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Periodic Table of the Elements

1 1A H Hydrogen 1.00794	2 IIA He Helium 4.002602											13 IIIA B Boron 10.811	14 IVA C Carbon 12.0107	15 VA N Nitrogen 14.00674	16 VIA O Oxygen 15.9994	17 VIIA F Fluorine 18.9984032	18 VIIIA Ne Neon 20.1797
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 Al Aluminum 26.981538	6 Si Silicon 28.0855	7 P Phosphorus 30.973761	8 S Sulfur 32.066	9 Cl Chlorine 35.453	10 Ar Argon 39.948
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 Ga Gallium 69.723	14 Ge Germanium 72.64	15 As Arsenic 74.92160	16 Se Selenium 78.96	17 Br Bromine 79.904	18 Kr Krypton 83.798
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.8457	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.409	31 In Indium 114.818	32 Sn Tin 118.710	33 Sb Antimony 121.760	34 Te Tellurium 127.60	35 I Iodine 126.90447	36 Xe Xenon 131.293
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 Tl Thallium 204.3833	50 Pb Lead 207.2	51 Bi Bismuth 208.98038	52 Po Polonium (209)	53 At Astatine (210)	54 Rn Radon (222)
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 to 71 Lanthanide series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 to 103 Actinide series	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium	118 Uuo Ununoctium

- Alkali metals
- Alkaline earth metals
- Transition metals
- Lanthanide series
- Actinide series
- Poor metals
- Nonmetals
- Noble gases
- C** Solid
- Br** Liquid
- H** Gas
- Tc** Synthetic

Atomic masses in parentheses are those of the most stable or common isotope.

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57 La Lanthanum 138.9055	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.500	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967
89 Ac Actinium (227)	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (288)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

The Future of Thorium as Nuclear Fuel

- Thorium # 90 on Periodic Table
- Discovered 1828; Radioactive 1898
- Three Times the Abundance of Uranium
- One Isotope Th_{232}
- Emits Alpha Particles

Thorium Supply and Demand

- Past demand: Gas Mantles
- MgTh Alloy
- W-Th Arc Welding; Carbon Arc Lamps
- Heat-Resistant Ceramics
- Petroleum Catalysts
- Problem: Radioactivity / Disposal

Thorium Resources

- Monazite (Ce-La-Nd-Pr-Y-Th) PO₄
- Thorite (ThU)SiO₄
- Abundant Resources
- Insignificant Demand
- No Exploration or Development

World Thorium Resources

- Monazite –Bearing Heavy Mineral Sands
- Typically 6-12% Th, 60-65 % REEs
- India 25% Australia 25%
- Turkey, Norway, Brazil, Canada, S Africa
- USA + Lemhi Pass, Idaho

Thorium as Nuclear Fuel

- Not Naturally Fissionable
- Requires Constant Neutron Bombardment
- $\text{Th}_{232} + \text{Neutron} = \text{U}_{233}$
- Startup from Uranium or Plutonium

Advantages of Thorium

- Emits Alpha Particles
- Produces No Plutonium
- Lesser Long-Lived Radionuclides
- No Chain Reaction = No Meltdown

Advantages of Thorium

- Greater Abundance
- Single Isotope = No Enrichment
- More Energy Efficient
- Burn Up Current Nuclear Waste

Disadvantages of Thorium

- No Fissile Isotopes
- Complicated Fuel Fabrication
- U_{233} Can Be Used for Nuclear Weapons
- Some Long-Lived Waste Products

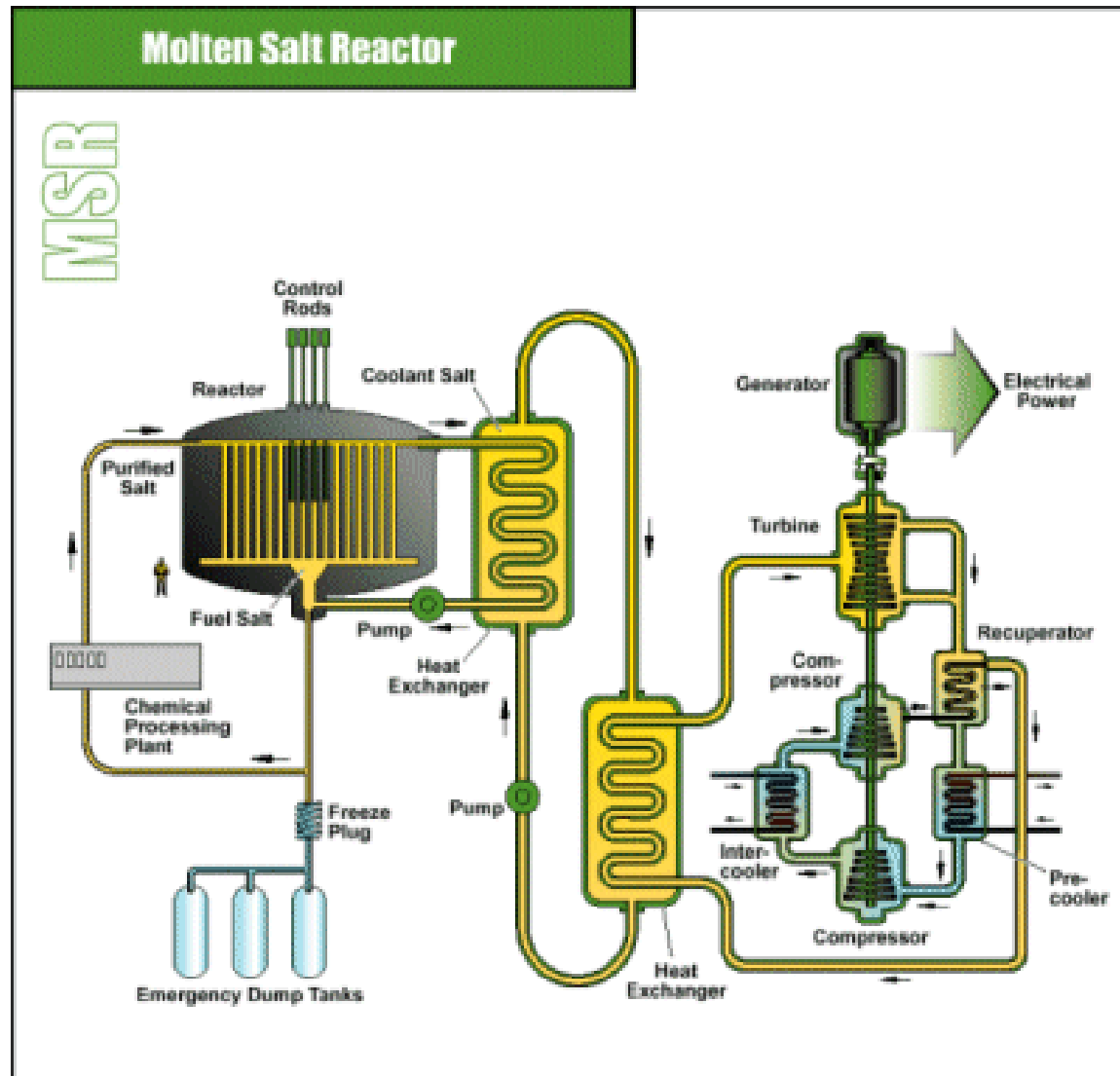
Types of Reactors

- Molten Salt Reactor
- Light Water Reactor
- Heavy Water Reactor
- High Temperature Gas Reactor
- Sodium -Cooled Fast Reactor

Past and Current Efforts

- Molten Salt Reactor USA 1964-1969
- India Heavy Water Prototype
- Brazil, China, Russia, South Africa, USA
- Modular Reactors

Molten Salt Reactor



Future Is Modular Reactors

- Both Uranium and Thorium
- Smaller = Lower Capital Expenditures
- Lesser Lead and Construction Times
- Power for Remote Locations
- Lightbridge Corp USA; Thor Energy Norway

Uranium Supply and Demand

- 2009 Demand: 186 million lbs
- 2009 Mined: 132 million lbs
- 54 million lb Deficit
- Megatons to Megawatts: 24 million lbs
- Stockpiles: 30 million lbs

Uranium Supply and Demand

- 443 Operating Plants Before Japan Disaster
- 425 Operating Plants Post Japan Disaster
- 3 % Demand Destruction
- Sovereign Stockpiles Dwindling
- Russia / US Conversion Agreement Ends 2013

Domestic Uranium Supply

- USA 52 million pounds Demand
- USA 4 million pounds Supply = 7%
- Kazakhstan #1; Russia #4; Niger #6
- Uzbekistan #9; China #10

Future for Thorium as Nuclear Fuel

- Thorium = Clean and Safe
- Technology is Proven
- Must Be Developed on Commercial Scale
- Small Modular Reactors are Promising
- Decade Away to Major Commercialization
- Will Supplement But Not Replace Uranium

Monday Morning Musings from Mickey the Mercenary Geologist



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