NON-FERROUS METALS

Non-Ferrous Metals
- Copper
- Tin & Bronze
- Lead & Silver
- Brass & Zinc
- Nickel
- Aluminum & Magnesium
- Beryllium & Titanium
- Niobium & Columbium
- Cobalt, Tantalum & Chromium
- Platinum

Categories
- Precious Metals
  - Gold, Silver, Platinum
- Base Metals
  - Old: Iron, Tin, Copper, Zinc, Lead
  - New: Nickel, Magnesium, Cobalt, Aluminum
- Specialty Metals
  - Niobium, Chromium, Beryllium, Titanium, Tantalum
- Pure Alloys
  - Bronze, Brass

Processing Considerations
- Melting Point
- Boiling Point
- Specific Gravity
- Atomic Bonds
- Reactivity
- Solubility

Copper
- General
  - Element, Cu
  - Melts At 1981°F
  - Boils At 2567°F
  - Specific Gravity = 8.9
  - Brownish-Red Color
- History
  - Prehistoric People
  - Egypt, Asia Minor, China, Cyprus, Crete, Am. Indians

Copper (Continued)
- Properties
  - Conducts Electricity & Heat
  - Resists Corrosion
  - Malleable & Ductile
  - Tensile Strength - 60 ksi
- Uses
  - Coins
  - Wire
  - Ornamental
  - Sheathing
Copper (Continued)

- Metallurgy
  - Native Copper
    - Crushed, Washed, & Smelted InChars
    - Ores Are Reduced With Carbon
  - Sulfide Ores (Chalcopyrite & Bornite)
    - 1% Cu, 12% Fe
    - Furnace Yields Crude Metallc Copper
    - Impure
  - Electrolysis Produces 99.9% Purity

Copper (Continued)

- Melted Native Copper
  - Heat From Above By Charcoal Fire
  - Lens-Like Ingot In Clay Lined Saucer Beneath Fire Bed
  - Forced Draught Or Chimney
  - Crucible Furnaces
    - Vertical Cylindrical Clay Shaft
    - Crucible Surrounded By Charcoal In Shaft
    - Free Draught
    - Used For Casting

Copper (Continued)

- Earliest Known Crucible Furnace
- Reconstruction
  - 3300 - 3000 BC
  - Chalcolithic Site
  - Abu Matar, Beersheba
  - Perrot (1951)
- Natural Draught Furnace
- Remelting Impure Copper

Copper (Continued)

- Melting & Casting Native Copper
  - Originated In Anatolia, Turkey (5000 to 4000 BC)
  - Spread From Asia Minor
  - First Copper Artifacts In Sialk, Iran (4500 BC)
  - Egyptian Artifacts (5000 to 4000 BC)
  - Supplies Of Native Copper Became Inaccessible To Supply Demand
  - Copper Artifacts After 3500 BC Contained Base Metal Impurities
    - Thus, Extracted From Ore

Copper (Continued)

- Smelting Of Oxide & Carbonate Copper Ores
  - Easily Smelted In Primitive Furnaces
  - Separate Copper, Iron & Other Unwanted Ores
  - Chalcolithic Smelting Furnaces At Timna (3000 BC)
    - Ho, Tap, Hoes, & Ho, Ingots, Found
    - Metal, Over, Separated From, Slag
  - Egyptians At Timna (1200 BC)
    - Reached Zenith At Timna (1100 BC)
  - Smelting Of Sulfide & Arsenic Copper Ores

Copper (Continued)

- Egyptians At Timna
  - 1200 BC
  - Reconstruction Of Remains Of Smelting Furnace
  - Copper Settles To Bottom Of Furnace Below Slag
  - Plane-Convex Ingots
Copper (Continued)
- Timna (1200 BC)
- Heated From Above
- Copper & Slag Tapped Simultaneously To Bed Of Sand
- Tap Hole For Slag

Heated From Above

Copper & Slag Tapped Simultaneously To Bed Of Sand

Tap Hole For Slag

Tin
- General
  - Element, Sn
  - Melts At 450°F
  - Boils At 4100°F
  - Specific Gravity = 7.28
- History
  - Tombs Of Ancient Egyptians
  - Exported From Cornwall, England

Tin (Continued)
- Properties
  - Highly Malleable & Ductile > 212°F
- Uses
  - Tin Plating
  - Tin Cans
  - Alloying
    - Bronze, (tin, & copper)
    - Solder, (tin, & lead)
    - Wt. Titanium

Metal Working
- Annealing
  - About 5000 BC
  - Heat Up Metal, Hammer, Cool Down (Repeat)
  - Used Ordinary Wood Fires
  - Without Heat Metal Becomes Too Hard & Brittle
- Smelting
  - Reduce Copper Ores To Copper
  - Two-Chamber Pottery Kiln
- Alloying
  - Result of Smelting Process (About 3000 BC)
  - Ores Bearing Different Metals

Bronze
- History - Well Established By 1500 BC
  - Arsenic Coppers Decline (3000 BC)
  - Iran - 2.5% Tin (3000 BC)
  - Sumeria - 8 to 10% (3000 - 2500 BC)
  - Egypt - 8 to 10% (2500 - 2000 BC)
  - Thailand - 8 to 10% (2000 BC)
  - China - 8 to 10% (2800 BC)
  - England (2200 BC)
  - Italy (1850 BC)
  - Spain (1700 BC)

Bronze (Continued)
- Uses In Ancient World
  - Weapons & Cutting Tools
    - Swords
    - Spears
    - Arrowheads
    - Shields
    - Axes, & Axes
  - Bowls & Cauldrons
  - Furnishing - Greece & Rome
    - Bed, & Table, Frames
    - Tripods, & Lamp, Stands
### Bronze (Continued)
- **Casting Techniques**
- **Rocking Crucible**
- **1600 - 1200 BC**
- **Greek Islands**
- **Sinai Region**

### Chinese Bronzes
- **Shang Dynasty (1500 BC)** to **Ch’in Dynasty (206 BC)**
- **Artistic Vessels**
  - Snakes, Dragons, Etc.
  - **Angyang (1400 - 1027 BC)**
  - Weight > 1.6 tons
  - **Multi-part Mold**
    - Pre-fired Clay Segments

### Lead
- **General**
  - Element, Pb
  - Melts At 662°F, Boils At 3164°F
  - Specific Gravity = 11.34
- **History**
  - Obtained From The Ore Galena
  - Also From Cerussite & Anglesite
  - Anatolian - 6500 BC
- **Uses**
  - Batteries, Cable Sheathing, X-Rays, Shielding
  - Radioactive Material

### Silver
- **General**
  - Element, Ag
  - Melts At 962°F
  - Boils At 2212°F
  - Specific Gravity = 10.5
- **History**
  - Extracted From Lead (About 4000 BC)
  - Silver-Rich Lead - Aegean Area
  - Valuable Material Till Roman Empire

### Silver (Continued)
- **Properties**
  - Lustrous (High Polish)
  - Most Malleable & Ductile
  - Excellent Electrical Conductivity
- **Uses**
  - Jewelry
  - Electrical Components
- **Processing**
  - Smelting Silver Ores
  - Chemically Precipitating Metallic Silver

### Brass
- **Origins Are Uncertain (Like Bronze)**
- **Accidentally From Smelting Process Of Zinc-Bearing Cooper Ores**
- **Zinc Not Naturally Found With Copper**
- **Artifacts**
  - **Cyprus (2000 BC)**
    - Copper, Zinc (4%), B. Th
  - **China (2000 BC)**
    - Copper & Zinc (5%)
  - **China (1200 BC)**
    - Copper & Zinc (10%)
**Zinc**

- **General**
  - Element, Zn
  - Melts At 788°F
  - Boils At 1665°F
  - Specific Gravity = 7.14
  - Silver-White Color
- **History**
  - Ores Known Since 1000 to 2000 BC
  - Element - Andreas Sigismund Marggraf (1746)
    - German Chemist

**Zinc (Continued)**

- **Properties**
  - Brittle
  - Insoluble In Water
  - Soluble In Alcohol, Acids, Alkalies
- **Uses**
  - Protective Coating
  - Galvanizing
  - Alloying With Copper
  - Die Castings

**Zinc (Continued)**

- Transform Ores To Oxides By High Temp
- Zinc Boils & Distills In Retort
- Also Can Be Subjected To Sulfuric Acid And Electrolyzed

**Nickel**

- **Paktong - Chinese**
  - Unknown Composition Till 1822 (Fyffe)
    - Copper-Nickel Alloy
    - Copper, Zinc, & Nickel
  - Chinese Used In 1st Century AD
  - Used In Coins & Cutlery
  - Shipped To England 1700s In Ingot Form
  - Unable To Produce In England
    - Metals Not Identified

**Nickel (Continued)**

- **General**
  - Element, Ni
  - Melts At 2651°F
  - Boils At 2730°F
  - Specific Gravity = 8.9 (Same As Copper)
  - Silver-White Color
- **History**
  - Discovered By Axel Cronstedt (1751)
  - Isolated Metal From Niccolite Ore
Nickel (Continued)

- Properties
  - Hardness
  - Malleable & Ductile
  - Magnetic Below 653°F
- Abundance
  - Largest Supplies In Quebec, Canada
  - Cuba (Meteors), Soviet Union, China, & Australia
  - No Reserves In US

Nickel (Continued)

- Uses
  - Coating - Protective & Ornamental
    - Iron, Steel
    - Electroplating In Nickel Solution
  - Alloy
    - Steel, Hardness, Strength
    - Automobile, Parts, Axes, Crankshafts, Etc.
    - Armor, Plate
  - Coins - 25% Nickel, 75% Copper
  - Batteries
    - Nickel-Cadmium

Nickel (Continued)

- Processing
  - Ores Are Smelted In Blast Furnace
    - Ingot, Of, Copper, & Nickel, Sulphide
  - Electrolytic Process
    - Copper, Nickel, Are, Separated
    - Different, Voltages, To, Different, Electrolyte
  - Mond Process (Ludwig Mond, England, 1889)
    - Copper, Recovered, In, Dikes, Sulfuric Acid
    - Nickel & Residues, Recovered, Impure, Metallic, Nickel
    - Carbon, Monoxide, Added, To, Produce, Nickel, Carbonyl
    - Gas, Heated, To, 392°F, Decomposes
    - Produces, Pure, Metallic Nickel

Aluminum

- General
  - Element, Al
  - Melts At 1220°F
  - Boils At 4473°F
  - Specific Gravity = 2.7
  - Silver-White Color
- History
  - Isolated By: Hans Christian Orsted (1825)
    - Danish Chemist
  - Chemical Process Involving Potassium Amalgam

Aluminum (Continued)

- Properties
  - Malleable & Ductile
  - Extremely Reactive
    - Aluminum, Nitride
    - Reactions, Corrosion
    - Alumina, Br. Hart
- Abundance
  - Most Abundant Metallic Compound In The World
  - Never Found Pure
    - Aluminum, Silicates
    - Bauxite, Impure, Hydrated, Aluminum, Bauxite

Aluminum (Continued)

  - Containers & Packaging, 31%
  - Building & Construction, 20%
  - Transportation, 24%
  - Consumer Products, 9%
  - Miscellaneous, 16%
- Production - 4 Million tons (1989)
- Cost - $1 Per Pound
Aluminum (Continued)

- Processing
  - Electrolytic Processing (1850s to 1870s)
    - Required Lumps, Anodes, DC Electrical Power
    - Decomposing Compounds, Repeated, As, Alumic, Bands
    - Heat, Obtained, Metals, Such as Na, Al, Ca, Be, Fe, Sulfate, Voltages
  - Hall & Heroult Simultaneously Discovered Electrolytic Process For Aluminum
  - Bayer Process

- Charles Martin Hall
  - 1886
  - Alumina Dissolved In Fused Cryolite (Natural Fluoride of Al & Na)
  - Sugar In Water Solution
  - Alumina/Cryolite Solution Is Good Conductor
  - Current Maintained Temperature
  - Separated By Electric Current & Cooled

Aluminum (Continued)

- Paul Louis Heroult
  - 1886
  - Same Process As Hall Except He Added Heat
  - Heat Not Necessary
  - Cryolite Is Not Consumed

Magnesium

- General
  - Element, Mg
  - Melts At 1200°F
  - Boils At 2025°F
  - Specific Gravity = 1.74
  - Lightest Stable Metal
  - Silver-White

- History
  - Isolated By Sir Humphry Davy (1808)
    - Brit. Chemist

Magnesium (Continued)

- Properties
  - Malleable & Ductile When Heated
  - Reactive With Acids
  - Reacts With Oxygen Above 1472°F

- Abundance
  - 6th Most Abundant Metallic Compound In The World
  - Found In Carnallite, Dolomite, & Magnesite

Magnesium (Continued)

- Uses
  - "Milk Of Magnesia"
  - Textiles - Refractory & Insulating Material
  - Epsom Salt
  - Cosmetics
  - Alloys
    - Castings
    - Artificial Limbs
    - Lamps, Indicators
  - Pure
    - Flash, Powders, In Aircraft, Bombs, Signal Flares
Magnesium (Continued)

- Similar To Aluminum Process
- Molten Magnesium Is Lighter Than Electrolyte

Beryllium

- General
  - Element, Be, Melts At 2349°F
  - Specific Gravity = 1.85 (Lightweight)
  - Called Glucinium (Sweet Tasting)

- History
  - Discovered By Frederick Wohler (1828)

- Uses
  - High Strength Per Weight
  - Corrosion Resistance At High Temperature
  - Space Applications - Structure & Propellant
  - Nuclear Reactors - Captures Neutrons

Titanium

- General
  - Element, Ti
  - Melts At 3020°F
  - Specific Gravity = 4.5
  - Also Called Menachite

- History
  - Discovered By William Gregor (1791)
    - Brittle, Fragile

- Uses
  - Pure Titanium Is Very Brittle When Cold
  - Aerospace Applications

Niobium Or Columbium

- General
  - Element, Nb
  - Melts At 4474°F
  - Specific Gravity = 8.57
  - Steel-Gray

- History
  - Discovered By Charles Hatchett (1801)
    - Brittle, Charcoal

- Uses
  - Alloying Metal For Stainless Steel
  - Corrosion Resistance At High Temperature

Cobalt

- General
  - Element, Co, Melts At 1495°F
  - Specific Gravity = 8.9
  - Low Strength, Low Ductility, Hardness

- History
  - Discovered By George Brandt (1735)
    - Soderberg, Chemist

- Uses
  - Permanent Magnets - Cobalt Steel
  - Tool Bits - Tungsten Carbide

Tantalum

- General
  - Element, Ta
  - Melts At 5425°F
  - Specific Gravity = 16.6

- History
  - Discovered By Baron Jons Jakob Berzelius (1820)
    - Soderberg, Chemist

- Uses
  - Corrosion Resistance, Compatibility, & Reactivity
    - Weight, Alloys, Wear, Electrical Cells
    - Human Body, - Pin, & Joints
    - Surgery & Dental Instruments
Chromium

- General
  - Element, Cr
  - Melts At 3375°F
  - Specific Gravity = 7.2
- History
  - Discovered By Louis Nicholas Vauquelin (1797)
    - French Chemist
- Uses
  - Corrosion Resistance, Compatibility, & Reactivity
    - Alloy, -, Hardness, Strength, Corrosion, Resistance
    - Stainless Steel

Platinum

- General
  - Element, Pt
  - Melts At 3222°F
  - Specific Gravity = 21.45
  - Weight & Hardness
  - Powder Metallurgy
- History
  - Discovered By William Brownrigg (1750)
- Uses
  - Chemically Inert - Surgical & Dental
  - Jewelry