1

Varmafræði

Sígild stórsæ kerfi - classical macroscopic systems

Kerfi - jaðar - umhverfi <---> opin eða lokuð kerfi

system - boundary - environment <---> open or closed systems

Jafnvægi - nærjafnvægi - ójafnvægi

(Stórsæ- smásæ kerfi)

(Tengsl við safneðlisfræði)

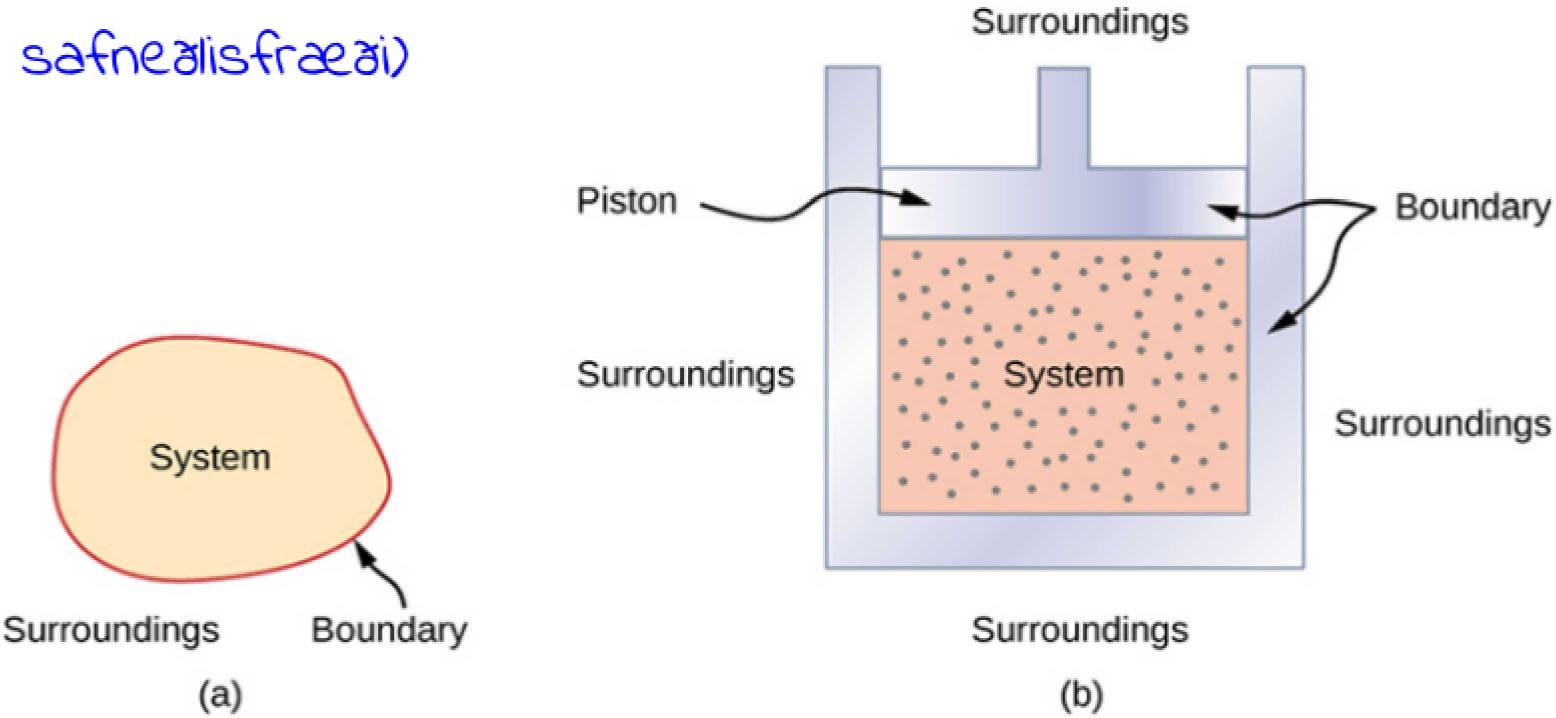


Figure 3.2 (a) A system, which can include any relevant process or value, is self-contained in an area. The surroundings may also have relevant information; however, the surroundings are important to study only if the situation is an open system. (b) The burning gasoline in the cylinder of a car engine is an example of a thermodynamic system.

openstax

Ástands jafna - breytur

$$f(p,V,T) = 0$$

til dæmis fyrir kjörgas

$$F(p,V,T) = pV - nRT = 0$$

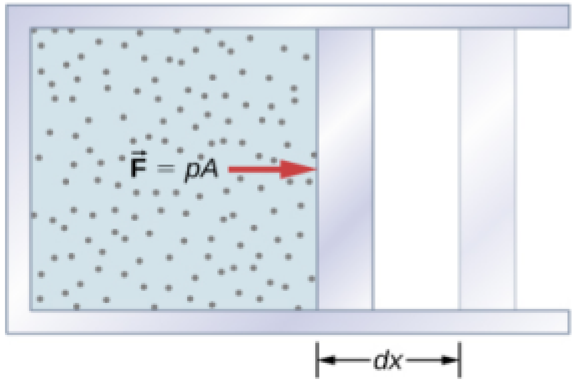
Magnbundnar breytur - extensive v.

Eðlisbundar breytur - intensive vari.

V, n

p, T

Vinna - varmi - innriorka



openstax

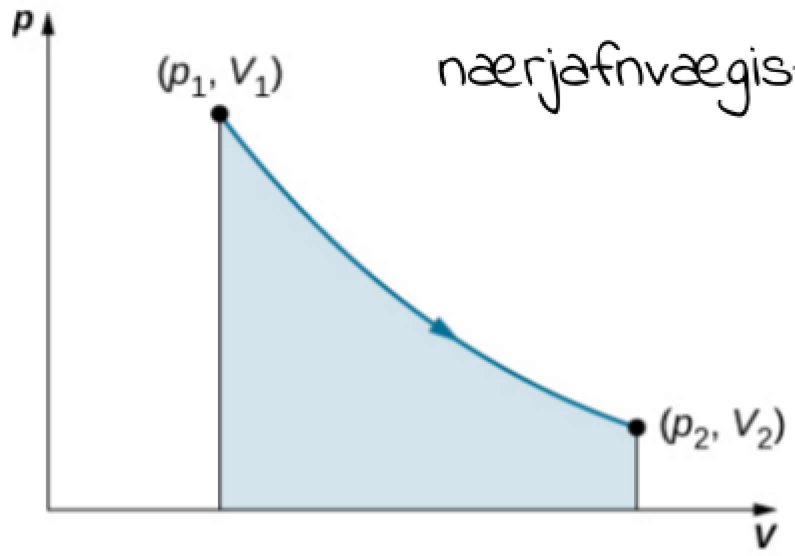
Figure 3.4 The work done by a confined gas in moving a piston a distance dx is given by $dW = Fdx = pdV$.

$$dW = F\,dx = pA\,dx$$

$$= p\,dV$$

$$\rightarrow W = \int_{V_1}^{V_2} p\,dV$$

Kjörgas



When a gas expands slowly from V_1 to V_2, the work done by the system is represented by the shaded area under the pV curve.

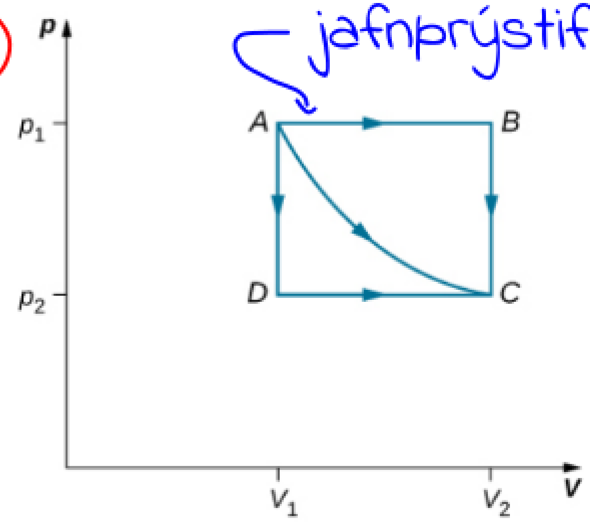
nærjafnvægisferli - quasi-static process

$$W_{AC} = \int_{V_1}^{V_2} p\,dV = nRT \int_{V_1}^{V_2} \frac{dV}{V}$$

Fast T - jafnhitaferli - isothermal process

$$W_{AC} = nRT \ln\left[\frac{V_2}{V_1}\right]$$

jafnþrýstiferli - isobaric p.



openstax

The paths *ABC*, *AC*, and *ADC* represent three different quasi-static transitions between the equilibrium states *A* and *C*.

$$W_{AB} = p\int_{V_1}^{V_2} dV = p(V_2 - V_1)$$

$$W_{BC} = 0 \quad \leftarrow \Delta V = 0$$

$$\rightarrow \quad W_{ABC} \neq W_{AC}$$

Vinnan er háð ferli í ástandsrúminu

Innriorka $$E_{int} = \left\langle \sum_i (K_i + U_i) \right\rangle$$

Kjörgas $$E_{int} = \left[\frac{3}{2} k_B T\right] n N_A = \frac{3}{2} nRT$$ einatóma

Fyrsta lögmál varmafræðinnar

openstax

First Law of Thermodynamics

Associated with every equilibrium state of a system is its internal energy E_{int}. The change in E_{int} for any transition between two equilibrium states is

$$\Delta E_{int} = Q - W \tag{3.7}$$

where Q and W represent, respectively, the heat exchanged by the system and the work done by or on the system.

$$dE_{int} = dQ - dW$$

Thermodynamic Sign Conventions for Heat and Work

Process	Convention
Heat added to system	$Q > 0$
Heat removed from system	$Q < 0$
Work done by system	$W > 0$
Work done on system	$W < 0$

Table 3.1

$$\Delta E_{int} = Q - W$$

fyrir ferlið frá B --> C var w = 0,
en ekkert var sagt um Q

openstax

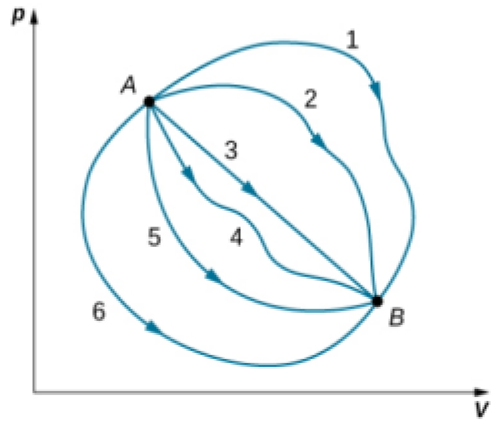


Figure 3.7 Different thermodynamic paths taken by a system in going from state *A* to state *B*. For all transitions, the change in the internal energy of the system $\Delta E_{int} = Q - W$ is the same.

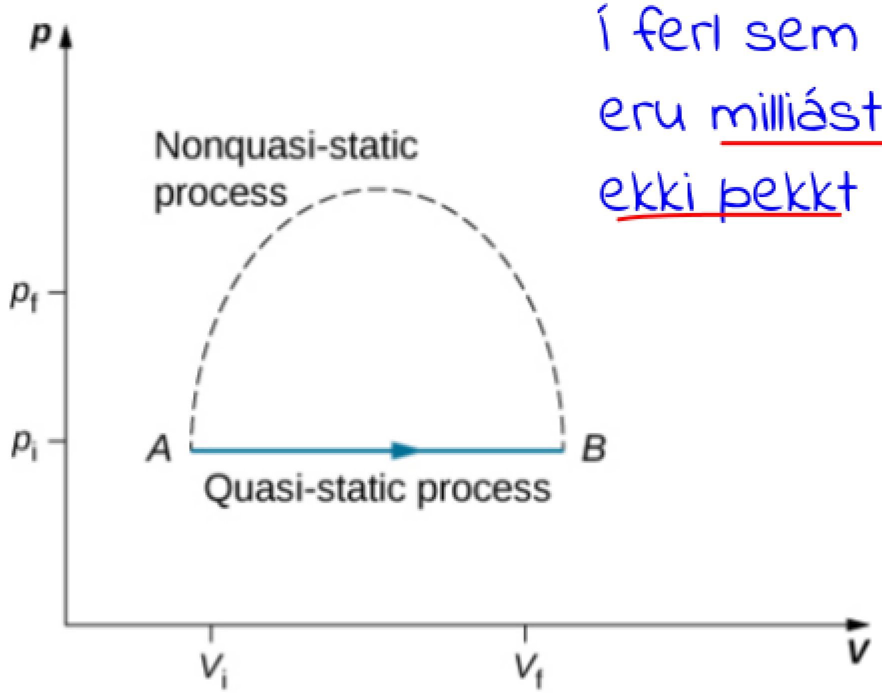
Often the first law is used in its differential form, which is

$$dE_{int} = dQ - dW. \tag{3.8}$$

Here dE_{int} is an infinitesimal change in internal energy when an infinitesimal amount of heat dQ is exchanged with the system and an infinitesimal amount of work dW is done by (positive in sign) or on (negative in sign) the system.

Fyrir allar leiðir frá A til B
er breytingin í innri orkunni
sú sama, en dw og dQ eru
breytilegar stærðir fyrir þær

varmafræðileg ferli



í ferl sem er ekki nærjafnvægisferli eru milliástöndin í ástandarúminu ekki þekkt

openstax

Figure 3.8 Quasi-static and non-quasi-static processes between states *A* and *B* of a gas. In a quasi-static process, the path of the process between *A* and *B* can be drawn in a state diagram since all the states that the system goes through are known. In a non-quasi-static process, the states between *A* and *B* are not known, and hence no path can be drawn. It may follow the dashed line as shown in the figure or take a very different path.

Jafnhitaferli, $\Delta T = 0$

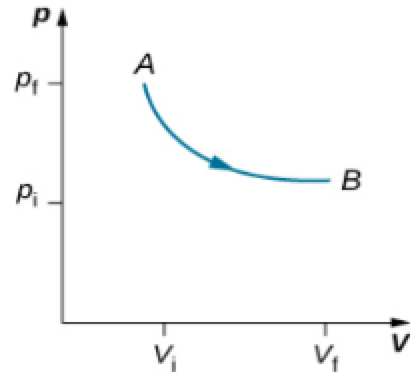
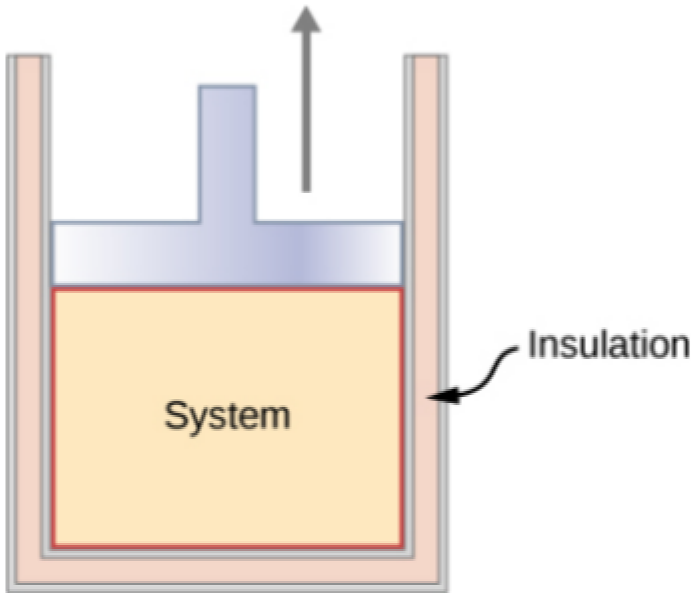


Figure 3.10 An isothermal expansion from a state labeled *A* to another state labeled *B* on a *pV* diagram. The curve represents the relation between pressure and volume in an ideal gas at constant temperature.

Óvermin ferli adiabatic process



openstax

$\Delta Q = 0$

Enginn varmi flæðir í eða úr kerfinu

Hringferli - lotuferli cyclic process

$\Delta E_{int} = 0, \quad \Delta W = \Delta Q$ fyrir hverja lotu

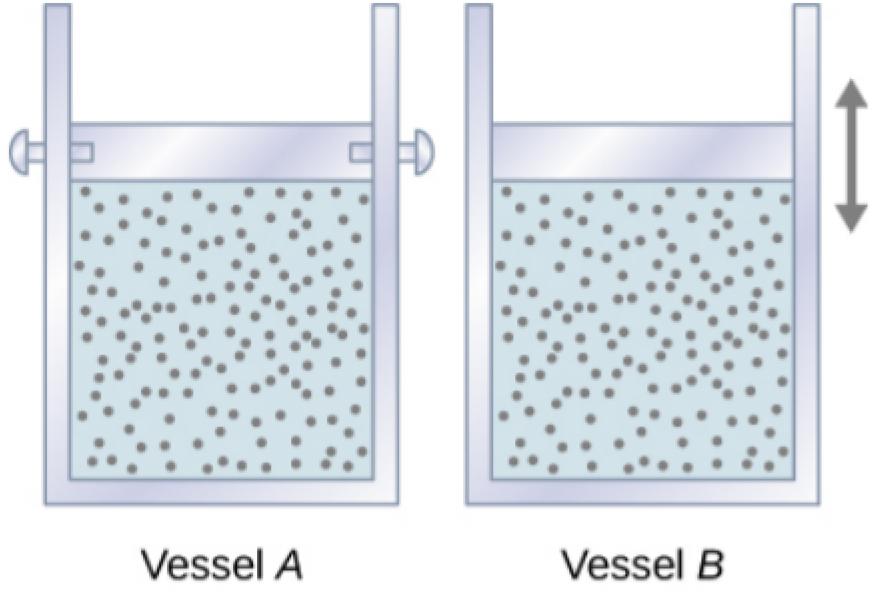
Jafnþrýstiferli isobaric process

$\Delta p = 0$

jafnrúmmálsferli isochoric process

$\Delta V = 0$

Tvenns konar varmarýmd kjörgass



openstax

A:

$$dE_{int} = dQ - dW$$
$$= dQ$$

$$dQ = C_V n\, dT$$

$$\rightarrow \quad dE_{int} = C_V n\, dT$$

C_V: mólar varmarýmd við fast rúmmál

C_p: mólar varmarýmd við fastan þrýsting

B:

$$dQ = C_p n\, dT$$

$$dW = p\,dV$$

$$d(pV) = d(RnT) = nR\,dT$$

$E_{int} = E_{int}(T)$

$$\rightarrow \quad dE_{int} = dQ - p\,dV = (nC_p - nR)\,dT$$

$$\boxed{C_p = C_V + R}$$

Fyrir kjörgas

$$C_V = \frac{d}{2} R$$

frelsisgráður d

Molar Heat Capacities of Dilute Ideal Gases at Room Temperature

Type of Molecule	Gas	C_p (J/mol K)	C_V (J/mol K)	$C_p - C_V$ (J/mol K)
Monatomic	Ideal	$\frac{5}{2}R = 20.79$	$\frac{3}{2}R = 12.47$	$R = 8.31$
Diatomic	Ideal	$\frac{7}{2}R = 29.10$	$\frac{5}{2}R = 20.79$	$R = 8.31$
Polyatomic	Ideal	$4R = 33.26$	$3R = 24.94$	$R = 8.31$

openstax

<u>Óvermnir ferlar fyrir kjörgas</u>

$$\Delta Q = 0$$

ekki nærjafnvægisferli

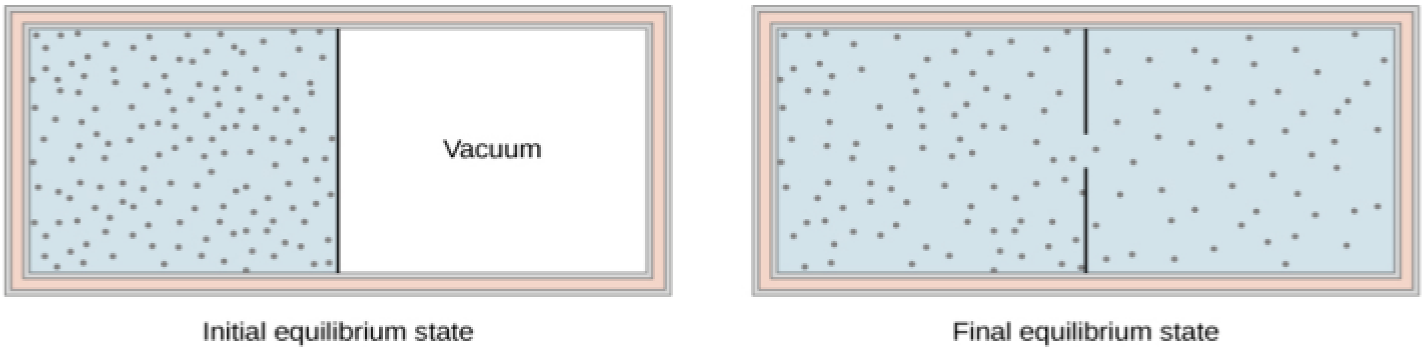


Figure 3.13 The gas in the left chamber expands freely into the right chamber when the membrane is punctured.

If the gas is ideal, the internal energy depends only on the temperature. Therefore, when an ideal gas expands freely, its temperature does not change.

Nærjafnvægis óvermið ferli

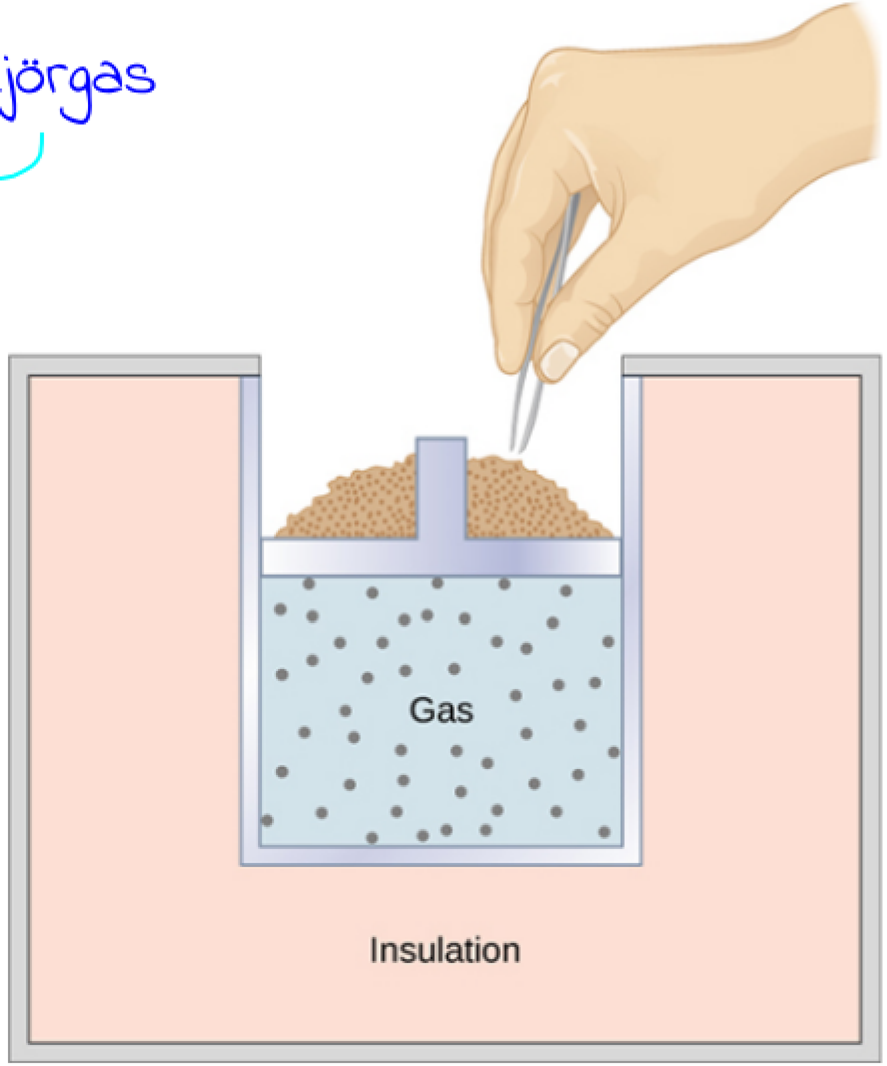
kjörgas

$$dQ = 0$$

$$dW = p\,dV$$

$$dE_{int} = C_v n\, dT$$

$$dE_{int} = dQ - p\,dV$$
$$= -p\,dV$$



openstax

Figure 3.14 When sand is removed from the piston one grain at a time, the gas expands adiabatically and quasi-statically in the insulated vessel.

$$C_v n\, dT = -p\,dV \rightarrow dT = -\frac{p\,dV}{nC_v}$$

$$dT = -\frac{p\,dV}{nC_v}, \qquad pV = nRT \rightarrow \underbrace{d(pV) = d(nRT)}$$

$$\rightarrow p\,dV + V\,dp = nR\,dT$$

$$\rightarrow dT = \frac{p\,dV + V\,dp}{nR}$$

$$\rightarrow -\frac{p\,dV}{nC_v} = \frac{p\,dV + V\,dp}{nR}$$

$$\rightarrow -nRp\,dV = nC_v\left[p\,dV + V\,dp\right]$$

$$\rightarrow \quad n C_V V\,dp + n[C_V + R]\,p\,dV = 0$$

$C_V + R = C_p$ og deilum með npV

$$\rightarrow \quad C_V \frac{dp}{p} + C_p \frac{dV}{V} = 0$$

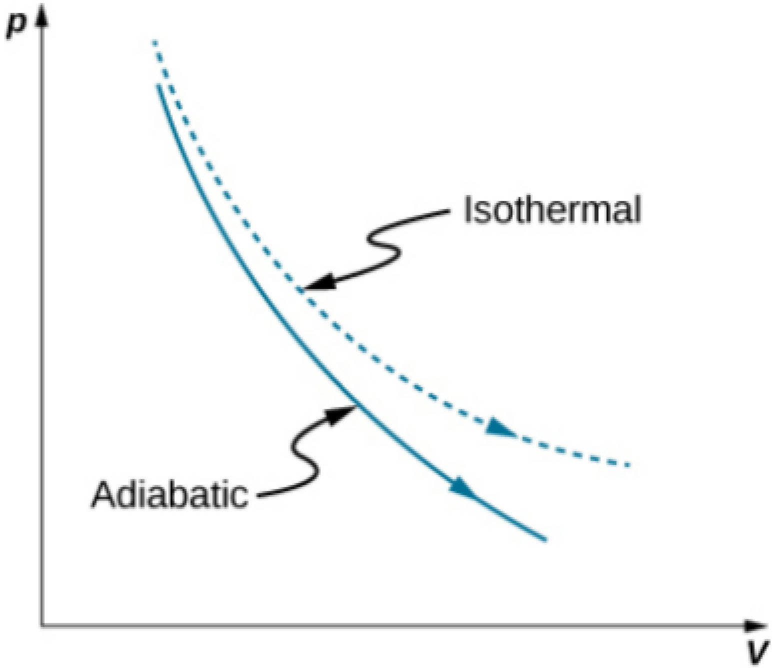
$$\rightarrow \quad \frac{dp}{p} + \gamma \frac{dV}{V} = 0 \qquad \text{með } \gamma = \frac{C_p}{C_V}$$

Heildum (óákveðið)

$$\int \frac{dp}{p} + \gamma \int \frac{dV}{V} = 0 \quad \rightarrow \quad \boxed{pV^{\gamma} = \text{fasti}}$$

Eins má leiða út

$$\boxed{\begin{aligned} p^{1-\gamma}\, T^{\gamma} &= \text{fasti} \\ T V^{\gamma-1} &= \text{fasti} \end{aligned}}$$



Quasi-static adiabatic and isothermal expansions of an ideal gas.

óvermið, hallatala: $\frac{dp}{dV} = -\gamma \frac{p}{V}$

Jafnhita, hallatala: $\frac{dp}{dV} = -\frac{p}{V}$

γ í næsta kafla