Chemistry 485

Spring, 2o1o — Exam #1

Distributed: Wed., 3 Mar. 2o1o

The questions in this exam may require information that can be found in the attached figure, the table, or the equation sheet. Scored on 100 point basis plus extra credit.

1. (20 points) ^{40}K is a natural radioactivity that is one of the important sources of background radiation for people. Potassium has two stable isotopes, ^{39}K at 93.2581% and ^{41}K at 6.7302%, while the half-life of ^{40}K is 1.29x10^{9} y with an abundance of 0.0117%. Potassium is also a significant component of clay-based Kitty litter and a typical shipment will trigger the radiation detectors at US border crossing points. What is the activity in Bq of a 1.00 g sample of natural KCl (MM=74.551 g/mol) due to the presence of ^{40}K?

2. (20 points) What is the activity in Bq of a sample of ^{18}F ($T_{1/2}$=109.8 min) that would be created during a 180 minute bombardment if the production cross section is 0.3 barns and the target has an areal density of 3.0x10^{20}/cm^{2}? The beam intensity during the irradiation is 6.0x10^{12}/s.

Short Answers (10 points each). Skip one question or answer all 7 for extra credit.

3. The ^{15}O is an important nucleus that is used in medical diagnostic procedures with PET systems. Write the complete balanced equation for the expected decay of ^{15}O.

4. Concisely describe the reason why positron emission requires more energy than electron capture decay.

5. ^{233}U is an extinct isotope of uranium ($T_{1/2}$=1.59x10^{5} y) that decays by alpha emission. (a) Write the balanced reaction for this decay. (b) Calculate the coulomb barrier for the REVERSE reaction of this decay.

6. Use the single particle shell model diagram (attached below) to predict the ground state nuclear spin and parity of the stable isotope ^{39}K. Be sure to indicate the configurations of the particles needed to make this prediction.

7. The cross sections for ALL neutron induced reactions increase at very low energies with the same slope on a log-log graph. What is the underlying cause for this uniform increase in the cross sections for neutron induced reactions at very low energies.

8. The medical isotope ^{18}F is produced in a (p,n) reaction. Write a balanced reaction for the production of ^{18}F based on this information.

9. What is the mass of a 60 kCi source of pure ^{18}F ($T_{1/2}$=109.8 min)?

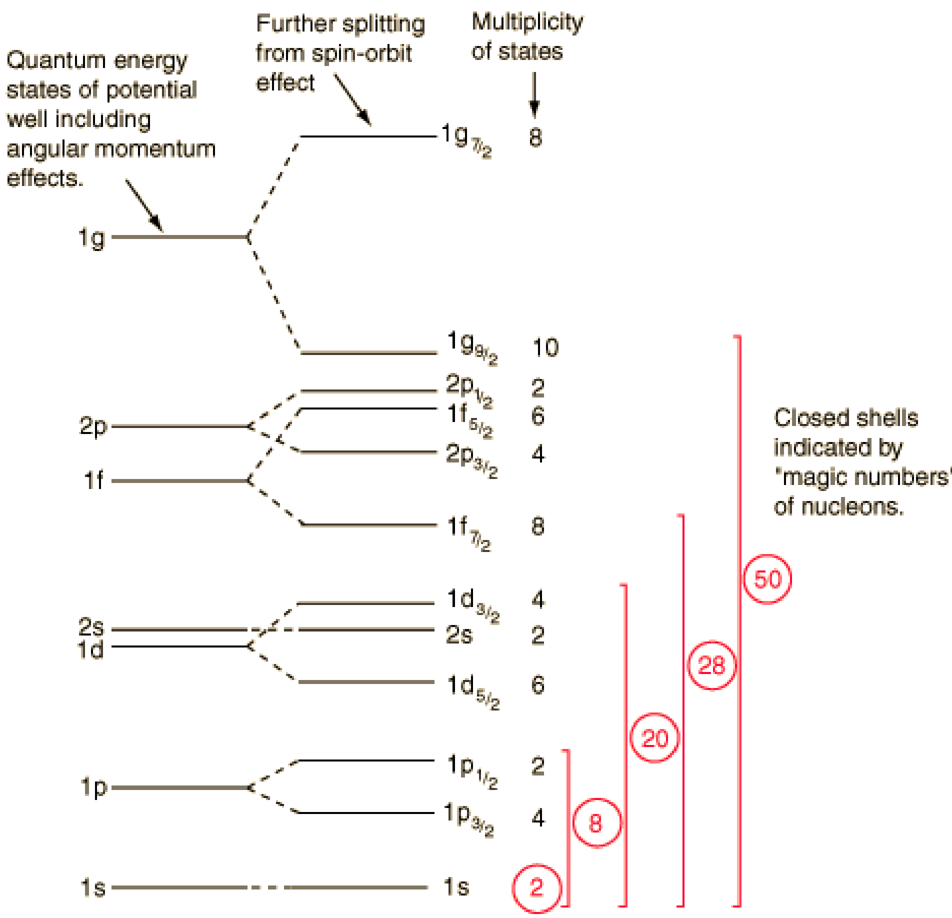

Table 1: Table of single particle decay rates for nuclear transitions.

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 = 1.602x10^{-19}J

1 Ci = 3.7x10^{10} Bq, 1 Bq = 1/s

k_B = 1.380x10^{-23}J/K

1 yr = 365.25 d = 8766 hr = 525,960 m = 3.156x10^7 s

$\hbar$ c = 197.49 MeV-fm

Potentially Useful Equations

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

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

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

$A = \lambda N$

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

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

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

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

$F_{\rm coulomb} = -q_1q_2e^2/4\pi\epsilon_0 r^2$

$V_{\rm coulomb} = q_1q_2e^2/4\pi\epsilon_0 r$

$V_{\rm coulomb} = Z_1Z_2 1.439 \text{MeVfm}/r$

$E = mc^2$

$E^2_{\rm total} = (m_0c^2)^2 + (pc)^2$

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

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

$p = m\ v$

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

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

$\lambda\ \nu = c$

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

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

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

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

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

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

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

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

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

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

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

$R = \rho_A \sigma \phi$

$\rho_A = \rho_n x$