

CSO202—Atoms, Molecules & Photons

Quiz – 1 (MM: 15)

(Aug. 30 2024, 9:00 AM – 9:30 AM, L2 & L4)

1. In the hard sphere reactive collision model, the collision cross section (σ) and the radii of the colliding atoms or molecules (r_1 and r_2) are important in deciding the nature of the reaction. For the reaction to be of the rebound type, what would be the required relationship between σ , r_1 , and r_2 ? 2

2. The concentric circles in the Newton Diagram correspond to the maximum expected speeds for the product molecule in the specific vibrational state (e.g., $v = 0, 1$, etc.) when the rotational quantum number, $J = 0$. What would be the change in the radius (r) of the product distribution for any specific concentric circle (consider the $v = 0$ case), when the relative translational energy of the reactants is doubled? 2

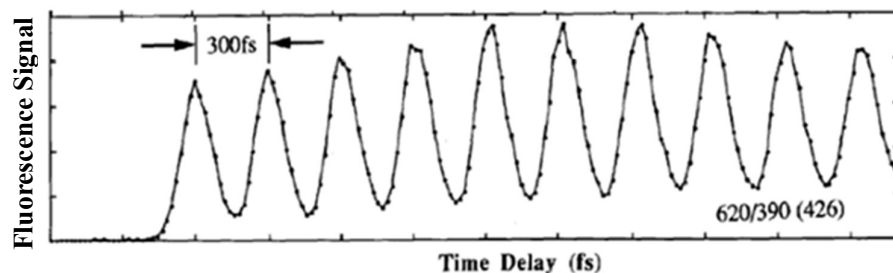
3. Consider the Reaction-1: $\text{O(g)} + \text{Br}_2\text{(g)} \rightarrow \text{BrO(g)} + \text{Br(g)}$, where Newton's diagram is largely symmetric in both hemispheres.

This contrasts with Reaction-2: $\text{K(g)} + \text{I}_2\text{(g)} \rightarrow \text{KI(g)} + \text{I(g)}$, where Newton's diagram is in the forward direction for the relative translational energy of the reactants is $15.13 \text{ kJ.mol}^{-1}$. Based on this, fill in the blacks in the following statements:

- a. Reaction-1 is an example of _____ (1) _____ reaction, where the reaction progresses through an intermediate that rotates many times before the product formation and thus the distribution is _____ (2) _____. 2
- b. Reaction-2 is an example of _____ (1) _____ reaction where the reaction cross section is larger than the collision impact parameter and is dominated by _____ (2) _____. 2
4. Consider an ultrafast Ti:Sapphire laser operating at 76 MHz, with a pulse width of 6 fs centered at a wavelength of 800 nm. Measuring such a short pulse is only possible if it is correlated with itself. You could treat the laser to output TEM_{00} mode and the temporal profile to be Gaussian so that it follows the condition for transform-limit as: $\Delta\nu\Delta t = 0.44$.
- a. What is the spectral bandwidth $\Delta\lambda$ (in nm) of this laser around 800 nm under the transform-limited condition? 2

Now let us consider how the spectral bandwidth (in nm) would change if we examine the CPM laser used by Zewail, which has a center wavelength of 600 nm. So, specifically:

- b. What would the spectral bandwidth value (in nm) be if the center wavelength of the laser is 600 nm while maintaining the same pulse width of 6 fs? 1
5. In the Femtosecond Transient Spectroscopy of I_2 photodissociation studied by Zewail's group, the observed fluorescence showed oscillations in time as follows:



Estimate the fundamental vibrational wavenumber (in cm^{-1}) of I_2 as per this observed oscillatory fluorescence signal. 2

6. PhotoActivated Localization Microscopy (PALM) allows obtaining images with a resolution beyond the diffraction limit. Developed by Eric Betzig and William E. Moerner around the year 2000, it was one of the two techniques awarded the 2014 Nobel Prize in Chemistry. The STIMulated Emission Depletion (STED) microscopy developed by Stefan Hell as early as 1994, was the other technique chosen for the 2014 Chemistry Nobel Prize. Give at least one specific difference between these two techniques super-resolution techniques. 2