Fisica do Calor (4300159)

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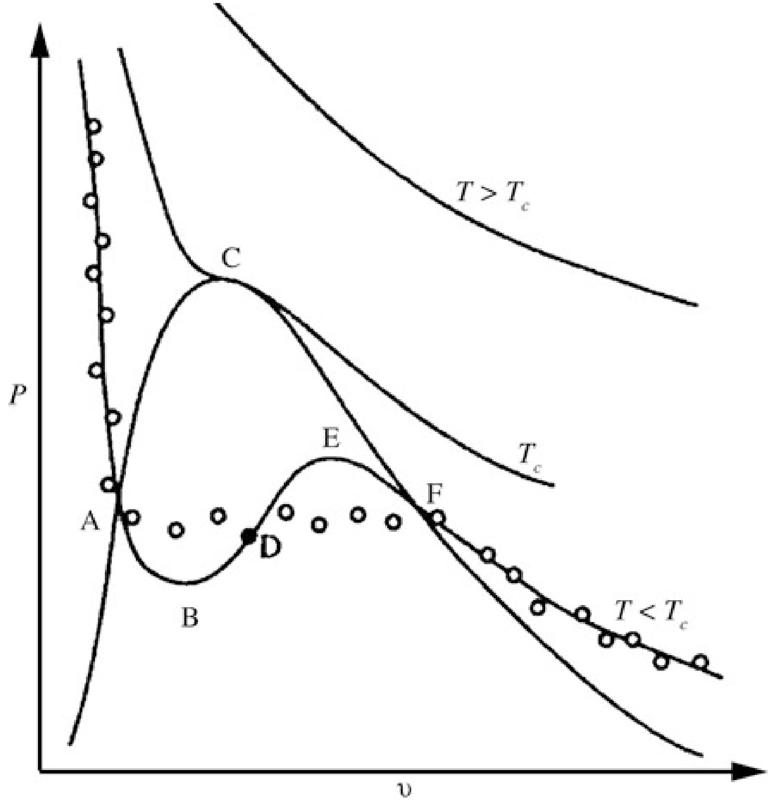
A05

Equação de Estado



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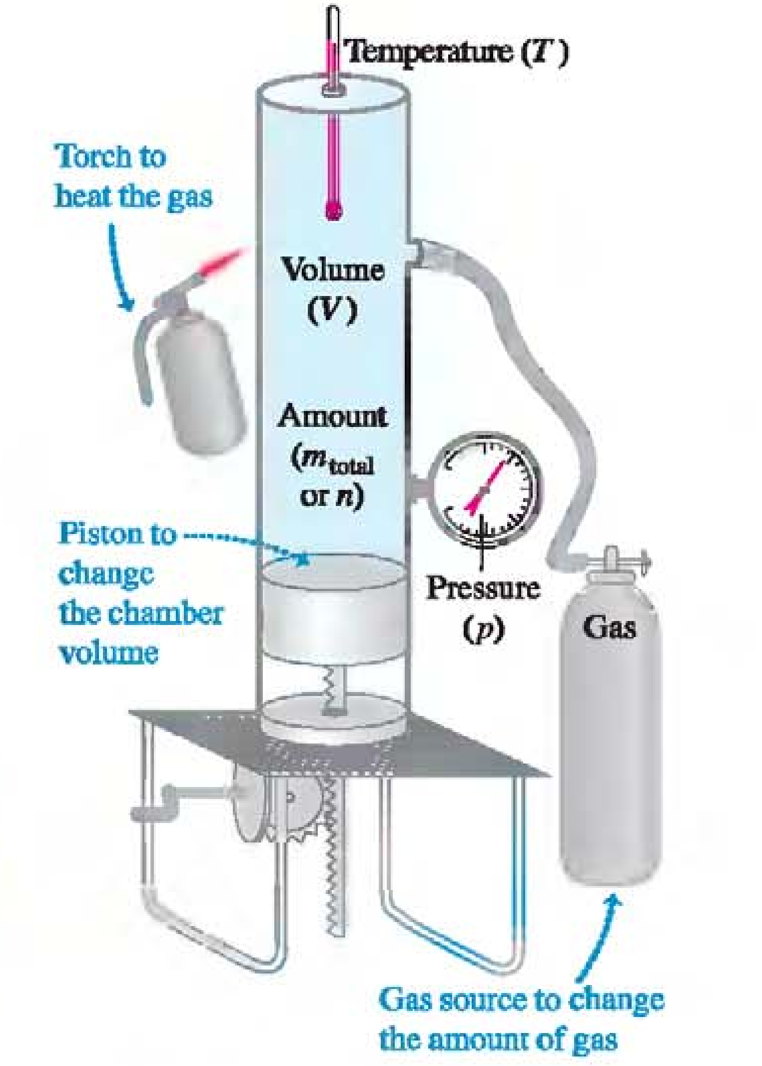
outubro 25	**Prova 3 3/4 - Primeira Lei da Termodinâmica - Aula Processos adiabaticos**
outubro 28	Processos reversíveis e irreversíveis (Corpo Humano)
novembro 1	Maquinas térmicas, Ciclo de Otto e Refrigerador (Corpo Humano)
novembro 4	Segunda Lei da Termodinâmica
novembro 8	Ciclo de Carnot
novembro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

Variáveis de Estado

Volume de um gás depende…
Depende da temperatura T, Pressão p e quantidade de substancia m ou n.
A relação entre p, V, T e m (ou n) é muito simples e conhecida como Equação de Estado…
chamamos assim, mesmo quando a equação não é conhecida.



Equação de Estado

A pressão constante
(Dilatação termica [A02 P7]):

$$V = V_0(1 + 3\alpha\Delta T)$$

Como o volume varia com a pressão? (*T* constante)

A temperatura constante:

$$V = V_0(1 - k\Delta p)$$

$$V = V_0(1 + \beta\Delta T - k\Delta p)$$

À baixa pressão e alta temperatura os gases se comportam em geral como perfeitos

Equação do gás Ideal

Lei de Boyle:

$$PV = \gamma_T$$

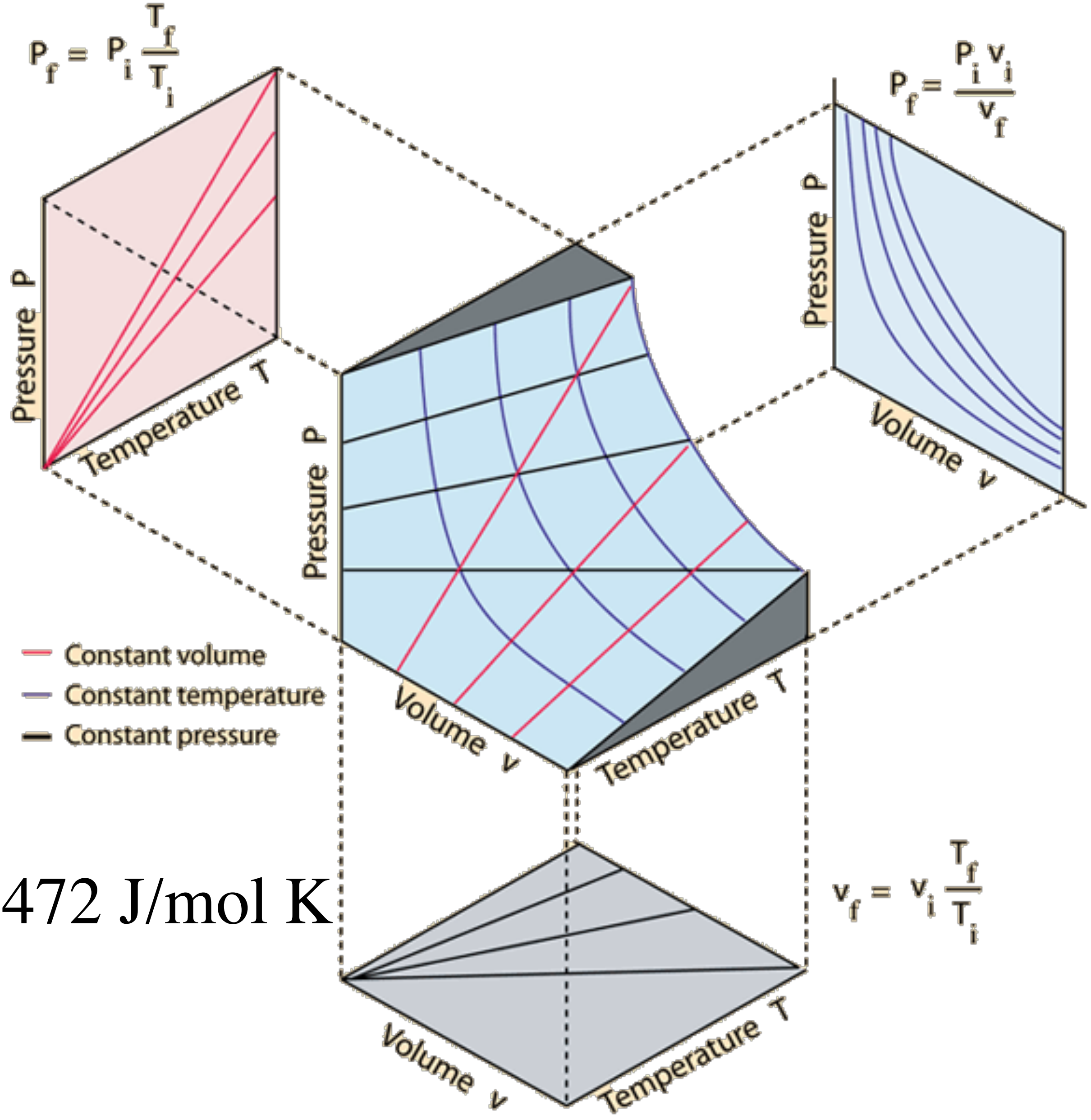
Lei de Amonton:

$$\frac{P}{T} = \gamma_V$$

Lei de Charles:

$$\frac{V}{T} = \gamma_P$$

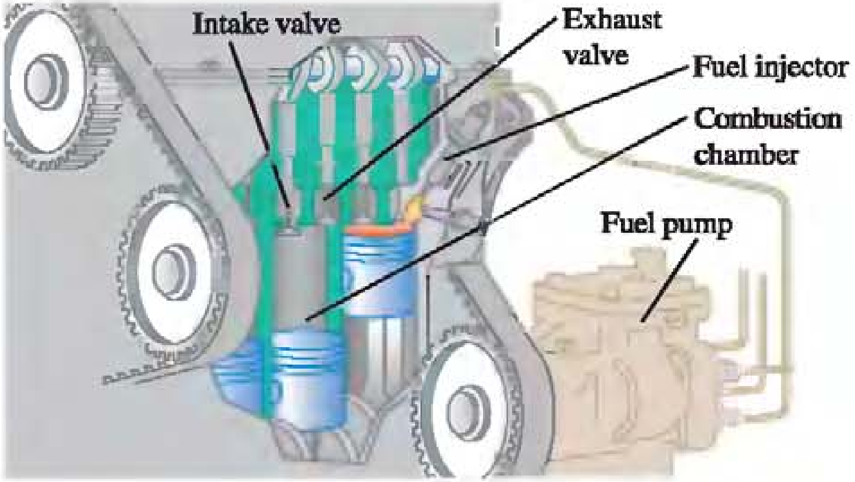
$$PV = nRT \qquad R = 8.314472 \text{ J/mol K}$$



Example 18.2 Compressing gas in an automobile engine

In an automobile engine, a mixture of air and gasoline is compressed in the cylinders before being ignited. A typical engine has a compression ratio of 9.00 to 1; this means that the gas in the cylinders is compressed to $1/(9.00)$ of its original volume (Fig. 18.3). The initial pressure is 1.00 atm and the initial temperature is 27°C. If the pressure after compression is 21.7 atm, find the temperature of the compressed gas.

18.3 Cutaway of an automobile engine. While the air–gasoline mixture is being compressed prior to ignition, the intake and exhaust valves are both in the closed (up) position.



SOLUTION

IDENTIFY: In this problem we are asked to compare two states of the same quantity of ideal gas. The target variable is the temperature in the compressed state. The intake and exhaust valves at the top of the cylinder in Fig. 18.3 stay closed during the compression, so the quantity of gas is constant.

SET UP: Let state 1 be the uncompressed gas, and let state 2 be the fully compressed gas. Then $p_1 = 1.00\ \text{atm}, p_2 = 21.7\ \text{atm}$, and $V_1 = 9.00\ V_2$. Converting temperature to the Kelvin scale by adding 273, we get $T_1 = 300\ \text{K}$; the final temperature T_2 is the target variable. The number of moles of gas n is constant, so we can use Eq. (18.6).

EXECUTE: Solving Eq. (18.6) for the temperature T_2 of the compressed gas, we get

$$\begin{aligned} T_2 &= T_1\frac{p_2V_2}{p_1V_1} = (300\ \text{K})\frac{(21.7\ \text{atm})\ V_2}{(1.00\ \text{atm})(9.00\ V_2)} \\ &= 723\ \text{K} = 450°\text{C} \end{aligned}$$

We didn't need to know the values of V_1 and V_2, only their ratio.

EVALUATE: Note that T_2 is the temperature of the air–gasoline mixture *before* the mixture is ignited; when burning starts, the temperature becomes higher still.

Example 18.3 Mass of air in a scuba tank

A typical tank used for scuba diving has a volume of 11.0 L (about 0.4 ft^3) and a gauge pressure, when full, of 2.10×10^7 Pa (about 3000 psig). The "empty" tank contains 11.0 L of air at 21°C and 1 atm $(1.013 \times 10^5 \text{ Pa})$. When the tank is filled with hot air from a compressor, the temperature is 42°C and the gauge pressure is 2.11×10^7 Pa. What mass of air was added? (Air is a mixture of gases, about 78% nitrogen, 21% oxygen, and 1% miscellaneous; its average molar mass is $28.8 \text{ g/mol} = 28.8 \times 10^{-3} \text{ kg/mol}$.)

SOLUTION

IDENTIFY: Our target variable is the *difference* between the mass present at the beginning (state 1) and at the end (state 2).

SET UP: We are given the molar mass of air, so we can use Eq. (18.2) to find the target variable if we know the number of moles present in states 1 and 2. We determine n_1 and n_2 by applying Eq. (18.3) to each state individually.

EXECUTE: We must remember to convert the temperatures to the Kelvin scale by adding 273 and to convert the pressure to absolute by adding 1.013×10^5 Pa. From Eq. (18.3), the number of moles n_1 in the "empty" tank is

$$n_1 = \frac{p_1V_1}{RT_1} = \frac{(1.013 \times 10^5 \text{ Pa})(11.0 \times 10^{-3} \text{ m}^3)}{(8.314 \text{ J/mol} \cdot \text{K})(294 \text{ K})} = 0.46 \text{ mol}$$

The volume of the metal tank is hardly affected by the increased pressure, so $V_1 = V_2$. The number of moles in the full tank is

$$n_2 = \frac{p_2V_2}{RT_2} = \frac{(2.11 \times 10^7 \text{ Pa})(11.0 \times 10^{-3} \text{ m}^3)}{(8.314 \text{ J/mol} \cdot \text{K})(315 \text{ K})} = 88.6 \text{ mol}$$

We added $n_2 - n_1 = 88.6 \text{ mol} - 0.46 \text{ mol} = 88.1$ mol to the tank. From Eq. (18.2), the added mass is $M(n_2 - n_1) = (28.8 \times 10^{-3} \text{ kg/mol})(88.1 \text{ mol}) = 2.54 \text{ kg}$.

EVALUATE: The added mass is not insubstantial: You could certainly use a scale to determine whether the tank was empty or full.

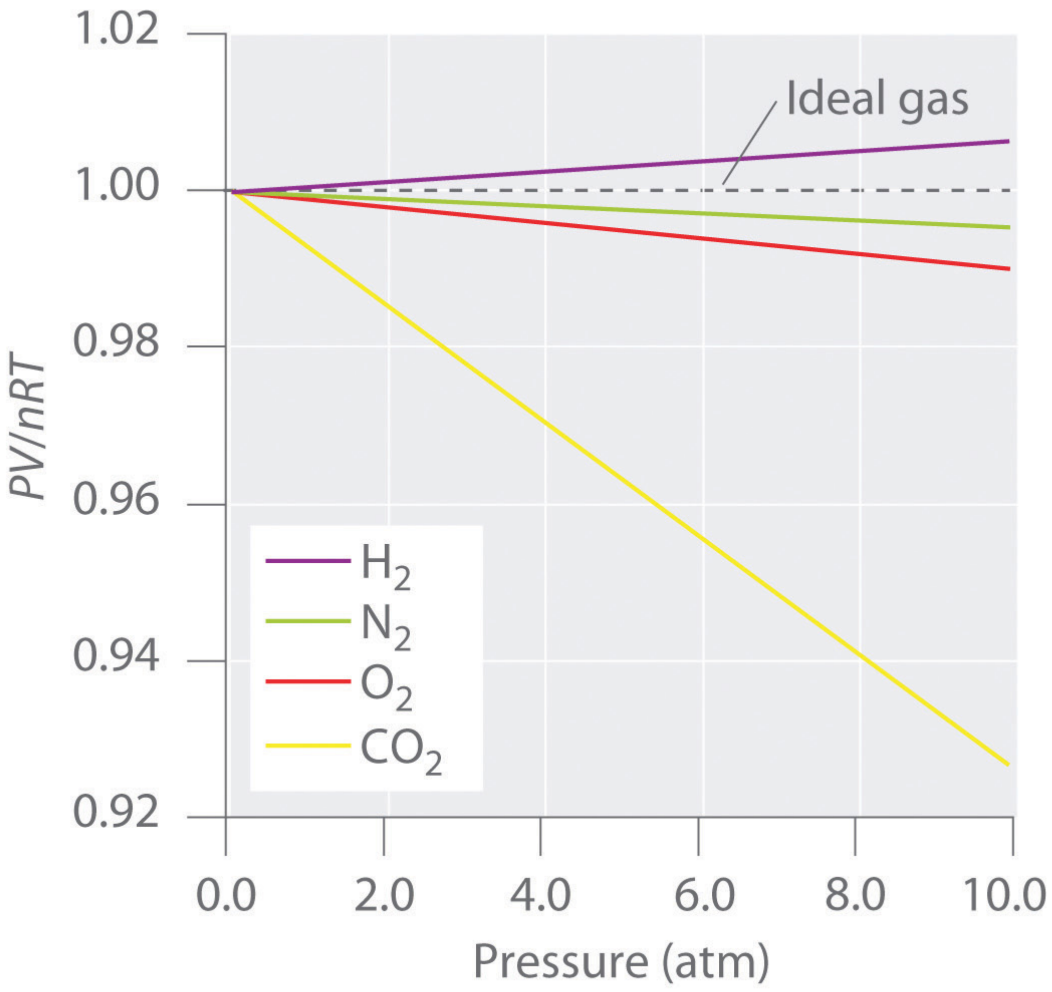
Could this problem have been solved in the same way as Example 18.2? The volume is constant, so $p/nT = R/V$ is constant and $p_1/n_1T_1 = p_2/n_2T_2$; this can be solved for n_2/n_1, the ratio of the final and initial numbers of moles. But we need the *difference* of these two numbers, not the ratio, so this equation by itself isn't enough to solve the problem.

Problemas na Equação do gás Ideal

$$PV = nRT$$

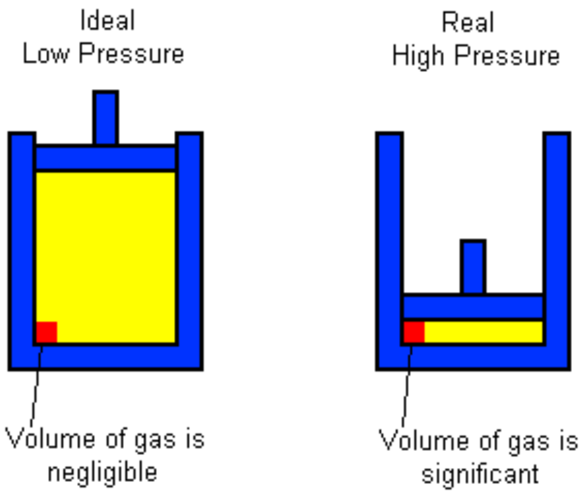
R = 8.314472 J/mol K

Ideal



$$V = \frac{nRT}{P}$$

$$\lim_{P\to\infty}\left(\frac{nRT}{P}\right) = 0$$



Equação do gás não Ideal

$PV = nRT$ $R = 8.314472$ J/mol K Ideal

Uma modificação da lei dos gases ideais foi proposta por Johannes D. van der Waals em 1873 para ter em conta o **tamanho molecular** e **forças de interação molecular**.

Eq. do van der Waals

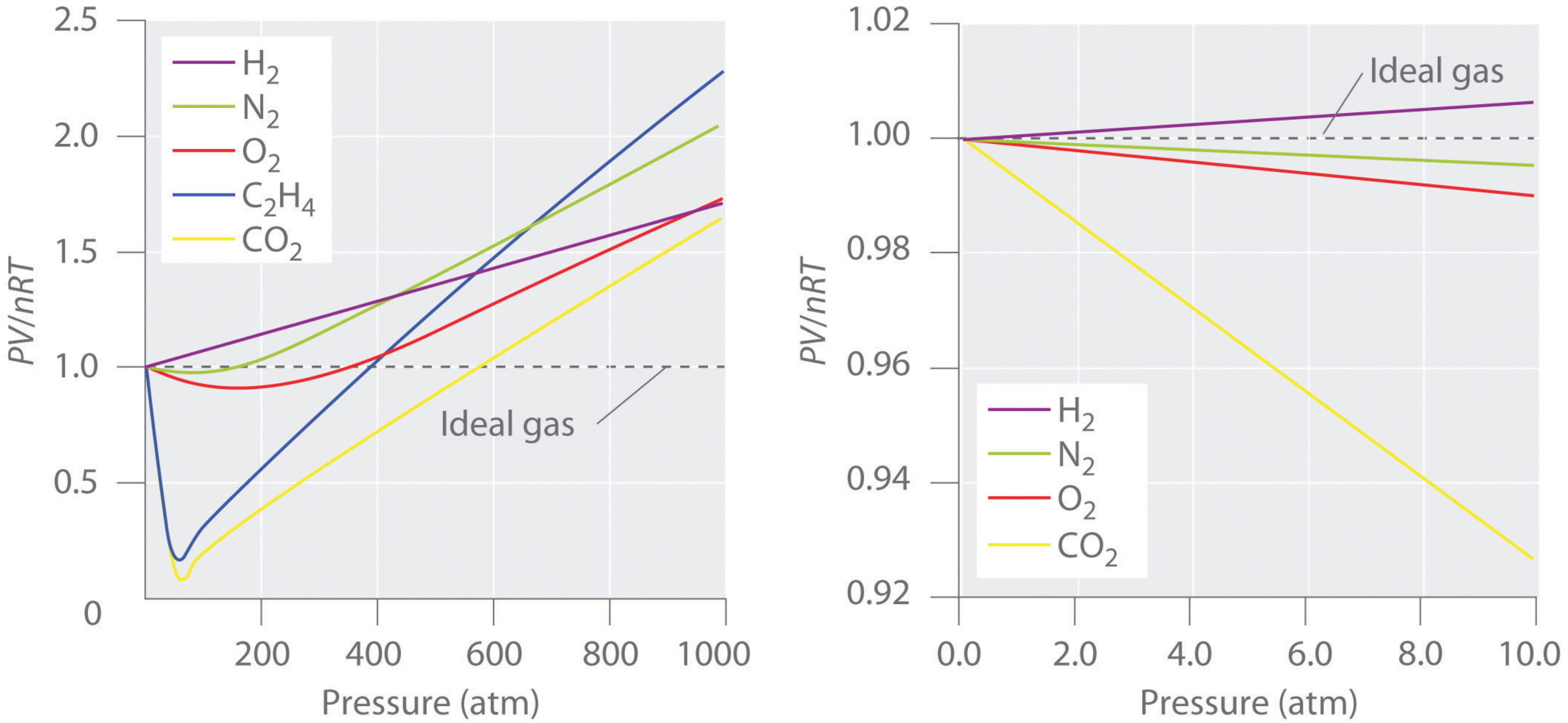
$$\left[P + \frac{a}{\left(\frac{V}{n}\right)^2}\right]\left(\frac{V}{n} - b\right) = RT$$

Gas Não Ideal

Coeficiente de van der Waals		
Gas	***a*** **(Pa m³)**	***b*** **(m³/mol)**
Helium	3.46×10^{-3}	23.71×10^{-6}
Neon	2.12×10^{-2}	17.10×10^{-6}
Hydrogen	2.45×10^{-2}	26.61×10^{-6}
Carbon dioxide	3.96×10^{-1}	42.69×10^{-6}
Water vapor	5.47×10^{-1}	30.52×10^{-6}

$v = V/n$ volume molar especifico

Equação do gás não Ideal



(a) *PV/nRT* at high pressures **(b) *PV/nRT* at low pressures**

$$PV = nRT\left[1 + \frac{a}{\left(\frac{V}{n}\right)^1} + \frac{b}{\left(\frac{V}{n}\right)^2} + \frac{c}{\left(\frac{V}{n}\right)^3} + \dots\right]$$

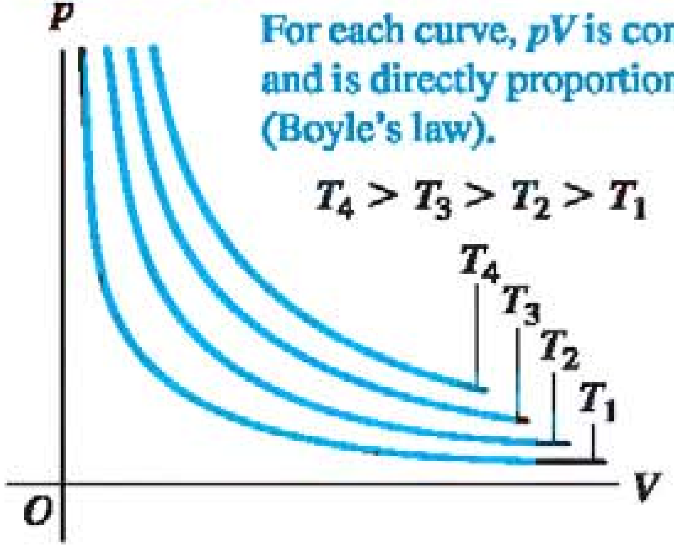
Nao Ideal

Eq. do Virial

Diagrama pV

18.6 Isotherms, or constant-temperature curves, for a constant amount of an ideal gas.

Each curve represents pressure as a function of volume for an ideal gas at a single temperature.

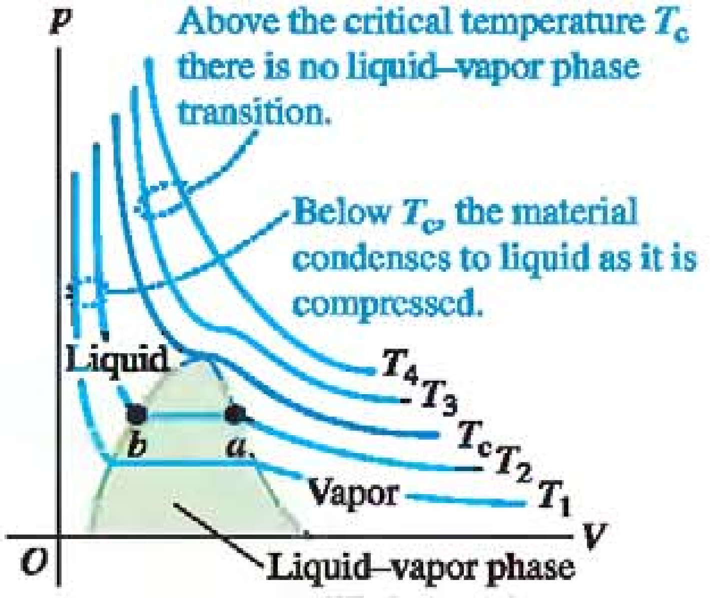


For each curve, pV is constant and is directly proportional to T (Boyle's law).

$T_4 > T_3 > T_2 > T_1$

18.7 A pV-diagram for a nonideal gas, showing isotherms for temperatures above and below the critical temperature T_c. The liquid–vapor equilibrium region is shown as a green shaded area. At still lower temperatures the material might undergo phase transitions from liquid to solid or from gas to solid; these are not shown in this diagram.

$T_4 > T_3 > T_c > T_2 > T_1$

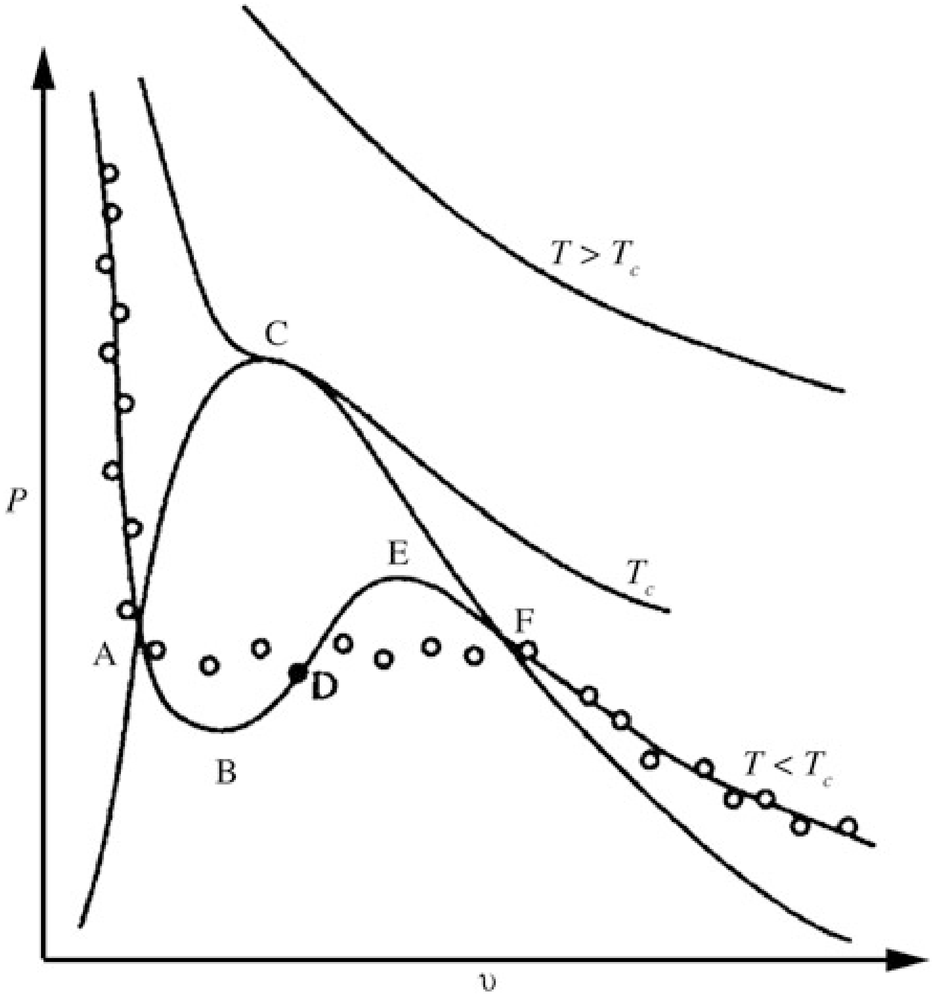


Above the critical temperature T_c there is no liquid–vapor phase transition.

Below T_c, the material condenses to liquid as it is compressed.

Liquid–vapor phase equilibrium region

Fig. 2.5 *p-v* diagram for pure substance showing isotherms in the region of critical point. *Solid lines* represent the values predicted by the Van der Waals equation of state. *Points* represents the experimental values



$$p = \frac{\Re T}{v - b} - \frac{a}{v^2} \tag{2.7}$$