Chem 312  
Homework 1: Lecture 1: Chart of the nuclides, Introduction, Part of Lecture 2 (Nuclear Properties)  
Assigned Wednesday 6 September, Due Monday 11 September, Homework Quiz 1 Wednesday 13 September.

1. What are the outcomes of the class?  
   a) Understand the fundamentals of radiation science  
   b) Understand chemical properties in radiation and radiochemistry  
   c) Comprehend and evaluate the production of isotopes and nuclear reactions  
   d) Comprehend radioactive decay  
   e) Utilization of nuclear properties in chemistry and research  
   f) Investigation of modern topics in radiochemistry  

2. Use the Chart of the Nuclides to answer the following questions  
   a) How many stable isotopes of Al? 1  
   b) How many stable isotopes of Ne? 3  
   c) What is isotopic abundance of $^{62}$Ni  
   d) How many Pb isotopes are the endpoint for natural decay? 3  
   e) What is the mass and isotopic abundance of $^{51}$V? 50.943964, abundance 99.750 %  
   f) What is the mass and isotopic abundance of $^{190}$Pt? 189.95993, abundance 0.014 %  
   g) What is the fission yield for the 135 isobar for the thermal fission of $^{235}$U? 6.54%  
   h) For the 135 isobar, what is the stable isotope and longest lived isotope from fission? Longest lived isotope $^{135}$Cs, stable isotope $^{135}$Ba  
   i) What is the spin and parity of $^{51}$Cr? 7/2-  
   j) Spin and parity of $^{12}$C? 0+  
   k) Spin and parity of $^{143}$Xe? 5/2-  
   l) Decay modes and decay energies of $^{212}$Bi? $\beta$ (2.251 MeV), $\gamma$ (727.3 keV), $\alpha$ (6.051 MeV), $\gamma$ (39.9 keV)  
   m) What is the half-life of $^{131}$I? 3.75E10 years  
   n) What is the half-life of $^{117}$La and how does it decay? Half life of 23 ms and proton decay  
   o) What is the half-life of $^{132}$Xe? The isotope is stable  
   p) Provide 7 facts on the isotope $^{95}$Zr obtained from the chart of the nuclides  
      1. Half life 64.02 days  
      2. $\beta^-$ decay  
      3. $\beta^-$ decay energy 0.368 MeV  
      4. Gamma decay observed  
      5. Two strong gamma energies, 756.7 keV and 724.2 keV  
      6. Total $\beta^-$ disintegration energy of 1.125 MeV  
      7. Produced by the $\beta^-$ decay of $^{95}$Y  
      8. Daughter is $^{95}$Nb  
      9. A fission product (6.3 % yield from fission of $^{235}$U, 6.3 % yield from fission of $^{233}$U, and 4.82 % yield from fission of $^{239}$Pu)
10. Spin and parity is 5/2+
11. can also calculate decay constant from ln2/half life

q) What is the melting point of U metal?  1135 °C (see periodic table)
r) Which isotope of Ba has an alpha decay?  ¹³⁴Ba
s) What is a neutron to proton ratio for a stable isotope of Z=20, Z=40, Z=60, Z=80 
   Z=20 (⁴⁰Ca), 20/20=1; Z=40 (⁵⁰Zr), 50/40=1.25; Z=60 (¹⁴²Nd), 82/60=1.37; Z=80 
   (²⁰⁰Hg), 120/80=1.5
t) What are the isotopes in the ²³⁵U decay series?

3. Write the reaction for the decays listed on slide 1-9 using other isotopes as examples?
The decays are
Alpha decay

\[ _{88}^{226} \text{Ra} \rightarrow _{86}^{222} \text{Rn} + ^{4}\alpha + \text{Energy} \]

Beta Decay

\[ _{53}^{131} \text{I} \rightarrow _{54}^{131} \text{Xe} + ^{-}\beta + \bar{\nu} + \text{Energy} \]

Positron Decay

\[ _{11}^{22} \text{Na} \rightarrow _{10}^{22} \text{Ne} + ^{+}\beta + \nu + \text{Energy} \]
Electron Capture

$^{26}_{13}\text{Al} + \beta^- \rightarrow ^{26}_{12}\text{Mg} + \nu + \text{Energy}$

Spontaneous Fission

$^{252}_{98}\text{Cf} \rightarrow ^{140}_{54}\text{Xe} + ^{108}_{44}\text{Ru} + ^4_0\text{n} + \text{Energy}$

4. Define isomer, isobar, isotone, isotope, and isomer
   Isotopes: Same Z different N
   Isobar: Same A (sum of Z and N)
   Isotone: Same N, different Z
   Isomer: Nuclide in excited state

5. Identify the isomer, isobars, isotones, and isotopes from the list below
   $^{97}\text{Ru}, ^{99m}\text{Tc}, ^{97}\text{Tc}, ^{95}\text{Nb}, ^{94}\text{Zr}, ^{114}\text{Tc}, ^{100}\text{Pd}, ^{100}\text{Tc}, ^{97}\text{Mo},$
   Isomer: $^{99m}\text{Tc}$
   Isotopes: $^{99m}\text{Tc}, ^{97}\text{Tc}, ^{100}\text{Tc}, ^{114}\text{Tc}$
   Isobar: $^{97}\text{Tc}, ^{97}\text{Mo}, ^{97}\text{Ru}$
   Isotone: $^{94}\text{Zr}, ^{95}\text{Nb}, ^{97}\text{Tc}, ^{100}\text{Pd}$

6. Describe the difference between x-rays and gamma decay
   Gamma decay is photon emission from the nucleus while x-rays are photons emitted from electron transitions or deceleration.

7. How are x-rays used to identify elements?
   Since x-ray can be generated due to electrons filling lower orbitals of higher energy, the photon energy is based on the energy level differences between the lower orbitals. For differences with core electron orbitals the energy describes the element with the relationship $\sqrt{\nu} = A(Z - Z_o)$

8. For beta decay why is the energy equal to the atomic mass difference between the parent and daughter isotopes?
   The atomic mass includes the electron mass. By definition the energy is the difference between the mass of the reactants (parent) minus the mass of the products (daughter and particles). For beta decay the reaction is $^A_Z\text{Z} \rightarrow ^A_{Z+1}\text{Z}+^\beta^- + \text{antineutrino} + \text{energy}$
   The beta particle and electron mass are equivalent, so the mass on the product size is $^A(Z+1)$ (neglect the antineutrino). Therefore the energy is equal difference of the atomic masses.