Capítulo 18

PROPIEDADES TERMICAS DE LA MATERIA.
GASES IDEALES

“Science is a way of thinking much more than it is a body of knowledge.”

– Carl Sagan

Goals for Chapter 18

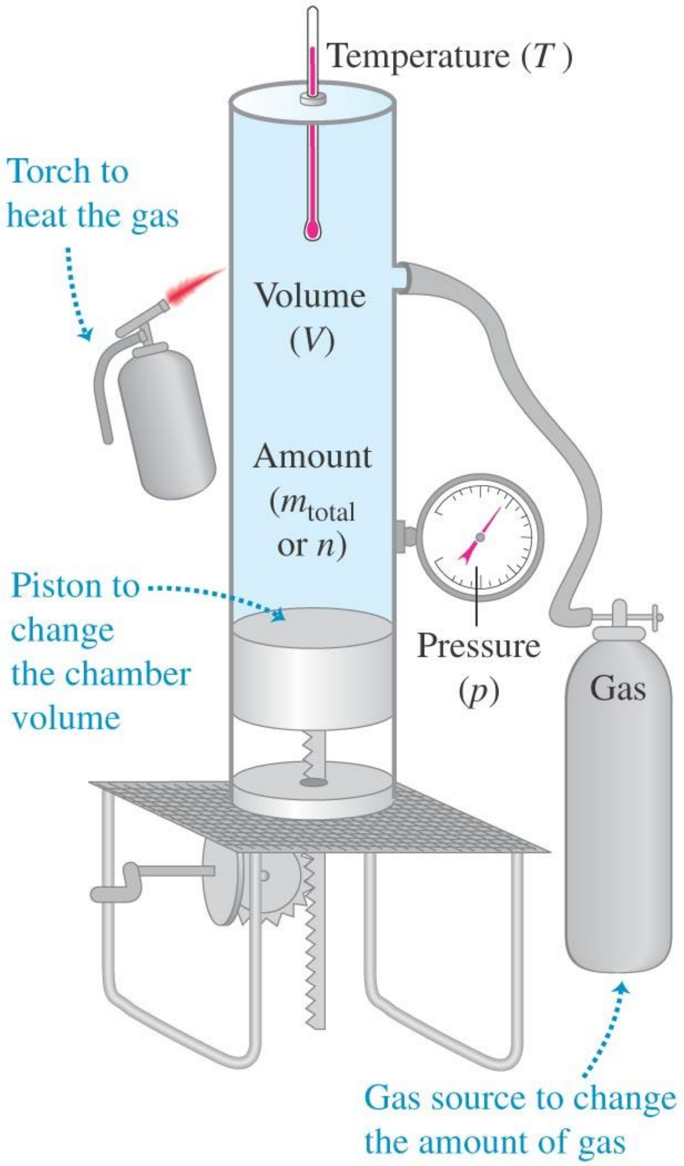
- To study equations of state
- To apply the molecular properties of matter
- To consider the kinetic-molecular model of an ideal gas
- To calculate heat capacities
- To consider molecular speeds
- To study phases of matter

Introduction

- Cooking is an artistic combination of burning fuel, careful control of heat, manipulation of molecules, and creative presentation. In the figure at right, you can see some students following a lesson in these very ideas.
- We'll study equations of state that describe the interaction of state variables like pressure, volume, and temperature.

Equations of state

- A first model for describing the behavior of a gas is the ideal-gas equation.
- Active study of gases is done by changing pressure, volume, temperature, or quantity of material and observing the result.



Ecuación del Gas Ideal

- Un mol de cualquier elemento químico es la cantidad de materia que contiene tantos átomos como los que hay en 12 g de carbono. La masas atómica de un átomo (o masa molecular de un compuesto) es equivalente a la masa de 1 mol. $m_{total} = nM$
- 1 mol de agua tiene una masa de 18 g (16 de O y 2 de H)
- 1 cc de aire contiene aprox. 2.7×10^{19} moléculas.
- La descripción macroscópica de un compuesto puede describir el comportamiento microscópico del mismo. Por ello se usan algunas variables conocidas como variables de estado: presión, volumen, empeeratura, número de moles, densidad, etc.
- En un gas ideal, la expresión que relaciona estas variables se conoce como Ecuación de Estado

$$pV=nRT$$

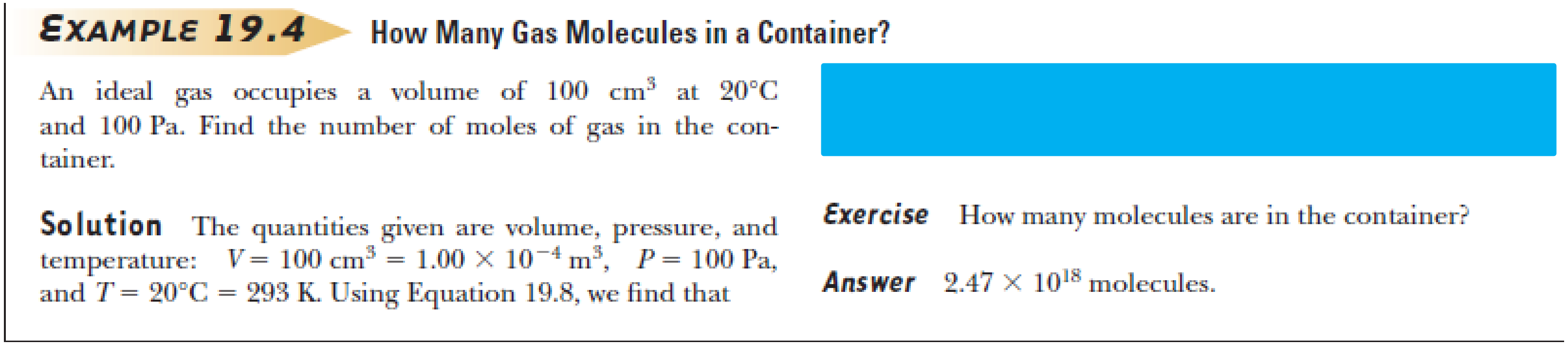
Tomás Rada Crespo Ph.D.

Ecuación del Gas Ideal

- N: número de moles en un gas
- $R=8.31\ J/mol*K$: Constante Universal de los gases
- T temperatura en Kelvin
- 1 mol de cualquier gas ocupa 22,4 Litros, a presión y temperatura estándar (1 atm y 273 K)
- El número de moléculas por moles es el **número de Avogadro** N_A, $N_A=6.02\text{x}10^{23}$ moléculas por mol, el número de moléculas es $N= N_A*n$
- La ley del gas ideal, se expresa como:

$$pV=NkT$$

k es la constante de Boltzmann $=R/ N_A=1.38\text{x}10^{-23}\ J/K$



EXAMPLE 19.4 How Many Gas Molecules in a Container?

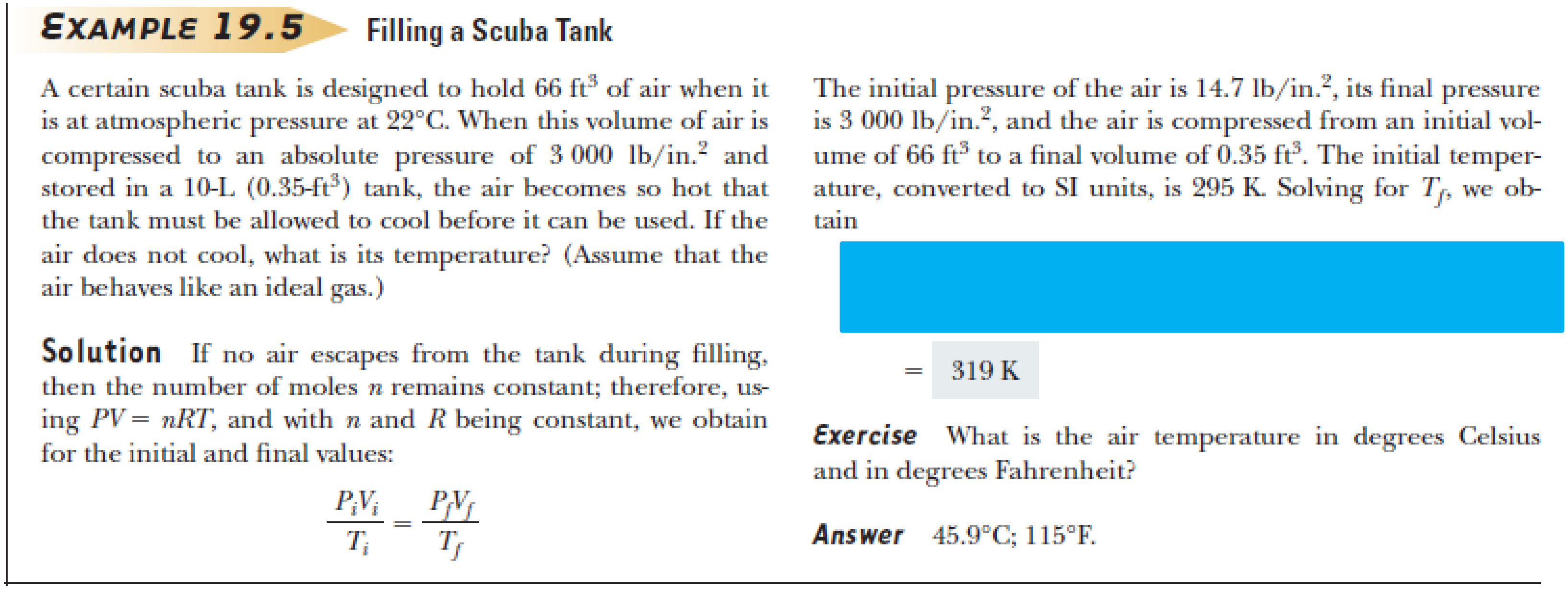
An ideal gas occupies a volume of 100 cm^3 at 20°C and 100 Pa. Find the number of moles of gas in the container.

Solution The quantities given are volume, pressure, and temperature: $V = 100\ \text{cm}^3 = 1.00 \times 10^{-4}\ \text{m}^3$, $P = 100$ Pa, and $T = 20°\text{C} = 293$ K. Using Equation 19.8, we find that

[redacted]

Exercise How many molecules are in the container?

Answer 2.47×10^{18} molecules.



EXAMPLE 19.5 Filling a Scuba Tank

A certain scuba tank is designed to hold 66 ft^3 of air when it is at atmospheric pressure at 22°C. When this volume of air is compressed to an absolute pressure of 3 000 lb/in.^{2} and stored in a 10-L (0.35-ft^3) tank, the air becomes so hot that the tank must be allowed to cool before it can be used. If the air does not cool, what is its temperature? (Assume that the air behaves like an ideal gas.)

Solution If no air escapes from the tank during filling, then the number of moles n remains constant; therefore, using $PV = nRT$, and with n and R being constant, we obtain for the initial and final values:

$$\frac{P_iV_i}{T_i} = \frac{P_fV_f}{T_f}$$

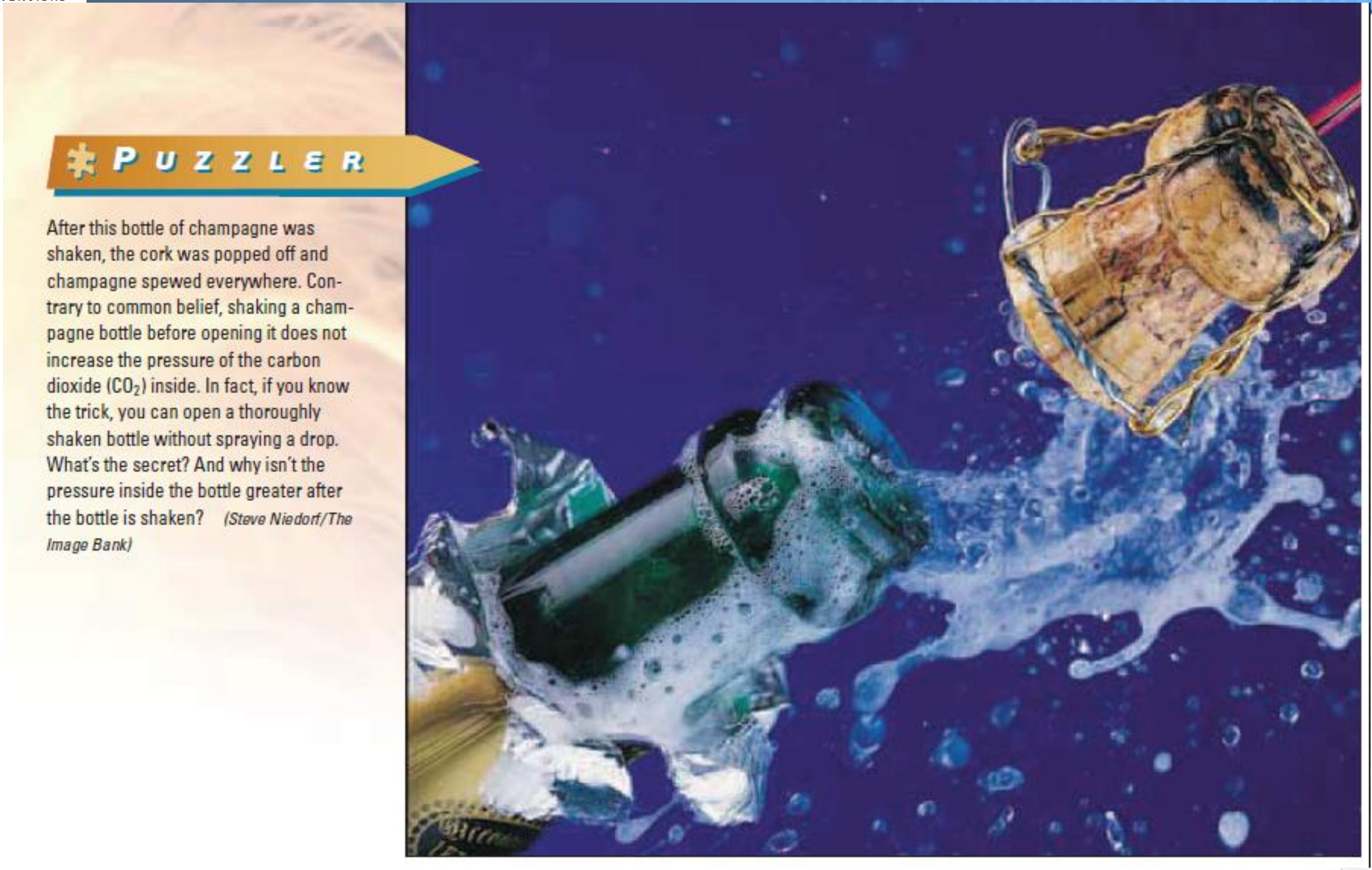
The initial pressure of the air is 14.7 lb/in.^{2}, its final pressure is 3 000 lb/in.^{2}, and the air is compressed from an initial volume of 66 ft^3 to a final volume of 0.35 ft^3. The initial temperature, converted to SI units, is 295 K. Solving for T_f, we obtain

[redacted]

$$= \boxed{319\ \text{K}}$$

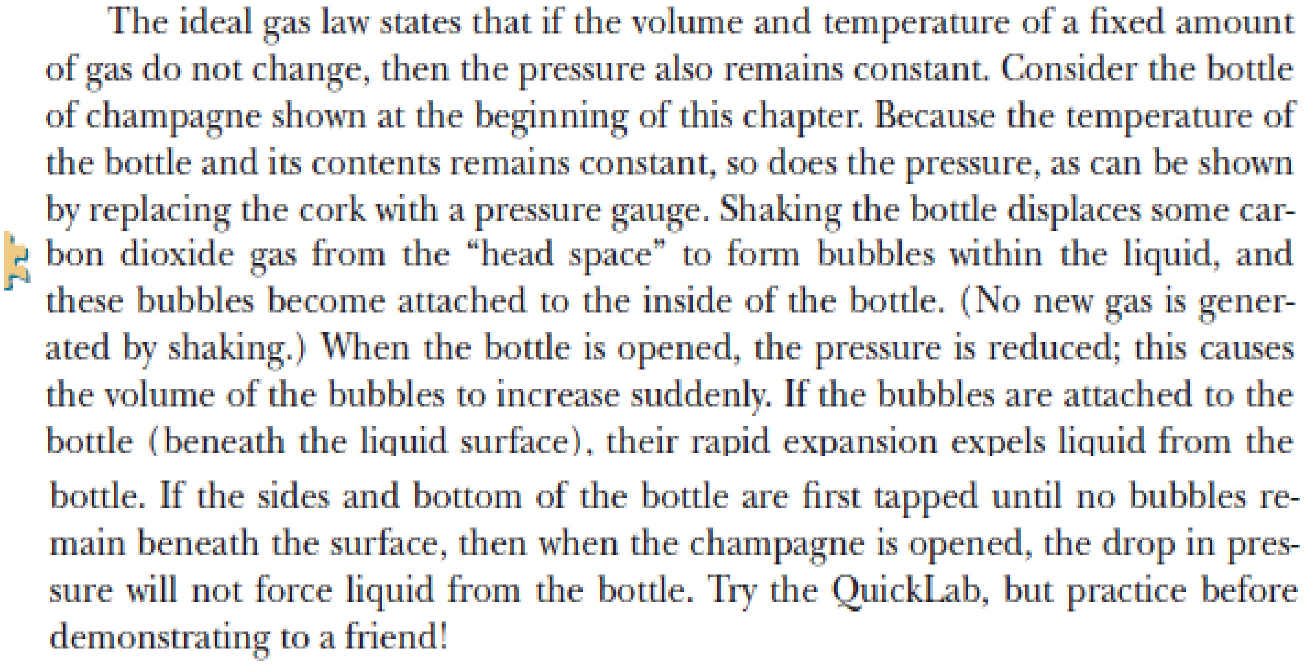
Exercise What is the air temperature in degrees Celsius and in degrees Fahrenheit?

Answer 45.9°C; 115°F.



PUZZLER

After this bottle of champagne was shaken, the cork was popped off and champagne spewed everywhere. Contrary to common belief, shaking a champagne bottle before opening it does not increase the pressure of the carbon dioxide (CO_2) inside. In fact, if you know the trick, you can open a thoroughly shaken bottle without spraying a drop. What's the secret? And why isn't the pressure inside the bottle greater after the bottle is shaken? *(Steve Niedorf/The Image Bank)*



The ideal gas law states that if the volume and temperature of a fixed amount of gas do not change, then the pressure also remains constant. Consider the bottle of champagne shown at the beginning of this chapter. Because the temperature of the bottle and its contents remains constant, so does the pressure, as can be shown by replacing the cork with a pressure gauge. Shaking the bottle displaces some carbon dioxide gas from the "head space" to form bubbles within the liquid, and these bubbles become attached to the inside of the bottle. (No new gas is generated by shaking.) When the bottle is opened, the pressure is reduced; this causes the volume of the bubbles to increase suddenly. If the bubbles are attached to the bottle (beneath the liquid surface), their rapid expansion expels liquid from the bottle. If the sides and bottom of the bottle are first tapped until no bubbles remain beneath the surface, then when the champagne is opened, the drop in pressure will not force liquid from the bottle. Try the QuickLab, but practice before demonstrating to a friend!

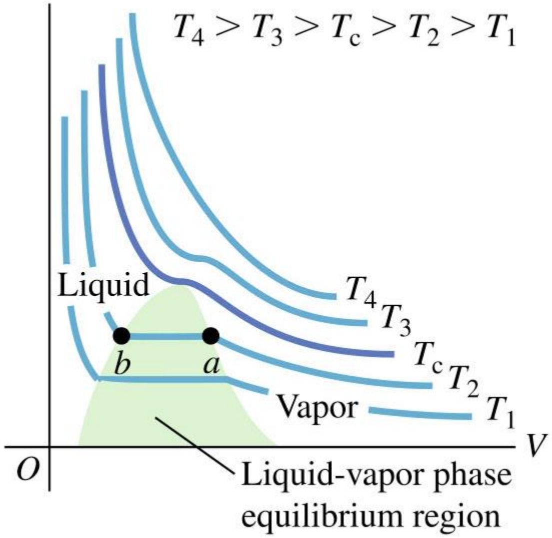
Graficas de pV e Isotermas

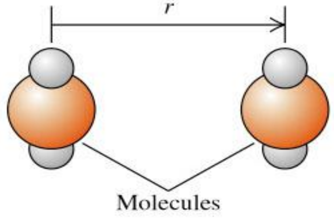
Toda la materia esta compuesta de átomos y moléculas.

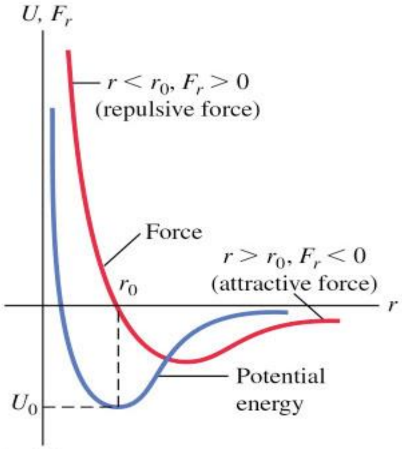
Las gráfica de P vs V se utilizan para relacionar las variables de estado y describir procesos termodinámicos. Se pueden presentar algunas variaciones de p y V a temperatura constante, esas curvas se llaman isotermas.

En el gas, las moléculas se mueven con independencia.

En los líquidos y sólidos están unidos por fuerzas intermoleculares de naturaleza eléctrica. Las fuerzas gravitacionales son despreciables.



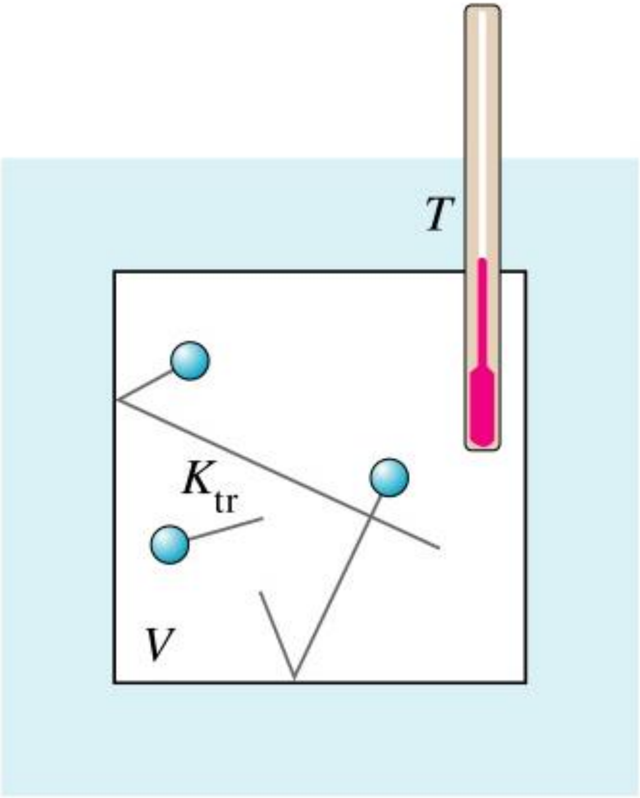


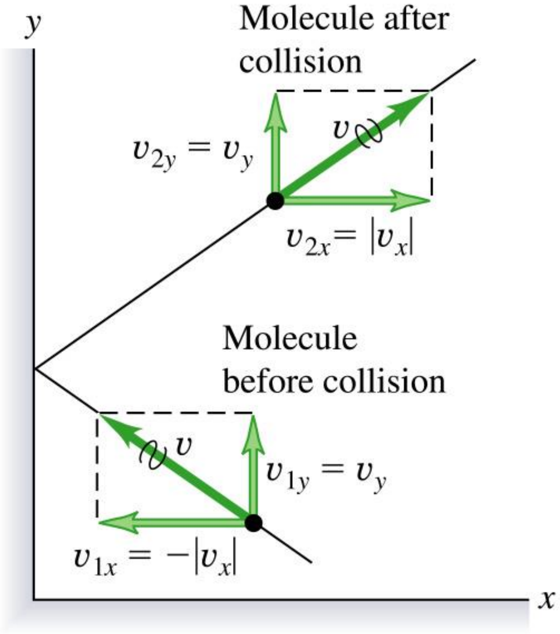


Modelo Cinético-Molecular del Gas Ideal

Este modelo representa el gas como un gran número de partículas que rebotan dentro de un recipiente cerrado. Cada choque transfiere una cantidad de movimiento dada por:

$$\Delta p_x = 2m|v_x|$$





Modelo Cinético-Molecular del Gas Ideal

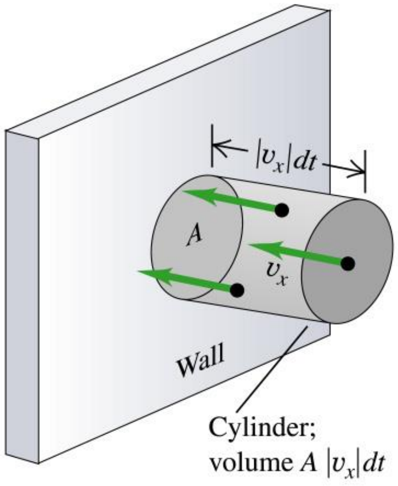
La rapidez promedio a la que la molécula transfiere cantidad de movimiento a la cara es:

$$\frac{\Delta p_x}{t} = \frac{2m|v_x|}{2L/v_x} = \frac{mv_x^2}{L} = F_{promedio}$$

Donde *L* representa la distancia de una cara a la otra en el recipiente que contiene el gas.

Y como presión es:

$$p_{resion} = \frac{F_{promedio}}{Area}$$



All molecules assumed to have same magnitude $|v_x|$ of x-velocity

Copyright © 2004 Pearson Education, Inc., publishing as Addison Wesley.

$$\boxed{p_{total/cara} = \frac{N \bullet mv_x^2}{L \bullet Area} = \frac{N m \overline{v_x^2}}{V}}$$

Modelo Cinético-Molecular del Gas Ideal

En el promedio, la s moléculas tienen la misma probabilidad de moverse en las direcciones x,y o z; por lo tanto, los valores promedios de … son iguales:

$$\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$$

La magnitud de la velocidad será entonces:

$$\overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2} = \overline{v^2} \Rightarrow \overline{v_x^2} = {}^{1}\!/_{3}\,\overline{v^2}$$

$$p = \frac{Nm\overline{v^2}}{3V} \wedge p = \frac{NkT}{V} \Rightarrow \frac{m\overline{v^2}}{3} = kT$$

Esto muestra que el cuadrado promedio de la velocidad molecular es proporcional a la temperatura

Además la raíz cuadrada de v^2 prom. se llama ***velocidad raíz cuadrática media o rms***

Tomás Rada Crespo Ph.D.

La Energía de un Gas Ideal

- Para determinar la energía comencemos con:

$$\frac{m\overline{v^2}}{3} = kT \Rightarrow m\overline{v^2} = 3kT$$

Al multiplicar por ½ tendremos:

$$\tfrac{1}{2} m\overline{v^2} = \frac{3kT}{2}$$

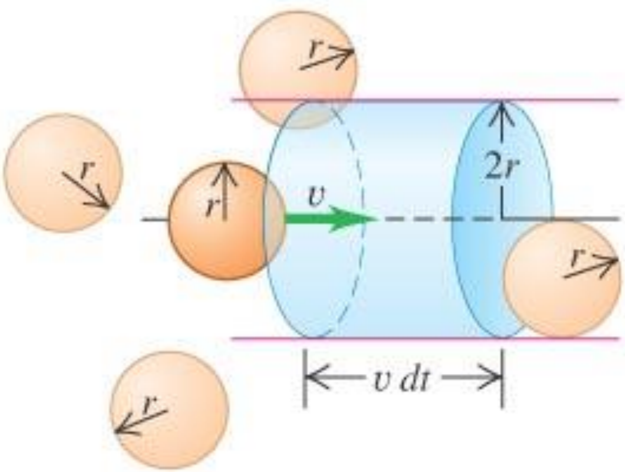
Para un número N de moléculas se obtiene que:

$$\tfrac{1}{2} Nm\overline{v^2} = \frac{3NkT}{2} = K = E_c$$

$$\boxed{E_c = 3/2\, nRT}$$

Tomás Rada Crespo Ph.D.

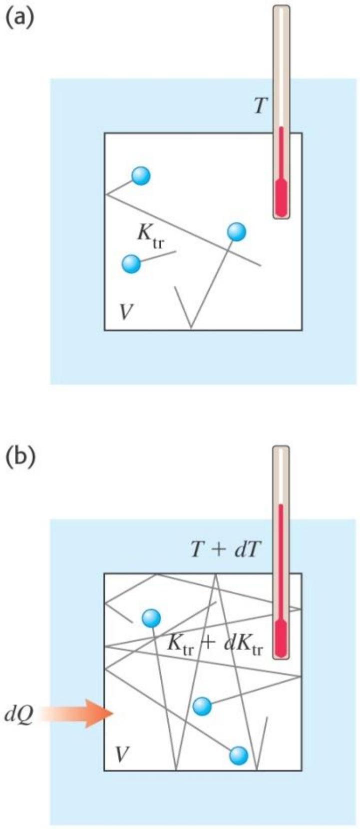
How often do atoms/molecules collide?



- If the size of each particle is determined to be of radius *r*, the space they present to other particles as a target can be calculated.
- A good example to demonstrate this “target” a molecule presents is to depict an atom as a basketball and roll two of them around one another. You can visualize how far apart they must remain to avoid collision.
- The distance an atom/molecule will travel without a collision is termed the “mean free path.”
- Follow Example 18.8.

How much heat energy can ensembles contain?

- An atom can absorb energy as the kinetic energy of its motion.
- A molecule can absorb energy in its translation, and also in its rotation and in the vibrations of one atom in its structure with respect to the others.
- Atomic/molecular energy absorbed is termed its “heat capacity.”



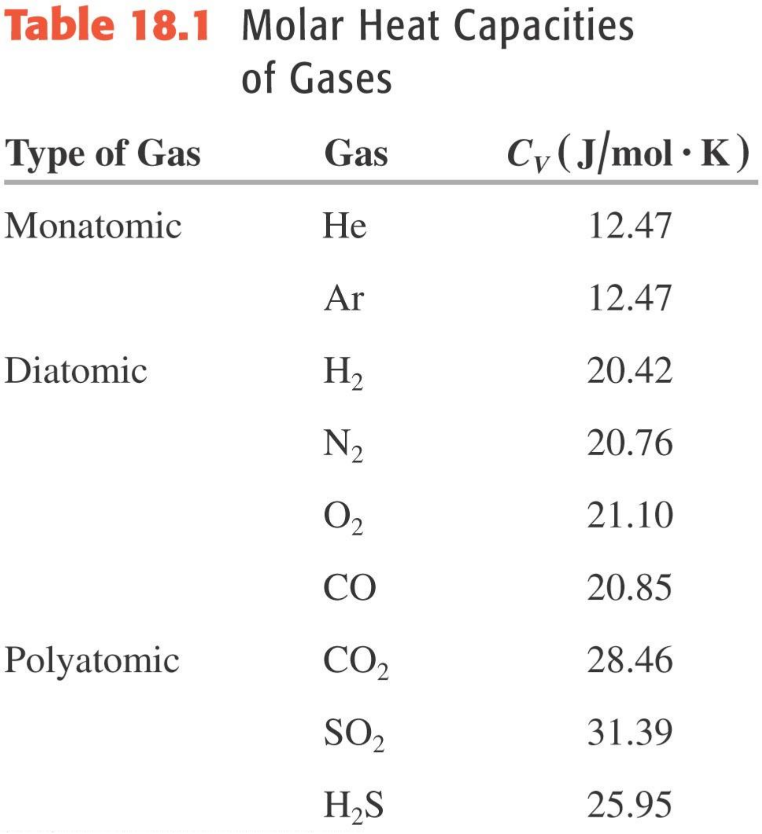
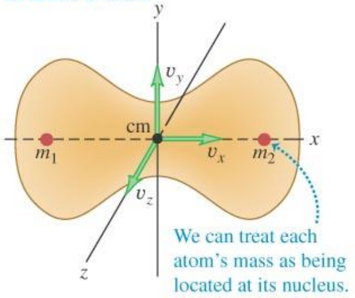


Table 18.1 Molar Heat Capacities of Gases

Type of Gas	Gas	C_V (J/mol · K)
Monatomic	He	12.47
	Ar	12.47
Diatomic	H_2	20.42
	N_2	20.76
	O_2	21.10
	CO	20.85
Polyatomic	CO_2	28.46
	SO_2	31.39
	H_2S	25.95

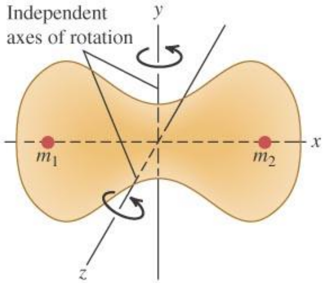
Illustration of heat absorption into degrees of freedom

(a) **Translational motion.** The molecule moves as a whole; its velocity may be described as the *x*-, *y*-, and *z*-velocity components of its center of mass.

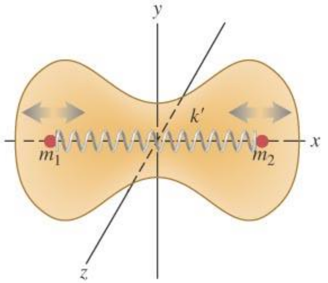


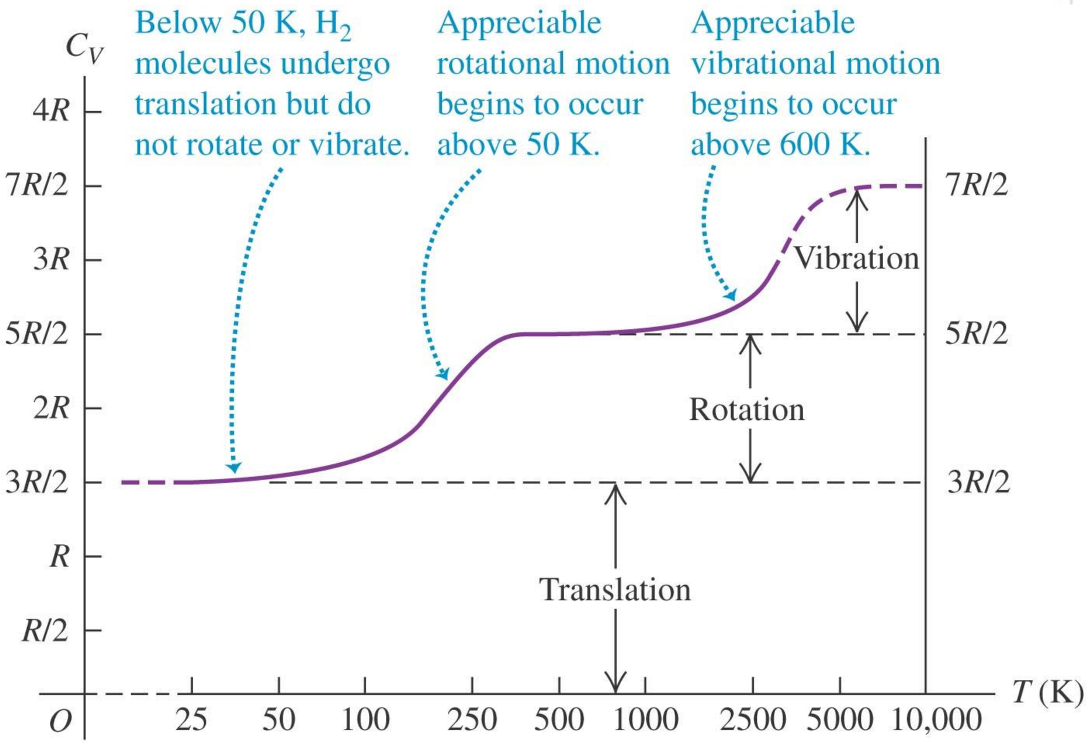
We can treat each atom's mass as being located at its nucleus.

(b) **Rotational motion.** The molecule rotates about its center of mass. This molecule has two independent axes of rotation.



(c) **Vibrational motion.** The molecule oscillates as though the nuclei were connected by a spring.





Below 50 K, H_2 molecules undergo translation but do not rotate or vibrate.

Appreciable rotational motion begins to occur above 50 K.

Appreciable vibrational motion begins to occur above 600 K.