1) [15 points] Chemists know that if a chemical reaction is exothermic (kinetic energy is released in the collision) then near threshold the combination $\sigma(A + B \rightarrow a + b)v_{rel}(A + B)$ approaches a constant. Here $v_{rel}(A + B)$ is the relative velocity of A and B. Show that this result is true by considering the reaction $A + B \rightarrow a + b$ where particles A and B have mass M and a and b have mass m, where M > m. Constrast this situation to the one where m > M. Hint: use the Golden Rule, write the energy as $E_i = m_i c^2 + p_i^2/2m_i$, (*i* means "initial" or "final") and assume the T-matrix is an angle-independent constant.

2) [20 points] How does a track form in a detector? Consider the scattering of a charged particle of initial momentum $\hbar \vec{k}$ off two atoms located at $\vec{r_1}$ and $\vec{r_2}$ into final momentum $\hbar \vec{k'}$. Assume that the potentials are like the ones we've seen already; that is, V(q) peaks at small q^2 . Carry the calculation far enough to show that the cross section is small unless \vec{k} and $\vec{k'}$ are nearly parallel, and are both nearly parallel to $\vec{r_1} - \vec{r_2}$. Use second order Born approximation. This problem is somewhat open ended.

There is an interesting early discussion of this problem scattered throughout Heisenberg's little 1930 book "The physical principles of the quantum theory." The Dover edition might scanned on line someplace for you to read.