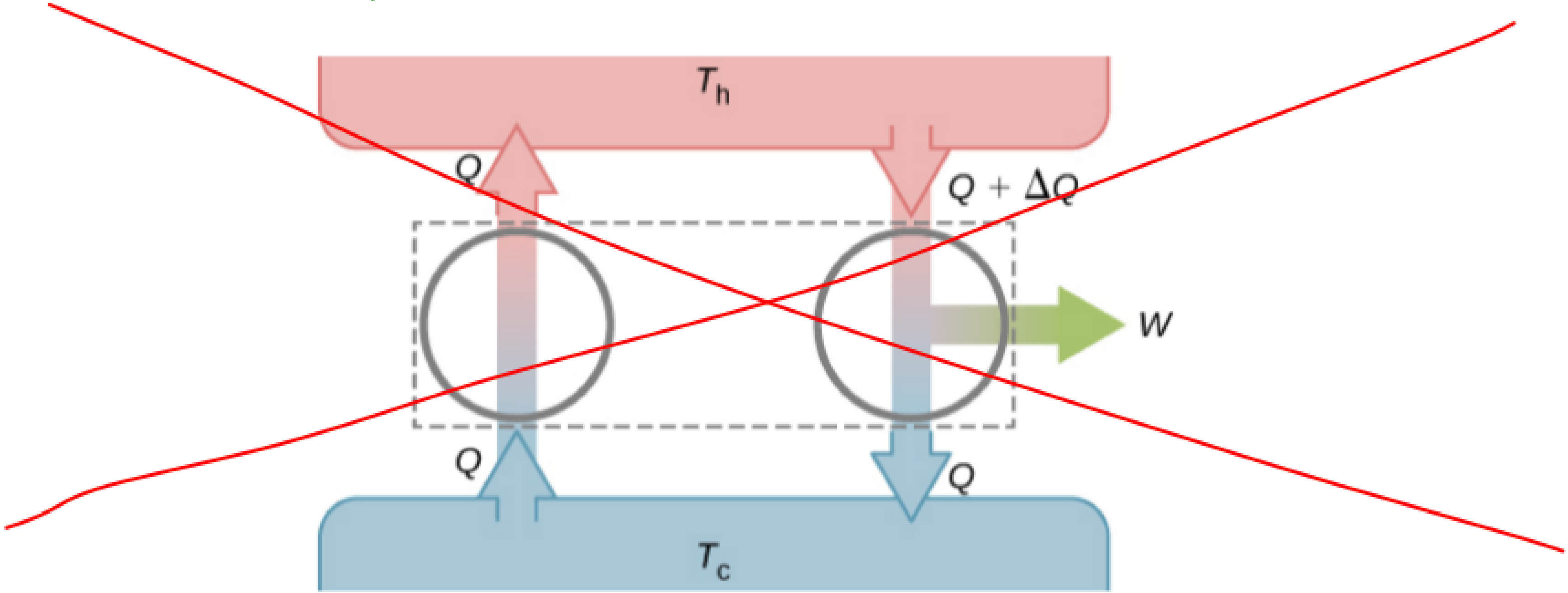

Combining a perfect refrigerator and a real heat engine yields a perfect heat engine because $W = \Delta Q$.

Skoðum

any reversible engine operating between two reservoirs
has a greater efficiency than any irreversible engine operating between the
same two reservoirs

all reversible engines operating between the same two reservoirs have
the same efficiency

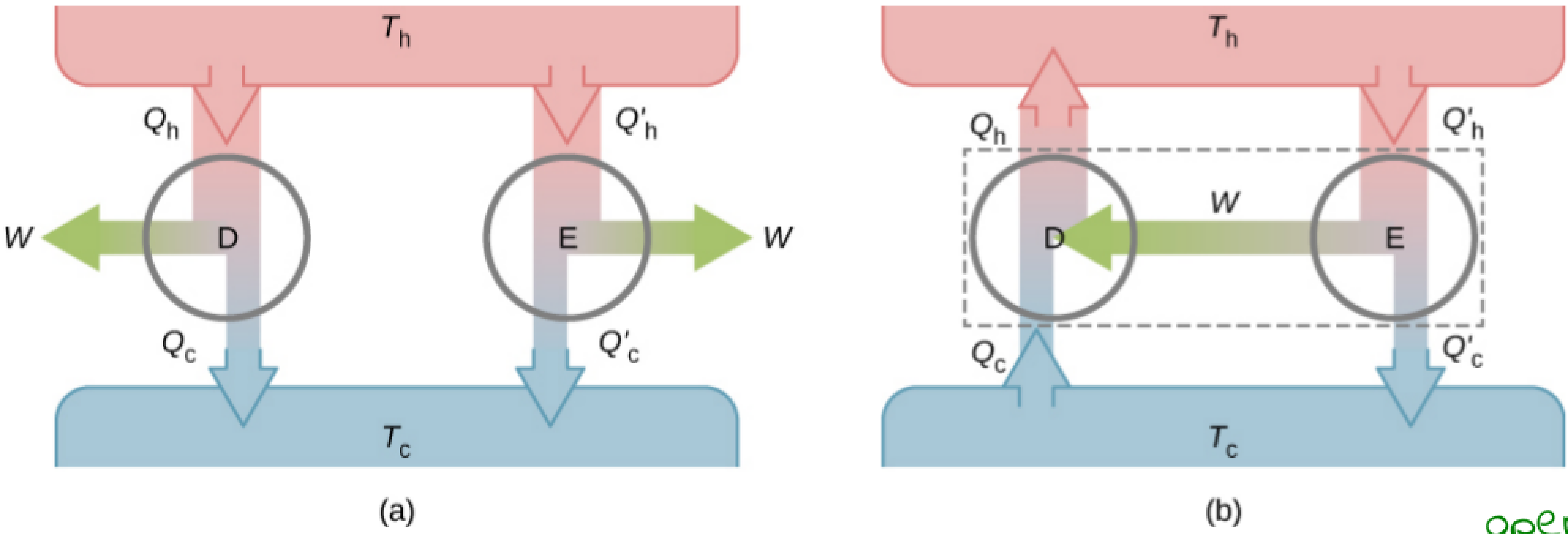

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Figure 4.10 (a) Two uncoupled engines D and E working between the same reservoirs. (b) The coupled engines, with D working in reverse.

* Ef D er jafngeng, E er eingeng með $e_E > e_D$, og
$W_D = W_E = W$ → $Q_h > Q'_h$, 1. Lögmál → $Q_c > Q'_c$.

$$\boxed{e = 1 - \frac{Q_c}{Q_h}}$$

Snúum við D og tengjum → (b), en
$Q_h > Q'_h$ og $Q_c > Q'_c$ → varmi fluttur úr $c \to h$,
ekki mögulegt → $e_{irr} > e_{rev}$ ekki hægt

* Ef báðar jafngengar fæst á sama hátt að $e_D = e_E$

Hringur Carnots

Jafngengt ferli, hæsta mögulega nýtni

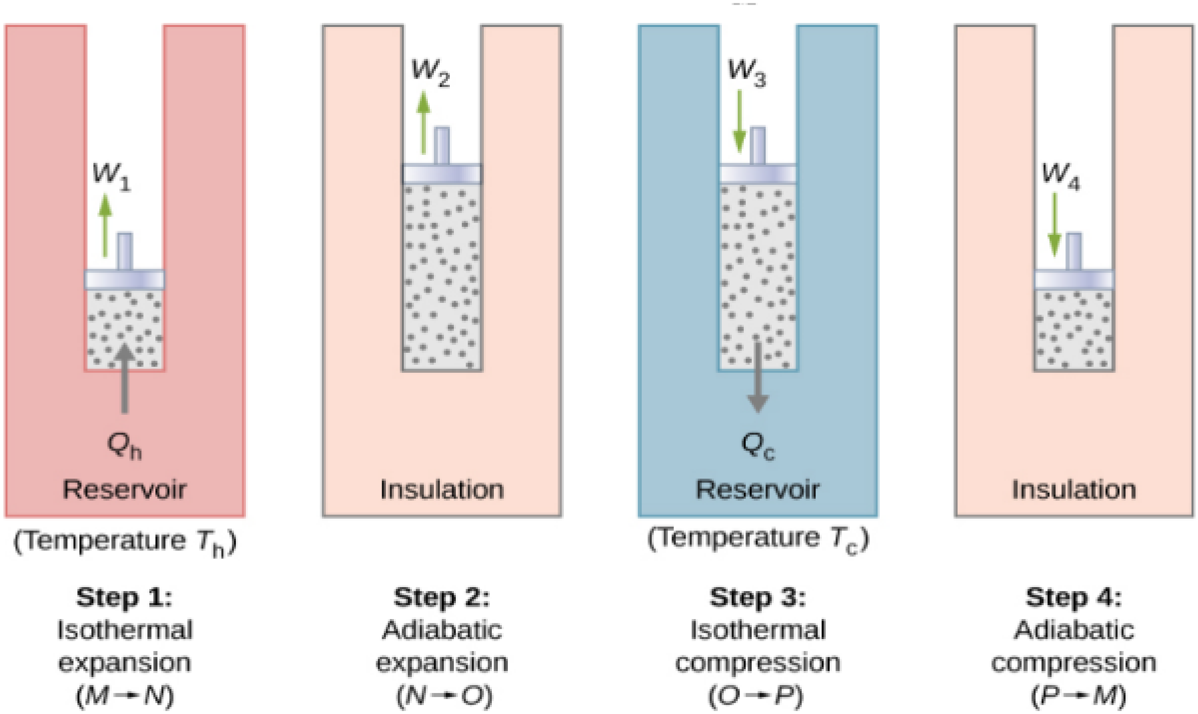

Figure 4.11 The four processes of the Carnot cycle. The working substance is assumed to be an ideal gas whose thermodynamic path *MNOP* is represented in Figure 4.12.

1. Kjörgas, jafnhita

$$\to \Delta E_{int} = 0$$

$$Q_h = W_1 = nRT_h \ln\left(\frac{V_N}{V_M}\right)$$

2. Óvermið

$$T_h V_N^{\gamma-1} = T_c V_O^{\gamma-1}$$

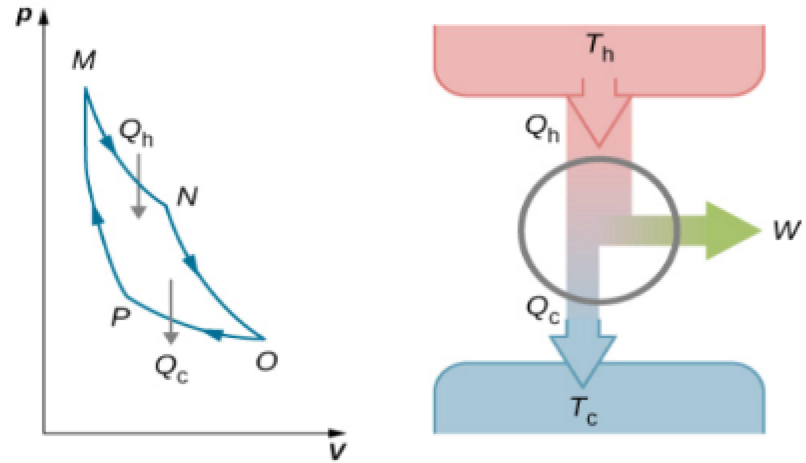

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Figure 4.12 The total work done by the gas in the Carnot cycle is shown and given by the area enclosed by the loop *MNOPM*.

3 Jafnhita

$$Q_c = nRT_c \ln\left(\frac{V_o}{V_p}\right)$$

4 Óvermið

$$T_c V_p^{\gamma-1} = T_h V_M^{\gamma-1}$$

$$\frac{Q_c}{Q_h} = \frac{T_c \ln\left(\frac{V_o}{V_p}\right)}{T_h \ln\left(\frac{V_N}{V_M}\right)}$$

og 2 og 4 $\rightarrow \frac{V_o}{V_p} = \frac{V_N}{V_M}$

$$\rightarrow \frac{Q_c}{Q_h} = \frac{T_c}{T_h}$$

$$\rightarrow \boxed{e = 1 - \frac{T_c}{T_h}}$$

Heildarvinna

$$W = W_1 + W_2 - W_3 - W_4$$

er ferillinn í pV-ritinu hringur $\rightarrow \Delta E_{int} = 0$

$$\boxed{W} = Q - \Delta E_{int} = \{Q_h - Q_c\} - \Delta E_{int}$$

$$= \boxed{Q_h - Q_c}$$

Fyrir Carnot kælivél og varmadælu fæst á sama hátt

$$\boxed{K_R = \frac{T_c}{T_h - T_c} \,, \qquad K_P = \frac{T_h}{T_h - T_c}}$$

Carnot's Principle

No engine working between two reservoirs at constant temperatures can have a greater efficiency than a reversible engine.

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Óreiða - entropy

Byrjum með jafngengt ferli við fast hitastig og skilgreinum

$$\boxed{\Delta S = \frac{Q}{T}}$$

Ef ferlið er ekki við fast T

$$\Delta S = S_B - S_A = \int_A^B \frac{dQ}{T}$$

Fyrir hring Carnots fæst

$$\Delta S = \Delta S_1 + \Delta S_2 + \Delta S_3 + \Delta S_4 = \frac{Q_h}{T_h} - \frac{Q_c}{T_c}$$

en fyrir hring Carnots gildir líka

$$\frac{Q_h}{T_h} = \frac{Q_c}{T_c} \rightarrow \Delta S = 0$$

Almennt fyrir jafngengt hringferli gildir

$$\boxed{\oint dS = \oint \frac{dQ}{T} = 0}$$

Second Law of Thermodynamics (Entropy statement)

The entropy of a closed system and the entire universe never decreases.

$\Delta S \geq 0$

3. lögmál varmafræðinnar (þarf skammtafræði)

$$\boxed{\lim_{T \to 0} \left(\Delta S\right)_T = 0}$$

Safneðlisfræði setur varmafræðinni grunn

$$\boxed{S = k_B \ln \Omega}$$

Ex. 4.8

óvermin

frjáls þensla

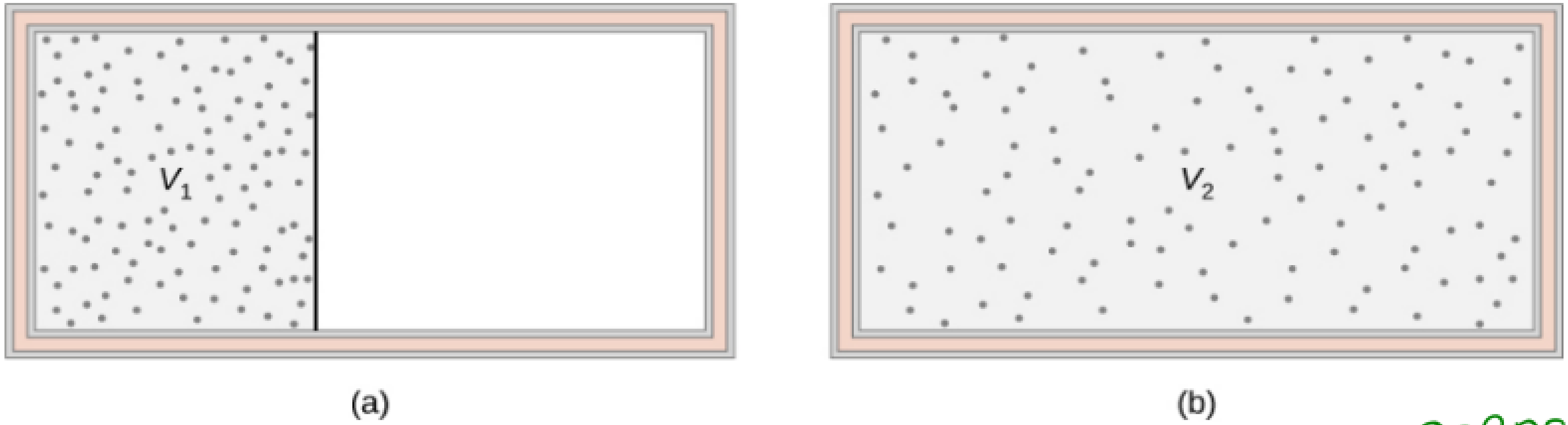

Figure 4.18 The adiabatic free expansion of an ideal gas from volume V_1 to volume V_2.

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kjörgas

$$\Delta T = 0 \rightarrow \Delta S = \frac{\Delta Q}{T}, \quad \Delta E_{int} = 0$$

$$Q = W = \int_{V_1}^{V_2} p\,dV = nRT \int_{V_1}^{V_2} \frac{dV}{V} = nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$\rightarrow \Delta S = \frac{\Delta Q}{T} = nR \ln\left(\frac{V_2}{V_1}\right) \geq 0$$

eingengt ferli