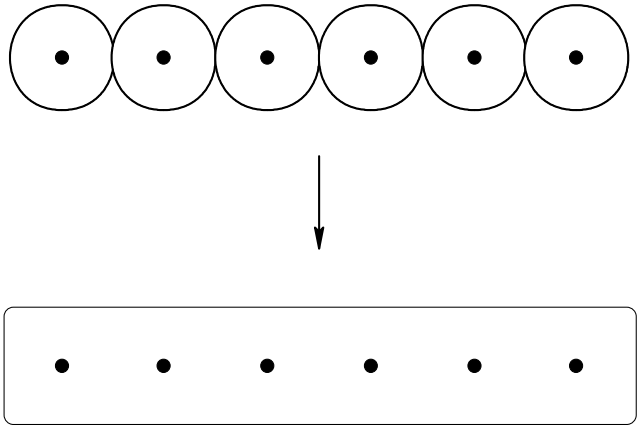
Types and Physical Properties of Solids

✔ Substances that are solids at room temperature usually fall into one of the following categories:

- Metals
- Ionic Solids
- Molecular Solids
- Network Solids
- Amorphous Solids

Metals

- Highly conductive of heat and electricity.
- Orbitals of valence electrons on individual atoms combine to produce electron bands extending over the entire metal structure.



- Delocalization and mobility of electrons in such bands accounts for conductivity.
- The metal structure consists of an orderly array of nuclei in a sea of electrons.
- Metal structures are built up by close packing of spherical atoms.

Physical Properties of Metals

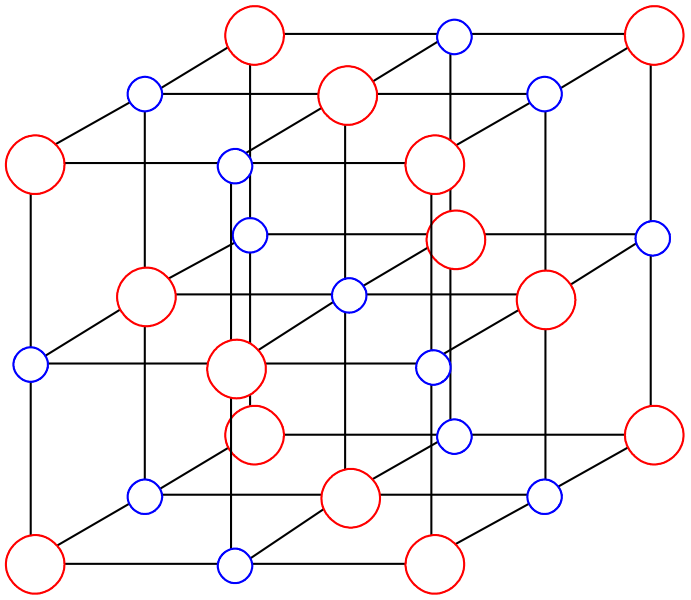
- Metallic structure is typically stable over a wide range of temperatures.

- As the number of valence electrons increases, metallic bonding tends to be stronger, resulting in typically high m.p. and b.p.
    - Alkali metals, with only one ns^1 electron to contribute to bonding have unusually low m.p. and b.p.
    - Most metals have a long liquid range.
        - ⇨ Gallium has the longest liquid range of any known substance:
          m.p. = 29.78 °C b.p. ≈ 2400 °C

Metal	m.p. °C	b.p. °C	Metal	m.p. °C	b.p. °C
Li	180	1326	Be	1278	2970
Na	97.5	889	Mg	649	1090
K	63.4	757	Ca	839	1484
Rb	38.8	679	Sr	769	1384
Cs	28.7	690	Ba	725	1640

Ionic Compounds

- Non-conductive, hard, crystalline, solids, composed of electrically equivalent numbers of cations and anions in an orderly, three-dimensional crystal lattice.



Cl^- Na^+

- Lattice energy increases with ion charge and decreases with ion separation.

Physical Properties of Ionic Compounds

- M.p. and b.p. tend to increase with lattice strength.
- Liquid ranges tend to be long, but somewhat shorter than for metals.

Compound	$U°$ kJ·mol	m.p. °C	b.p. °C
NaCl	786.8	801	1413
NaBr	751.8	747	1390
NaI	703	661	1304
MgO	3795	2852	3600
CaO	3414	2614	2850

Molecular Compounds

- Held together by intermolecular forces: London dispersion, dipole-dipole, hydrogen bonding.

- M.p. and b.p. typically lower than other solids.
    - B.p. rarely above 400 ^{o}C.

- Relatively short liquid ranges.

Network Solids

- Network solids consist of infinite arrays of covalently bonded atoms. (No individual molecules.)
- Among the hardest substances known.
- Typically very high m.p. and b.p.
- Examples include both elements and compounds.

Solid	m.p. (^{o}C)	b.p. (^{o}C)
C (graphite)	>4000	>4200
C (diamond)	>4000	>4200
SiO_2 (quartz)	1670	2230
SiC (silcon carbide)	>2700 (decomp.)	n/a

Amorphous Solids

✏ Glass is the most familiar example of an amorphous solid, but many plastics such as polyethylene and nylon are also amorphous solids.

✔ Less ordered structures than crystalline solids.

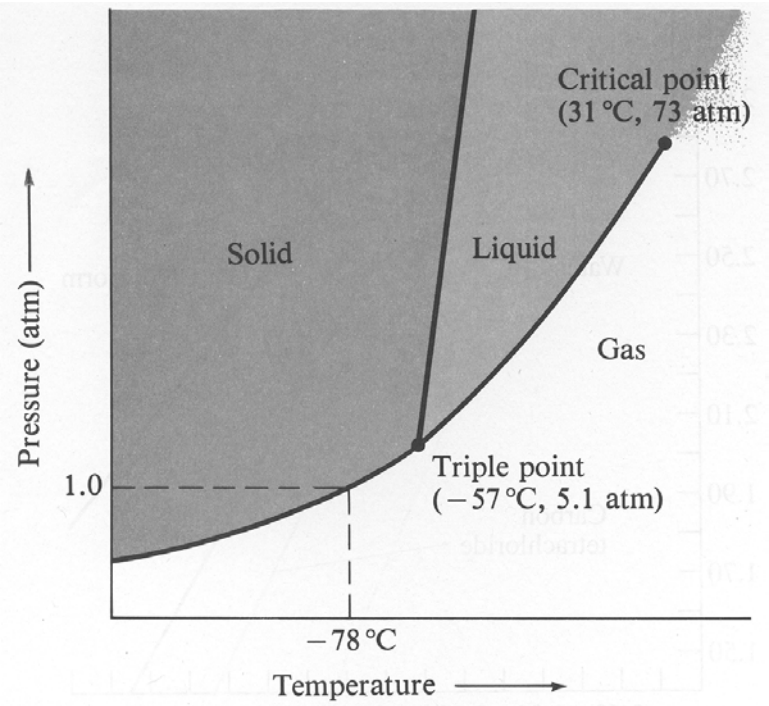
✔ Have short-range order among near-neighbor units, but long-range order is lacking.

✔ Tend to break in unpredictable ways.

✔ Melting points tend to be similar but somewhat lower than more ordered substances of similar composition.

Phase Diagrams

Phase Diagram for CO_2



- ✔ Only one phase exists for any *T*-*P* combination entirely in a phase region.

- ✔ Lines represent *T*-*P* combinations where two phases are in equilibrium (phase transitions).

- ✔ The **triple point** is a *T*-*P* combination at which all three phases are simultaneously in equilibrium.

- ✔ Critical point is a *T*-*P* combination beyond which a gas cannot be liquified with increased pressure.