Molecules and Light

PhET Sim Design Document

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Public URL:
https://docs.google.com/Doc?docid=0Ab-bfyyKuh9uZGR3cmY3cGZfMTUwZDJjemtxNjY&hl=en&authkey=CI7zko8L

Abstract:
Do you ever wonder how a greenhouse gas affects the climate, or why the ozone layer is important? Use the sim to explore how light interacts with molecules in our atmosphere.

Contents

Audience

Who is our audience? Look at K12 standards from AAAS below:

By end of 8th grade:

- Light and other electromagnetic waves can warm objects. How much an object's temperature increases depends on how intense the light striking its surface is, how long the light shines on the object, and how much of the light is absorbed.
- Light from the sun is made up of a mixture of many different colors of light, even though to the eye the light looks almost white. Other things that give off or reflect light have a different mix of colors.
- There are a great variety of electromagnetic waves: radio waves, microwaves, infrared waves, visible light, ultraviolet rays, X-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest.

By end of 12th grade:

- When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between. The change in energy occurs when light is absorbed or emitted, so the light also has distinct energy values. The light emitted or absorbed by separate atoms or molecules (as in a gas) can be used to identify what the substance is.

Learning Goals

Updated:

- Explore how light interacts with molecules in our atmosphere
- Identify that absorption of light depends on the molecule and the type of light
- Relate the energy of the light to the resulting motion
- Identify that energy increases from microwave to ultraviolet
- Predict the motion of a molecule based on the type of light it absorbs
- Identify how the structure of a molecule affects how it interacts with light

TL: Students to be able to: *(Items in italics are for teachers only)*

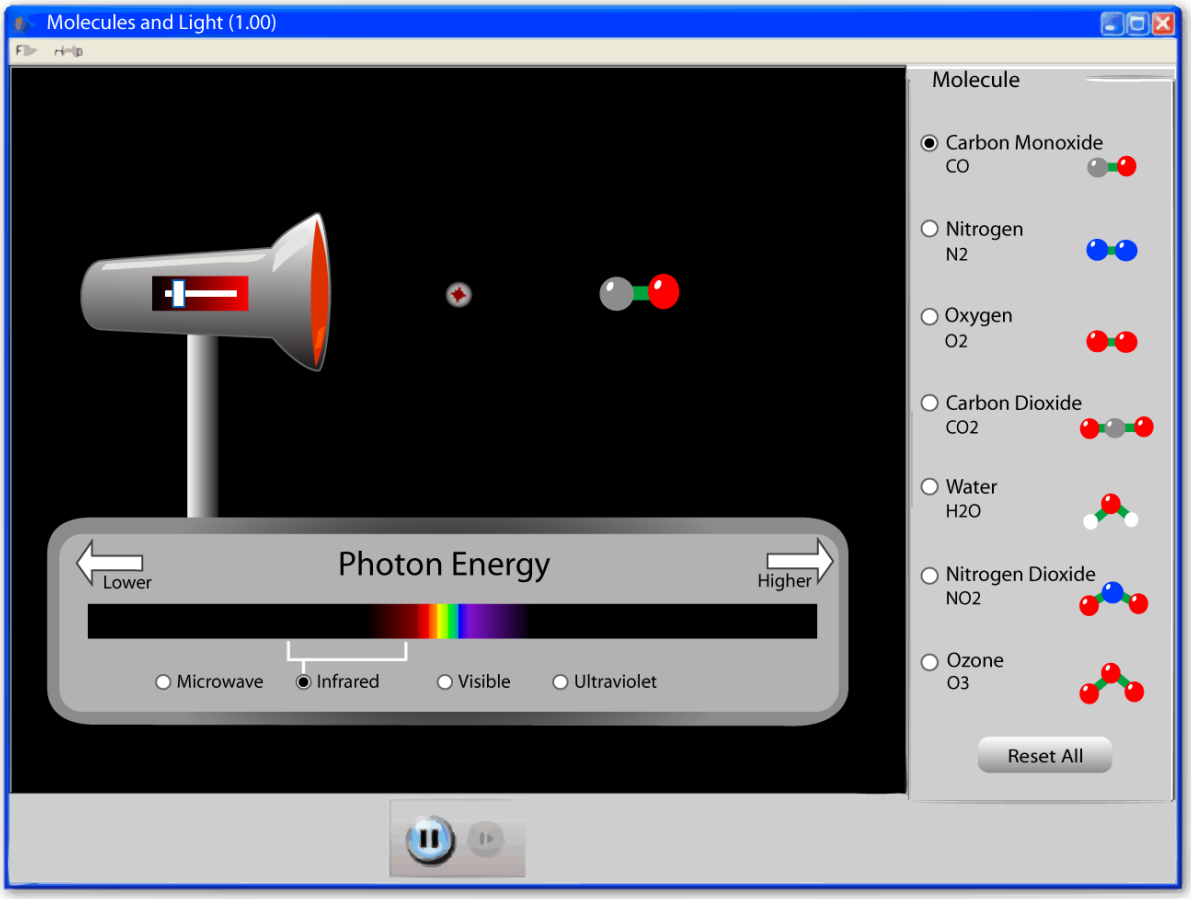
- Design experiments to see how some types of electromagnetic radiation (light) may interact with molecules found in large amounts in our atmosphere (like carbon dioxide)
- Identify how motion of atmospheric gases is affected by microwaves, infrared, visible, and ultraviolet radiation. *(not every photon is absorbed, molecule will rotate, vibrate, etc. based on the type of photon absorbed, the radiation frequency needed to change the motion is specific to the molecule)*
- Relate the amount of energy of the electromagnetic radiation to resulting motion *(photon energy increases from Microwave to UV and so does the motion)*
- Identify that there are a great variety of electromagnetic waves: radio waves, microwaves, infrared waves, visible light, ultraviolet rays, X-rays, and gamma rays. These wavelengths vary from radio waves, the longest, to gamma rays, the shortest. (*use the image to help with this learning goal)*

Original:

- light interacts with molecules
- the way it interacts depends on the molecule and the type of light
- not every photon is absorbed
- be able to predict whether the molecule will rotate, vibrate, etc. based on the type of photon absorbed
- photon energy increases from Microwave to UV
- advanced: identify how structure affects the behavior

Mockup

Below is a drawing that represents the desired appearance of this simulation.



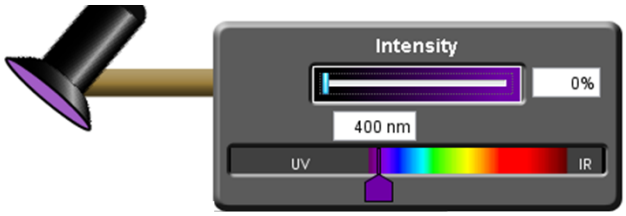
We need to decide what we want each molecule to do for each type of light:

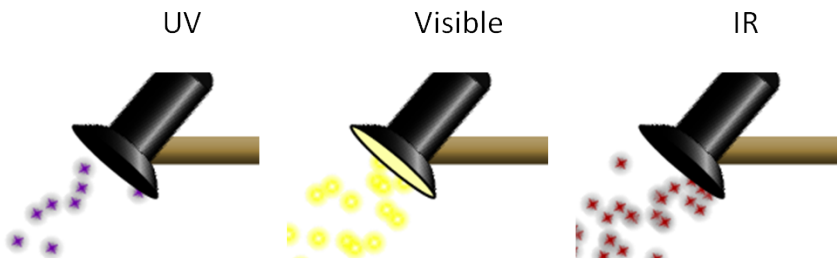
	Micro	**IR**	**Visible**	**UV**
Energy (cm-1)	0.033-3.3	10-400 (far), 400-4000 (mid), 4000-13000 (near)	13000-26000	26000-50000 (near)
N2	nothing	nothing	nothing	nothing
O2	nothing	nothing	nothing	nothing
CO	absorbs, rotates, re-emits	absorbs, vibrates (stretches), re-emits	nothing	nothing
CO2	nothing	absorbs, vibrates (bends), re-emits	nothing	nothing
H2O	absorbs, rotates, re-emits	absorbs, vibrates (bends), re-emits	nothing	nothing
NO2	absorbs, rotates, re-emits	absorbs, vibrates (bends), re-emits	absorbs, excites, re-emits	absorbs, breaks apart into NO and O
O3	absorbs, rotates, re-emits	absorbs, vibrates (bends), re-emits	nothing	absorbs, breaks apart into O2 and O

Enumerating the strategies:
1. nothing
2. absorbs, rotates, re-emits
3. absorbs, vibrates (bends or stretches), re-emits
4. absorbs, excites, re-emits
5. absorbs, breaks apart into components

Other notes:

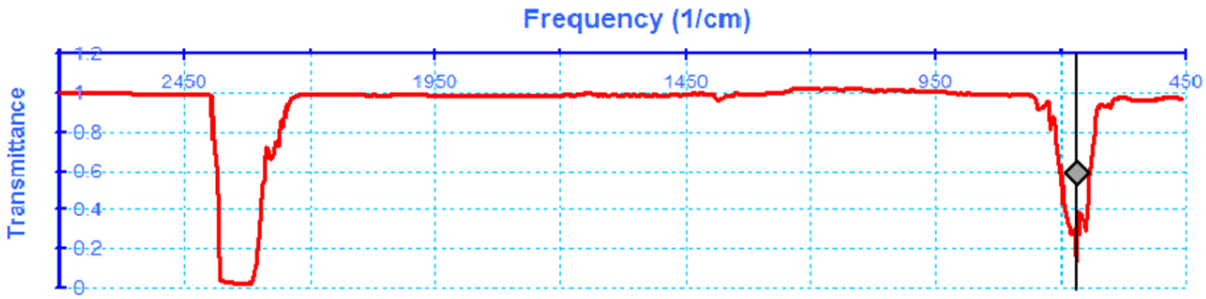
- we need a "**Return Molecule**" button when bonds break
- see *Laser* sim for example of electronic absorption
- is it okay to show the CO *stretch* in the IR when the other molecules *bend*?
- see the *Photoelectric Effect* sim for example of UV, visible, and IR photons

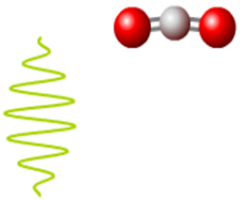




Online Resources

http://www.chem.arizona.edu/chemt/C21/sim/
see: CO2 absorption, CFC absorption





Teaching Ideas

From *Survival Handbook for the New Chemistry Instructor*:

To teach the electromagnetic radiation concept, you could explain how the ozone hole, global warming, and microwave ovens are all related by the fact that electromagnetic radiation of varying energies is responsible for each phenomenon. For example:

- UV radiation (high energy) breaks the ozone molecule apart, thereby contributing to the ozone hole. [Also: Ozone absorbs solar UV radiation. UV radiation is harmful because it has enough energy to break chemical bonds. Without ozone, more solar radiation would reach the surface.]
- IR radiation from the Earth (lower energy) causes carbon dioxide molecules to stretch and bend (without breaking bonds) and eventually is returned to warm the Earth.
- Microwaves (lowest energy) causes water molecules in food to rotate (not break or stretch bonds), thereby causing friction between the rotating molecules that heat the food.

Discussion

09/13/10 - *Mark McCaffrey*

MM: We look forward to the new panel on molecular absorption. When will it be released? Is there any interest at your end of hearing out thoughts on the challenges/opportunities of a sim that also addresses how different bandwidths are filtered by different layers of the atmosphere, etc?

KP: We are going to be doing a Molecules and Light sim that will be the 3rd tab of greenhouse broken out into its own sim, but with other molecules like O3, etc, and other ranges of radiation - UV, microwaves. At some point we will do more of a college-level of this type of sim with absorption spectra. That might be the time when we could consider coupling to an advanced greenhouse.

MM: If you are ever interested in discussing the idea you describe of the 3rd tab, let me know. Our focus is on the basics of climate science and the idea of other molecules and wavelengths is very much what we're looking for since (from research and experience) we know students and even many teachers who don't have a climate or physics background get confused about these fundamental concepts, which admittedly are not always intuitive to grasp.

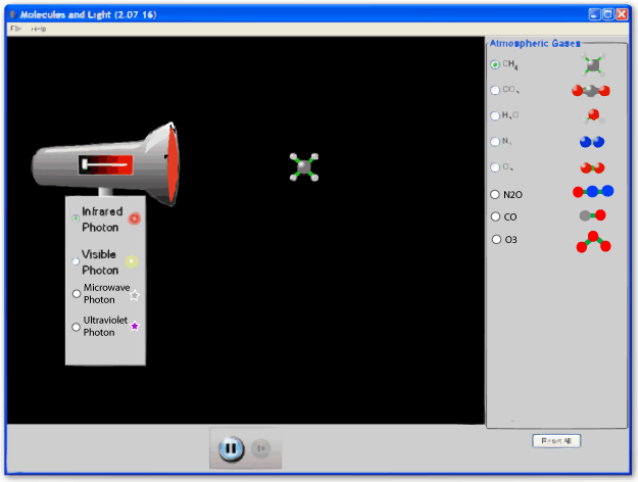
09/30/10 - *Goals*

KL: Thank you for all of the ideas during the meeting today!

Trish: can you search the K12 standards for anything about light interacting with molecules?
Robert: can you look at the table in the Google doc and enter what you expect to see for each molecule and each type of light?

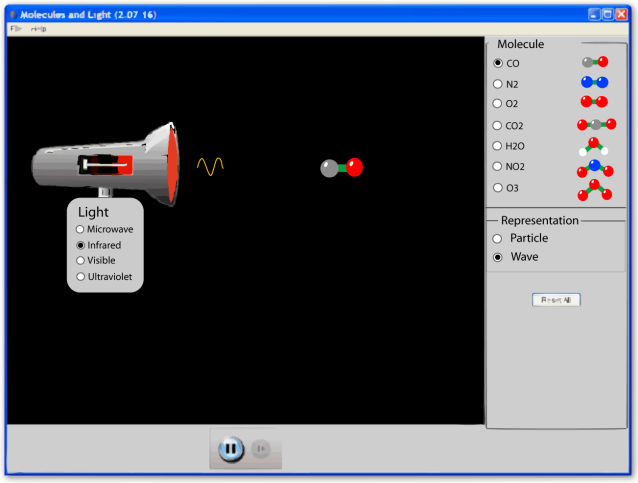
10/13/10 - *First Sketch*

JB: I modified a screen shot of the Photon Absorption tab to have no enclosing box, no "Build Atmosphere" option, additional compounds to choose from for the target, and additional photon emission selections. I thought I would run it by you to see if it looks like what you had in mind. Please let me know if this matches your thinking. If so, I'll go ahead and insert it into the spec.



10/19/10 - *Second Sketch*

JB: Sketch is attached. Let me know if you feel it is ready to be placed into the spec and, if not, what should be changed.



10/21/10 - *Photons vs. Waves*

- No wave representation of light b/c we can't show correct scale

- Show representation of EM spectrum; label high & low energy, but no #s

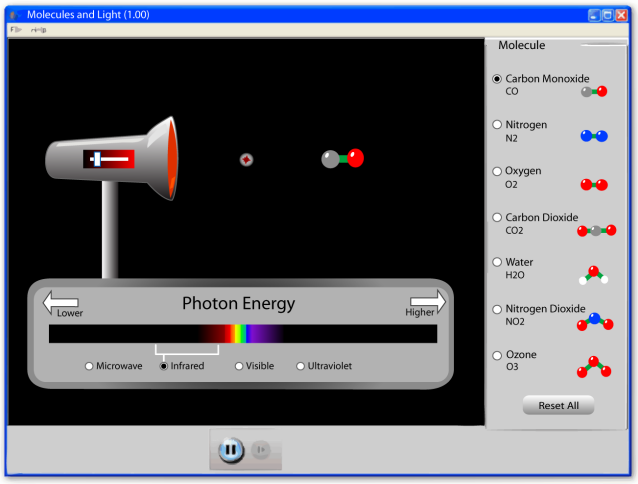
10/28/10 - *Wording*

- Match the photons used in photoelectric effect for the frequencies, but leave the ones in greenhouse sim (including the photon absorption tab) the same as they currently are (i.e. in version 3.0).
- Title of the control: Photon Energy (instead of Wavelength).
- Take "energy" off of the arrow labels so that they just say "Higher" and "Lower".
- Make the spectrum fade to black and have no color in both the IR and UV ranges.
- Add the chemical names on the molecule selector.

10/28/10 - *Third Sketch*

JB: Updated sketch is attached. This includes all changes recommended at today's meeting of the chemistry group. I'll also put this into the spec.

Let me know if anyone sees a need for any additional changes.



KP: Looks good to me ... a small detail, the final should have subscripts in the chemicals.

11/18/10 - *Electronic absorption & Resonance structures*

- Halo for non-oscillating energy absorption.
- Representing delocalized bonds (i.e. resonant structures): Choose one arbitrarily rather than using any dotted lines or anything. Have it random when it appears in the play area, and have it always break on the single bond. It can always appear the same way in the control panel.

12/02/10 - *Rotation & Dissociation*

http://www.colorado.edu/physics/phet/dev//greenhouse/3.01.03/

- Rotate a little slower so that re-emission is more noticeable. Maybe half the speed shown in 3.01.02.
- Yes on the random direction and random stop location for rotation.
- For now, don't worry about constraining emission direction.
- Should oscillate in whatever orientation it ends up in after rotation.
- There is a desire to have the wave view of light, we will discuss with Kathy.
- Dissociation: Should maintain the angle of the bonded pair.
- Dissociation: Should NOT oscillate before disassociating – should just break apart.
- Dissociation of O3: Neither fragment should emit any photons after separating (or before for that matter).

- Need a “Return Atom” button that should appear after dissociated atoms move off of the screen.
- Robert will email Maggie Tolbert about this sim and whether the dissociation behavior is reasonable, and whether the rest of it is reasonable.
- If it’s not too hard to show the O2 oscillating after dissociation, it should be implemented.
- Robert will think about whether the O2 should spin after O3 dissociates. For now, it should not.
- Speed of dissociation on O3 looks good on version 3.01.02, no changes needed.

12/13/10 - *Interface*

We talked about putting a label *on* the flashlight, but decided to first try flipping the radio buttons so that they are *closer* to the flashlight.

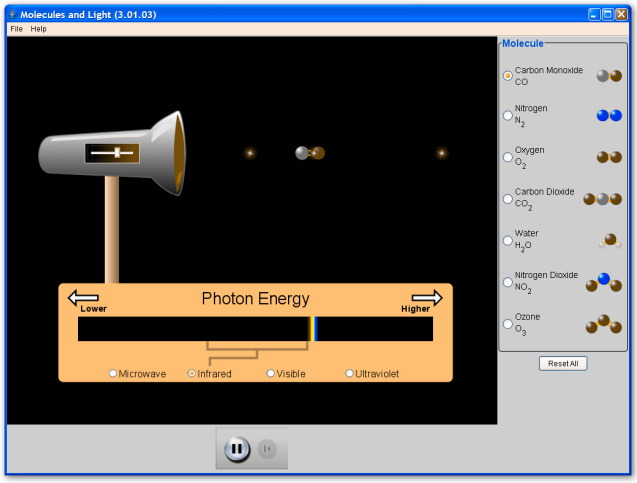
- Bigger font on the photon wavelength selectors
- Flip orientation of the photon energy control
- Use "Return Molecule" instead of “Restore Molecule”
- Make oxygen a little more orange so that it is more visible to color blind people against the black background, RGB = 255, 85, 0

12/13/10- we had a meeting, but didn't get to discuss the concern that Trish and Robert have about students thinking that the photons are acting in a kinematic way because they look like particles and we would like to discuss some more about a second representation that is wave-ish. We decided to bring it up again on the 16th.
-pat loeblein 12/13/10 1:04 PM

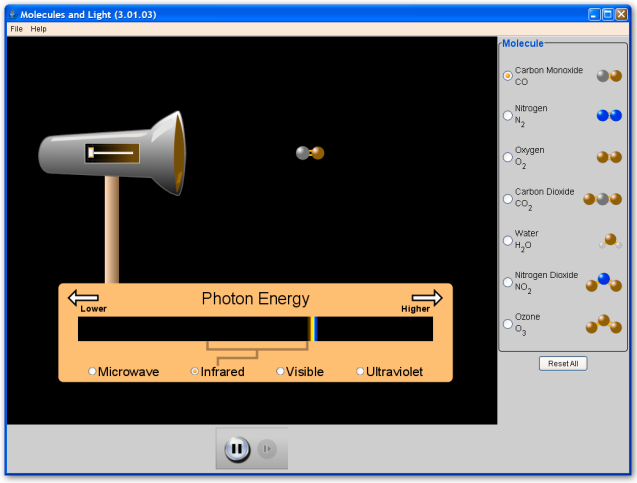
12/15/10 - *Colorblind Test*

JB: Thought y’all might find this interesting. The names of the attached files should make it clear what each represents, and I was struck by the magnitude of the difference for protanope color blindness, especially since I can barely see the difference between the version with red oxygen versus the version with slightly orange oxygen.

Red oxygen



Orange-ish oxygen



12/21/10 - *Wave Representation*

JB: I've published a new version of Molecules and Light at the link below. This version implements, as far as I know, all of the specified functionality. The dev page will contain a list of the recent changes.

Please give the sim a good test drive and provide any feedback.

The one outstanding issue that I know of on this sim is whether to try to incorporate any sort of wave representation.

http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.06/

JB: During today's weekly PhET meeting we briefly discussed the issue of whether there needs to be a wave representation of the photons in the Molecules & Light sim. The conclusion was that you should go ahead with interviews on the sim and see if many students draw erroneous conclusions about the nature of the photon-molecule interaction, and if so, whether such incorrect conclusions might be remedied by some sort of wave representation. Barring any bugs found during testing, I think that the current version should work fine for these interviews.

Let me know if you want me to sketch up some wave-oriented representations for use during these interviews.

12/29/10 - *Photon Control Label*

KL: I asked a few family members to play with this sim over the break:

http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.06/

One thing I noticed is that they all tried to click on the arrows for "lower" and "higher" energy. John is now working to make the arrows change the type of light.

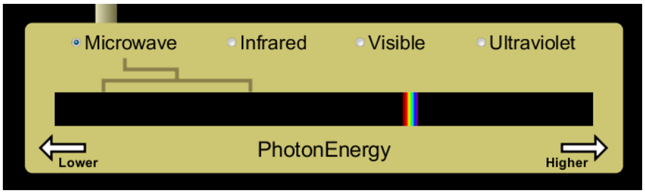
Also, the older folks did not see/use the slider on the flashlight until prompted to do so, but the college-age one found it right away.

Another thing I noticed is that they did not seem to know what was coming out of the flashlight. I heard the photons called "protons" and "electrons". One idea I had is to give the control box in the play area a title, such as "light". I attached before and after pictures.

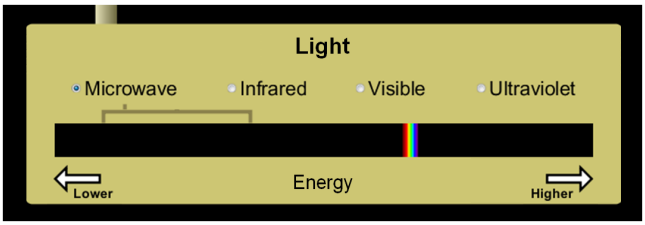
I will recruit students for interviews once classes begin on Jan 10 - hopefully this will tell us if we need to add a wave representation.

In lieu of a chemistry meeting this week, can you think about these ideas and give some feedback? Also, Robert: can you send Maggie Tolbert the link and ask her whether the absorption behavior is reasonable?

Before:



After:



JB: Here is a new version of Molecules & Light with the changes we discussed yesterday, i.e. bigger radio buttons and interactive arrows. These are nice changes – I like 'em.

http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.07/

KL: I like the changes too! I still think we need a title for the control box in the play area, as in the attached picture.

KP: I like the changes too. In terms of the title, I really like having the radio buttons at the top. I would like to keep the word Photon in the sim ... so perhaps keep 'Photon Energy' where it is, and maybe as an alternative, we can add some white text above the lamp that changes and says "Microwave Light", etc ...?

KL: I think the problem was that they did not associate the word "photon" with what was coming out of the flashlight. I'd rather not add more text, so let's wait and see what more formal interviews show.

JB: I am a bit reluctant to use the term "Light" in this context since I think most people think of light as the portion of the spectrum that is visible. Very few people (other than physicists) think of their microwaves as
emitting light.

The Wikipedia entry for light starts off with this: "Light is the portion of electromagnetic radiation that is visible to the human eye, responsible for the sense of sight." Here is the link: http://en.wikipedia.org/wiki/Light.

So, if we decide to label it at all, I would gravitate towards something like "Photons" or a label near the emitter that says "Photon Emitter".

01/05/11 - *Darin Toohey feedback*

KL: I work for PhET, and we recently designed a new sim on photon absorption to complement our existing sim on the greenhouse effect.

The latest version of the new sim is at:
http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.08/

(To launch the sim, click on the "production" link next to "Molecules and Light".)

We are about to begin interviews with students, but we'd also like to get your opinion as teachers and experts.

Can you take a look at the sim and tell us what you think? In particular, are the approximations we made for the absorption behavior reasonable?

Also, please let us know if you'd like to use this sim in your class this semester!

DT: Thanks for the link. How accurately are you trying to represent these processes? If you are just trying to convey basics (microwaves=rotation, infrared=vibration, etc.) you are mostly ok, although absorption of visible light by NO2 is dissociative). If you are trying to be even more accurate, there are some important details that are missing. Since I don't program these kinds of applets, I'm not sure how easy these details would be to convey, but I'll list a few anyway.

Photodissociation typically produces excited state products - in the case of ozone, this could be represented as an O2 fragment that vibrates and/or emits a photon (infrared, in this case). Same could be done with the NO fragment for NO2. If you want to get even more detailed, some of the O atom fragments of O3 photolysis could emit a photon (this would represent O(1D)), although this is a rare process...but it's extremely important in atmospheric chemistry.

CO absorbs in narrow bands in the ultraviolet, although it's not dissociative (unless the energies are very high). It's a convenient way to detect CO - by fluorescence.

For CO2, H2O, O3, and NO2, are you only trying to convey the bending mode in the infrared? The stretch modes (symmetric and asymmetric) are pretty important too.

Absorption of infrared will excite rotations as well as vibrations. And absorption of visible will excite vibrations and rotations.

Finally, I can't help but think how much more powerful the demo would be if one could have a slider over the wavelength (energy) scale in order to show how the behavior of these molecules changes dramatically for very small changes. For example, some IR frequencies are good at exciting bending modes, while higher IR energies will excite stretch modes. Similarly, low energy visible light won't break NO2, but higher visible energies will, and low energy UV will not break ozone, higher energy UV will produce excited state fragments, etc. I know this is a higher level of programming, but it would be a great tool, if it could be done.

I hope this is helpful. It's great that you are doing this!

KL: Thank you for the quick response - this is exactly the type of feedback we need!

We had a hard time deciding where to draw the line on accuracy with this sim. The issue is not how difficult it is to program, but what the learning goals are, and what population of students (high school, college) we hope to target. We did talk about a more advanced sim with a slider for photon energy, as you suggest.

Would the sim in its current form (with NO2 dissociation in the visible) be useful to you as a teacher, or is it too basic? We can certainly make it more detailed.

DT: The quick answer is 'yes' - any animation that can help convey a topic such as this would be useful. Books try to depict this in figures, so I think the real question is whether or not the sim is better than a figure.

It seems to me (just my opinion here, and not based on any experience) that if you want to keep it simple, then you probably don't need the different types of molecules. I realize what you are trying to

illustrate with the different examples, but then by having all those examples, you are (more or less) acknowledging that there are important details. So there are homonuclear and heteronuclear diatomics, linear and bent polyatomics, and molecules that absorb in the visible and ultraviolet. So already, for a class like my ATOC 1060, this is more detail than I usually present. But then, when I talk about the behavior of a fewer number of examples, I try to go into detail about the absorption process itself, which you have simplified.

So maybe there is a compromise here - you can have two levels of 'sim,' one that has a few examples to show what absorption of various 'classes' of EM radiation, as you have done already, and then a second one that brings in other molecules as examples of more complex behavior, and this could be where you try to illustrate the additional details I mentioned previously.

Just a thought...

KL: I like your idea to separate the examples from the process! We often do this in sims by using tabs - we give students more detail in portions, rather than all at once. This may be a sim that could benefit from tabs. I will bring this up at our next design meeting.

01/06/11 - *NO2 dissociation*

We decided to leave the NO2 intact in the visible, since NO2 only dissociates in the blue, and we show a yellow photon in the sim.

RP: Hello everyone. I've attached a couple of slides from Jose Jimenez' Atmospheric Chemistry lectures (http://cires.colorado.edu/jimenez/AtmChem/CHEM-5151_S05_L7.pdf). I think this confirms what we concluded at our last meeting: while NO2 does dissociate when exposed to the very shortest wavelengths in the visible region (<415 nm), for the most part absorption of visible light does not lead to dissociation.

01/10/11 - *Cora Randall feedback*

CR: I've only skimmed the comments others have sent out on this, so I hope I'm not repeating anything. Maybe I just missed it, but one thing that I think would be very useful here is to have an explanation of what's going on (in words), rather than just a picture.

Also, it looks like the visible photons don't react with ozone at all. But ozone has a strong absorption band at 600 nm that is used routinely in remote sensing.

KL: Thank you for the comments! We can make ozone absorb in the visible - should it behave like the current NO2 absorption?

We try not to add text to the sims if at all possible, so teachers can more readily adapt it for their students. But I do think this sim in particular may need more guidance from teachers.

DT: I think that Cora's comment about ozone should be considered as possibilities for the sliding wavelength scale. To first order, ozone doesn't absorb very much in the visible - certainly relative to NO2, which is a brown gas at very low concentrations. The ozone band that Cora is referring to is quite useful for long path remote sensing, but otherwise does very little in the atmosphere as far as absorption or visibility. So if one could develop a second demo that allowed for a slider for wavelength, one could illustrate these kinds of effects in a better way, than just a single process for "this is what happens in infrared, or visible, or UV, etc."

Another aspect that would be useful to illustrate in such a sliding wavelength scale demo would be the cross section, or efficiency, of absorption. One could use a meter attached to a detector, for example, to illustrate a crude Beers Law, so that a weak absorption could give a small deflection on a meter, whereas a stronger absorption, like for NO2, would give a bigger deflection.

In my mind, Cora's comment is similar to the one I made where one has to be careful not to include

too many different aspects in one simulation - otherwise, the time it would take to explain all the subtleties would take away from the main message. Perhaps the issue is in the choice of molecule - ozone (and some of the others, for that matter) doesn't just absorb in one region. Water, for example, absorbs in the deep UV, as well as the microwave and infrared. So picking a molecule for each wavelength region is the tough part, unless you are just trying to illustrate the main spectral features, and not all the more subtle ones.

KL: Thank you for the clarification! In the same vein, we decided to keep the NO2 visible absorption as is in the current sim - ie, no photodissociation - due to the info from Robert Parson below:

Hello everyone. I've attached a couple of slides from Jose Jimenez' Atmospheric Chemistry lectures (http://cires.colorado.edu/jimenez/AtmChem/CHEM-5151_S05_L7.pdf). I think this confirms what we concluded at our last meeting: while NO2 does dissociate when exposed to the very shortest wavelengths in the visible region (<415 nm), for the most part absorption of visible light does not lead to dissociation.

We will show NO2 dissociation when we add a slider for photon energy, and we will also think about how to best show absorption cross sections.

DT: Yes, NO2 (and ozone, and most molecules, for that matter) will have regions that are dissociative, and those that aren't. The reason that NO2 photolysis in the visible is so important is that it forms ozone in the troposphere. So we tend to think of absorption of visible light by NO2 as being the critical step in that process. Non-dissociative absorption is interesting, but it doesn't do much, other than give NO2 some color in the visible (and add a tiny bit of heat to the atmosphere).

Again, I think the issue is that one has to be careful in their choice of molecules to represent something simple, without raising lots of other issues that are, potentially, far more interesting.

01/13/11 - *Response to interviews*

Notes from Dev meeting:
Kelly talked about interviews. First student thought the spectrum shown would change for different molecules. They were confused. Both students didn't understand what photon energy was referring to. Recruited from weather and the atmosphere, a class for non-majors. One student noticed details of rotation and patterns of breaking apart. Tried to connect to everyday experience. Both used word light. One student talked about waves and rays. Second only started talking about photon after slowed down. Took one student a while to figure out the slider. Kelly said slider looks different on her computer. When slider all the way to right misinterpreted bouncing instead of absorbing. Kathy suggested change max rate. Helpful to see if actually does something quickly. Kelly suggested get rid of spectrum all together. Will discuss more this afternoon. John suggested labeling, microwave photon, infrared photon, etc.

Notes from Chem meeting:
- Add arrows back with captions to the inside: "Higher Energy" and "Lower Energy"
- Slow max emission rate, about equal to current 1/2 way point
- Add button and ability to show spectrum. (KP wants to show the types of light *belong* on a spectrum) Translatable. Grab an image initially and incorporate. Caption: "Show Light Spectrum"
- Follow up on mini-slider handle
- Fix up the photon images

01/20/11 - *Spectrum window*

Notes from Dev meeting:
- Where to put photon icon?
- What to show in spectrum?

Changes to photons/radio buttons. Will recode a picture of light spectrum to make it easy to understand and make it translatable. Talk about light spectrum further. Also, look into vertical

orientation… and move photon pictures to make them look less like radio buttons. Slider – on Win7 and Vista it is really small. It is just how it is… not easy to fix but will probably be useful since all future sims with sliders will be small.

Notes from Chem meeting:
- Have a single arrow on control panel to depict the direction of increasing energy instead of the current two arrows.
- Slower rotation - “lazier” sort of look

Remove visible light zoom-in from the bottom
Add energy arrow, should be fun looking, same as on the main tab
Regions named and inside spectrum so that it is clear they are regions, not individual frequencies
Keep the wave representation
Kelly and John will work together to draw up a representation and then circulate it for review so that we can get an agreement before starting to code up a translatable version.

01/21/11 - *Energy arrow*

JB: This version includes the bulk of what was discussed during yesterday’s Chemistry Group meeting. There is a full list of the changes on the dev page, but the main things we need feedback on are:

- The window that appears when the “Show Light Spectrum” button is pressed. This is a custom sketch now (as opposed to an image downloaded from the web), and once approved I will create a translatable version. The wave at the bottom is known to be lame – this is just a sketch, and it’s hard to create something like that by hand, so it will look better in the final version.
- The energy arrow on the photon selector panel. I tried to make it match the one in the spectrum window, but it is a little too bright and eye catching for my taste, so I want your input. I think I need to make it a bit smaller and less bright, but still somehow visually connected to the one they will see in the spectrum window.

Link: http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.12/

KL: My slider looks the same - did you not include the fix in this version?

The window is so large that it is hard to see the sim behind the window. Do you plan to eventually scale this down? Also, is "UV" translatable? I feel less strongly about the wave representation now.

I agree that the energy arrow in the play area is distracting. Do we really need to use the same arrow in both places? Also, it should only say "Increasing energy". I'd prefer a line arrow, with the text above or below.

JB: The slider isn't fixed, since the problem is in common code and I need to follow up with some of the other developers before making the change.

The window can be smaller. It is large now so that the numbers are readable. It would be great if you could give me some sense of how much smaller it should be (e.g. 70% of the current size).

The same arrow and caption were used so that it would be easier for users to make the connection between the photons on this panel and the spectrum. I think that this was suggested in the meeting. We don't have to do it, but it sounded like a good idea to me. I think it would be good to at least use the same caption, but we could easily go with a smaller and less distracting arrow.

KL: I'd say the window should be as small as possible, but such that the text (and numbers) are still readable. It's the same size as the play area now, so maybe 50% smaller?

I don't think the arrow has to be the same in both places for students to make the connection. I also hesitate to put the word "frequency" in the play area, since we only show photons and it's another

word for students to make sense of.

TL: I think it looks ok.

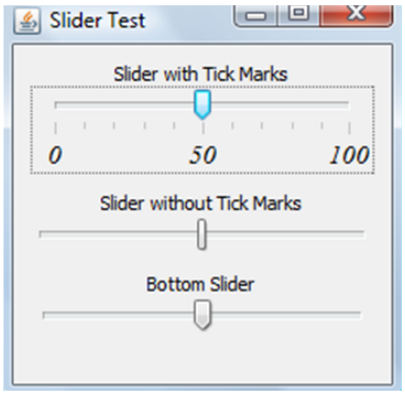
KP: I definitely agree not to use the word frequency in the play area

01/24/11 - *Slider issue*

JB: Since each of you run somewhat different OS configurations, could you please run the following app and send me a screen shot of what it looks like? This is to gather data on the slider issue that Kelly pointed out for Molecules and Light.

Link: http://www.colorado.edu/physics/phet/dev/temp/slider-test.jnlp

KL: Here is a screenshot using Vista.



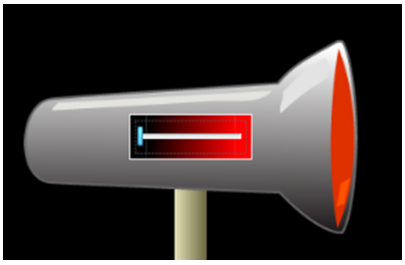
CM: If the narrow slider thumb for tickless sliders really bothers you, try setting property Slider.thumbWidth.
List of JSlider properties is here: http://www.java2s.com/Tutorial/Java/0240__Swing/CustomizingaJSliderLookandFeel.htm

Or set your own custom thumb like this:
http://www.java2s.com/Code/Java/Swing-Components/ThumbSliderExample2.htm
The disadvantage here is that you need to do this for each slider, or create a subclass that's used whenever you need a slider. In either case, not a good solution.

Either of these would be preferable to forcing an incorrect (but wider) thumb using setPaintTicks(true). And any solutions should be wrapped in "if PhetUtilities.isWindows() { /* your code here */ }".

If it were me, I'd live with it. For better or worse, that's the Win L&F.

KL: The problem is not aesthetic - it's that students do not use the slider thumb.



SR: I don't think Windows respects the "Slider.thumbWidth" property:

http://stackoverflow.com/questions/1374801/java-adjusting-jslider-looks-on-windows-laf

Here's another way to set the thumb icon, which doesn't require subclassing everywhere:
http://www.java2s.com/Tutorial/Java/0240__Swing/SettingThumbIconforJSlider.htm

But "if (PhetUtilities.isWindows()) setPaintTicks(true)" might be a good solution since it keeps the slider looking like the rest of the windows laf instead of a button we try to draw ourselves.

CM: If students are not using this thumb, then presumably this is a problem with all tickless sliders on Windows. Are you proposing that we need to call setPaintTicks(true) for every slider we use? Or are we somehow going to be selective about which sliders we decide are important enough to warrant this workaround?

This is one more thing that we're unlikely to remember to do, like the setOpaque workaround needed for many Swing components.

KL: The problems in this case are that: 1) the slider is embedded on an image, and 2) it is not labeled. And students *must* use it for anything to happen in the sim.

CM: The ticket is assigned to phetcommon, and says that this problem "appears in a number of simulations". So I'm inferring that this is a general problem for all tickless Windows sliders. If we're solving the problem for one slider, that's easy, pick any of the solutions proposed so far. If we need to solve this for all sliders, that's a different issue, and I have yet to hear an acceptable solution. So... What is the scope of the problem that we're trying to solve here?

SR: It sounded like Kelly said that this specific instance is particularly problematic because of the location and behavior of the slider:

Since there is no clear need or solution for applying this to all sliders, we could just apply it on a case-by-case basis for now.

JB: I wouldn't worry too much about it being assigned to phetcommon. I'm not saying that it needs to be solved in all sims, but I felt that I shouldn't implement a change for M&L without at least considering the other sims that
use this same class. So the question is, in our collective opinion, does this need to be changed for all sims, just M&L, or none of them?

I would like to change it in M&L, and I think Kelly would too. Feel free to express an opinion in the ticket about fixing it in the other sims.

CM: Yes, I do understand the issue in Molecule and Light. But I'm trying to reconcile with what's in the ticket, where this is identified as a general problem. This is a problem (for the same reasons that Kelly mentioned) in Greenhouse Effect, Lasers, Color Vision (mitigated by use of a Wiggle Me), Optical Tweezers (see the laser power slider), ... If you want to solve these one at a time, that's fine with me. In the longterm that will be more expensive, and more difficult to change.

CM: Why in M&L and not in Greenhouse? They are the same user interface, with the same problem, in the same project.

JB: Yes, apologies for the lack of clarity, I meant in both Greenhouse and M&L.

(Also see Unfuddle ticket 2682)

01/25/11 - *Light spectrum*

- Worked on the arrow on the control panel until it looked reasonable.
- Scaled the spectrum to about 75% of the size in 3.01.12 (current version) and decided that this looked better.

- Made the spectrum wider so that UV can be Ultraviolet.

01/27/11 - *Website info*

- Spectrum looks ok in 3.01.12, John should go ahead with translatable version
- RP: consider wave representation in advanced sim (add Spectroscopy sim to pipeline)
- CO has a triple bond
- For teaching tips: students may think the photon *collides* with the molecule, helps to slow down photon rate
- Write activity: find patterns, etc.
- Update credits - Is it possible to make them unique per flavor?
- Trish will check learning goals in spec and update (if needed) so that they can be put into the sim page when published.

01/31/11 - *White background*

JB: At the last meeting we decided that Isotopes should have an options feature that allows setting the background of the black area in the 2nd tab to be white. This would apparently make it easier to create activities that can be easily photocopied. Do we need this feature added to the Molecules & Light sim as well?

KL: The screenshots that I used for the M&L activity looked fine on a black-and-white printer. How much time would it take to implement the feature?

JB: I would guess that it would take an hour. This is rough, since I haven't done it before, but it seems pretty straightforward.

KL: I don't see a need, but Trish may differ.

KP: Sam and JO are doing the same thing for Gravity and Orbits right now. It seems like a pretty useful feature for teachers.

01/31/11 - *Wavelength units*

JB: Should we use meters (m) or nanometers (nm) to label the wavelength side of the spectrum diagram in M&L? I mistakenly used nanometers in the prototype drawing but labeled it as meters, so we need to decide which one we really want.

KP: I vote for meters.
TL: Meters make more sense to my students.
KL: Definitely meters.
RP: Yes, meters.
JB: OK - meters it is.

02/01/11 - *Resizable spectrum*

JB: I'm almost done coding up the spectrum window, and it occurred to me that since it is now done in software rather than as a static image, we could easily support allowing the window to be resized. I could potentially see this as being useful in a lecture situation if a teacher wanted to maximize it in order to make it more visible on a projected screen. The down side is that blowing it up could hide the main sim window behind it.

What do you think – worth doing? I would estimate about ½ hr of my time to do this.

KL: If it would only take 30 mins to code, then I say go ahead and make the window resizable.

02/02/11 - *New spectrum*

JB: See the list on the link for a detailed list of changes, but the main change is the addition of a translatable, resizable version of the spectrum window. This should be considered a release candidate for the first production version of this sim, so please test accordingly.

http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.14/

KL: This is very close! Here are a few comments on the spectrum:

The "rainbow" for the visible region is flipped.

The wave representation looks a bit stretched in the radio region. Is this code or a picture?

Reset did not change the spectrum back to its default size. The default size could also be a little bigger.

TL: I tested ths sim for about 15 minutes and did not break it. I personally found it easiest to just put the EM slider on about 1/2 power and toggle through the molecules to see what happens. I did write Kelly a note about the fact that I was a bit unclear how to interpret the "glowing". I really didn't even notice it for a while and had to go back through all the photon regions to see when it occurred. I do think many teachers will not know how to explain the photon capture and release, although I can imagine how I will use this to talk more about emission spectra. Presently, I use Models of the Hydorgen atom, but it is nice to have an example where students can see molecules since they know that Hydrogen model for anything is a grand over-simplification for the rest of material.

I think this is a very useful sim and that we will get good use of it by teachers.

JB: Comments below.

The "rainbow" for the visible region is flipped.
[JB]: Dang! I noticed this initially when I created it, then forgot to fix it. I'll take care of it.

The wave representation looks a bit stretched in the radio region. Is this code or a picture?
[JB]: It is code. We can tweak it during the chem meeting if you like.

Reset did not change the spectrum back to its default size.
[JB]: I had not thought at all about hooking this in with reset. I guess it makes sense. Since the default condition is for the spectrum diagram to be hidden, reset all should hide it, set it back to its default size, and move it back to its default position. Agreed?

The default size could also be a little bigger.
[JB]: I will make it a touch larger.

02/03/11 - *Wave model*

KL: I was trying to think of a way to model the spectrum wave, and I had the idea to piece together sine functions. Is there an easier/better way to do this?

JB: This is fairly close to what the code does, except that I change the frequency continuously to avoid discontinuities in the wave form.

KL: Did you use a "chirp" to generate the wave?

http://en.wikipedia.org/wiki/Chirp

JB: Well, yes, though I didn't know that this was the term. I just coded it up pretty much like it describes in the article.

02/03/11 - *Meeting notes*

Notes from Dev meeting:
Molecules and Light – doing final push to publish. Biggest change is adding of Light Spectrum – fully translatable. Written in picilo(sp?) so it can be resized. Visible spectrum needs flipped. Will discuss in Chem meeting. Another Q for everyone… what should "reset all" do. Kathy thinks it should close light spectrum and reset to default size. Probably will publish by next meeting. Kathy – can Kelly (or Emily) email it to Texas teachers to see if they want to use next time.

Notes from Chem meeting:
- Changes to Spectrum diagram, include flipped visual portion, changes to wavelength picture, larger default size, and the window's behavior on a "Reset All" look good.
- There are no more todo items, so John should publish for review and, if there are no changes requested by end of day on this coming Monday, this should be published to the production server.

02/04/11 - *After dissociation*

JB: I was just looking through these tips and noticed the part about dissociation producing exited products. It would be quite easy for me to change the sim so that the O2 produced in the ozone dissociation and the NO produced in the NO2 dissociation are actually vibrating. I'm thinking that we might as well, and then we wouldn't need this tip.

You folks ok with that?

KL: I really do not think it is a goal of this sim to show what happens after dissociation, but I will let Robert decide.

JB: I agree that it's not a goal. But, if one of the behaviors that the sim exhibits requires a line item in the teaching tips document, and that behavior is easy to change, it seems to make sense to change it. If students notice that the vibration is occurring after dissociation, they may learn something. If they don't notice, no problem, since it wasn't a goal anyway. It's sort of like "Bonus Learning" :)

KL: Yes, but it could also be distracting. We make so many other *drastic* approximations in this sim that it seems weird to include this detail.

RP: I tend to agree. Also, in the UV-B region (the wavelengths that are of most interest for the application to the ozone layer), I don't think there is much vibrational excitation (I will check on this). One more thing that could go into a more advanced Spectroscopy sim...

JB: OK, based on Robert and Kelly's input, I won't implement post-dissociation vibration. Just to see what it looked like, I prototyped it, and it took me literally 10 minutes to implement, so it would be easy to do it either way. However, since Robert says that there isn't much vibration in the UV-B region, it seems to make sense to leave it out.

We should probably amend the teaching tips to say that in SOME UV bands, vibration can occur in the products of dissociation.

02/04/11 - *Release candidate*

JB: This version is a release candidate for the Molecules and Light sim. Please check it out and let me know if you find any issues. If possible, I'd like to get all feedback by end of the day on Monday.

http://www.colorado.edu/physics/phet/dev/greenhouse/3.01.16/

Below are the changes since the last version:

- Added a feature where the background can be changed to white. This is done to support the creation of activities that need to be photocopied in black & white.

- Made the spectrum window disappear and go back to its original size and position when Reset All is pressed.
- Switch to exponential chirp
- Flipped the visible spectrum
- Made the default size of the spectrum window fixed
- Fixed the location of the arrow pointing to the visible spectrum

02/08/11 - *Split from Greenhouse*

JB: The more I think about it, the more I think that I should break out Molecules and Light into its own sim, rather than being a flavor of Greenhouse. I did it as a flavor in order to maximize code reuse and save time, but it ended up diverging a lot from the Photon Absorption tab anyway. Splitting it out would solve the issue about the credits, and would also allow this sim to go out initially as version 1.0 instead of the 3.whatever version that it will be if it is releases as a flavor of Greenhouse. It would also decouple updates for the two sims, since now an update of Molecules & Light would trigger updates for Greenhouse. It is also less likely to confuse translators. And besides, after talking this over with Sam and Chris, I get a sense that this sort of thing isn't really what the flavor concept was intended to support anyway. It was more about doing things like Faraday, where there are several very similar versions of what is essentially the same simulation.

I would like to do this, but it will probably take several hours of work, and I wanted to run it by the two of you first. I feel it is worth it for the reasons outlined above and to simplify long-term maintenance of this sim. Are you okay with it?

KP: OK, do it. I'm pretty sure this is going to take more time, but I guess its probably better in the long run. Hopefully I worry for no reason, but I do worry about bugs creeping into both sims, so please take extra care and we'll need to do very thorough testing on both when its done.

JB: With copious amounts of help from Sam, I'm happy to announce that Molecules and Light has been separated from the Greenhouse project into its own separate project. The separation effort went quite well, and I think both Sam and I were ultimately quite happy with the result.

Please give it one more test drive, making sure to check the credits, and if we find no issues I will post it to the production server.

http://www.colorado.edu/physics/phet/dev/molecules-and-light/0.00.02/

Interviews

Recruited students from ATOC 1050: Weather and the Atmosphere

S1M
01/12/11 v 3.02.00
(EM observed)

Warm-up:
International affairs, Italian, 2nd year
Likes science, not math, no sim use

Sim:
Says diff types of light waves
Clicks arrows, radio buttons
Thinks it shows the spectrum of the molecules
Says not sure why it did not move (the spectrum)
Finds slider after 1 min - says ok, turned it on
Says MW spins H2O, but the waves are not always sent off in diff directions; vis waves go through,

UV same
Picks CO: MW spins, heats it up; IR heats too, but slower; predicts that vis & UV do nothing
Picks N2: not affected; same for O2
Picks CO2 - not affected by MV, probably not IR - oh, no, IR changes it; vis, UV do nothing
Picks H2O: MW heats up fast, IR slower, vis, UV do nothing
Picks NO2: MV speeds it up, IR less; vis causes it to *blink* - UV rays break it apart
Picks O3: MW speed it up again, occasionally *bounce* off it; IR makes it wiggle, vis nothing, UV ray breaks it up
Again, says not sure why it did not move (the spectrum) - oh, it tells you where visible light is - thought it (the spectrum) would change for each molecule
Says did not see slider at first
Says not sure *why* UV breaks O3
Calls photons *rays* - not sure what photons are
Thinks motion means it *heats* up
Says the sim shows what diff types of light do to the molecules - interacts in diff ways
Heat = moves, vibrates
Says MW is hottest - UV just penetrates
Says NO2 is only one affected by vis - not sure *why*
Wants explanation
Learn? diff types of waves affect molecules in diff ways - not sure *why* it's diff

Follow-up:
Spent about 15 mins on sim

Notes:
Did not notice slider at first
Tried each molecule with each type of light - very systematic
Thought the "spectrum" would change for each molecule (see example below)
Called photons: light, waves, rays - not sure what photons were
Equated motion with heat, so thought MW was the hottest
Learned that diff types of waves affect molecules in diff ways - but not sure *why* it's diff

S2M
01/12/11 v 3.02.00
(EM led)

Warm-up:
Architecture, 3rd year
Used lots of design software

Sim:
Sees buttons for type of light, molecules
Clicks on arrows, reset
Clicks on flashlight, says it puts light through molecules
Says can change how fast the *little dots* come out
Says the angled ones break up (in the UV) - *wonder* if same for IR
Says some *bounce* off, some go through
Says CO gets pulled, also bounces - MW makes it spin
Calls it "reactions"
Says vis & UV go through CO
Picks N2: nothing happens, same for O2

Picks CO2: IR makes it bounce off every now & then
Picks H2O: MW makes it spin, some light bounces off
Picks NO2: IR makes it move, vis makes it light up, UV makes it break
Picks O3: MW makes it spin both ways, some IR bounces off, some goes through, UV makes it break the 1st time it's *hit*
Learn? UV more reactive than other types; H2O not reactive; if molecule has bend, it can break
Thinks it's a *reaction* when it breaks
Dots? Could be photons, not sure
Tries to find pattern for IR - says IR photons *hit* molecule
When NO2 lights up: maybe absorbs photons, heats up
Says could add curve to show diff wavelengths
Says not sure what "photon energy" refers to
Wants label on flashlight (intensity)
Says when slider to right (in vis), like noon in July
Curious if about the atmosphere
Says you learn what types of light interact w/ molecules in the atmosphere
When low intensity: most of the time it absorbs, then *spits* it out
Thinks the photons should be distorted after go through water
Says diff reactions for each type of light and each type of molecule
Wants info for each molecule - O3 is most reactive - curious *why*
Notices that single bond breaks
Says he knows MW heat water up - give molecules energy
Notices CO spins both ways
Says MW is the one that makes it spin - curious *why* - says IR makes it bounce
Says N2 & O2 do nothing - tells me they are "stable", maybe why so common
Still thinks the photon should change after it goes through water - knows light gets distorted in water
Slows down NO2: when absorbs photon, spits it back out - likens it to radiant heat
Says IR also spits out after absorbs; MW also "emits"
Says O3 is reactive - then says something about e-s and orbits (?)
Curious about pause button - oh! can study reaction step-by-step
Wants to rewind
Says teacher could pause & explain *why*

Follow-up:
Spent about 30 mins on sim

Notes:
Used the word *bounce* a lot until he lowered the rate of photons - then used the word *absorb*, said that it "spits it back out"
Called photons: light, dots, then photons
Said you learn what types of light interact w/ molecules in the atmosphere
Thought the photon should change after it went through water - knew light gets distorted in water
Paid attention to details, like direction of spin, how the single bond breaks, etc.
Kept on playing...

S3F
01/13/11 v 3.01.10

Warm-up:
Anthropology, 1st year
Used PhET in HS physics

Sim:
Clicks arrows first - clicks really fast!
Says it shows what diff types of light do to molecules
Says the higher you go, it splits some of the compounds
Says diff types of light *react* diff w/ molecules

Says this one (NO_2) takes some particles in...
Says it *reacts* diff with every one - it holds in vis, takes in IR, bounces them out
Says it takes in the MV ones - looks like it takes in lot of energy, b/c it moves faster, then expels out
Says O_2 did not *react*
Says no need for arrows - later says "energy" helpful
Says it shows how molecules bond
Calls the photons "beads", or *particles*, coming out of light
Says the light goes to higher energy - some react w/ high energy, some don't, not sure *why*
Pauses the sim
Photons? Particles of light
Moving? Says molecule takes in particles w/ high enough energy to make it move
Says maybe it changes properties - does not move it, goes in there & affects it
Wants to know what it (absorption) means
Pattern? It was random what reacted w/ what
Wants a key to explain it (absorption)
Says when think of light, think of wave, a ray coming out, not little beads
Off camera: said at first thought arrows did something diff, since already in order of energy

Follow-up:
Spent about 10 mins on sim

Notes:
Did not play w/ sim while talking
Clicked on arrows too fast, not very systematic
Did not find any patterns - thought it was random
Called photons: beads, particles of light
Said the molecule "takes in" particles w/ high enough energy to make it move
Said the sim shows that diff types of light *react* diff w/ molecules - not sure *why*

S4M
01/14/11 v 3.01.11

Warm-up:
Music, 2nd year
Thinks science is cool, no sim use

Sim:
Tries to click on molecule in play area
Turns on slider, clicks arrows, then buttons
Says he is trying diff *waves* to see if will go through it, what happens
Says he's going to "try a diff molecule"
Realizes he can click on arrows
Says on UV, the last two molecules "go away" - tries to see which molecules *leave*
On MW, goes quickly through each molecule
Pauses, steps - asks: what is reset?
Says just testing diff ones to see what happens
Tries vis w/ each molecule
Learn? It's a model to see what happens when diff energies go through molecules
Says not sure what it means, but MW spins the last 3 molecules, shoots it out a diff way
Says UV takes the last 2 apart
Says on most, the energy goes through, nothing happens
Says vis lights it (NO_2) up, not sure what it means
Says not sure why molecule spins
(Someone interrupts)
Vibration? Says the IR *ray* goes in and bounces around, then shoots back out some other way
Photons? A single ray, maybe concentrated light
Pattern? Noticed that UV cut single bond for last 2 molecules

Wants more explanation - see what it does, not sure *why*
Learn? Shows what happens when diff rays go through molecules
Wants to know *why* MV spins it
Pauses, steps
Says it looks like it (IR) comes in, bounces around, comes out

Follow-up:
Spent about 10 mins on sim

Notes:
Did not seem to be systematic
Called the photons: energy, rays
Said the IR ray goes in and bounces around, then comes back out
Said the sim is a "model" to show what happens when diff rays go through molecules
Wanted to know *why* diff rays do diff things

S5F
01/25/11 v 3.01.13
(bad Camtasia audio)

Warm-up:
Business, 1st year
Used PhET in HS physics

Sim:
Clicks on spectrum, then radio buttons
Asks: what is the purpose?
Uses slider, says it controls the speed
On MW: clicks down list
Clicks on spectrum
On IR: clicks down list
Says not sure what happens to molecule when light goes into it
Also says the diff motions are hard to identify
On vis: clicks down list
On UV: same
Tries to see if speed of the light changes what happens to the molecule
Clicks reset
Says it shows how diff energies of light affect the diff molecules - some are not affected, some only affected by certain ones
Also shows where the light goes - it goes into it and bounces off in diff direction, or straight through
Says vis only affects NO2 - looks like it absorbs the light, then it bounces off
Clicks on spectrum
Says for some of the energies, speed does not affect what happens, only how quickly it happens
On O3: clicks through 'photons'
Says O3 is affected by MW, IR & UV light, but not vis light
Clicks on spectrum - to see why vis does not affect most of the molecules, but UV does, has higher energy than vis
(Drinks water)
On MW: pauses, then steps
Says for H2O, when MW light hits the molecule, looks like it is absorbed, which makes it spin or move, and as soon as another one hits it, it leaves
Says for NO2, once light is absorbed, it has to do full cycle or circle until the next light can be dismissed from molecule; same for O3
On IR: pauses, then steps
Says it looks like the same process for all light that the molecule is affected by - the light is absorbed, it takes the energy, doing a motion, when motion is complete it rejects the light, then new light can come in

Picks a molecule, clicks through 'photons'
Says N2 & O2 not affected - maybe because it only has 1 element - but that does not apply to O3
Wonders if bonds affect the action when light is absorbed - but says she can find no pattern
Says for H2O, looks like only the white balls absorb the MW light, not the red one; then sees not true
Photons? Not sure what light travels as
Spectrum? Good to see how much the energy increases, did not use wavelength
In HS, had more direction, but did not need it here
Likes the step button

Follow-up:
Spent about 20 mins on sim

Notes:
Clicked on the spectrum first, also used the slider handle (changes to the sim)
Very systematic
Tried to see if speed (intensity) of light changed what happens to molecules - saw that speed did not affect what happens, only how quickly it happens
Said the sim shows how diff energies of light affect the diff molecules - some not affected, some only affected by certain ones
Used the word "absorb" after she saw the NO2 glow
Used the spectrum to find out why visible light did not affect most of the molecules, when UV did
Used the step button to figure out what happens to molecules when light is absorbed - said it takes the energy, moves, when motion is complete it rejects the light, then new light can come in
Tried to find patterns for the molecules based on structure

Overall:
Words students used for photons: light, energy, waves, rays, dots, beads, particles of light, photons (only when on screen)
Water prompted a couple of students to connect to what they already know - microwaves heat up water, light is distorted in water, etc.
A couple of students equated more motion with more energy
When the light was not as "intense", students said the molecules "take in" the photon, not that the photon "bounces off" the molecule - two students used the word "absorb"
Students used the arrows more after the spectrum was removed (now the arrow is not interactive)
All students said the sim shows what happens when diff (photons) interact w/ diff molecules - most wanted to know *why*