PHY4154 Nuclear and Particle Physics: Assignment 3

(1) Use the Bethe-von Weizsäcker semi-empirical binding energy formula, and calculate the binding energy per nucleon for Iron and Uranium.

(2) Which is the most stable nuclide with $A = 16$, and which for $A = 208$? Calculate using the semi-empirical formula and look up the name. (Make a graph if needed).

(3) Calculate the amount of energy released in the fission process: ${}^{235}_{92}\text{U} \to {}^{87}_{35}\text{Br} + {}^{145}_{57}\text{La} + 3n$

(4) Iron isotopes ${}^{49}\text{Fe}$ and ${}^{51}\text{Fe}$ are both known short-lived positron emitters, but ${}^{50}\text{Fe}$ has not yet been discovered. Compute the expected value for the nuclear mass of ${}^{50}\text{Fe}$

(5) Given that the ordering of the nuclear levels is

$$1S_{\frac{1}{2}};\ 1P_{\frac{3}{2}};\ 1P_{\frac{1}{2}};\ 1D_{\frac{5}{2}};\ 1D_{\frac{3}{2}};\ 2S_{\frac{1}{2}};\ 1F_{\frac{7}{2}};\ 2P_{\frac{3}{2}};\ 1F_{\frac{5}{2}}$$

explain the ground state spin and parity assignments for ${}^{3}_{2}\text{He}(\frac{1}{2}\ +)$, ${}^{27}_{13}\text{Al}(\frac{5}{2}\ +)$, ${}^{41}_{21}\text{Sc}(\frac{7}{2}\ -)$. (Hint: recall how parity depends on ℓ).

(6) Estimate the separation of the $1p_{\frac{1}{2}}$ and $1d_{\frac{5}{2}}$ energy levels for nuclei with $A \sim 16$ given the ordering of nuclear levels in previous problem, and that total binding energy for oxygen isotopes is ${}^{15}\text{O} = 111.96\ \text{MeV}$, ${}^{16}\text{O} = 127.62\ \text{MeV}$, ${}^{17}\text{O} = 131.76\ \text{MeV}$.

(7) Read the wikipedia article on NMR (NMR:Wikipedia). You can skip the Applications part.

(8) Which one is more stable, ${}^{124}_{50}\text{Sn}$, or ${}^{200}_{80}\text{Hg}$? I am interested in arguments for which one is more stable (rather than explicit calculations).

(9) Find the binding energy for the last neutron in ${}^{4}\text{He}$, given following AMU: $m({}^{4}\text{He}) = 4.00260u$, $m({}^{3}\text{He}) = 3.016030u$.

(10) How far will be the two impact points of single ionized ${}^{23}\text{Na}$ and ${}^{24}\text{Mg}$ ions on the screen after passing one semicircle? The mass difference between the two ions is $\Delta m = 1.20333u$. The fields of the velocity selector are $E = 1000\ N/C$ and $B_1 = 0.1$ T. The diverting magnetic field is $B_2 = 0.01$ T. The structure of the mass spectrometer is as follows:

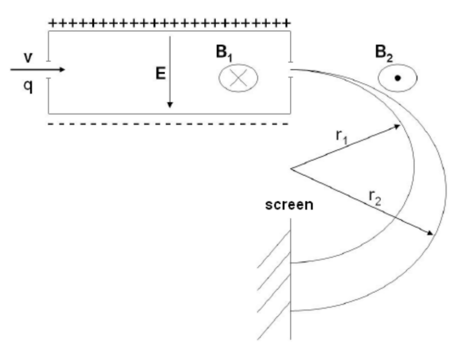
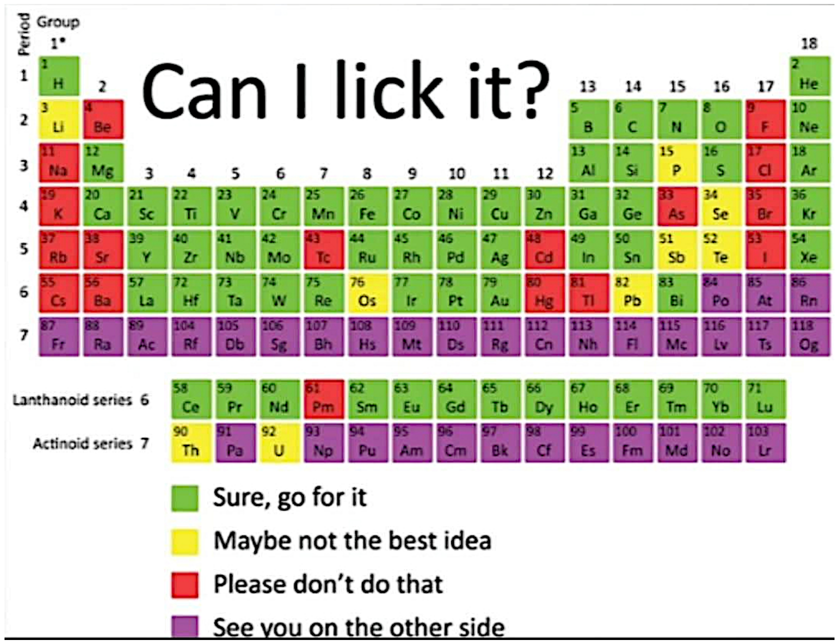


Figure 1: Diagram of a Dempster-type mass spectrometer

(11) Consider the following meme that I found.



I was wondering: for the elements that it's not okay to lick (the yellow, red, and purple ones) - the reason to not lick them could be due to chemical problems, which for us can be thought of as atomic physics problems, i.e. where the reactions of atoms (between the element and your tongue) are driven by atomic physics (i.e. electromagnetic mostly). Are there any elements where the "don't lick" is because of nuclear physics? [Either way, eventually its going to be a biological problem]

To normalize, let us say that the area of contact between your tongue and the element surface is about 1 cm^2. Also you have 10 g of the element in front of you. Look up units of radioactivity (i.e. how radioactive is something). I like to start here [Radiation Chart]. You are encouraged to talk to your colleagues majoring in chemistry and biology.

Once you complete all problems in this assignment, and you have some time, have fun exploring What if? [Randall Munroe is awesome!].