Stability

Stability is usually not considered this early in a 100 level chem course, & not as a separate subject. We need to consider it because the existence of all living things is absolutely dependent on their ability to <u>*acquire energy from unstable things*</u>*.*

I. If something exists for a relatively long time, we say it is *stable*. (Equilibrium vs. kinetics?) If something exists for a brief time & then changes, it was *unstable*.

II. What makes nuclei be stable?

A. Ratio of n/p^+ (see “band of stability” graph)

1. ~1/1 for elements (d) with few p^+ ($p^+ \leq 20$) (Ca has 20 p^+)
2. Approaches 1.5/1 for as p^+ increases toward 83 (Bi has 83 p^+)

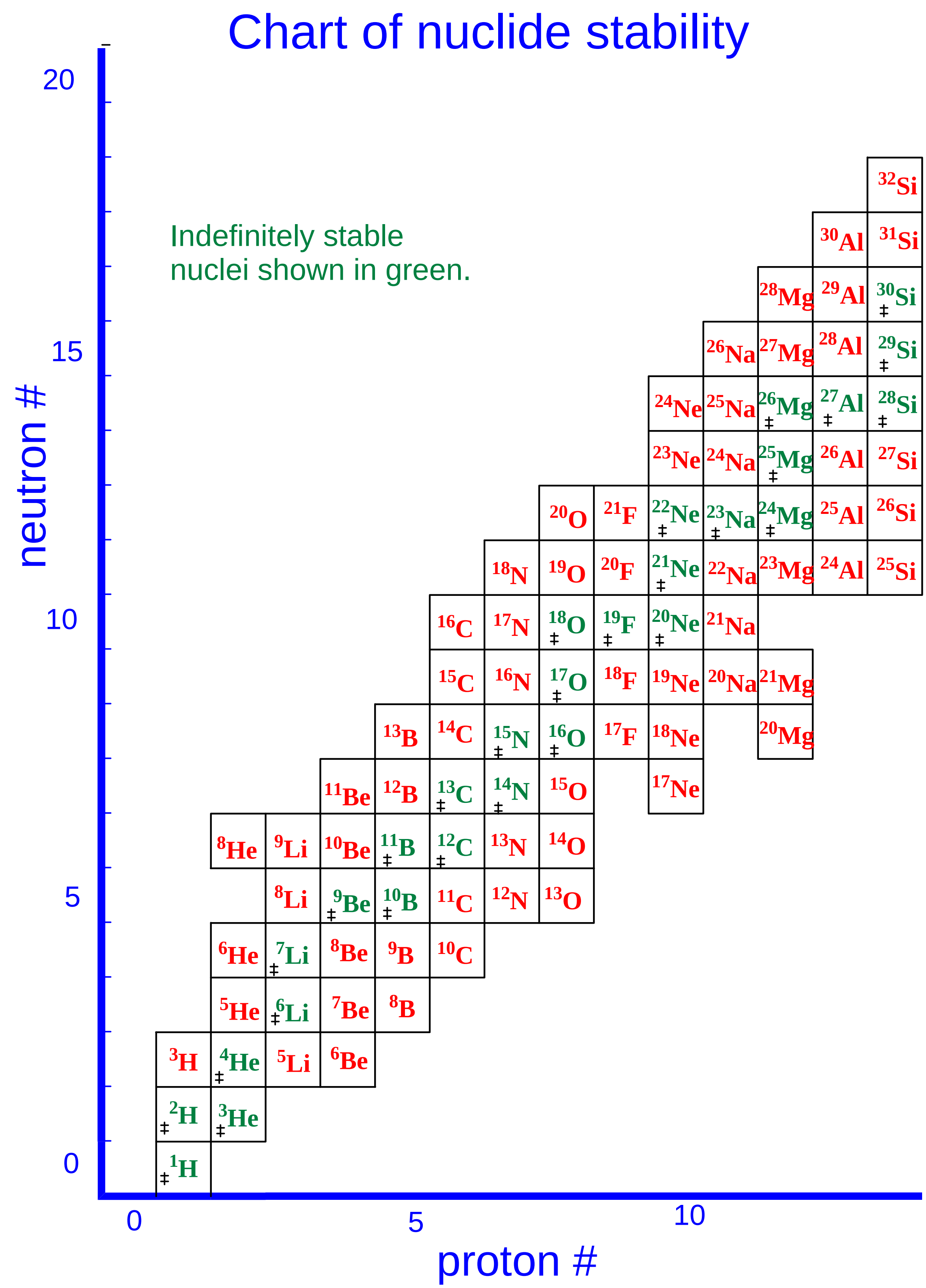
B. Size: Bismuth (Bi): heaviest element w/ indefinitely stable forms. All forms of all elements w/ $p^+ > 83$ are unstable (do radioactive decay).

C. Even vs. odd n and p^+ #’s. Even # have more types of stable nuclei.

D. Example: isotopes (d) of carbon. (^{12}C is the most abundant isotope.)

	^{12}C	^{13}C	^{14}C	^{14}C radioactively decays to: $^{14}N^+$
p^+	_____	_____	_____	_____
n	_____	_____	_____	_____
e^-	_____	_____	_____	_____

Write a chemical equation to show how ^{14}C decays into $^{14}N^+$. Remember principle of *conservation of charge*.



Nuclide refers to a specific proton/neutron combination present in an atom.

III. What makes atoms & ions be stable? Depends on e^-.
Focus: Lewis Octet Principle. (Some unstable atoms form ions.)

Do e^- configurations of C, Ne, Mg, and I.

A. For representative elements a ***full valence shell is stable***. The valence e^- are those in the outermost *s* & *p* orbitals.

1. Circle the valence (d) electrons in the e^- configuration of Ne.

2. More examples:

   Is the C atom above stable? _____ Why or why not? ____________

   Is the Ne atom above stable? ______ Why or why not? ____________

   Is the I atom above stable? _____ Why or why not? _______________

   What about the I^- ion? ______________________

   Is the Mg atom? ______ Why or why not? _______________________

   What about the Mg^{2+} ion? _________________________ (valence shell e^- ?)

How do Mg^{2+} ions form? $Mg^o \rightarrow Mg^{2+} + 2\,e^-$ (A Mg atom loses 2 e^-)

Energy level diagram?

How do I^- ions form? $I^o + e^- \rightarrow I^-$ (An I atom gains one e^-)

Does stability depend on the environment?

B. For transition metals, lanthanides, & actinides it's trickier. Ex.:

1. Gold (Au) is quite stable as an atom Au^0, & unstable as Au^{1+} or Au^{3+}
2. Iron (Fe) is moderately stable as Fe^0, Fe^{2+}, and Fe^{3+}. It can be shifted back and forth between these forms by altering the environment.
3. Manganese (Mn): relatively unstable as Mn^0 & fairly stable as Mn^{2+}.

C. Most of our emphasis is on the representative elements. I-VIII

IV. Before leaving this area, we must know what the numbers below the elemental symbols on the periodic table mean.

6
C
12.011

A. For example, look at carbon on the Periodic Table:

B. 12.011 is for the weight (amu) of the average C atom <u>on earth</u>

C. Instruments like the mass spectrometer allow chemists to make accurate determinations of the weight and abundance of the different isotopic forms of an element.

Aside: The atomic mass unit (amu) is <u>defined</u> relative to a ^{12}C atom. One atom of ^{12}C is defined to weigh 12 amu. (How many s.f. in that?)

D. Carbon isotopic mass & abundance data:

isotope	abundance (%)	mass (amu)
^{12}C	98.89	12.00000
^{13}C	1.11	13.00335

source: *CRC Handbook, 59th ed.*

E. Qualitatively: The weight of the average atom should be quite close to 12. Most of the C atoms are ^{12}C. Also, it should be a little bit above 12, because the ^{13}C atoms weigh more than 12 amu.

F. Quantitatively: Calculation of the average weight

^{12}C component: 12.00000 amu × 98.89 ⁄ 100 = 11.86<u>68</u> amu
^{13}C component: 13.00335 amu × 1.11 ⁄ 100 = + 0.144<u>3372</u> amu

average 12.01<u>11372</u> amu

This is close to the 12.011 amu atomic weight value in Periodic Table.

G. Closing thoughts:

a) Why/how does the atomic weight value given in the Periodic Table for ^{12}C have 5 s.f., and the value calculated above have only 4 s.f.? ____

____

b) What is limiting s.f. above, the % abundance measurement or the mass measurement? ________________________________

c) The % abundance is also called the natural abundance. Do you think the natural abundance values on earth are the same as those on other planets, meteors, asteroids, etc.? ____________________

d) Sum masses of particles in a ^{12}C atom:

$$
\begin{array}{lll}
p^{+} & 6 \times 1.0073 = & 6.0438 \\
n & 6 \times 1.0087 = & 6.0522 \\
e^{-} & 6 \times 0.0054858 = & +\ 0.0032914\underline{8} \\
\hline
 & & 12.0992\underline{9148} \text{ amu}
\end{array}
$$

12.0993 is significantly more than 12.0000. What's happening here? The ***mass deficit***!!! Nuclei have enough *binding energy* to...

V. Development of the Periodic Table (Mendeleev) *This discussion is important in helping you understand how science works and why humans have found it useful.*

A. Origin: Mendeleev organized the elements into a table based on chemical & physical properties & weight (p^+ had not yet been found).

1. Chemical properties similar within a column:

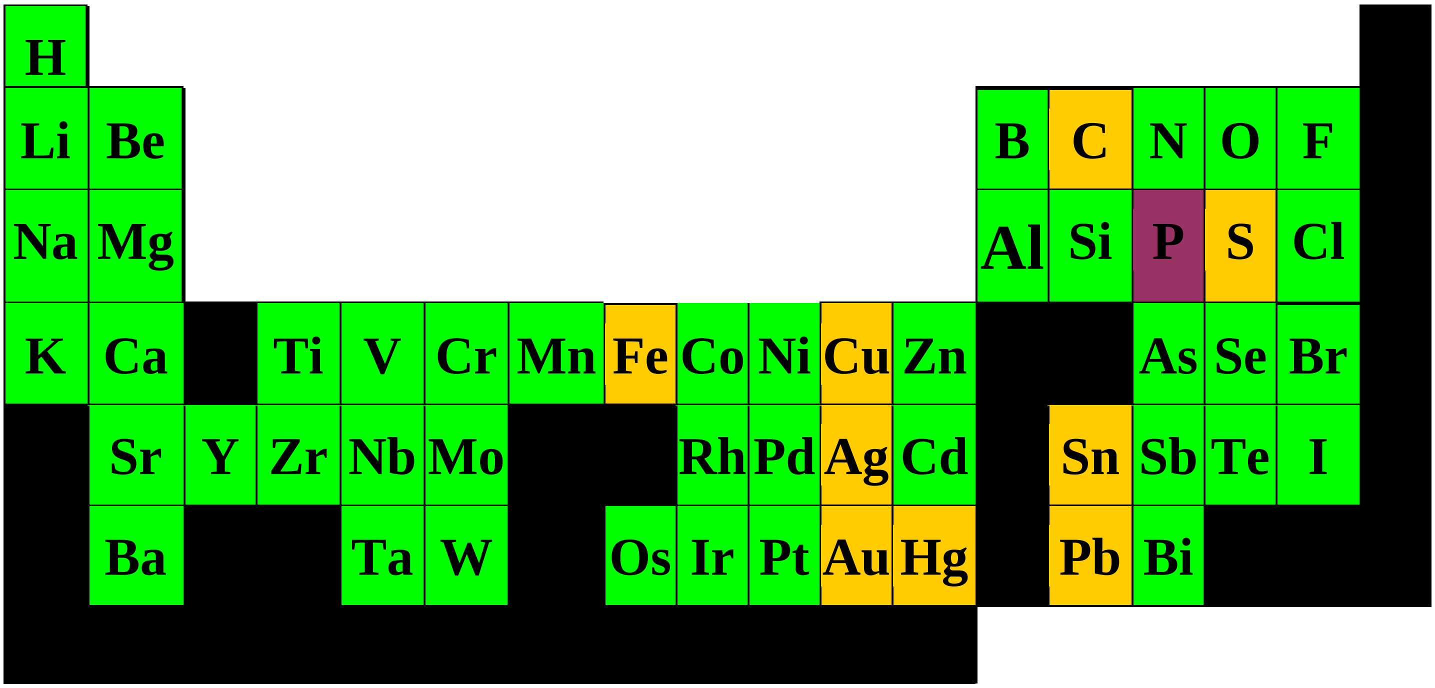
CH_4	**N**H_3	H_2**O**	H**F**
SiH_4	**P**H_3	H_2**S**	H**Cl**
			H**Br**

2. Increasing atomic weight (from left to right). That is, F weighs more than O, O weighs more than N, *etc*.

B. When he did this he saw gaps (see p. 6). *Important*:

1. He thought the gaps were elements existed that had not yet been discovered.
2. For the gap below silicon, he made very specific predictions (interpolation) of the properties of this undiscovered element. ("Eka-silicon")

Periodic Table of the Elements Known in Mendeleev's Time



Note: Some of the lanthanides & actinides were known by 1839, but these groups have been omitted for clarity. Mendeleev was able to use the elements shown above to make some striking predictions based on periodicity.

X Known since ancient times

P Discovered in the Middle Ages

X Discovered 1735-1839

Date source: http://education.jlab.org/qa/discover_ele.html

C. About 15 years after his prediction, "Eka-silicon" (Ge) was discovered & found to have properties very close to those he predicted.

	predicted for eka-silicon	measured for Ge
Atomic wt.	72	72.59
Density (g/cm^3)	5.5	5.32
Density Cl compound (g/cm^3)	1.9	1.84

from *Chemistry 3rd ed.*, Atkins & Jones

*Scientists were impressed by the **predictive power** of Mendeleev's ideas!!!*

D. Why are elements in the column in the Periodic Table similar in their chemical reactivity?

1. Representative elements in the same column have the same valence e^- numbers.

2. Because of this they tend:
   a) to form the same types of ions
   b) to have similar (not identical) chemical reactivities

E. Why aren't elements in the same column [ex.:oxygen (O) & selenium (Se)] identical in chemical reactivity?

1. nuclei are different, which influences outer e^-

2. different amounts of inner e^- (which cause electrostatic shielding) between nuclei & outer e^-

G. Other ways to classify elements:

1. Metals
   a) Most tend to lose e⁻
   b)) Conduct heat & electricity well
   c)) Shiny, form into thin sheets & wires, *etc.*

2. Non-metals
   a) Most tend to gain e⁻
   b) Often don't conduct heat & electricity well

3. Metalloids have intermediate properties.