chapter 5 (lecture 6)

10) Let's investigate the kaon system.

(a) Is $|K^0\rangle$ a P-eigenstate, a C-eigenstate, and/or a CP-eigenstate? Why?

(b) Consider the state $|K^0_+\rangle = \frac{1}{\sqrt{2}}\left[|K^0\rangle + |\bar{K}^0\rangle\right]$. If we assume that the state $|K^0_+\rangle$ is CP even (i.e. with CP eigenvalue +1), what does that imply for the sign *convention* in the C transformation of $|K^0\rangle$? And how does $|\bar{K}^0\rangle$ transform under the C operation? Is $|K^0_+\rangle$ a CP-eigenstate?

(c) Why does the $|K^0_+\rangle$ purely decay to 2 pions (if CP is conserved)?

(d) What does the CP eigenvalue of a final state with 3 pions ($|\pi^+\pi^-\pi^0\rangle$) depend on?

(e) Why do you expect different lifetimes for the two CP-eigenstates in the kaon system?

(f) The Cronin-Fitch experiment showed that, in fact, a fraction of the long-living kaons decays to 2 pions. This is not due to CP violation in the decay, but this is due to the fact that the long-living kaon contains a fraction of the CP-even eigenstate:

$$|K^0_L\rangle = \frac{1}{\sqrt{1+|\epsilon|^2}}\left(|K^0_-\rangle + \epsilon|K^0_+\rangle\right)$$

Show that $\epsilon \neq 0$ implies "CP violation in mixing".

(g) Is $|K^0_L\rangle$ a CP-eigenstate? Why?

(h) The value of ϵ can be determined with the semi-leptonic decay $K^0_L \to e^\pm\pi^\mp\nu_e$. Draw the Feynman diagram for $K^0 \to e^+\pi^-\nu_e$.

(i) Express $|K^0_L\rangle$ in terms of $|K^0\rangle$, $|\bar{K}^0\rangle$ and ϵ.

(j) Show that the charge assymetry for the decay $K^0_L \to e^\pm\pi^\mp\nu_e$ is sensitive to the real part of ϵ: $A_{+-} \approx 2\Re\,\epsilon$ (see Section 5.5).