1) A Rb atom (electron spin $\frac{1}{2}$) collides with a Xe atom; during the collision the electron couples to the rotational angular momentum $N$ (which you can assume is a fixed classical vector during the collision) via $H = \hbar \gamma(t)N \cdot S$. Find the probability that an initially spin-up atom changes to a spin-down atom. Write your answer in terms of $\theta = \int \gamma(t)dt$ and average over the directions of $N$.

2) Suppose there is an external magnetic field $Bz$ applied. Show that the probability from prob 1) is unaffected to first order as long as $\mu_B B \ll \hbar T$, where $T$ is the duration of the collision.

3) During those same collisions, there is also an interaction $\alpha \mathbf{K} \cdot \mathbf{S}$ that causes the nuclear spin ($K = 3/2$) to change states as well. For each of the possible initial $m_K, m_S$ states in which the atoms can collide, calculate the relative probability of making a transition to the possible final states $m_K', m_S'$.

4) An atom with two states $g, e$ of opposite parity that differ in energy by $\hbar \omega_0$ is subjected to a light field with a frequency chirp: $\omega(t) = \omega_0 + \Delta(t)$. Let the Rabi frequency $\Omega$ be constant. Use first-order perturbation theory to calculate the probability that an atom in state $g$ at $t = -\infty$ will be in state $e$ at $t = \infty$. Evaluate the integral for a linear chirp $\Delta(t) = \Delta t$. 