PhET Tips for Teachers **Molecules and Light**

Tips for controls:

- The photons are not emitted from the source until you move the slider. Many students did not immediately find the slider.
- You can **Pause** the sim and then use the **Step** feature to study the process in more detail. This helped students interpret the process as absorption rather than a collision. You can also get one photon to emit if you push the slider to the right and then back to the left quickly.
- The Light Spectrum window is resizable.
- You can change the background color of the sim to white in the **Options** menu.

Important modeling notes / simplifications:

- The sim only shows the basic absorption process for each class of radiation – that is, microwaves = rotation, infrared = vibration, etc. But in the real world, absorption of infrared 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_2, H_2O, NO_2 and O_3 all have stretch vibrational modes in the infrared, O_3 absorbs weakly in the visible, and absorption of visible light by NO_2 is dissociative at some wavelengths (blue or violet). The ultraviolet 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_3, the O_2 fragment would vibrate and/or emit a photon (in UV regions of high energy). The same is true for the NO fragment of NO_2. These are not shown in the sim.
- The sim randomly picks a single resonance structure for NO_2 and O_3 rather than showing delocalized bonds.

Insights into student use / thinking:

- 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.
- 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.
- When the light was not as intense – that is, when 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.
- All students said the sim shows what happens when different types of light interact with different molecules. Most wanted to know why. We plan to make a more advanced sim on spectroscopy in the future. If you teach younger students, you could say that every molecule has different energy levels, and this determines the amount of energy it can absorb.

Suggestions for sim use:

- This sim could be used in conjunction with **The Greenhouse Effect** or **Microwaves**
- For tips on using PhET sims with your students see: **Guidelines for Inquiry Contributions** and **Using PhET Sims**
- The sims have been used successfully in homework, lectures, in-class activities, and lab activities. Use them for introduction to concepts, learning new concepts, reinforcement of concepts, as visual aids for interactive demonstrations, or with in-class clicker questions. To read more, see **Teaching Physics using PhET Simulations**
- For activities and lesson plans written by the PhET team and other teachers, see: **Teacher Ideas & Activities**

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