

Rayleigh Scattering

Sunlight, an electromagnetic wave, polarizes atmospheric nitrogen molecules by **inducing their electrons to oscillate with the same frequency as the light, creating temporary electric dipoles**. These oscillating dipoles then re-emit electromagnetic radiation, effectively scattering the light in various directions. Because this scattering is more efficient for shorter wavelengths, blue light is scattered more intensely than red light, leading to the blue color of the sky. [1, 2, 3]

The Polarization Process

1. **Incident Light as a Wave:** Sunlight travels as an electromagnetic wave, with its oscillating electric field interacting with the electrons in nitrogen molecules.
2. **Induced Dipoles:** This oscillating electric field forces the electrons within the nitrogen molecule to shift their positions, creating a temporary, oscillating electric dipole moment. The molecule's charge distribution is temporarily displaced.
3. **Oscillation Frequency:** The electrons oscillate at the same frequency as the incoming light. [1, 2, 4, 5]

The Scattering Process

1. **Re-emission of Radiation:** The oscillating electric dipole then re-emits electromagnetic radiation. This re-emitted radiation is what we observe as scattered light.
2. **Wavelength Dependency:** The intensity of this scattered light is inversely proportional to the fourth power of the light's wavelength ($\propto \frac{1}{\lambda^4}$).
3. **Shorter Wavelengths Scattered More:** This means that shorter wavelengths, such as blue and violet light, are scattered much more strongly by atmospheric molecules than longer wavelengths like red light. [1, 2, 6, 7]

Result: The Blue Sky When we look at the sky, we are primarily seeing the light that has been scattered by the nitrogen and oxygen molecules in the atmosphere. Because blue light is scattered far more effectively than red light, the sky appears blue to our eyes. [3, 6, 8]

Which electrons in a nitrogen molecule experience the most polarization from sunlight, the core electrons, the sigma bonding electrons, or the pi electrons?

The most polarizable electrons in a nitrogen molecule are the pi electrons, which are found in the triple bond. This is because valence electrons in general, and pi electrons in particular, are less tightly held by the nucleus than core electrons, making them more susceptible to distortion by the electric field of sunlight.

Valence electrons vs. core electrons

- **Core electrons:** These are the inner-shell electrons that are tightly bound to the nucleus and shielded from outside forces. Due to their close proximity to the nucleus, the strong

electrostatic attraction makes them much less mobile and therefore significantly less polarizable.

- **Valence electrons:** These are the outermost electrons that are involved in chemical bonding and reside in molecular orbitals that extend over a larger volume. They are less strongly held by the nuclei and are the primary contributors to a molecule's polarizability.

The two nitrogen atoms are joined by a triple bond, which consists of one sigma bond and two pi bonds.

Sigma electrons: These electrons are concentrated directly between the two nuclei and are held relatively tightly in place.

Pi electrons: These electrons occupy orbitals that are more diffuse, or spread out, above and below the internuclear axis. This means they are located further away from the attractive force of the nuclei, making their electron cloud more easily deformed by an external electric field. As a result, they are more polarizable than the sigma electrons.

Polarizability and Rayleigh scattering

The higher polarizability of the pi electron cloud is a key factor in Rayleigh scattering for nitrogen.

- **Greater distortion:** The oscillating electric field of sunlight causes a greater displacement in the diffuse electron cloud of the pi electrons.
- **Induced dipole:** This creates a larger induced oscillating dipole moment, which then re-radiates light more intensely.

Anisotropic polarizability: The polarizability of the nitrogen molecule is not the same in all directions. It is more polarizable along the axis of the bond where the pi electron cloud is most diffuse, which influences the angular and polarization properties of the scattered light.

AI responses may include mistakes.

[1] https://en.wikipedia.org/wiki/Rayleigh_scattering

[2] <https://www.youtube.com/watch?v=dz55uhAJuw>

[3] [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/mtr/opt/mch/sct.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/opt/mch/sct.rxml)

[4] <https://www.sciencedirect.com/topics/medicine-and-dentistry/rayleigh-scattering>

[5] <https://www.vedantu.com/physics/polarization-by-scattering>

[6] <http://sites.science.oregonstate.edu/~giebultt/COURSES/ph332/Reading/Ch13.1.pdf>

[7] <https://www.youtube.com/watch?v=-Xx7sPPTu3Y>

[8] <https://www.sciencedirect.com/topics/chemistry/rayleigh-scattering>