NUCLEAR REACTIONS

Definitions:

Atomic Number or **Nuclear Charge:** The number of protons in the nucleus. This determines which element is present. It's the whole number of the element on the periodic chart.

Mass Number: The sum of the protons (Atomic Number) plus the neutrons. It is not on the periodic chart. (mn = p + n).

Isotope: The same element (atomic number) with a different mass (Mass Number) caused by a different number of neutrons.

Atomic Weight: The average of the Mass Numbers of the isotopes. It is the decimal number of the element on the periodic chart.

i.e.. **Uranium** has an atomic number of 92 (92 protons). Its atomic weight is 238.0289 (grams/mol).

Two of its isotopes are $_{92}U^{235}$ and $_{92}U^{238}$ (Note that the mass number is a superscript and that the atomic number (nuclear charge) is a subscript).

Some nuclear particles:

Alpha particle, α, is a helium^4 nucleus, $_2He^4$

Beta particle, β, is an electron, $_{-1}e^0$

Proton, p , is a particle whose mass=1 and whose charge is +1, $_1H^1$

Neutron, n , is a particle with no charge and whose mass equals that of a proton, $_0n^1$

Positron, $_{+1}e^0$ the positive electron, an anti-particle, $_{+1}e^0$

Gamma ray, χ , is an electromagnetic wave, $_0\chi^0$

Neutrino, ν , a "ghost particle" with no charge nor mass, $_0\nu^0$ (It's involved in beta decay radioactivity reactions).

Balancing Nuclear Reactions:

The sum of the numbers on the right must equal the sum of the numbers on the left (top and bottom). Use the above particles or the periodic chart to find the unknown particle. (Remember that the atomic number tells the element).

i.e. $_{2}He^{4} + {}_{4}Be^{9} \text{ ---> } {}_{6}C^{12} + {}_{0}n^{1}$

Copy into notes and find the missing particle: (Answers below).

1. $_{2}He^{4} + {}_{8}O^{16} \text{ ---> } {}_{7}N^{14} + ?$
2. $_{2}He^{4} + {}_{13}Al^{27} \text{ ---> } {}_{14}Si^{30} + ?$
3. $_{1}H^{2} + {}_{5}B^{10} \text{ ---> } {}_{6}C^{11} + ?$
4. $_{84}Po^{210} \text{ ---> } ? + {}_{2}He^{4}$
5. $? \text{ ---> } {}_{83}Bi^{212} + {}_{-1}e^{0}$

Ans: 1= $_{3}Li^{6}$ 2= $_{1}H^{1}$ 3= $_{0}n^{1}$ 4= $_{82}Pb^{206}$ 5= $_{82}Pb^{212}$

TRANSMUTATION—

Making new isotopes beyond Uranium...

i.e. $_{0}n^{1} + {}_{92}U^{238} \text{ ---> } {}_{93}Np^{239} + {}_{-1}e^{0}$ (Ooooh, a new isotope!)

but then... (Oh, oh, watch out!)

NUCLEAR FISSION & THE CHAIN REACTION—

Fission means “breaking up”.

$_{92}U^{235} + {}_{0}n^{1} \text{ ---> } {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\ {}_{0}n^{1}$ + BIG ENERGY!

The three new neutrons are available for continuing a chain reaction!!

NUCLEAR BOMB-- The Critical Mass (about 50 kilograms) is the minimum amount of ${}_{92}U^{235}$ needed to sustain a chain reaction. Remember that the neutrons must hit the nucleus of the atom (the flea in Yankee Stadium) to cause another fission. So to make the bomb one *merely* needs to accumulate the critical mass and it's BOOOOOOM!
However the big problem is to separate the ${}_{92}U^{235}$ from natural uranium. Ooops, ${}_{92}U^{235}$ is only 0.7% of natural uranium, and being an isotope, it's chemically identical to the other isotopes of U.
Three methods for rich folks, The Diffusion Process, the Centrifuge Process or The Nuclear Reactor Process.

THE NUCLEAR REACTOR-- ☛ Copy the diagram from the text.

A reactor needs these basic parts:

Fuel-- a fissionable isotope like ${}_{92}U^{235}$

Moderator-- a substance like graphite to slow the neutrons to efficient reaction speeds.

Control Rods-- like cadmium to absorb neutrons to control the reaction rate.

Coolant-- like water to remove the heat of reaction to make steam for power. Nuclear power is steam engines in action.

Shielding-- like concrete to keep the rays of reaction inside the reactor and out of the environment.

NUCLEAR FUSION & MASS DEFECT—

Fusion means putting together.

The energy of the sun and of the H-Bomb!

$${}_{1}H^{2} + {}_{1}H^{3} \text{ ---> } {}_{2}He^{4} + {}_{0}n^{1}$$

Reactants:	2 H	2.01471	g/mol
	3 H	3.01707	
		5.03178	
Products:	4 He	4.00390	
	1 n	1.00893	
		5.01283	

Reactants total:	5.03178
Products total:	5.01283
	________
Mass Defect	0.01895 Oooops.. A Mass Loss!!!!

Where did it go??? Ah, Yaz, **$E = mc^2$**

where E is the energy in Joules, m is the <u>mass loss</u> in Kg, and c is the speed of light (in m/s)^2.

WOW!

COMPARISON OF ENERGIES:

PHYSICAL CHANGE--

Rearrangement of molecules, no new substance formed.
Involves electrons, van der waals forces, and hydrogen bonding.
Crystals
Melting
Evaporation

CHEMICAL CHANGE--

Rearrangement of atoms, new chemical substances formed. Involves electron transfer and sharing.
Chemical reactions of various types.

NUCLEAR CHANGE--

Rearrangement of the atomic nuclei, new elements, isotopes and sub-atomic particles formed.
Energy is from the Mass Defect in **$E = mc^2$**
Transmutation
Fission
Fusion
Particle interactions.

RATIOS OF ENERGIES:

Physical :	Chemical :	Nuclear
1 :	100 :	1,000,000

GASP!

THE FOUR FORCES:

FORCE	RANGE (m)	STRENGTH	ROLE
Gravitation	Infinite	1	Holds planets and stars together.
Weak Nuclear	10^{-15}	10^{28}	Radioactive Decay
Strong Nuclear	10^{-15}	10^{41}	Binds Protons & Neutrons
Electromagnetic	Infinite	10^{39}	Binds Atoms to form molecules, propagates light, electromagnetic waves.

BUILDING BLOCKS OF MATTER:

PARTICLE	DESCRIPTION	EXAMPLE
Lepton	"Dimensionless", $<10^{-35}$m.	Electron
Muon	Does not participate in the strong force.	Neutrino
Quarks	Small, $<10^{-18}$m. Participate in strong force.	Top, Bottom
Mesons	Larger than electrons, smaller that protons the forces in the nucleus.	Tau, Pi

Here Endeth the Nuclear Notes