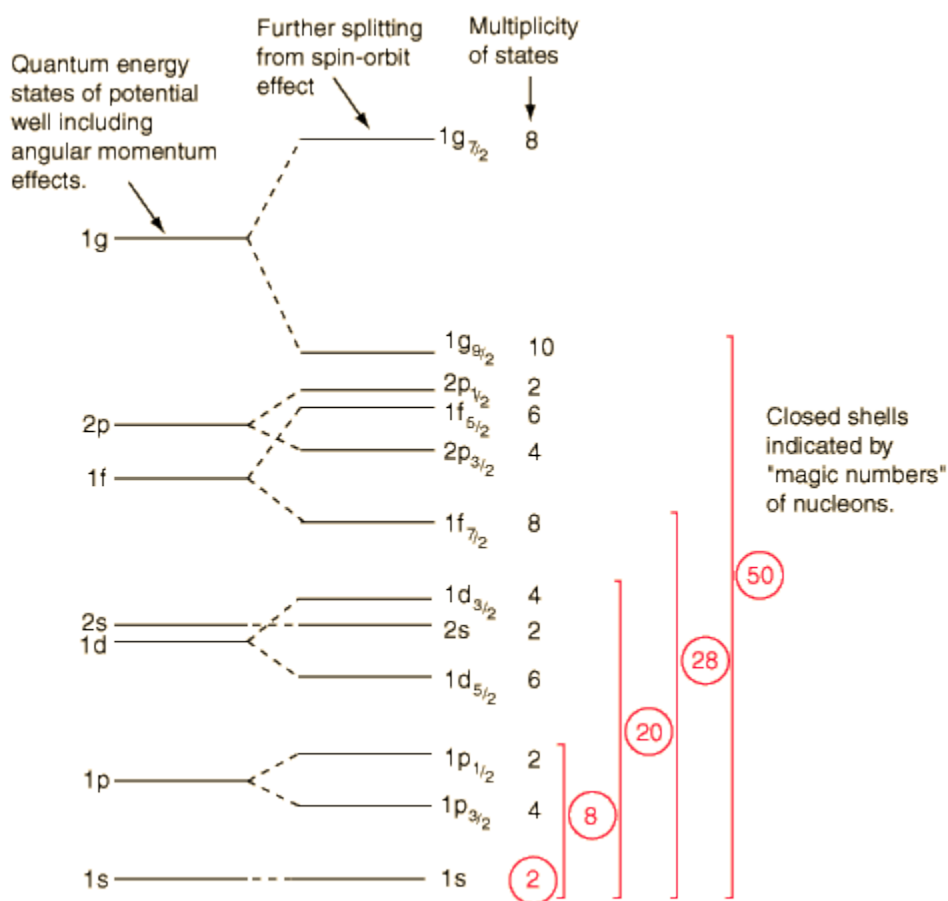


Nuclear Chemistry Cumulative Examination

Wednesday, 17 November 2010

This examination is concerned with the general structure of nuclei and simple nuclear shell model as discussed in the textbook Modern Nuclear Chemistry by Loveland, Morrissey & Seaborg.

The exam has a total of 50 points.



1. (20 points) The deuteron, ${}^2\text{H}$ or simply " d ", is the simplest nucleus but its properties provide a large amount of information about the nuclear force. It is also the lightest self-mirror nucleus. Answer the following ten questions related to the deuteron and isospin.
 - (a) There are only two plausible values for the total angular momentum, j , of the ground state of the deuterium nucleus, what are they? Which value of j corresponds to the ground state configuration for the deuterium nucleus?

- (b) The nucleus $^{30}\text{P}_{15}$ is an odd-odd self-mirror nucleus has a valence proton in the $\pi 2s_{1/2}$ and a valence neutron in the $\nu 2s_{1/2}$ orbitals. What do you expect the spin and parity of the ground state of ^{30}P will be and why?
 - (c) What is the configuration of nucleons (proton and neutron orbital occupancy) in tritium? What is the ground state spin of a tritium nucleus?
 - (d) Isospin is a pseudo-quantum number used to describe nuclear states in light nuclei. What are the values of the isospin, T , and its projection, T_z , for the ground state of deuterium?
 - (e) Identify the three possible isobars for $A=2$.
 - (f) Give the value of isospin, T , and its projection, T_z , for the ground state of each of the three $A=2$ isobars.
 - (g) How does the relative stability (for example, mass or binding energy) change in a set of isobars as one goes from neutron deficient to neutron rich?
 - (h) Based on your answers to the previous questions, the deuteron should have an excited state. Do you expect this state to be bound or unbound?
 - (i) What are the values of the isospin, T , and its projection, T_z , for the excited state of the deuteron?
 - (j) Give a general description of how an unbound nuclear state would decay.
2. (15 points) ^{10}B is used as a neutron absorbing material in a variety of applications due to its high cross section for the (n,α) reaction. This reaction actually produces the product ^7Li in the nuclear ground state and in its first excited state. (A) What does the simple nuclear shell model predict for the nucleon configurations and for the spin and parity of the ground state of ^7Li ? (B) What does this model predict for the spin and parity of the first excited state of ^7Li ? (C) How would the predictions of the simple shell model for states in ^7Be compare to your answers for states in ^7Li ?
3. (15 points) The vast majority of the material in our solar system (and the universe) is H and He is thought to have been made in the big bang and to be unchanged since that time. An extremely simple picture of the big bang is a high energy explosion in which neutrons and protons have sufficient kinetic energy to undergo all sorts of (sequential) nuclear reactions before the whole system blows apart and the reactions stop. (A) Based on the nuclear shell model, explain why heavier elements ($Z>2$) could not be produced in the big bang. (B) What is the source of energy for our sun? (C) In contrast to the solar system, the most abundant isotope on earth is Oxygen. What is the second fundamental hindrance to production of oxygen in the sun [in addition to the answer to part (A)]?