Andrew's Review Session

1 Nuclear Reactions

$$R = \sigma \phi N \tag{1}$$

- **cross section**: measure of the relative probability for the reaction to occur; units of b= 10^{-24}cm^2
- σ used to determine activity

Kinematics

$$X(a,b)Y$$
$$Q = (m_X + m_a - m_Y - m_b)c^2$$
$$Q = T_Y + T_b - T_X - T_a$$

- Exothermic Q>0 :
  $m_X + m_a > m_Y + m_b$,
  $T_Y + T_b > T_X + T_a$
- Endothermic Q<0 :
  $m_X + m_a < m_Y + m_b$,
  $T_Y + T_b < T_X + T_a$
- Ultimately, equation 11.5 from Krane
- reaction reaches excited states of Y:
  $Q_{ex} = (m_X + m_a - m_{Y*} - m_b)c^2$
  $Q_{ex} = Q_0 - E_{ex}$
- compound nucleus
  $Q = -T_a = (m_X + m_a - m_{C*})c^2 - E_{ex}$

Population of an excited state of a daughter nucleus by alpha or beta decay can then de-excite by gamma-decay or IC.

2 Nuclear Structure

What do the models predict? E(4+)/E(2+), Q(2+), energy levels, spin parity assignments

What mass region is a particular model the best description? Vibration: A<150, Rotation 150<A<190 and A>230
Depending on the model, what is the size of the gap between the ground state and the first excited state?

Shell Model vs. Collective Model ("liquid drop")

- shell model: a blend of infinite well and SHO
  single particle (a single valence proton or neutron)
  multi-particle (unpaired protons or neutrons)
  magic numbers: 2, 8, 20, 28, 50, 82, 126, 184
- Vibration Model (collective)
- Rotational Model (collective)

3 Decay Modes

What makes a decay mode preferred over another? Which nuclei are more likely to go through a particular decay?

For all decay modes, transitions with the least change in angular momentum are preferred

3.1 α-Decay

- $$Q = (m_X - m_{X'} - m_\alpha)c^2 = T_{X'} - T_\alpha = B(\alpha) + B(X') - B(X) \tag{2}$$
- preferential for removing 5-8 MeV through decrease of mass (mode preferred by have heavy nuclei)
- a Coulomb repulsion effect, strong force
- emission of α is preferred over other particles is because it is the most energy efficient, B/A
- large disintegration energies (Q) had short half-lives; adding neutrons to a nucleus reduces the disintegration energy
- occurs through tunneling
- half life increases with increasing Coulomb Barrier
  How do you increase the Coulomb Barrier? Example: carrying away a larger amount of angular momentum
- hindrance: similarity of the initial and final wave functions
- permitted values of l_α
- discrete energy spectrum

3.2 β-Decay

- method for sliding down the mass parabola
- represents the drive to reach a more optimal charge ratio
- drawing a relation to the Semi Empirical Mass Formula, ways to increase the Binding Energy (i.e. more stable configuration):
  increase symmetry $\rightarrow$ decreases $a_{sym}(A-2Z)^2/A$
  decrease proton repulsion
  increase pairing
- $\beta+$ decay and electron capture have thresholds, $2m_ec^2$ and $B_n = 13.6eV \times \frac{Z^2}{n^2}$, respectively. In addition, these two decays compete.
- Selection Rules: which is preferred and why?
- continuous energy spectrum (exception: EC results in a monoenergetic neutrino)

3.3 γ-Decay

- preferred mode for carrying away angular momentum from excited states (rearrangement of nucleons into a more stable spatial arrangement)
- Selection Rules: Which transition are possible?
- WE (based on single particle model) conclusions
- Gamma-decay and IC compete
  IC is a low energy event (decreasing transition energy)
  large change in J results in more probable IC
  IC is more important for heavy nuclei 0+ to 0+ transition occurs by IC
- Compton scattering characteristics: relationship between electron shells, their binding energy, and absorption cross section

4 General

- half-life trends
- selection rules
- conservation of energy and momentum