Chemistry 485

Spring, 2o1o — Practice Exam #1
Distributed: Wed., 24 Feb. 2o1o — Due: Mon., 1 Mar. 2o1o
(100 points total)

1. Short Answers (10 points each). The questions in this practice exam may require information on masses or mass defects for various nuclides.
   (a) What is the activity of a 1.0 microgram sample of pure ^{14}C?
   (b) Use the Z_A function to determine the expected nuclear decay for ^{66}As.
   (c) What is the activity in curies of a sample of ^{11}C ($T_{1/2}$=20.4 min) that is created during a 30 minute bombardment at a production rate of 2x10^6/s?
   (d) Recall that two of the terms in the semi-empirical mass formula contain the atomic number. Write down these two terms and concisely describe why this term is needed in the mass formula.
   (e) The isotope ^{81}Kr ($T_{1/2}$=229 ky) is produced in the atmosphere in a way similar to ^{14}C and is also used to determine the age of water supplies that are deep underground. The measured ^{81}Kr/Kr isotope ratio in one sample was found to be 1.54x10^{-13} while the the equilibrium atmospheric ^{81}Kr/Kr ratio is 5.20x10^{-13}. Make an estimate of how long this sample has been out of equilibrium with the atmosphere.
   (f) Use the single particle shell model diagram (attached below) to predict the ground state nuclear spin and parity of ^{63}Cu. Be sure to indicate the configurations of the particles needed to make this prediction.
   (g) What are mirror nuclei, give a example of mirror nuclei. What feature of the nuclear force is exhibited by mirror nuclei?
   (h) The nuclear spin and parity of the ground state of the ^{7}Li is 3/2- while the spin and parity of the lowest lying excited state is 1/2- at an energy of 0.478 MeV. (1) What is the expected multipolarity and character of the photon that would lead from this excited state to the ground state? (2) Use the single-particle estimates to calculate the decay constant for this excited state.

2. (20 points) The ^{64}Cu isotope is one of the unusual nuclides that can undergo beta decay in two directions. (1) Write balanced nuclear equations for both decay modes. (2) Calculate the Q-value for the decay to the nuclide with a lower atomic number. (3) State why or why-not the ^{64}Cu isotope can decay by positron emission.

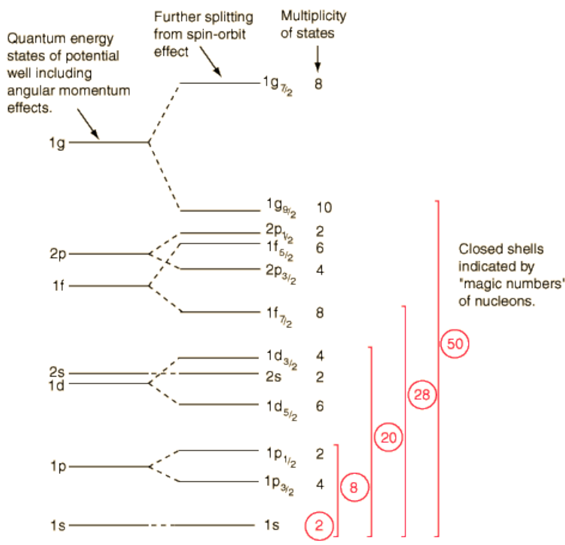

Table 1: Table of single particle decay rates for nuclear transitions.

Angular Momentum	Electric $\Delta\pi$	Electric $\lambda_{SP}(\mathrm{s}^{-1})$	Magnetic $\Delta\pi$	Magnetic $\lambda_{SP}(\mathrm{s}^{-1})$
1	yes	$1.03\text{x}10^{14} A^{2/3} E_\gamma^3$	no	$3.15\text{x}10^{13} E_\gamma^3$
2	no	$7.28\text{x}10^{7} A^{4/3} E_\gamma^5$	yes	$2.24\text{x}10^{7} A^{2/3} E_\gamma^5$
3	yes	$3.39\text{x}10^{1} A^{2} E\gamma^7$	no	$1.04\text{x}10^{1} A^{4/3} E_\gamma^7$
4	no	$1.07\text{x}10^{-5} A^{8/3} E_\gamma^9$	yes	$3.27\text{x}10^{-6} A^{2} E_\gamma^9$

Potentially Useful Constants 24 Feb 10

$h = 6.626 \text{ x } 10^{-34}$ J sec

$c = 2.99792 \text{ x } 10^{8}$ m sec^{-1}

$N_A = 6.0221 \text{ x } 10^{23}$ mole^{-1}

hydrogen mass = $1.67263 \text{ x } 10^{-27}$ kg = 938.7906 MeV

1 MeV/c^{2}u = 931.50

neutron mass = $1.67493 \text{ x } 10^{-27}$ kg = 939.5731 MeV

1. u = $1.6605 \text{ x } 10^{-27}$ kg

electron mass = $9.1094 \text{ x } 10^{-31}$ kg = 0.511 MeV

$e^2/4\pi\epsilon_0$= 1.439 MeV-fm

electron charge = $1.60218 \text{ x } 10^{-19}$ Coul

$\epsilon_0 = 8.8542 \text{ x } 10^{-12}$Coulomb^2 J^{-1} m^{-1}

1 eV = $1.602 \text{x} 10^{-19}$J

1 Ci = $3.7 \text{x} 10^{10}$ Bq, 1 Bq = 1/s

$k_B = 1.380 \text{x} 10^{-23}$J/K

1 yr = 365.25 d = 8766 hr = 525,960 m = $3.156 \text{x} 10^{7}$ s

$\hbar$ c = 197.49 MeV-fm

Potentially Useful Equations

$r = 1.2 \text{ fm } A^{1/3}$

$V_{\text{sphere}} = 4\pi\ r^3/3$

$A_{\text{sphere}} = 4\pi\ r^2$

$A = \lambda N$

$\lambda = 1/\tau = ln2/T_{1/2}$

$\lambda = 0.693/T_{1/2}$

$F(x) = -\frac{d}{dx}V(x)$

$\rho(R) = \rho_0/(1 + e^{(r-R)/a})$

$F_{\text{coulomb}} = -q_1 q_2 e^2/4\pi\epsilon_0 r^2$

$V_{\text{coulomb}} = q_1 q_2 e^2/4\pi\epsilon_0 r$

$V_{\text{coulomb}} = Z_1 Z_2 1.439 \text{MeVfm}/r$

$E = mc^2$

$E^2_{\text{total}} = (m_0 c^2)^2 + (pc)^2$

$E_{\text{total}} = \gamma m_0 c^2$

$\lambda_{\text{deB}} = h/p = h/mv$

$p = m\ v$

$T_{\text{nonRel}} = \frac{1}{2}\ m\ v^2 = p^2/2m$

$E_{\text{photon}} = h\ \nu$

$\lambda\ \nu = c$

$E_{\text{photon}} = p\ c$

$BE(Z, A) = [Z * M(^1H) + N * M(^1n) - M(Z, A)]c^2$

$\Delta(Z, A) = M(Z, A) - A$

$BE(Z, A) = a_V A - a_S A^{2/3} - a_C \frac{Z^2}{A^{1/3}} - a_A \frac{(A-2Z)^2}{A} \pm \delta$

$Z_A \approx \frac{A}{2} \frac{81}{80+0.6A^{2/3}}$

$\frac{dN_1}{dt} = -\lambda_1 N_1$

$N_1(t) = N_1^0 e^{-\lambda_1 t}$

$A_1(t) = A_1^0 e^{-\lambda_1 t}$

$\frac{dN_2}{dt} = \lambda_1 N_1 - \lambda_2 N_2$

$N_2(t) = \frac{\lambda_1}{\lambda_2-\lambda_1} N_1^0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right) + N_2^0 e^{-\lambda_2 t}$

$A_2 = R\left(1 - e^{-\lambda_2 t}\right)$

$R = \rho_A \sigma \phi$

$\rho_A = \rho_n x$