CERAMICS, GLASS AND REFRACTORIES

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1) INTRODUCTION

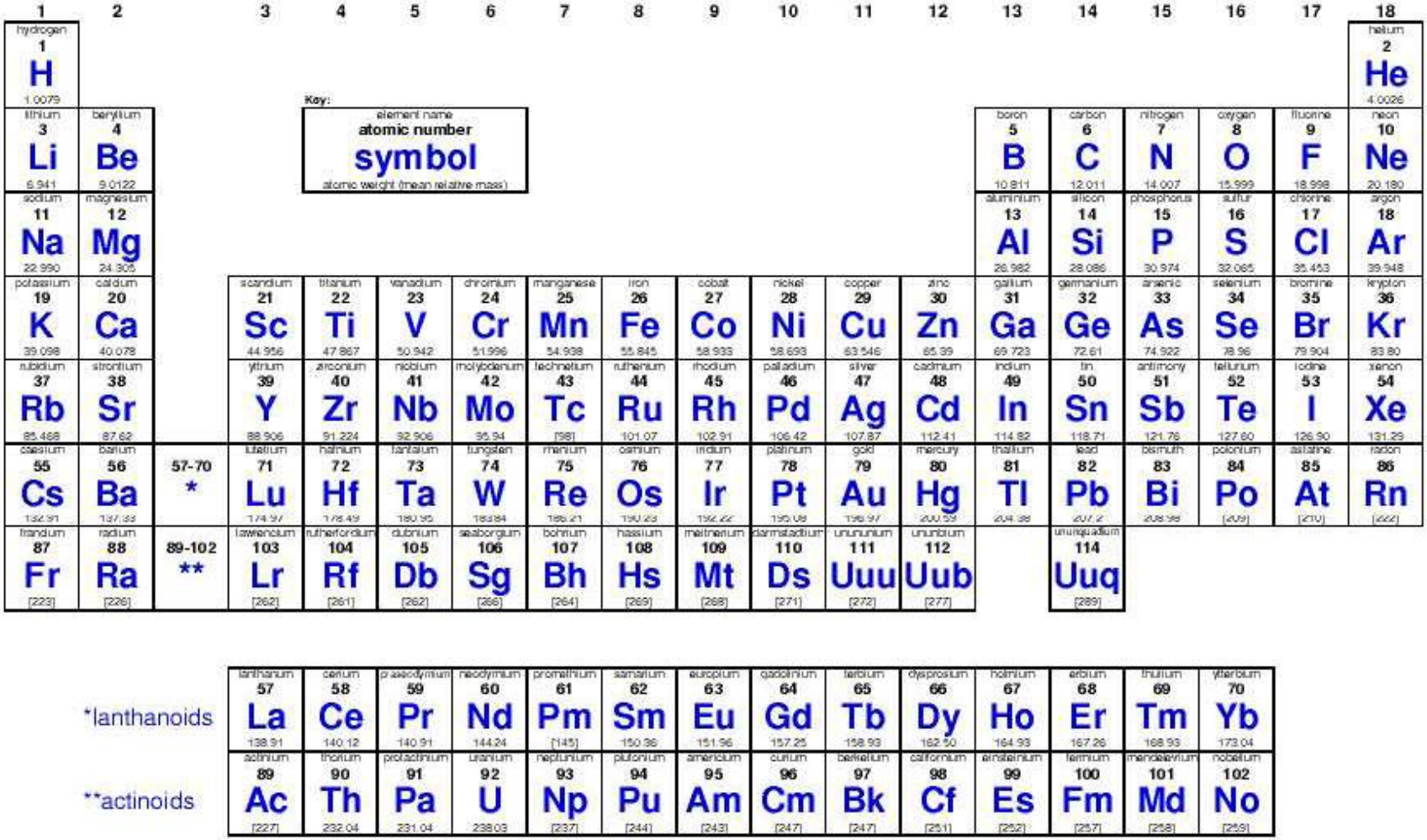
The word ceramic is derived from the Greek *keramos, which means "potter's " or "pottery."*

The term has long included all products made from fired clay, for example bricks, fireclay refractories, sanitary ware, and tableware. So the term "ceramic," while retaining its original sense of a product made from clay, began to include other products made by the same manufacturing process and more advance processing.

These are the technical ceramics family and most frequently they are oxides, nitrides, and carbides. However, we also classify diamond and graphite as ceramics.

Definition of Ceramics: Inorganic Materials made from Metals and Non Metals united by ionic and/or covalent bonds

Can be: crystalline, amorphous or mixture of both



Periodic Table - Our “Raw Material".

Material : Atoms arranged in a particular way to achieve desired properties

Material Properties and Atoms Arrangement

Material Properties (Rough Classification)

Electrical Properties
Magnetic Properties
Mechanical Properties
Thermal Properties
Optical Properties

The central question of Materials Science:

Which atoms? And, how should they be arranged to obtain desired properties?

General Properties of Ceramics

Brittleness
⇒ Mixed covalent and ionic bonding, brittle at RT but not necessary at HT
High Compressive strength
High Young's Modulus and high melting points
⇒ Strong bonds (covalent and /or ionic)
• Limited electrical and thermal conductivity
⇒ Absence of electronic cloud (directional bond)
• Low thermal shock resistance
⇒ Coefficients of thermal expansion and thermal conductivity are low
• Refractory
⇒ Stability at high temperature (NO CREEP)
• Resistance to oxidation/corrosion
⇒ Chemical stability

CLASSIFICATION

Glasses

Based on SiO_2 + additives for $\downarrow T_f$ (Temperature of Formation)

Traditional Ceramics (clay products)

- Porous ceramics (bricks, pottery, china)
- Compact ceramics (porcelain, earthware)
- Refractory ceramics

Clay: $Al_2O_3 \cdot SiO_2 \cdot H_2O$

Silica: SiO_2

Feldspar: $K_2O \cdot Al_2O_3\ 6SiO_2$

Egineering Ceramics or Advanced Ceramics :

- Refractory ceramics (SiC, Al_2O_3, ZrO_2, BeO, MgO).
- Piezoelectrics and Ferroelectrics: $BaTiO_3$, $SrTiO_3$
- Electro-optics: $LiNbO_3$
- Abrasive ceramics: nitrides and carbides Si_3N_4 , SiC
- Molecular membranes
- Superconductive ceramics ($YBa_2Cu_3O_7$)
- Biomaterials : Hydroxyapatite

Areas of Applications

Property	Applications (examples)
Thermal	
Insulation	High-temperature furnace linings for insulation (oxide fibers such as SiO2, A12O3, and ZrO2)
Refractoriness	High-temperature furnace linings for insulation and containment of molten metals and slags
Thermal conductivity	Heat sinks for electronic packages (AlN)
Electrical and dielectric	
Conductivity	Heating elements for furnaces (SiC, ZrO2, MoSi2)
Ferroelectricity	Capacitors (Ba-titanate-based materials)
Low-voltage insulators	Ceramic insulation (porcelain, steatite, forsterite)
Insulators in electronic applications	Substrates for electronic packaging and electrical insulators in general (Al2O3, A1N)
Insulators in hostile environments	Spark plugs (Al2O3)
Ion-conducting	Sensor and fuel cells (ZrO2, A12O3, etc.)
Semiconducting	Thermistors and heating elements (oxides of Fe, Co, Mn)
Nonlinear *I-V* characteristics	Current surge protectors (Bi-doped ZnO, SiC)
Gas-sensitive conduct	Gas sensors (SnO2, ZnO)

Property	Applications (Example)
Magnetic and superconductive	
Hard magnets	Ferrite magnets [(Ba, Sr)O6Fe2O3]
Soft magnets	Transformer cores [(Zn, M)Fe2O3, with M = Mn, Co, Mg]; magnetic tapes (rare-earth garnets)
Superconductivity	Wires and SQUID magnetometers (YBa2Cu3O7)
Optical	
Transparency	Windows (soda-lime glasses), cables for optical communication (ultra-pure silica)
Translucency and chemical inertness	Heat- and corrosion-resistant materials, usually for Na lamps Al2O3MgO)
Nonlinearity	Switching devices for optical computing (LiNbO3)
IR transparency	Infrared laser windows (CaF2, SrF2, NaCl)
Nuclear applications	
Fission	Nuclear fuel (UO2, UC), fuel cladding (C, SiC), neutron moderators (C, BeO)
Fusion	Tritium breeder materials (zirconates and silicates of Li, Li2O); fusion reactor lining (C, SiC, Si3N4)

Property	Applications (Example)
Chemical	
Catalysis	Filters (zeolites); purification of exhaust gases
Anticorrosion	Heat exchangers (SiC), chemical equipment in corrosive environments
Biocompatibility	Artificial joint prostheses (Al2O3) 
Mechanical	
Hardness	Cutting tools (SiC whisker-reinforced A12O3, Si3N4)
High-temperature strength retention	Stators and turbine blades, ceramic engines (Si3N4)
Wear resistance	Bearings (Si3N4)