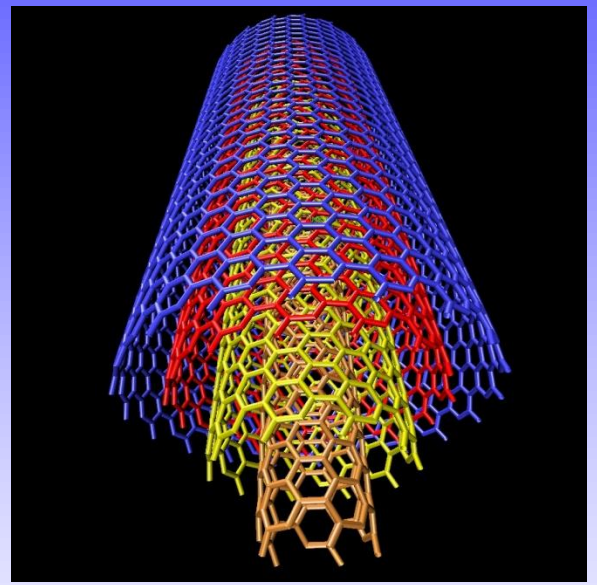
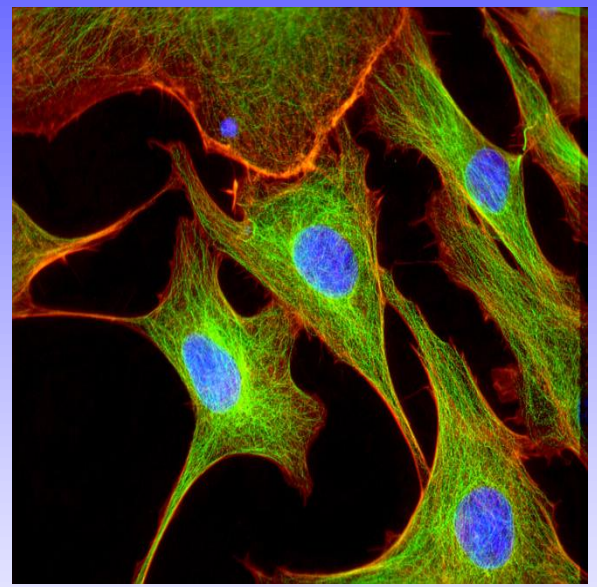
# Building a Universe





**Auburn Mountainview**

**Karl Steffin, 2001**

**8/14/2025**

# By end of this lesson, I can…

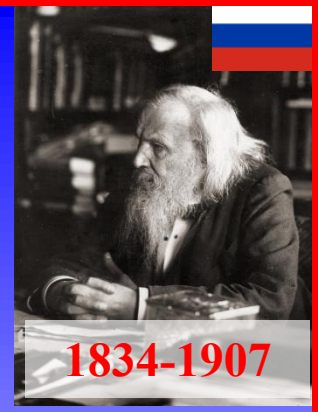
- **AS1: describe the differences between chemical and physical changes.**
- **AS3: calculate the charge of an element in order write an ion.**
- **AS4: use the atomic number and atomic mass number of an isotope, to draw and label a model of the isotope's atomic structure.**
- **AS5: use the relative mass and abundance of isotopes to calculate the atomic mass of an element.**
- **AS7: use the periodic table to find elements based on their properties…**

# The Subatomic Particles

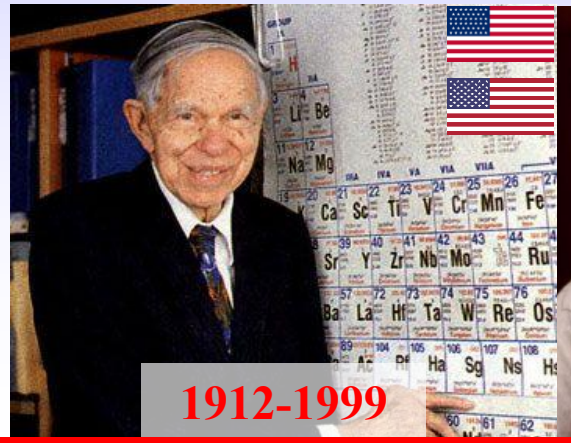
- **'All' elements contain the same three particles:**

| Particle | Charge (q) | Mass (amu) |
|---|---|---|
| **Proton ($p^+$)** | **1** | **1** |
| **Electron ($e^-$)** | **-1** | **1/1900** |
| **Neutron ($n^o$)** | **0** | **1** |

# The Periodic Table

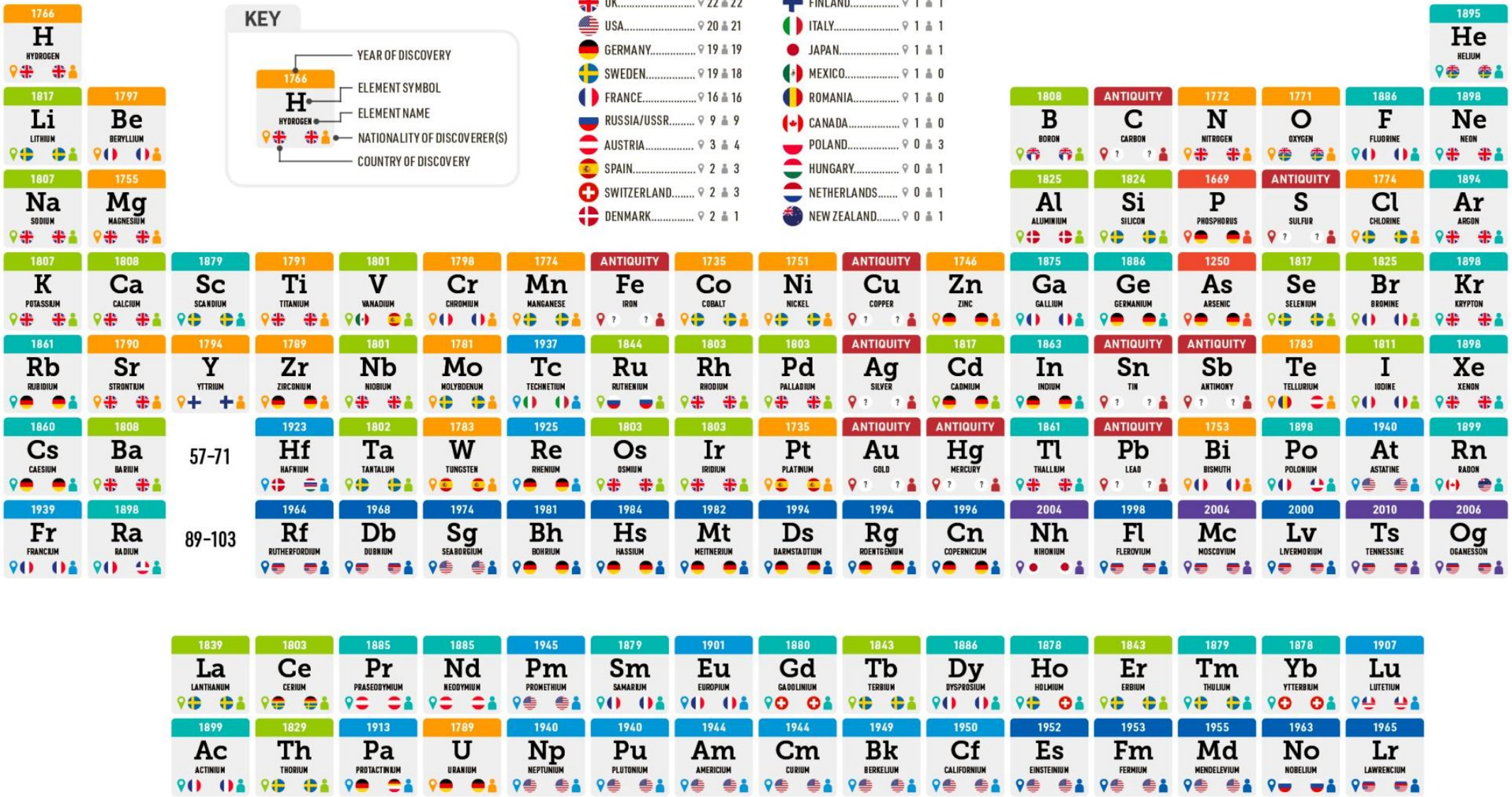



- **Contains data on all of the elements.**
  - **Credited to Dmitri Mendeleev in 1869.**
- **As of 2010 118 elements have been synthesized.**
  - **New elements can be named after a mythological concept, a mineral, a place or country, a property or a scientist (normally dead: Seaborg, Oganessian).**




# 1 PERIODIC TABLE OF ELEMENT DISCOVERIES

ANTIQUITY | 1200–1700 | 1701–1800 | 1801–1850 | 1851–1900 | 1901–1950 | 1951–2000 | 2001–PRESENT



# 23 PERIODIC TABLE OF ELEMENT PRICES

## KEY

- £5–£10 per kilogram
- £10–£100 per kilogram
- £100–£1000 per kilogram
- £1000–£5000 per kilogram
- >£5000 per kilogram
- Price unknown

Note: element prices can vary significantly with quantity and purity

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H HYDROGEN £18.14 | | | | | | | | | | | | | | | | | He HELIUM £30.99 |
| Li LITHIUM £88.76 | Be BERYLLIUM £638 | | | | | | | | | | | B BORON £1831 | C CARBON £18.41 | N NITROGEN £2.13 | O OXYGEN £0.49 | F FLUORINE £1458 | Ne NEON £483 |
| Na SODIUM £2.33 | Mg MAGNESIUM £1.73 | | | | | | | | | | | Al ALUMINIUM £1.47 | Si SILICON £1.47 | P PHOSPHORUS £230 | S SULFUR £0.08 | Cl CHLORINE £1.15 | Ar ARGON £1.96 |
| K POTASSIUM £9.99 | Ca CALCIUM £4.55 | Sc SCANDIUM £11508 | Ti TITANIUM £2.89 | V VANADIUM £17.34 | Cr CHROMIUM £5.86 | Mn MANGANESE £1.58 | Fe IRON £0.06 | Co COBALT £45.65 | Ni NICKEL £7.05 | Cu COPPER £4.53 | Zn ZINC £2.17 | Ga GALLIUM £213 | Ge GERMANIUM £1407 | As ARSENIC £1.33 | Se SELENIUM £23.30 | Br BROMINE £3.38 | Kr KRYPTON £1.07 |
| Rb RUBIDIUM £11293 | Sr STRONTIUM £4.14 | Y YTTRIUM £26.85 | Zr ZIRCONIUM £17.75 | Nb NIOBIUM £32.22 | Mo MOLYBDENUM £12.28 | Tc TECHNETIUM No data | Ru RUTHENIUM £2343 | Rh RHODIUM £58952 | Pd PALLADIUM £26393 | Ag SILVER £355 | Cd CADMIUM £1.52 | In INDIUM £262 | Sn TIN £15.34 | Sb ANTIMONY £5.41 | Te TELLURIUM £42.72 | I IODINE £21.48 | Xe XENON £7.06 |
| Cs CAESIUM £56312 | Ba BARIUM £422 | La-Lu | Hf HAFNIUM £1085 | Ta TANTALUM £183 | W TUNGSTEN £19.58 | Re RHENIUM £1255 | Os OSMIUM £9866 | Ir IRIDIUM £23926 | Pt PLATINUM £20325 | Au GOLD £29298 | Hg MERCURY £29.49 | Tl THALLIUM £5677 | Pb LEAD £1.76 | Bi BISMUTH £7.93 | Po POLONIUM No data | At ASTATINE No data | Rn RADON No data |
| Fr FRANCIUM No data | Ra RADIUM No data | Ac-Lr | Rf RUTHERFORDIUM No data | Db DUBNIUM No data | Sg SEABORGIUM No data | Bh BOHRIUM No data | Hs HASSIUM No data | Mt MEITNERIUM No data | Ds DARMSTADTIUM No data | Rg ROENTGENIUM No data | Cn COPERNICIUM No data | Nh NIHONIUM No data | Fl FLEROVIUM No data | Mc MOSCOVIUM No data | Lv LIVERMORIUM No data | Ts TENNESSINE No data | Og OGANESSON No data |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| La LATHANUM £5.37 | Ce CERIUM £5.37 | Pr PRASEODYMIUM £65.21 | Nd NEODYMIUM £46.03 | Pm PROMETHIUM No data | Sm SAMARIUM £11.01 | Eu EUROPIUM £198 | Gd GADOLINIUM £42.20 | Tb TERBIUM £422 | Dy DYSPROSIUM £269 | Ho HOLMIUM £1074 | Er ERBIUM £72.88 | Tm THULIUM £4757 | Yb YTTERBIUM £1228 | Lu LUTETIUM £4810 |
| Ac ACTINIUM No data | Th THORIUM £135 | Pa PROTACTINIUM No data | U URANIUM £44.31 | Np NEPTUNIUM No data | Pu PLUTONIUM No data | Am AMERICIUM No data | Cm CURIUM No data | Bk BERKELIUM No data | Cf CALIFORNIUM No data | Es EINSTEINIUM No data | Fm FERMIUM No data | Md MENDELEVIUM No data | No NOBELIUM No data | Lr LAWRENCIUM No data |

Based on data from http://www.leonland.de/elements_by_price/list

# Navigating the Periodic Table

- Rows (↔) are called periods (7 total).
- Columns (↕) are called families or groups.
- Electrons tell us when to start a new period.
- Elements are given a one or two letter symbol.
  - Ex: Li, He, Ne, C, V, W, Ti.
- Most of the time the name and symbol are the same
  - Li is Lithium, O is Oxygen

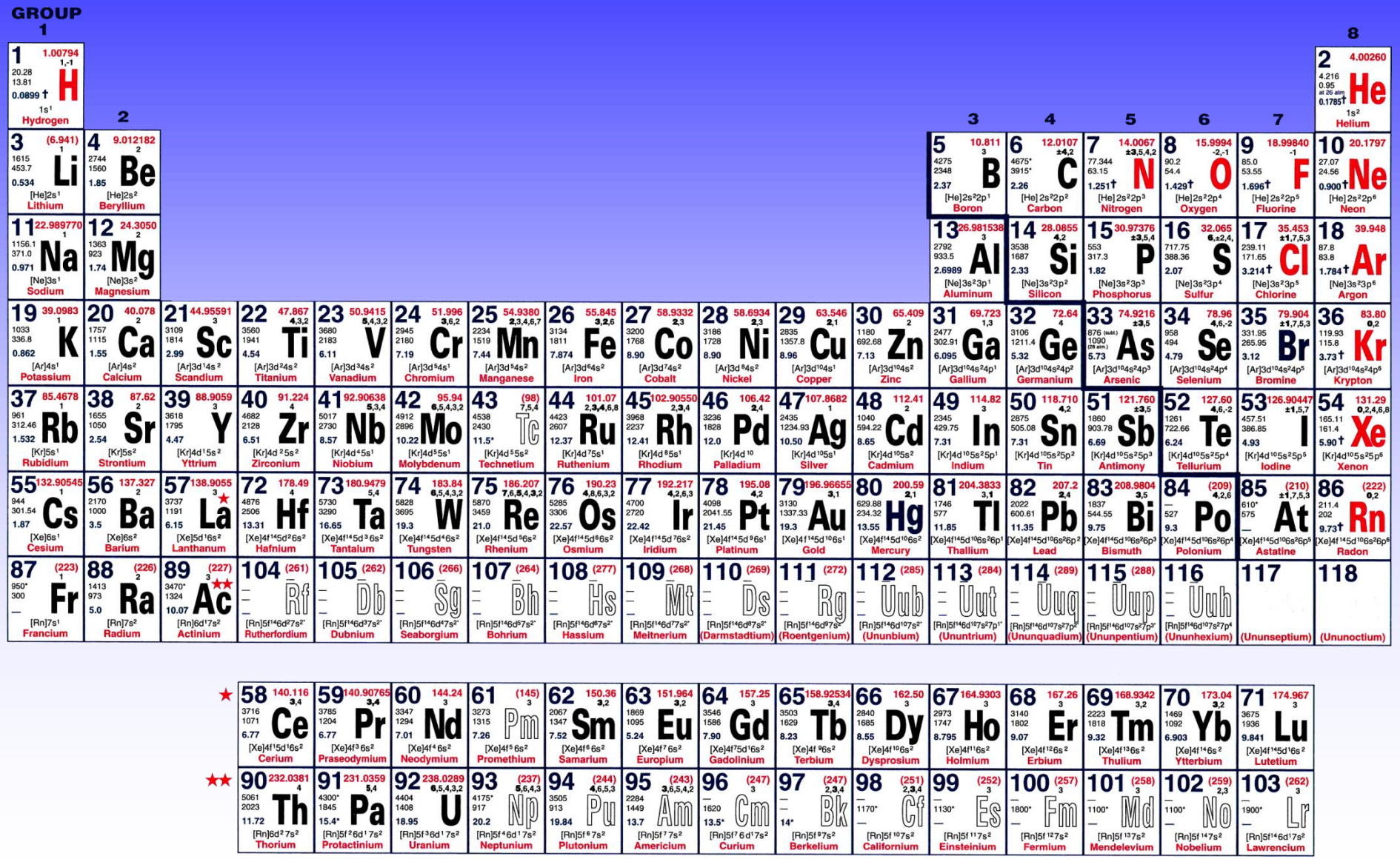
# Trivial: Names that do not follow set rules

| Name | Symbol | Derivative | Meaning |
|---|---|---|---|
| Antimony | Sb | Stibium | Aribic/Egyptian: Eye Paint |
| Copper | Cu | Cuprum | Latin: From Cyprus |
| Gold | Au | Aurum | Latin: Glowing Dawn |
| Iron | Fe | Ferrum | Latin: Holy/Strong Metal (Sword) |
| Lead | Pb | Plumbum | Latin: Soft Metals |
| Mercury | Hg | Hydrargyros | Greek: Liquid Silver |
| Potassium | K | Kalium | Arabic: Plant Ashes |
| Silver | Ag | Argentum | Indo-European: White, Shining, Money |
| Sodium | Na | Natrium | Arabic/Egyptian: Soda |
| Tin | Sn | Stannum | Indo-European: Dripping |
| Tungsten | W | Wolfram | German: Wolf froth (Tin stealer) |

# Protons

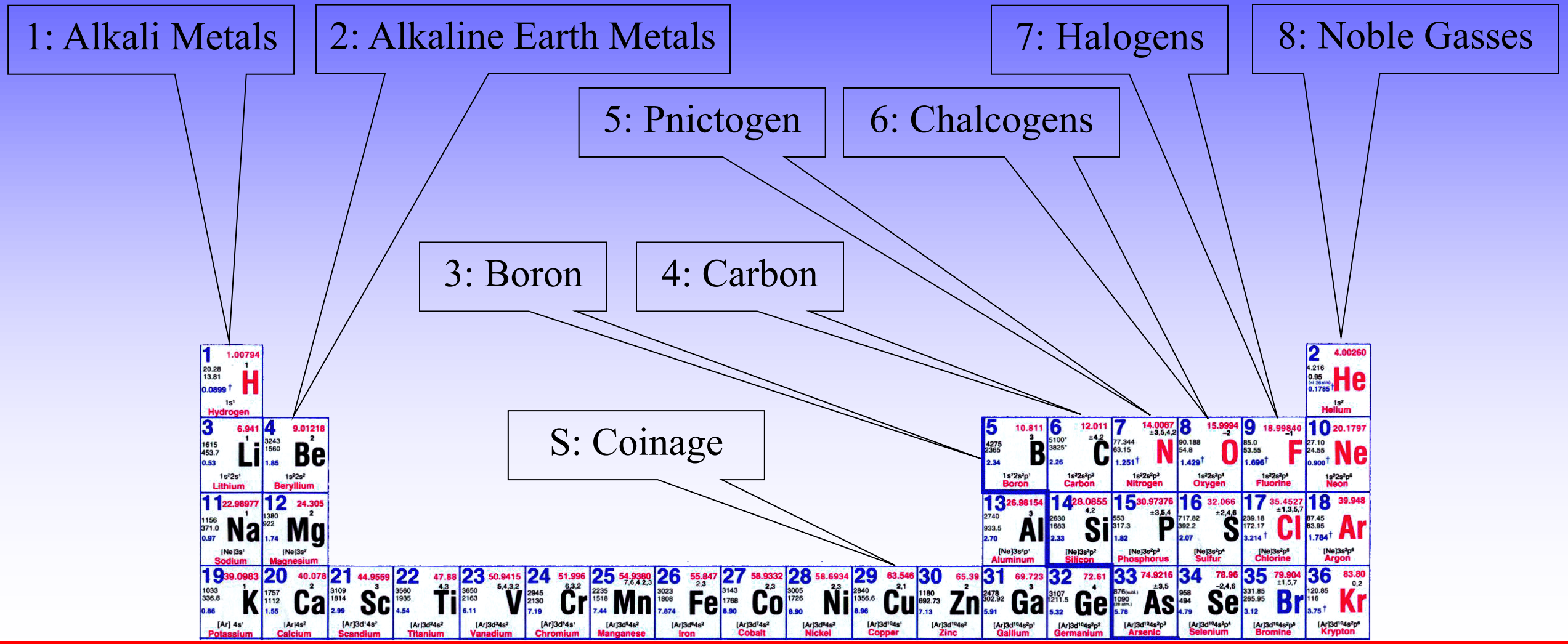
- **Elements are assigned an Atomic Number (Z) according to the number of protons in their nucleus.**
  - **Example: All Hydrogen atoms (H) have only 1 $p^+$.**
  - **Example: All Carbon atoms (C) have only 6 $p^+$.**
- **Elements are placed on the periodic table according to ascending proton number.**
  - **Example: Helium (He) has 2 $p^+$ so it is the second element to appear on the periodic table.**

# The Periodic Table (~2005)



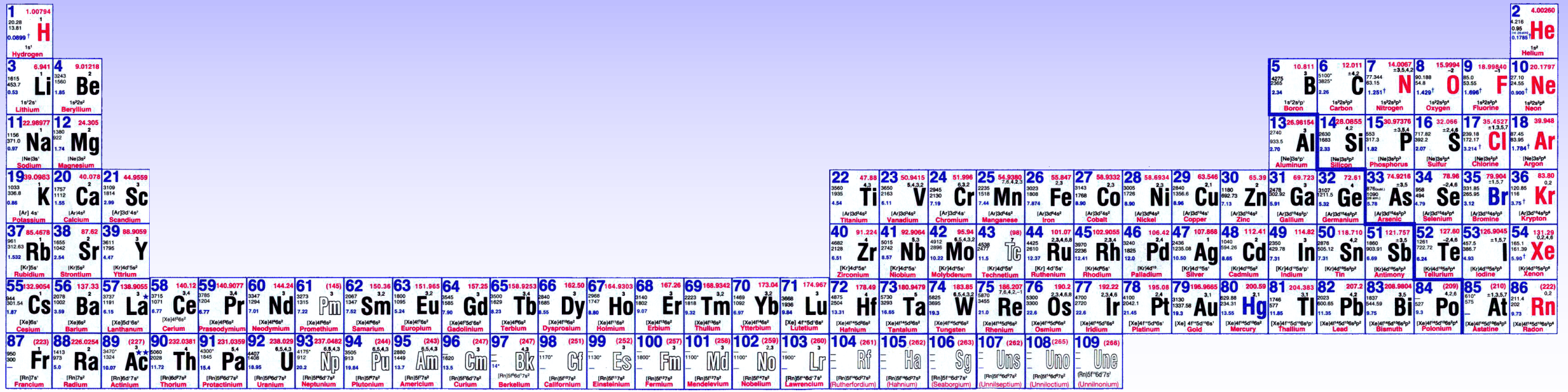
# Families/Groups

- **Columns share similar properties, and most are given a trivial name.**



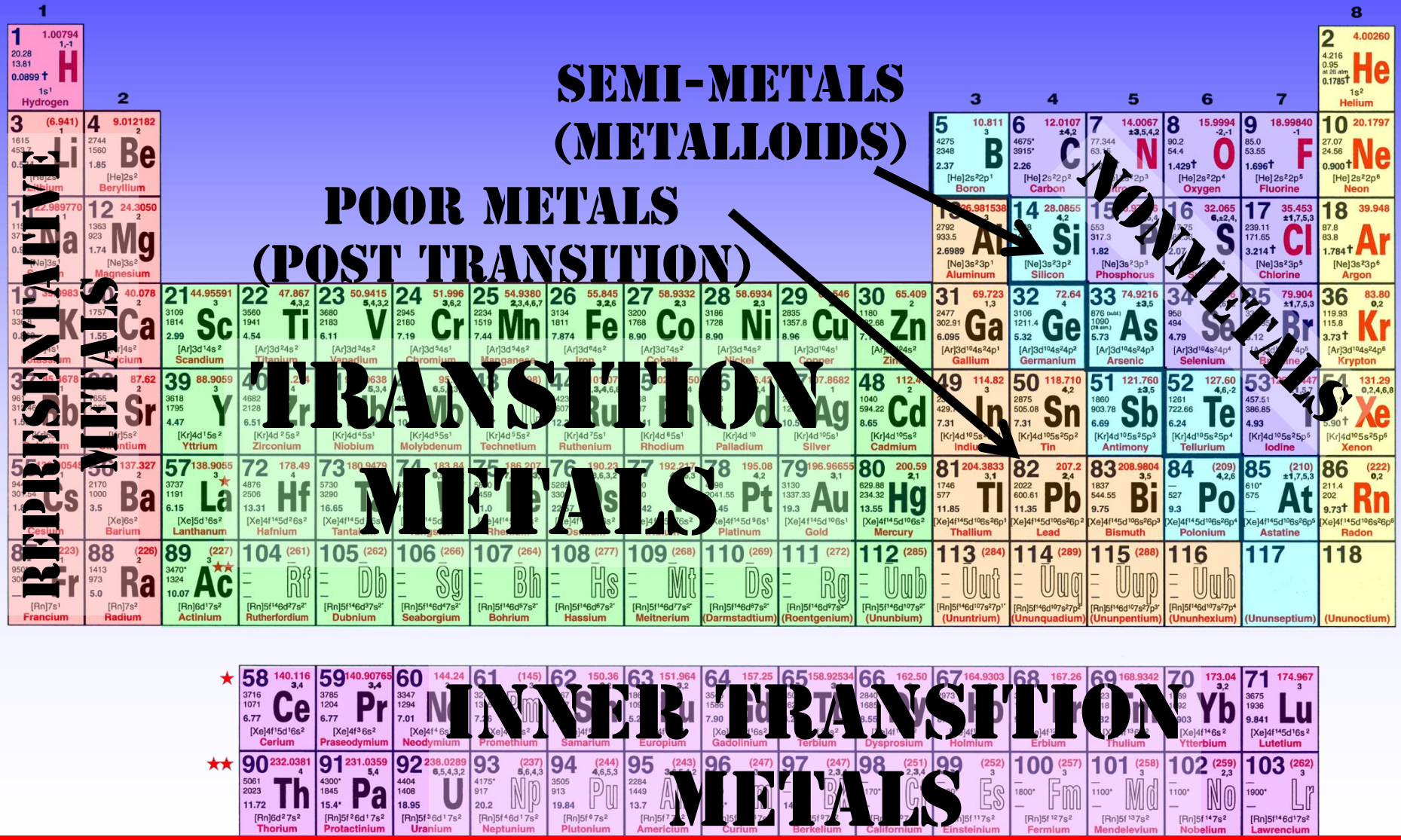
# Out of Place

- Most of the columns in the middle don't have family names.
- Due to spacing some elements have been moved from their middle spot to the bottom.



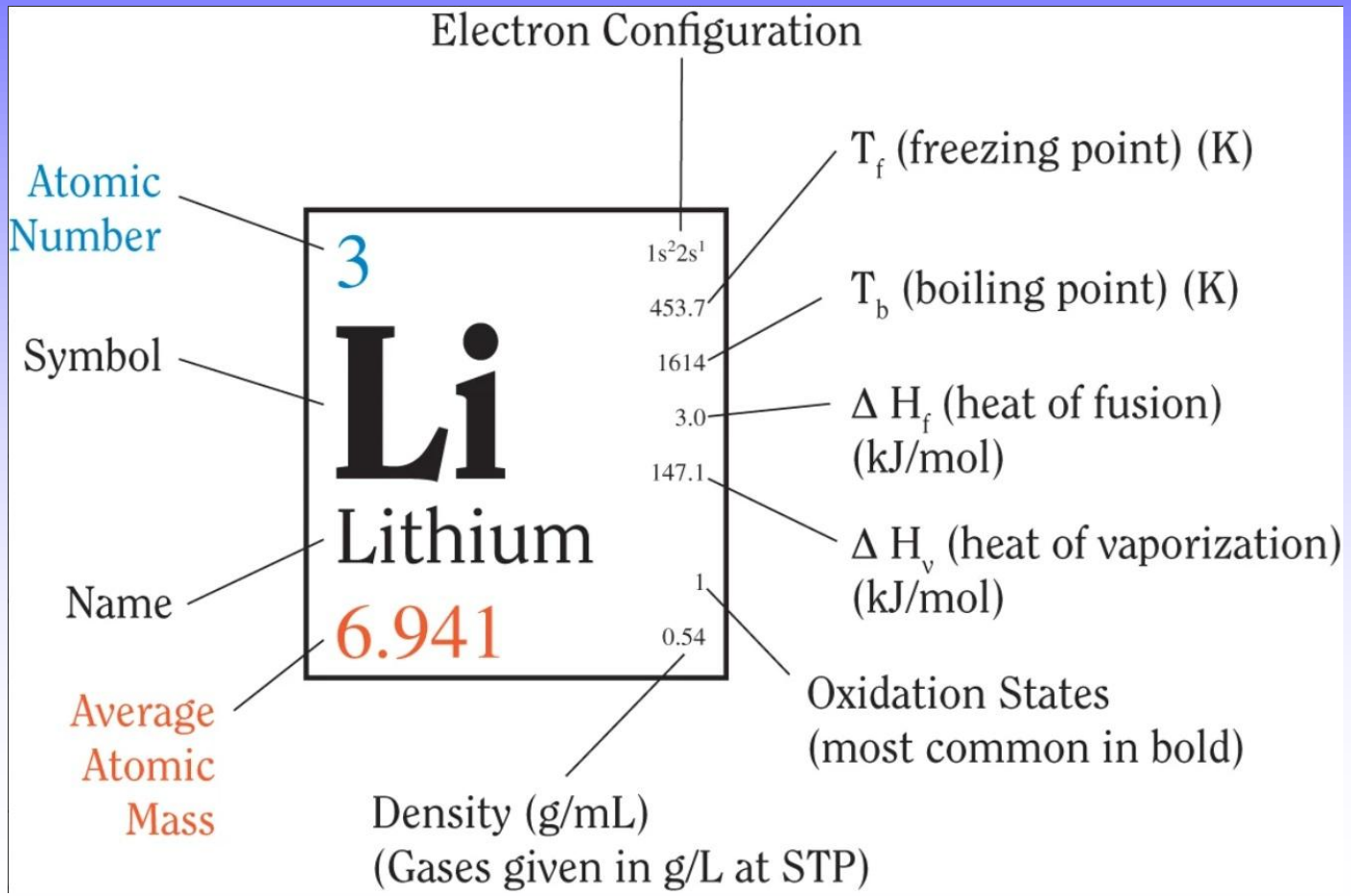
# General Trends

**Elements have three main groups: Metal, Metalloids, and Nonmetals.**



# Tip of the Periodic Iceberg

- **A periodic table contains a great deal of information.**
- **Find the key and make use of it.**



# Electrons: Making Ions

- **On the periodic table or unless specifically told, protons equal electrons.**
- **Ion: when an element's $p^+ \neq e^-$.**
- **An ion is considered electrically charged.**

# Ionic Example: Is Al with 16 $e^-$ an ion?

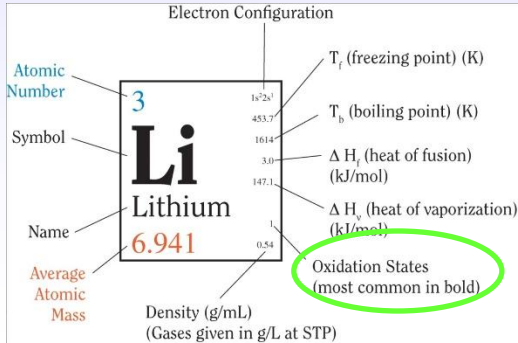
- Al always has 13 p+.
- Solve by subtracting $e^-$ from $p^+$.
  - 13 – 16 = -3
- x<0 so yes, it is an Ion and called an Anion.
- If x>0 then it would be an Ion called a Cation.
- If x=0 ($e^- = p^+$) then it would not be an Ion (Neutral).

# Ions: Symbolic

- To write an Ion two pieces of information are needed
  - The element's symbol
  - The charge (both mag and + or -)
- Write the element and then the charge in the upper right-hand corner.
- For 1+ or 1-: you may drop the '1'
- Examples: $Al^{3+}$, $Li^{+}$, $Mg^{2+}$, $Cl^{-}$, $O^{2-}$.

# Be Careful

- **Common errors and things to look out for.**
  - **You CAN NEVER remove protons!**
    - **Adding $e^-$ means increasing the negative charge.**
    - **Removing $e^-$ means increasing the positive charge.**
  - **Don't take away more $e^-$ then there are to start.**
    - **Ex: $Li^{4+}$ (Lithium only has 3 protons so max is $Li^{3+}$)**
  - **Oxidation States tell which ions are possible.**



# Write Symbolically

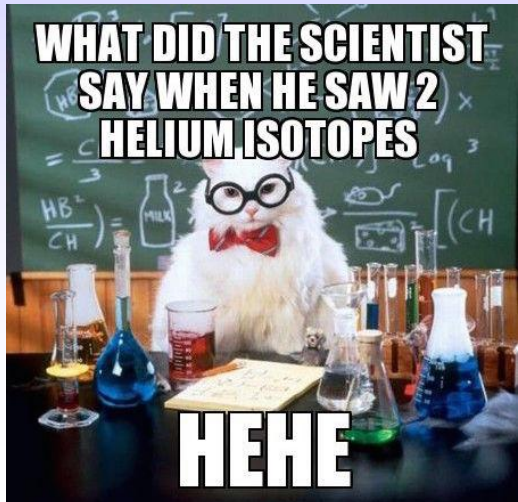
- Uranium of charge +3.
- Oxygen with 10 electrons.
- Iron with 29 electrons.
- The most common form of element 9.

| $U^{3+}$ | $O^{2-}$ | $Fe^{3-}$ | $F^{-}$ |
|---|---|---|---|
| Z = 92 | 8-10 | 26-29 | P Table |

# Neutrons: Making Isotopes

- While a $n^o$ has no charge to contribute, its mass is almost the same as a $p^+$.
- By adding or subtracting $n^o$ subtle changes must occur in an element's properties.
- When two or more elements have the same number of $p^+$ but different $n^o$ this is called an…

**Isotope**



# Symbolic Form

- **Symbolic Form was mentioned with ions.**
- **Symbolic Form can also be used to describe an atom on the Periodic Table.**

$$p^+ + n^o = w$$

$$p^+ = Z\,X\,{}_{n^o}$$

**w: Atomic Weight. Unless specifically told look this up on the Periodic Table.**

**For Isotopes: Always rounded to a whole number**

**Notes: Writing the $n^o$ is redundant: KISS.**

**This form is not mixed with the Ion Symbolic Form.**

# Writing Isotopes

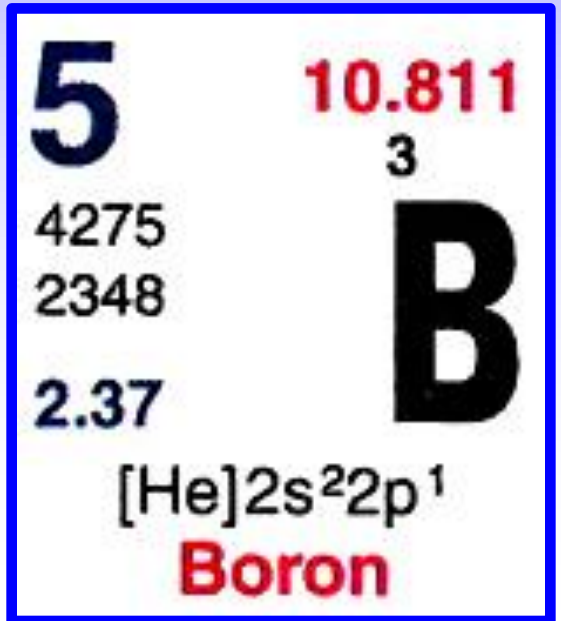
- **Isotopes can be shown two ways; symbolic and written. There are three Carbon's; They have 6 n$^o$, 7 n$^o$ and 8 n$^o$ respectively.**

$^{12}_{6}C_{6}$ $^{13}_{6}C_{7}$ $^{14}_{6}C_{8}$

**Carbon-12** **Carbon-13** **Carbon-14**

# Periodic Table

- The atomic weight is listed on most periodic tables.
- Atomic Weight: Mass of the element.
- Here is information on Boron
- Its atomic weight is 10.8?
- How is this possible?
  - Remember: $p^+ = 1$, $n^o = 1$, $e^- = .005$
  - Z = 5 so $n^o$ has to be either 5 or 6 not 5.8?



# Weighted Average

- **The number appearing on the periodic table is called a Weighted Average.**
- **Let's look at the isotopes of Boron.**

| Written | Symbolic | Weight | Abundance |
|---|---|---|---|
| Boron-10 | ${}^{10}_{5}B$ | 10.0 | 19.4% |
| Boron-11 | ${}^{11}_{5}B$ | 11.0 | 80.6% |

# Calculating Weighted Ave.

**To calculate:** $(AW_1)(ab\%_1) + (AW_2)(ab\%_2) + (AW_3)(ab\%_3) = Wa$

**AW: Atomic Weight of Isotope**

**ab%: Abundance of Isotope (as a decimal)**

**Ex: Boron**

**Wa = 10.0 (.194) + 11.0 (.806)**

**Wa = 1.94 + 8.866**

**Wa = 10.806**

# Wrap Up

| Proton ($p^+$) | Electron ($e^-$) | Neutron ($n^o$) |
|---|---|---|
| Big particle in Nucleus | Small particle orbits Nucleus | Big particle in Nucleus |
| Equals the atmic number | Ion: $p^+ \neq e^-$ | Isotope: same $p^+$, different $n^o$ |
| Defines the element (DNA) | Cation: more p+ than e- | Unstable: $\alpha/\beta/\gamma$ |
| Can not be added or removed | Anion: less p+ than e- | Half Life: Probability of decay |

## Ions

**Symbol:** $X^{p^+ - e^-}$

**Example: Phosphorus with 17 electrons.** $P^{-2}$

## Isotopes

**Symbol:** ${}^{w}_{z}X$

**Example: Phosphorus with 16 neutrons.** ${}^{31}_{15}P$

**Written:** Element-w

Phosphorus-31