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## Chapter 7

### Gases, Liquids, and Solids

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Chapter 7-1

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## Gases, Liquids, and Solids

→ CO 7.1

Ice, water, and mist are simultaneously present in this winter scene in Yellowstone National Park.



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Chapter 7-2

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## Hydro-power from potential energy



Betty Weiser/Photo Researchers

← Fig. 7.1  
The water in the lake behind the dam has potential energy as a result of its position.

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Chapter 7-3

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## Kinetic Energy and Collisions

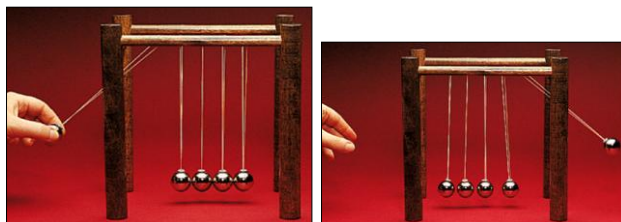


Fig. 7.2

Upon release, the steel ball on the left transmits its kinetic energy through a series of elastic collisions to the ball on the right.

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Chapter 7-4

## Properties of Gases, Liquids, and Solids

Property	Solid State	Liquid State	Gaseous State
volume and shape	definite volume and definite shape	definite volume and indefinite shape; takes the shape of its container to the extent that it is filled	indefinite volume and indefinite shape; takes the volume and shape of the container that it completely fills
density	high	high, but usually lower than corresponding solid	low
compressibility	small	small, but usually greater than corresponding solid	large
thermal expansion	very small; about 0.01% per °C	small; about 0.10% per °C	moderate; about 0.30% per °C

Table 7.1

## Arrangement of Particles in three States

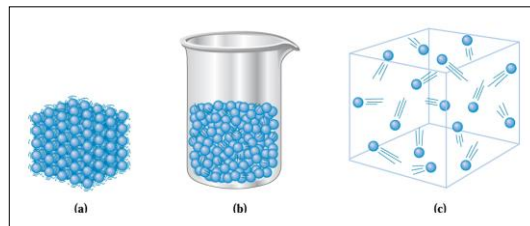


Fig. 7.3

(a) In a solid, the particles are close together. (b) In a liquid, the particles slide freely over one another. (c) In a gas, the particles are in random motion.

## Gases in random motion

→ Fig. 7.4

Gas molecules can be compared to billiard balls in random motion, bouncing off one another.



## Popping into different states

→ CC 7.1



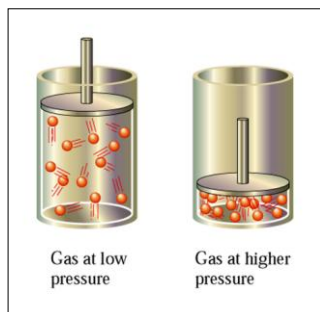
Phil Degginger/Color-Pic

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## Compressibility of gases

→ Fig. 7.5

When a gas is compressed, the amount of empty space in the container is decreased.



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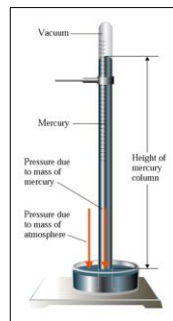
Chapter 7-9

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## Barometer: Measuring the Pressure of gases

← Fig. 7.6

The essential components of a mercury barometer are a graduated glass tube, a glass dish, and liquid mercury.



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## Boyle and the gas Laws

→ Fig. 7.7

Robert Boyle was self-taught. Through his efforts, the true value of experimental investigation was first recognized.



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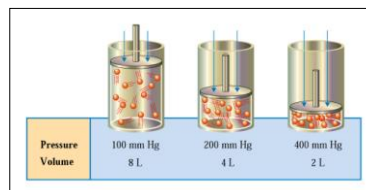
Chapter 7-11

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## Boyles' Law:

← Fig. 7.8

Data illustrating the inverse proportionality associated with Boyle's law.



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Chapter 7-12

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## Charles Law

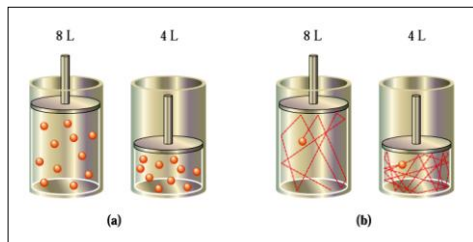


Fig. 7.9 When the volume of a gas at constant temperature decreases by half, the average number of times a molecule hits the container walls is doubled.

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## Application of Boyle's Law



← Fig. 7.10  
Filling a syringe with a liquid is an application of Boyle's law.

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## Charles and gas laws

→ Fig. 7.11

Jacques Charles in the process of working with hot-air balloons made the observations that led to the formulation of what is now known as Charles's law.



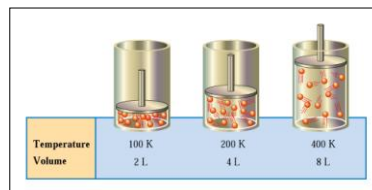
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## Charles Law



← Fig. 7.12  
Data illustrating the direct proportionality associated with Charles's law.

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## Dalton and the Partial Pressure

→ Fig. 7.13

John Dalton had an interest in the study of weather.



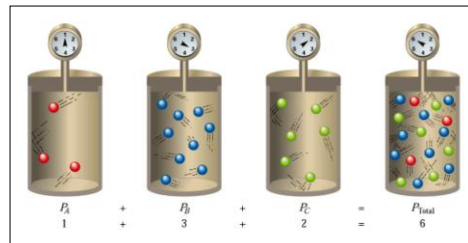
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## Dalton's law of partial pressures

Fig. 7.14

A set of four containers can be used to illustrate Dalton's law of partial pressures. The pressure in the fourth container equals the sum of the first three.

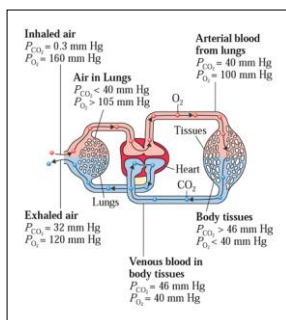


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## Blood gases and their solubility

→ CC 7.2

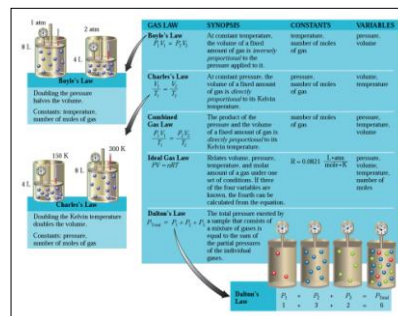


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## Summary of gas laws

→ CAG 7.1

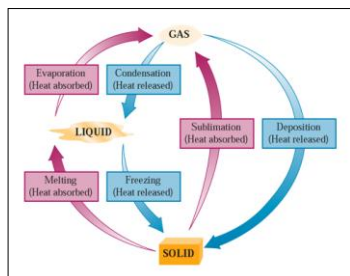


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Chapter 7-20

## Changes of states

→ Fig. 7.15  
There are six changes of state possible for substances.



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Chapter 7-21

## Sublimation of Iodine



(a) The beaker contains iodine crystals.



(b) Iodine has an appreciable vapor pressure even below its melting point.

Fig. 7.15

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Chapter 7-22

## Vapor pressure and equilibrium

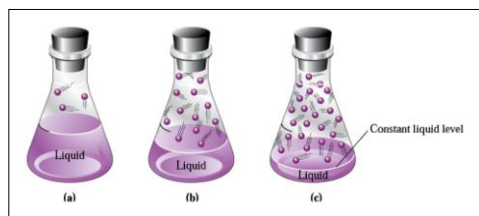


Fig. 7.17

(a) the liquid level drops for a time, (b) then becomes constant. At that point a state of equilibrium has been reached in which (c) the rate of evaporation equals the rate of condensations.

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## Boiling point of liquids

→ Fig. 7.18  
Bubbles of vapor form within a liquid when the temperature of the liquid reaches the liquid's boiling point.



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## How you cook? Low or high pressure



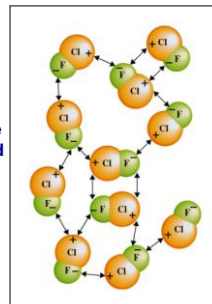
Brian Bailey/Network. Aspen

← Fig. 7.19  
The converse of the pressure cooker "phenomenon" is that food cooks more slowly at reduced pressure.

## Intermolecular forces: Dipole-dipole

→ Fig. 7.20

There are many dipole-dipole interactions possible between randomly arranged CIF molecules.



## Vapor pressure and the temperature

Temperature (°C)	Vapor Pressure (mm Hg)	Temperature (°C)	Vapor Pressure (mm Hg)
0	4.6	50	92.5
10	9.2	60	149.4
20	17.5	70	233.7
25 <sup>a</sup>	23.8	80	355.1
30	31.8	90	525.8
37 <sup>b</sup>	37.1	100	760.0
40	55.3		

<sup>a</sup>Room temperature  
<sup>b</sup>Body temperature

Table 7.2

## Pressure cooker: how does it work?

Pressure Cooker Setting (additional pressure beyond atmospheric, lb/in. <sup>2</sup> )	Internal Pressure in Cooker (atm)	Boiling Point of Water (°C)
5	1.34	108
10	1.68	116
15	2.02	121

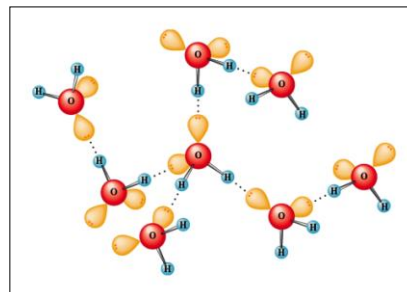
Table 7.4

## Boiling point and Elevation

Location	Feet Above Sea Level	$P_{atm}$ (mm Hg)	Boiling Point (°C)
top of Mt. Everest, Tibet	29,028	240	70
top of Mt. McKinley, Alaska	20,320	340	79
Leadville, Colorado	10,150	430	89
Salt Lake City, Utah	4,390	650	96
Madison, Wisconsin	900	730	99
New York City, New York	10	760	100
Death Valley, California	-282	770	100.4

Table 7.3

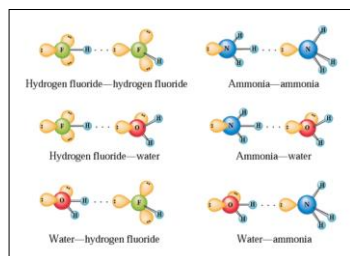
## Strongest intermolecular force: The hydrogen bonding



← Fig. 7.21  
Depiction of hydrogen bonding among the water molecules.

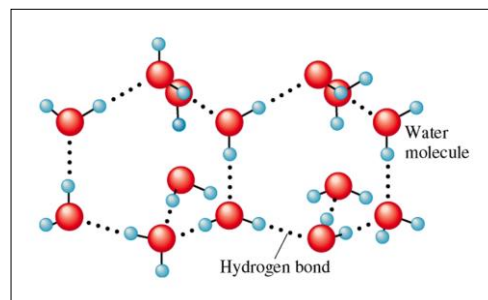
## Three types of hydrogen bonding

→ Fig. 7.22  
Diagrams of hydrogen bonding involving selected simple molecules.



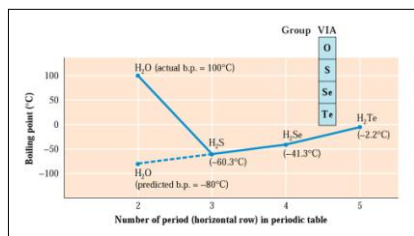
## Hydrogen bonding in ice

→ CC 7.3





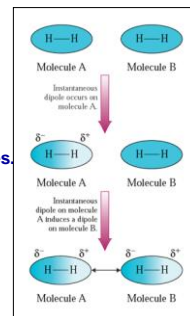
## How does hydrogen bonding affect properties



← Fig. 7.23  
If there were no hydrogen bonding between water molecules, the boiling point of water would be approximately -80°C.

## London Dispersion Forces:

→ Fig. 7.24  
Nonpolar molecules can develop instantaneous dipoles and induced dipoles.



## Summary of intermolecular forces

→ CAG 7.2

