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What is Wrong with Raman Effect?

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Abstract: ***This paper provides a holistic picture of the Raman effect that had not been explained in the original research by Raman by showing the entire picture of what happens when a photon from a light source collides with a molecule from a reference object.***

Keywords: Photon, Molecule, Kinetic Energy, Collision

I. INTRODUCTION

The Raman effect, also known as the Raman scattering or Raman spectroscopy, is a scattering phenomenon in which light interacts with matter and causes a change in its wavelength. This change in wavelength results in the emission of scattered light with wavelengths that are both higher (Stokes lines) and lower (Anti-Stokes lines) than the incident light. The Raman effect is a valuable tool in chemistry and physics for studying the vibrational and rotational states of molecules [1][12] & [2].

A. Mechanism of Raman Scattering

When a beam of light strikes a molecule, it interacts with the electrons and nuclei of the molecule. The incident light can either be scattered elastically, without any change in wavelength, or inelastically, with a change in wavelength. Elastic scattering is the dominant process and is responsible for the familiar phenomenon of reflection. Inelastic scattering, on the other hand, is a weaker process and is responsible for the Raman effect [5]. In Raman scattering, the incident light excites the electrons of the molecule to a virtual state, which is an unstable state that does not exist in the real ground state of the molecule. This virtual state is a higher energy state than the ground state, but it is not as high in energy as an excited state [4]. The molecule then relaxes back to the ground state, emitting a photon with a lower wavelength (Stokes line) or a higher wavelength (Anti-Stokes line)[6]. The frequency of the scattered light is given by the following equation:

$f' = f + \Delta f$

where:

- f is the frequency of the incident light
- Δf is the Raman shift
- f' is the frequency of the scattered light

The Raman shift is the difference in frequency between the incident light and the scattered light. The Raman shift is typically measured in wavenumbers (cm^{-1}).

Types of Raman Scattering

There are two main types of Raman scattering:

1. Stokes Raman scattering: This occurs when the scattered light has a lower frequency (longer wavelength) than the incident light. This happens when the molecule relaxes from a virtual state to a vibrationally excited state.
2. Anti-Stokes Raman scattering: This occurs when the scattered light has a higher frequency (shorter wavelength) than the incident light. This happens when the molecule relaxes from a virtual state to the ground state.

Anti-Stokes Raman scattering is much less common than Stokes Raman scattering because it requires more energy [3] & [7][11].

II. OBSERVATIONS

The collision between the molecule and the photon of light is not perfectly inelastic but the bodies stick together for a brief moment before separating as opposed to bodies stick together and move as one object after the collision. Following are the scenarios possible during the collision depending on various factors such as their frequency, wavelength, and phase of the molecule and the photon:

1. Same frequency but different wavelength in phase (Constructive Interference or Resonance)
   When two objects have the same frequency but different wavelengths collide in phase, they will interfere constructively, resulting in a wave with a larger amplitude. This is because the peaks and troughs of the two waves will coincide, reinforcing each other.
2. Same frequency but different wavelength out of phase (Destructive Interference)
   When two objects have the same frequency but different wavelengths collide out of phase, they will interfere destructively, resulting in a wave with a smaller amplitude. This is because the peaks of one wave will coincide with the troughs of the other wave, cancelling each other out.
3. Different frequency but different wavelength in phase
   When two objects have different frequencies but different wavelengths collide in phase, they will beat, resulting in a wave with an amplitude that varies over time. This is because the two waves will not be in phase at all times, but they will be in phase at some times and out of phase at other times.

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4. Different frequency but different wavelength out of phase
   When two objects have different frequencies but different wavelengths collide out of phase, they will also beat, but the amplitude of the resulting wave will be smaller than if the two waves were in phase. This is because the two waves will cancel each other out more often than if they were in phase.
5. Same frequency and same wavelength in phase (Superposition)
   When two objects have the same frequency and same wavelength collide in phase, they will simply add together, resulting in a wave with the same frequency and wavelength but a larger amplitude.
6. Same frequency and same wavelength out of phase
   When two objects have the same frequency and same wavelength collide out of phase, they will cancel each other out completely, resulting in no wave at all [8], [9] & [10].

III. DISCUSSIONS

This means that the molecule and the photon after the collision can lose kinetic energy with both going to a lower energy state and the remaining energy being converted into other forms of energy. Also, the two bodies can completely stop moving if they were previously moving at same frequency and same wavelength but where out-of-phase during collision. Raman's resonance is also possible if their frequency are similar and they are in-phase. Similarly, destructive interference can also occur in case of out-of-phase collision. The higher the wavelength of light, either the two particles go to a lower energy state after collision or the molecule gains energy after the collision but the photon losses energy depending on the frequency, wavelength and phase of the two bodies. It is also possible that both gained energy after the collision due to resonance, superposition or constructive interference as described earlier. Also, the photon can gain energy after the collision (resulting in lower wavelength and thus higher frequency) depending on the properties of the bodies and the nature of the collision. The Raman effect only considers the two scenarios of either the molecule gaining energy or losing energy and vice versa for the photon and does not consider the other three missing states of both being lower, both being higher and both coming to a complete standstill. This paper provides a complete holistic representation of what happens when two particles collide, such in a photon from a light source interacting with a molecule of a substrate, thus connecting the dots that were missing in the original paper submitted by C. V. Raman.

IV. CONCLUSION

The paper thus describes the remaining scenarios that were missing in the original research conducted by Raman as a part of the Raman effect and completes the unfinished research on particle collision in quantum physics.

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