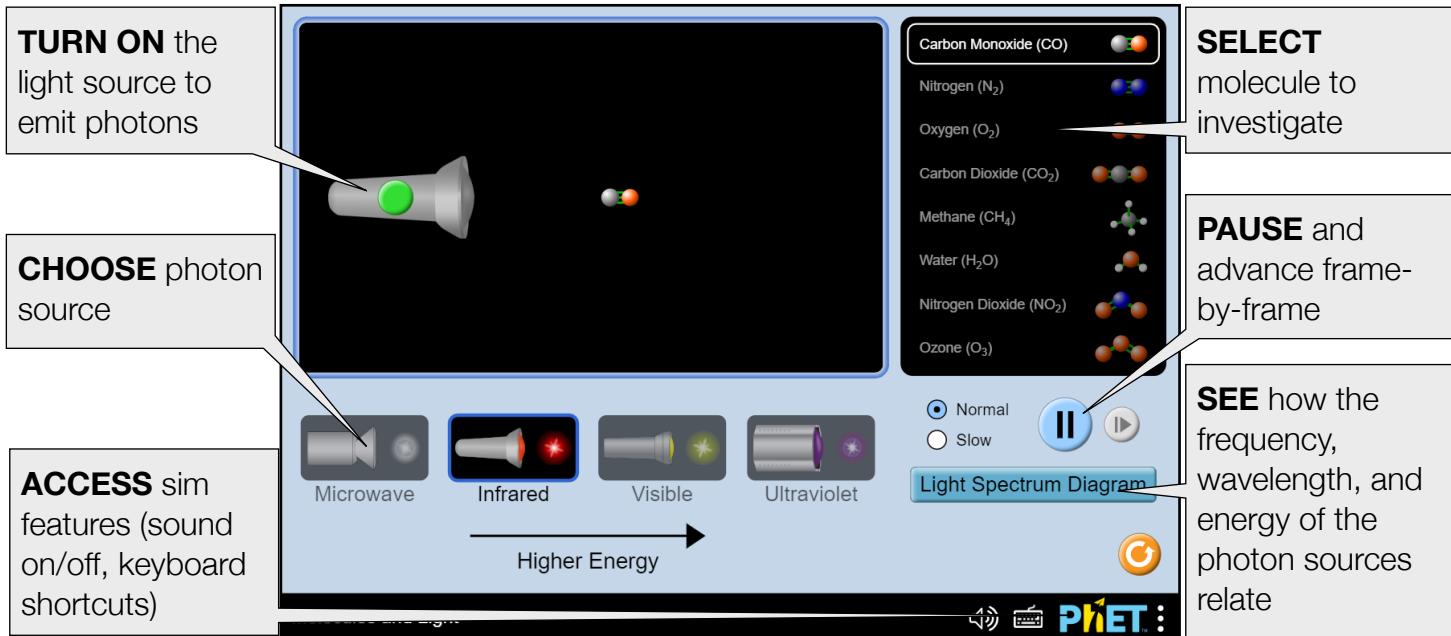


The **Molecules and Light** simulation explores how light interacts with molecules in our atmosphere.



## Insights into Student Use

- Many students will systematically explore the sim without being given any direction (e.g. investigating how IR interacts with all molecules before moving onto the next photon source).
- The photons are not emitted from the source until you move the slider. Some students may not immediately find the slider, though many do.
- Words students used for photons in interviews included: light, energy, waves, rays, dots, beads, and particles of light (the word “photon” does not appear in the sim).
- Water prompted a couple of students to connect to what they already knew – microwaves heat up water, light is distorted in water, etc.
- When the light was not as intense (i.e. the rate of photons was slow) students were more likely to say that the molecules “take in” the photon, and not that the photon “bounces off” the molecule. Only two students used the word “absorb.” Students may need more guidance to understand that photons do not collide with the molecule.
- A couple of students equated more motion with more energy, and thus thought microwave and infrared had more energy than visible. We added the light spectrum to reinforce the correct energy order.

Light Spectrum Diagram

## Model Simplifications

- The sim only shows the basic absorption process for each class of radiation (e.g. IR = vibration). In reality, absorption of IR can excite rotations along with vibrations, and absorption of visible (denoted in the sim by the “glow”) can excite vibrations and rotations.

- Each photon represents a range of energy, but not all absorptions in that range are shown. Some examples of what is not included: CO<sub>2</sub>, H<sub>2</sub>O, NO<sub>2</sub> and O<sub>3</sub> all have stretch vibrational modes in the IR, O<sub>3</sub> absorbs weakly in the visible, and absorption of visible light by NO<sub>2</sub> is dissociative at some wavelengths (blue or violet). The UV photon comes from the UV-B region (290-320 nm), which is the range absorbed by the earth's ozone layer; at shorter wavelengths the other molecules also absorb UV.
- Photodissociation often produces excited state products. In the case of O<sub>3</sub>, the O<sub>2</sub> fragment would vibrate and/or emit a photon (in UV regions of high energy). The same is true for the NO fragment of NO<sub>2</sub>. These are not shown in the sim.
- The sim randomly picks a single resonance structure for NO<sub>2</sub> and O<sub>3</sub> rather than showing delocalized bonds.
- For the case in which absorbance does occur, the probability is simply set to 50% so that students experience the idea that not every photon will be absorbed. In reality, the probabilities vary with wavelength and molecule identity.

## Customization Options

Query parameters allow for customization of the simulation, and can be added by appending a '?' to the sim URL, and separating each query parameter with a '&'. The general URL pattern is:

`...html?queryParameter1&queryParameter2&queryParameter3`

For example, in Molecules and Light, if you want to mute audio (`sound=muted`), and disable external links (`allowLinks=false`) use:

`https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_all.html?sound=muted&allowLinks=false`

To run this in Spanish (`locale=es`), the URL would become:

`https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_all.html?locale=es&sound=muted&allowLinks=false`

Query Parameter and Description	Example Links
<code>locale</code> - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the <a href="#">Translations tab</a> . Note: this only works if the simulation URL ends in “_all.html”.	<code>locale=es</code> (Spanish) <code>locale=fr</code> (French)
<code>sound</code> - if muted, audio is muted by default. If disabled, all audio is permanently turned off.	<code>sound=muted</code> <code>sound=disabled</code>
<code>allowLinks</code> - when <code>false</code> , disables links that take students to an external URL. Default is <code>true</code> .	<code>allowLinks=false</code>

## Suggestions for Use

### Connect to the real world:

Ask students to use their observations to explain...

- why a microwave oven heats up food
- which gases are considered greenhouse gases

- why the ozone layer is important
- which gases do not react with any of the radiation and why that might be important (e.g. O<sub>2</sub>)

### Predicting the reactivity of a new molecule:

Provide students with a molecule not found in the sim such as HCN, CH<sub>2</sub>O, NH<sub>3</sub>, or CH<sub>4</sub> and ask students to predict how it will interact with the different types of radiation. It may be helpful to have students first explore the shape and polarity of this molecule using the [Molecule Polarity](#) simulation.

## Inclusive Features

### Sounds and Sonification

- Each photon-molecule interaction has its own sound to emphasize the type of interaction. Photodissociation, vibration, rotation, and electronic excitation each play a unique sound. Absorption and emission of the photon also each play their own sound to mark the exact moment it occurs.
- Bending and stretching modes play the same sound to emphasize the type of interaction with IR.
- Light-matter interaction resulting in stretching/bending and rotation play sounds that pan across the left and right speakers. Use headphones to get the most out of the this stereo sound feature!
- While selecting light sources, the pitch of the photons increases moving to higher energy sources. Selecting a light source also plays a sound that increases in pitch moving higher in energy.
- See the Sound Features Video for more useful tips on how concepts and sound are integrated in this sim. See the published [Sound Design Documentation](#) for more details on all sounds in this simulation.

### Interactive Description

- This simulation features interactive description to support non-visual access, delivered only while using screen reader software. See the [Introduction to Interactive Description video](#) for more info on how to use this feature.
- Teachers can [access the A11y View here](#) to decide if this sim's interactive description meets their instructional needs. *Reminder: A11y View is not intended for student use and will not provide a good experience for learners using screen reader software.*

See the simulation page for all supported inclusive features.

See all published activities for Molecules and Light [here](#).

For more tips on using PhET sims with your students, see [Tips for Using PhET](#).