Nuclear Chemistry
Cumulative Examination

Wednesday, 27 February 2o13

Write your answers to the following questions *in the order listed*. Make sure that the answers are well-organized and self-explanatory. The total number of points on this exam is 50.

1. (2 point each) Give concise and accurate answers to the following questions:
   (a) What is the key feature of two nuclides that are said to have the same "isospin projection?"
   (b) What is the key feature of two nuclides that are said to be"isomers?"
   (c) What is the relationship between the partial half-life and (full) half-life of a radionuclide?
   (d) Write a COMPLETELY balanced equation for the β^+ decay of the nuclide ^{22}Na (Z=11, a nuisance activity with a half life of 2.60 years that is often produced when accelerated beams strike aluminum).
   (e) The *lepton number* is conserved in nuclear decay. What is a lepton in this context?

2. (5 points each) The ^{132}Sn nuclide is something of a special nuclide because it is strongly produced in the fission of uranium, it is a so-called doubly-magic nucleus, and it decays with a half-life of 39.7s. The ground state intrinsic spin and parity of ^{132}Sn is 0^+ and it decays with a Q-value of 3119 keV to the radioactive nucleus ^{132}Sb that has a ground-state intrinsic spin/parity of 4^+. This beta decay takes place via an allowed Gammow-Teller transition between the initial and final states.
   (a) What are the intrinsic spins and their relative alignment for the particles that are emitted from the nucleus in an allowed Gammow-Teller β^- decay?
   (b) Would you expect this beta decay to go directly from the ground state of the parent to the ground state of the daughter nucleus? Explain why or why not.
   (c) Suppose that some of the β^- decay goes to an excited state. What is the most likely decay mode of this state and how will the lifetime of this state compare to the β^- decay lifetime of the parent?
   (d) The beta decay of the daughter nucleus ^{132}Sb has a significantly larger Q-value of 5508 keV even though it is "closer to stability." This is an example of a general phenomena in the beta decay of nuclei with even mass numbers. Explain the basis for why the decay of this daughter has a larger Q-value than it's parent decay.

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3. (10 points each) The A=132 mass chain accounts for 4.3% of the yield of fission fragments from the thermal-neutron fission of ^{235}Uand 4.95% from thermal-neutron fission of ^{233}U.

   (a) (i) What is meant by the term "thermal neutron?" (ii) Give a detailed explanation of why these nuclei can undergo fission with a thermal neutron whereas the much more abundant uranium isotope, ^{238}U, does not.

   (b) Use conservation of (1) momentum, (2) mass and (3) energy to make an estimate of the kinetic energy of an A=132 fission fragment from the fission of ^{236}U. For this estimate you can ignore neutron emission, assume that the fissioning nucleus is at rest, and the energy released by the fission process is 200 MeV.