Chem 103 Lecture 9a
Admin:
Return: Test #2 88±27
(59% ±18)
A≥ 120 ;   B≥ 105 ; C ≥ 70
Highest: 147/150 (98%)

Last time:

1) batteries
2) corrosion

Today: 1) electrolysis
2) Nuclear chem

Electrolysis:
b) Electrolysis cells (nonspontaneous)

Useful in electrolysis:

current and charge transferred:

Charge = q = #moles of electrons x charge of a mole of electron = nF   F=96500Coul)

If X moles of Cu^{2+} --> Cu, then q transf'd=

(X moles of Cu^{2+})(2 mol e/mol Cu^{2+})(96,485 Coul)

Current = flow of charge = coul/s = i.
So, charge = (i)(t) = coul.

Moles electrons transferred = it/F

#mol substance = it/nF (where n=stoichiometric factor)

for example: $Cu^{2+} + Zn \rightarrow Cu(s) + Zn^{2+}$

check the oxidation numbers, we know then that:
$Cu^{2+} + 2e^- \rightarrow Cu$ (here n = 2)
And $Zn \rightarrow Zn^{2+} + 2e^-$ (here n=2)

Example:

$2\ H_2O \rightarrow 2\ H_2 + O_2$ what is n=? (i.e #e^- transferred

eg. Water is hydrolyzed to oxygen and hydrogen gas.
a) How many mLs of H_2 gas will be generated if water is hydrolyzed at 3.0 V for 2.0 hours at 1.80 amperes? (assume STP conditions)
b) Write the half reactions
c) determine the reaction in the anode.
d) which half reaction will generate acidic conditions?

Solution:

Balanced equation:

$2H_2O \rightarrow 2H_2 + O_2$

so n =4, i =1.80 A , t =2.0 x60x60=7200sec
mol H_2 = it/nF=(2.0)(7200)/(4)(96500)
= 0.0373 mol

V = nRT/P = .0373(.0821)(273)/(1)=0.836L
= 836 mL

nuclear chemistry:

0) Nuclear chemistry: bridges chem & physics
-Diff from other areas of chemistry:
chem rxns involve e's (moderate E's)
nuke rxns involve nuclei (extremely high E)

-Involved modern technolgies:
power plants to wrist watches, & smoke detectors.
- controversial uses: nucl bombs, nucl. plants

1) Nuclear reactions: result of unstable nuclei. Spontaneous. Irreversible.
- called "nuclear *decay*"
  - the unstable nuclei are called *radionuclides*
- nuclear rxns release radiation
  - powerful forces involved and energies tremendous. so large they are described by $E=mc^2$.
  - Referred to as "*ionizing radiation*" to differentiate from less energetic

radiation (like light, IR and near UV)

2) Types of radiation, particles in nuclear decay:
Their symbols:
In general: $_{z}^{A}X$ where: z = atomic # =charge and
A=atomic mass #= #protons(p)+#neutrons(n)

nuclear decay lead to release of
3 major kinds of radiation:

particle	symbol	charge	mass(amu)
alpha	$_{2}^{4}\alpha$, α, $_{2}^{4}He$	+2	4
beta	$_{-1}^{0}\beta$, $_{-1}^{0}e$	-1	0
gamma	$_{1}^{0}\beta$, $_{-1}^{0}e$	-1	0

symbols of nuclear particles (*nucleons*):

neutron $_{0}^{1}n$ proton $_{1}^{1}p$ positron $_{+1}^{0}\beta$, $_{1}^{0}e$

atomic mass #

symbol of a nucleus: $_{Z}^{A}X$

where: atomic # (charge),

(3) Nuclear Decay : spontaneous breakdown of unstable nuclei

example:
$_{6}^{12}C$ is "*carbon –12* " = it's the most common isotope of C

(it has 6 protons & 6 neutrons)

But there is also: Carbon-14: (it has 8 neutrons) Carbon-14 is unstable and undergoes decay:

$_{6}^{14}C \rightarrow _{7}^{14}N + _{-1}^{0}e$ ("beta emission")

we can detect presence of C-14 from
β emission.

(4) Balancing nuclear reactions:
note how to balance nuclear equations: A and Z must balance. Write #'s for ease of balancing.

Example of nuclear reactions (fill in blanks):

$_{8}^{15}O \rightarrow$ ______ + $_{-1}^{0}e$ type: _______ emission

$_{84}^{210}Po \rightarrow$ ______ + $_{2}^{4}\alpha$ type: _____ emission

$_{94}^{241}Pu + _{8}^{16}O \rightarrow 5\ _{0}^{1}n$ + ____ type: _______

$_{7}^{14}N + _{-1}^{0}e \rightarrow _{6}^{14}C$ type: ______________

In beta emission Z increases in

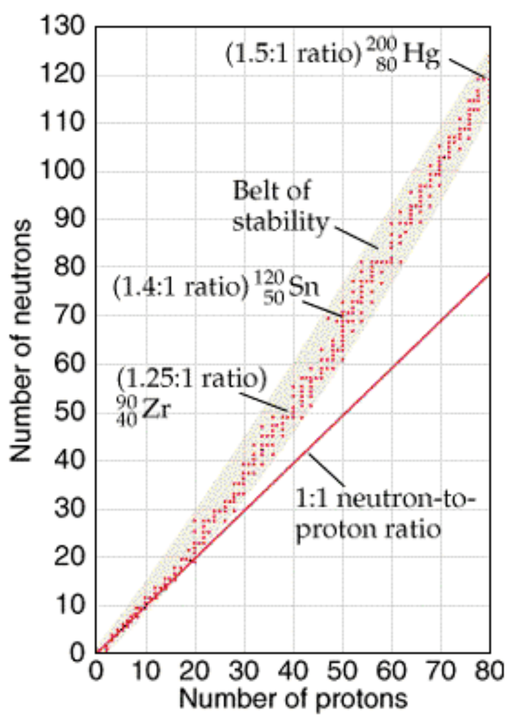
$$^{1}_{0}n \rightarrow {}^{1}_{1}p^{+} + {}^{0}_{-1}e^{-}\ (\beta\text{-emission})$$

In positron emission Z decreases in

$$^{1}_{0}p^{+} \rightarrow {}^{1}_{0}n + {}^{0}_{1}e^{+}\ (\text{positron or } \beta^{+}\text{-emission})$$

(see any mistakes?)

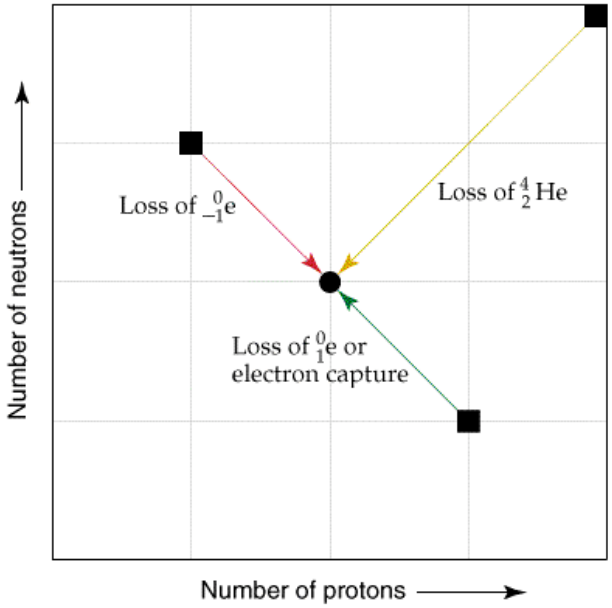
(5) Belt of stability: describes reln of #n vs # p.



It's important to look at the ratio of # n / # p
At low z values, this ratio is 1 but at higher z values, it diverges toward >1.
From He to Ca(z=20) have p:n = 1:1 (n/p=1) and to Bi(83), more than n/p >1.
think of it as n needed to moderate the tremendous repulsion of p's.

(6) Radioactive elements:
Above 83, all elements are radioactive. Even #Z tends to be stable, even#n also tends to be stable.

If above the belt: β emission to increase Z if below the belt: can do positron emission or electrc



Understand the differences:

Say we have C-14: that's above the belt of stability. (beta emission):

$_{6}^{14}C$ - - - > $_{7}^{14}N$ + $_{-1}^{o}e$

say we have:C-10

a) can have electron capture: $_{6}^{10}C$+ $_{-1}^{o}e$ - - -> $_{5}^{10}B$

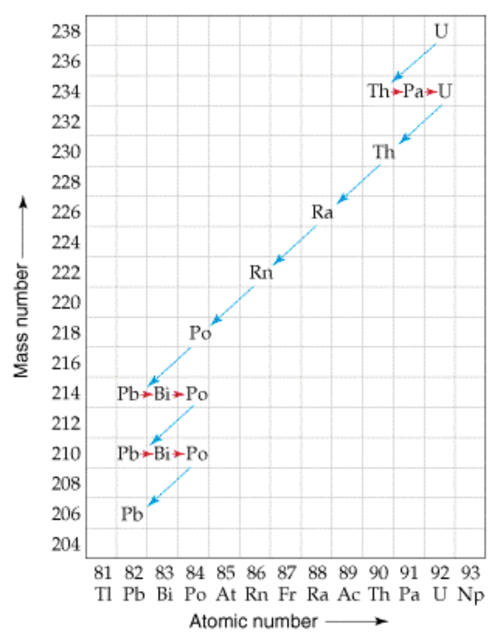
b) can have positron emission: $_{6}^{10}C$ - - -> $_{5}^{10}B$+ $_{1}^{o}e$

Note that elements above 80 tend to undergo alpha emission (both n and p decrease by 2)

(7) Radioactive series: Often, nucl. decay involves a *radioactive series*

For uranium, U-238: U-238->Th-234 -> U=234, e

(see below for the radioactive series for U-238)



(8) **Binding energy** (BE): a measure of the force holding the nucleons together in a nucleus:

consider:

^1_1H $+^1_0n$ → ^2_1H ΔE=-2.15x10^8 kJ/mol
1.007825 1.008665 2.01420 g/mol

mass defect, Δm = loss of mass (due to <u>nonconservation</u> of matter)

The missing mass is converted into energy by Einstein'ss equation: $E = mc^2$
Δm = products - reactants masses =2.001410-(2.00380)=-.00239g/mol
$\Delta E=(\Delta m)c^2$= (2.39x10^6kg/mol) x(3.00x$10^8 m^2/s^2$)=
= -2.15x10^{11}J/mol

(9) **Binding energy (BE/n) per nucleon**:a measure of nuclear stability
Binding energy (BE)= energy required to separate nucleus into its individual nucleons:

In the above case, BE per nucleon:
2.15x10^{11}J/2=1.08x10^{11}J/nucleon

^4_2He: BE/n=6.84x10^{11} J/nucleon (more stable)

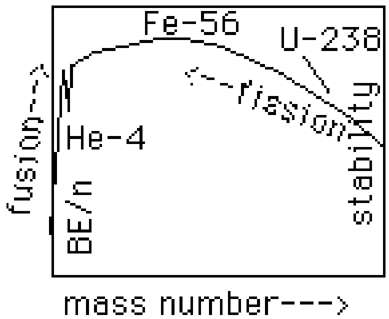
(10) All spontaneous nuclear reactions are **exothermic**.

Note :all exothermic rxns (both nuclear and chemical) convert mass to energy but in chem rxns, Δm's too small to detect and we say: *conservation of mass* holds.

BE per nucleon: 2.15x10^{11}J/2=1.08x10^{11}J/mol n
for ^4_2He: BE/ncln=6.84x10^{11} J/mol ncln (more stable)

plot of BE/nucln: shows that most stable are around Fe-56. (the greater the BE/nucleon, the greater the stability of the nucleus. That means all elements are thermod unstable rel to Fe-56.

Heavier elements tend to break up into smaller nuclei by fission to come closer to Fe-56 while smaller nuclei tend to fuse (fusion) to form larger nuclei to be closer to Fe-56.



11) **Rates of decay:**
Radioactive decay is essentially **1st order**.

1st order rxns have a half life indep of starting amount: It is always the same no matter how long it's been sitting around…

N-->products:

$dN/dt=-kN$ $dN/N=-kdt$

integrating both sides: $\ln(N/N_o)=-kt$; $N=N_oe^{-kt}$.

If $t= t_{1/2}$ $N=.5N_o$:
(by definition) $t_{1/2}$ = *half life*

$\ln(.5)=-kt_{1/2}$: $-0.693= -kt_{1/2}$: $k=(0.693)/ t_{1/2}$

so $N=N_oe^{-0.693t/t_{1/2}}$
If $t_{1/2}$= 3yrs, how much will remain after 12 years? (ie 12/3=4 half lives)

$N=N_o(1/2)^4 =N_o/8$

(N is meas'd indir as Curie (Ci). or in dpms.)
if N_o=12 mCi at t=0 and N=8 mCi at t=120 days, what is t1/2=? ln(8/12)=-k(120)=>-.0405=-120k
k=3.38E-3: t1/2=.693/3.3E-3=205 days.artificial