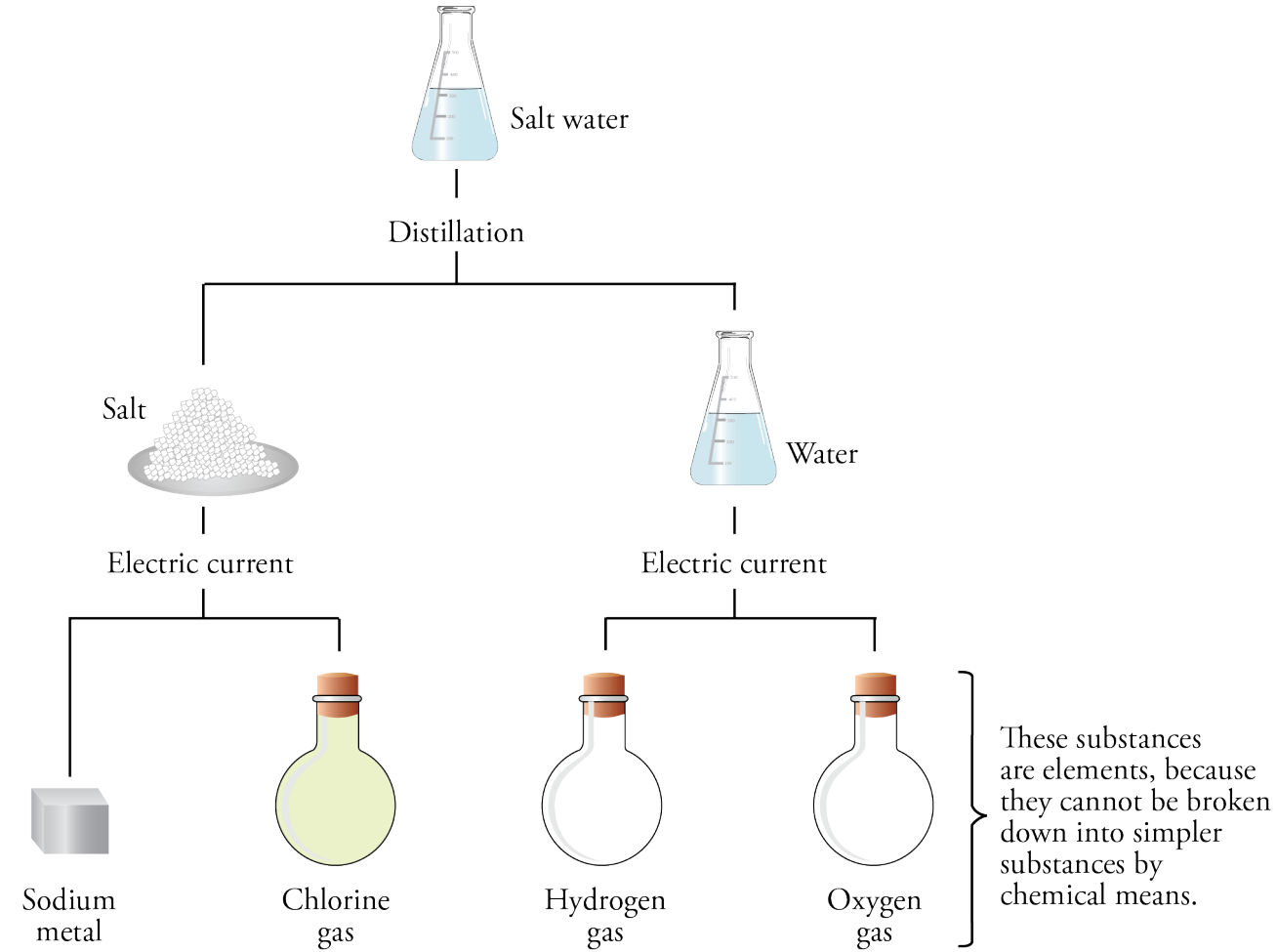
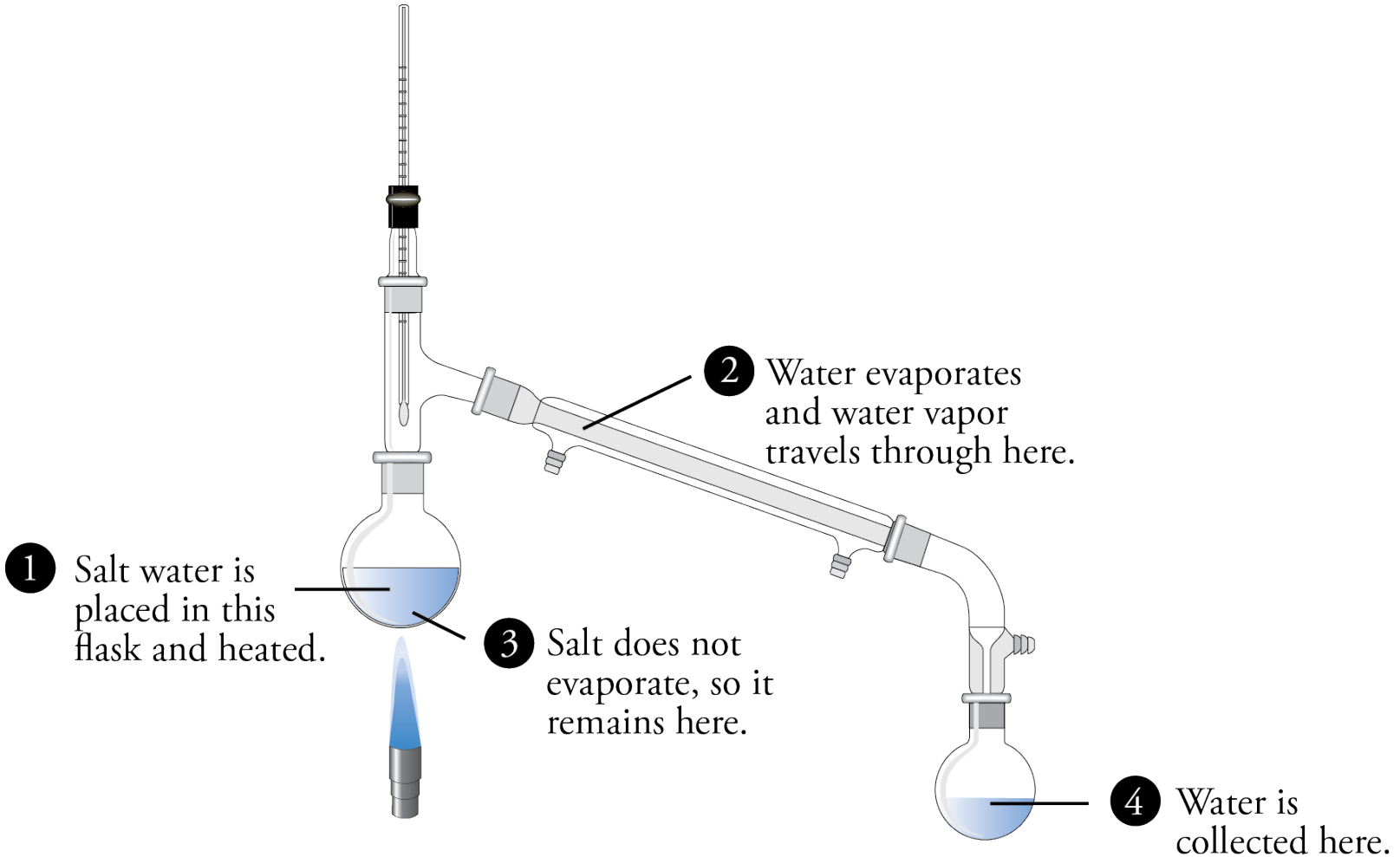
Science and Technology

The Chemical Elements, Isotopes, Nuclear Stability, and Radioactivity

Separation of Salt Water



Distillation



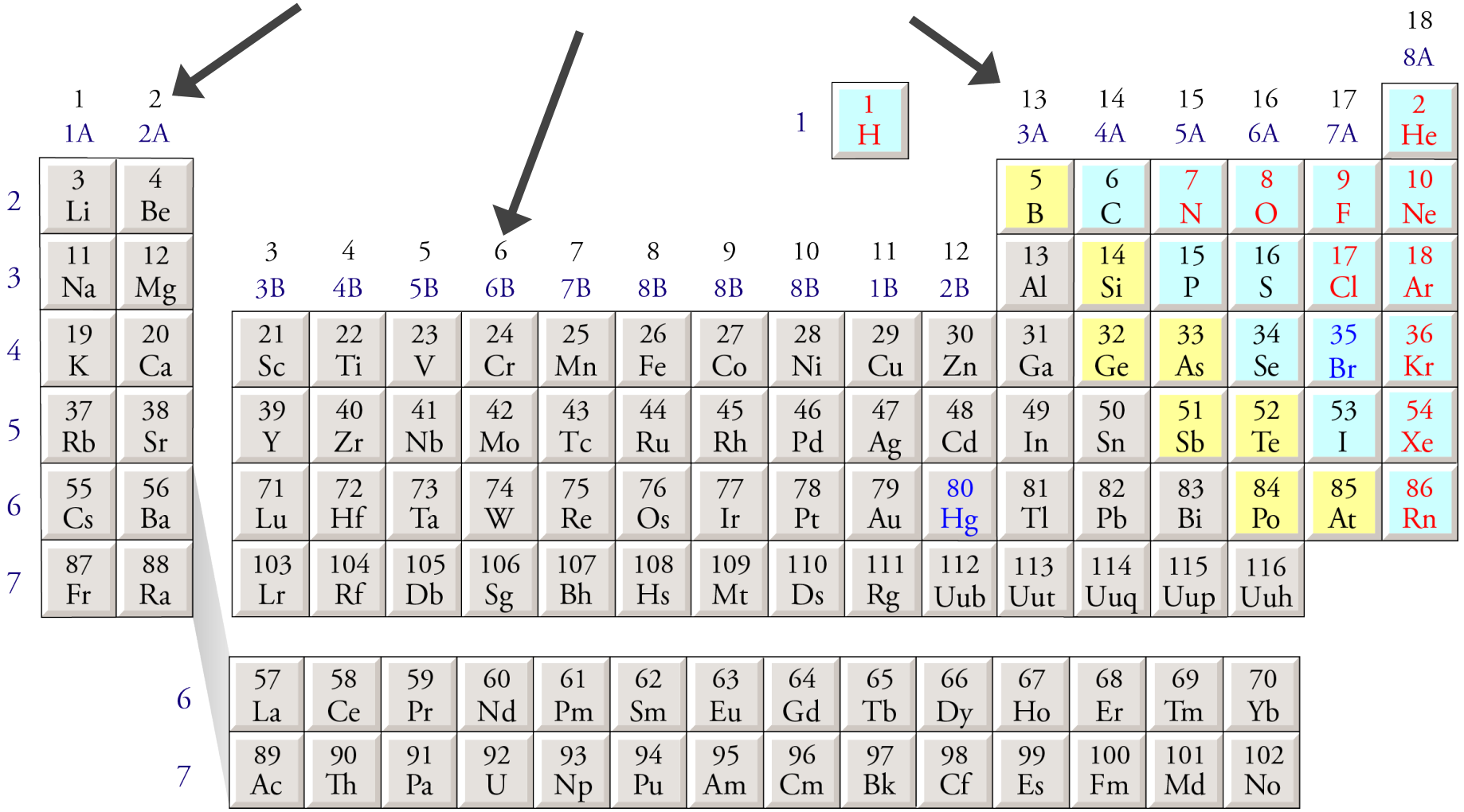
118 Known Elements

- 83 are stable and found in nature.
  - Many of these a very rare.
- 7 are found in nature but are radioactive.
- The rest are not natural on the earth.
  - 2 or 3 of these might be found in stars.

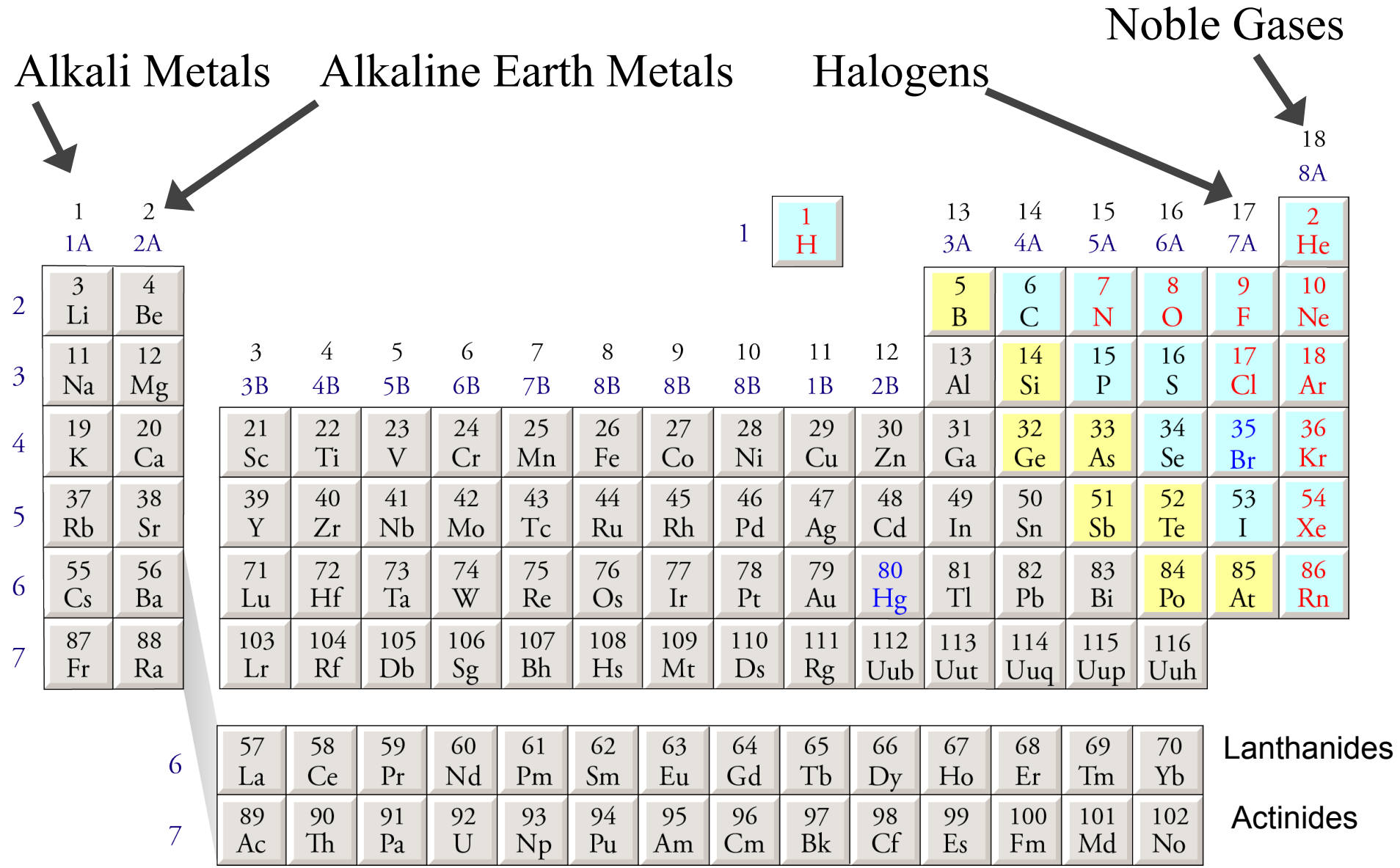
Common Elements

- Hydrogen, H
- Carbon, C
- Nitrogen, N
- Oxygen, O
- Fluorine, F
- Sodium, Na
- Phosphorus, P
- Potassium, K
- Sulfur, S
- Chlorine, Cl
- Boron, B
- Uranium, U
- Plutonium, Pu

Group Numbers on the Periodic Table



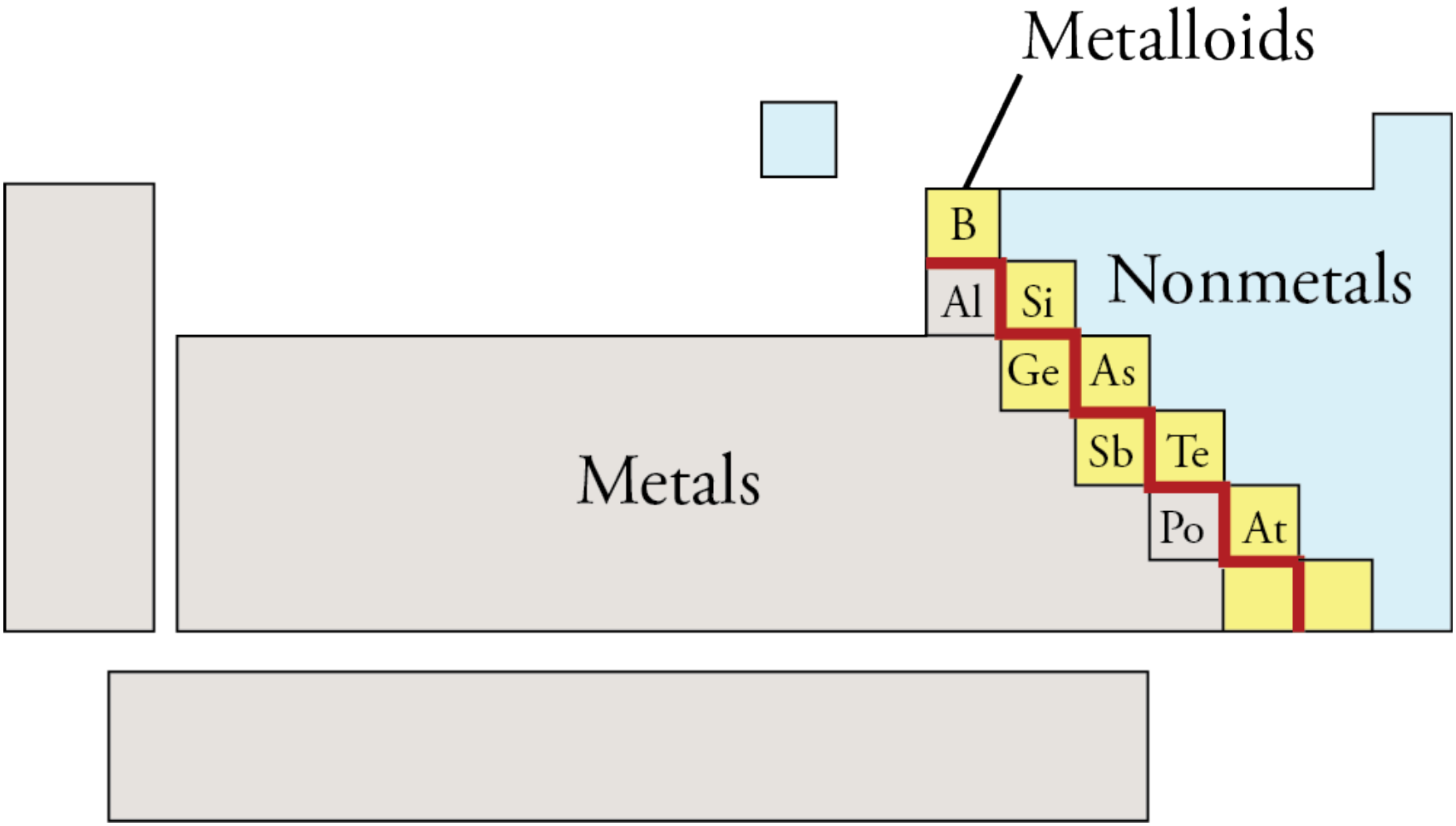
Group Names


Alkali Metals
Alkaline Earth Metals
Halogens
Noble Gases
1 1A
2 2A
3 3B
4 4B
5 5B
6 6B
7 7B
8 8B
9 8B
10 8B
11 1B
12 2B
13 3A
14 4A
15 5A
16 6A
17 7A
18 8A
1 H
2 He
2 Li Be B C N O F Ne
3 Na Mg Al Si P S Cl Ar
4 K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
5 Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
6 Cs Ba Lu Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
7 Fr Ra Lr Rf Db Sg Bh Hs Mt Ds Rg Uub Uut Uuq Uup Uuh
6 La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb
7 Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No
Lanthanides
Actinides

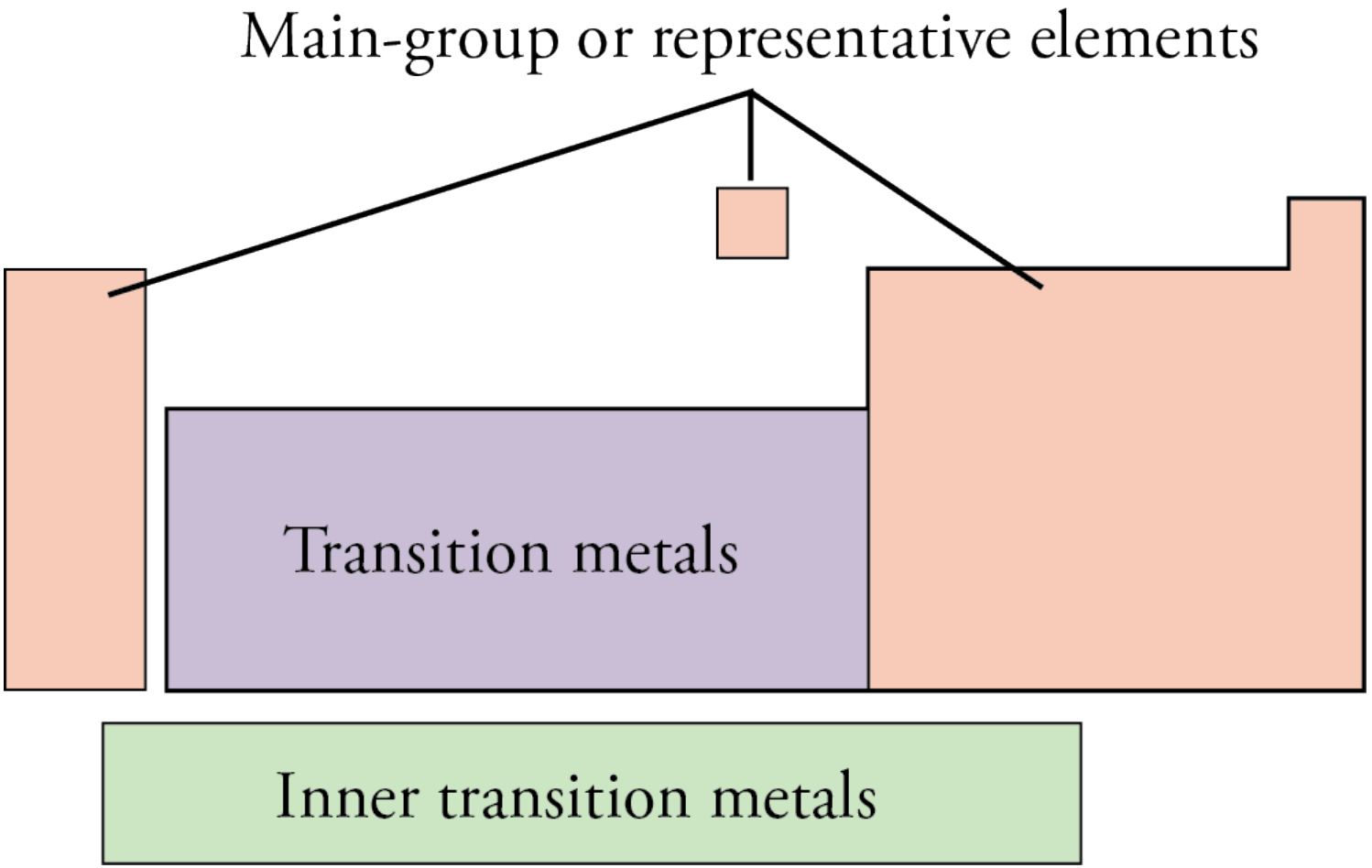
Characteristics of Metallic Elements

- Metals have a shiny metallic luster.
- Metals conduct heat well and conduct electric currents in the solid form.
- Metals are malleable.
  - For example, gold, Au, can be hammered into very thin sheets without breaking.

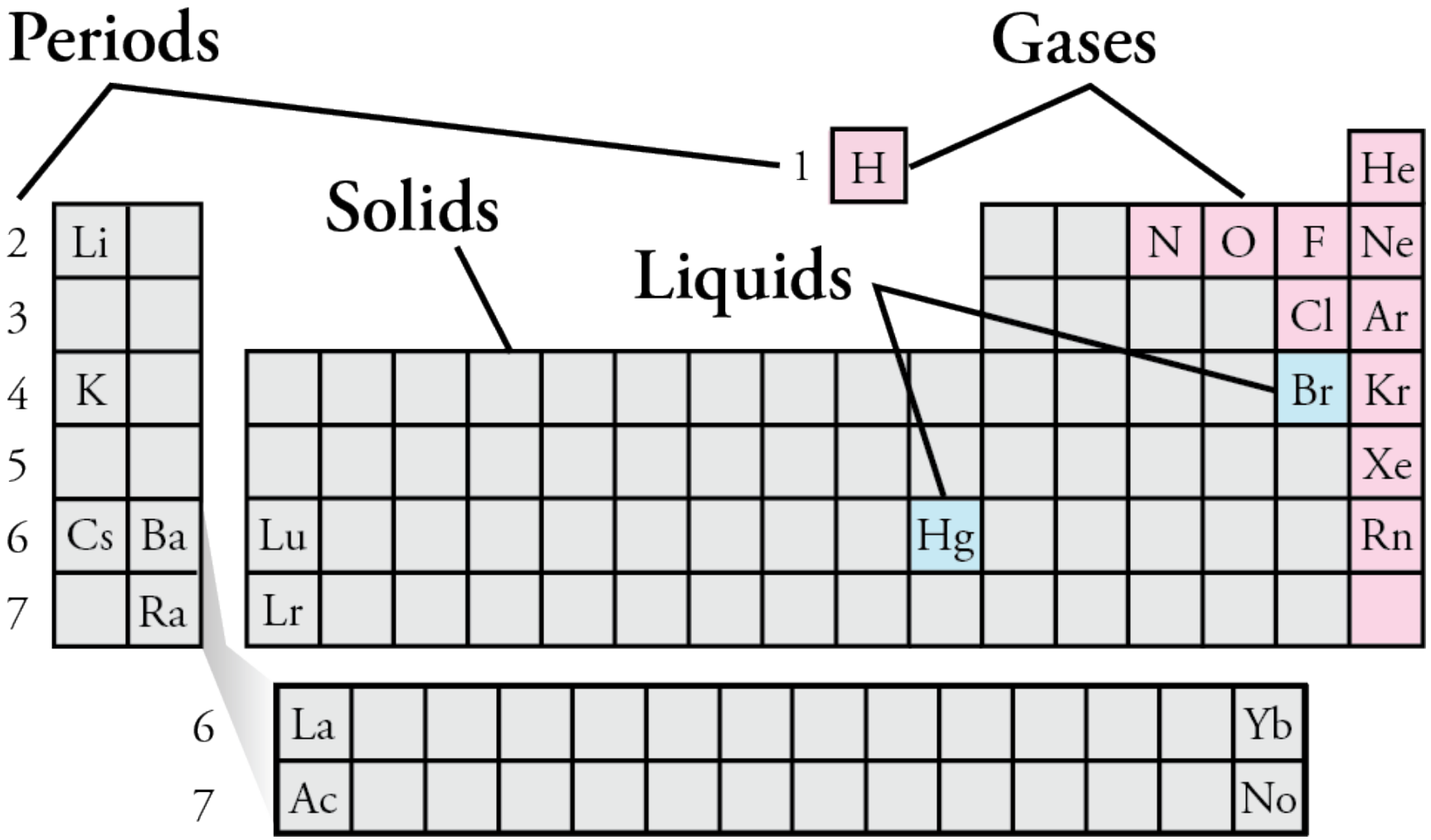
Metals, Nonmetals, and Metalloids



Classification of Elements



Solid, Liquid, and Gaseous Elements



Atoms

- Tiny…about 10^{-10} m
  - If the atoms in your body were 1 in. in diameter, you'd bump your head on the moon.
- Huge number of atoms in even a small sample of an element
  - 1/2 carat diamond has 5×10^{21} atoms… if lined up, would stretch to the sun.

Particles in the Atom

- **Neutron (n)**

  0 charge 1.00867 u in nucleus

- **Proton (p)**

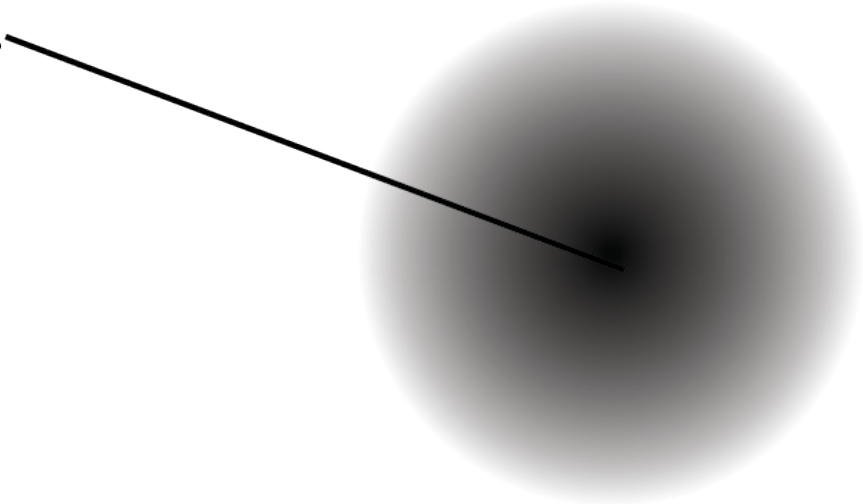
  +1 charge 1.00728 u in nucleus

- **Electron (e^-)**

  –1 charge 0.000549 u outside nucleus

Electron Cloud for Hydrogen Atom

The negative charge is most intense at the nucleus and diminishes in intensity with increased distance from the nucleus.



http://preparatorychemistry.com/Hydrogen_1.html

Helium Atom

http://preparatorychemistry.com/helium_atom.html

The Electron

"If I seem unusually clear to you, you must have misunderstood what I said."

Alan Greenspan,

Head of the Federal Reserve Board

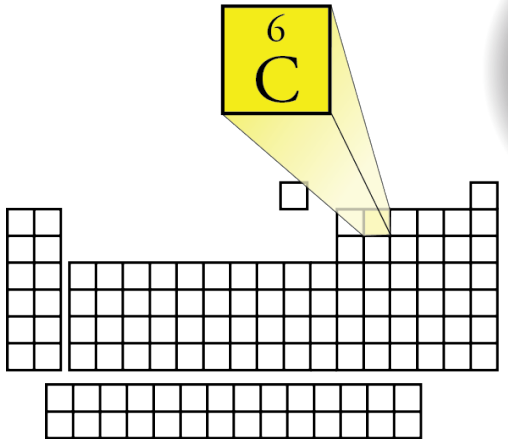
"It is probably as meaningless to discuss how much room an electron takes up as to discuss how much room a fear, an anxiety, or an uncertainty takes up."

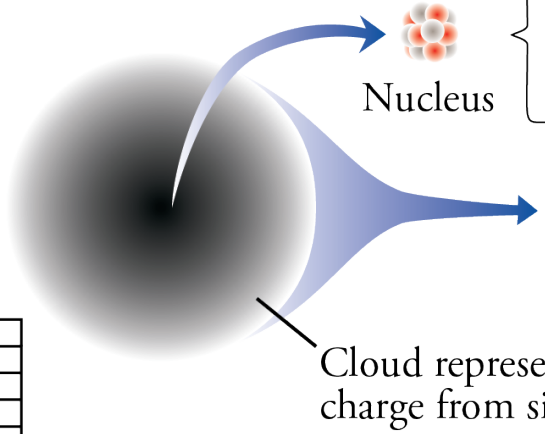
Sir James Hopwood Jeans,
English mathematician, physicist and astronomer (1877-1946)

Carbon Atom

Carbon atom

6 protons
6 neutrons
(in most carbon atoms)
6 electrons
(in uncharged atom)



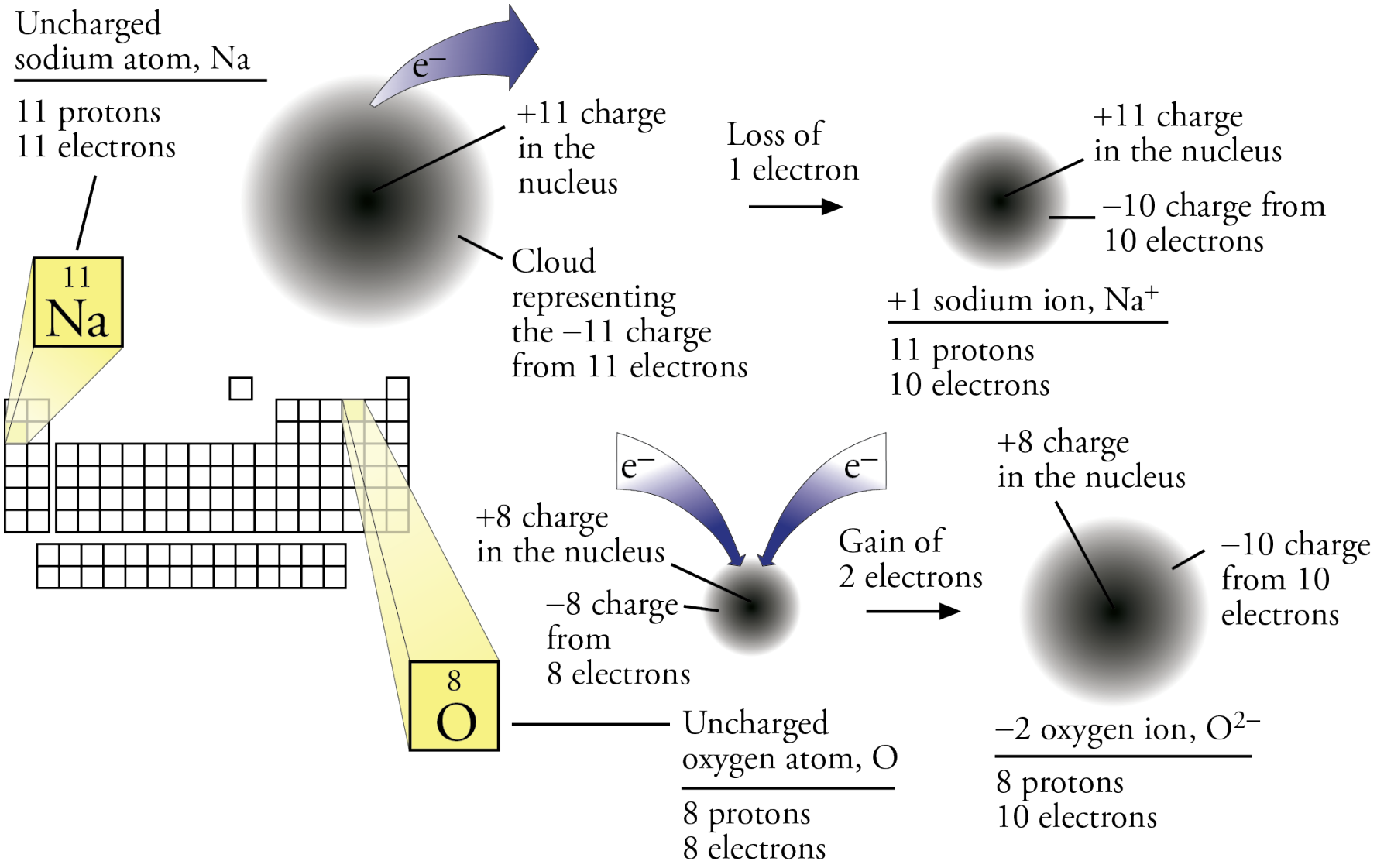


Particle		Charge	Mass
proton		+1	1.00728 u (1.6726×10^{-24} g)
neutron		0	1.00867 u (1.6750×10^{-24} g)
e^-	electron	−1	0.000549 u (9.1096×10^{-28} g)

Ions

- ***Ions*** are charged particles due to a loss or gain of electrons.
- When particles lose one or more electrons, leaving them with a positive overall charge, they become ***cations***.
- When particles gain one or more electrons, leaving them with a negative overall charge, they become ***anions***.

Example Ions



Effect on Chemical Changes

- Electrons
  - Can be gained, lost, or shared…actively participate in chemical changes
  - Affect other atoms through their -1 charge
- Protons
  - Affect other atoms through their +1 charge
  - Determine the number of electrons in uncharged atoms
- Neutrons
  - No charge…no effect outside the atom and no direct effect on the number of electrons.

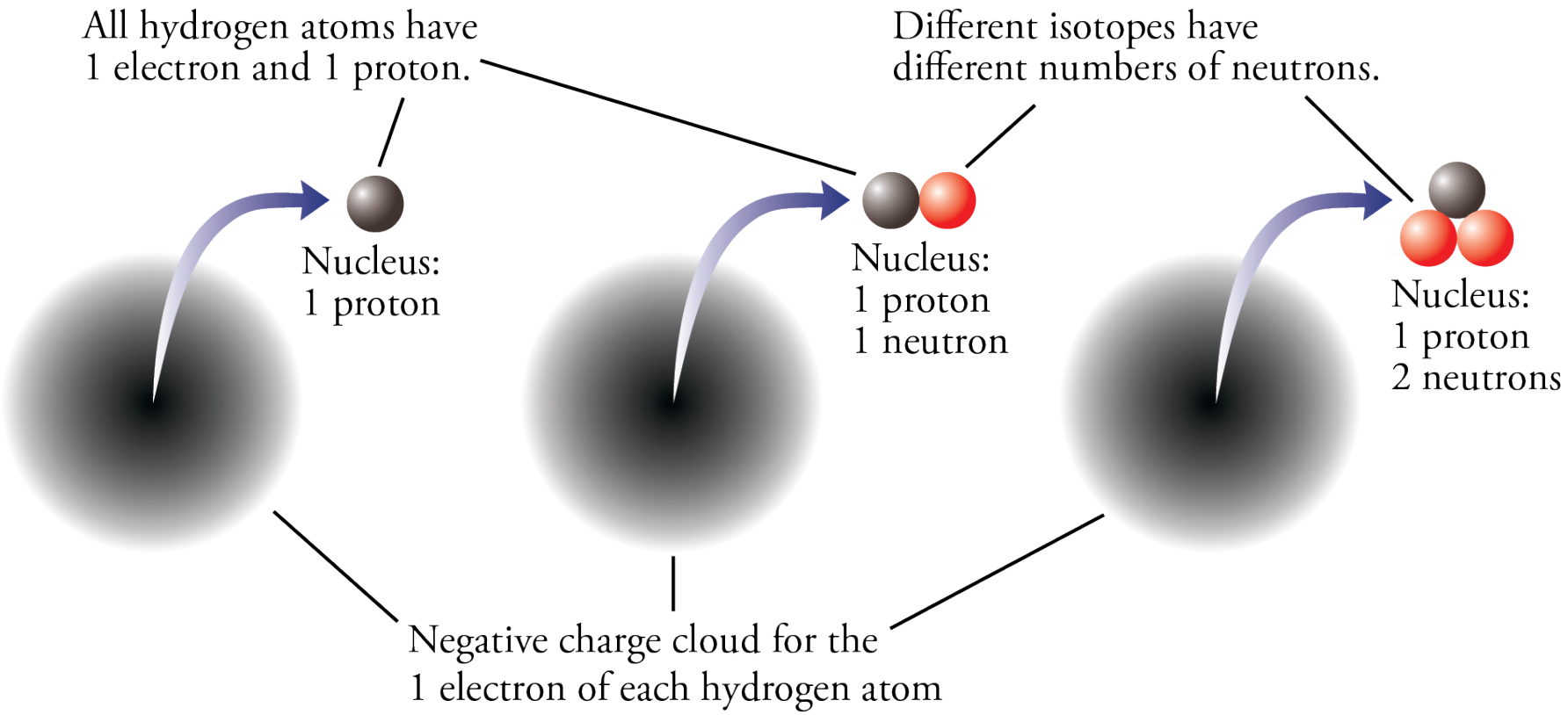
Nuclides

- ***Nuclide*** = a particular type of nucleus, characterized by a specific atomic number and nucleon number
- ***Atomic Number*** = the number of protons
- ***Nucleon number*** or *mass number* = the number of ***nucleons*** (protons and neutrons) in the nucleus of a nuclide.

Isotopes

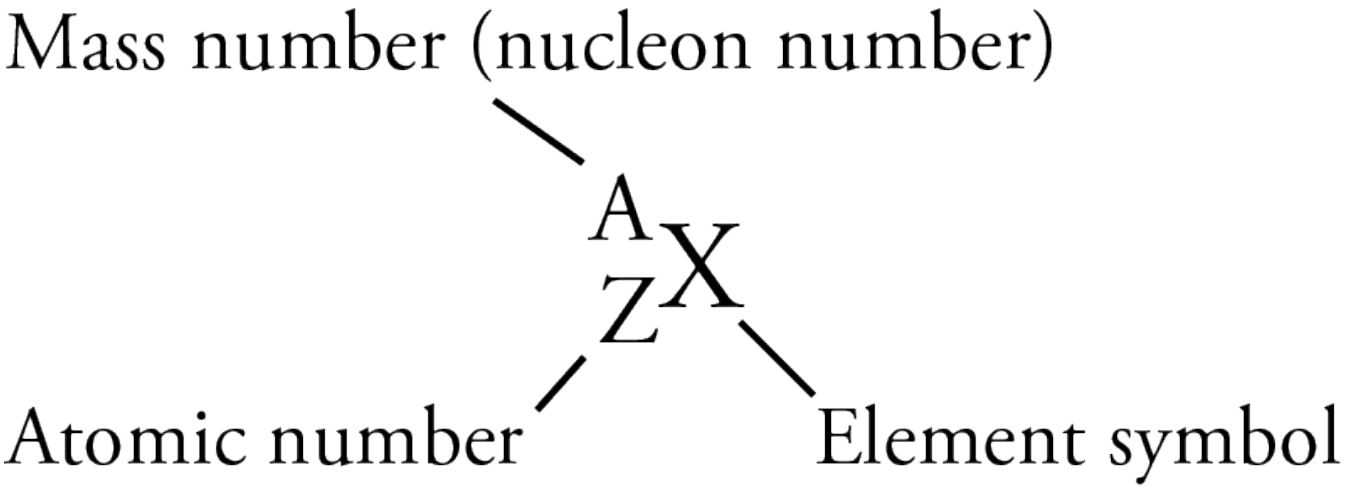
- ***Isotopes*** are atoms with the same atomic number but different mass numbers.
- ***Isotopes*** are atoms with the same number of protons and electrons in the uncharged atom but different numbers of neutrons.
- ***Isotopes*** are atoms of the same element with different masses.

Isotopes of Hydrogen



http://preparatorychemistry.com/Hydrogen_1.html
http://preparatorychemistry.com/Hydrogen_2.html
http://preparatorychemistry.com/Hydrogen_3.html

Isotope Symbolism



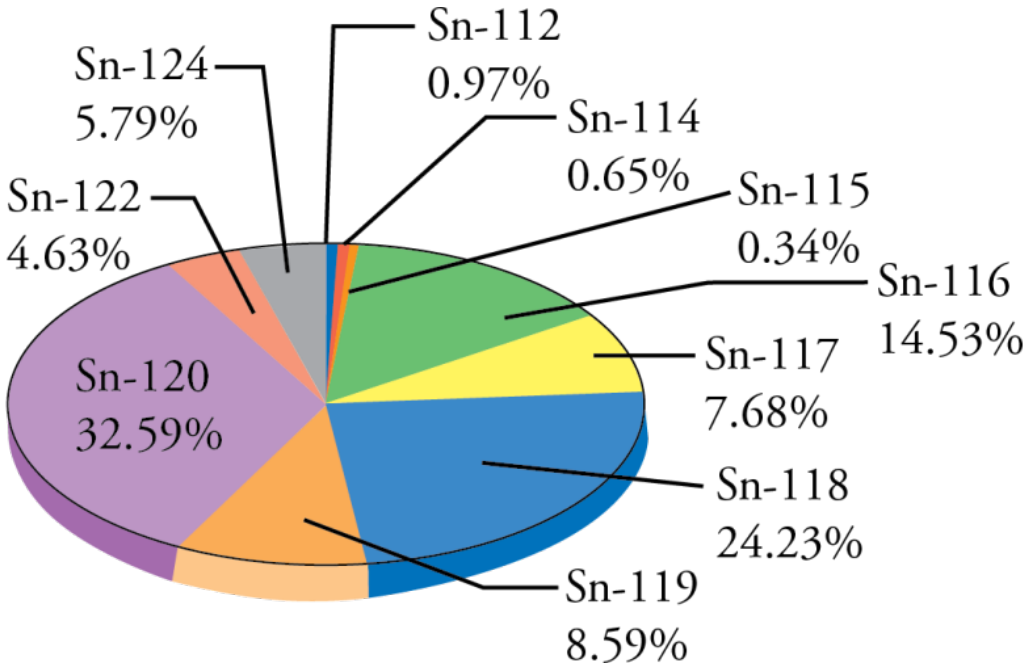
Most abundant isotope of uranium $^{238}_{92}U$

An aluminum cation, Al^{3+} $^{27}_{13}Al^{3+}$

Krypton and Detection of Reprocessing of Nuclear Fuel

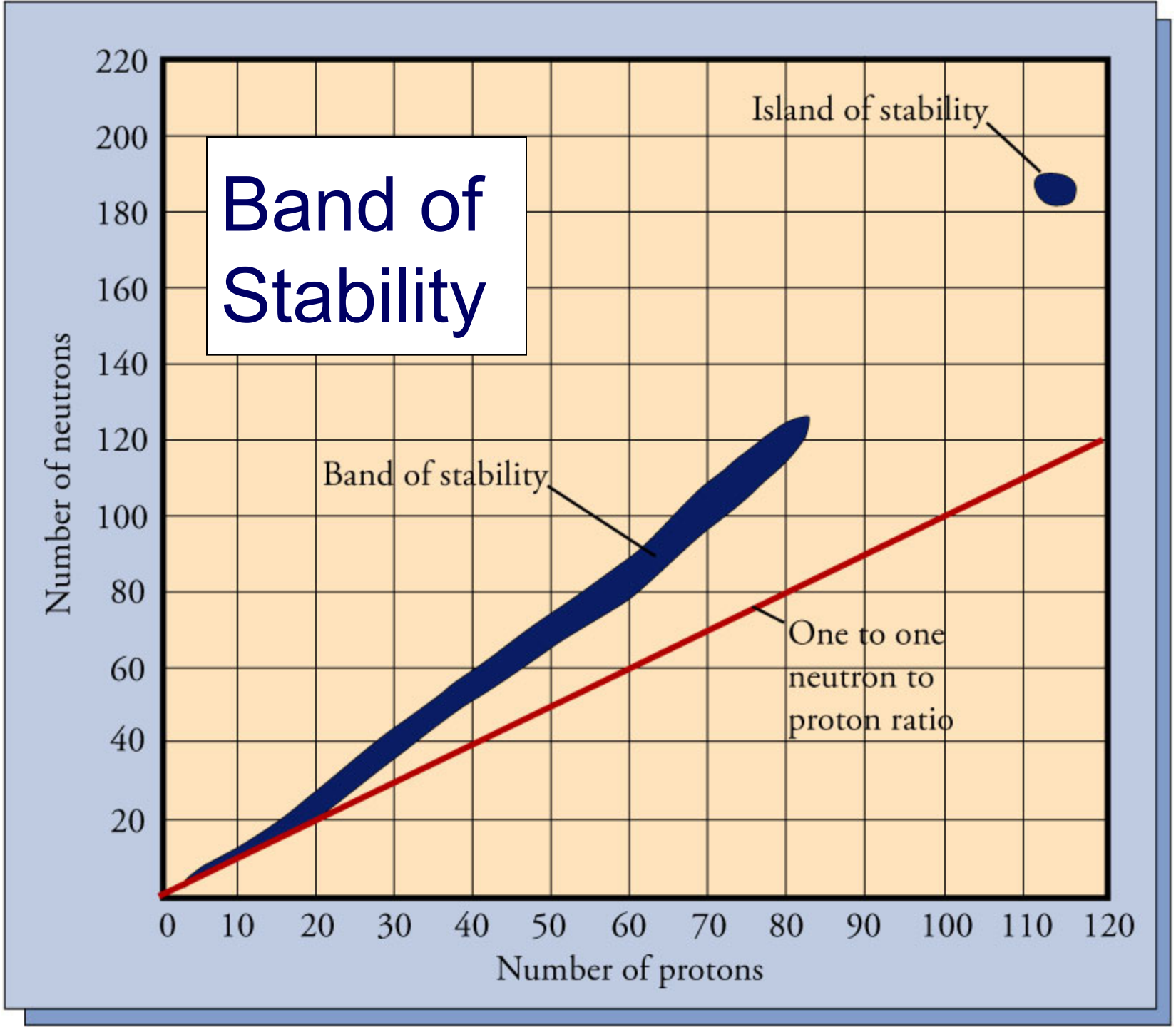
- As a noble gas, krypton, Kr, is very stable and unreactive.
- In nuclear power plants, about three atoms of krypton-85 are produced for every 1000 fissions (i.e. it has a fission yield of 0.3%).
- When nuclear fuel is crushed in reprocessing, the gaseous krypton is released.
- Therefore, detection of elevated level of Kr-85 are an indication that nuclear fuel is being reprocessed.

Tin has ten natural isotopes.



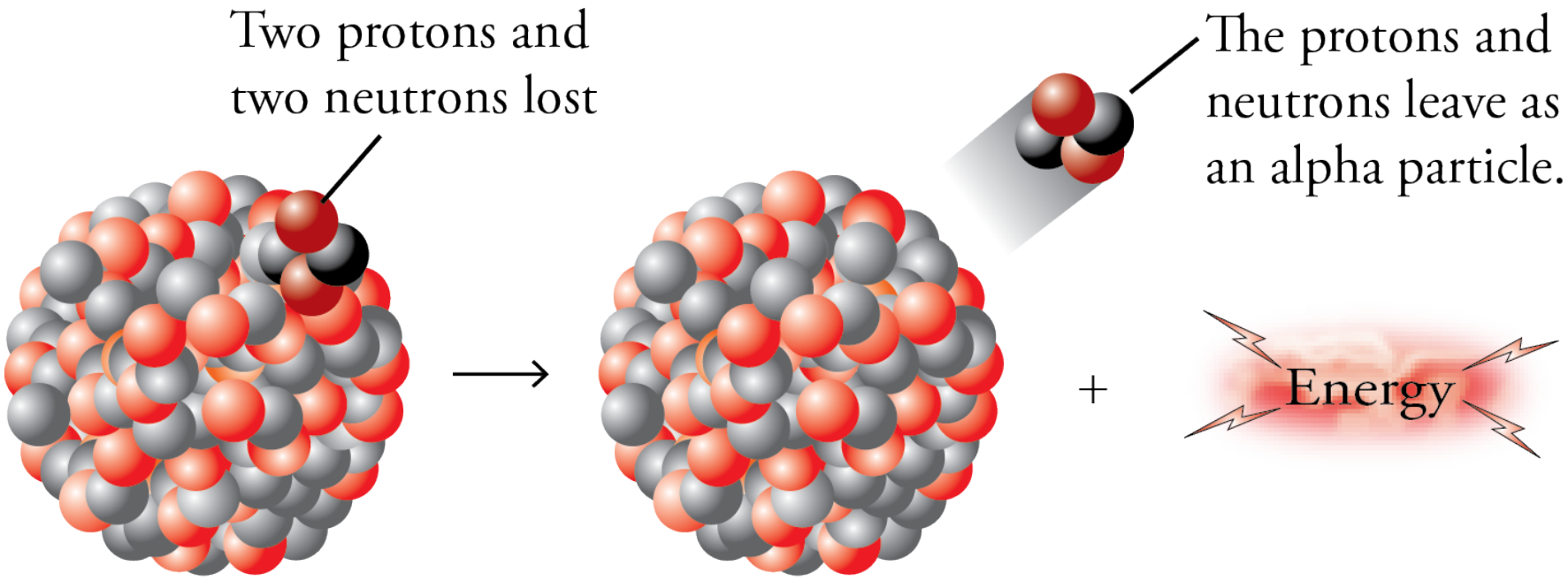
Nuclear Stability

- ***Electrostatic force*** = the force that causes opposite electrical charges to attract each other.
- ***Strong force*** = the force between nucleons (protons and neutrons).
- Neutrons increase the attraction from the strong force without increasing electrostatic repulsion between nucleons.


Band of Stability
Island of stability
Band of stability
One to one neutron to proton ratio
Number of neutrons
220
200
180
160
140
120
100
80
60
40
20
0
10
20
30
40
50
60
70
80
90
100
110
120
Number of protons

Alpha Emission

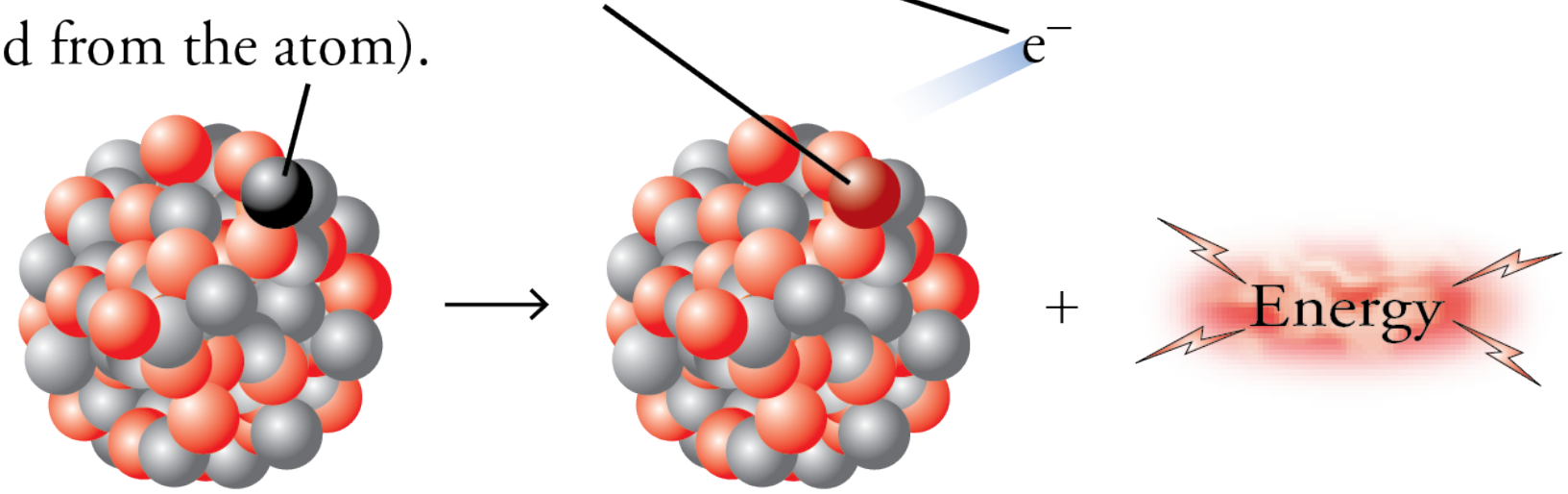
$$^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$



Beta Emission

$$^{131}_{53}\mathrm{I} \longrightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$$

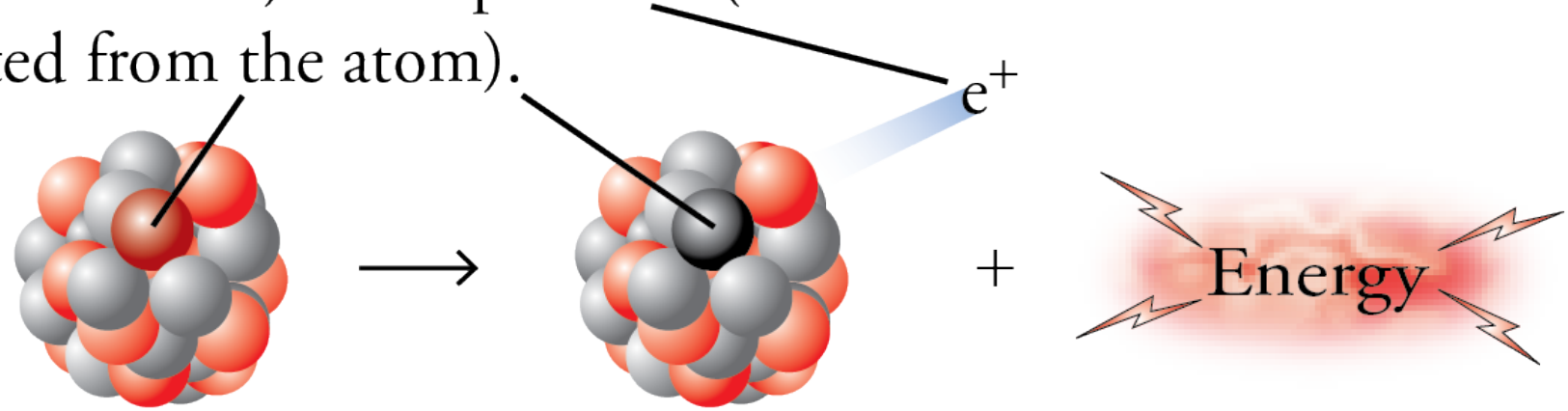
A neutron becomes a proton (which stays in the nucleus) and an electron (which is ejected from the atom).



Positron Emission

$$^{40}_{19}\mathrm{K} \longrightarrow {}^{40}_{18}\mathrm{Ar} + {}^{0}_{+1}\mathrm{e}$$

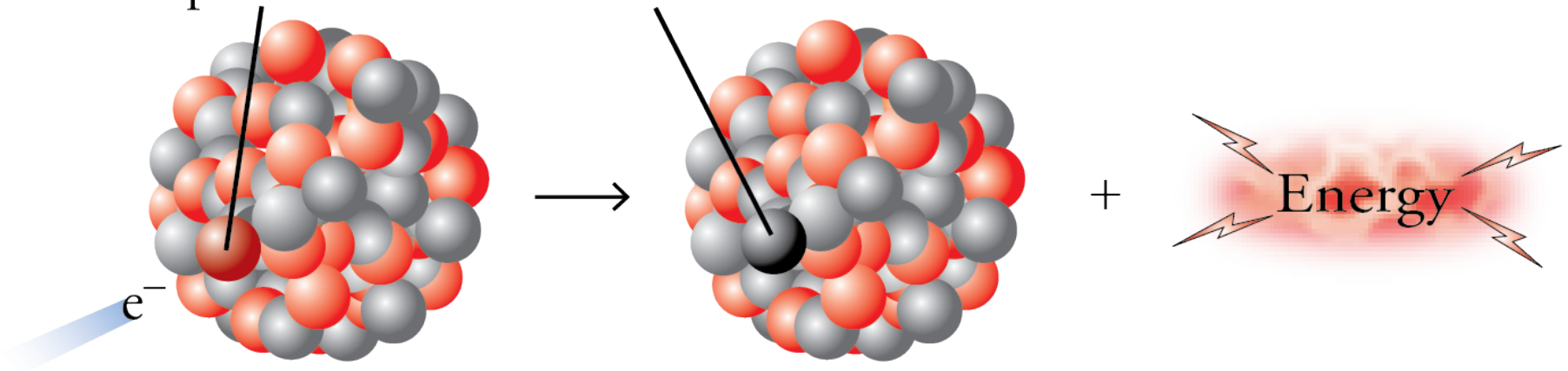
A proton becomes a neutron (which stays in the nucleus) and a positron (which is ejected from the atom).



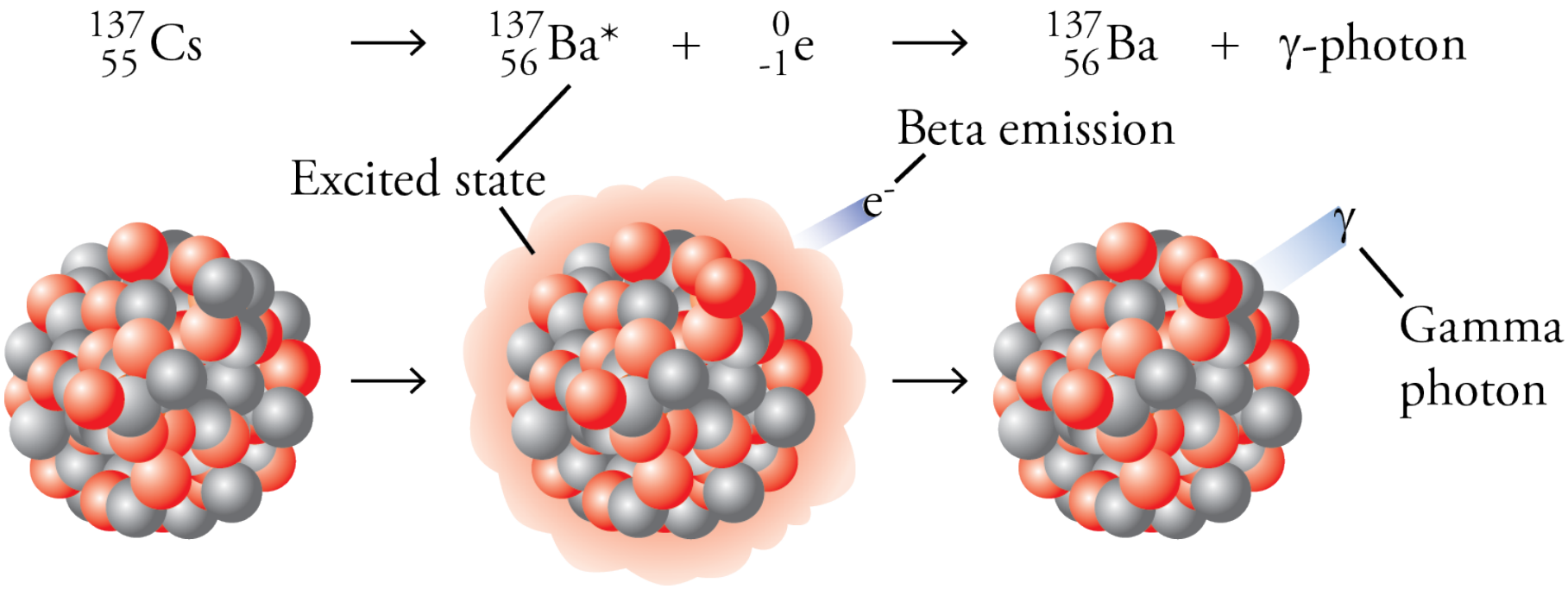
Electron Capture

$$ {}^{0}_{-1}e + {}^{125}_{53}I \longrightarrow {}^{125}_{52}Te $$

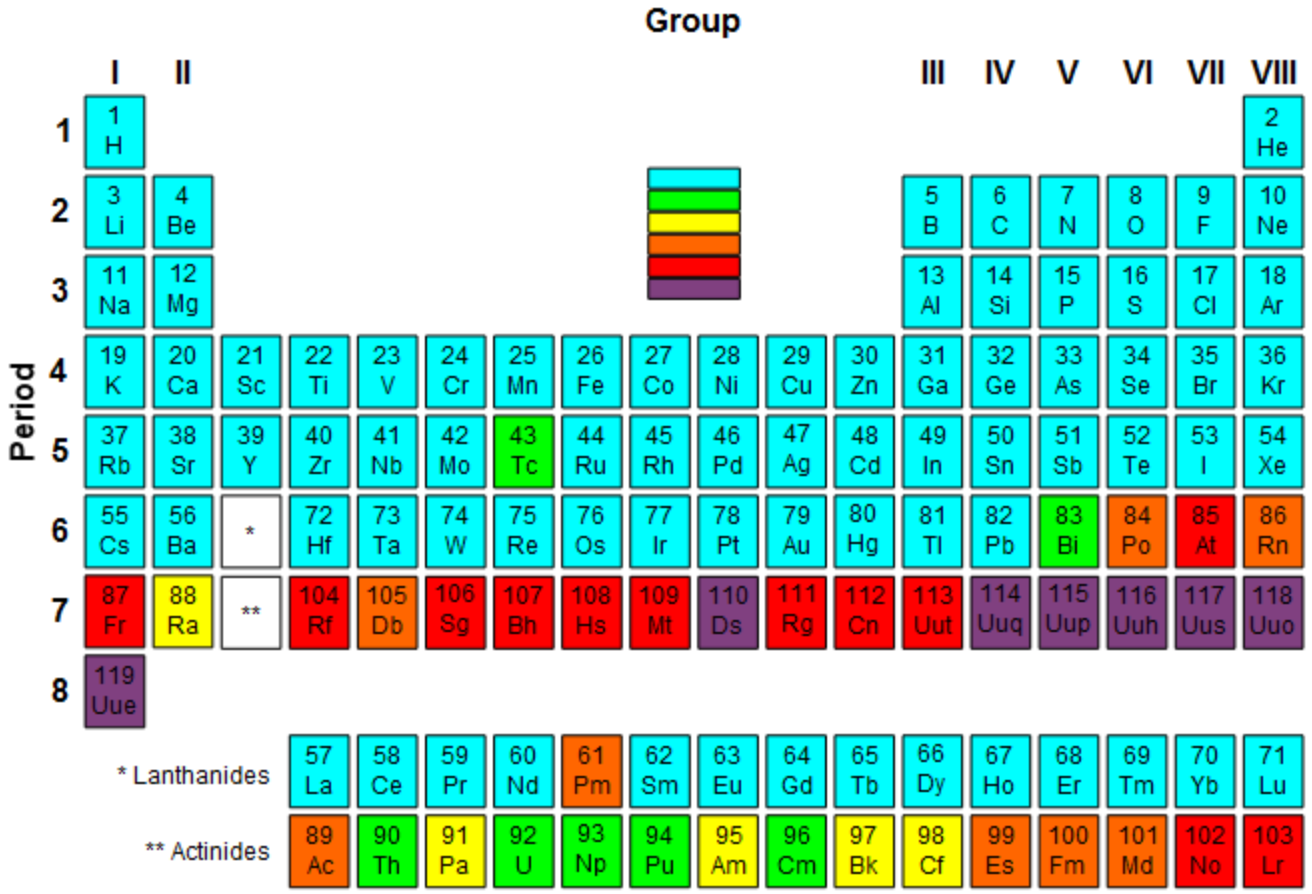
An electron combines with a proton to form a neutron.



Gamma Emission



The Periodic Table: Radioactivity and Isotopes



Stable elements.

Radioactive elements with isotopes with very long decay half-times. Their half-life of over a million years gives them very small or negligible radioactivities and thus may be handled without any precautions.

Radioactive elements that may present low health hazards. Their half-life of over 500 years allows them to have commercial applications owing to their radiation levels being similar to background radiation.

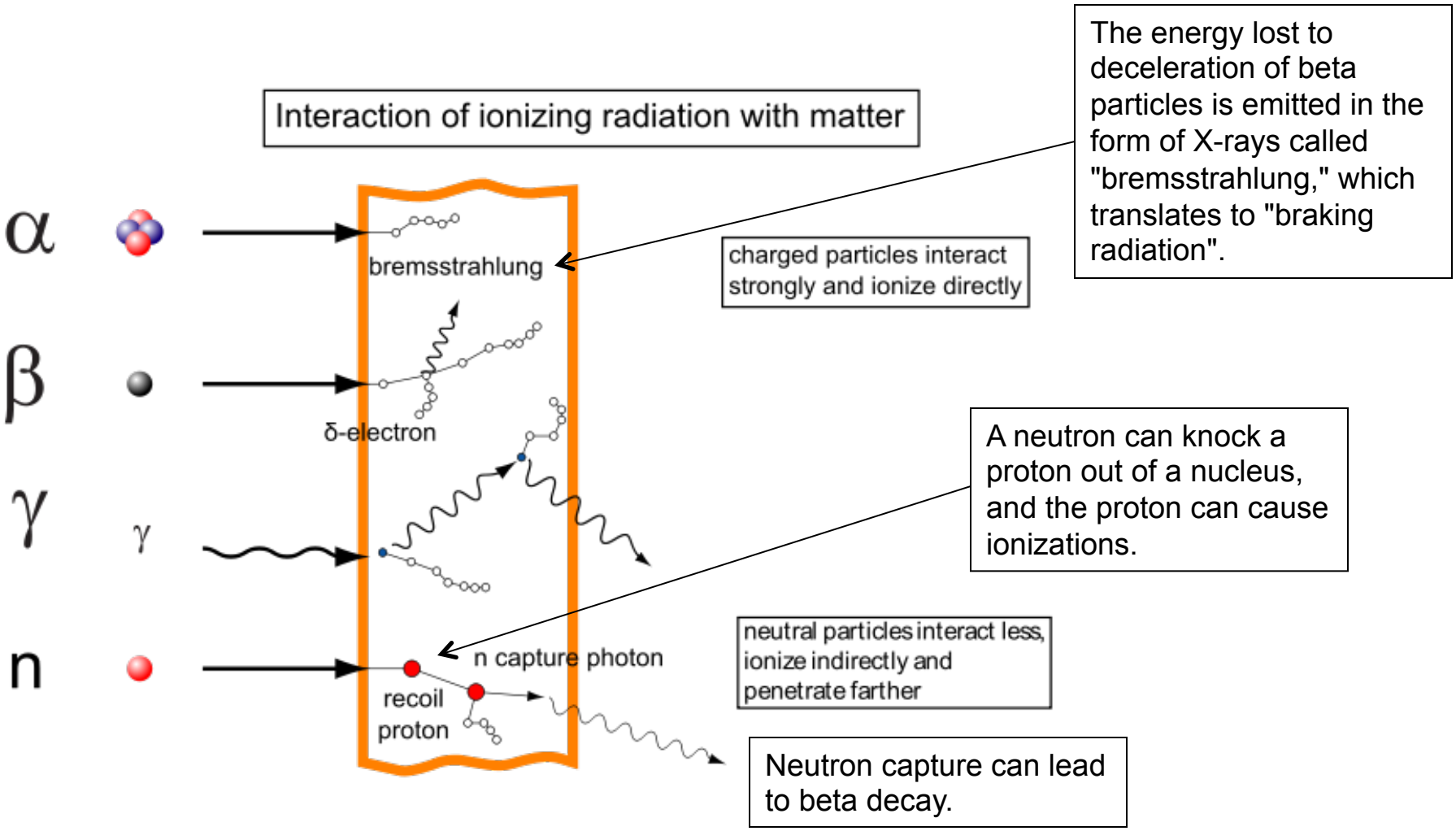
Radioactive elements that are known to pose high safety risks. Their half-life of over a day and their radioactivity levels give them little potential for any commercial use other than as radiation sources.

Highly radioactive elements. Because of their half-life as low as a couple of minutes, they pose severe health risks and is unlikely that they will receive any use outside basic research.

Extremely radioactive elements. Very little is known about these elements, and they will likely never receive any attention outside research laboratories

Ionizing Radiation

- All of the forms of radioactive emissions can lead to the formation of ions.



Radiation Effect on Body

- Radioactive emissions ionize atoms and molecules. This leads to free radicals (particles with unpaired electrons). For example,

  $H_2O \rightarrow H_2O^{\bullet +} + e^-$

  $H_2O^{\bullet +} + H_2O \rightarrow H_3O^+ + {}^{\bullet}OH$

  $H_2O + e^- \rightarrow H^{\bullet} + OH^-$

- Ionizing radiation is generally harmful and potentially lethal.
- High doses can cause visually dramatic radiation burns, and/or rapid death through acute radiation syndrome.

http://en.wikipedia.org/wiki/Acute_radiation_syndrome

Structure of Some Elements

http://preparatorychemistry.com/element_properties_flash.htm

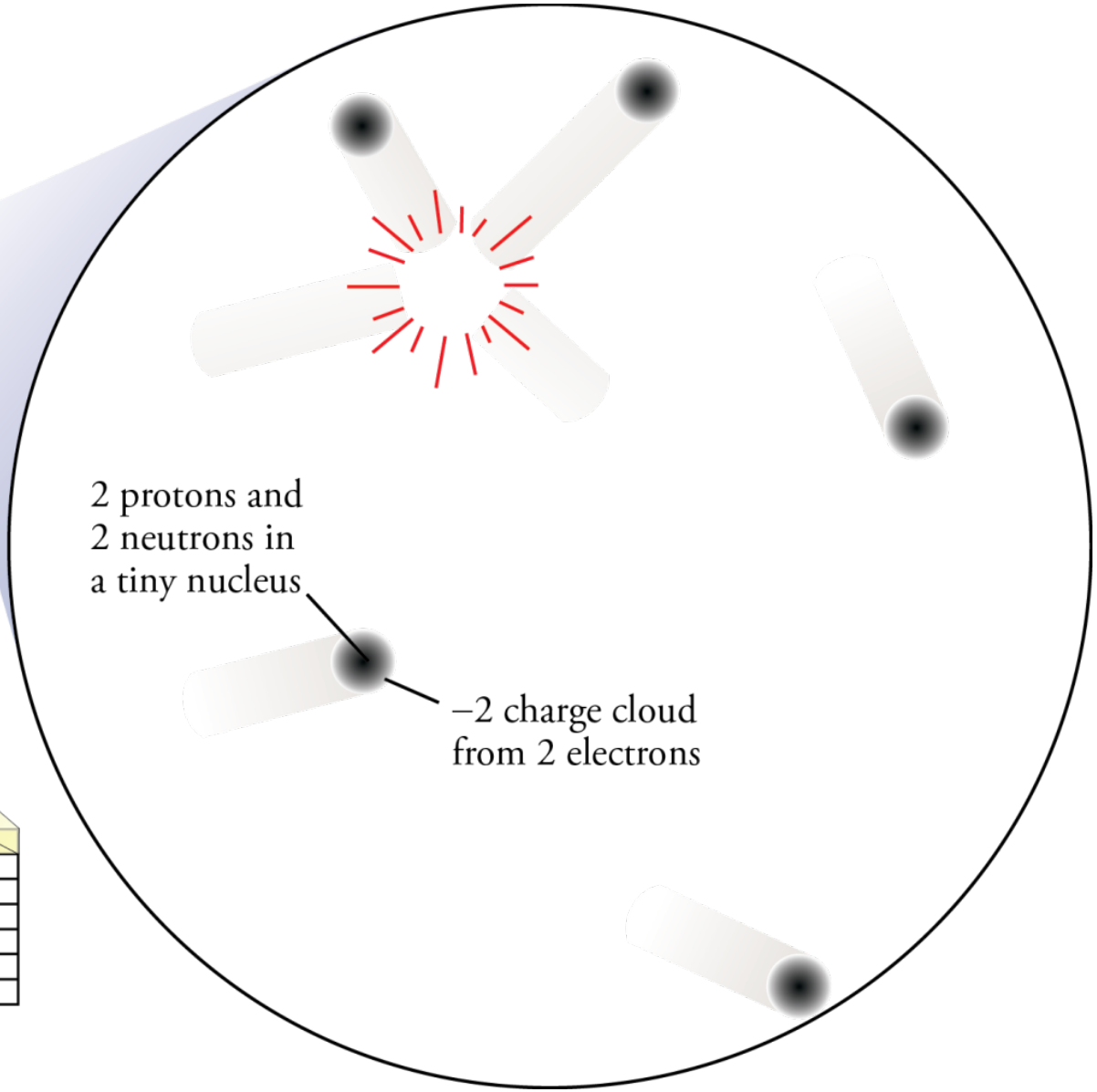
- Particles
  - Noble gases – atoms
  - Other nonmetals - molecules
    - Diatomic elements – H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2
    - S_8, Se_8, P_4
    - C(diamond) huge molecules

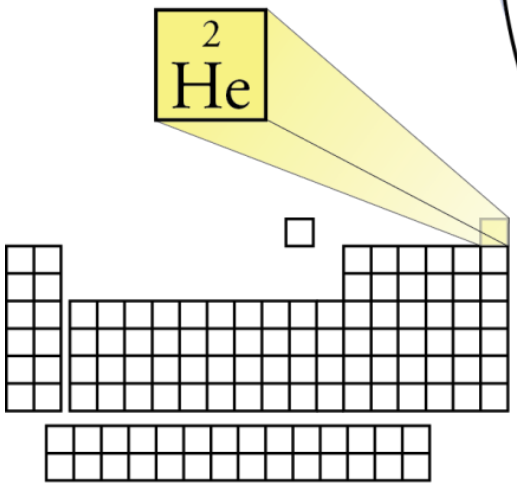
    http://preparatorychemistry.com/Bishop_Jmol_Carbon.htm
  - Metallic elements – cations in a sea of electrons

To Describe Structure of Elements (2)

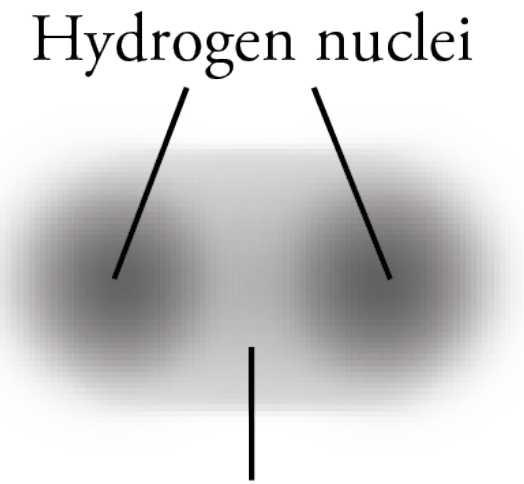
- Solid, liquid, or gas?
  - Gases - H_2, N_2, O_2, F_2, Cl_2, He, Ne, Ar, Kr, and Xe
  - Liquids – Br_2 and Hg
  - Solids – the rest
- Standard description of (1) solid, (2) liquid, (3) gas, or (4) metal.

Helium Gas, He

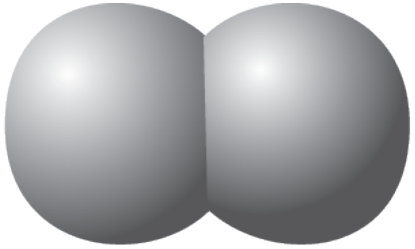




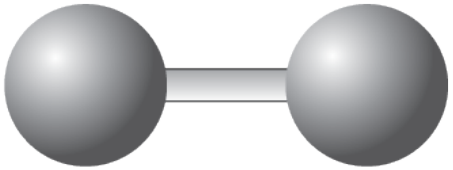
Hydrogen, H_2, Molecule



The two electrons generate a charge cloud surrounding both nuclei.

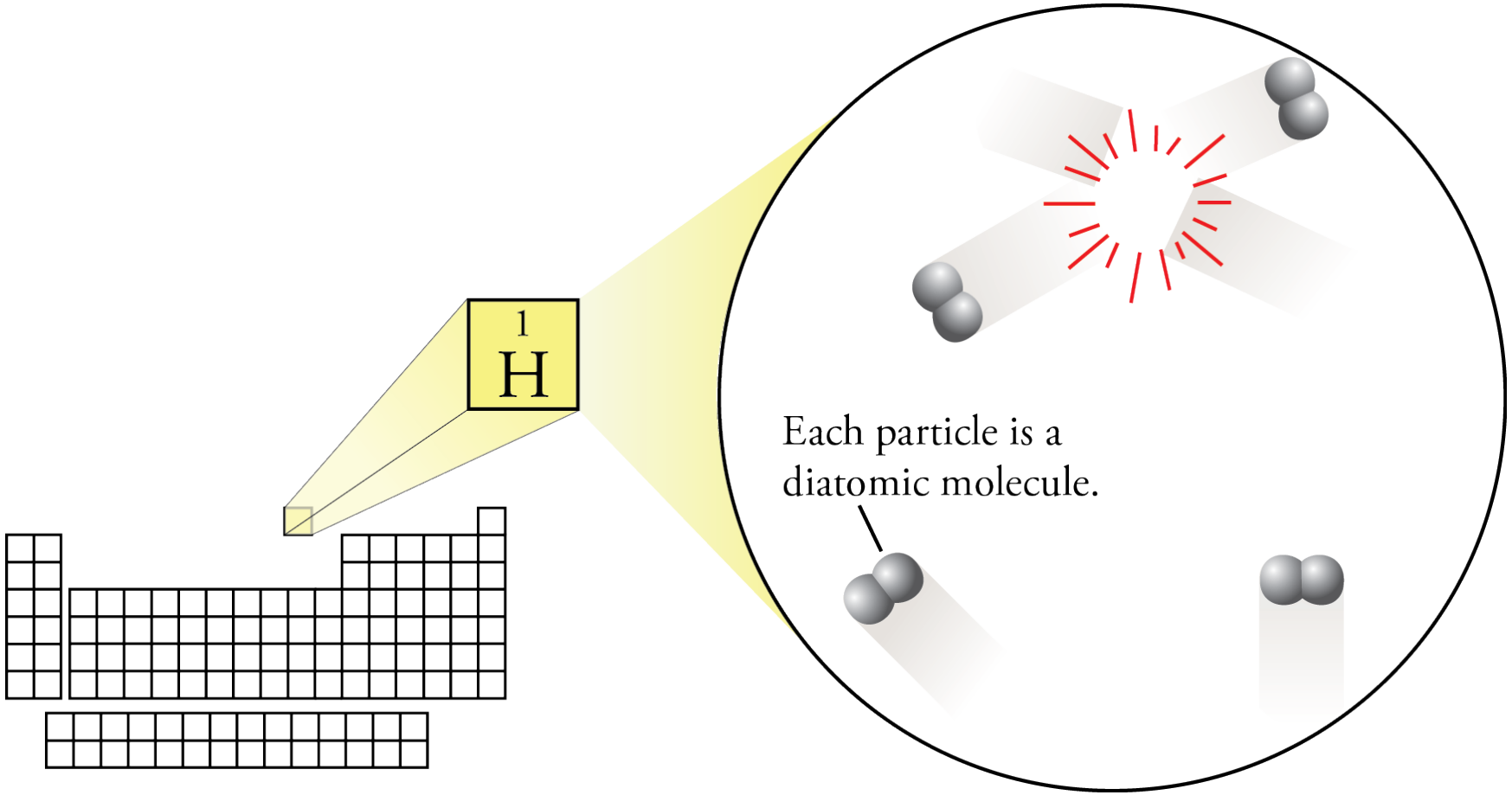


Space-filling model
Emphasizes individual atoms

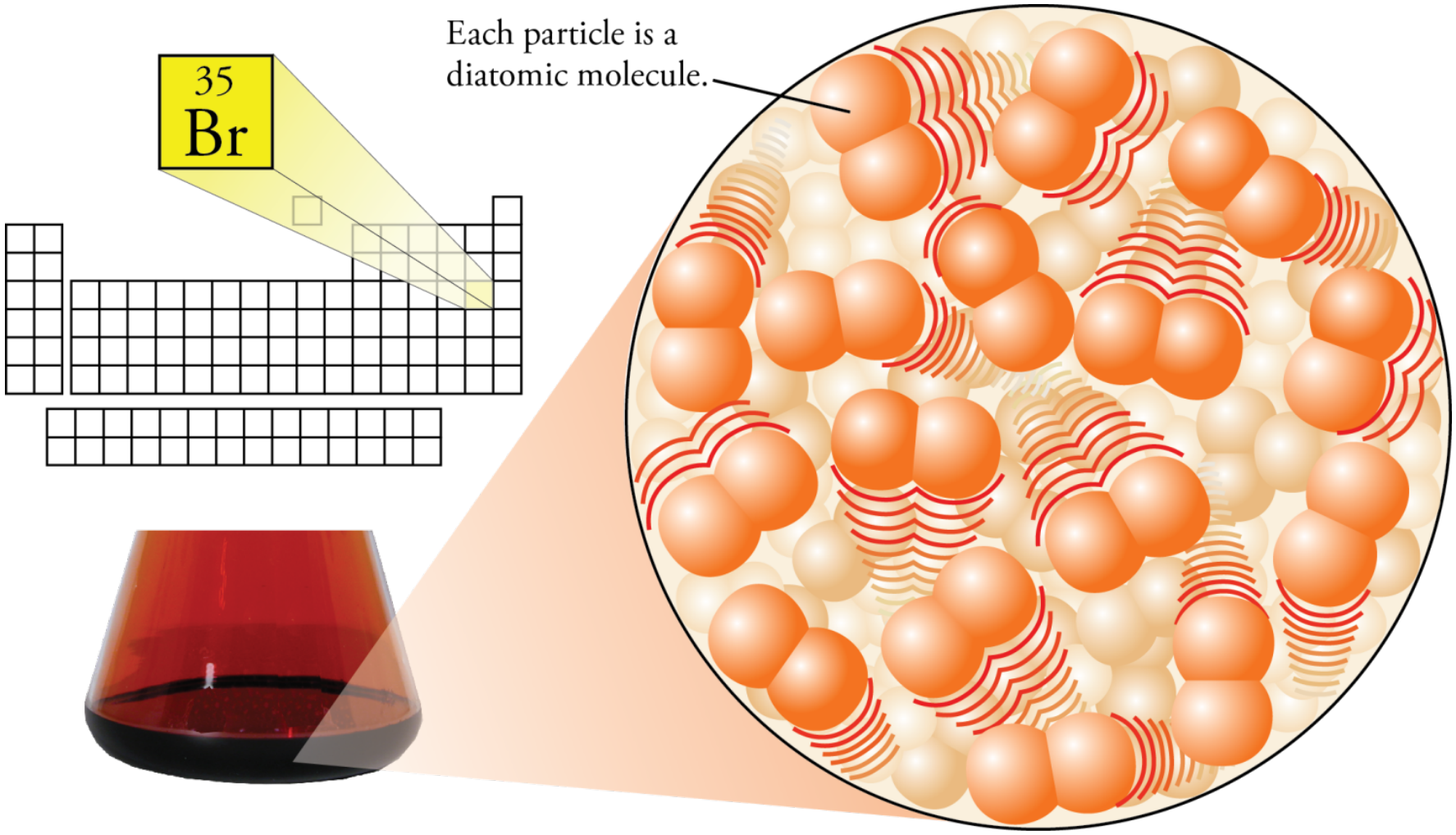


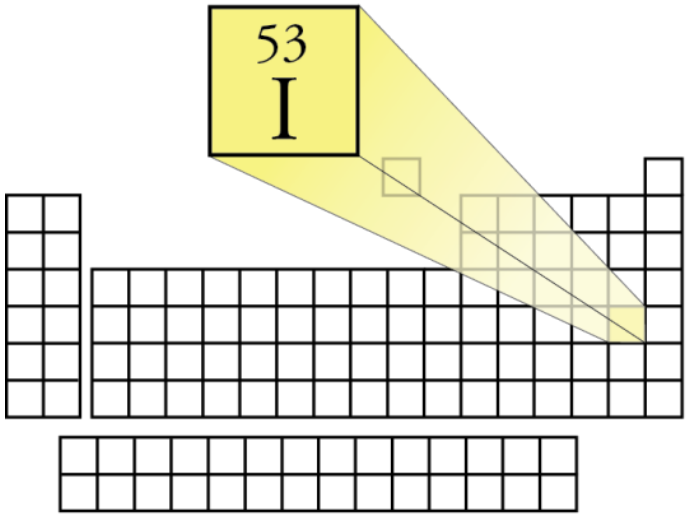
Ball-and-stick model
Emphasizes bond

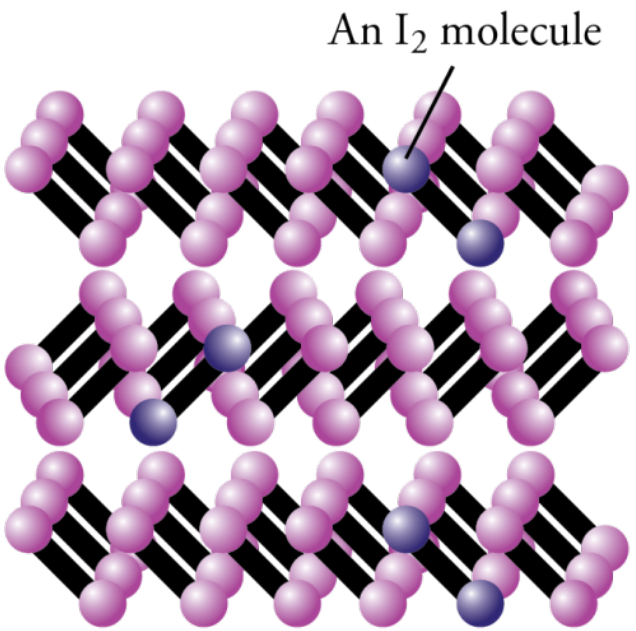
Hydrogen Gas, H_2



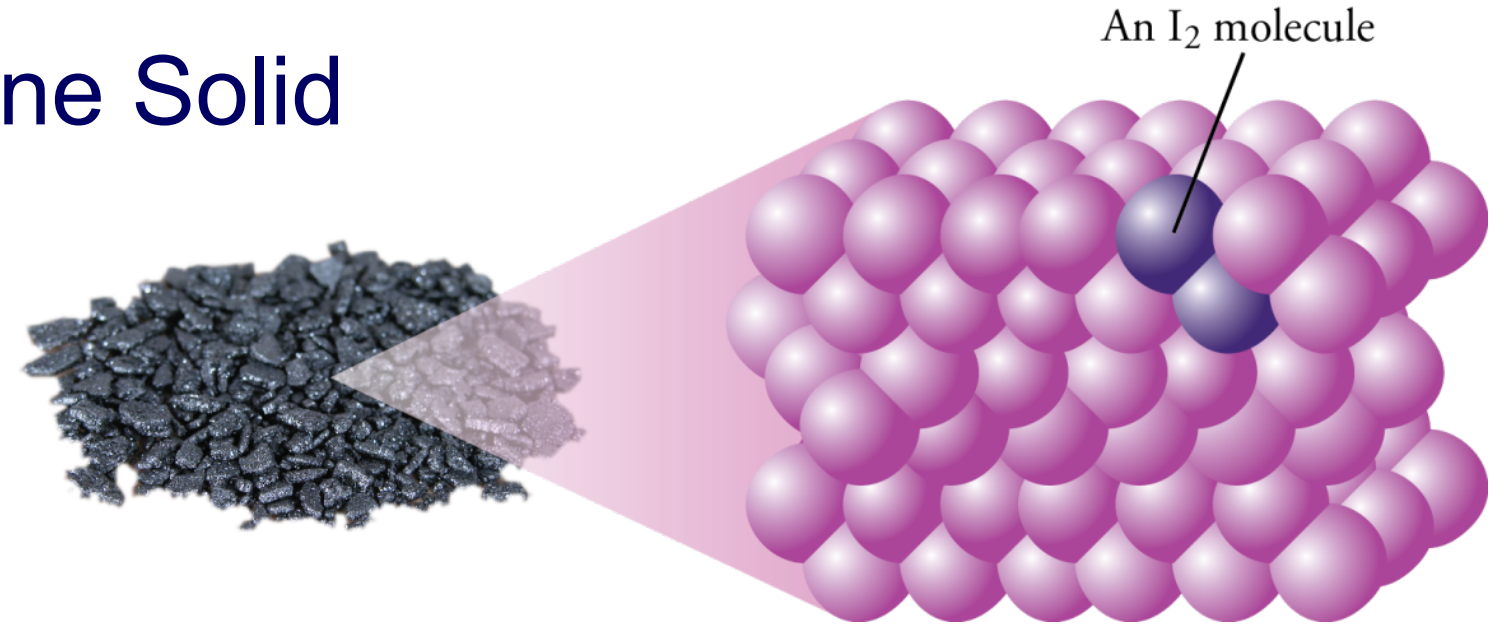
Bromine Liquid







Iodine Solid



Typical Metallic Solid and Its "Sea of Electrons"