States of Matter
Lesson 4.3

CHEMISTRY 2
HONORS

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Bonding in Solids

- There are four types of solid:
  - Covalent molecular (formed from molecules) - usually soft with low melting points and poor conductivity.
  - Covalent network (formed from atoms) - very hard with very high melting points and poor conductivity.
  - Ionic (formed from ions) - hard, brittle, high melting points and poor conductivity.
  - Metallic (formed from metal atoms) - soft or hard, high melting points, good conductivity, malleable and ductile.

TABLE 11.7 Types of Crystalline Solids

Type of Solid	Form of Unit Particles	Forces Between Particles	Properties	Examples
Molecular	Atoms or molecules	London dispersion, dipole-dipole forces, hydrogen bonds	Fairly soft, low to moderately high melting point, poor thermal and electrical conduction	Argon, Ar; methane, CH_4; sucrose, $C_{12}H_{22}O_{11}$; Dry Ice™, CO_2
Covalent-network	Atoms connected in a network of covalent bonds	Covalent bonds	Very hard, very high melting point, often poor thermal and electrical conduction	Diamond, C; quartz, SiO_2
Ionic	Positive and negative ions	Electrostatic attractions	Hard and brittle, high melting point, poor thermal and electrical conduction	Typical salts—for example, NaCl, $Ca(NO_3)_2$
Metallic	Atoms	Metallic bonds	Soft to very hard, low to very high melting point, excellent thermal and electrical conduction, malleable and ductile	All metallic elements—for example, Cu, Fe, Al, Pt

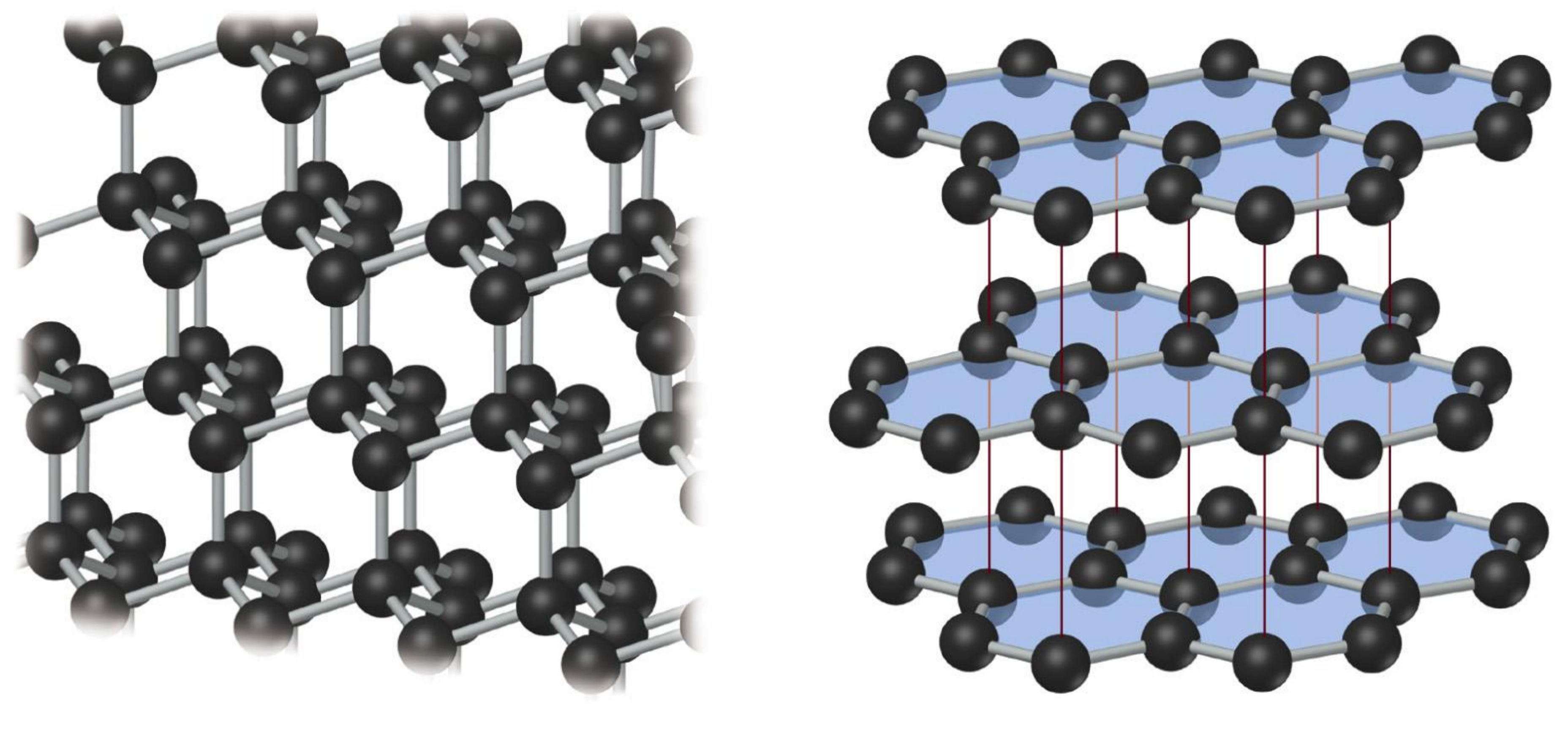
Molecular Solids

- Intermolecular forces: dipole-dipole, London dispersion and H-bonds.
- Weak intermolecular forces give rise to low melting points.
- Room temperature gases and liquids usually form molecular solids at low temperature.
- Efficient packing of molecules is important (since they are not regular spheres).

Covalent-Network Solids

- Forces: covalent bonds.
- Atoms held together in large networks.
- Examples: diamond, graphite, quartz (SiO_2), silicon carbide (SiC), and boron nitride (BN).
- In diamond:
  - each C atom has a coordination number of 4; each C atom is tetrahedral; there is a three-dimensional array of atoms.
  - Diamond is hard, and has a high melting point (3550 °C).

Covalent-Network Solids



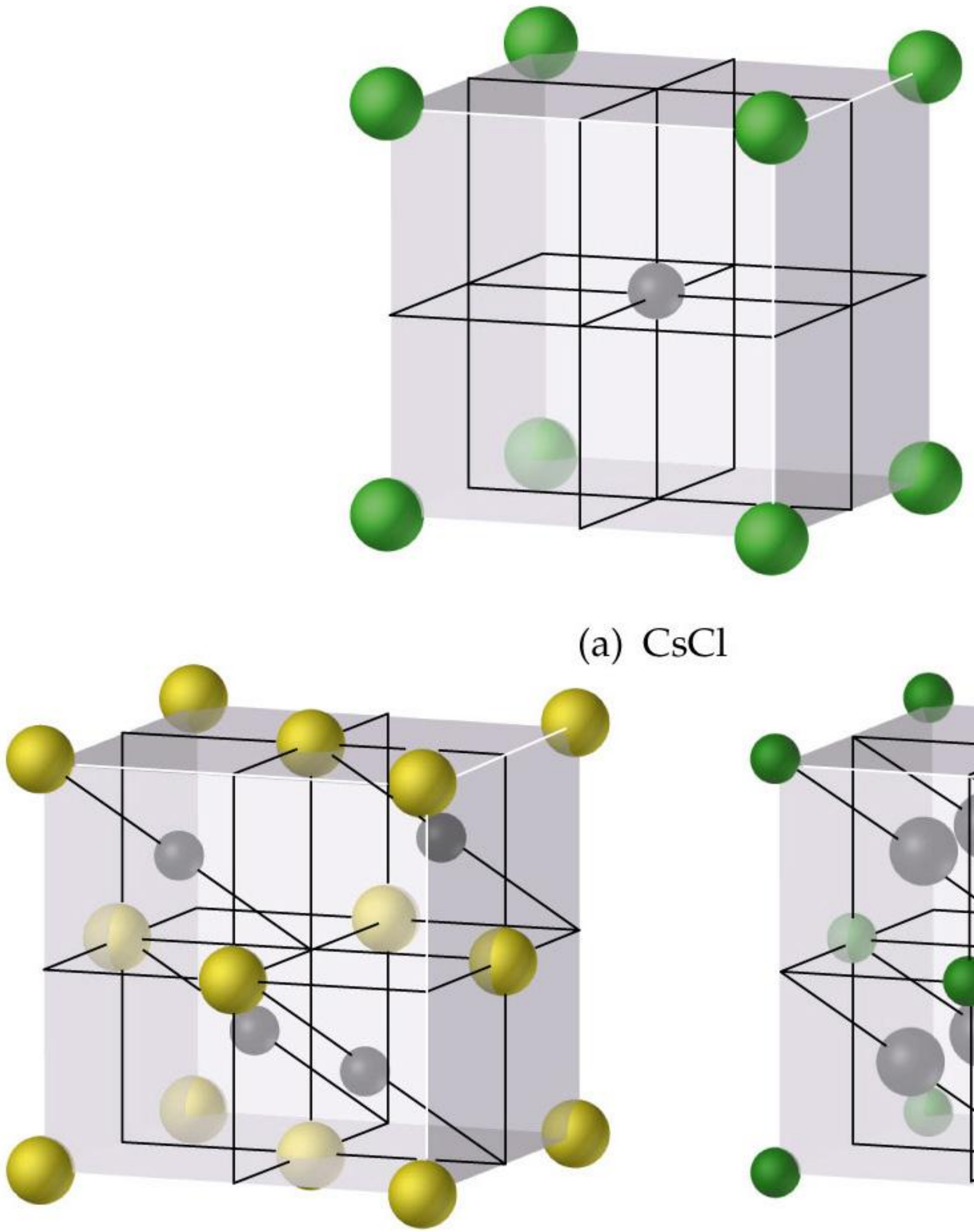
(a) Diamond (b) Graphite

- In graphite
  - each C atom is arranged in a planar hexagonal ring;
  - layers of interconnected rings are placed on top of each other;
  - the distance between C atoms is close to benzene (1.42 Å vs. 1.395 Å in benzene);
  - the distance between layers is large (3.41 Å);
  - electrons move in delocalized orbitals (good conductor).

Ionic Solids

- Ions (spherical) held together by electrostatic forces of attraction.
- There are some simple classifications for ionic lattice types.

Ionic Solids



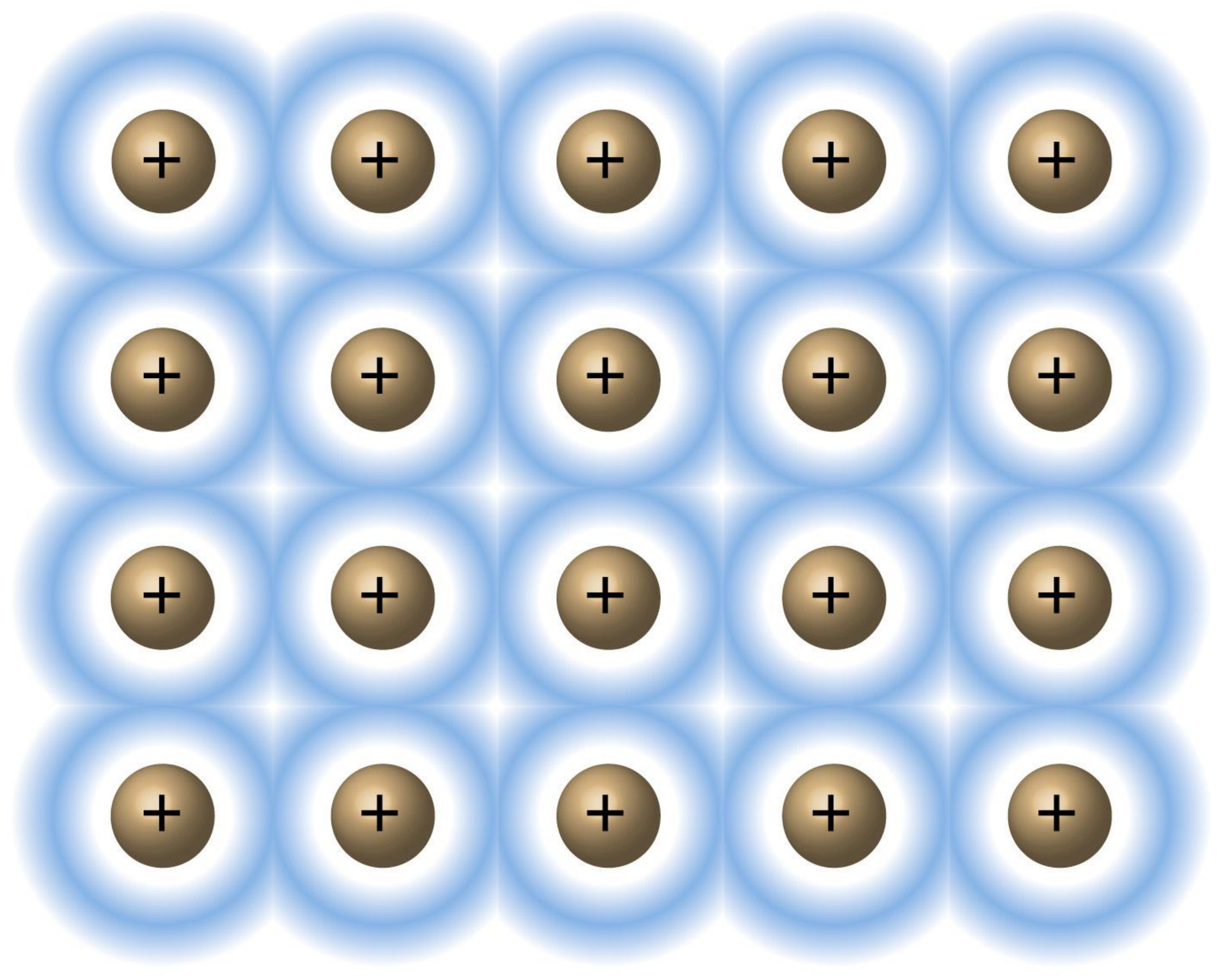
(a) CsCl

(b) ZnS

(c) CaF_2

Metallic Solids

- Problem: the bonding is too strong for London dispersion and there are not enough electrons for covalent bonds.
- Resolution: the metal nuclei float in a sea of electrons.
- Metals conduct because the electrons are delocalized and are mobile.



Characteristics of Gases

- Gases are highly compressible and occupy the full volume of their containers.
- When a gas is subjected to pressure, its volume decreases.
- Gases always form homogeneous mixtures with other gases.
- Gas molecules only occupy about 0.1 % of the volume of their containers.

TABLE 10.1 Some Common Compounds That Are Gases At Room Temperature

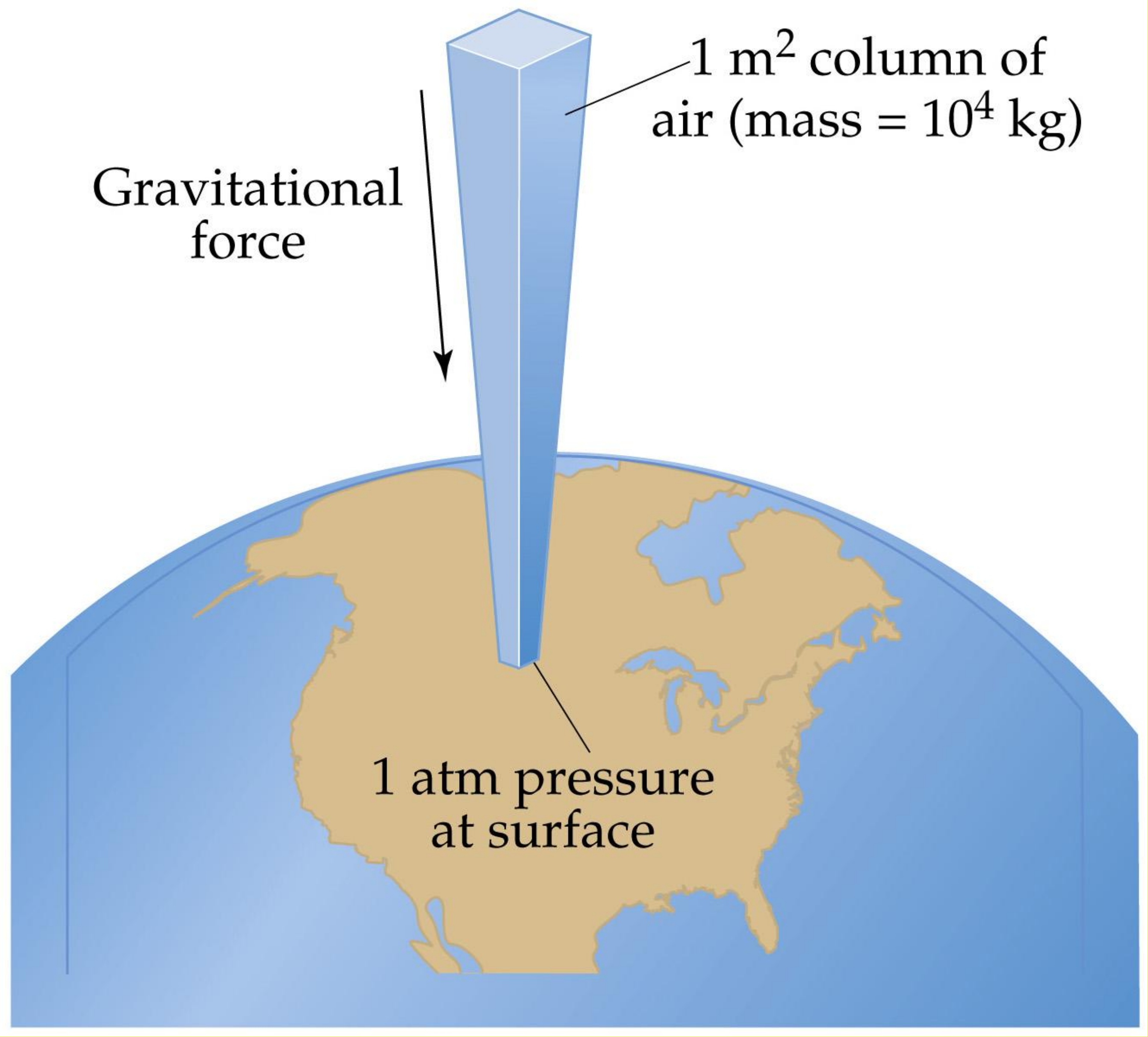
Formula	Name	Characteristics
HCN	Hydrogen cyanide	Very toxic, slight odor of bitter almonds
H_2S	Hydrogen sulfide	Very toxic, odor of rotten eggs
CO	Carbon monoxide	Toxic, colorless, odorless
CO_2	Carbon dioxide	Colorless, odorless
CH_4	Methane	Colorless, odorless, flammable
C_2H_4	Ethylene	Colorless; ripens fruit
C_3H_8	Propane	Colorless; bottled gas
N_2O	Nitrous oxide	Colorless, sweet odor, laughing gas
NO_2	Nitrogen dioxide	Toxic, red-brown, irritating odor
NH_3	Ammonia	Colorless, pungent odor
SO_2	Sulfur dioxide	Colorless, irritating odor

Pressure

- Pressure is the force acting on an object per unit area:

$$P = \frac{F}{A}$$

- Gravity exerts a force on the earth's atmosphere
- A column of air 1 m^2 in cross section exerts a force of 10^5 N.
- The pressure of a 1 m^2 column of air is 100 kPa.


1 m2 column of
air (mass = 104 kg)
Gravitational
force
1 atm pressure
at surface

Atmosphere Pressure and the Barometer

- SI Units: 1 N = 1 $kg.m.s^{-2}$; 1 Pa = 1 N m^{-2}.
- Atmospheric pressure is measured with a barometer.
- If a vacated tube is inserted into a container of mercury open to the atmosphere, the mercury will rise 760 mm up the tube.
- Standard atmospheric pressure is the pressure required to support 760 mm of Hg in a column.
- Units: 1 atm = 760 mmHg = 760 torr = 1.01325×10^5 Pa = 101.325 kPa.

Examples – Convert the following pressures:

1. 658.2 mm Hg to kPa

2. 1.85 atm to torr

3. 337.3 kPa to atm

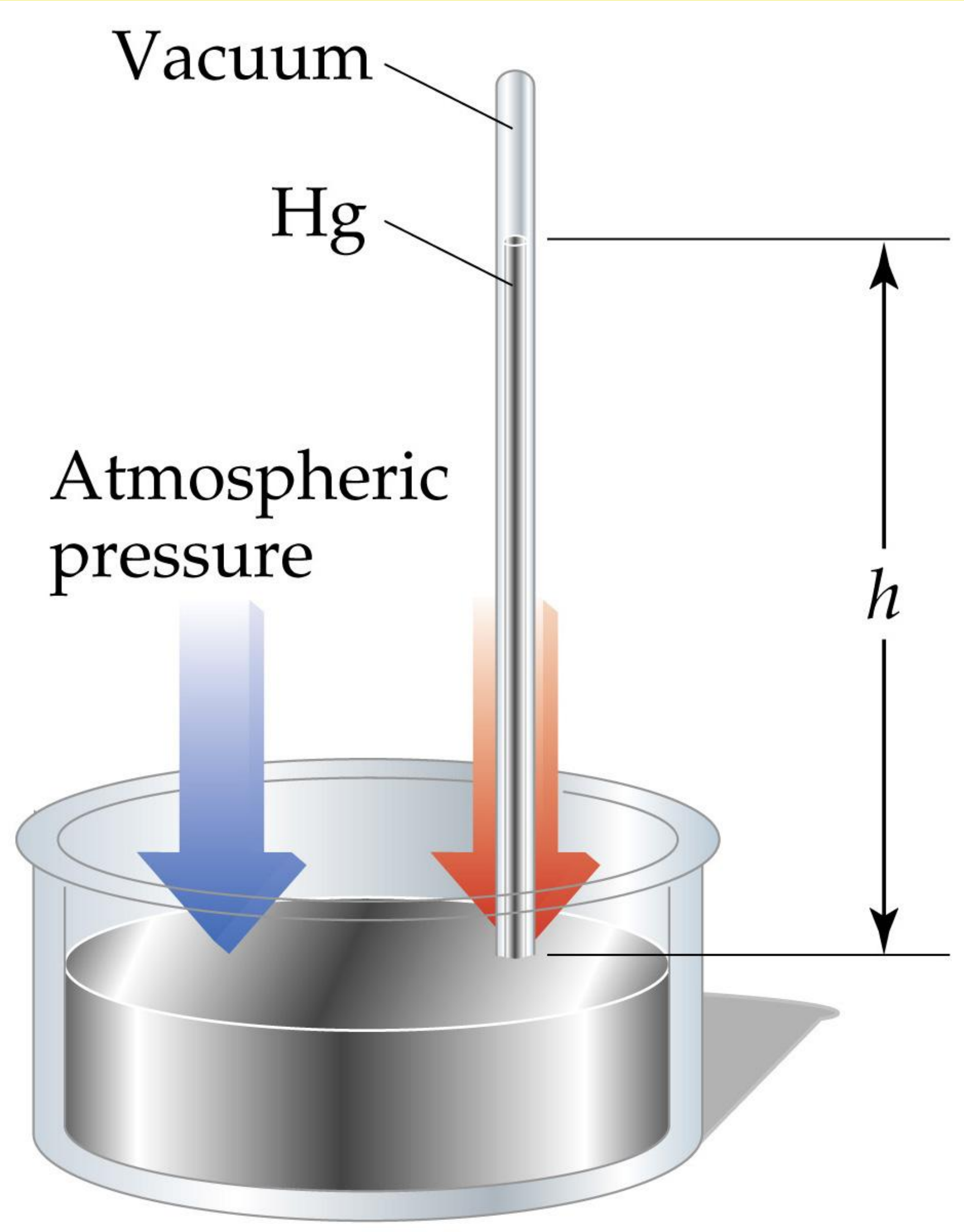
Examples – Convert the following pressures:

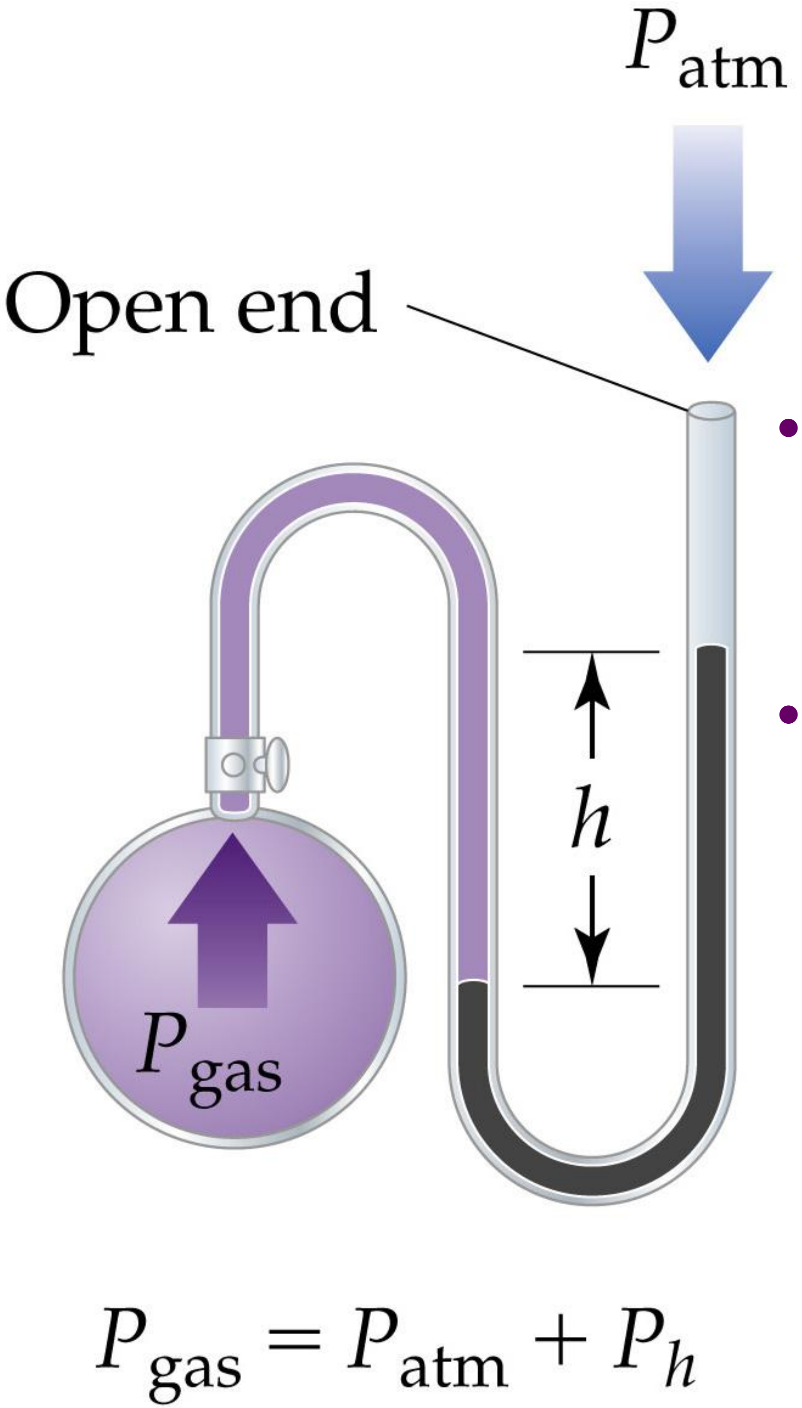
1. 658.2 mm Hg to kPa — 87.75 kPa

2. 1.85 atm to torr — 1410 torr

3. 337.3 kPa to atm — 3.329 atm

Atmosphere Pressure and the Barometer





Pressure and the Manometer

- The pressures of gases not open to the atmosphere are measured in manometers.
- A manometer consists of a bulb of gas attached to a U-tube containing Hg:
  - If $P_{gas} < P_{atm}$ then $P_{gas} + P_h = P_{atm}$.
  - If $P_{gas} > P_{atm}$ then $P_{gas} = P_{atm} + P_h$.

Example – The mercury in a manometer is 46 mm higher on the open end than on the gas bulb end. If atmospheric pressure is 102.2 kPa, what is the pressure of the gas in the bulb?

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813 mm Hg

108 kPa