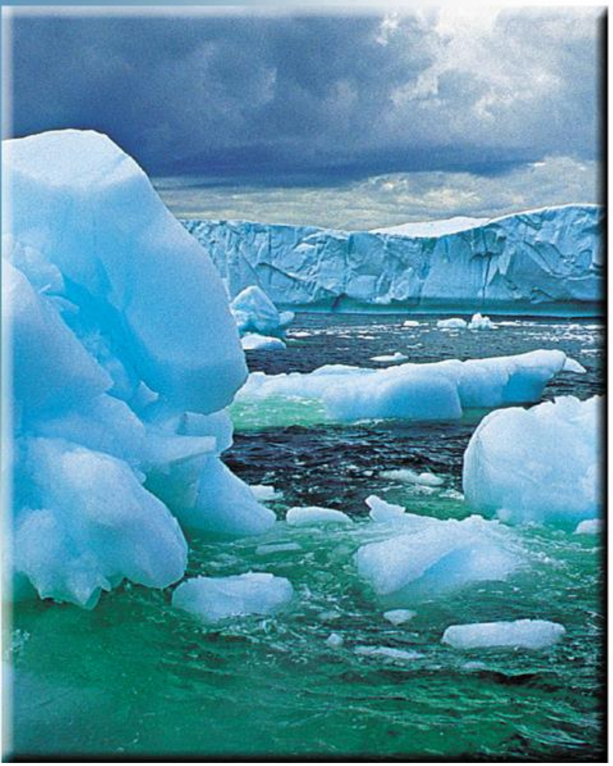
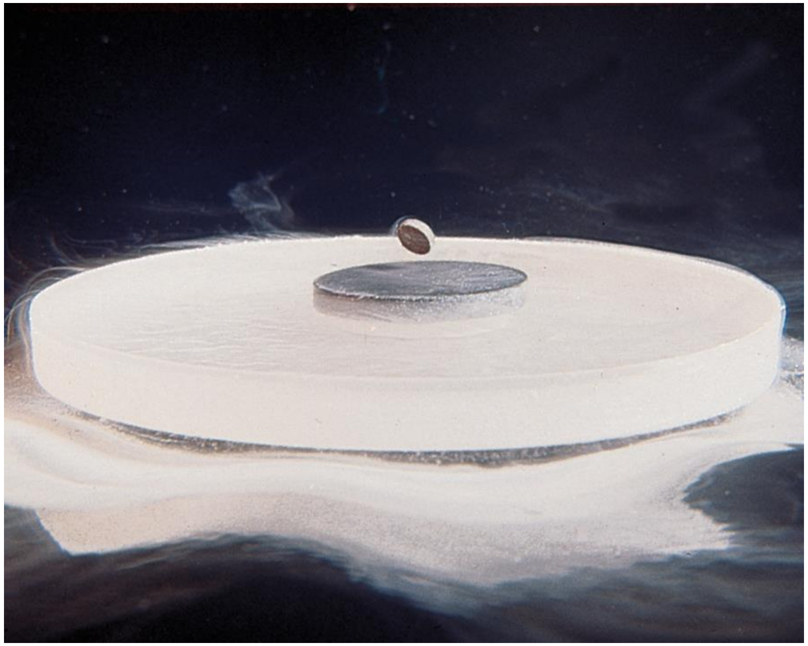




Solids

LCD
Liquid Crystal Display

Optical microscope: This is the most commonly used type of microscope and uses visible light to magnify objects. It can be further classified into various subtypes, such as the compound microscope, stereo microscope, and digital microscope.

Electron microscope: This type of microscope uses a beam of electrons instead of light to magnify objects. It can be further classified into two subtypes, transmission electron microscope (TEM) and scanning electron microscope (SEM).

tinh thẻ

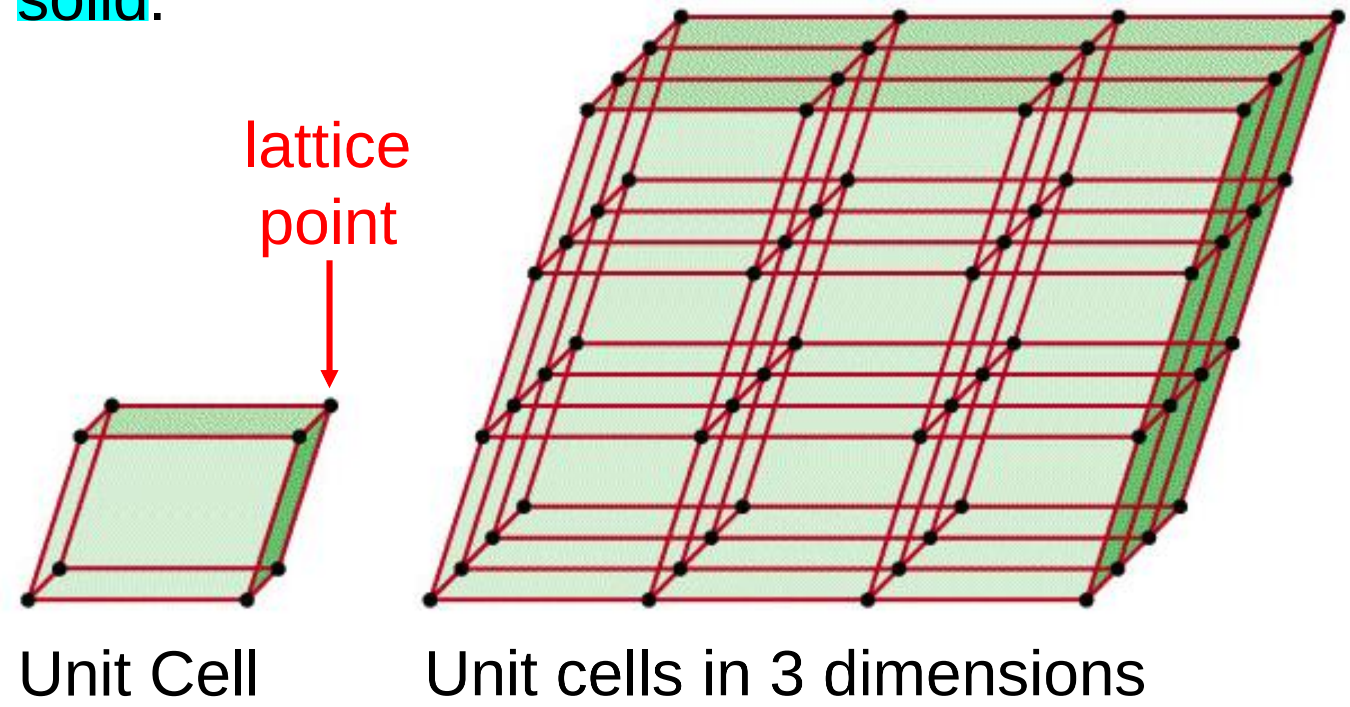
A ***crystalline solid*** possesses rigid and long-range order. In a crystalline solid, atoms, molecules or ions occupy specific (predictable) positions. see them in atomic/moleculea scale to know ì they are crystal

vô định hình

An ***amorphous solid*** does not possess a well-defined arrangement and long-range molecular order.

cấu thành cơ bản của tinh thể

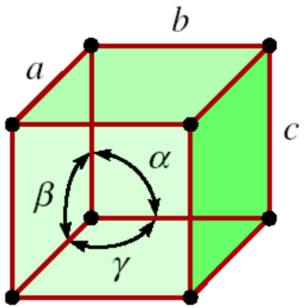
A ***unit cell*** is the basic repeating structural unit of a crystalline solid.



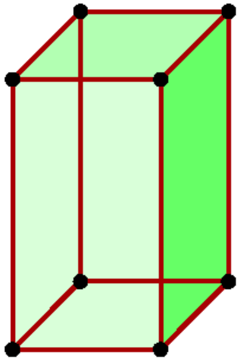
At lattice points:

- Atoms
- Molecules
- Ions

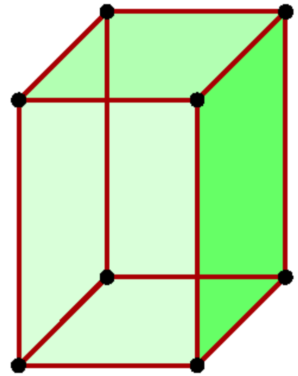
Seven Basic Unit Cells



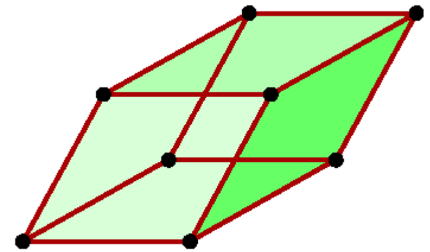
Simple cubic
$a = b = c$
$\alpha = \beta = \gamma = 90°$



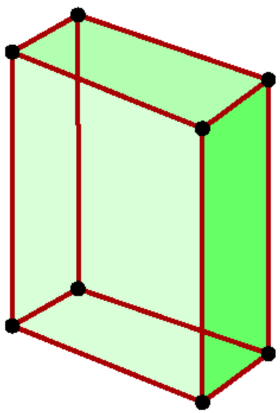
Tetragonal
$a = b \neq c$
$\alpha = \beta = \gamma = 90°$



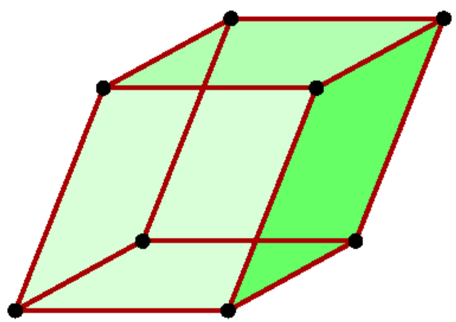
Orthorhombic
$a \neq b \neq c$
$\alpha = \beta = \gamma = 90°$



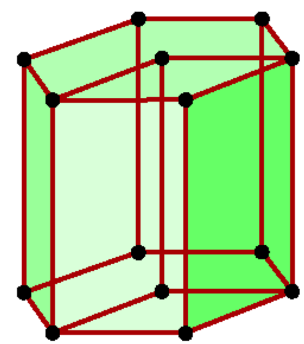
Rhombohedral
$a = b = c$
$\alpha = \beta = \gamma \neq 90°$



Monoclinic
$a \neq b \neq c$
$\gamma \neq \alpha = \beta = 90°$

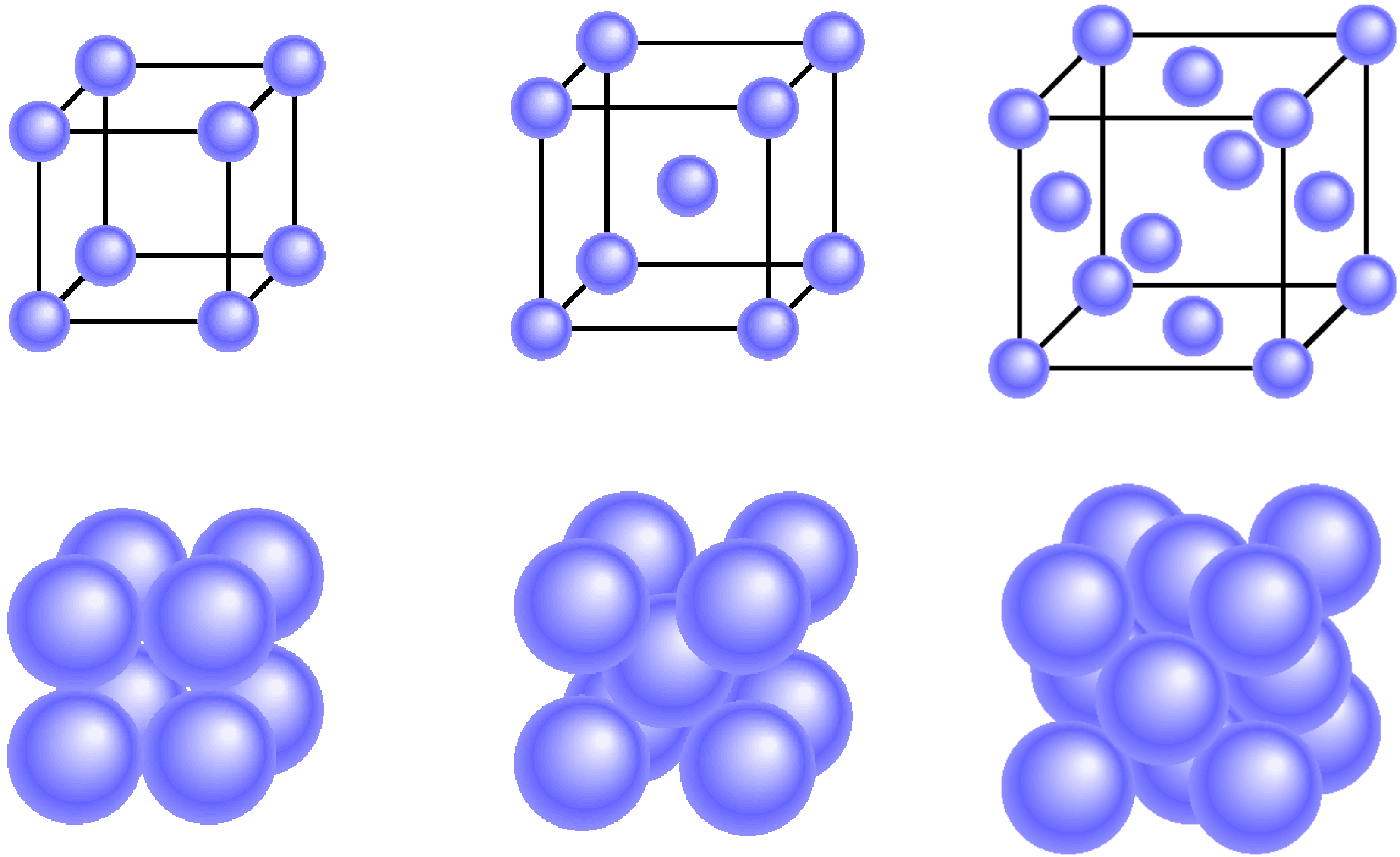


Triclinic
$a \neq b \neq c$
$\alpha \neq \beta \neq \gamma \neq 90°$



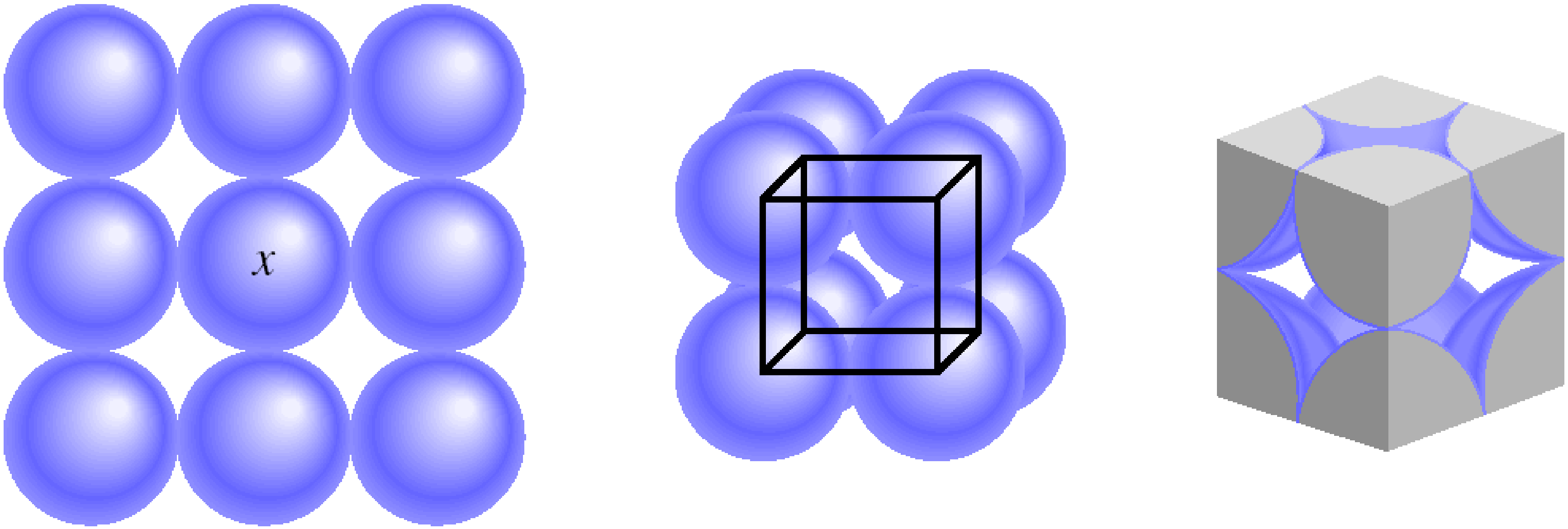
Hexagonal
$a = b \neq c$
$\alpha = \beta = 90°, \ \gamma = 120°$

Three Types of Cubic Unit Cells

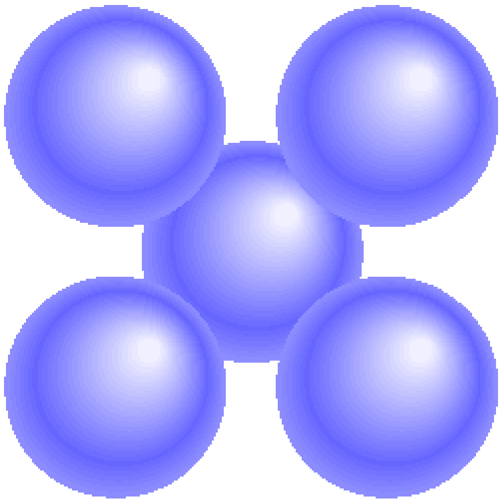


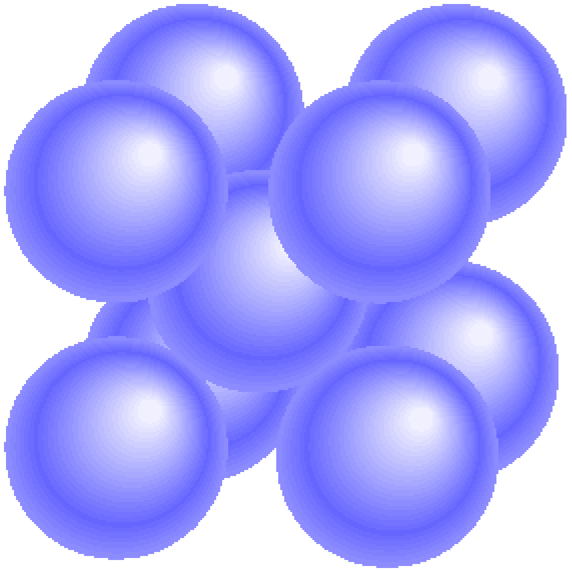
Simple cubic   Body-centered cubic   Face-centered cubic

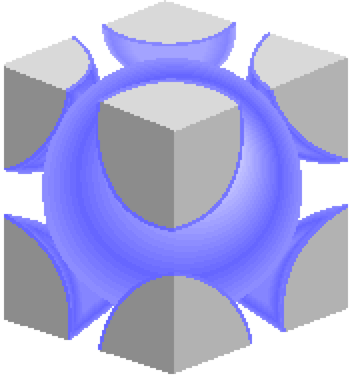
Arrangement of Identical Spheres in a Simple Cubic Cell



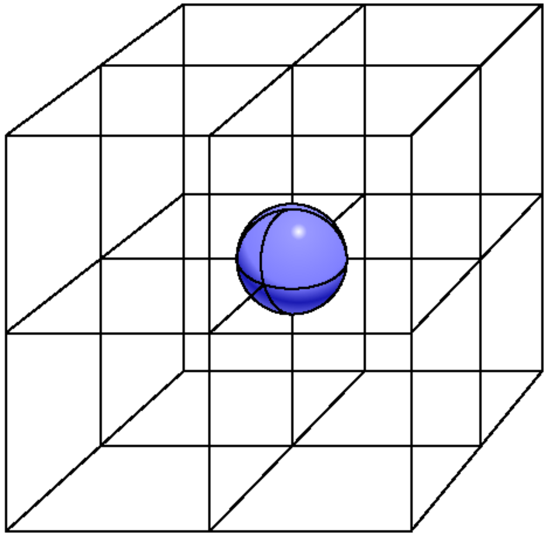
Arrangement of Identical Spheres in a Body-Centered Cubic Cell



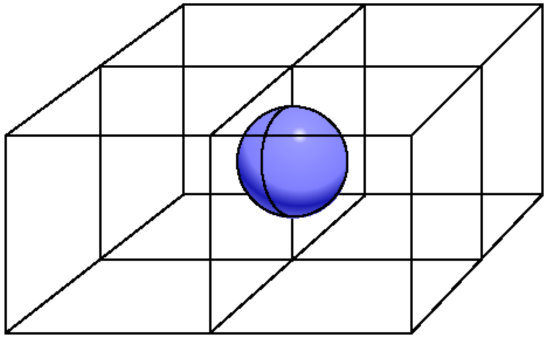




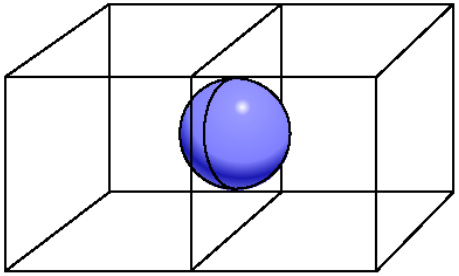
A Corner Atom, a Edge-Centered Atom and a Face-Centered Atom



Shared by 8
unit cells



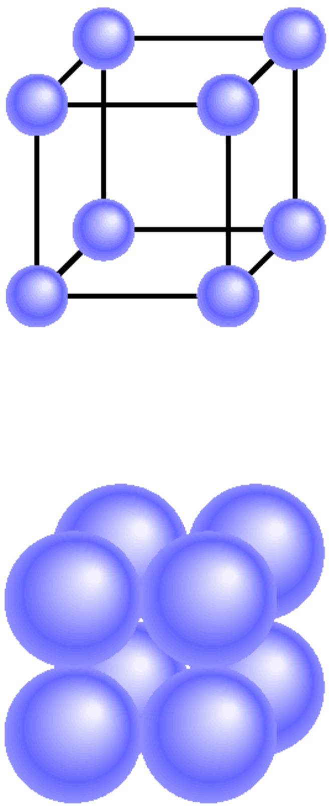
Shared by 4
unit cells



Shared by 2
unit cells

inside

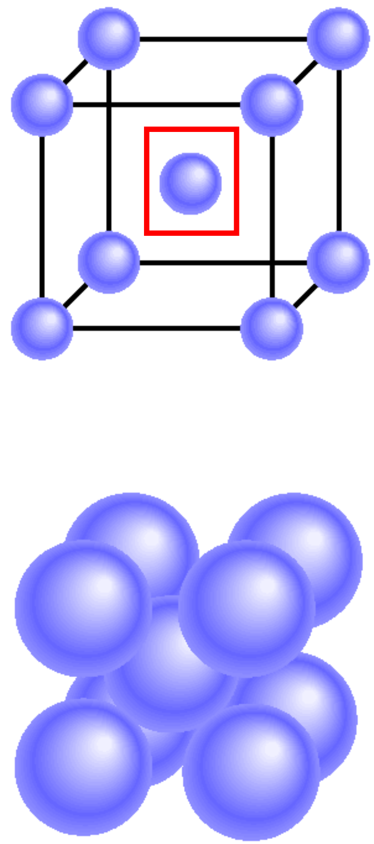
Number of Atoms Per Unit Cell



Simple cubic

1 atom/unit cell

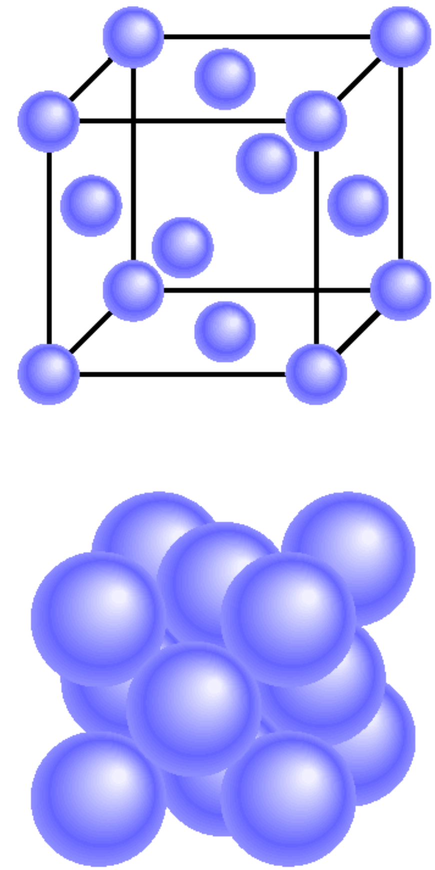
(8 x 1/8 = 1)



Body-centered cubic

2 atoms/unit cell

(8 x 1/8 + 1 = 2)



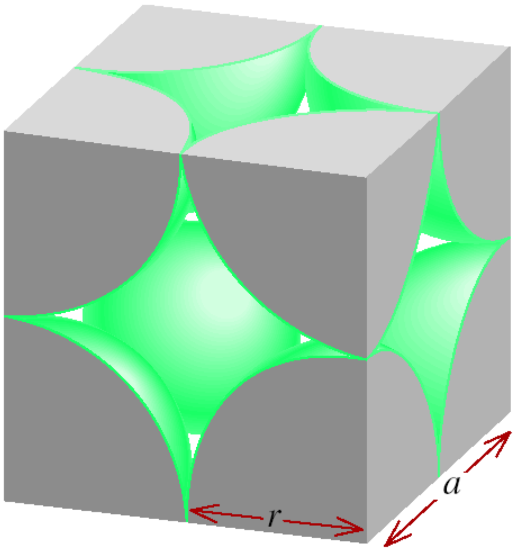
Face-centered cubic

4 atoms/unit cell

(8 x 1/8 + 6 x 1/2 = 4)

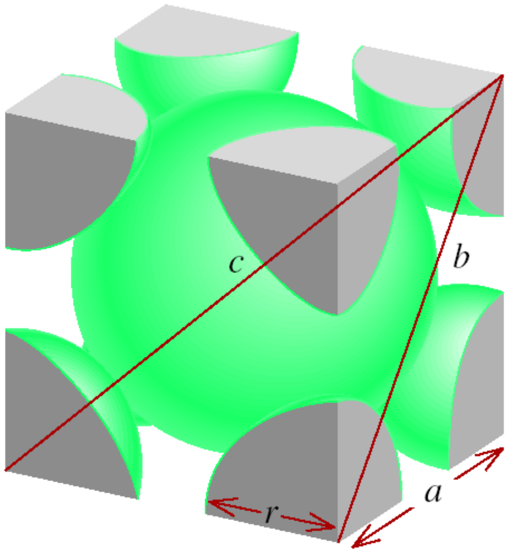
Thus, in a face-centred cubic unit cell, we have: 8 corners × 1/8 per corner atom = 8 × 1/8 = 1 atom. 6 face-centred atoms × 1/2 atom per unit cell = 3 atoms.

Relation Between Edge Length and Atomic Radius



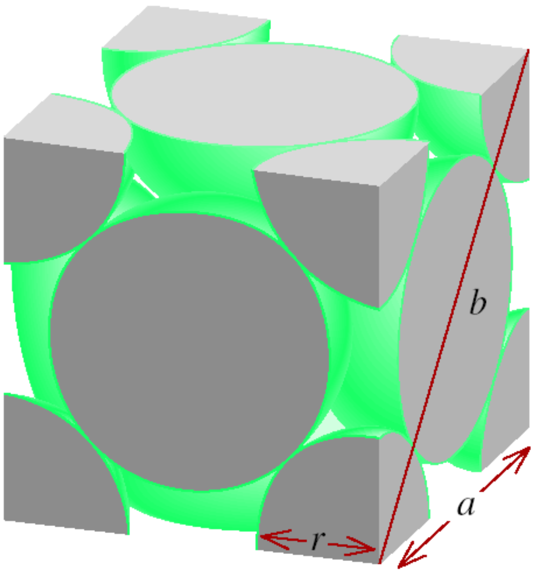
scc

$$a = 2r$$



bcc

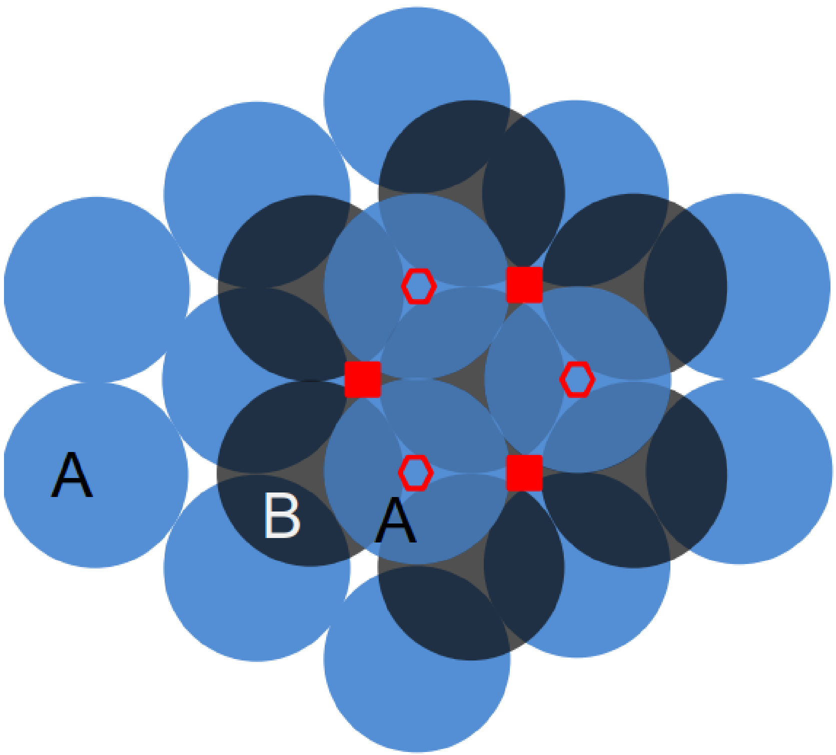
$$b^2 = a^2 + a^2$$
$$c^2 = a^2 + b^2$$
$$= 3a^2$$
$$c = \sqrt{3}a = 4r$$
$$a = \frac{4r}{\sqrt{3}}$$

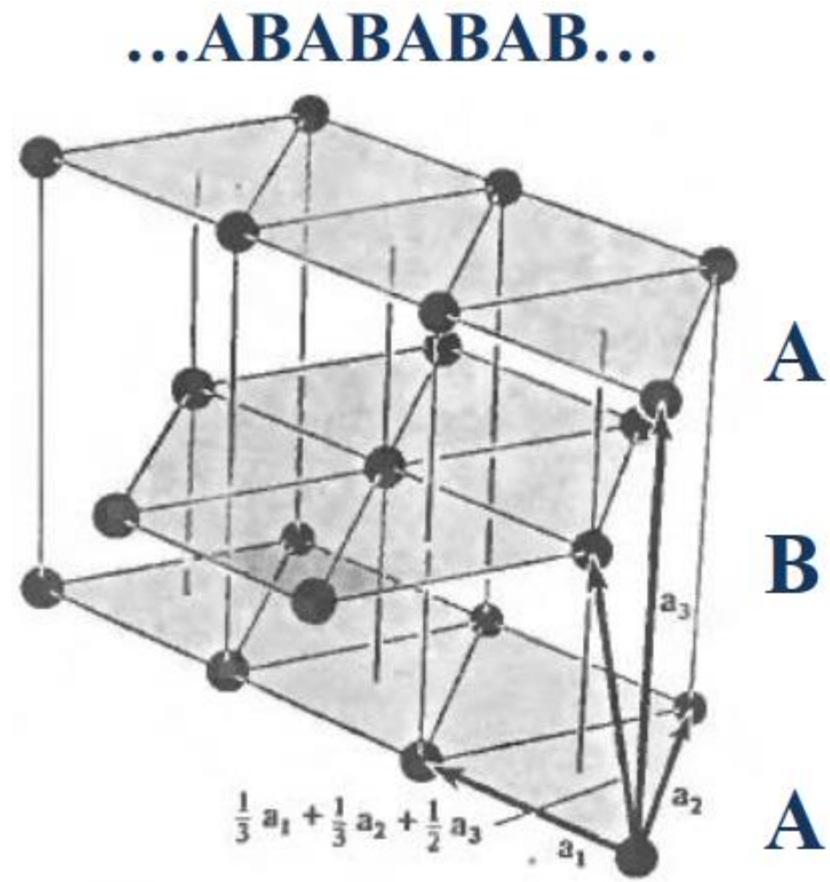


fcc

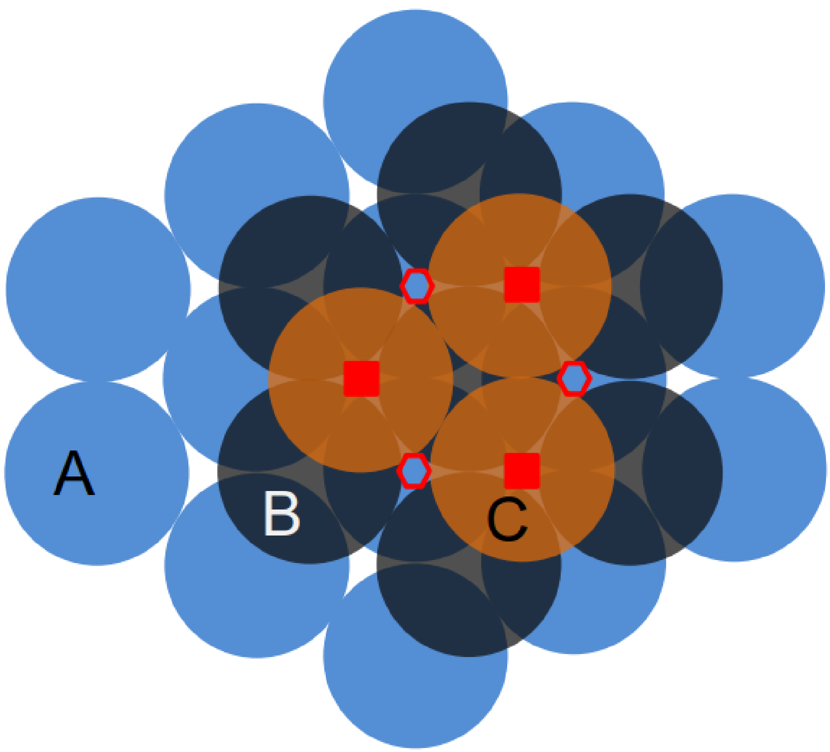
$$\underline{b = 4r}$$
$$b^2 = a^2 + a^2$$
$$16r^2 = 2a^2$$
$$a = \sqrt{8}r$$

Hexagonal Close Packed (HCP) Structure

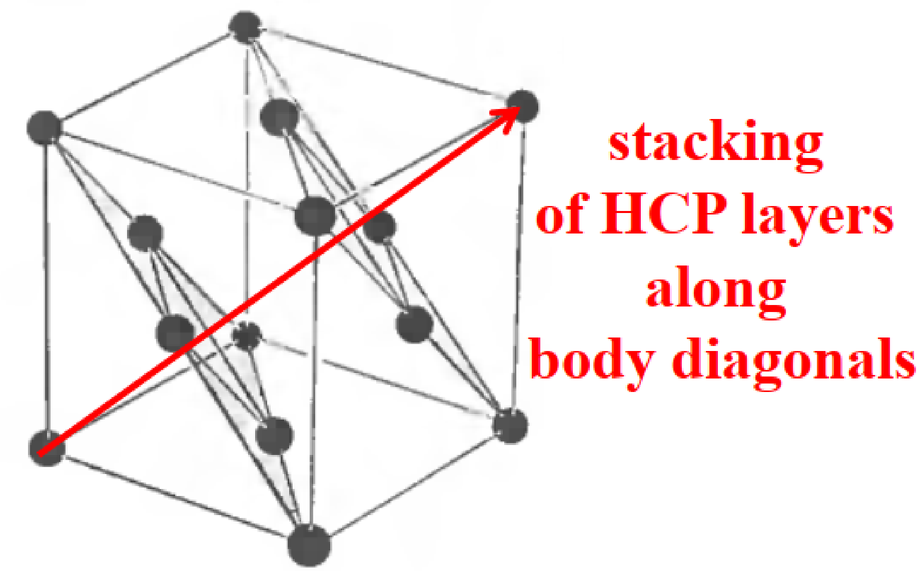




Cubic Close Packed (CCP) Structure



...ABCABCABC...



It turns out that the CCP structure is just the FCC Bravais lattice!

When silver crystallizes, it forms face-centered cubic cells. The unit cell edge length is 409 pm. Calculate the density of silver.

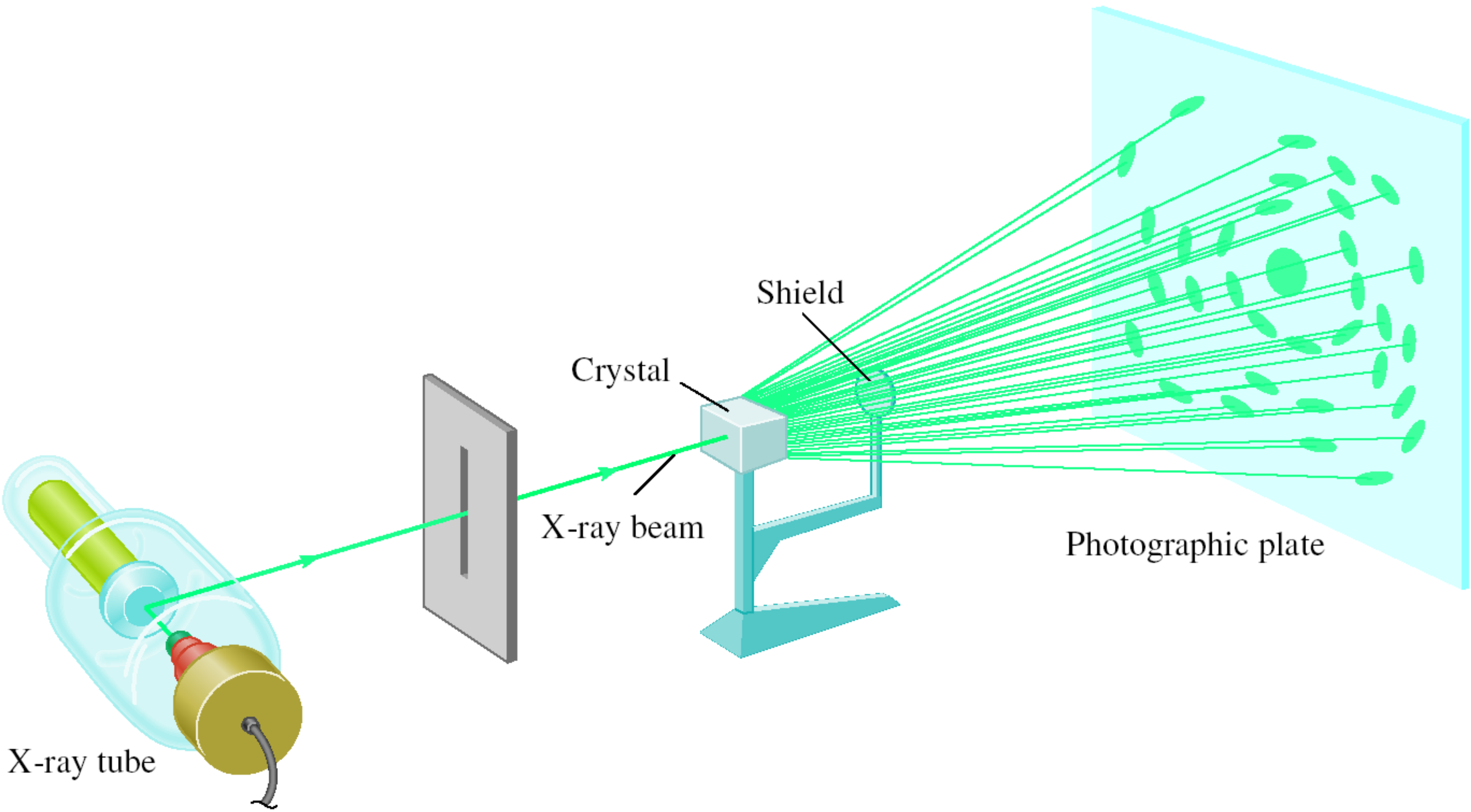
$$d = \frac{m}{V} \qquad V = a^3 = (409 \text{ pm})^3 = 6.83 \times 10^{-23} \text{ cm}^3$$

4 atoms/unit cell in a face-centered cubic cell

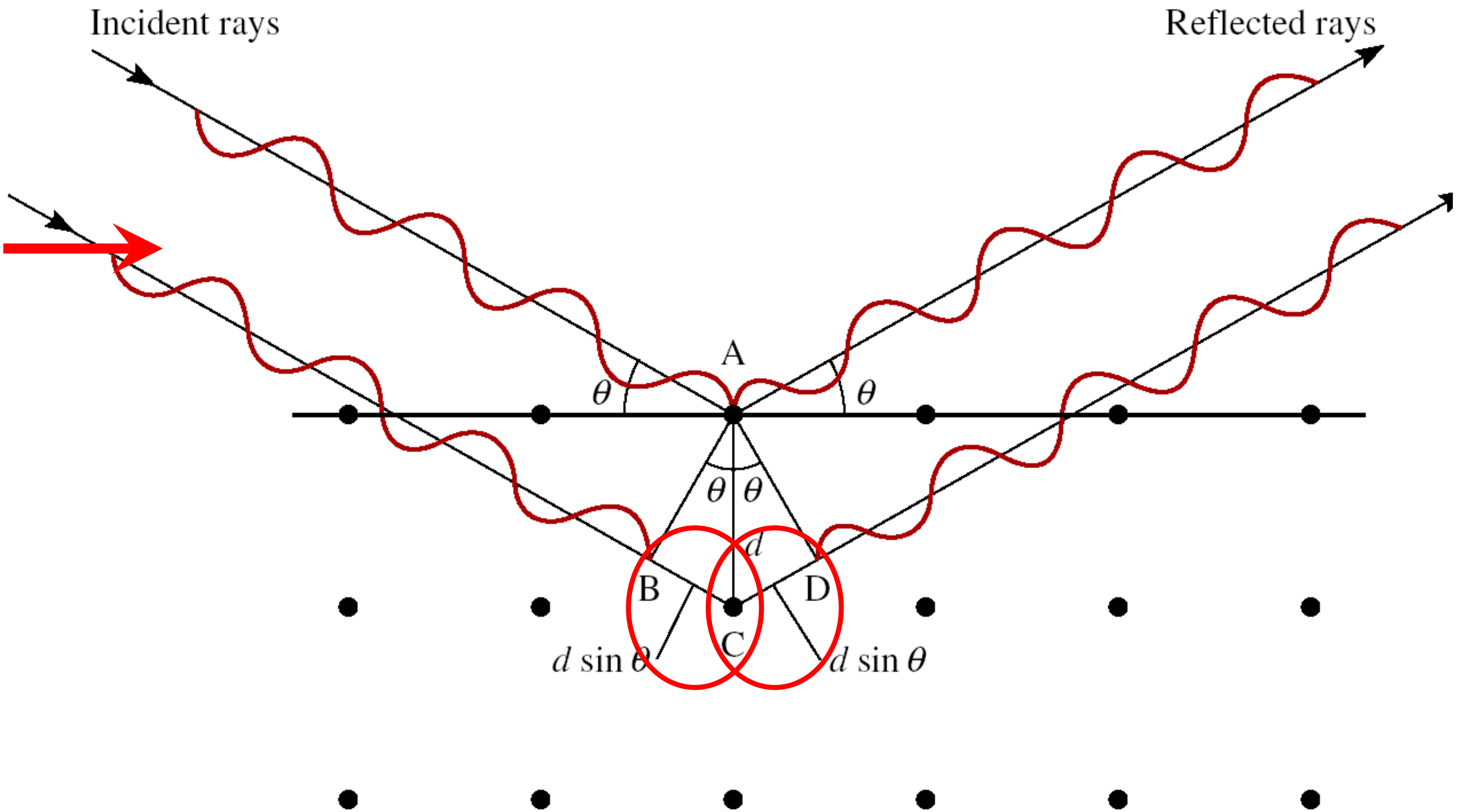
$$m = 4 \text{ Ag } \cancel{\text{atoms}} \times \frac{107.9 \text{ g}}{\cancel{\text{mole}} \text{ Ag}} \times \frac{1 \cancel{\text{ mole}} \text{ Ag}}{6.022 \times 10^{23} \cancel{\text{ atoms}}} = 7.17 \times 10^{-22} \text{ g}$$

$$d = \frac{m}{V} = \frac{7.17 \times 10^{-22} \text{ g}}{6.83 \times 10^{-23} \text{ cm}^3} = 10.5 \text{ g/cm}^3$$

An Arrangement for Obtaining the X-ray Diffraction Pattern of a Crystal.



Reflection of X rays from Two Layers of Atoms.



Extra distance = BC + CD = $2d \sin\theta = n\lambda$ (Bragg Equation)

X rays of wavelength 0.154 nm are diffracted from a crystal at an angle of 14.17°. Assuming that *n* = 1, what is the distance (in pm) between layers in the crystal?

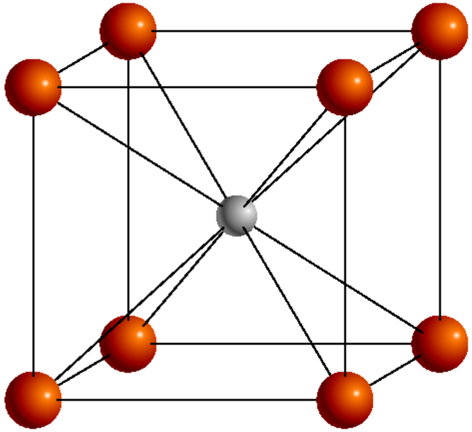
$n\lambda = 2d \sin \theta$ $\quad n = 1 \quad \theta = 14.17^{o} \quad \lambda = 0.154 \text{ nm} = 154 \text{ pm}$

$$d = \frac{n\lambda}{2\sin\theta} = \frac{1 \text{ x } 154 \text{ pm}}{2 \text{ x } \sin 14.17} = 314.0 \text{ pm}$$

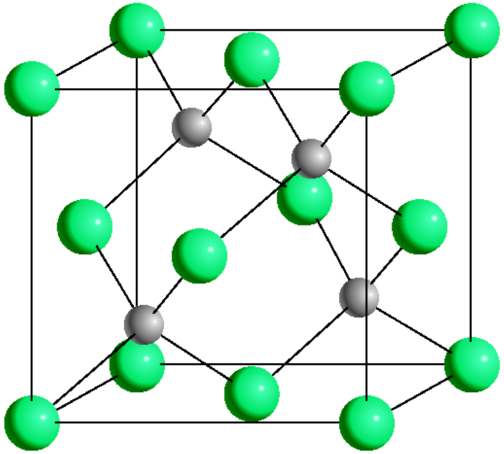
Types of Crystals

Ionic Crystals

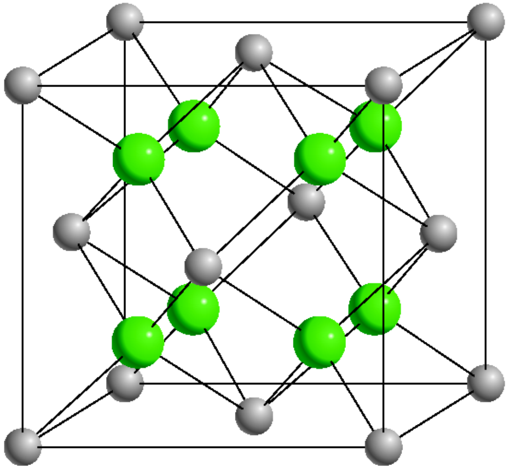
- Lattice points occupied by cations and anions
- Held together by electrostatic attraction
- Hard, brittle, high melting point
- Poor conductor of heat and electricity



CsCl



ZnS

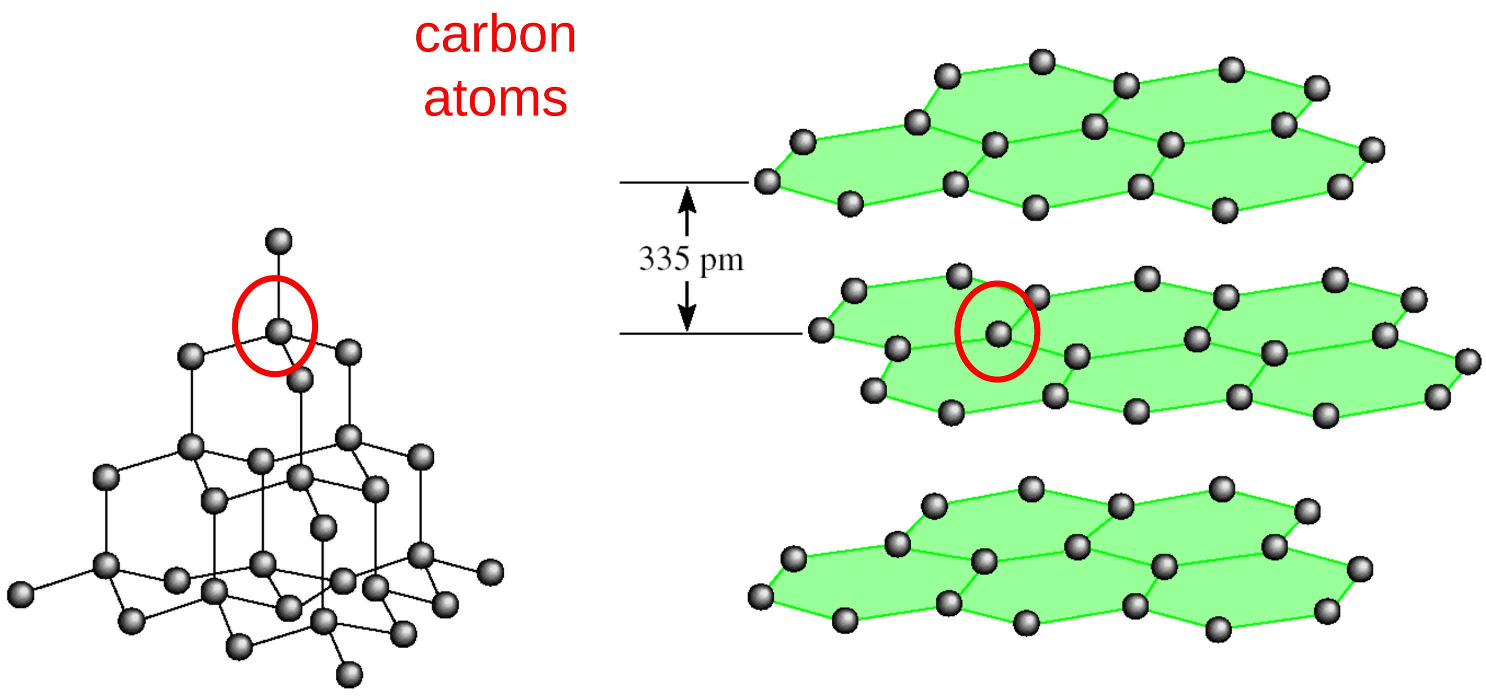


CaF_2

Types of Crystals

Covalent Crystals

- Lattice points occupied by atoms
- Held together by covalent bonds
- Hard, high melting point
- Poor conductor of heat and electricity



diamond

graphite

Types of Crystals

Molecular Crystals

- Lattice points occupied by molecules
- Held together by intermolecular forces
- Soft, low melting point
- Poor conductor of heat and electricity

water

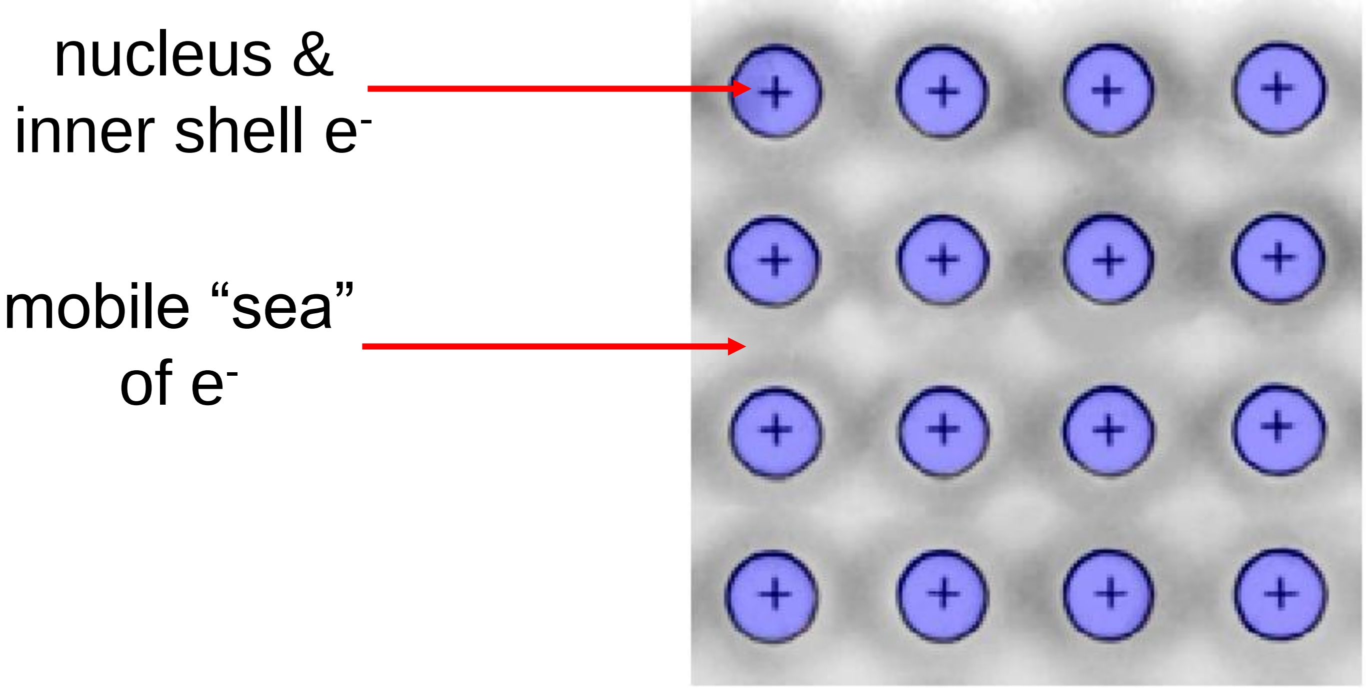
benzene

Types of Crystals

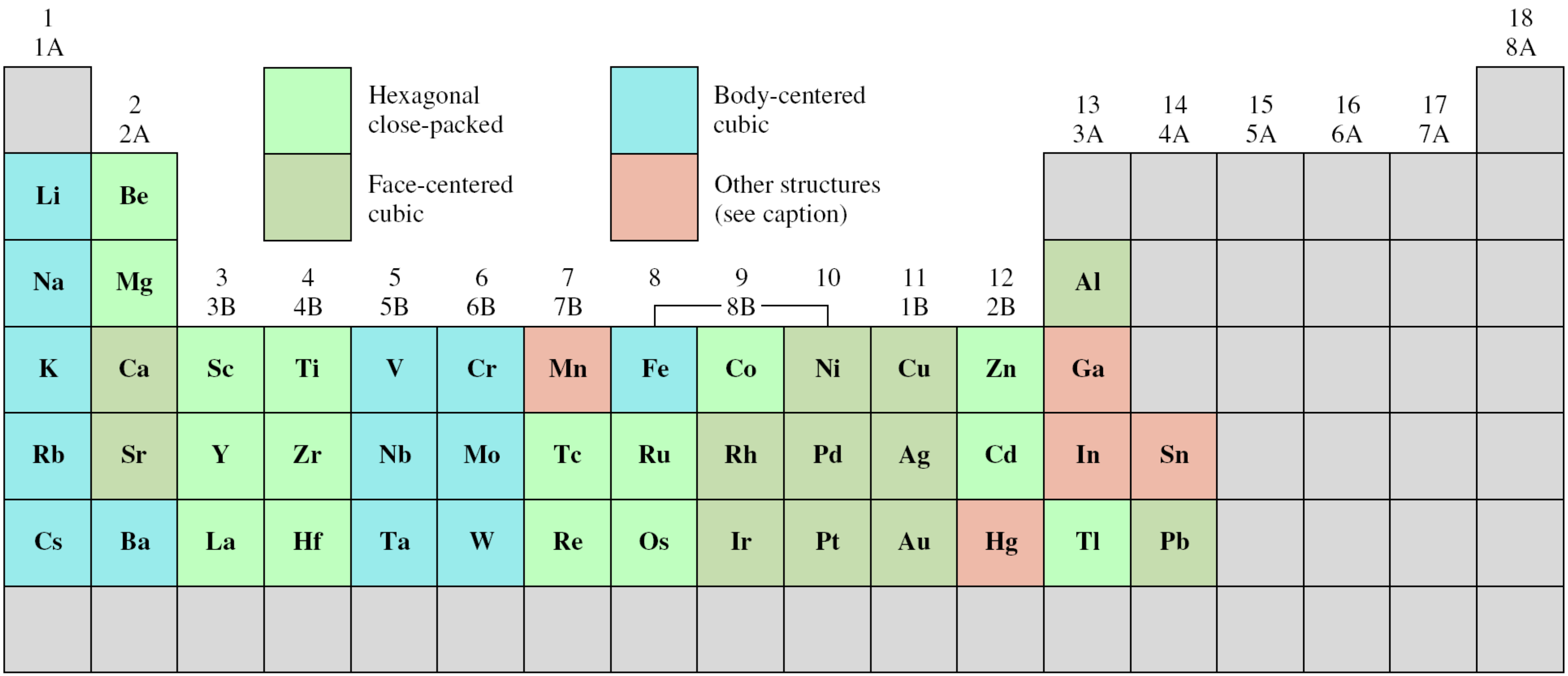
Metallic Crystals

- Lattice points occupied by metal atoms
- Held together by metallic bonds
- Soft to hard, low to high melting point
- Good conductors of heat and electricity

Cross Section of a Metallic Crystal



Crystal Structures of Metals



Types of Crystals

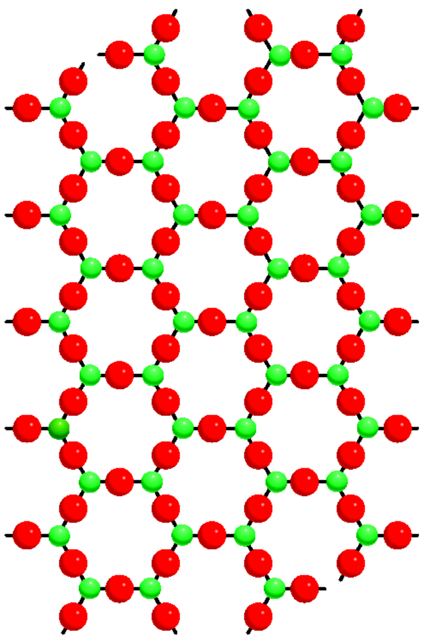
TABLE 11.4 Types of Crystals and General Properties

Type of Crystal	Force(s) Holding the Units Together	General Properties	Examples
Ionic	Electrostatic attraction	Hard, brittle, high melting point, poor conductor of heat and electricity	$NaCl$, LiF, MgO, $CaCO_3$
Covalent	Covalent bond	Hard, high melting point, poor conductor of heat and electricity	C (diamond),† SiO_2 (quartz)
Molecular*	Dispersion forces, dipole-dipole forces, hydrogen bonds	Soft, low melting point, poor conductor of heat and electricity	Ar, CO_2, I_2, H_2O, $C_{12}H_{22}O_{11}$ (sucrose)
Metallic	Metallic bond	Soft to hard, low to high melting point, good conductor of heat and electricity	All metallic elements; for example, Na, Mg, Fe, Cu

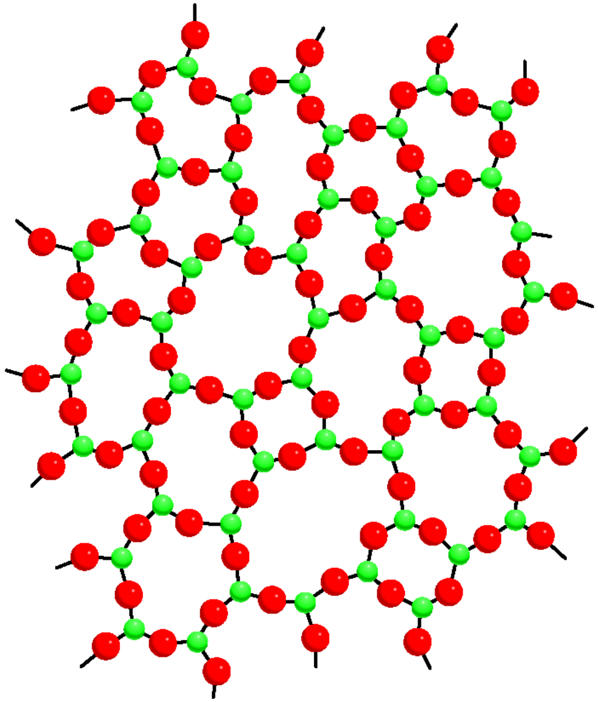
*Included in this category are crystals made up of individual atoms.
†Diamond is a good thermal conductor.

An ***amorphous solid*** does not possess a well-defined arrangement and long-range molecular order.

A ***glass*** is an optically transparent fusion product of inorganic materials that has cooled to a rigid state **without crystallizing**

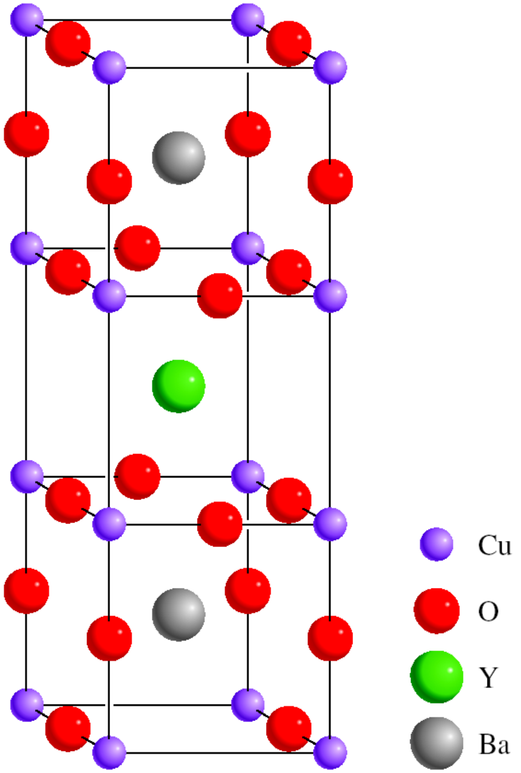


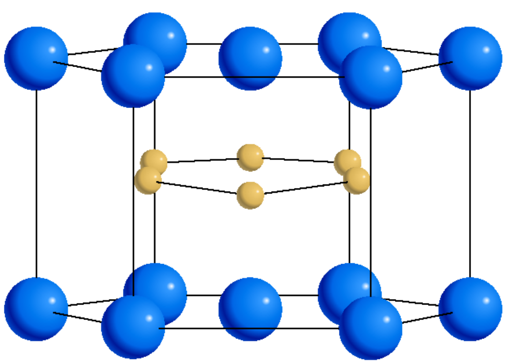
Crystalline quartz (SiO_2)



Non-crystalline quartz glass

Chemistry In Action: High-Temperature Superconductors



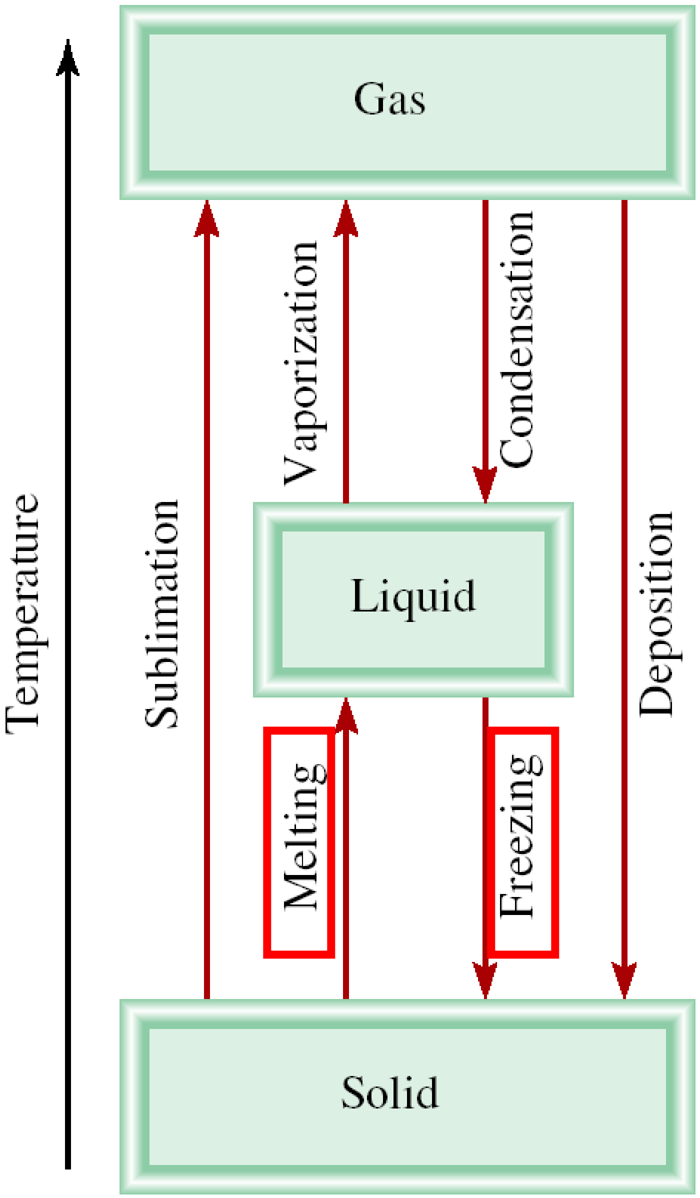


MgB_2

Solid-Liquid Equilibrium

$H_2O\ (s) \rightleftharpoons H_2O\ (l)$

The ***melting point*** of a solid or the ***freezing point*** of a liquid is the temperature at which the solid and liquid phases coexist in equilibrium



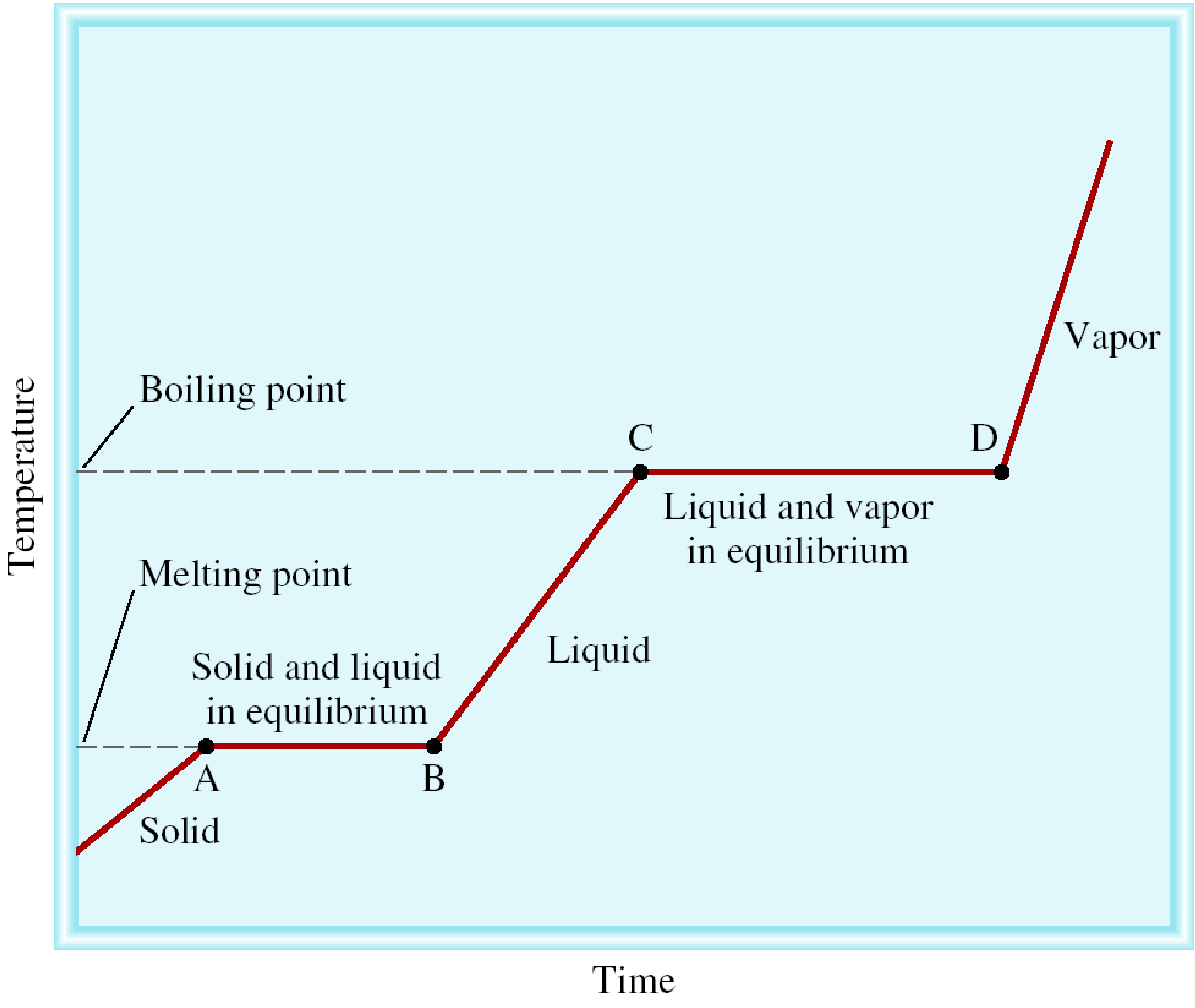
Molar heat of fusion (ΔH_{fus}) is the energy required to melt 1 mole of a solid substance at its freezing point.

TABLE 11.8 Molar Heats of Fusion for Selected Substances

Substance	Melting Point* (°C)	ΔH_{fus} (kJ/mol)
Argon (Ar)	−190	1.3
Benzene (C_6H_6)	5.5	10.9
Diethyl ether ($C_2H_5OC_2H_5$)	−116.2	6.90
Ethanol (C_2H_5OH)	−117.3	7.61
Mercury (Hg)	−39	23.4
Methane (CH_4)	−183	0.84
Water (H_2O)	0	6.01

*Measured at 1 atm.

Heating Curve



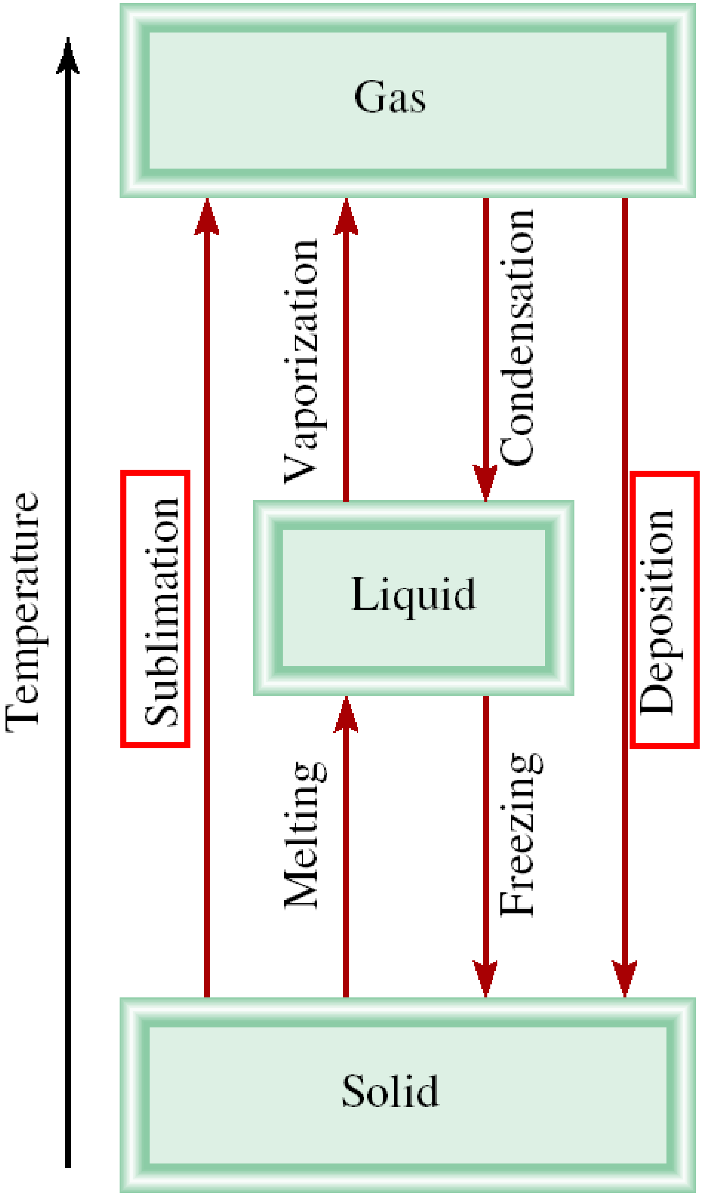
Solid-Gas Equilibrium

$$H_2O\,(s) \rightleftharpoons H_2O\,(g)$$

Molar heat of sublimation (ΔH_{sub}) is the energy required to sublime 1 mole of a solid.

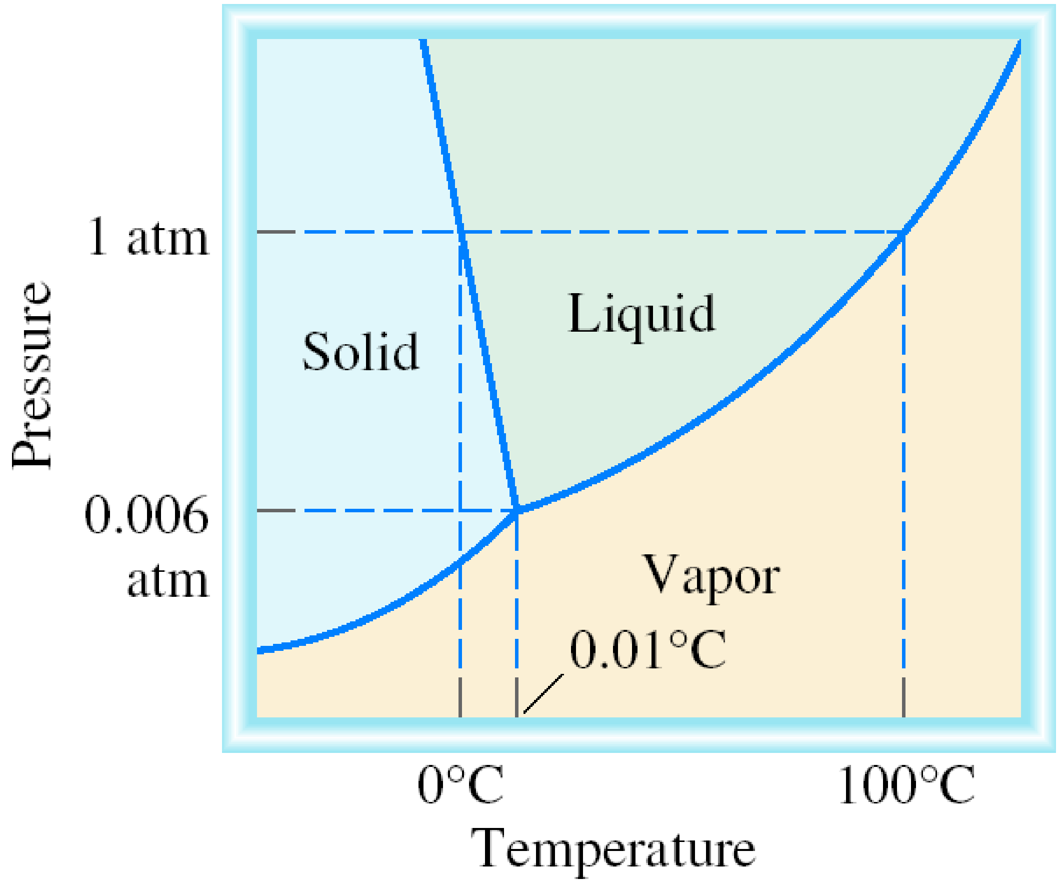
$$\Delta H_{sub} = \Delta H_{fus} + \Delta H_{vap}$$

(Hess's Law)

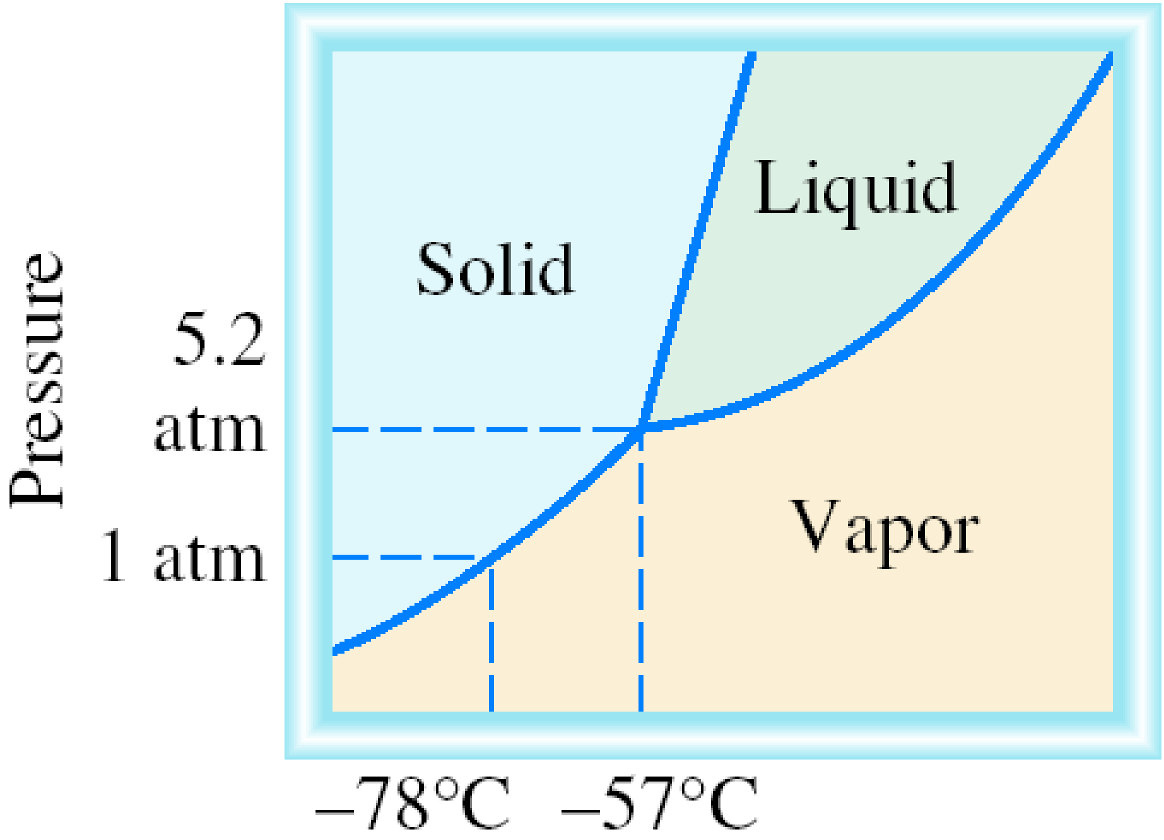


A ***phase diagram*** summarizes the conditions at which a substance exists as a solid, liquid, or gas.

Phase Diagram of Water

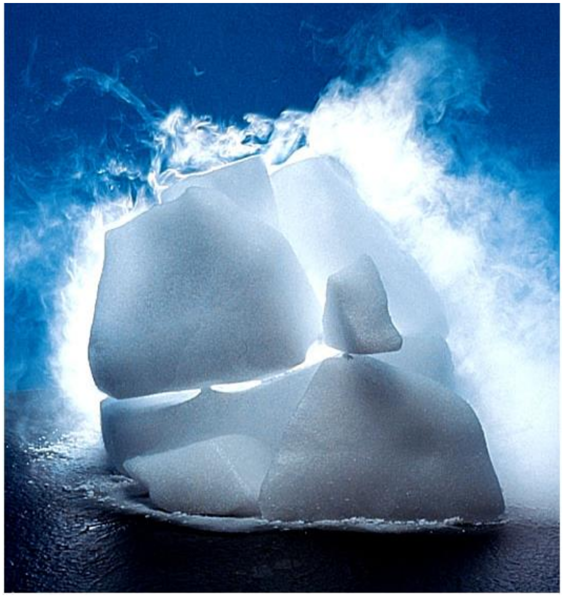


Phase Diagram of Carbon Dioxide

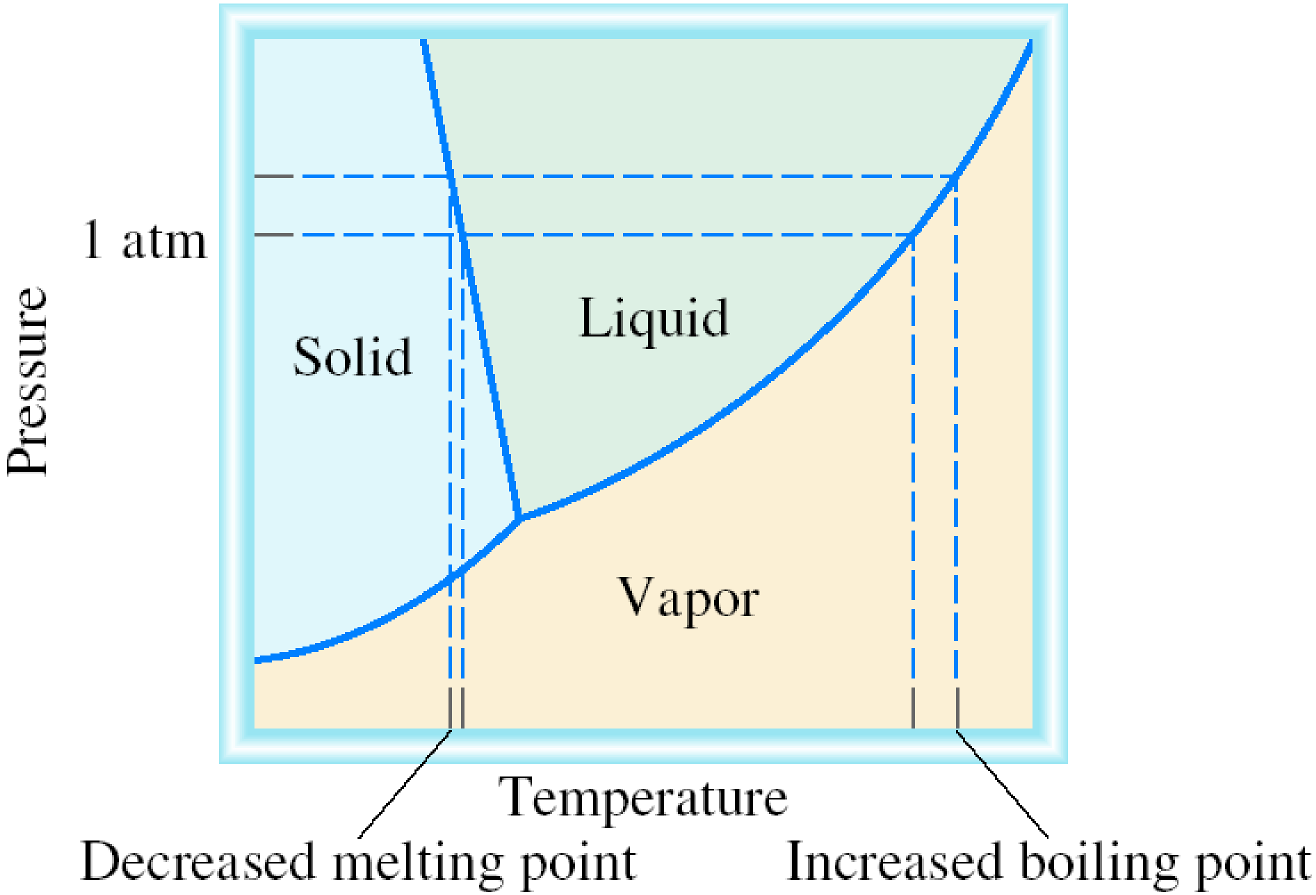


At 1 atm

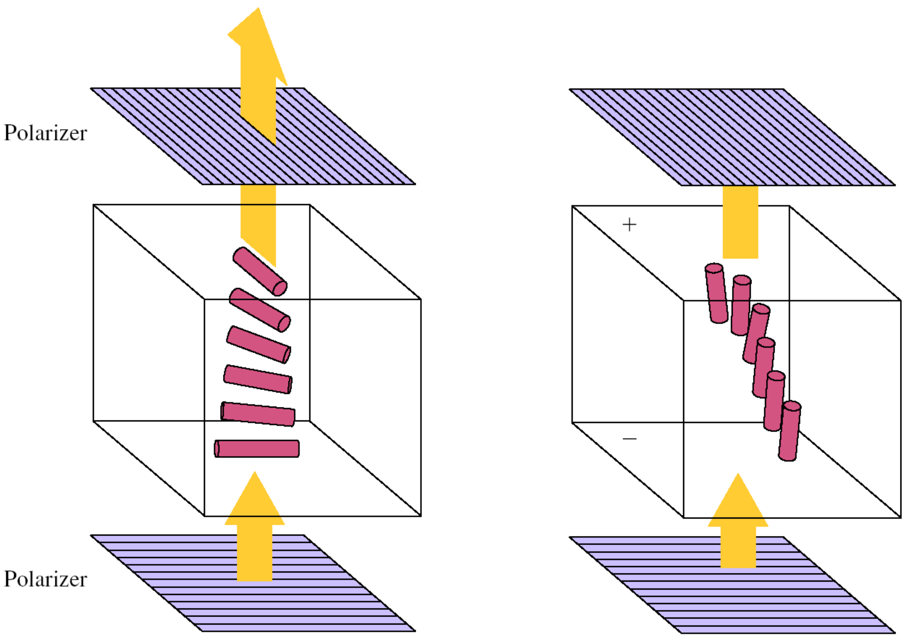
$CO_2\ (s) \longrightarrow CO_2\ (g)$

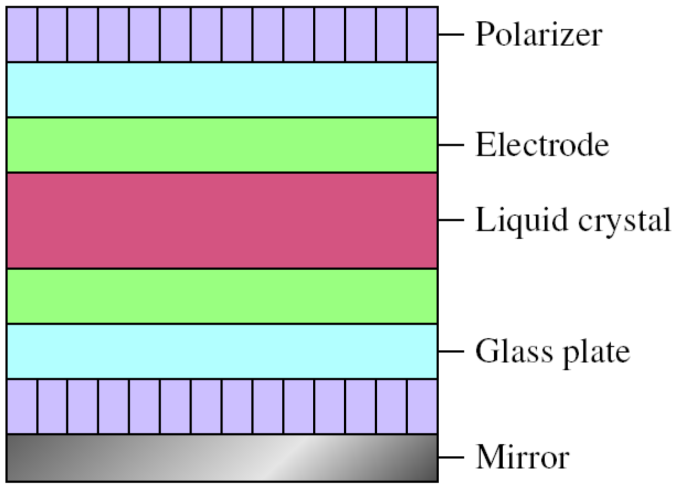


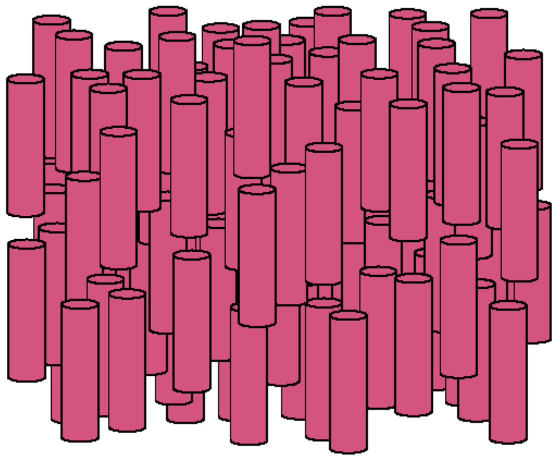
Effect of Increase in Pressure on the Melting Point of Ice and the Boiling Point of Water



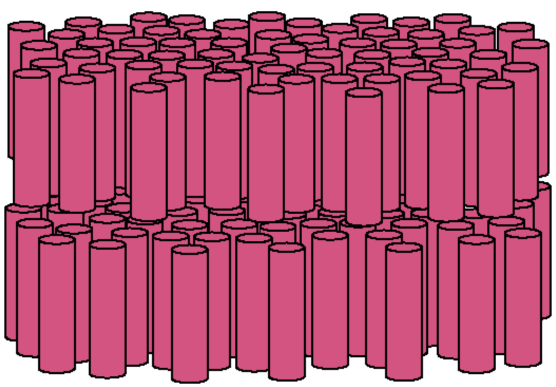
Chemistry In Action: Liquid Crystals







Nematic



Smectic