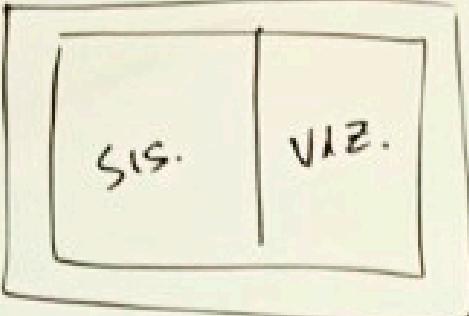
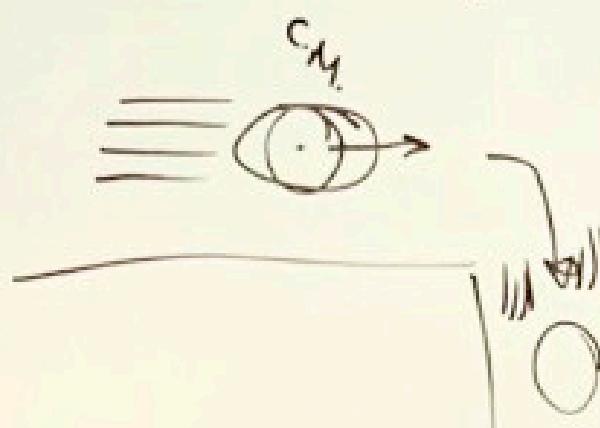


* TROCAS DE ENERGIA



$$\Delta E_m^{sis} + \Delta E_n^{viz} + \Delta U^{sis} + \Delta U^{viz} = 0$$

REF.
VARIACAO DE POSICAO E MOMENTO (MECANICO)



$$\Delta U^{sis} + \Delta U^{viz} = 0$$

SEM DISSIPACAO

$$\Delta E_m^{sis} + \Delta E_n^{viz} = 0$$

1. INSEGUNDA LEI DA MECANICA

2. REF. NO CENTRO DE MASSA

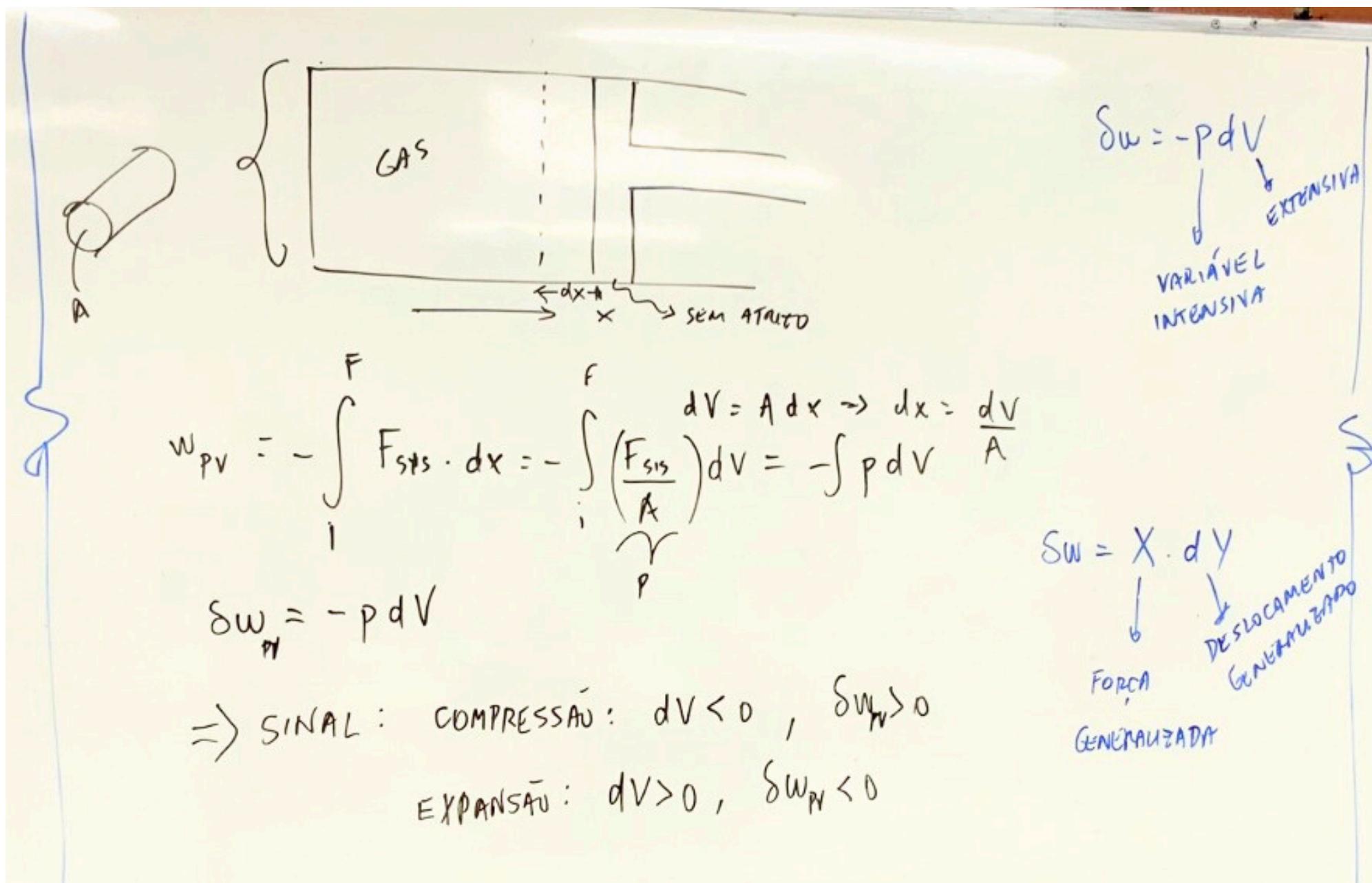
$$U = ? = E_{c(total)} + E_p(total)$$

* TRABALHO

$$W = \int_i^f \vec{F}_{viz} \cdot d\vec{s} = - \int_i^f \vec{F}_{sis} \cdot d\vec{s}$$

DESLOCAMENTO GENERALIZADA

FORCA GENERALIZADA



\Rightarrow INEXATTIDÀ

$$\delta w = M(x,y)dx + N(x,y)dy$$

$$M(x,y) = 0 \Rightarrow \left(\frac{\partial M}{\partial y} \right)_x = 0$$

$$N(x,y) = x \Rightarrow \left(\frac{\partial N}{\partial x} \right)_y = 1$$

VARIABLE
DE CAMINHO
(DIFERENCIAR
INEXATO)

TIPO	EQ.	DEFINIÇÕES
TRAB. MECÂNICO LINEAR	$S_w = F_x d_x$	F_x : COMPONENTE X DA FORÇA EXERTIDA PELA VIZ.
ESTIRAMENTO OU COMPRIMENTO DE HASTE OU MOLA	$S_w = F d l$	F : ESTRESSE (POSITIVO OU NEGATIVO) l : COMPRIMENTO
TRABALHO GRAV.	$S_w = m g d h$	m : MASSA, h : ALTURA g : ACCELERAGÃO DE QUEDA LIVRA
TRABALHO SUPERFICIAL	$S_w = \gamma d A$	γ : TENSÃO SUPERFICIAL A : ÁREA

Table 3.1 Some kinds of work

Kind	Formula	Definitions
Linear mechanical work	$\mathrm{d}w = F_x^{\text{sur}} \mathrm{d}x$	F_x^{sur} = x -component of force exerted by surroundings $\mathrm{d}x$ = displacement in x direction
Shaft work	$\mathrm{d}w = \tau_b \mathrm{d}\vartheta$	τ_b = internal torque at boundary ϑ = angle of rotation
Expansion work	$\mathrm{d}w = -p_b \mathrm{d}V$	p_b = average pressure at moving boundary
Surface work of a flat surface	$\mathrm{d}w = \gamma \mathrm{d}A_s$	γ = surface tension, A_s = surface area
Stretching or compression of a rod or spring	$\mathrm{d}w = F \mathrm{d}l$	F = stress (positive for tension, negative for compression) l = length
Gravitational work	$\mathrm{d}w = mg \mathrm{d}h$	m = mass, h = height g = acceleration of free fall
Electrical work in a circuit	$\mathrm{d}w = \Delta\phi \mathrm{d}Q_{\text{sys}}$	$\Delta\phi$ = electric potential difference = $\phi_R - \phi_L$ $\mathrm{d}Q_{\text{sys}}$ = charge entering system at right
Electric polarization	$\mathrm{d}w = \mathbf{E} \bullet \mathrm{d}\mathbf{p}$	\mathbf{E} = electric field strength \mathbf{p} = electric dipole moment of system
Magnetization	$\mathrm{d}w = \mathbf{B} \bullet \mathrm{d}\mathbf{m}$	\mathbf{B} = magnetic flux density \mathbf{m} = magnetic dipole moment of system

Table 1 Conjugate pairs of variables in work terms for the fundamental equation for U^a .

Type of work	Intensive variable	Extensive variable	Differential work in dU
Mechanical			
Pressure-volume	$-P$	V	$-PdV$
Elastic	f	L	fdL
Gravitational	$\psi = gh$	$m = \sum M_i n_i$	$\psi dm = \sum gh M_i dn_i$
Surface	γ	A_s	γdA_s
Electromagnetic			
Charge transfer	ϕ_i	Q_i	$\phi_i dQ_i$
Electric polarization	\mathbf{E}	\mathbf{p}	$\mathbf{E} \bullet d\mathbf{p}$
Magnetic polarization	\mathbf{B}	\mathbf{m}	$\mathbf{B} \bullet dm$
Chemical			
Chemical: no reactions	μ_i	n_i (species)	$\mu_i dn_i$
Chemical: reactions	μ_i	n_{ci} (components)	$\mu_i dn_{ci}$

^aHere $\psi = gh$ is the gravitational potential, g is the gravitational acceleration, h is height above the surface of the earth, m is mass, M_i is molar mass, ϕ_i is the electric potential of the phase containing species i , Q_i is the contribution of species i to the electric charge of a phase, z_i is the charge number, F is the Faraday constant, f is force of elongation, L is length in the direction of the force, γ is surface tension, A_s is surface area, \mathbf{E} is electric field strength, \mathbf{p} is the electric dipole moment of the system, \mathbf{B} is magnetic field strength (magnetic flux density), and \mathbf{m} is the magnetic moment of the system. In some electrochemical systems, $Q_i = Fz_i n_i$ so that $dQ_i = Fz_i dn_i$. The dots indicate scalar products of vectors. Some of the other work terms can be written in vector notation. Other types of work terms are possible, and some of the expressions for differential work are more complicated; for example, the force on a solid may be represented by a tensor and ψ may be a centrifugal potential. The term γdA_s applies to flat surfaces.

* PAREDES

- SISTEMA ISOLADO: NÃO TROCA ENERGIA OU MAT. COM A VIZ.
- SISTEMA FECHADO: TROCA DE ENERGIA SEM TROCA DE MATERIA
- SISTEMA ABERTO: TROCA DE ENERGIA E MATERIA

\Rightarrow ENERGIA NA FORMA DE CALOR: DIATERMICA (SIM)

\Rightarrow ENERGIA NA FORMA DE TRABALHO: ADIABÁTICA (NÃO)

\Rightarrow ENERGIA NA FORMA DE TRABALHO: RÍGIDA (NÃO)

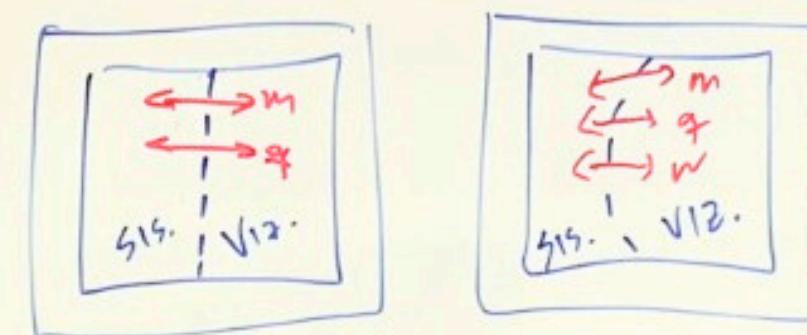
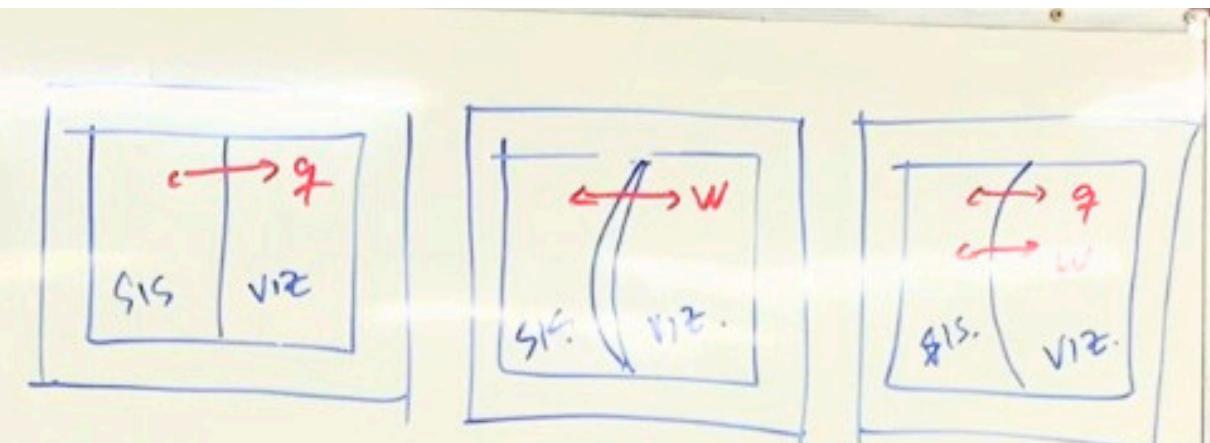
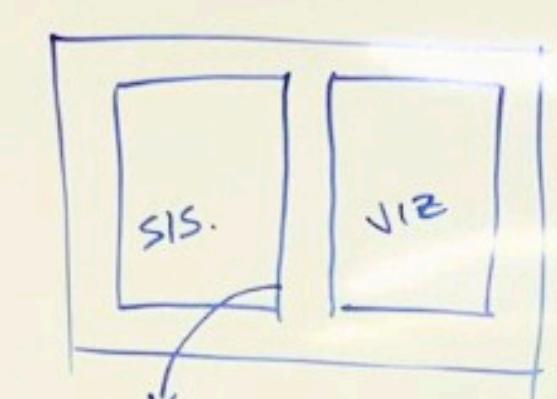
FLEXÍVEL (SIM)

\Rightarrow ENERGIA POR TRANSFERÊNCIA DE MAT.: PERMEÁVEL (SIM)
SEMI-PERMEÁVEL (ALGUMAS SIM, ALGUMAS NÃO)
IMPERMEÁVEL (NÃO)

PA
(N)

PAREDE ISOLANTE
(NEM CALOR NEM
TRABALHO)

SISTEMA ISOLADO



• PRIMEIRA LEI P/ DIFERENTES SISTEMAS

$$dU^{SIS} + dU^{VIZ} = 0 = dU^{\text{TOT}}$$

\Rightarrow SISTEMAS ABERTOS:

$$\begin{aligned} dU &= \delta q + \delta w + dU_{MAT} \\ &= \delta q + \sum_i x_i dy_i + \sum_k dU_{MAT}^k \end{aligned}$$

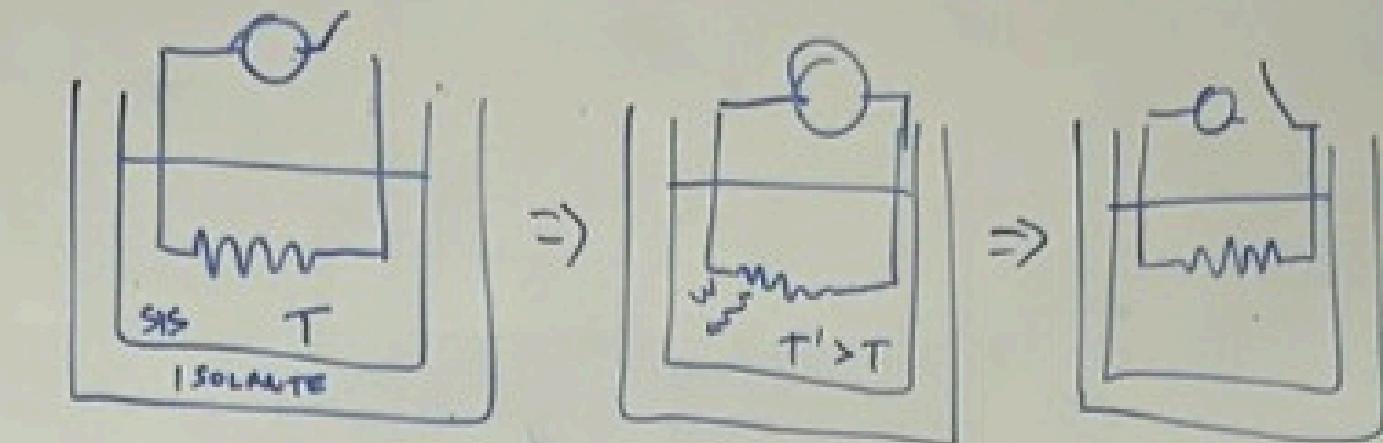
\Rightarrow SISTEMAS FECHADOS $dU_{MAT} = 0$

$$dU = \delta q + \delta w = \delta q + \sum_i x_i dy_i$$

\Rightarrow SISTEMAS ISOLADOS: $dU_{MAT} = 0, \delta q, \delta w = 0$

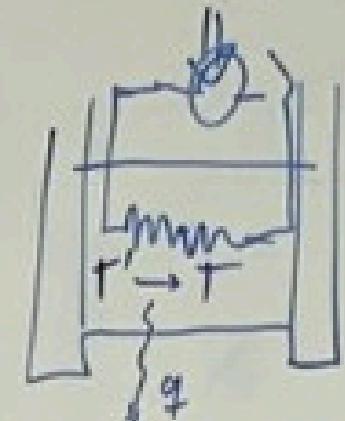
$$dU = 0$$

• EXPERIMENTOS DE TAUDE



$$W(VIZ \rightarrow SIS) = -K q(SIS \rightarrow VIZ)$$

↓
CONSTANTE



$$\int \delta w = -K \int \delta q \Rightarrow \oint \delta w = -K \oint \delta q$$

$$\oint \delta w = - \oint \delta q$$

$$\oint (\delta w + \delta q) = 0 \Rightarrow \oint dU = 0$$

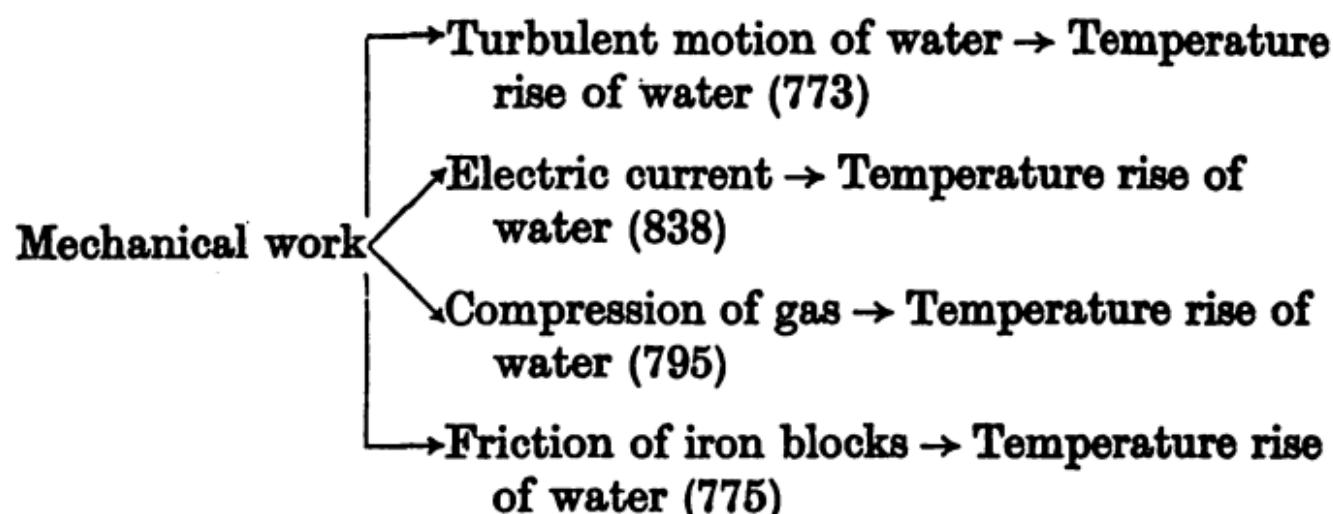
$$\begin{aligned} \int dU &= 0 & \text{B} &= \Delta U \\ A &= U_B - U_A & \text{A} &= U_B - U_A \end{aligned}$$

electrical machine, the resultant electric current being passed through a coil immersed in the water;†

(c) experiments in which mechanical work was expended in the compression of a gas in a cylinder, the latter being immersed in the water;§

(d) experiments in which the mechanical work was expended on two pieces of iron which rubbed against each other beneath the surface of the water.||

The scheme of Joule's experiments was thus as follows:



The figures in brackets show the number of foot-pounds of work needed to raise the temperature of 1 lb. of water by 1 °F. The result of the most accurate series of experiments, those with the paddles, is equivalent to 4.16 joules/cal (15 °C), which is close to the present accepted value of 4.184. However, the significant conclusion is that each of the four different methods of transforming work into a temperature rise gives essentially the same result—at any rate to within the accuracy which could be attained in these early experiments.†

Now in each of the experiments the water was enclosed by an approximately adiabatic wall (as previously defined), apart from certain openings necessary for the introduction of the paddle shaft, etc. By including not only the water but also certain other items in the total thermodynamic system under discussion, each of Joule's experimental arrangements may be regarded as consisting of an adiabatic enclosure together with an external source of work; the adiabatic wall is set into motion and creates a change of state within the enclosure. Therefore, the conclusion to be drawn is that the performance of a given amount of work, on a quantity of adiabatically enclosed water, causes the same temperature rise (i.e. the same change of state), by whatever method the process is carried out.

The first law is based mainly on the series of experiments carried out by Joule between 1843 and 1848. The most familiar of these experiments is the one in which he raised the temperature of a quantity of water, almost completely surrounded by an adiabatic wall,* by means of a paddle which was operated by a falling weight. The result of this experiment was to show an almost exact proportionality between the amount of work expended on the water and the rise in its temperature. This result, considered on its own, is not very significant; the really important feature of Joule's work was that the paddle-wheel experiments gave *the same proportionality* as was obtained in several other quite different methods of transforming work into the temperature rise of a quantity of water. These were as follows:

(a) the paddle-wheel experiments;†

(b) experiments in which mechanical work was expended on an

* For each of the experimental systems now to be described, the student should ask himself, What exactly is the system which is regarded as being enclosed by adiabatic and moving walls? This is perhaps least obvious in experiment (b).

† Phil. Mag. 31 (1847), 173; 35 (1849), 533.

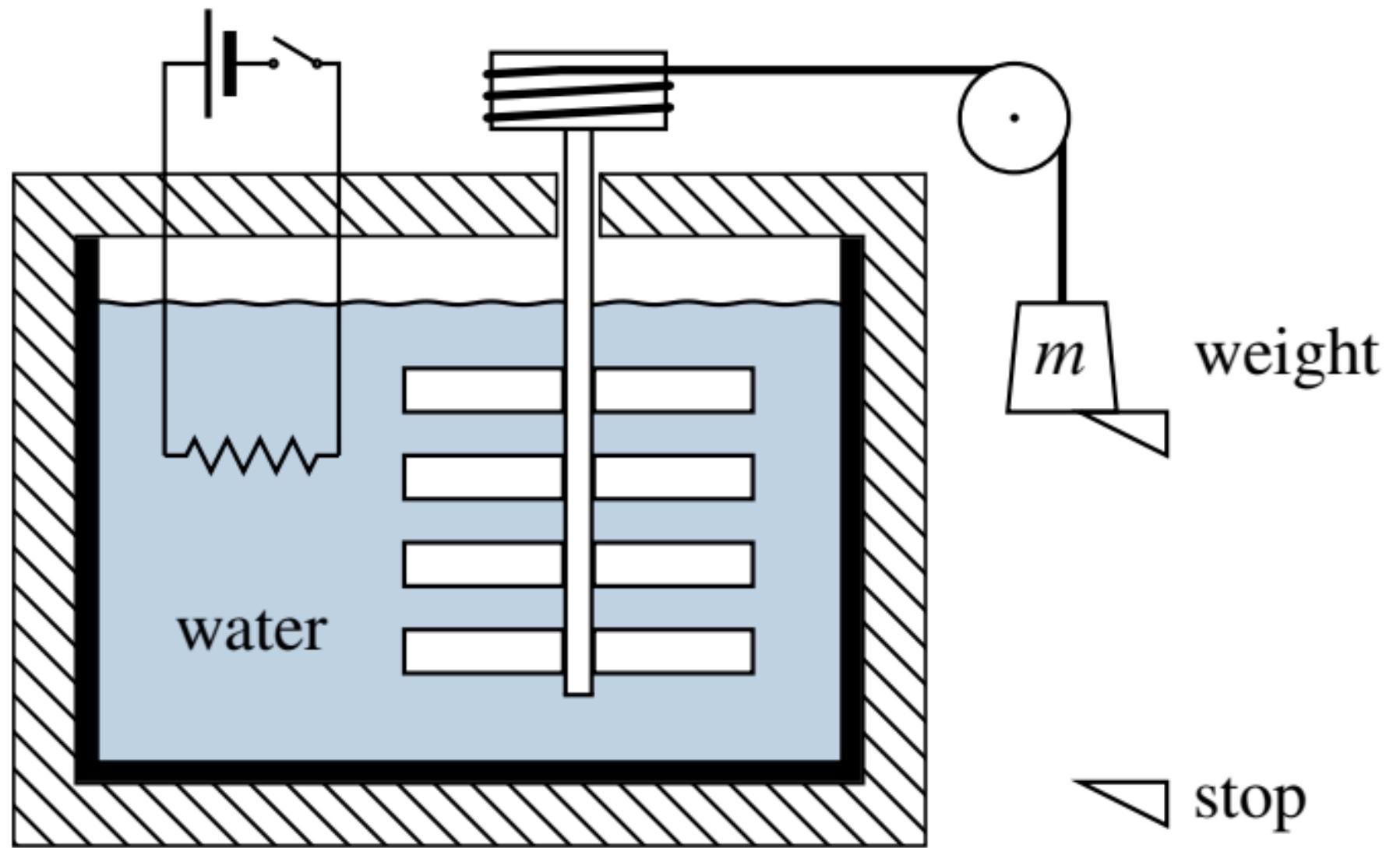
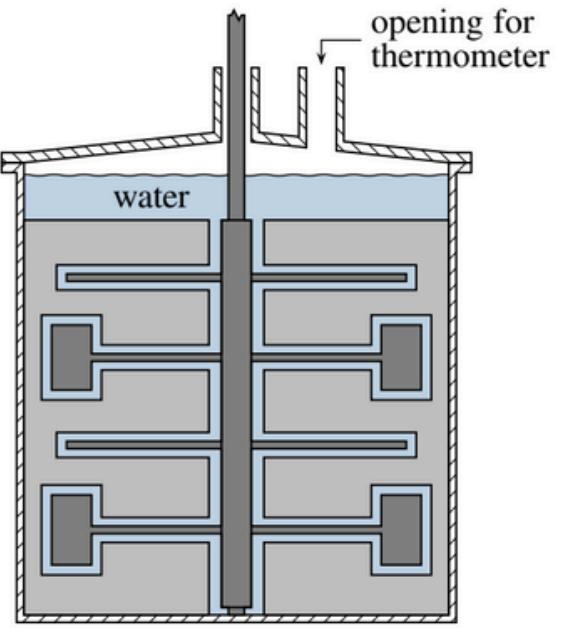


Figure 3.1 System containing an electrical resistor and a paddle wheel immersed in water. Cross-hatched area: removable thermal insulation.



MIRKO JUNGE / COMMONS.WIKIMEDIA.ORG

(a)



(b)

Figure 3.13 Joule paddle wheel.

(a) Joule's original paddle wheel on exhibit at the Science Museum, London.

(b) Cross-section elevation of paddle wheel and water in copper vessel. Dark shading: rotating shaft and paddle arms; light shading: stationary vanes.

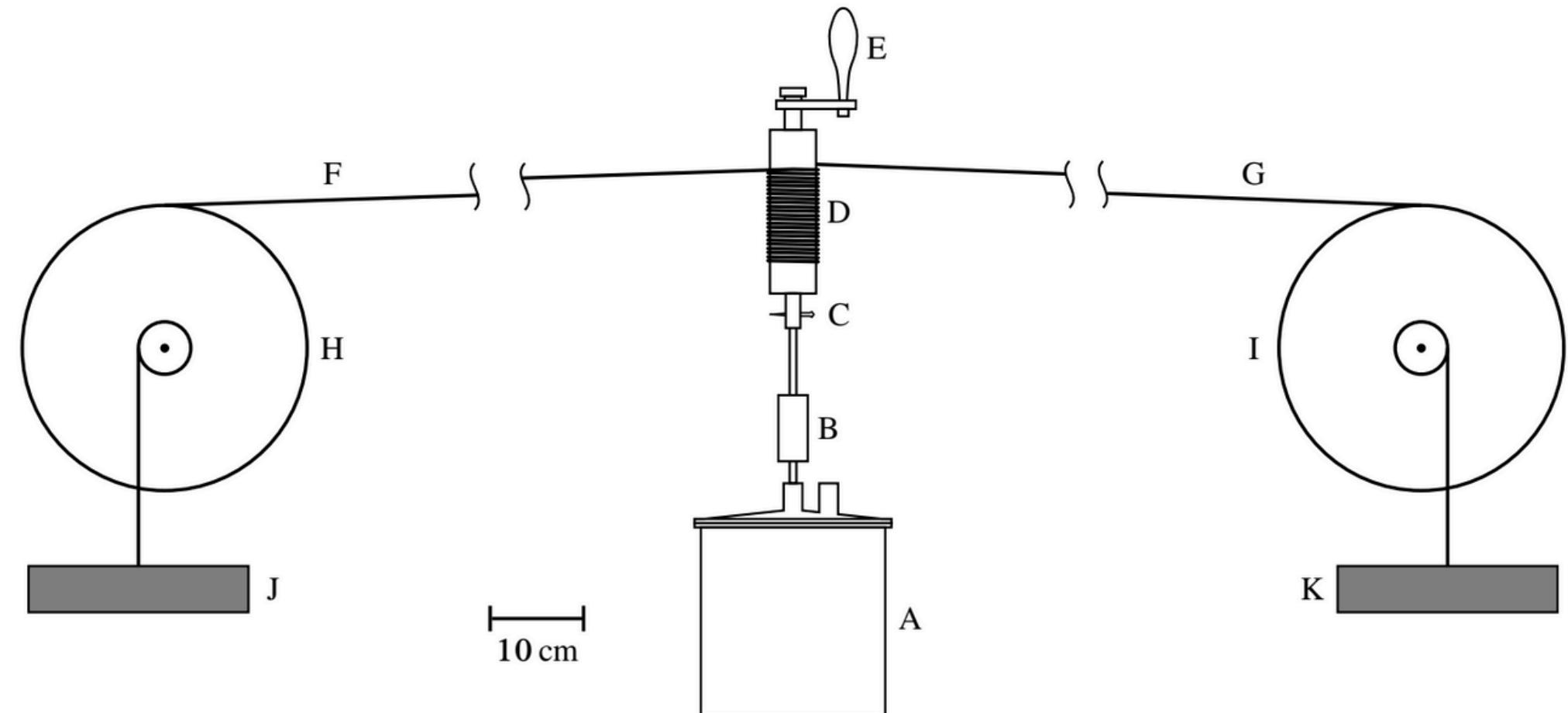
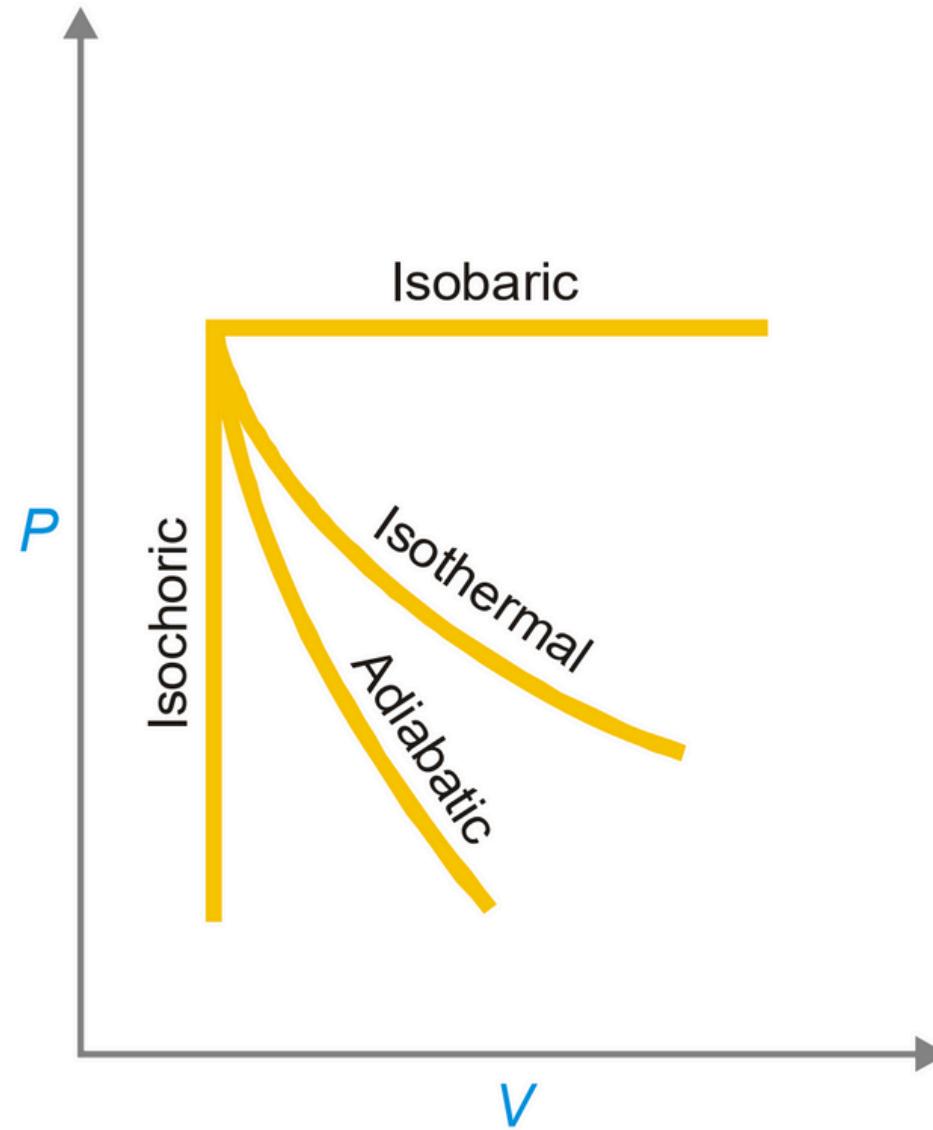
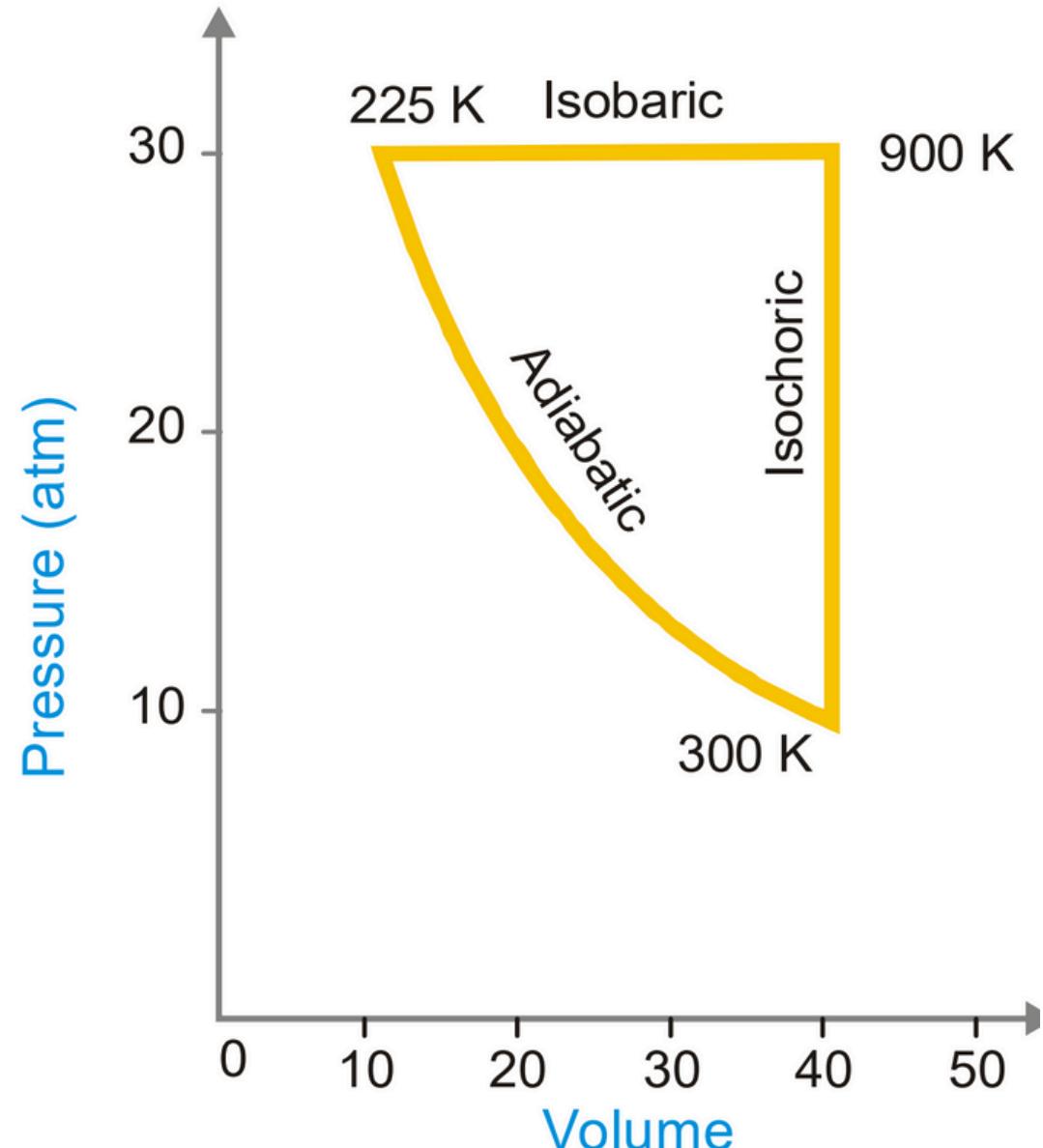


Figure 3.14 Joule's apparatus for measuring the mechanical equivalent of heat (re-drawn from a figure in Ref. [91]).

Key: A—paddle wheel and vessel (see Fig. 3.13); B—wood thermal insulator; C—pin used to engage paddle wheel shaft to roller; D—roller; E—crank used to wind up the weights; F, G—strings; H, I—pulley wheels; J, K—weights (round lead disks, viewed here edge-on).



(a)



(b)

■ **Figure 7.5**

(a) Four basic thermodynamic processes; (b) A cyclic process.

$$C = \frac{dq}{dT}$$

CAPACIDADE
CALORÍFICA

$$C_V = \left(\frac{\partial q}{\partial T} \right)_V$$

$$C_P = \left(\frac{\partial q}{\partial T} \right)_P$$

$$n = \frac{m}{M} \rightarrow \tilde{C}_V = \frac{1}{m} \left(\frac{\partial q}{\partial T} \right)_V$$

$$\bar{C}_V = \frac{1}{n} \left(\frac{\partial q}{\partial T} \right)_V$$

$$\tilde{C}_P = \frac{1}{m} \left(\frac{\partial q}{\partial T} \right)_P$$

$$\bar{C}_P = \frac{1}{n} \left(\frac{\partial q}{\partial T} \right)_P$$

• TERMODINÂMICA SÓ LIDA COM VARIACÕES,
NÃO RESUMITÓS

$$\Delta U = \int_A^B dU = U_B - U_A \xrightarrow[\text{(o)}]{\substack{\text{ESTADO} \\ \text{PADRÃO}}} \Delta U = (U_B - U) + (U_A - U)$$

ΔU_B° ΔU_A°

• TRABALHO ADIABÁTICO E POTENCIAL TERMODINÂMICO

→ TRABALHO MECÂNICO

$$W = \Delta E_k = -\Delta E_p$$

$$\Delta E_k + \Delta E_p = 0$$

$$E_k + E_p = \text{cte}$$

SISTEMA CONSERVATIVO
FORÇAS CONSERVATIVAS

$$W_{i \rightarrow f}^m = W_{i \rightarrow f}$$

$\vec{F} = -\vec{\nabla}V$

Força
POTENCIAL
FORÇAS CENTRAIS

$F(r) = -\frac{dV(r)}{dr}$

$$W_{i \rightarrow f}^m = \int \vec{F} \cdot d\vec{s}$$

$\stackrel{z=L}{=} m \int a \cdot dx = \int \frac{dv}{dt} v dt$

$\stackrel{L \text{ DIM.}}{=} \frac{dv}{dt}$

$v = \frac{dx}{dt}$

$dx = v dt$

$$= \frac{mv_f^2 - mv_i^2}{2} = E_k(f) - E_k(i) = \Delta E_k$$

$$W = \Delta E_k$$

$$W = \int \vec{F} \cdot d\vec{s} = \int F(r) \cdot dr$$

CENTRAIS

$$= - \int \frac{dV(r)}{dr} dr = \int dV(r) = V(p)$$

$$= -V(i) = \Delta E_k$$

→ TRABALHO TERMODINÂMICO

$$dU = \delta q + \delta w = \delta q + \sum_i X_i dy_i \quad (\text{SIS. FEC.})$$

PROCESSO ADIABÁTICO ($\delta q = 0$)

$$dU = \delta w_{\text{ADIA}} = \sum_i X_i dy_i$$

$$\left(\frac{\partial U}{\partial y_i} \right)_{y_j=y_{j0}} \frac{\partial}{\partial y_i} \left[\overbrace{x_1 dy_1 + \dots + x_i dy_i + \dots}^0 \right] = x_i$$

TRABALHO TERMOD.

TRABALHO MEC.

$$x_i = \left(\frac{\partial U}{\partial y_i} \right)_{\text{ADIA}, f}$$

POTENCIAL TERMODINÂMICO

$$F = -\frac{dV}{dr} \rightarrow \text{POT.}$$

DES.

$$\Delta E_m = \Delta E_k + \Delta E_p = 0 \Rightarrow E_m = \text{cte}$$

$V = \text{cte}$

• APLICAÇÕES DA 1^a LEI

⇒ FUNÇÕES RESPOSTA

→ MEDIDAS EXPERIMENTAIS

EXPANSIVIDADE
TÉRMICA

$$\alpha = \frac{1}{V} \left(\frac{\partial V}{\partial T} \right)_P \xrightarrow{\text{obs: } \frac{\partial V}{\partial T} \propto \frac{nR}{T}} \frac{1}{V} \frac{nR}{P} > \frac{1}{T}$$

COMPRESSIBILIDADE

ISOTÉRMICA

$$\beta = -\frac{1}{V} \left(\frac{\partial V}{\partial P} \right)_T \xrightarrow{\text{obs: } \frac{\partial V}{\partial P} \propto \frac{nRT}{V}} = -\frac{1}{V} \frac{nRT}{P^2}$$

$$\left(\frac{\partial V}{\partial P} \right)_T \left(\frac{\partial P}{\partial T} \right)_V \left(\frac{\partial T}{\partial V} \right)_P = -1$$

$$\left(\frac{\partial P}{\partial T} \right)_V = -\frac{\left(\frac{\partial V}{\partial T} \right)_P}{\left(\frac{\partial V}{\partial P} \right)_T} = -\frac{1}{V} \frac{\left(\frac{\partial V}{\partial T} \right)_P}{\left(\frac{\partial P}{\partial T} \right)_V} = \frac{\alpha}{\beta}$$

→ EQUAÇÕES DE ESTADO $V(P, T)$

$$dV = \left(\frac{\partial V}{\partial P} \right)_T dP + \left(\frac{\partial V}{\partial T} \right)_P dT$$

$$= \alpha V dT - \beta V dP = \frac{\delta q}{dT}$$

$$= V [\alpha dT - \beta dP]$$

• RELAÇÕES ENTRE $C = \overbrace{C_p, C_v}^{C_p = C_v}$ E U

$$U = U(V, T) \quad \text{FECHADO}$$

$$dU = \left(\frac{\partial U}{\partial T} \right)_V dT + \left(\frac{\partial U}{\partial V} \right)_T dV = \cancel{\delta q} + \delta w$$

$$\left(\frac{\partial U}{\partial T} \right)_V + \left[P + \left(\frac{\partial U}{\partial V} \right)_T \right] dV = \cancel{\delta q}$$

$$C = \frac{\delta q}{dT}$$

$$= \left(\frac{\partial U}{\partial T} \right)_V + \left[P + \left(\frac{\partial U}{\partial V} \right)_T \right] \frac{dV}{dT}$$

$$C_V = \left(\frac{\delta q}{dT} \right)_V = \left(\frac{\partial U}{\partial T} \right)_V$$

$$C_P = \left(\frac{\delta q}{dT} \right)_P$$

$$= C_V + \left[P + \left(\frac{\partial U}{\partial V} \right)_T \right] \left(\frac{\partial V}{\partial T} \right)_P$$

$$C_p - C_v = \left[P + \left(\frac{\partial U}{\partial V} \right)_T \right] \left(\frac{\partial V}{\partial T} \right)_P$$

RELAÇÃO TERMODINÂMICA

$$C_p - C_v = \left[P + \left(\frac{\partial U}{\partial V} \right)_T \right] \cdot V \alpha$$

$$\left(\frac{\partial U}{\partial V} \right)_T = \frac{C_p - C_v}{\alpha V} - P$$

$C_p = C_v + \left[P + \left(\frac{\partial U}{\partial V} \right)_T \right] V \alpha$

$\left(\frac{\partial U}{\partial V} \right)_T \stackrel{(1)}{=} \frac{C_p - C_v - P}{\alpha V}$

$\underbrace{\left(\frac{\partial U}{\partial V} \right)_T}_\text{PRESSÃO INTERNA} = 0 \quad (\text{GÁS IDEAL})$

$\Pi_T = \left(\frac{\partial U}{\partial V} \right)_T \stackrel{(2)}{=} T \left(\frac{\partial P}{\partial T} \right)_V - P$

$\Pi_T = T \cdot nR - P$

RELACOES DE MAXWELL

1) GÁS IDEAL $PV = nRT$

$\left(\frac{\partial P}{\partial T} \right)_V \cdot \left[\frac{\partial}{\partial T} \left(\frac{nRT}{V} \right) \right] = \frac{nR}{V}$

$\Pi_T = 0$

SEM INTERAÇÕES ENTRE OS PARTICULOS

2) GAS DE IDU

$$PV = nRT$$

$$\left(P + \frac{a}{V^2}\right) \left(\bar{V} - b\right) = RT$$

$$P + \frac{a}{V^2} = \frac{RT}{\bar{V} - b} \Rightarrow P = \frac{RT}{\bar{V} - b} - \frac{a}{V^2}$$

$$\left(\frac{\partial P}{\partial T}\right)_V = \frac{R}{\bar{V} - b} \Rightarrow T \left(\frac{\partial P}{\partial T}\right)_V = \frac{RT}{\bar{V} - b}$$

$$\Pi_T = \frac{RT}{\bar{V} - b} - P = \frac{RT}{\bar{V} - b} - \frac{RT}{\bar{V} - b} + \frac{a}{V^2}$$

$$\Pi_T = \frac{a}{V^2}$$

INTERACCIÓN

P_{INT}

(1) + (2)

$$\left(\frac{\partial U}{\partial V}\right)_T = \frac{C_P - C_V}{V\alpha} - P = T \left(\frac{\partial P}{\partial T}\right)_V - 1$$

$$T \left(\frac{\partial P}{\partial T}\right)_V = \frac{C_P - C_V}{V\alpha}$$

\uparrow ANTESES

$$T \frac{\alpha}{\beta} = \frac{C_P - C_V}{V\alpha} \Rightarrow C_P - C_V = \frac{\alpha}{\beta} TV$$

SUBSTANCIA
 PURAS o en
 GASES

GAS IDEAL

$$\alpha = \frac{1}{T}$$

$$\beta = \frac{1}{P}$$

$$C_P - C_V = \frac{\left(\frac{1}{T}\right)}{\frac{1}{P}} TV = \frac{V}{T} \cdot \frac{P}{T} = \frac{PV}{T} = 1R$$

$$PV = nRT \Rightarrow \frac{V}{T} = \frac{nR}{P}$$

$$C_p - C_v = nR \text{ ou } \bar{C}_p - \bar{C}_v = R$$

PERMÍTTE
W COM FSE

PROCESSOS EM GASES

- ISOBÁRICOS ($P = cte$)

- ISOQUÍMICOS ($V = cte$)

- ISOTÉRMICOS ($T = cte$)

- ADIABÁTICOS ($\delta_q = 0$)

PROCESSO

EXPL.
COMPL.

ADIABÁTICO

$$1^{\text{a}} \text{ LEI: } dU = \delta_q + \delta_w = \delta_q - pdV$$

$$\delta_q = dU + pdV = \left(\frac{\partial U}{\partial T}\right)_V dT + \left(\frac{\partial U}{\partial V}\right)_T dV + pdV = 0$$

$T \parallel$ CAS VACUUM

C_V

$$C_V dT + pdV = 0$$

$$\frac{C_V}{T} dT + \frac{pdV}{V} = 0 \quad \left[\frac{1}{T} \cdot \frac{1}{n} \right] \Rightarrow \frac{\bar{C}_V}{T} dT + R \cdot \frac{dV}{V} = 0$$

$$\frac{\bar{C}_V}{T} dT + (\bar{C}_p - \bar{C}_V) \frac{dV}{V} = 0 \quad \left[\frac{1}{\bar{C}_V} \right]$$

$$\frac{dT}{T} + \left[\frac{\bar{C}_p - \bar{C}_V}{\bar{C}_V} \right] \frac{dV}{V} = 0$$

$$\gamma = \frac{\bar{C}_p}{\bar{C}_V} = \frac{C_p}{C_V} \rightarrow \frac{dT}{T} + [\gamma - 1] \frac{dV}{V} = 0$$

$$\int_{T_i}^{T_f} \frac{dT}{T} + [\gamma - 1] \int_{V_i}^{V_f} \frac{dV}{V} = 0$$

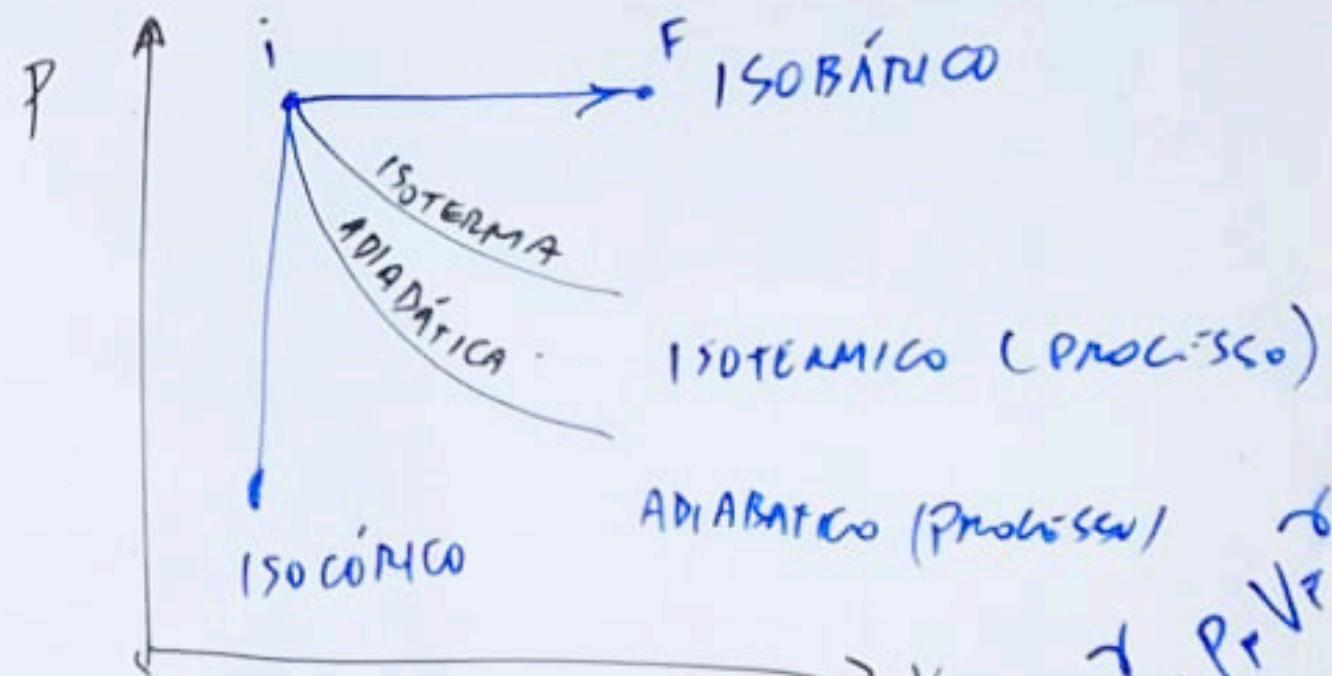
$$\ln \left[\frac{T_f}{T_i} \right] + \frac{(\gamma - 1)}{\gamma} \ln \left(\frac{V_f}{V_i} \right) = 0$$

$$\ln \left[\left(\frac{T_f}{T_i} \right) \cdot \left(\frac{V_f}{V_i} \right)^{\gamma-1} \right] = 0 \quad (\text{EXP})$$

$$\left(\frac{T_F}{T_i}\right) \left(\frac{V_F}{V_i}\right)^{\gamma-1} = \frac{T_F V_F^{\gamma-1}}{T_i V_i^{\gamma-1}} = 1$$

$$T_i V_i^{\gamma-1} = T_F V_F^{\gamma-1} \Rightarrow T^{\gamma-1} = cte$$

ADIABÁTICO
GÁS IDEAL



$$PV \leftarrow TV \quad T = \frac{PV}{nR}$$

$$T_i V_i^{\gamma-1} = \frac{P_i V_i \cdot V_i^{\gamma-1}}{nR} = \frac{P_i V_i^{\gamma}}{nR} = \frac{P_F V_F^{\gamma}}{nR}$$

$$PV^{\gamma} = cte$$

$$T_i V_i^{\gamma-1} = T_F V_F^{\gamma-1} \quad P_i V_i^{\gamma} = P_F V_F^{\gamma}$$

(GÁS IDEAL)

P T

$$V_F^{\gamma} \cdot V_i^{\gamma-1}$$

$$P_i \left[\frac{nRT_i}{P_i} \right]^{\gamma} = P_F \left[\frac{nRT_F}{P_F} \right]^{\gamma}$$

$$\cancel{P_i^{-\gamma} \cdot P_i^{\gamma} \cdot (nR)^{\gamma} \cdot T_i^{\gamma}} = P_F^{1-\gamma} \cdot (nR)^{\gamma} \cdot T_F^{\gamma}$$

$$P_i^{1-\gamma} \rightarrow P_i^{1-\gamma} T_i^{\gamma} = P_F^{1-\gamma} T_F^{\gamma}$$

$$P \cdot P^{\gamma} T^{-\gamma} = cte$$

$$\left(\frac{T}{P} \right)^{\gamma} = cte$$

HYPOTANGE'S LAW

ENTALPIA

- PROCESSOS A PRESSÃO CONSTANTE SUGEREM UMA NOVA FUNÇÃO DE ESTADO.

$$dU = \delta q + \delta w = \underbrace{\delta q_p}_{\substack{P=\text{const} \\ \text{TRAN. PV}}} - P dV$$

$\delta q_p = dU + PdV$

$$\underbrace{\oint \delta q_p}_{\substack{\text{FUNÇAO} \\ \text{DE} \\ \text{CAMINHO}}} = \underbrace{\oint dU}_{\substack{\parallel \\ 0}} + P \underbrace{\oint dV}_{\substack{\parallel \\ 0}} = 0$$

FUNÇAO DE ESTADO

$$\oint \delta q_p = \oint (dU + PdV) = \oint dH$$

PRESSÃO CONSTANTE

$$dH = dU + PdV = dU + PdV + Vdp$$

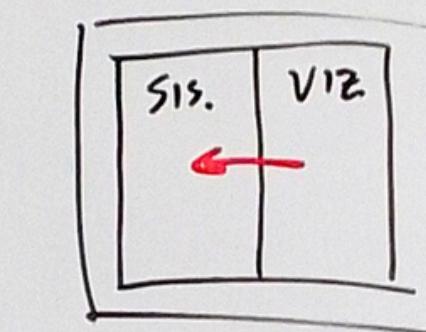
$$\left. \begin{aligned} & Q_{dT=0}^0 \\ & \delta H^0 \end{aligned} \right\}$$

ENTALPIA

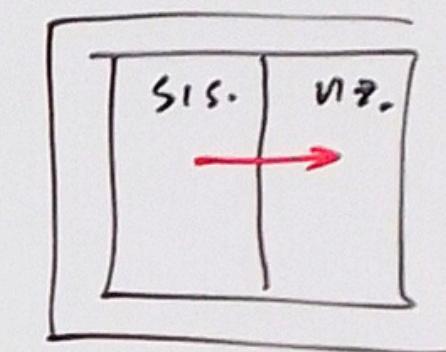
$$\left. \begin{aligned} & \Delta H^0 \\ & \delta H^0 \end{aligned} \right\}$$

$dH > 0$ ENDOTÉRMICA

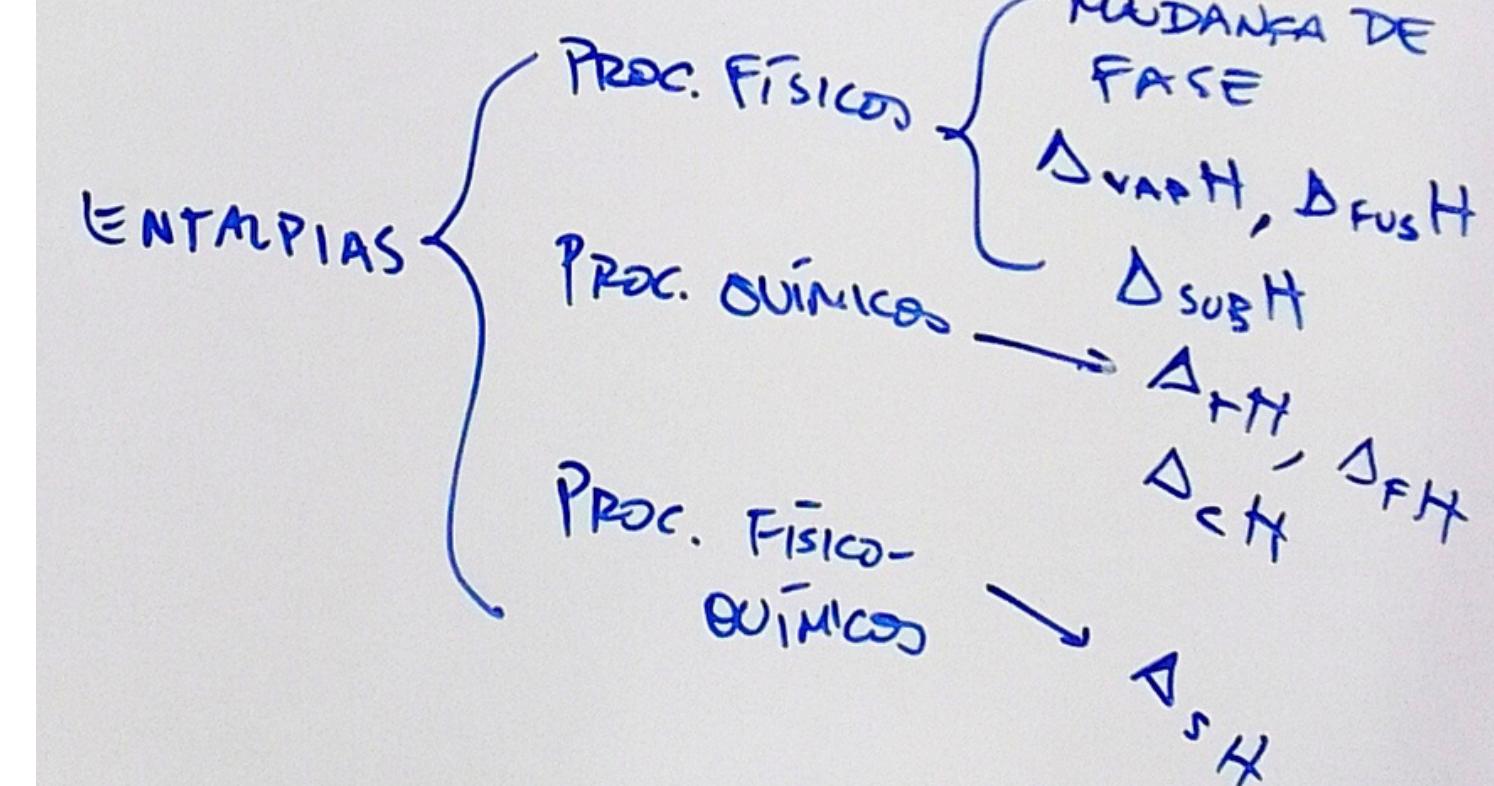
$dH < 0$ EXOTÉRMICO



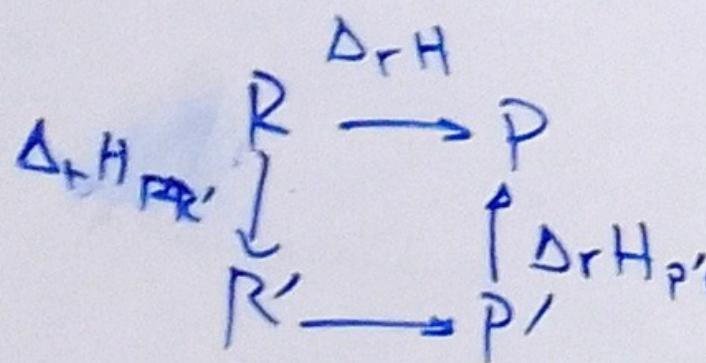
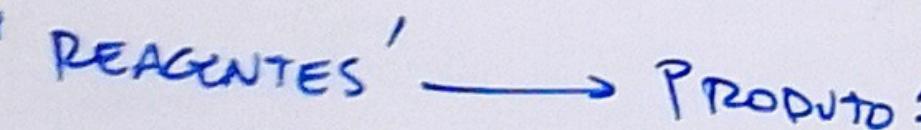
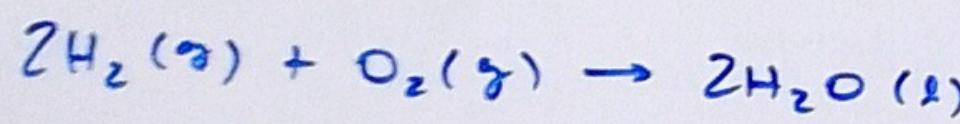
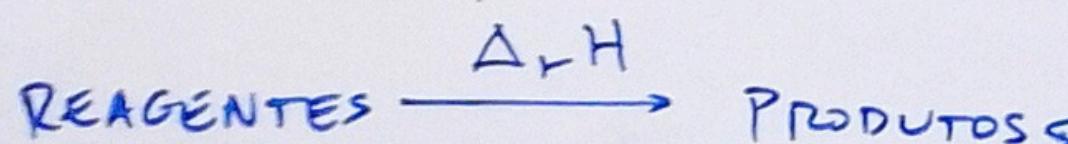
$dH > 0$
ENDOTÉRMICO



$dH < 0$
EXOTÉRMICO



ENTALPIA

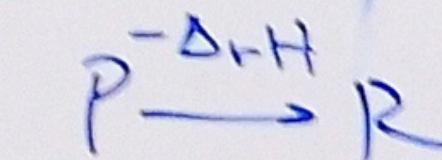
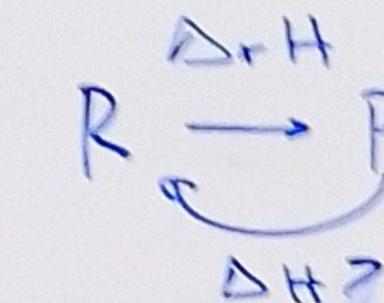


$$\begin{aligned} \Delta_r H_{R'P'} &= \Delta_r H_{RR'} + \Delta_r H_{R'R'^*} \\ &\quad + \Delta_r H_{R'P'^*} \end{aligned}$$

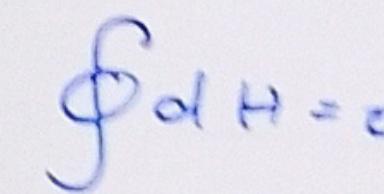
H ESS

H É FUNÇÃO DE ESTADO

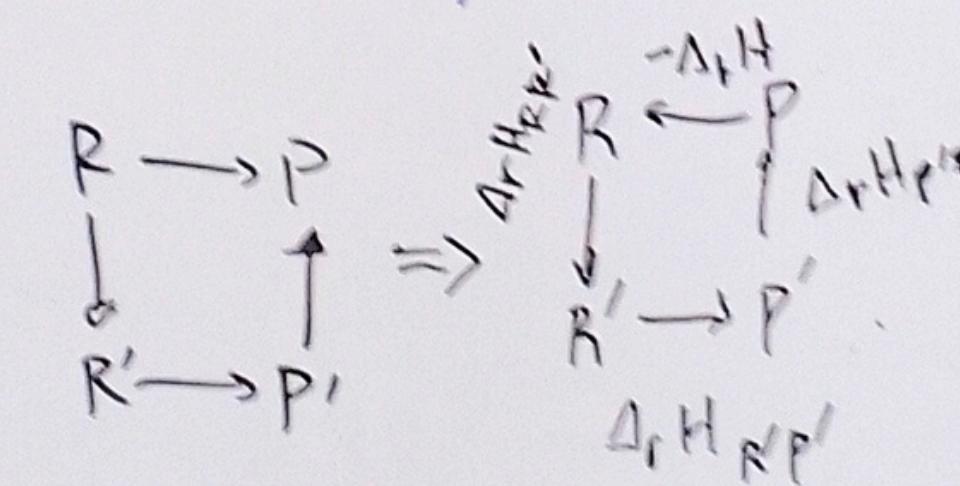
$$\oint dH = 0$$



$$\oint dU = 0$$



$$\begin{aligned} \Delta_r H + \Delta H &= 0 \\ \Delta H &= -\Delta_r H \end{aligned}$$



$$\oint dH = -\Delta_r H + \Delta_r H_{RR'} + \Delta_r H_{R'R'^*} + \Delta_r H_{R'P'^*} = 0$$

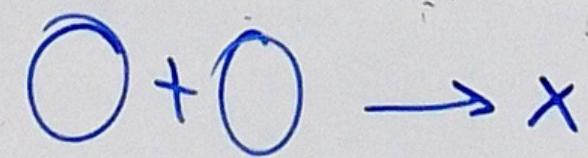
$$\underline{\Delta_r H = \Delta_r H_{RR'} + \Delta_r H_{R'P'} + \Delta_r H_{P'}}.$$

ENTALPIA

$$\int_A^B dU = U_B - U_A \xrightarrow{\text{PADRÃO}} \\ = (\underbrace{U_B - U_0}_{\Delta U_B^\circ}) - (\underbrace{U_A - U_0}_{\Delta U_A^\circ})$$

ENTALPIAS DE FORMAÇÃO

$\Delta_F H^\circ(X)$
 A ENTRALPIA DA REACAO DE FORMAÇÃO



AOS ELEMENTOS
 NA FORMA MAIS ESTÁVEL
 NA TEMPERATURA

