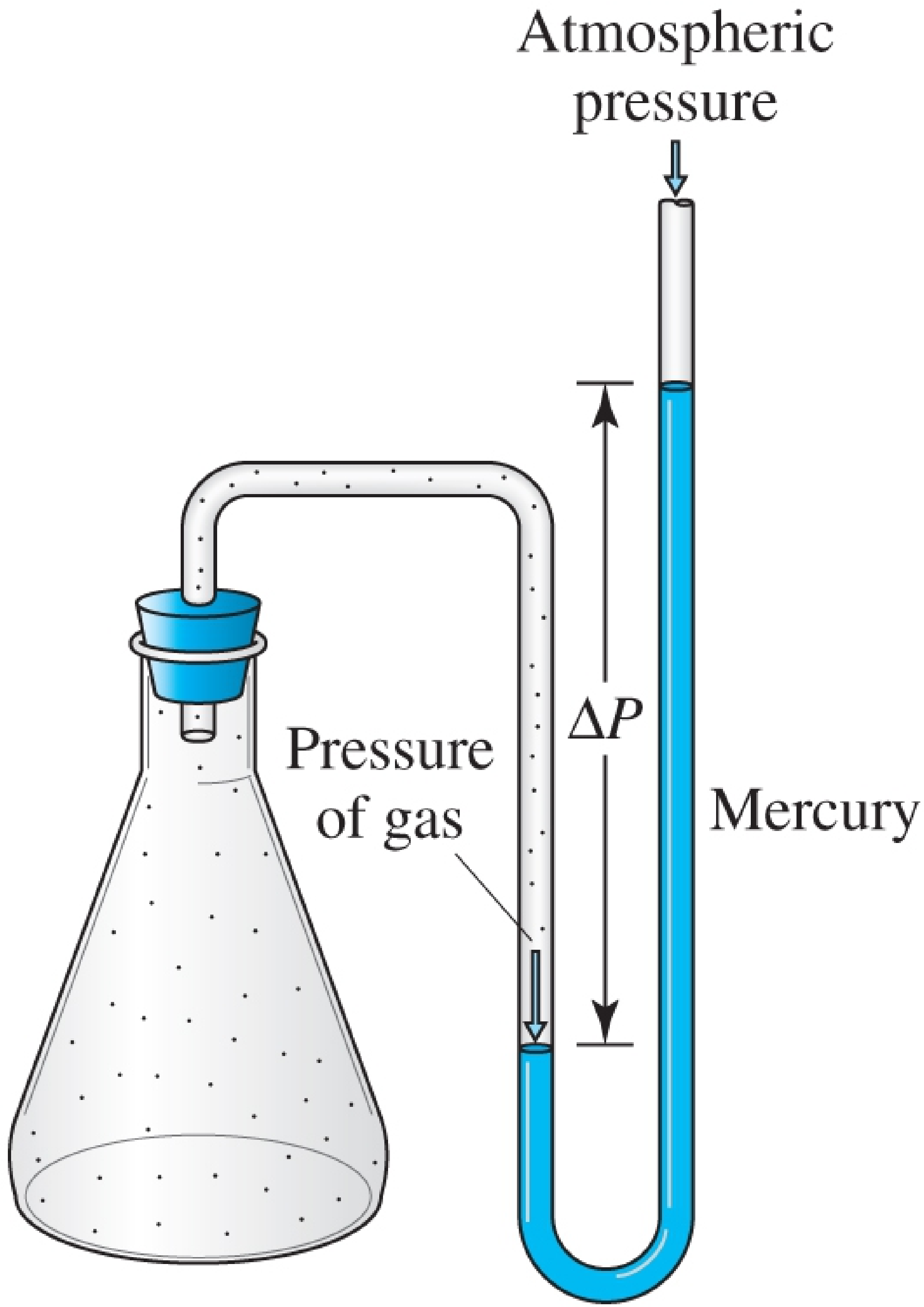
- Pressure = force per unit area
- If the same force is applied to a smaller area, the pressure is increased
- Atmospheric pressure – the pressure exerted by the atmosphere at sea level
    - At higher altitudes, there is less atmosphere above, so the pressure is less


Atmospheric pressure
ΔP
Pressure of gas
Mercury

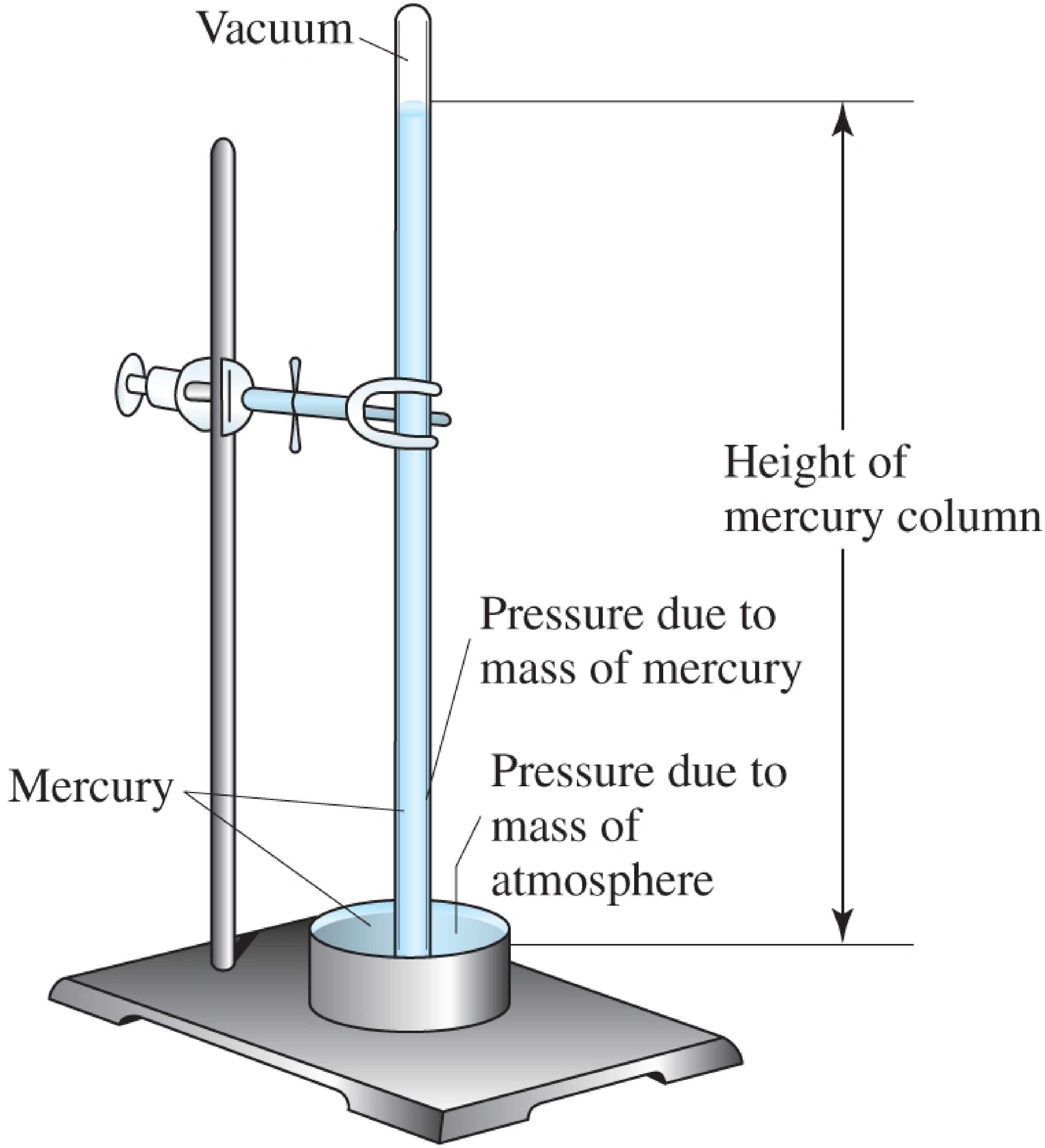

Vacuum
Height of mercury column
Pressure due to mass of mercury
Mercury
Pressure due to mass of atmosphere

TABLE 12.2 Units of Pressure and Their Relationship to the Unit Atmosphere

Unit	Relationship to Atmosphere	Area of Use
Atmosphere	—	gas law calculations
Millimeters of mercury	760 mm Hg = 1 atm	gas law calculations
Inches of mercury	29.92 in. Hg = 1 atm	weather reports
Pounds per square inch	14.68 psi = 1 atm	stored or bottled gases
Pascal	1.013×10^5 Pa = 1 atm	calculations requiring SI units

Ideal gas – no intermolecular forces between gas particles

Most gases deviate from ideal behavior at very low temperatures or very high pressures.

- At low temperatures, particles move more slowly and are better able to interact.

- At high pressures, particles are pushed closer together and so are more likely to interact.

TABLE 12.1 Color, Odor, and Toxicity of Elements and Common Compounds That Are Gases at Ordinary Temperatures and Pressures

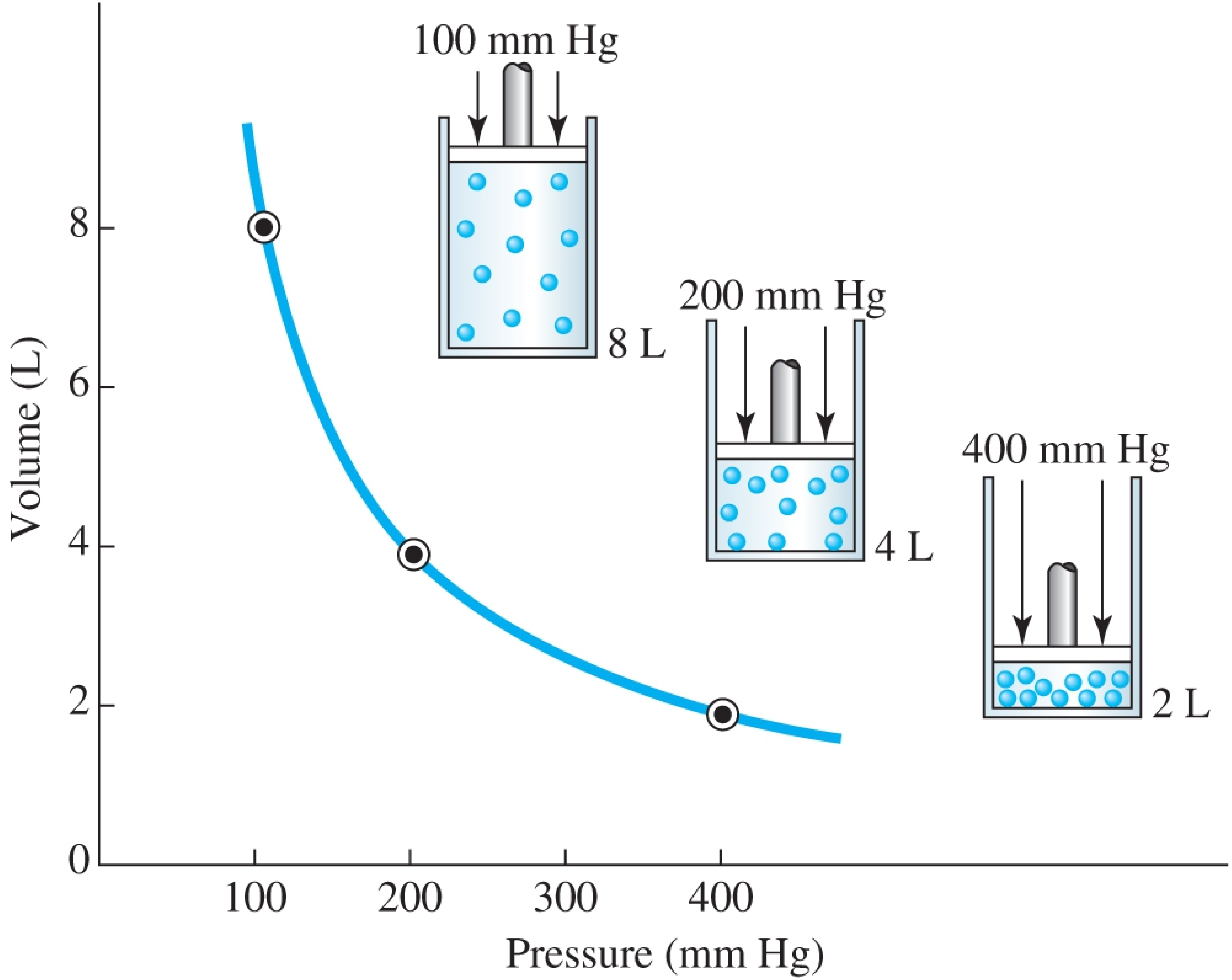
Element		Properties
H_2	hydrogen	colorless, odorless
O_2	oxygen	colorless, odorless
N_2	nitrogen	colorless, odorless
Cl_2	chlorine	greenish-yellow, choking odor, toxic
F_2	fluorine	pale yellow, pungent-odor, toxic
He	helium	colorless, odorless
Ne	neon	colorless, odorless
Ar	argon	colorless, odorless
Kr	krypton	colorless, odorless
Xe	xenon	colorless, odorless
Rn	radon	colorless, odorless
Compound		**Properties**
CO_2	carbon dioxide	colorless, faintly pungent odor
CO	carbon monoxide	colorless, odorless, toxic
NH_3	ammonia	colorless, pungent odor, toxic
CH_4	methane	colorless, odorless
SO_2	sulfur dioxide	colorless, pungent choking odor, toxic
H_2S	hydrogen sulfide	colorless, rotten egg odor, toxic
HCl	hydrogen chloride	colorless, choking odor, toxic
NO_2	nitrogen dioxide	reddish-brown, irritating odor, toxic

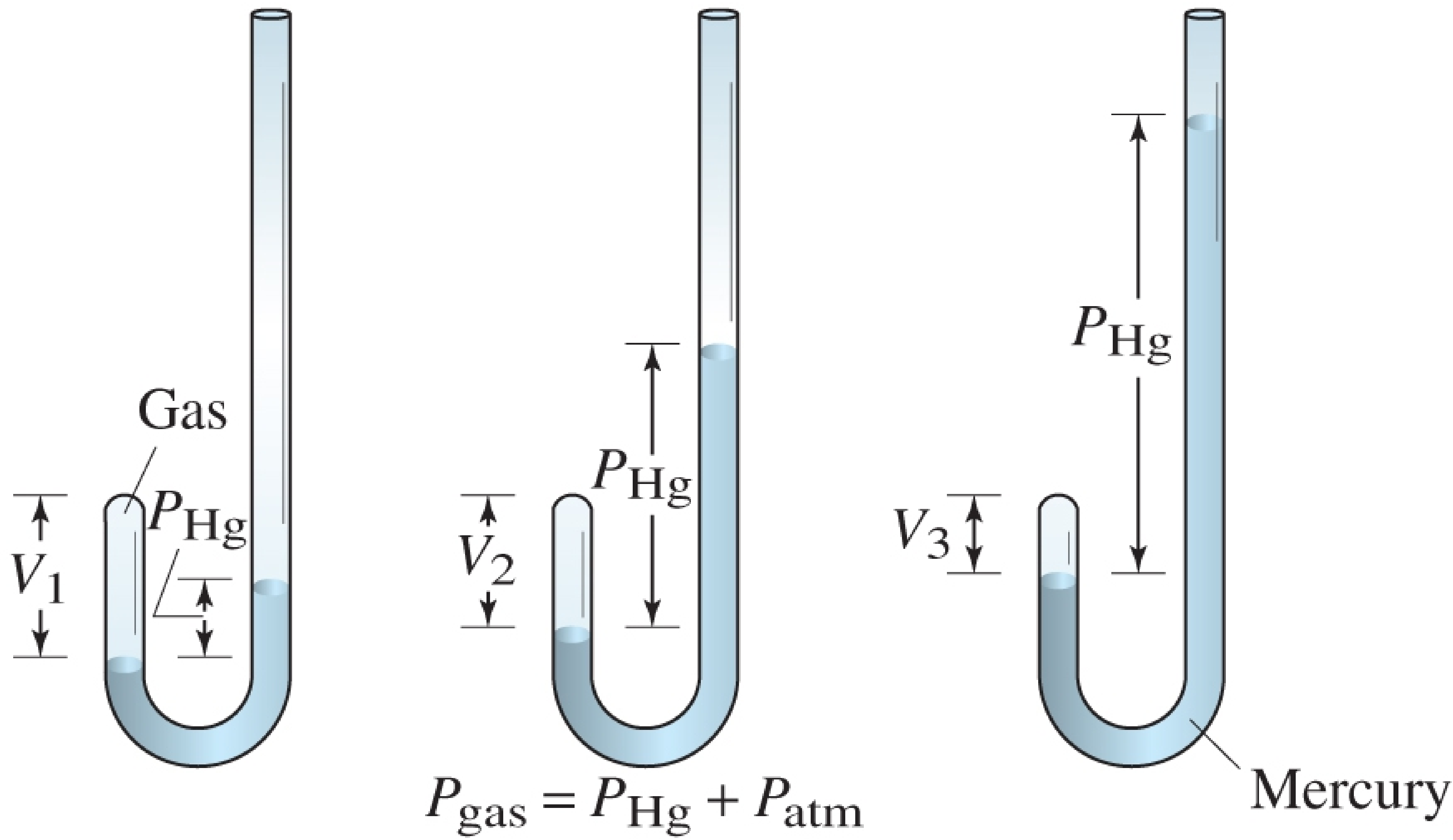
Ideal gas relationships

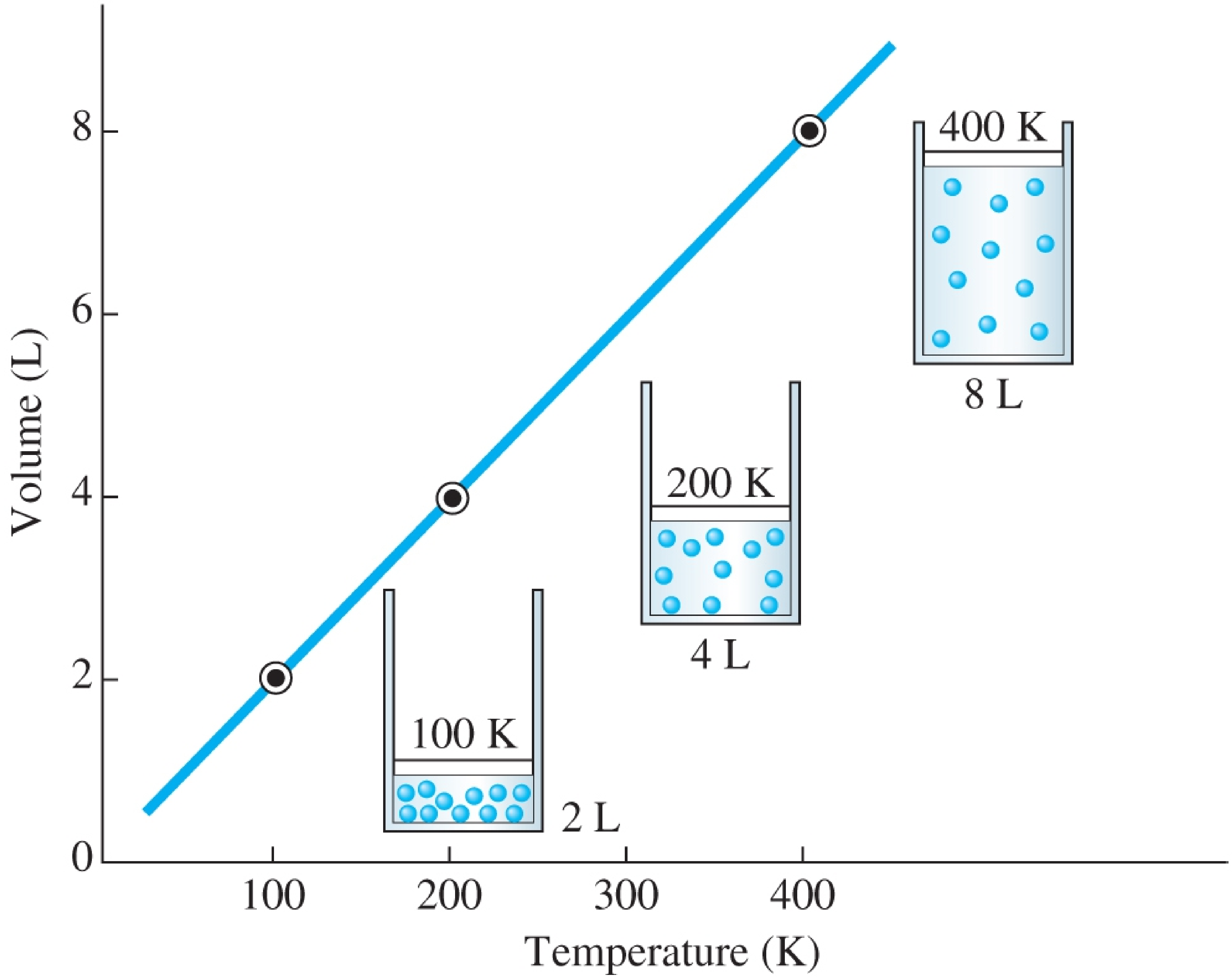
- Volume vs. pressure – inversely proportional
  - If the pressure is doubled, the volume is halved

- Volume vs. temperature – directly proportional
  - If the absolute temp. is doubled, the volume is also doubled

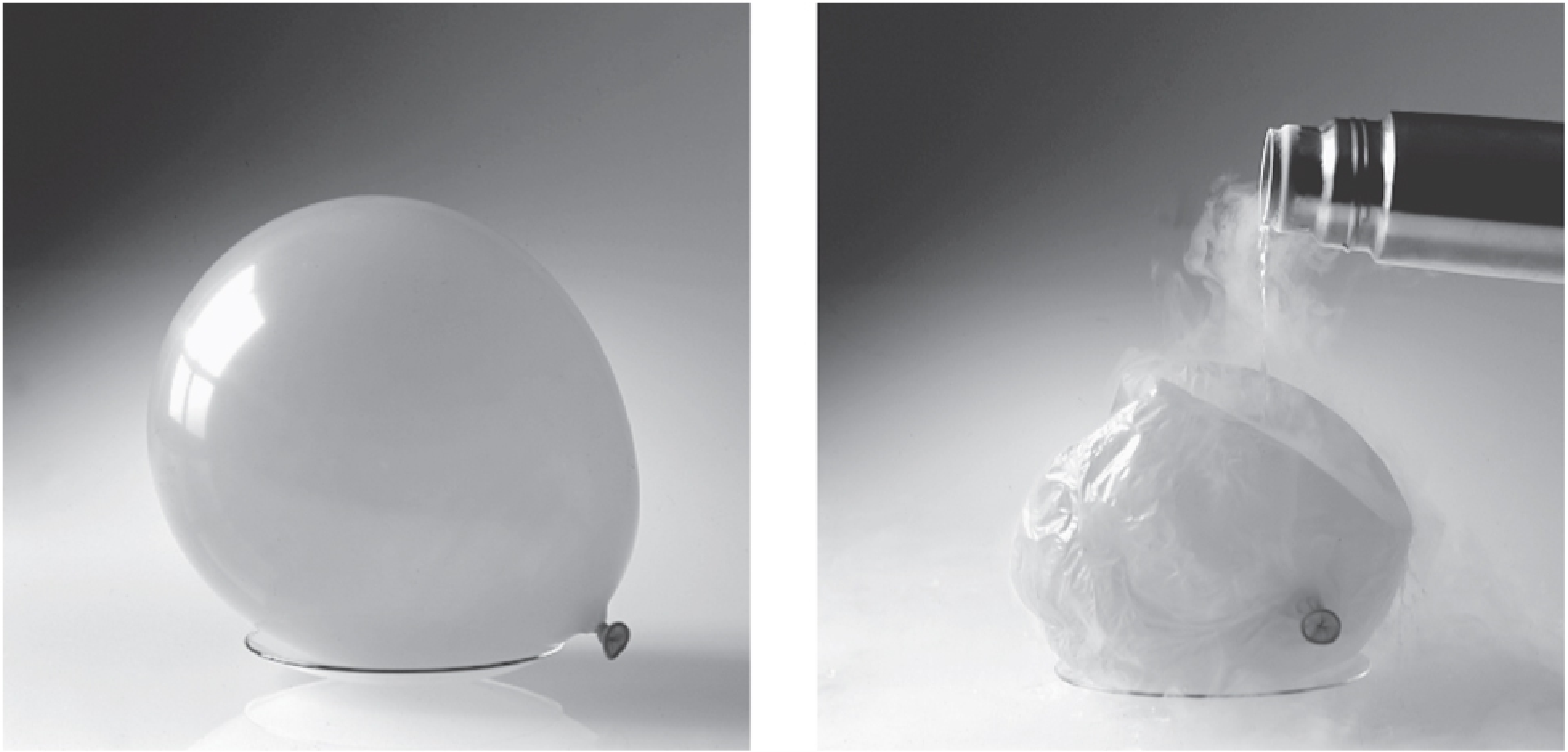
- Pressure vs. temperature – directly proportional
  - If the temperature is doubled, so is the pressure

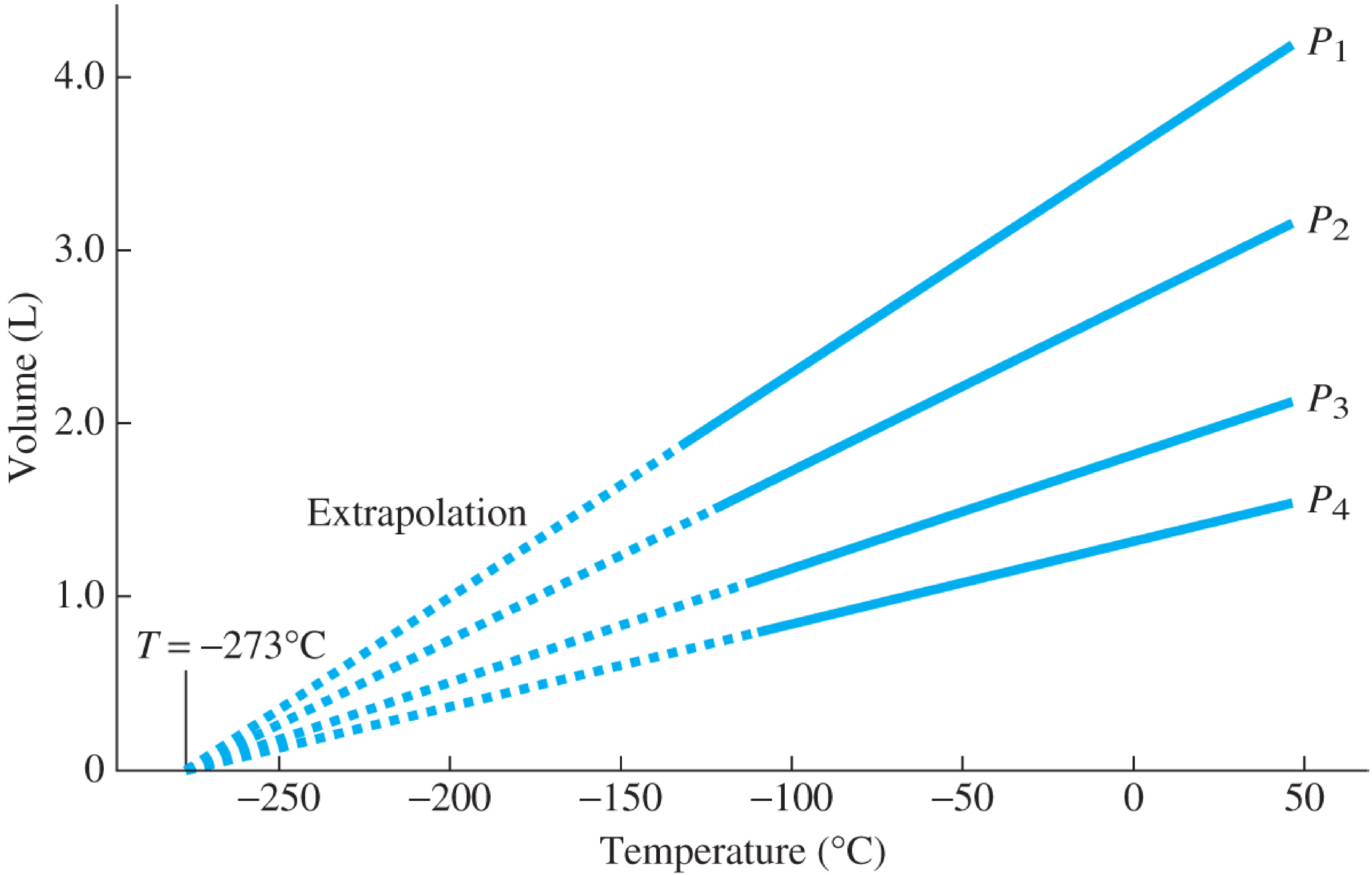

100 mm Hg
8 L
200 mm Hg
4 L
400 mm Hg
2 L
Volume (L)
0
2
4
6
8
100
200
300
400
Pressure (mm Hg)


Gas
P_{Hg}
V_1
V_2
P_{Hg}
$P_{gas} = P_{Hg} + P_{atm}$
V_3
P_{Hg}
Mercury

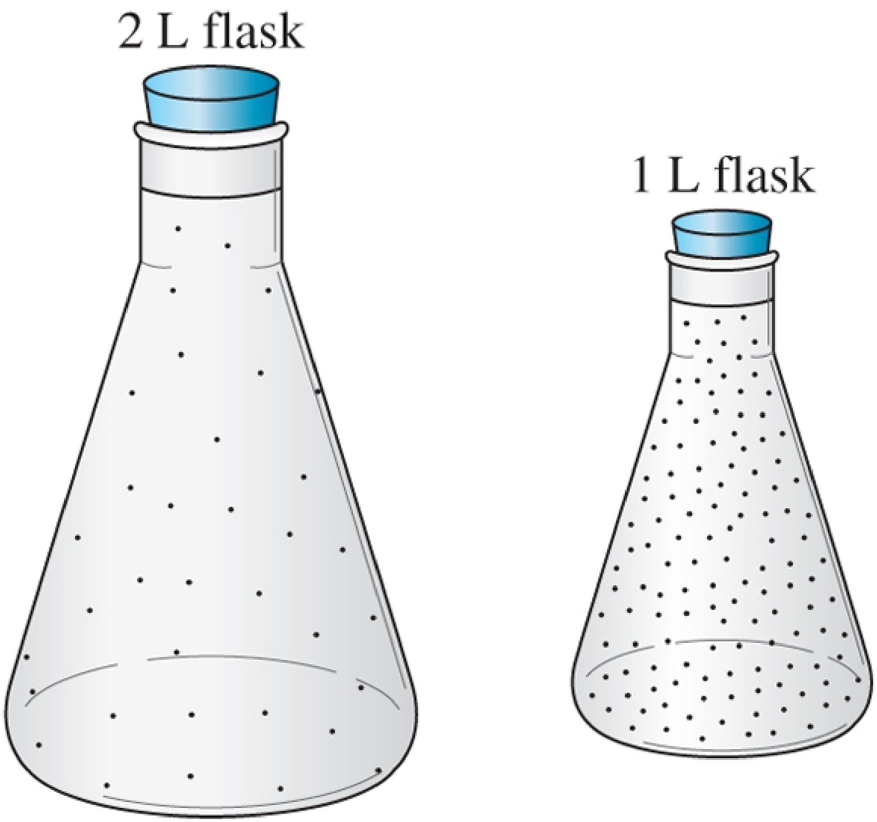


8
6
4
2
0
Volume (L)
100
200
300
400
Temperature (K)
100 K
2 L
200 K
4 L
400 K
8 L



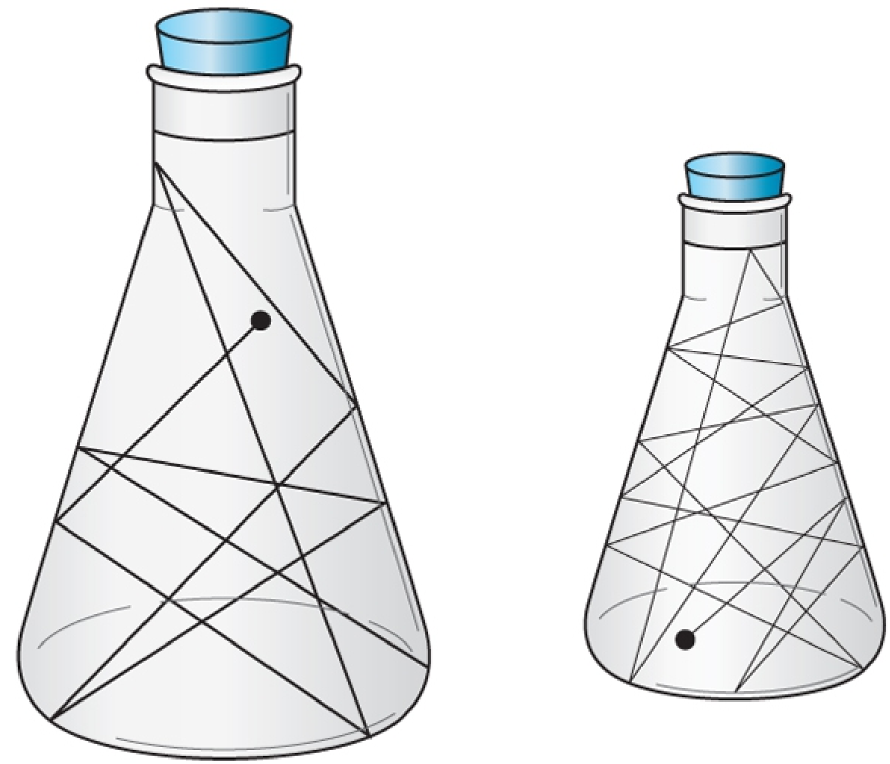


P_1
P_2
P_3
P_4
4.0
3.0
2.0
1.0
0
Volume (L)
Extrapolation
T = −273°C
−250
−200
−150
−100
−50
0
50
Temperature (°C)



The volume is decreased by one-half.

(a)



A given molecule hits container walls twice as often.

(b)

TABLE 12.3 Relationship of the Individual Gas Laws to the Combined Gas Law

Law	Constancy Requirement (for a fixed mass of gas)	Mathematical Form of the Law
Combined gas law	none	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
Boyle's law	$T_1 = T_2$	Since T_1 and T_2 are equal, substitute T_1 for T_2 in the combined gas law and cancel. $\frac{P_1V_1}{\cancel{T}_1} = \frac{P_2V_2}{\cancel{T}_1}$ or $P_1V_1 = P_2V_2$
Charles's law	$P_1 = P_2$	Since P_1 and P_2 are equal, substitute P_1 for P_2 in the combined gas law and cancel. $\frac{\cancel{P}_1V_1}{T_1} = \frac{\cancel{P}_1V_2}{T_2}$ or $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
Gay-Lussac's law	$V_1 = V_2$	Since V_1 and V_2 are equal, substitute V_1 for V_2 in the combined gas law and cancel. $\frac{P_1\cancel{V}_1}{T_1} = \frac{P_2\cancel{V}_1}{T_2}$ or $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Combined Gas Law

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Temperature must be in an absolute scale (Kelvin)

Avogadro's Law – At a given temperature and pressure, the volume occupied by one mole of an ideal gas is constant, independent of the composition of the gas.

At 1 atmosphere pressure and 273 K (called standard temperature and pressure, STP), one mole of an ideal gas occupies 22.4 liters.

22.4 L of air, therefore, has a mass of about 29 grams (80% N_2, with a formula mass of 28 g/mol).

22.4 L of helium has a mass of only 4 g, which is much less dense than air.

Ideal Gas Law

$$PV = nRT$$

P = pressure
V = volume
n = moles
R = ideal gas constant
T = absolute temperature

Dalton's Law of Partial Pressure – the total pressure of a gas sample is equal to the sum of the partial pressures exerted by each gas in the sample.

$$P_{total} = P_1 + P_2 + P_3 + ...$$

Under constant conditions (total pressure, volume, temperature) the partial pressures are directly related to the mole fractions of each gas.

TABLE 12.5 The Major Components of Clean, Dry Air

Gaseous Component	Formula	Mole Fraction	Partial Pressure (mm Hg) When Total Pressure Is 760.0 mm Hg
Nitrogen	N_2	0.78084	593.4
Oxygen	O_2	0.20948	159.2
Argon	Ar	9.34×10^{-3}	7.1
Carbon dioxide	CO_2	3.1×10^{-4}	0.24
Neon	Ne	2×10^{-5}	0.02
Helium	He	1×10^{-5}	0.01

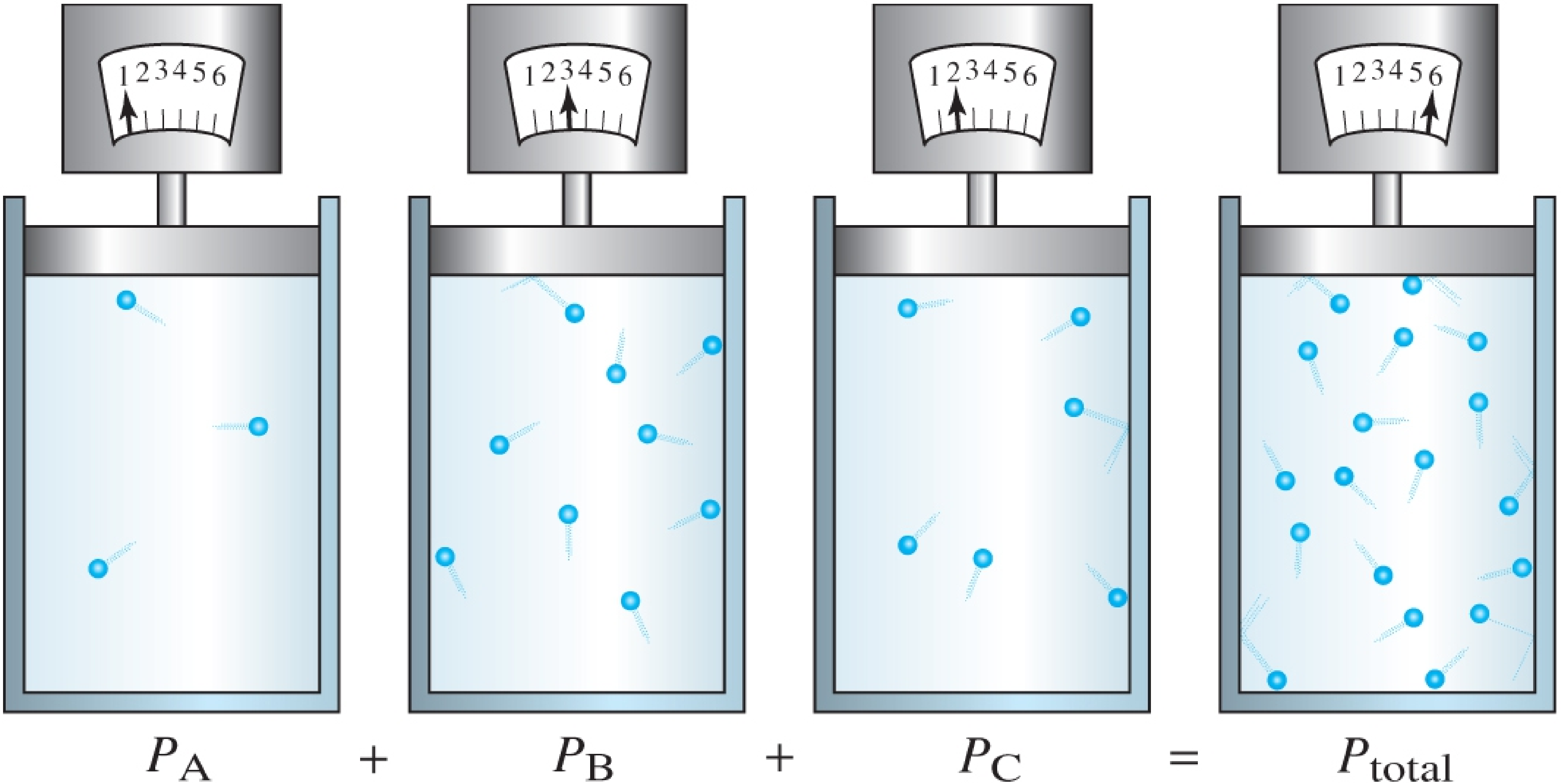

1 2 3 4 5 6
1 2 3 4 5 6
1 2 3 4 5 6
1 2 3 4 5 6
P_A
+
P_B
+
P_C
=
P_{total}

TABLE 12.6 Vapor Pressure of Water at Various Temperatures

T(°C)	Vapor Pressure (mm Hg)	*T*(°C)	Vapor Pressure (mm Hg)	*T*(°C)	Vapor Pressure (mm Hg)
15	12.8	22	19.8	29	30.0
16	13.6	23	21.1	30	31.8
17	14.5	24	22.4	31	33.7
18	15.5	25	23.8	32	35.7
19	16.5	26	25.2	33	37.7
20	17.5	27	26.7	34	39.9
21	18.7	28	28.3	35	42.2

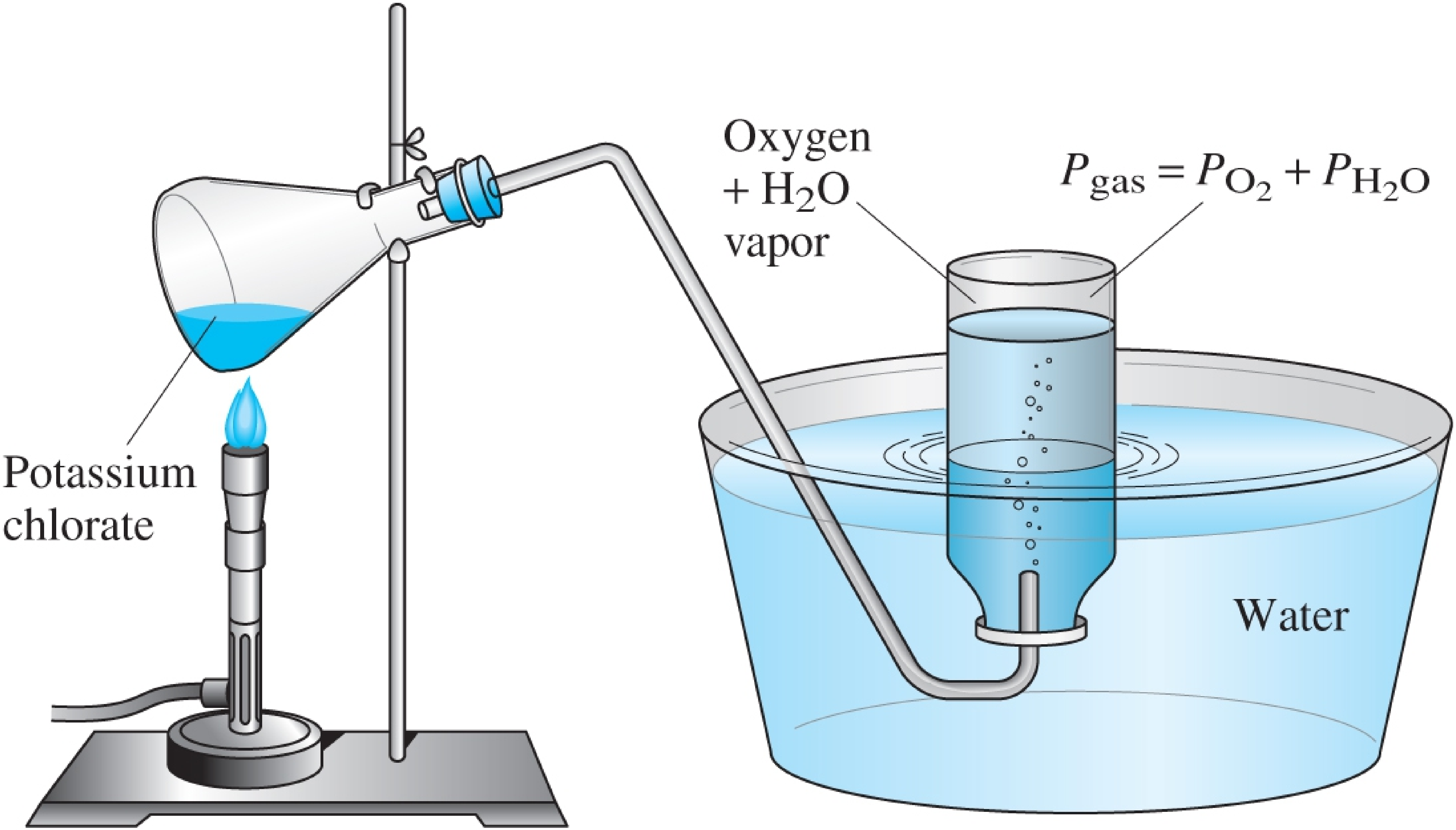

Oxygen
+ H_2O
vapor
$P_{gas} = P_{O_2} + P_{H_2O}$
Potassium
chlorate
Water

TABLE 12.4 Ways in Which Equation Coefficients May Be Interpreted

For the general equation	2A (g)	+	3B (g)	⟶	C (g)	+	2D (g)
The ratio of molecules is	2	:	3	:	1	:	2
The ratio of moles is	2	:	3	:	1	:	2
The ratio of volumes of gas (at the same temperature and pressure) is	2	:	3	:	1	:	2