Fisica do Calor (4300159)

Prof. Adriano Mesquita Alencar
Dep. Física Geral
Instituto de Física da USP

B05

Energia Interna de um Gas Ideal

Provinha (3/4)

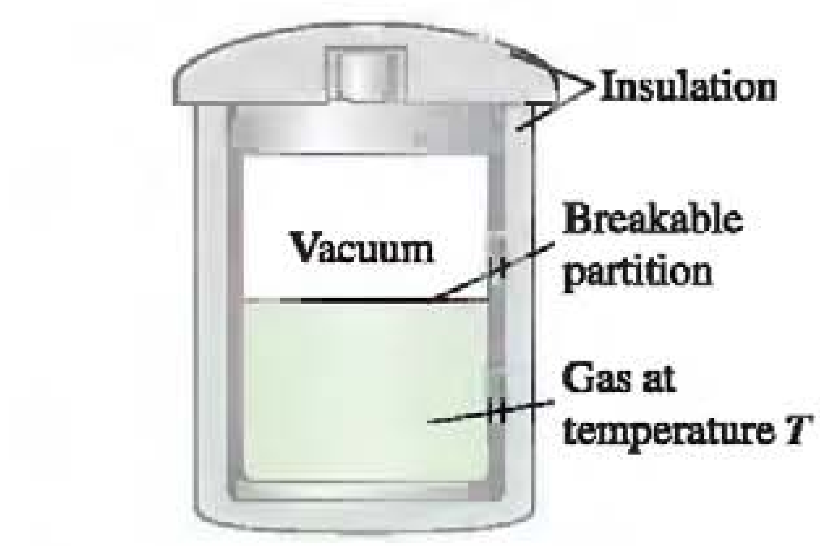
9.5 Um mol de um gás ideal, contido num recipiente munido de um pistão móvel, inicialmente a 20 °C, se expande isotermicamente até que seu volume aumenta de 50%. A seguir, é contraído, mantendo a pressão constante, até voltar ao volume inicial. Finalmente, é aquecido, a volume constante, até voltar à temperatura inicial, (a) Desenhe o diagrama *P-V* associado; (b) Calcule o trabalho total realizado pelo gás nesse processo.

Data	Programa do curso
August 9	Temperatura e escalas
August 12	Expansão Térmica
August 16	Calorimetria
August 19	Condução, convenção Radiação (Corpo Humano)
August 23	Equação de Estado
August 26	Propriedades moleculares da Matéria
August 30	**(Aula de Exercícios e Revisão)**
September 2	**Aula Modelo do Gas Ideal**
September 6	Feriado
September 9	Feriado
September 13	**Prova 3 1/4 - Temperatura e Calor** - Capacidade Têrmica
September 16	Velocidade molecular (Corpo Humano)
September 20	**(Aula de Exercícios e Revisão)**
September 23	**Prova 3 2/4 - Propriedades da Matéria - Aula Fases da matéria**
September 27	Prova 1: Temperatura, Calor e Propriedades da Matéria
September 30	Calor e trabalho
October 4	A primeira lei da Termodinâmica
October 7	Processos termodinâmicos
October 11	Semana de Ensino (IFUSP)
October 14	Semana de Ensino (IFUSP)
October 18	Termodinâmica do Gas Ideal
October 21	**(Aula de Exercícios e Revisão)**
October 25	**Prova 3 3/4 - Primeira Lei da Termodinâmica - Aula Processos adiabaticos**
October 28	Processos reversíveis e irreversíveis (Corpo Humano)
November 1	Maquinas térmicas, Ciclo de Otto e Refrigerador (Corpo Humano)
November 4	Segunda Lei da Termodinâmica
November 8	Ciclo de Carnot
November 11	**(Aula de Exercícios e Revisão)**
November 15	Feriado
November 18	Entropia Micro estados
November 22	**Prova 3 4/4 - Segunda Lei da Termodinâmica - Aula Micro estados**
November 25	Prova 2: Primeira e Segunda Lei da Termodinâmica
November 29	Prova Sub

Processos Isolados

$$\Delta U = 0 \qquad \text{e} \qquad Q = W = 0$$

19.17 The partition is broken (or removed) to start the free expansion of gas into the vacuum region.



T também é constante

A energia interna de um gas ideal depende APENAS da temperatura, independe da pressão e volume

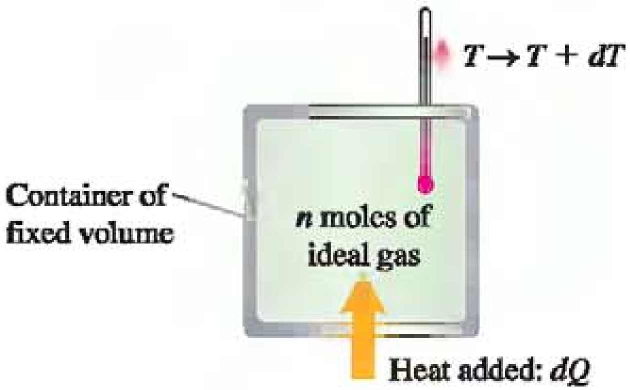
Para gases não ideais a temperatura muda durante expansão livre

U depende de energia potencial e cinética

Capacidade térmica de um gas ideal

19.18 Measuring the molar heat capacity of an ideal gas (a) at constant volume and (b) at constant pressure.

(a) Constant volume: $dQ = nC_V dT$



Porque eles seriam diferentes?

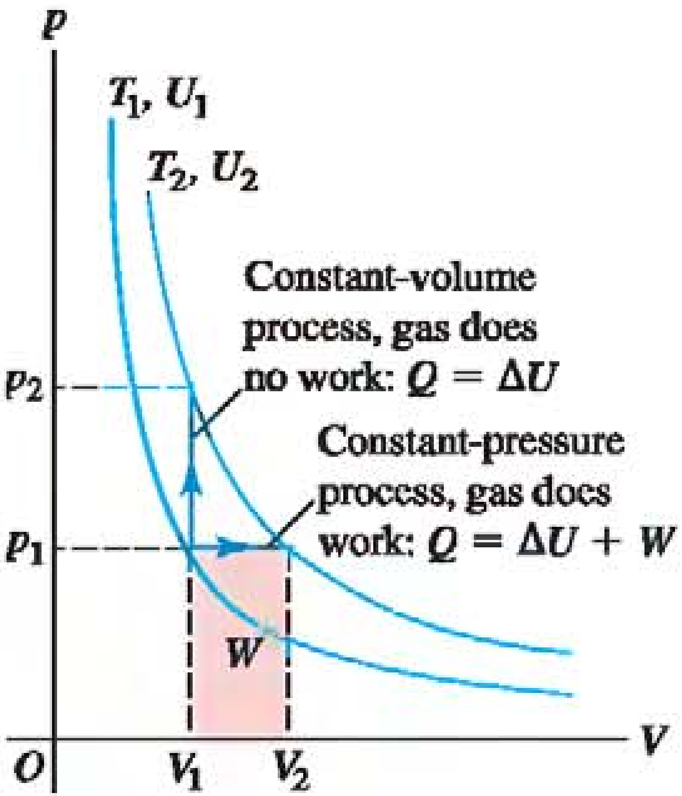
Volume constante

Sistema não realiza trabalho

$$Q = \Delta U$$

$$C_p > C_V$$

19.19 Raising the temperature of an ideal gas from T_1 to T_2 by a constant-volume or a constant-pressure process. For an ideal gas, U depends only on T, so ΔU is the same for both processes. But for the constant-pressure process, more heat Q must be added to both increase U and do work W. Hence $C_p > C_V$.



Por definição:

$$dQ = nC_v dt$$

Todavia (Primeira Lei):

$$dQ = dU + dW$$

como: $dW = 0$

$$dU = nC_v dt$$

dU depende apenas de *T*

Por definição:

$$dQ = nC_p dt$$

$$dW = pdV$$

$$dW = nRT$$

$$p_1 V = nRT$$

$$V = \frac{1}{p_1} nRT$$

$$dV = \frac{1}{p_1} nRdT$$

$$nC_p dT = dU + nRdT$$

$$nC_p dT = nC_v dT + nRdT$$

$$C_p = C_v + R$$

Table 19.1 **Molar Heat Capacities of Gases at Low Pressure**

Type of Gas	Gas	C_V (J/mol · K)	C_p (J/mol · K)	$C_p - C_V$ (J/mol · K)	$\gamma = C_p/C_V$
Monatomic	He	12.47	20.78	8.31	1.67
	Ar	12.47	20.78	8.31	1.67
Diatomic	H_2	20.42	28.74	8.32	1.41
	N_2	20.76	29.07	8.31	1.40
	O_2	20.85	29.17	8.31	1.40
	CO	20.85	29.16	8.31	1.40
Polyatomic	CO_2	28.46	36.94	8.48	1.30
	SO_2	31.39	40.37	8.98	1.29
	H_2S	25.95	34.60	8.65	1.33

Processos Adiabáticos

Ou o sistema esta isolado ou é rápido o suficiente para não sair ou entrar calor

$$Q = 0 \qquad \Delta U = -W$$

Para qualquer processo, seja o processo adiabático ou não:

$$dU = nC_v dt$$

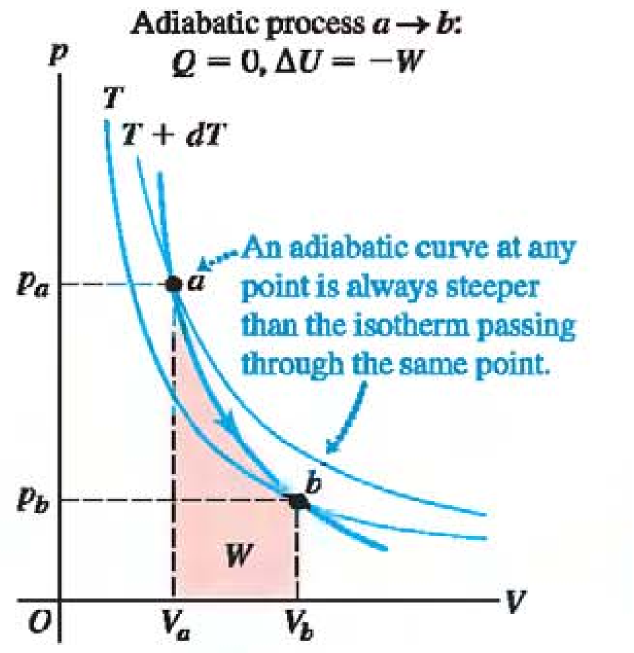
$$dW = pdV$$

Para um processo adiabatico

$$dU = -dW$$

$$-pdV = nC_v dT$$

19.20 A pV-diagram of an adiabatic ($Q = 0$) process for an ideal gas. As the gas expands from V_a to V_b, it does positive work W on its environment, its internal energy decreases ($\Delta U = -W < 0$), and its temperature drops from $T + dT$ to T. (An adiabatic process is also shown in Fig. 19.16.)



Processos Adiabáticos

$$-pdV = nC_v dT$$

$$p = nRT/V$$

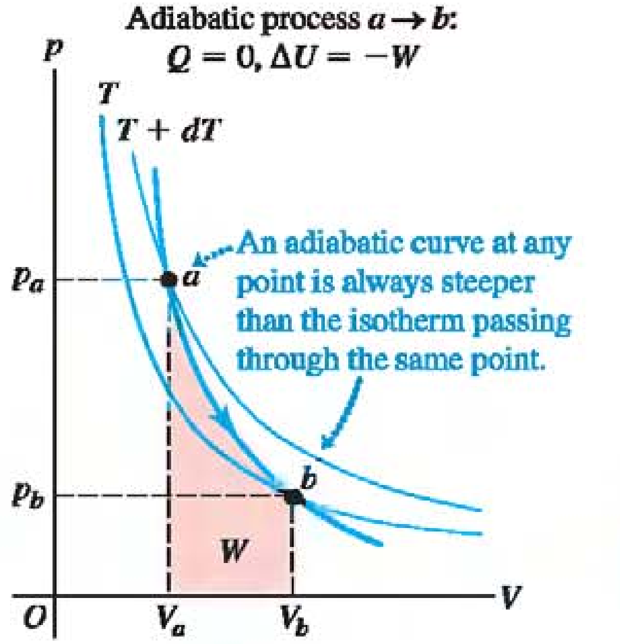
$$nC_v dT = -\frac{nRT}{V} dV$$

$$\frac{dT}{T} + \frac{R}{C_v}\frac{dV}{V} = 0$$

$$\frac{R}{C_v} = \frac{C_p - C_v}{C_v} = \frac{C_p}{C_v} - 1 = \gamma - 1$$

$$\frac{dT}{T} + (\gamma - 1)\frac{dV}{V} = 0$$

19.20 A pV-diagram of an adiabatic ($Q = 0$) process for an ideal gas. As the gas expands from V_a to V_b, it does positive work W on its environment, its internal energy decreases ($\Delta U = -W < 0$), and its temperature drops from $T + dT$ to T. (An adiabatic process is also shown in Fig. 19.16.)



Processos Adiabáticos

$$\frac{dT}{T} + (\gamma - 1)\frac{dV}{V} = 0$$

γ é sempre maior que 1, (γ -1) > 0

se $dV > 0$, isso implica $dT < 0$

se $dV < 0$, isso implica $dT > 0$

$$\int \frac{dT}{T} + \int (\gamma - 1)\frac{dV}{V} = 0$$

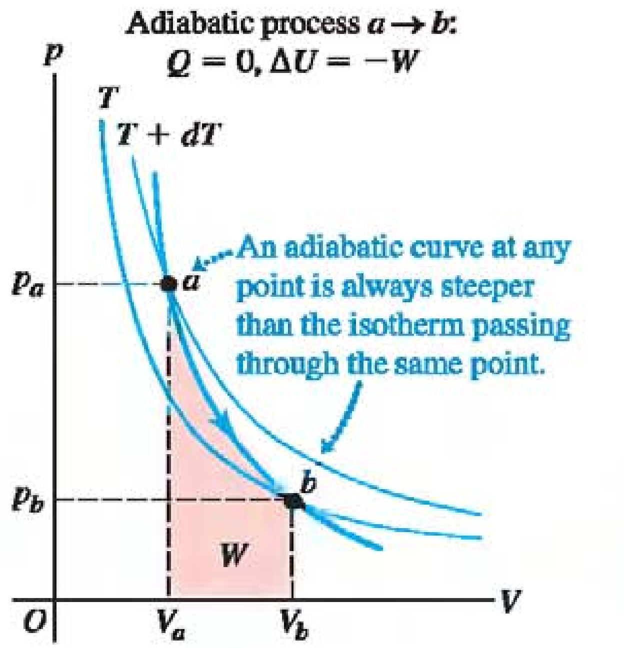
$$\ln T + (\gamma - 1)\ln V = \text{constante}$$

$$\ln T + \ln V^{\gamma - 1} = \text{constante}$$

$$\ln(TV^{\gamma - 1}) = \text{constante}$$

$$TV^{\gamma - 1} = \text{constante}$$

19.20 A pV-diagram of an adiabatic ($Q = 0$) process for an ideal gas. As the gas expands from V_a to V_b, it does positive work W on its environment, its internal energy decreases ($\Delta U = -W < 0$), and its temperature drops from $T + dT$ to T. (An adiabatic process is also shown in Fig. 19.16.)



Processos Adiabáticos

$$TV^{\gamma-1} = \text{constante}$$ T em Kelvin

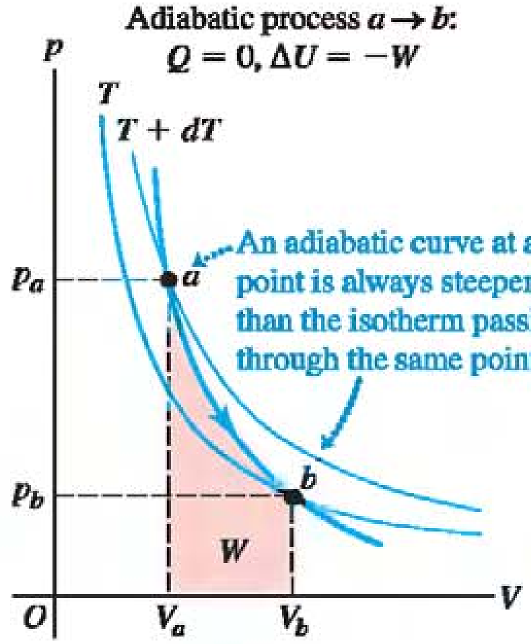
$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

Podemos encontrar a mesma relação para a pressão

$$T = pV/nR$$

$$p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$$

19.20 A pV-diagram of an adiabatic ($Q = 0$) process for an ideal gas. As the gas expands from V_a to V_b, it does positive work W on its environment, its internal energy decreases ($\Delta U = -W < 0$), and its temperature drops from $T + dT$ to T. (An adiabatic process is also shown in Fig. 19.16.)



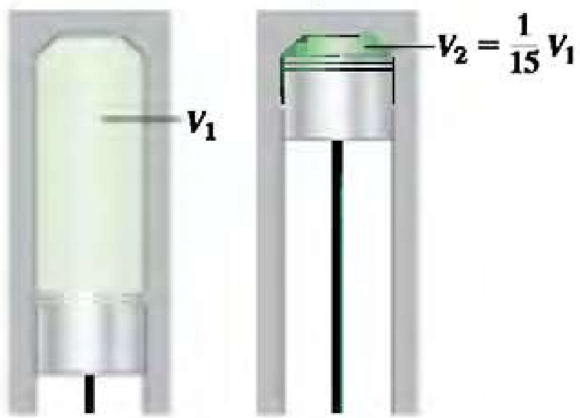
Example 19.7 Adiabatic compression in a diesel engine

The compression ratio of a diesel engine is 15 to 1; this means that air in the cylinders is compressed to $\frac{1}{15}$ of its initial volume (Fig. 19.21). If the initial pressure is 1.01×10^5 Pa and the initial temperature is 27°C (300 K), find the final pressure and the temperature after compression. Air is mostly a mixture of diatomic oxygen and nitrogen; treat it as an ideal gas with $\gamma = 1.40$.

SOLUTION

IDENTIFY: Since this problem involves the adiabatic compression of an ideal gas, we can use the ideas of this section.

19.21 Adiabatic compression of air in a cylinder of a diesel engine.



SET UP: We are given the initial pressure $p_1 = 1.01 \times 10^5$ Pa and the initial temperature $T_1 = 300$ K, and we are told that the ratio of initial and final volumes is $V_1/V_2 = 15$. We can find the final temperature T_2 using Eq. (19.22) and the final pressure p_2 using Eq. (19.24).

EXECUTE: From Eq. (19.22),

$$T_2 = T_1\left(\frac{V_1}{V_2}\right)^{\gamma-1} = (300\ \text{K})(15)^{0.40} = 886\ \text{K} = 613°\text{C}$$

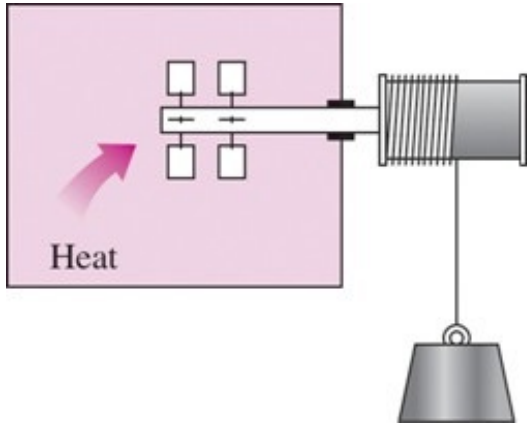
From Eq. (19.24),

$$p_2 = p_1\left(\frac{V_1}{V_2}\right)^{\gamma} = (1.01 \times 10^5\ \text{Pa})(15)^{1.40}$$
$$= 44.8 \times 10^5\ \text{Pa} = 44\ \text{atm}$$

EVALUATE: If the compression had been isothermal, the final pressure would have been 15 atm, but because the temperature also increases during an adiabatic compression, the final pressure is much greater. When fuel is injected into the cylinders near the end of the compression stroke, the high temperature of the air attained during compression causes the fuel to ignite spontaneously without the need for spark plugs.

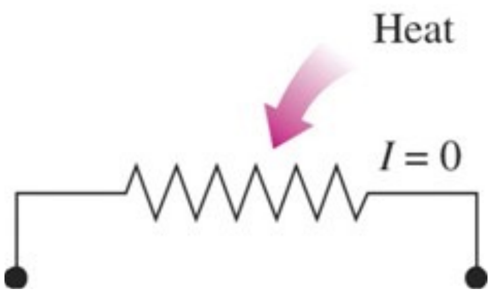
Segunda Lei da Termodinâmica

Um copo de café nunca esquenta em um ambiente frio



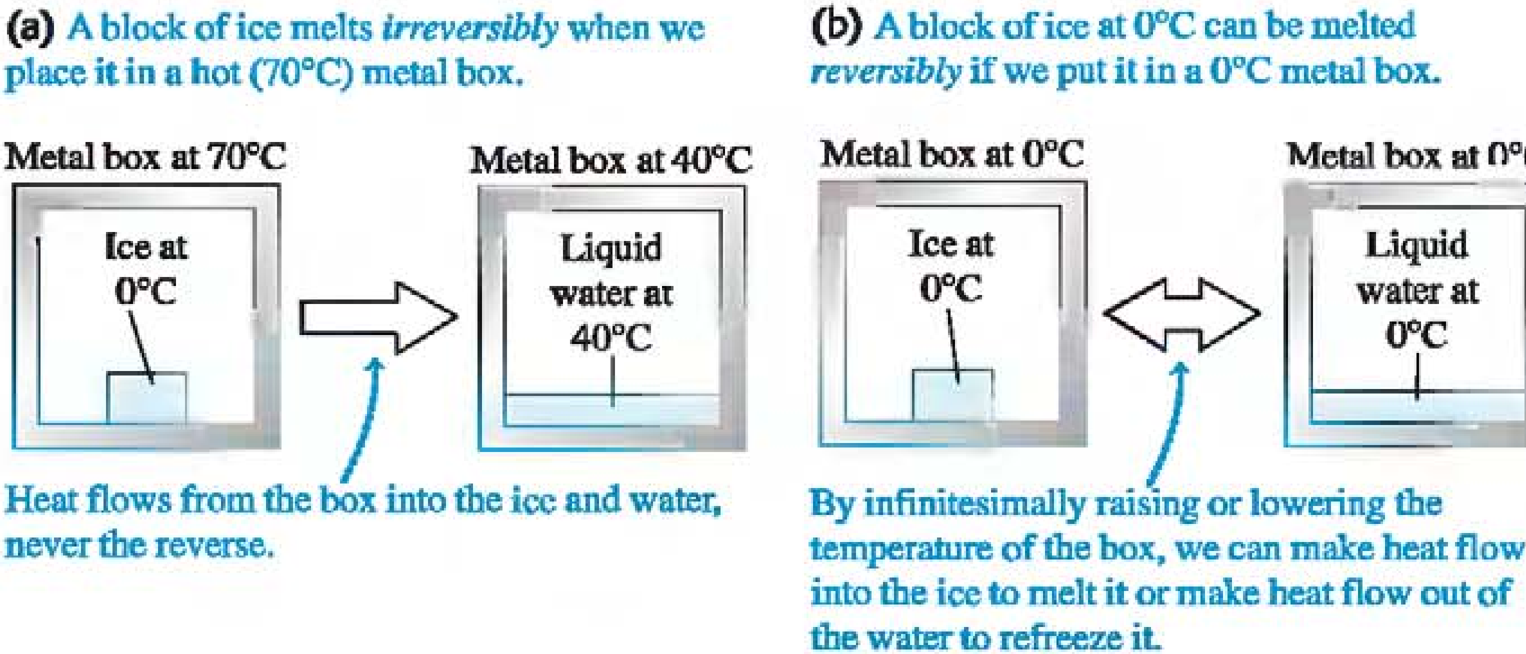
Transferir calor para uma roda com remos não vai fazer ela rodar

Transferir calor para uma resistência não vai gerar eletricidade



Esses processos não podem ocorrer, mesmo que eles não violem a primeira lei da termodinâmica

Irreversibilidade!!!



Idealizado reversível, muito proximo ao equilíbrio termodinâmico