# Periodic table of the elements

IUPAC names

Since 2016

| 1 | | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H | 2 | | | | | | | | | | | | | | | | 2 He |
| 3 Li | 4 Be | | | | | | | | | | | 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 11 Na | 12 Mg | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |
| 19 K | 20 Ca | 21 Sc | 22 Ti | 23 V | 24 Cr | 25 Mn | 26 Fe | 27 Co | 28 Ni | 29 Cu | 30 Zn | 31 Ga | 32 Ge | 33 As | 34 Se | 35 Br | 36 Kr |
| 37 Rb | 38 Sr | 39 Y | 40 Zr | 41 Nb | 42 Mo | 43 Tc | 44 Ru | 45 Rh | 46 Pd | 47 Ag | 48 Cd | 49 In | 50 Sn | 51 Sb | 52 Te | 53 I | 54 Xe |
| 55 Cs | 56 Ba | 57-71 La | 72 Hf | 73 Ta | 74 W | 75 Re | 76 Os | 77 Ir | 78 Pt | 79 Au | 80 Hg | 81 Tl | 82 Pb | 83 Bi | 84 Po | 85 At | 86 Rn |
| 87 Fr | 88 Ra | 89-103 Ac | 104 Rf | 105 Db | 106 Sg | 107 Bh | 108 Hs | 109 Mt | 110 Ds | 111 Rg | 112 Cn | 113 Nh | 114 Fl | 115 Mc | 115 Lv | 117 Ts | 118 Og |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lanthanides | 57 La | 58 Ce | 59 Pr | 60 Nd | 61 Pm | 62 Sm | 63 Eu | 64 Gd | 65 Tb | 66 Dy | 67 Ho | 68 Er | 69 Tm | 70 Yb | 71 Lu |
| Actinides | 89 Ac | 90 Th | 91 Pa | 92 U | 93 Np | 94 Pu | 95 Am | 96 Cm | 97 Bk | 98 Cf | 99 Es | 100 Fm | 101 Md | 102 No | 103 Lr |

# Heavy elements - Np synthesis

- Neptunium was the first synthetic transuranium element of the actinide series discovered
  - isotope $^{239}$Np was produced by McMillan and Abelson in 1940 at Berkeley, California
  - bombarding uranium with cyclotron-produced neutrons
    → $^{238}$U(n,γ)$^{239}$U, beta decay of $^{239}$U to $^{239}$Np ($t_{1/2}$=2.36 days)
  - Chemical properties unclear at time of discovery
    → Actinide elements not in current location
    → In group with W
- Chemical studies showed similar properties to U
- First evidence of 5f shell
- Macroscopic amounts
  - $^{237}$Np
    → $^{238}$U(n,2n)$^{237}$U
      * Beta decay of $^{237}$U
    → 10 microgram

# Heavy elements - Pu synthesis

- Plutonium was the second transuranium element of the actinide series to be discovered
  - The isotope $^{238}Pu$ was produced in 1940 by Seaborg, McMillan, Kennedy, and Wahl
  - deuteron bombardment of U in the 60-inch cyclotron at Berkeley, California
    - → $^{238}U(^{2}H, 2n)^{238}Np$
      - * Beta decay of $^{238}Np$ to $^{238}Pu$
  - Oxidation of produced Pu showed chemically different
- $^{239}Pu$ produced in 1941
  - Uranyl nitrate in paraffin block behind Be target bombarded with deuterium
  - Separation with fluorides and extraction with diethylether
  - Eventually showed isotope undergoes slow neutron fission

# Heavy elements - Am and Cm discovery

- Problems with identification due to chemical differences with lower actinides
  - Trivalent oxidation state
- $^{239}Pu(^{4}He,n)^{242}Cm$
  - Chemical separation from Pu
  - Identification of $^{238}Pu$ daughter from alpha decay
- Am from $^{239}Pu$ in reactor
  - Also formed $^{242}Cm$
- Difficulties in separating Am from Cm and from lanthanide fission products

# Heavy elements - Bk and Cf discovery

- Required Am and Cm as targets
  - Needed to produce theses isotopes in sufficient quantities
    → Milligrams
  - Am from neutron reaction with Pu
  - Cm from neutron reaction with Am
- $^{241}Am(^{4}He,2n)^{243}Bk$
  - Cation exchange separation
- $^{242}Cm(^{4}He,n)^{245}Cf$
  - Anion exchange

# Heavy elements - Einsteinium and Fermium

- Debris from Mike test
  - 1st thermonuclear test
- New isotopes of Pu
  - 244 and 246

    → Successive neutron capture of $^{238}U$
  - Correlation of log yield versus atomic mass
- Evidence for production of transcalifornium isotopes
  - Heavy U isotopes followed by beta decay
- Ion exchange used to demonstrate new isotopes

# Heavy elements - Md and No discovery

- 1st atom-at-a-time chemistry
  - $^{253}Es(^{4}H,n)^{256}Md$
- Required high degree of chemical separation
- Use catcher foil
  - Recoil of product onto foil
  - Dissolved Au foil, then ion exchange
- No controversy
  - Expected to have trivalent chemistry
  - 1st attempt could not be reproduced
    - → Showed divalent oxidation state
  - $^{246}Cm(^{12}C,4n)^{254}No$
    - → Alpha decay from $^{254}No$
    - → Identification of $^{250}Fm$ daughter using ion exchange

# Heavy elements - Lr discovery

- $^{249, 250, 251}$Cf bombarded with $^{10,11}$B
- New isotope with 8.6 MeV, 6 second half life
  - Identified at $^{258}$Lr

# Superheavy Elemens - Why Study?

- **Test validity of the Extrapolations of the Periodic Table**
- **Determine the Influence of Relativistic Effects on Chemical Properties**
- **Help to Predict the Chemical Properties of the Heavier Elements**
- **Determine Nuclear Properties of the Heaviest Elements**

# Superheavy Elemens - Stability?