Nuclear Chemistry Cumulative Examination
January 20, 2010

The examination will focus on nuclear forces. Support all answers with brief justifications where appropriate. A periodic table is available on the wall at the front of the room.

Q1 (11 points): Copy the following table into your examination booklet, and fill in the open boxes.

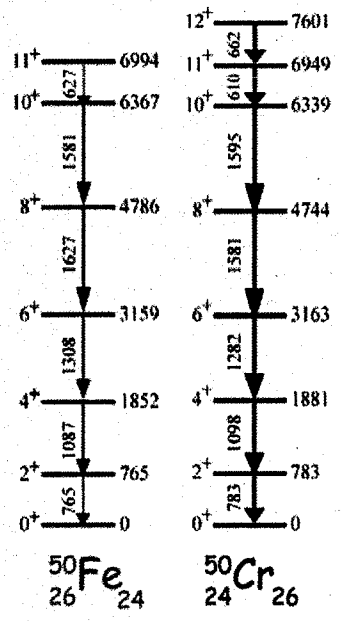
Force	Range (m)	Force Carrier	Relative Strength
Strong			1
Weak			
Electromagnetic			
Gravitational			

Q2 (8 points): Which of the following statements are true?

- The strong force is attractive
- The strong force changes with nuclear charge
- The strong force is a saturating force
- The strong force acts independent of spin

Q3 (8 points): The low-energy level yrast structures for ^{50}Fe (Z=26) and ^{50}Cr (Z=24) are show below.

- Why are the level structures so similar?
- Why are the level energies slightly lower in ^{50}Fe?

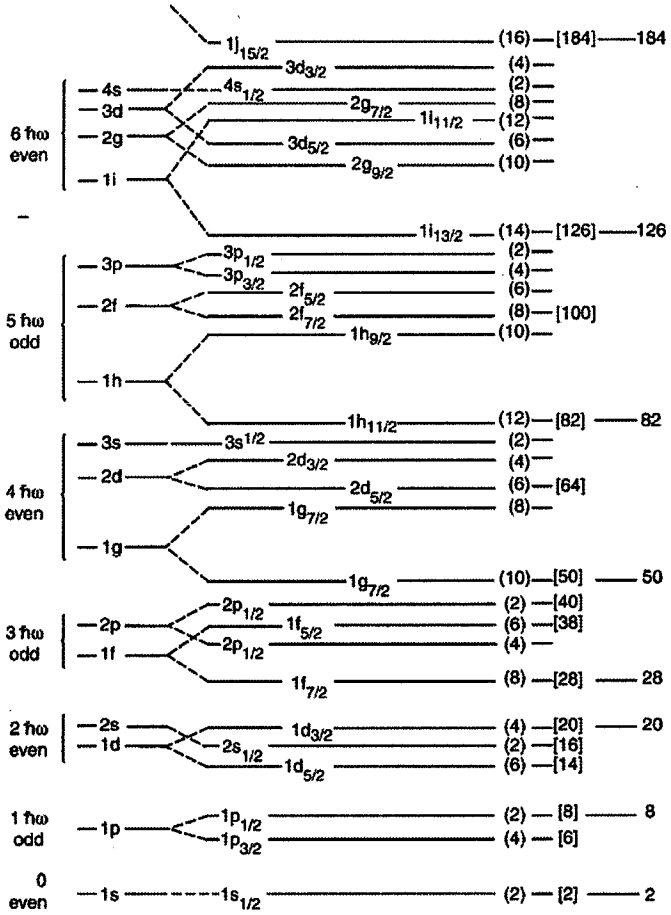


Q4 (20 points): Sketch the nuclear potentials estimated from the one-dimensional analytical expressions listed below. Give at least one positive and one negative attribute for each expression as a useful representation of the nuclear force.

- Square Well $V(r)=V_0$ for $r<R$; $V=0$ for $r>R$
- Harmonic Oscillator $V(r)=0.5kr^2$
- Woods-Saxon $V(r)=-V_0/[1+\exp(\{r-R\}/a)]$
- Yukawa $V(r)=-g^2\, e^{-mr}/r$

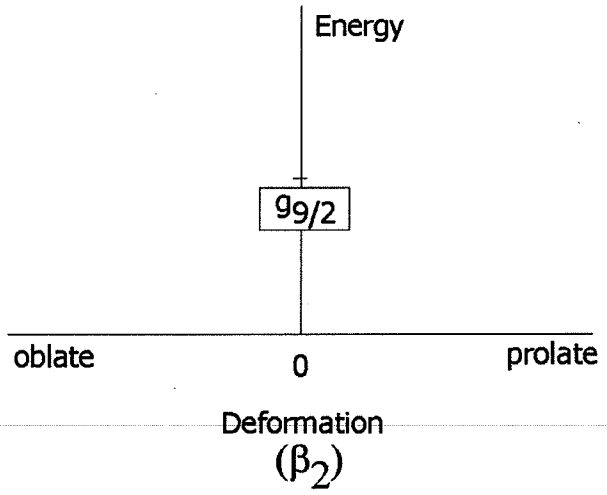
Q5 (12 points): Use the figure below depicting the energy levels derived from the schematic shell model to answer the following questions.

- What is the degeneracy of the $1p_{3/2}$ orbital?
- In the shell model ^{16}O (Z=8) is a closed shell nucleus and has spin and parity 0^+. What are predicted values for the spin and parity of ^{15}O and ^{17}O?
- For even-even nuclei (e.g., ^{16}O) the ground state spin and parity is always 0^+. How is this observation explained?



Q6 (10 points): In a universe differing from ours only by the sign of the spin-orbit potential, what would be the magic numbers?

Q7 (10 points): Reproduce the diagram below in your exam booklet. Sketch the expected splitting of the $g_{9/2}$ shell model state as a function of β_2 in a deformed potential with axial symmetry. Label each level with its correct value of the projection of angular momentum along the symmetry axis and its degeneracy.



Q8 (10 points): Starting with the relation that density is equal to mass over volume, show that the central nuclear density is essentially independent of nuclear mass.

Q9 (10 points): What is the basis for the nuclear property dubbed isospin? Give the possible range of values of isospin (T), as well as the value of the three-axis component of isospin (T_z), for the ground state of ^{17}F (Z=9).