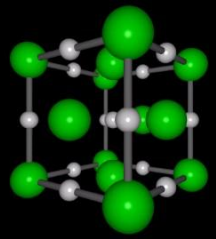
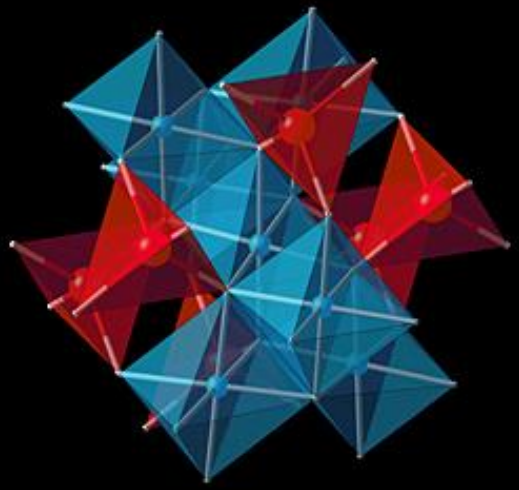
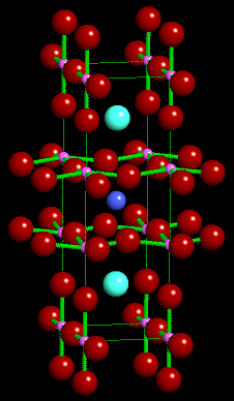
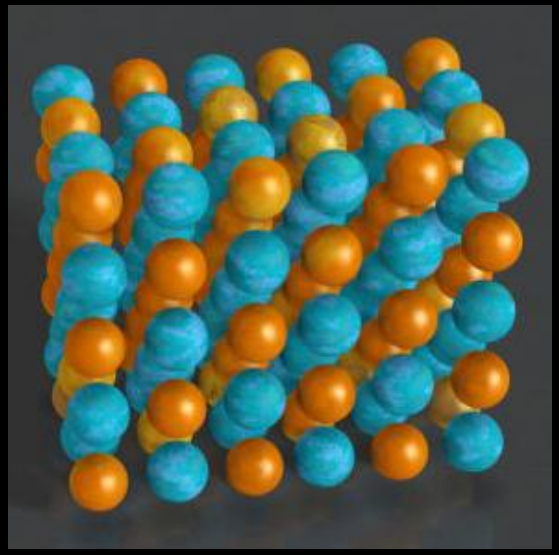


# Solids









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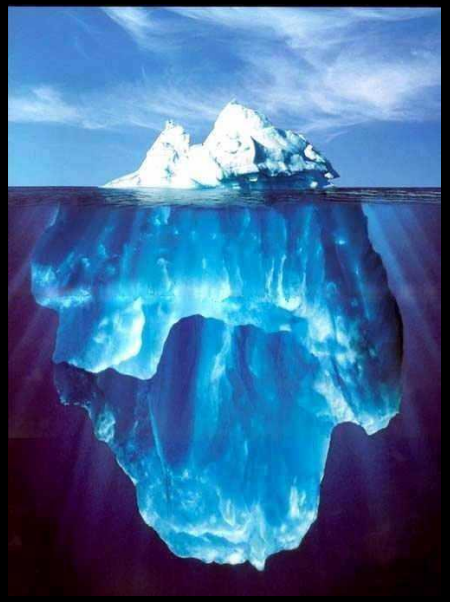
# States of Matter-Solid

| | |
|---|---|
| **Form** | **Rigid** |
| **Compressibility** | **Very Low (Exam→ Not Compressible)** |
| **Shape** | **Constant (definite)** |
| **Volume** | **Constant (definite)** |
| **Particle Movement** | **Vibration in fixed position** |

**Example: Ice**





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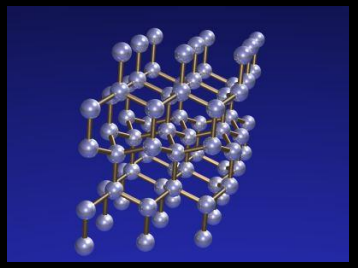
# Three Types of Crystalline Solids

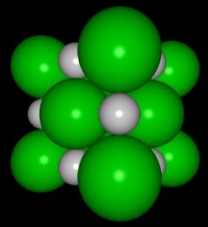
**Atomic** — **Atoms**

**Diamond**



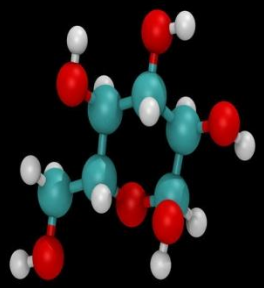
**Ionic** — **Ions**

**Sodium Chloride**



**Molecular** — **Molecules**

**Glucose**





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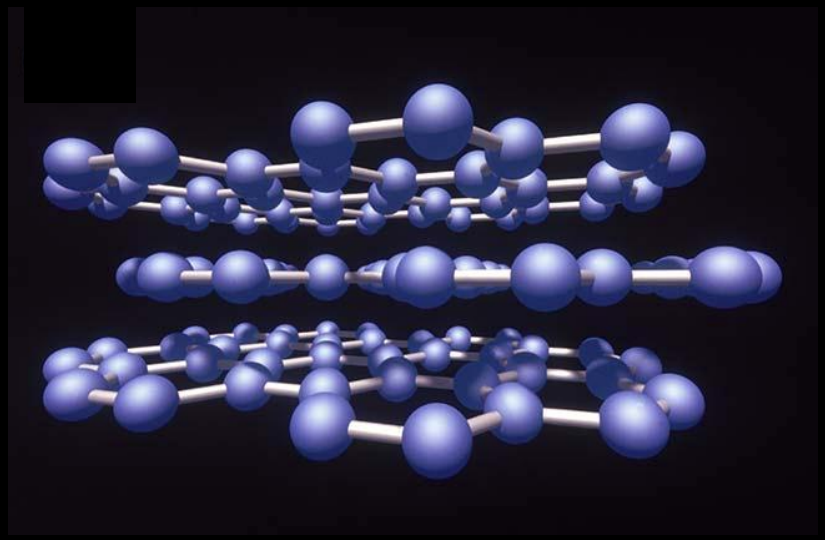
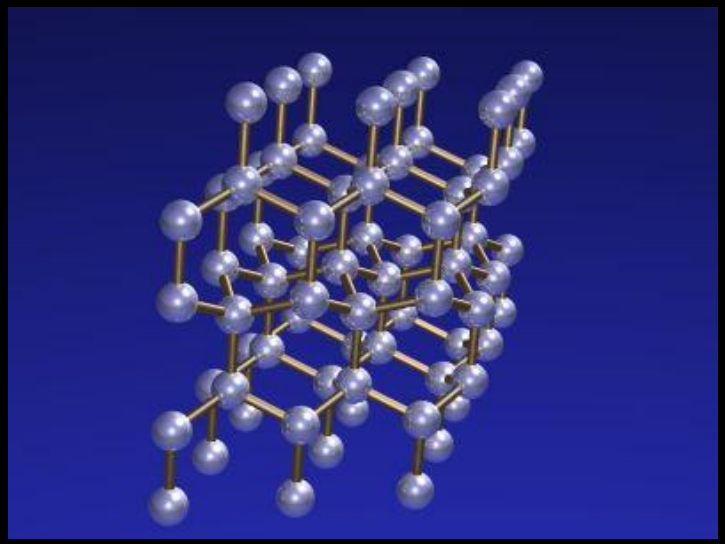
# Solids: Physical Properties

## Macro properties observed

## Determined by atomic level geometry & forces



**Graphite**



**Diamond**



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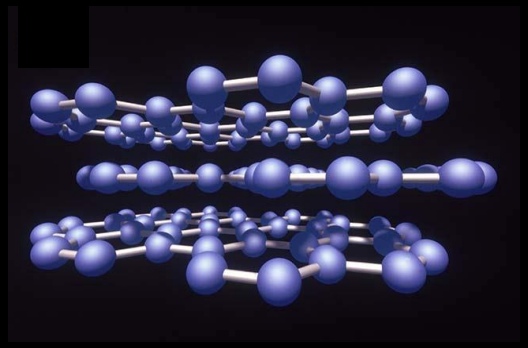
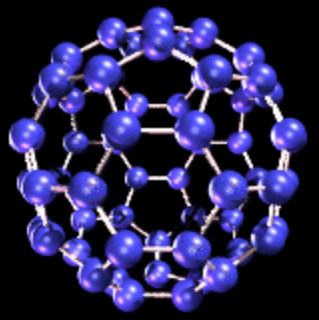
# Atomic Solids





## Characteristics:

Graphite

$C_{60}$ Bucky Ball

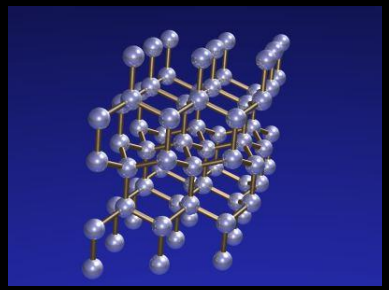
Fundamental Unit: Atom

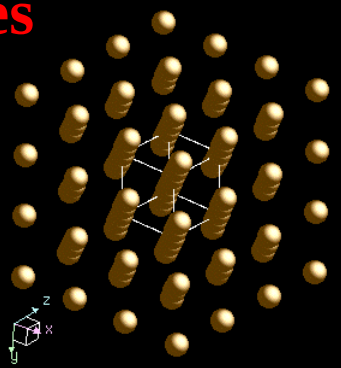
Shape determined by atoms packing geometry

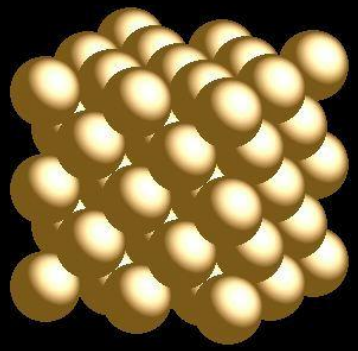
(Atoms at every vertex of rigid geometrical shape)

Represented by chemical formula

Variable Properties







Diamond

Iron

Gold



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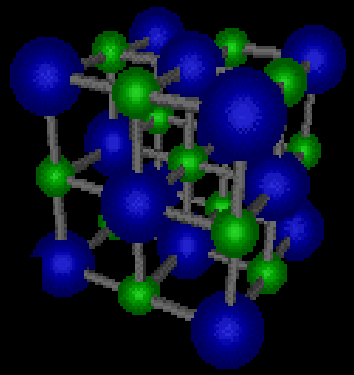
# Ionic Solids

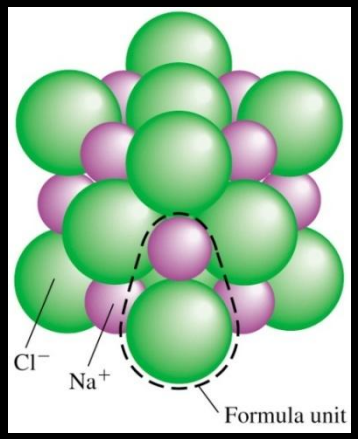


## Characteristics:

**Large Matrix of Charged Particles**
**Shape determined by ion charges and size**

**Represented by Formula Unit**

**High Melting Point >> 200 $^{o}$C**
**Brittle … easily cleaved**
**Good Electrical Conductors in $H_2O$ or melted**




**Strong Attractive Forces**
**400 – 1100 kJ / mole**



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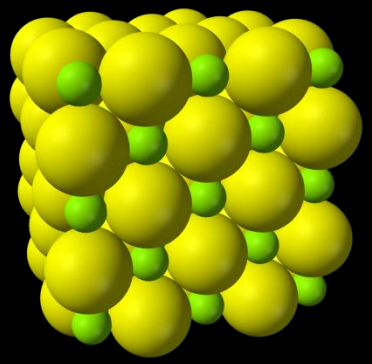
# Ionic Solids

**Ionic Bond (Attractive force between ions governed by Coulomb**

$$F \propto q_1 q_2 / r^2$$



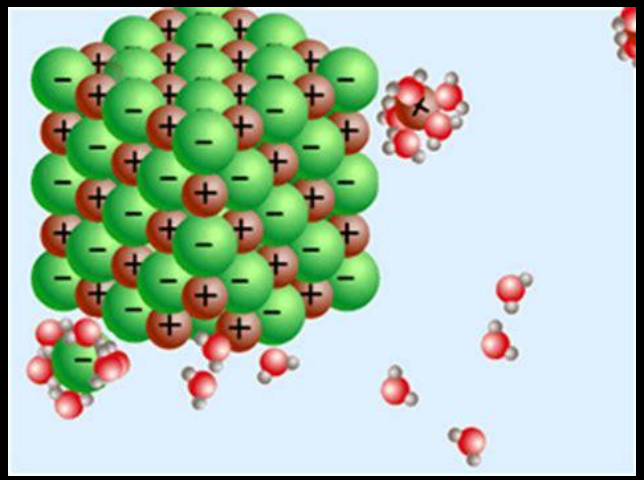
**Higher melting point:**

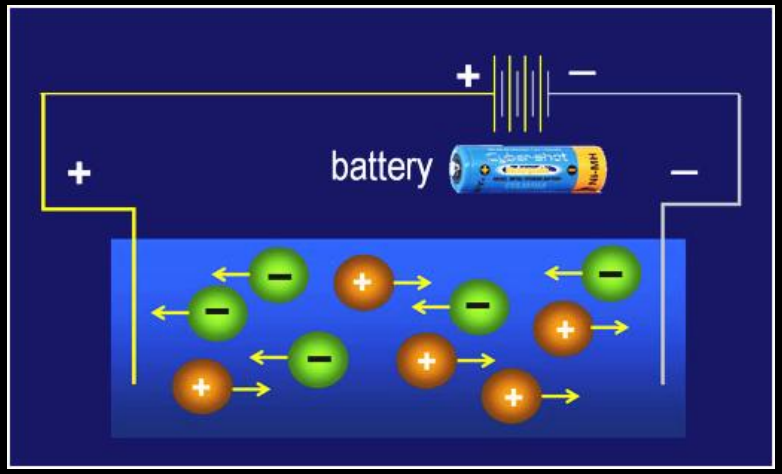
- Greater charge: stronger force
- Smaller ions; $r^2$ smaller

**Higher boiling point**

- Lower vapor pressure

**Dissolving a result of ions becoming hydrated**





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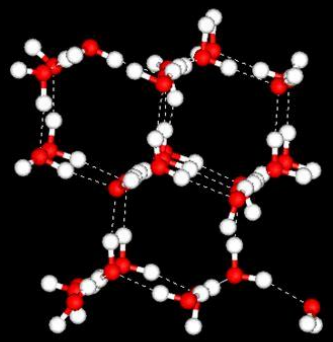
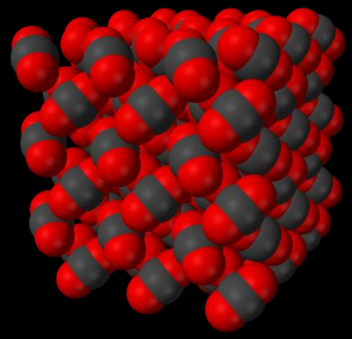
# Molecular Solids



Solid $H_2O$



Solid $CO_2$

## Characteristics:

Fundamental Unit: Molecule

Shape determined by molecular geometry

Represented by chemical formula

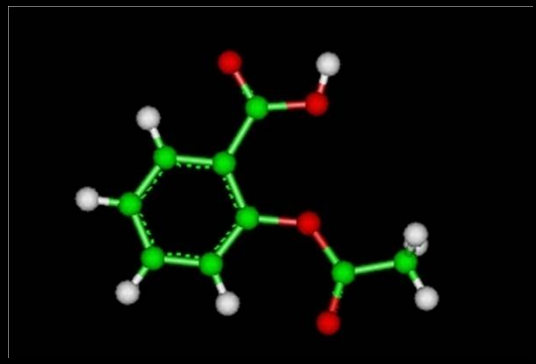
Low Melting Point < 200 °C

$S_8$

Low Attractive Forces

- H-Bonds
- Dipole-Dipole
- London Dispersion

10 – 40 kJ / mole



Aspirin



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# Identify the type of crystalline solid:

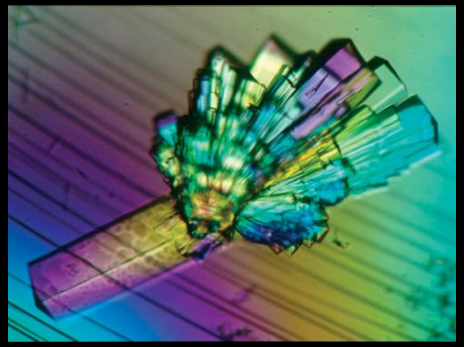
**Ammonia: Molecular**

**Iron: Atomic**

**Cesium fluoride: Ionic**

**Argon: Atomic**

**White phosphorus ($P_4$): Molecular**





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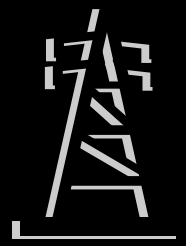
# Metals - Left Side Periodic Table



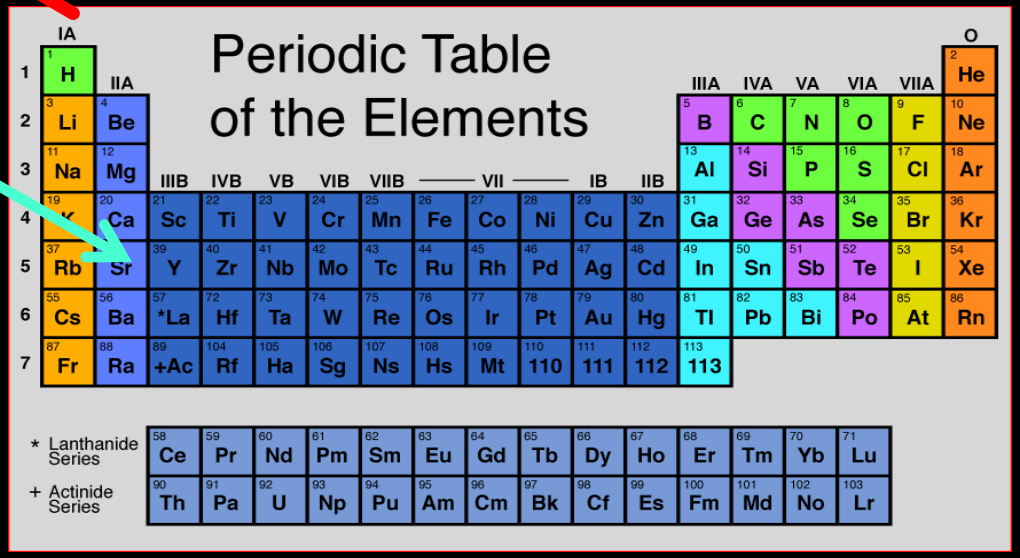
- Metallic shine or luster
- Flexible
- Solids (mostly) @ room temp
- Ductile - can be drawn into wires
- Malleable - can be pounded into thin sheets
- Conduct heat & electricity

**More Metallic**

# Metals

**Most Elements**
**(> 80)**

**Beyond Iron:**
**"Heavy Metals"**



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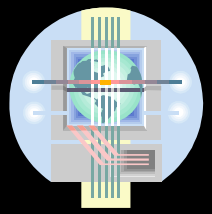
# Metalloids (Semi-Metals) – "Staircase"

**Properties (metallic or nonmetallic) depend on environment**

**Semi-conductors**

- **good conductor at high T**
- **poor conductor at low T**

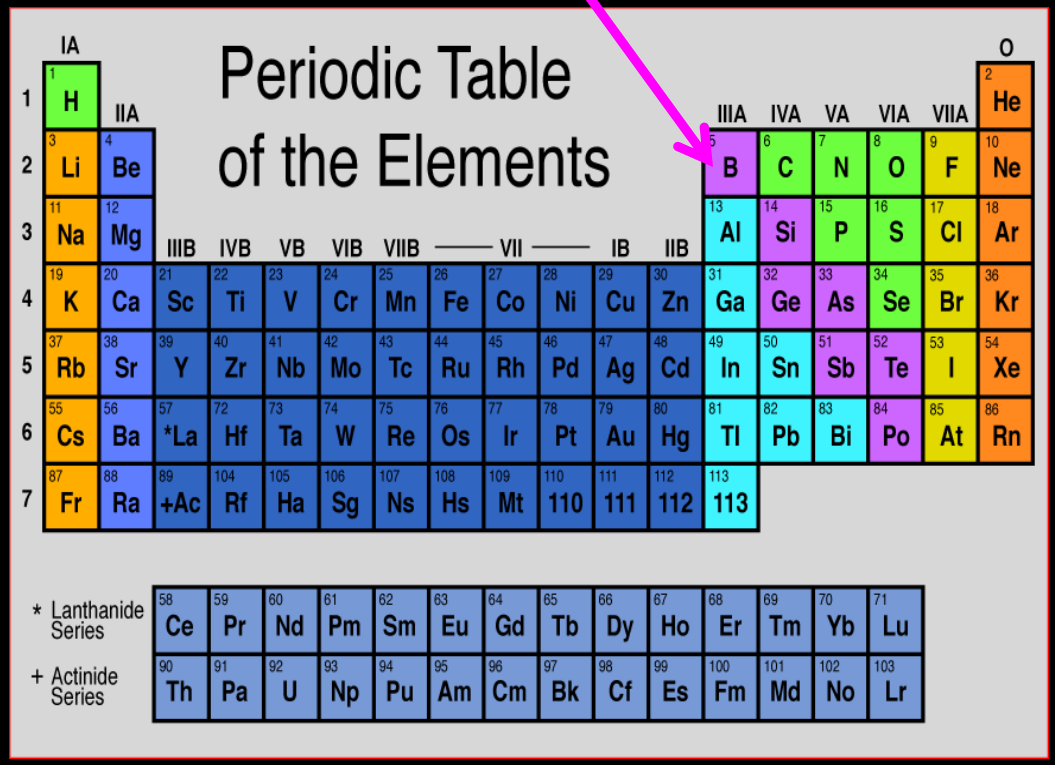


- **B Boron**
- **Si Silicon**
- **Ge Germanium**
- **As Arsenic**
- **Sb Antimony**
- **Te Tellurium**
- **Po Polonium ?**
- **At Astatine ??**

**6 , 7, or 8 Elements**

**At on some, Most consider At a halide**

**Staircase**



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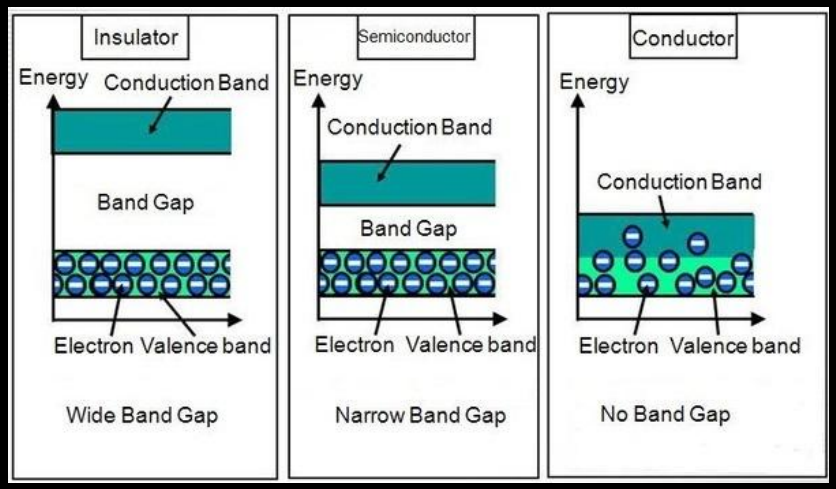
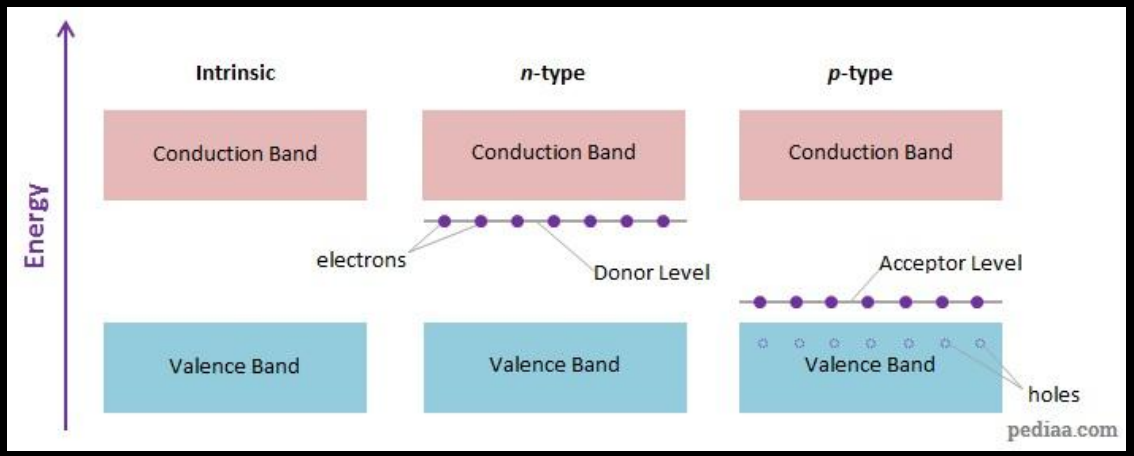
# Semi-Conductors: Current Flow Depends on Energy Gap

## Electrons reside in two possible energy states:

## Valence and Conductance




**Conductance depends on relative energy difference Between bands**



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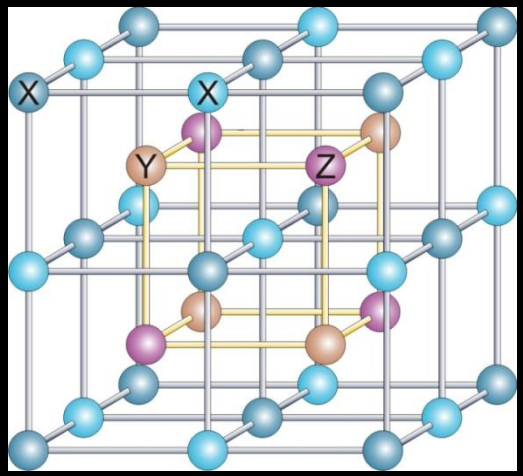
# Alloys: A Solid Dissolved in a Solid

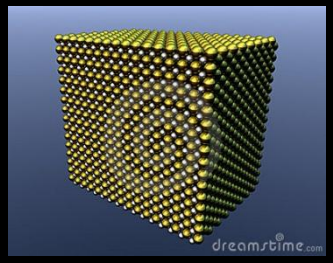
**More than one metal element in crystal structure**

**Primary Metal:** Base (Solvent)
**Secondary Metal:** Solute

2 components = Binary
3 components = Tertiary
4 components = Quaternary
5 components = Quinary




**Mixture of metals: changes physical properties**



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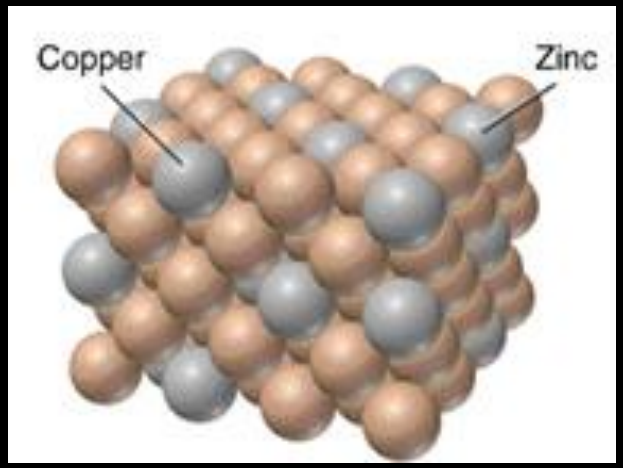
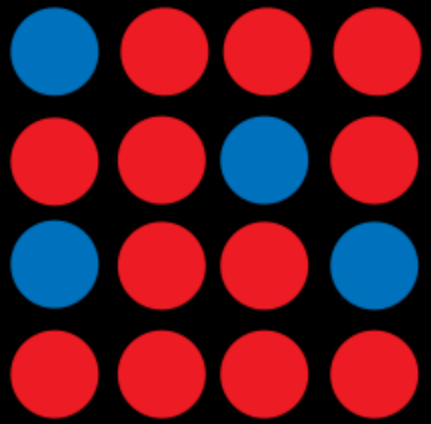
# Substitutional Alloys

## SOME atoms of base metal replaced




Brass



Schematic

**Sterling silver (93% silver, 7% copper)**
**Brass (67% copper, 33% zinc)**
**Bronze (88% copper, 12 % tin; but composition variable)**
**Pewter (85% tin, 7% copper, 6% bismuth, 2% antimony)**



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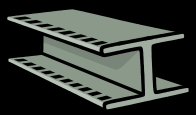
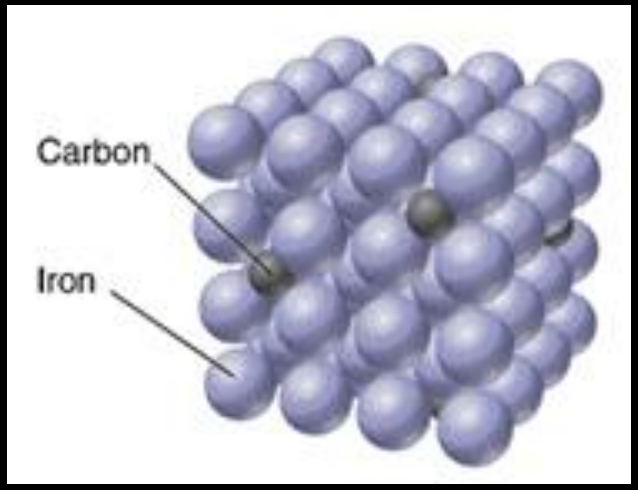
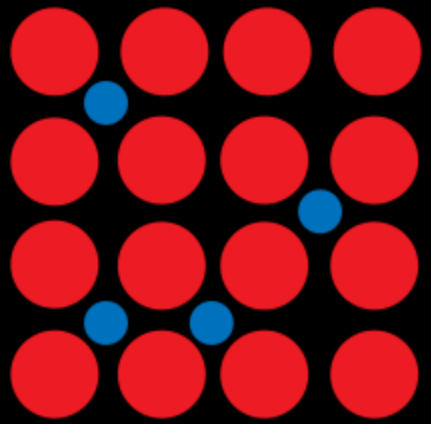
# Interstitial Alloys



## Smaller element atoms reside between metal atoms




Steel



Schematic

**Smaller atoms significantly alter physical properties**

**Provide alternate bonding network**



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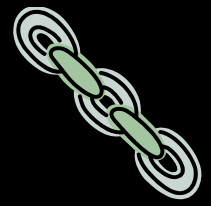
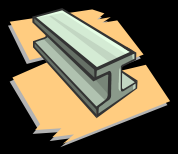
# Interstitial Alloys

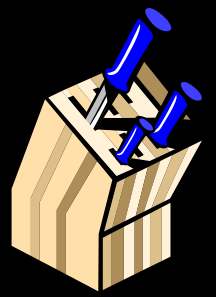


**Number of interstitial atoms defines alloy properties**

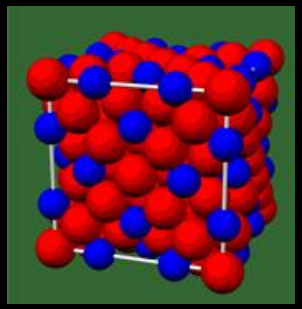
**Mild steels (<0.2% carbon): malleable ductile**
**chains, nails, and cables**

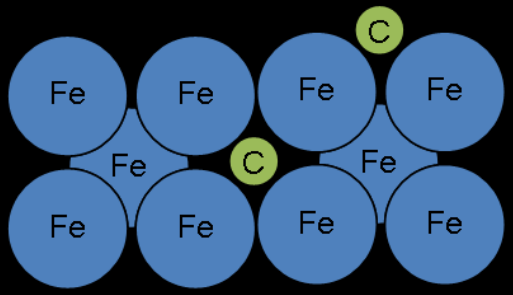


**Medium steels (0.2-0.6% carbon): harder than mild steels**
**rails and structural beams.**



**High-carbon steels (0.6-1.5% carbon): very hard**
**springs, tools, and knives**





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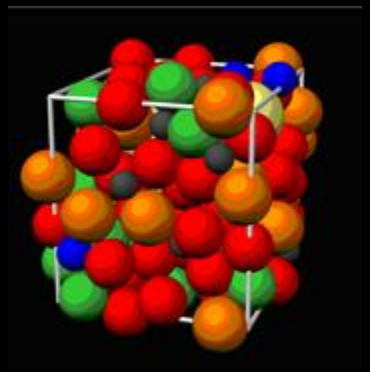
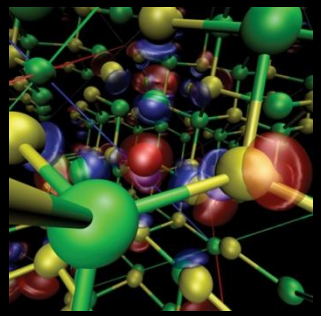
# Combination Alloy: Substitutional & Interstitial

## Stainless Steel

**Start:** Interstitial alloy of Fe & C
**Substitute:** Some Fe with Cr & Ni







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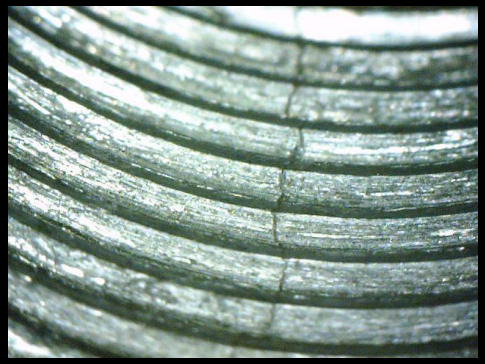
# Famous Failures

**Titanic:**

**Cheap Wrought Iron Rivets Below Waterline**

**Slag impurities made rivets brittle**



**Aluminum Compressed Gas Cylinders**

**Cracks in head and neck of cylinder**

**Failures typically occur at different metal interfaces**



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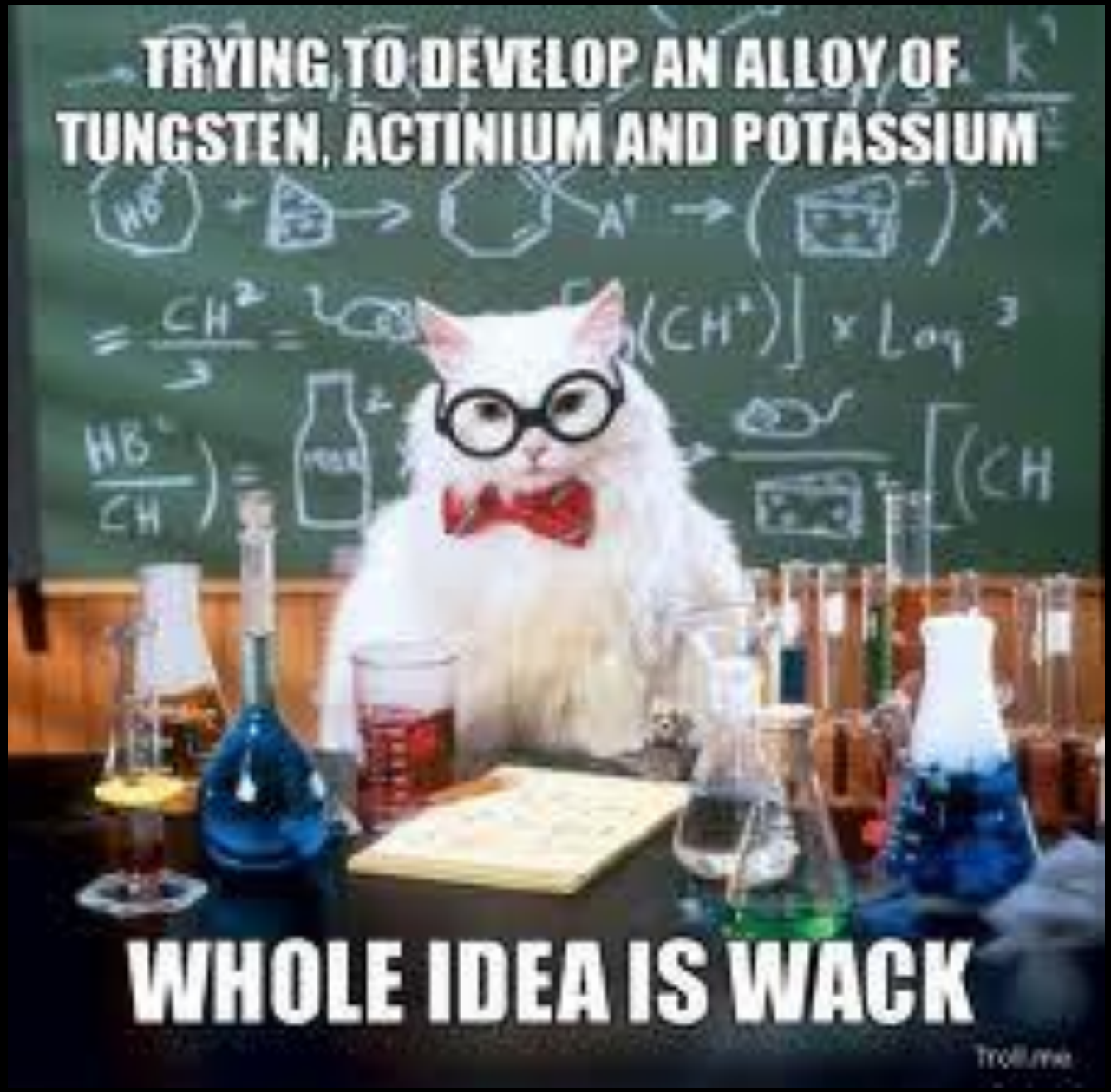
TRYING TO DEVELOP AN ALLOY OF TUNGSTEN, ACTINIUM AND POTASSIUM
WHOLE IDEA IS WACK

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