Isotopes and Atomic Mass

Other title ideas:
Isotopes
Isotopes and Elements
Element Mass - Isotopes
Suzanne B: Abundant Isotopes

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Public URL:
https://docs.google.com/document/pub?id=1ViqZX7bAw-mahQgbN8eF_sNePDvC1GbA46PMgG5utg4

Abstract:
Are all atoms of an element the same? How can you tell one isotope from another? Learn how to calculate the average atomic mass of an element.

Contents

Learning Goals

Suzanne B on the *Build an Atom* sim:

As I was making He, there was no distinction between He-3 and He-4, but my instinct felt that

He-4 is such an important isotope that its abundance should somehow be reflected here. Ditto for all of the other elements as I think it helps users better understand atomic mass. I like the way the element lights up in the periodic table. Is it possible to have a small pop-up window come up once the user has created one stable isotope? The window could be very simple and include the atomic mass, the isotopes and their abundances. As the user adds neutrons the specific isotope in the popup could change color (or whatever).

Suzanne also said her students are confused by the non-integer atomic mass. We hope this sim will address both of her concerns. After using this sim, a student should be able to:

- define the term "isotope"
- compute the mass number of an isotope
- recognize that some isotopes are more abundant than others
- describe the average atomic mass of an element

TL updated the learning goals

- Define "isotope" using mass number, atomic number, number of protons, neutrons and electrons
- Compare and contrast: element, atom, isotope
- Given the number of protons, neutrons and electrons, find the mass and name of an isotope
- Given the name of an element and the number of neutrons, find the mass of an isotope
- Give evidence to support or dispute: "In nature, the chance of finding one isotope of an element is the same for all elements."
- Find the average atomic mass of an element given the abundance (probably a less technical term would be better) and mass of its isotopes

National Standards/Benchmarks (on NDSL http://strandmaps.nsdl.org/?id=SMS-MAP-2369 or AAAS http://www.project2061.org/publications/bsl/online/index.php?chapter=4#D4)

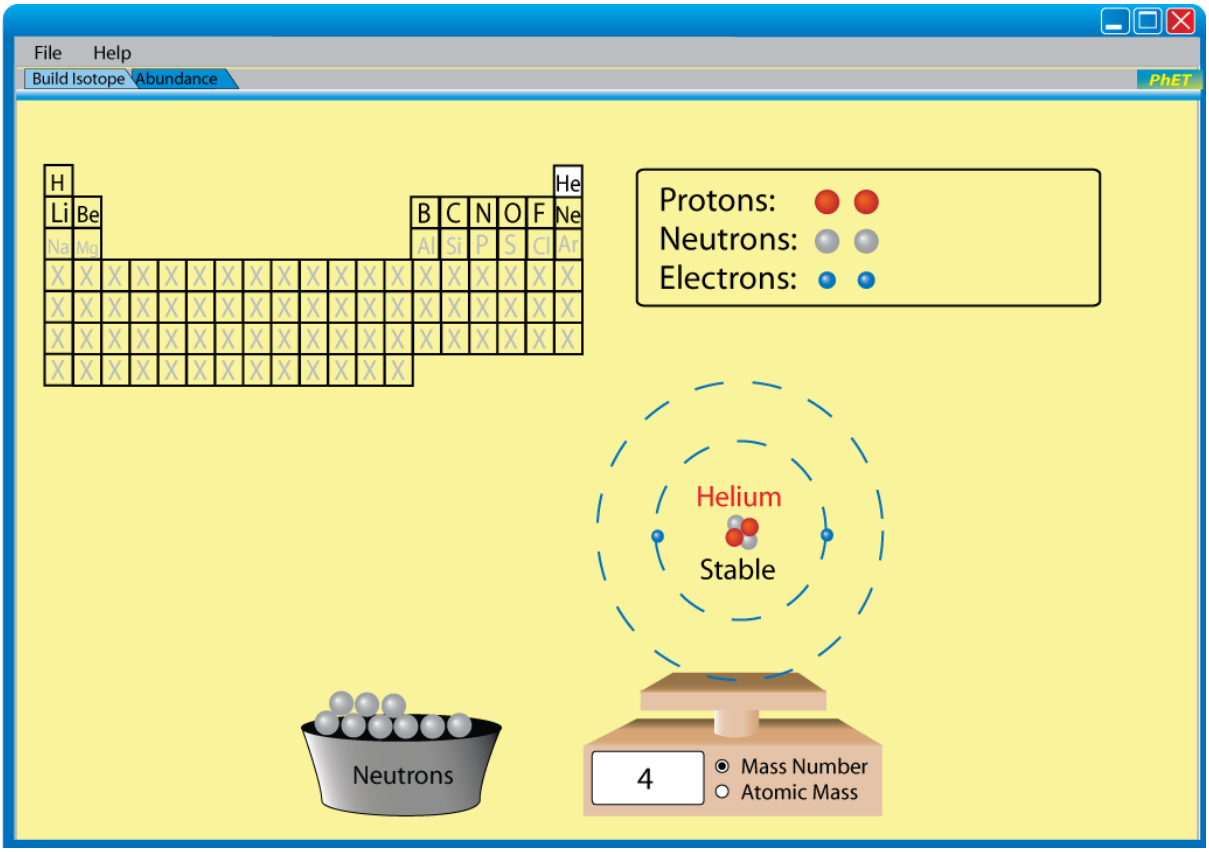
NSES Content Standard B Physical Science Standards
Introductions to Structure of Atoms

- AAAS:
    - 6-8 Going into details of the structure of the atom is unnecessary at this level, and holding back makes sense. By the end of the 8th grade, students should have sufficient grasp of the general idea that a wide variety of phenomena can be explained by alternative arrangements of vast numbers of invisibly tiny, moving parts. Possible differences in atoms of the same element should be avoided at this stage. Historically, the identical nature of atoms of the same element was an assumption of atomic theory for a very long time.When isotopes are introduced later, to explain subsequent observations, they can be a surprise and a lesson in the nature of progress in science. The alternative—teaching

atoms' variety at the same time as the notion of their identity—seems likely to be prohibitively confusing to most students.
    - 9-12 Understanding the general architecture of the atom and the roles played by the main constituents of the atom in determining the properties of materials now becomes relevant. Having learned earlier that all the atoms of an element are identical and are different from those of all other elements, students now come up against the idea that, on the contrary, atoms of the same element can differ in important ways. This revelation is an opportunity as well as a complication—scientific knowledge grows by modifications, sometimes radical, of previous theories. Sometimes advances have been made by neglecting small inconsistencies, and then further advances have been made later by attending closely to those inconsistencies.Students may at first take isotopes to be something in addition to atoms or as only the unusual, unstable nuclides. The most important features of isotopes (with respect to general scientific literacy) are their nearly identical chemical behavior and their different nuclear stabilities. Insisting on the rigorous use of isotope and nuclide is probably not worthwhile, and the latter term can be ignored.
- **NSTA**
    - *Structure of atoms*
        - The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element
- Specific Benchmarks:
    - Although neutrons have little effect on how an atom interacts with other atoms, the number of neutrons does affect the mass and stability of the nucleus. Isotopes of the same element have the same number of protons (and therefore of electrons) but differ in the number of neutrons. *4D/H3* (ID: SMS-BMK-0191)
    - Atoms are made of a positively charged nucleus surrounded by negatively charged electrons. The nucleus is a tiny fraction of the volume of an atom but makes up almost all of its mass. The nucleus is composed of protons and neutrons which have roughly the same mass but differ in that protons are positively charged while neutrons have no electric charge. *4D/H1* (ID: SMS-BMK-0189)

Mockup

First Tab - Make Isotopes



The student can select an element in the **periodic table**. Should one already be selected, or should the student select the first element?

A Bohr model of the most abundant isotope of that element will appear on top of a scale, along with a readout of the number of protons, neutrons and electrons, the name of the element, and a bucket of neutrons. The elements are limited to the first 2 rows of the periodic table because we show the Bohr model. Should the most abundant isotope appear, or should the student make the element stable by adding neutrons?

UPDATE: We use a cloud model instead of a Bohr model.

The student can only interact with the **neutrons** - they can add neutrons to the model or return neutrons to the bucket. In this way, they learn that isotopes are atoms that have the same number of protons but different numbers of neutrons. The student can select a new element in the periodic table to change the number of protons.

The scale gives a readout of the **mass number,** which is the sum of the protons and neutrons in the atom. Do we also want to show the **atomic mass** of stable isotopes? Yes! The student can use radio buttons to show “Mass number” or “Atomic mass.” If an isotope is unstable, we do not show an atomic mass.

UPDATE: We also show the **symbol** and **abundance** of the isotope.

The table below lists all **stable** isotopes for the first 3 rows of the periodic table. All other isotopes are radioactive. If the student makes an isotope that is not listed in the table, the nucleus will shake and the word “Unstable” will appear under the nucleus.

NIST table:

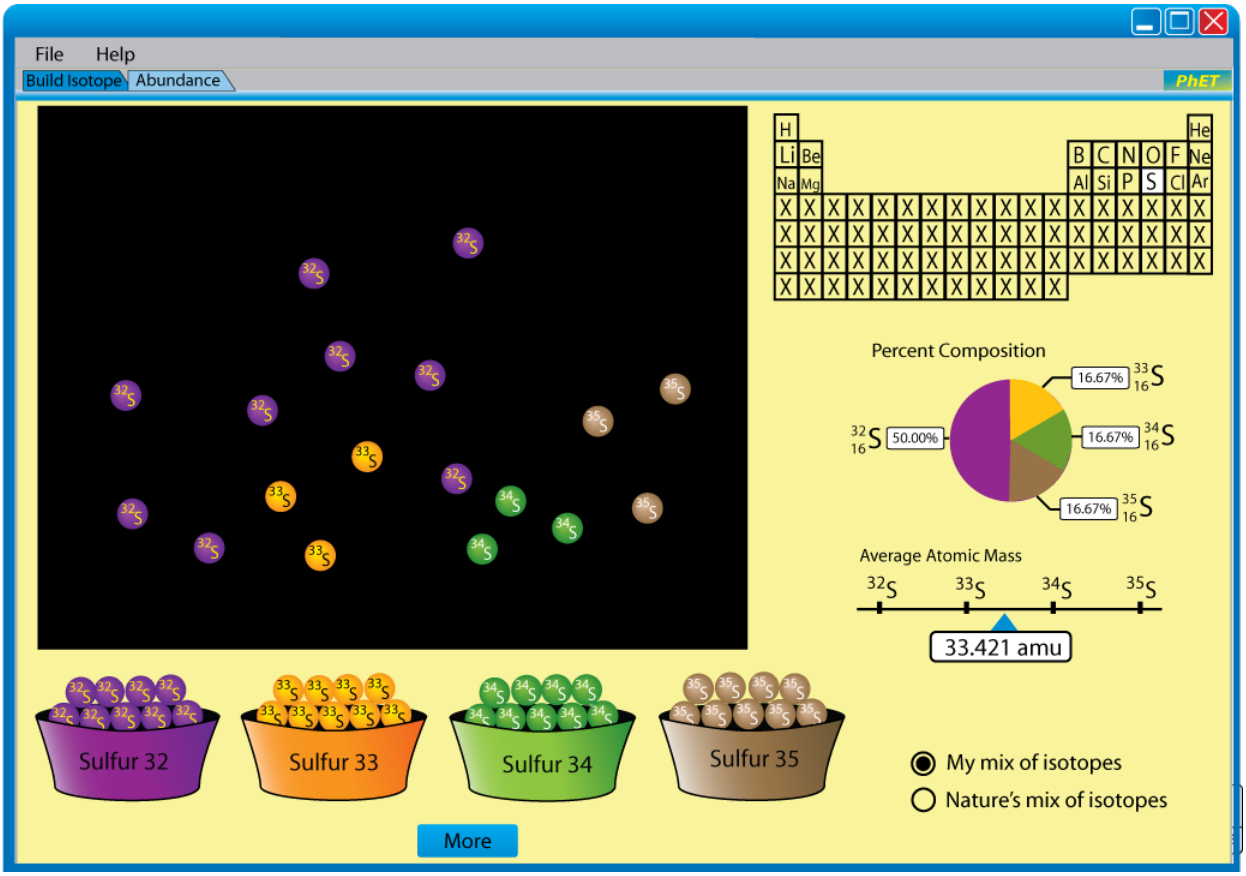
Isotope	Protons	Neutrons	Mass Number	Atomic Mass	Abundance %
H				**1.00794**	
1-H	1	0	1	1.00783	99.9885
2-H	1	1	2	2.01410	0.0115
3-H	1	2	3	3.01605	--
He				**4.00260**	
3-He	2	1	3	3.01603	0.0001
4-He	2	2	4	4.00260	99.9999
Li				**6.941**	
6-Li	3	3	6	6.01512	7.59
7-Li	3	4	7	7.01600	92.41
Be				**9.01218**	
9-Be	4	5	9	9.01218	100
B				**10.811**	
10-B	5	5	10	10.01294	19.9
11-B	5	6	11	11.00931	80.1
C				**12.0107**	
12-C	6	6	12	12.00000	98.93
13-C	6	7	13	13.00335	1.07
14-C	6	8	14	14.00324	--

N				**14.0067**	
14-N	7	7	14	14.00307	99.636
15-N	7	8	15	15.00011	0.364
O				**15.9994**	
16-O	8	8	16	15.99491	99.757
17-O	8	9	17	16.99913	0.038
18-O	8	10	18	17.99916	0.205
F				**18.99840**	
19-F	9	10	19	18.99840	100
Ne				**20.1797**	
20-Ne	10	10	20	19.99244	90.48
21-Ne	10	11	21	20.99385	0.27
22-Ne	10	12	22	21.99139	9.25
Na				**22.98977**	
23-Na	11	12	23	22.98977	100
Mg				**24.3050**	
24-Mg	12	12	24	23.98504	78.99
25-Mg	12	13	25	24.98584	10.00
26-Mg	12	14	26	25.98259	11.01
Al				**26.98154**	
27-Al	13	14	27	26.98154	100
Si				**28.0855**	
28-Si	14	14	28	27.97693	92.223
29-Si	14	15	29	28.97649	4.685
30-Si	14	16	30	29.97377	3.092
P				**30.97376**	

31-P	15	16	31	30.97376	100
S				**32.065**	
32-S	16	16	32	31.97207	94.99
33-S	16	17	33	32.97146	0.75
34-S	16	18	34	33.96787	4.25
36-S	16	20	36	35.96708	0.01
Cl				**35.453**	
35-Cl	17	18	35	34.96885	75.76
37-Cl	17	20	37	36.96590	24.24
Ar				**39.948**	
36-Ar	18	18	36	35.96755	0.3365
38-Ar	18	20	38	37.96273	0.0632
40-Ar	18	22	40	39.96238	99.6003

Second Tab - Mix Isotopes

We use S below as it is an extreme case of 4 stable isotopes.

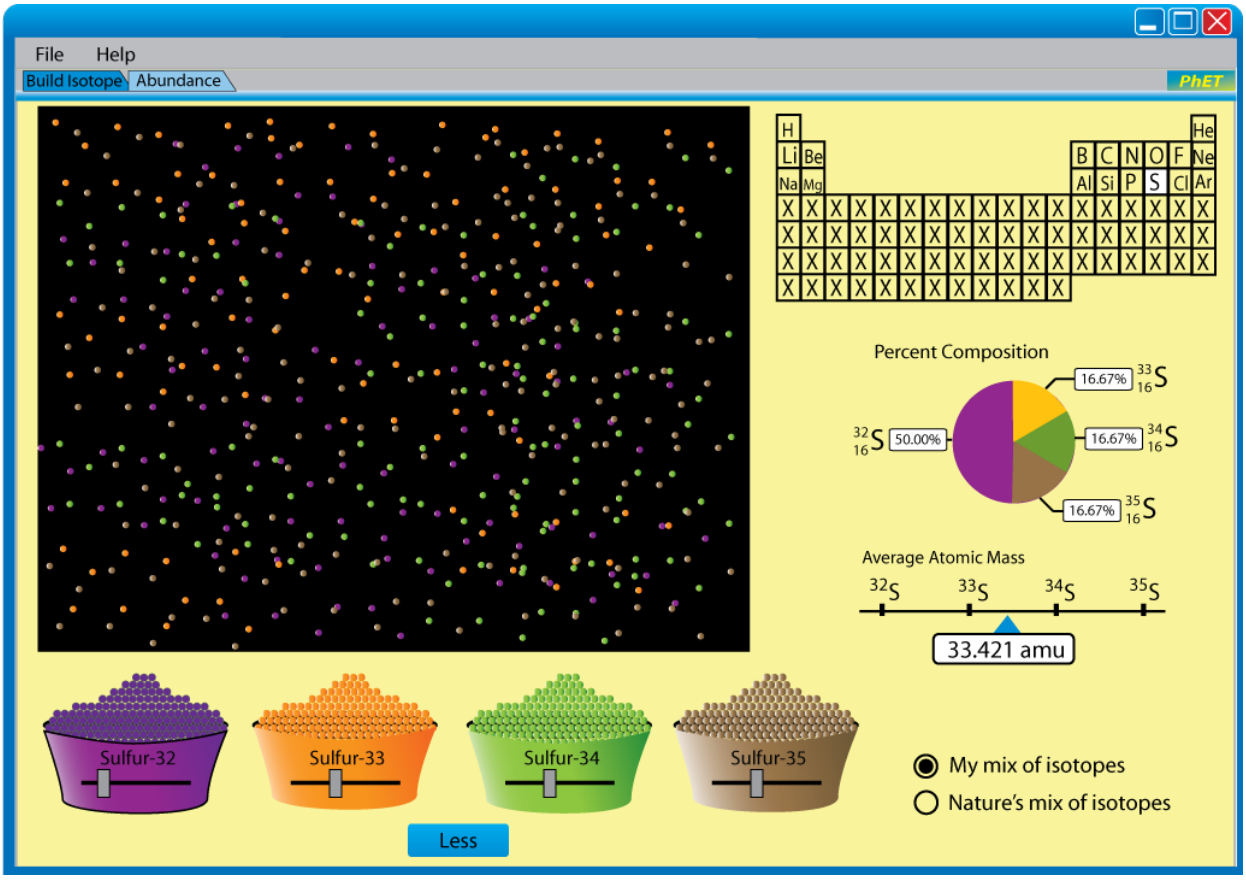


The student can select an element in the first 3 rows of the periodic table.

Buckets will appear that are each filled with a different stable isotope of that element. The student can add isotopes to the larger "bucket" in 2 ways: they can drag in the isotopes, or click the "**More**" button to use sliders. What should happen when students click on "**Less**"?

The sim will compute the average atomic mass of the isotopes (shown on a line chart), and the percentage of each isotope (shown as a pie chart).

The student can elect to display "**Nature's mix**". They cannot interact with the isotopes when this radio button is selected.



The average atomic mass of an element takes into account the atomic mass of each isotope and the percentage of the element that exists as that isotope.

If we want students to be able to ***make*** the correct atomic mass:

We can round (half to even) the atomic mass to 3 decimal places, and round the percent abundance to 2 decimal places. Thus, the sliders need to go up to 10,000.

Because of this:

- Li works out to 6.940 instead of 6.941
- Si works out to 28.085 instead of 28.086
- S works out to 32.066 instead of 32.065
- Ar works out to 39.947 instead of 39.948

But He needs 4 decimal places for the percent abundance - the sliders need to go up to 1,000,000, and the student needs to enter 999,999 atoms of 4-He, and 1 atom of 3-He.

If we only want students to ***see*** the correct atomic mass, the sliders can go to 100. Is this not more in line with the goals of the sim?

Online Resources

Table of nuclides
http://www-nds.iaea.org/relnsd/vchart/index.html

Changing ideas about the periodic table of elements and students' alternative concepts of isotopes and allotropes
http://onlinelibrary.wiley.com/doi/10.1002/tea.10076/abstract
"The Periodic Table of Elements (PTE) is one of the organizing principles in chemistry. Originally it was a list of elements (as substances). Later, the PTE developed into a list of atoms of the elements. However, isotopes and allotropes are difficult to integrate into the PTE. Therefore, difficulties in understanding these terms can be expected. The investigation set off to study secondary school students' concepts of isotopes and allotropes and how the concepts are linked to the PTE. Three specific research questions were addressed: (a) How do secondary school students describe the relationship between fundamental particles constituting an atom? (b) How do they conceive isotopes? and (c) What are students' concepts of graphite and diamond? Multiple choice items were given to 3074 senior high school students. In addition, six interviews were conducted with senior high school students. The data analysis revealed students' alternative concepts, which distinguished between standard atoms and atoms of isotopes. ***Standard atoms contain neutrons and protons in equal numbers and are more stable. The atomic masses are expressed as integers.*** Moreover, students considered graphite and diamond as isotopes. The analysis of the results shows that students actively tried to make sense of what they had experienced."

Teaching Tips

See pdf on website.

Discussion

11/23/10 - *More or Less*

- Scale bar that shows average mass
- Label the atoms (like in RDG), no need for entire symbol
- Pie chart with percent of each isotope
- Buckets with sliders, 100 of each. Can switch to a view where they pull atoms individually from the buckets, 10 of each.
- "More" button gives them the slider, changes to "Less". "Less" hides slider. Every time pressed the atom space is cleared.

11/30/10 - *Radio Buttons*

First tab: radio buttons for “Mass number” and “Atomic mass”
Second tab: radio buttons for “My mix” and “Nature’s mix”

12/02/10 - *Bohr Model*

TL wants symbol in pie chart (w/ atomic #) to reinforce same # of protons

We discussed whether to use a cloud view instead of a Bohr model view on the first tab, and tabled the question for now. We will discuss with Kathy when she returns.

12/09/10 - *Symbol*

KP: put symbol on 1st tab to tie in to 2nd tab

12/13/10 - *Pie Chart*

- Put the chemical symbol off to the side of the % readout on the pie chart
- If we show the atomic # on the pie chart, do we need to show it elsewhere? Start with it only on the pie chart, and see if confusing in interviews.

01/06/11 - *Abundance*

- The elements in the PT need to look more selectable - try 3D
- In 1st tab: should we add a checkbox for “show natural abundance” that gives % readout?
- EM: will students think abundance is not fixed since they can change it in 2nd tab?

01/13/11 - *Periodic Table Buttons*

<u>Notes from Dev meeting:</u>
Got request to make periodic table with buttons. Trying to convey which parts of table enabled and disabled. Concern that looks like keyboard. Will talk about at chem group meeting. Thoughts? Kathy likes how change shape when mouse over. Noah said bottom buttons look like could become enabled in future. Might be misleading. Recommendation to make bottom ones not buttons. Not definite decision. Also added scale. Choose mass number or atomic mass. Created a software structure that maps atomic number and number of neutrons and abundance in nature. All atomic weights, all the way up to atomic number 115. What do we do when create impossible isotopes? Demonstrated. Have not decided what to do. Mike suggested fly apart. Kathy does not want to do anything as need to go through these isotopes to build other stable ones. Will see how students interpret. Soon will spend effort on second tab.

Notes from Chem meeting:

- Debutton lower periodic table
- Make all isotopes stable when added
- Put the symbol on the first tab
- Add abundance indicator to first tab
- Add check boxes to control indicator visibility
- Wait for 2nd tab for interviews
- In interviews: see how students interact w/ neutrons

01/20/11 - *Abundance*

Notes from Dev meeting:

- Now shows element and name in box as user selects different element. Need to further discuss using decimal places for natural abundance.
- Will students see the “atomic mass” button?

Notes from Chem meeting:

- Leave the abundance indicator.
- Abundance label is okay, at least for now, but we may change it to: Relative Abundance, Natural Abundance, Abundance in Nature, or Abundance on Earth.
- Try changing background color of legend to make it look more separate. White was suggested.
- In interviews: how do students interact w/ the legend?
- First tab title: Isotopes
- Second tab title: Isotope Mixtures, or Isotope Soup
- For very small amounts of an isotope (e.g. Carbon 14), say "Very small".
- Take the charge indicator off of the symbol, since it will always be zero in this sim.
- Default for indicators: Symbol on, Abundance off.
- Abundance indicator: put number in a box preceded by a colon or the whole thing with abundance on top, a line, and then the reading.
- Make the name of the element on the symbol bigger (will have to decouple from BAA).
- Element name should include isotope, e.g. Boron-11.
- Make the neutron bucket taller.
- Move stable label down a bit – it starts to overlap nuclei for the heavier elements, e.g. Neon.

01/21/11 - *Isotope names*

JB: Sam and I are making the mods to the Isotopes sim, and one of the mods is to specify the isotope in the chemical name (e.g. Carbon-14). I’m not sure whether the convention is to write these with or without a hyphen, for example, “Carbon-14” or “Carbon 14”. I did some searching, and it looks like the former is more common, and that’s what we are going with for now, but I’d like to hear from you folks if you feel strongly either way.

KL: From Wikipedia:
Isotopes when written out are common nouns, and should begin with the uncapitalized element name, followed by a hyphen (not an em dash or en dash) and then the mass number. Examples are carbon-14 and uranium-235. The uncapitalized name of elements when written out (but not in symbol form) follows IUPAC convention for chemical elements, and is not changed when the isotope is written out.

JB: Okay, we will use the hyphen.
You said that we should use uncapitalized names. Currently in BAA we use capital names for all element names presented under the symbol. I'm assuming that this should be changed, and uncapitalized names should be used in both sims. True?

KL: If we were to use carbon-14 at the start of a sentence, we would capitalize it, so I think we are okay.

TL: All the books I have used include a hyphen as cited by Wikipedia. I think capital is fine too.

SR: Something that bothers me about the way "Hydrogen-1" is shown in the sim is that it looks like "hydrogen minus one". Maybe students will think that means hydrogen but missing a proton or something. Is anybody else worried about this? At a minimum we should look for this during interviews.

KL: I will make a note to look for this interpretation in interviews - but hopefully students will figure it out after they interact with different isotopes.

01/24/11 - *Interface issues*

JB: A new version is available here which implements many of the items from last Thursday's meeting, and puts a picture on to the 2nd tab. A list of the changes is available on the launch page, please have a look. Thanks to Sam for collaborating on a number of these items.

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.00.03/

KL: The individual features work fine in this tab, but as a whole I think we have some interface issues - perhaps because we added features after the original design.

I played around with the location of the features, but I am still not happy with the result.

We really need to consider user scenarios. For instance, since the most stable isotope is already given, why would a student play around with the neutrons?

TL: One thing that I think seems very important is the point that Kelly brings up about what would get a student to interact with the bucket of neutrons. When I was testing it yesterday, it was obvious that there was no motivation to do anything but select elements using the periodic

table. I do not have a possible solution in mind other than a neutron shooter, which we already said was not good because it is too inviting to just shoot and not go to other elements.

KP: Kelly's rearrangement looks good to me, I wasn't too bothered with the other arrangement either, though. We had suggested making the bucket of neutrons taller to help get them closer to the nucleus.

The motivation for in-depth interaction might have to come from an activity. I think interview data will help us better identify a solution - if there is one. But I don't see a need to do that until we have the 2nd tab done.

Notes from John/Kelly meeting:

Isotopes, 2nd tab:
Buckets should lose particles when the user takes something out of them, i.e. not be infinite. This should be true in both modes, i.e. with large and small atoms.

When showing "nature's mix", the buckets should be empty and we are in the "small particle" view. Sliders should go away from the buckets when showing nature's mix.

Max the number of particles at 1000 and fudge from there for nature's isotope mixture. If 1000 is too many - either from programmatic or visual standpoint - we can reduce it.

Isotopes, 1st tab:
John: Follow up with Trish on weird looking buttons on periodic table.

Kelly had a drawing of a version of the first tab that is layed out differently. She will modify this drawing as follows and then circulate to the group. Mods are:
- Solid but cartoony looking electron cloud
- 4 neutrons in the bucket
- +/- icons in the min/max buttons
- Abundance indicator with no line to pie chart, chart has highlighted section that represents proportion of element.

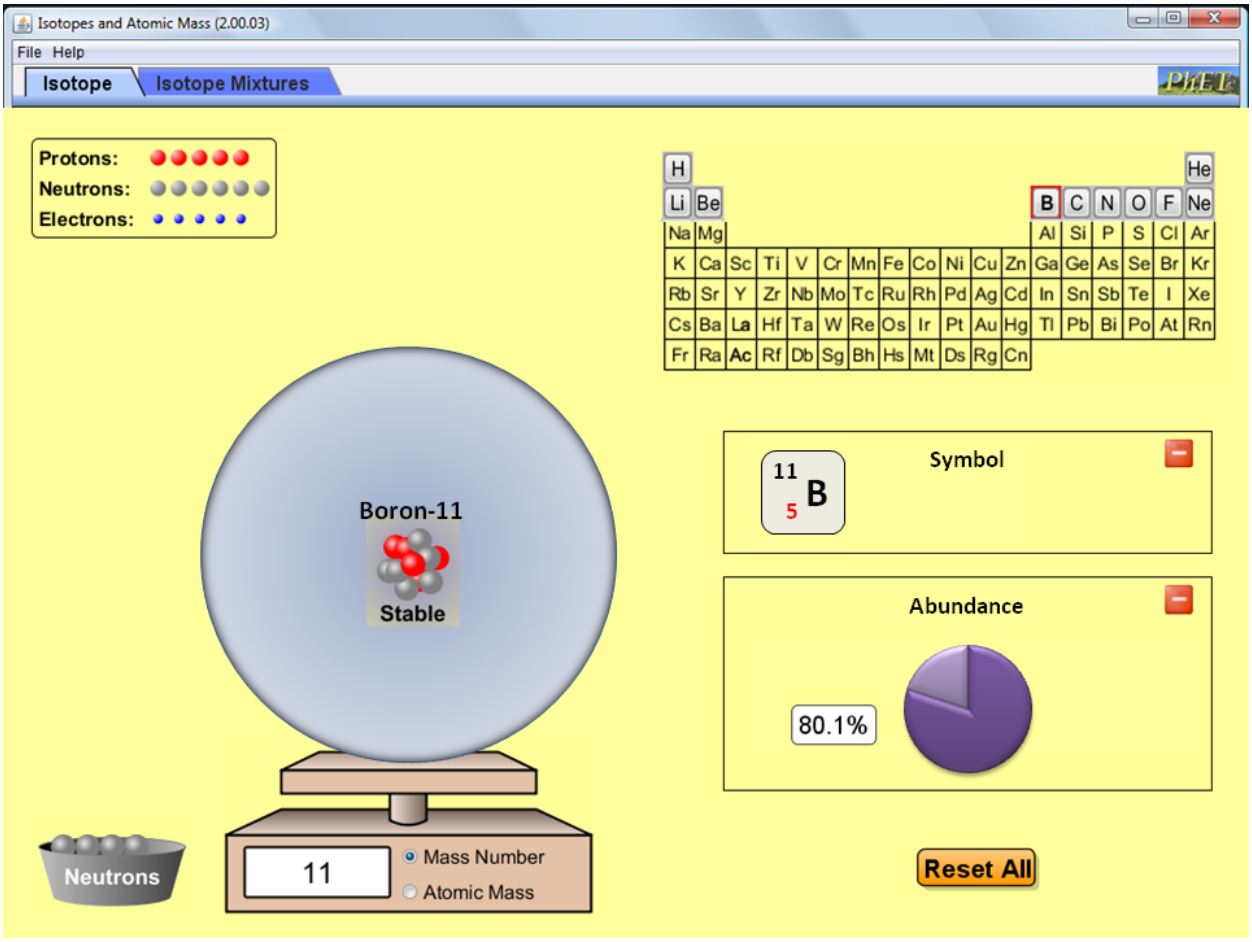
Kelly will propose removal of the atomic number (aka the proton count) from the symbol representation.

TL: I wonder what is your reasoning for this proposal.

I thought we had already decided that it helps make the point that the atomic number stays the same for isotopes and only the mass changes. We discussed that the idea is difficult for students and key to understanding isotopes.

01/26/11 - *New layout*

KL: Here is a new layout for the first tab of Isotopes:



I used a different representation for the atom. This one looks more solid, and will better correspond to what we use in the second tab. It also looks like it could actually sit on a scale.

I reduced the number of neutrons in the bucket to 4. Students tend to want to use all of the particles in the bucket, but since the isotope is already stable, there is no need for them to make ever more unstable isotopes - they may expect to see the nucleus break apart.

I removed the background of the periodic table, so that only the interactive elements are prominent.

The symbol and abundance boxes work like the boxes in Build an Atom. I think both could be minimized on startup.

I added a pie chart for the abundance, and a reset button. Trish: I did not remove the atomic number from the symbol, and I saved the image as a JPEG.

KP: Since I won't be around tomorrow - I'll send a few thoughts now.

- I think the rearrangement of layout in this looks good.
- I think making the background yellow on non-interactive part of the periodic table will work well and attract users to pushing what we want them to push.
- Minimization of Abundance and Symbol seem good and consistent with build-an-atom.
- On the Abundance, I'd like to somehow have the portion of the circle that isn't being used look more blank - like be the background yellow color or something. Also, I think it would be good if the readout (80%) didn't move regardless of how small of a fraction of the isotope it was - so that might argue for making the "beginning of the circle be at the line that goes from the center to the left point on the circle" instead of the top where it starts now- its hard to say in words but hopefully someone can visualize this suggestion.
- I don't particularly care for the solid view of the atom. If consensus is to move away from bohr model view, I'd be more inclined to use the cloud view from build-an-atom. Kelly - I understand the motivation, but the solidness of it seems odd to have it that way with the nucleus particles showing (at least to me).
- I like reduction to 4 neutrons.

KL: I like the idea to use yellow in the pie chart.

01/27/11 - *Cloud view, Units*

- Everyone likes the new layout that Kelly L sketched up.
- John will experiment with the cloud view of the atom, possibly give it a white border, or some other edge.
- John should add an option to set the background of the area where the isotopes go to white.
- The pie charts should have lines on them to make them easier to photocopy in activities.
- Label on scale should be: Atomic Mass (amu).
- Robert will investigate the atomic mass units and determine whether it would be better to use u or Dalton over amu (probably not).

02/01/11 - *Suzanne Feedback*

SB: Is there going to be a game? An everyday context of an atomic mass analog might be nice here (like the sandwich making activity) How about fruit at a fruit stand? You put apples on the scale and the scale can tell you the mass of the apple. When you put it into the bag there is some sort of readout that tells you the average mass per apple in the bag. I think it is easier to conceptualize with a small number of items to average. You could characterize each fruit by its average mass per piece. The story line can continue, perhaps. You could use that characteristic of the fruit to come up with a combination that would be less then, say, 1000 lbs for shipping purposes. Like, you are shipping fruit to make fruit baskets for all of the contestants in a spelling bee, which combinations of apples, oranges, watermelons and bananas could you ship? or something like that...games are fun. Practice helps.

KL: Thank you for the comments!

We decided on "Isotopes and Atomic Mass" for the title.

There is no explicit game in this sim, but we do hope that students will try to create "Nature's mix" in the second tab. We will see if that is the case in interviews! I like your idea to use an analogy - it seems like it would be a great in-class activity with actual fruit and scales.

02/03/11 - *Atom representation*

Notes from Dev meeting:
Isotopes and Atoms – new updated version. Foggy version of electrons that still has a clear boundary and is sitting on top of scale. Will wait on interviews for feedback. RP noticed middle school was using cloud version that looked like this. Abundance pie chart has a little bit of "overbite" and Sam and John will work together on that. Pie chart gives visual indication of abundance. Thinks this tab is pretty much done – waiting on feedback. Done some background research on 2nd tab (mixtures).

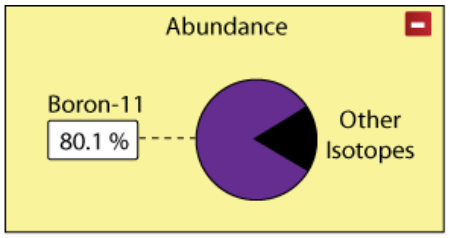
Notes from Chem meeting:

- We tweaked the atom representation a bit during the meeting in an attempt to make it more blue so that the users will connect the electrons in the key with the cloud around the atom.
- We discussed the units and label on the scale, and decided to leave it as it currently is, which is that is says "Atomic Mass (amu)"
- It was brought up that the pie chart is a bit confusing with no labels, so John and Kelly worked on some sketches of alternatives. John will clean up and send around.
- We should indicate Tritium abundance as "very small" instead of zero.
- John should do color blind testing on this.

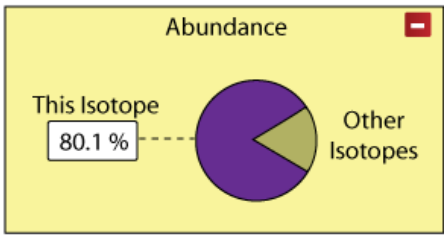
02/03/11 - *Abundance indicator*

JB: In the meeting we just had, we were kicking around ideas for changes to the abundance indicator on the first tab of Isotopes. We decided to put together some sketches and send them around and get everyone's input, so here they are. I've also attached a screen shot of the sim in case you need a reminder of the context.

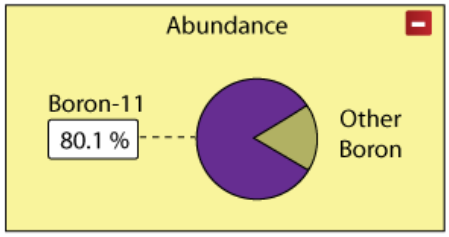
A.



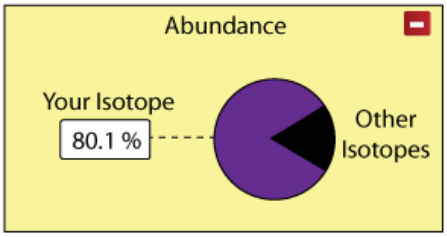
D.



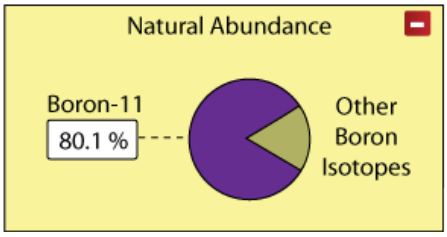
B.



E.



C.



EM: Color: I'm in favor of having the "other isotopes" segment be as close to the yellow background color as possible, to deemphasize that part. So for color, I like option D the best. Is there a reason not to have the "other isotopes" wedge the same color as the background?

Label: I think isotope should be in the label, to make it clear what you're referring to. Of secondary importance would be the specific name (Boron-11), but I think it would be useful for it to be there, so perhaps something in two lines that looks like:

Boron-11
Isotope

Misc: I may have missed the window for discussing the dashed line that connects the current isotope abundance with the purple wedge, but I find it kind of distracting. As an alternative, the percentage values (and maybe the words themselves) could be in bright purple to match the purple wedge.

RP: I lean towards (C), but I don't have a strong opinion.

JB: BTW, feel free to mix and match parts from the various options, or suggest alternatives. These are meant to represent just a few of the possible combinations, and we aren't strictly limited to this set.

KP: I also would like to see the yellow be closer to the background color. I like the phrase "This isotope" but also agree that the specific name would be good. Maybe 2 lines

This Isotope:
Boron-11

I don't have strong feelings about the dashed line.
Making the text purple seems reasonable, too.
I have a slight preference for "Natural Abundance", but not strong.

TL: I agree with Kathy, but please check for color blindness before implementing the purple.

02/04/11 - *Atomic mass units*

RP: OK team, I've now looked up the discussion of atomic mass and atomic mass units in 15 chemistry textbooks - 11 standard first year college-level General Chemistry books, one Introductory Chemistry book, and three Honors General Chemistry books. ("Introductory Chemistry" is usually taken by students who have not had (or who need to review) high-school chemistry, while "Honors" is taken by students with exceptionally good preparation (such as additional math and physics courses in high school. The copyright dates range from 1998 to 2012. I looked at two things:

What name do they give to the weighted average of isotope masses (i.e. the number that goes in the periodic table).

What units do they use for isotopic masses and for the above weighted average?

IUPAC says that isotope masses have units of "u" or "Da" (Daltons), that the weighted average is called the Relative Atomic Mass, and this latter quantity is to be regarded as dimensionless. Only one of the 15 (one of the three honors books) does this.

7 books call the weighted average "Atomic Mass" and report both it and isotope masses in amu.
4 books call the weighted average "Average Atomic mass" and also use amu for both.
1 book uses both "Average Atomic mass" and "atomic mass", again with amu.
1 book uses "Atomic mass" with units "u".
1 book uses "Average atomic mass" with units "u".
1 book avoids the entire issue by using "Molar Mass", in g/mol, for elements as well as compounds.

So it looks like amu is overwhelmingly preferred. I suggest that stick with it, and that we use "average atomic mass" as the name for the weighted average, since it won't cause confusion to have that one extra word.

JB: Thanks for looking into this. I had no idea that there were this many variations and differences, but it sounds like we have a clear idea of how we're going to handle it, so that's good.

02/10/11 - *Abundance indicator, Part 2*

- Top caption: Natural Abundance
- Left caption: This Isotope, don't say chemical
- Right caption: Other <chemical> Isotope
- Keep black outline
- Keep dotted line

Ask about wording in interviews

03/03/11 - *Notes from Chem meeting*

Isotopes and Atomic Mass, 1st tab

- No "Other Isotopes" caption when there aren't any.
- Consider separating from Build an Atom, John will discuss with Sam
- Have empty portion of pie chart be same as background.
- Have the indicators closed at startup.
- Make legend be same background color as legend, smaller. Look like BAA.
- Make the label on the atom have mass number, e.g. Lithium-7

Isotopes and Atomic Mass, 2nd tab

- Have the indicators be in closeable boxes like in the first tab.
- Make sliders with a single atom as a key and a numerical indicator when in "More" mode.
- Show the empty buckets for the "Nature's Mix" view
- Retain the state - i.e. where individual isotope instances are - when moving from one element to the other
- Have a "Clear Box" button that clears particles from the chamber for the currently selected element.
- Have a "Reset All" button that, well, resets everything.
- Average mass readout - use thinner surrounding line, larger font if possible.
- Spell sulfur with an f (and not a ph).

Isotopes and Atomic Mass: Questions that John & Kelly discussed after the meeting, made initial decisions on, and will review with group at next meeting:

What should show on pie chart when nothing in chamber?

- For now, leave it as showing nothing.

Is there any benefit in allowing the users to move the atoms when they are showing nature's mix?

- No, so leave it as is.

Should we show radioactive trace isotopes that actually exist in nature, like hydrogen-3 and

carbon-14?

- For now, no. Discuss at next meeting though since we have some concern about Carbon-14.

Should we show isotopes with abundance values lower than 1/1000?

- For now, add at least one of each element. An alternative would be to make it probabilistic. Discuss at next chem group meeting.
- Those isotopes are: Hydrogen-2, Helium-3, Oxygen-17, Sulphur-36

For “Nature’s Mix”, should we use fixed number of particles, or vary based on magnitude of difference?

- Stick with fixed number of particles.

Interview questions:

- Do students try to grab protons from the legend?
- Do students expect the “more” button to add atoms to the box?

03/10/11 - *Notes from Chem meeting*

Review of Isotopes sim:

- Change color of element label from red to black (since the mass number now disconnects it from the protons) and make font larger.
- Remove dialog from Reset All button but leave the button itself
- Have a dotted circle for the pie chart when nothing is in the chamber (2nd tab)
- Continue showing at least one isotope even when abundance is less than 1 part in 1000

Other notes:
- change font color and size for element name
- make confirm box for reset all look more friendly? EM: looks diff than sim, scary for MS students. do we need one in 1st tab?
- numbers on sliders or none (yes)? text box in line (no) or on top (yes)?
- boxes are open on startup in 2nd tab. use open dotted circle for % composition
- JB activity idea: which isotope is the standard?
- EM: we should interview teachers!
- what about rare isotopes? always show one in 2nd tab (yes for now), never show, or use some probability (no)?

03/17/11 - *Notes from PhET meeting*

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.02/

JB: Ok so this is Isotopes – minor changes to 1st tab – mass number as part of the name, we changed the color to black, font enlarged, and that changes with the amount of neutrons you have in there. Also, the confirmation dialog removed. I think the 1st tab is 100% done. On the 2nd tab a lot of work here… the sliders now work. I haven’t enclosed the sliders in anything. Doing this makes me think it would be kinda cool to have an “averages and proportions” sim.

Periodic table works. Stateful behavior that was requested is a little difficult. Whatever you have set up on the previous on you can go back to that. I have changed the layout algorithm and the sliders are basically in the same place as the buckets.
KP: I wonder how this is going to internationalize. We do allow the translation of all the chemical names. Do they go over the text box that has the number in it? – Could move number box down.
MD: What about change the text to symbol then say actual name text below (only once).
KP: That would alleviate the translation issues. Is the pie chart supposed to have percentages?
JB: Yes! That is on to-do list for this sim. Also, in natures mix, in a case where we show 1000 particles and the ratio is less than 1:1000 then you always just show 1. The problem is that the chart right now shows what is in the viewable area… not what is real . Going to have to do some sort of override for this.
CM: Add testing on mac to that.
JB: The one big issue with the whole thing is … Carbon 12 is reference
MD: Should we use lattice for metals, random for gases? [NO]
KP: A good thing to put in teacher tips is that we are not trying to denote a certain lattice.
JB: Does this make it beyond a middle school sim?
TL: I think when you go to carbon it should have the same number of significant figures.
RP: Freshman rule is exact numbers are shown as exact numbers.
KP: What is the rule JB is using in the sim? Is it 5 digits no matter what?
JB: I'm probably just cutting off all the ending 0's. Should I make it always 5? Everyone: yes
JB: Ok then we are consistent with what's going on with the scale.

03/17/11 - *Outside Feedback*

KL: John is working on adding the percent readouts to the second tab of Isotopes so we can ask teachers for feedback and do some interviews the week after Spring break.

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.02/

Kathy: who should I send this to for feedback?
Emily: can you forward the emails of chemistry students who wanted to volunteer but that you did not get a chance to interview?

KP: For feedback, let's include
Suzanne Brahmia <brahmia@rci.rutgers.edu>
Sue Doubler <sue_doubler@terc.edu>

And then also notify the Chem Advisory Group - saying that it was developed primarily for 6-12 students but could be used at the intro college level as well. And ask them if they have any feedback.

KL: Can you remind me who Sue Doubler is? Is she a MS teacher, an education professor, etc.?

KP: Sue Doubler works at TERC in Cambridge, MA - she is a curriculum designer at the elementary - middleschool level.

EM: Here's the list of students. These are students currently in Gen Chem II. Some of them may also be in Physics I or II. The undergraduate interview you set up last week that I did for BCE would also be a good person to interview if you're looking for someone with no chemistry background.

03/18/11 - *Version of Isotopes for interviews*

JB: I got a version together that implements the pie chart labels, but towards the end of this effort I ran into a bunch of problems. I believe I have solved most if not all of these issues, but as a result this has had VERY LITTLE TESTING. I suggest you play with it for a while and determine if it is really solid enough for interviews. I would do more testing, but I'm out of time.

Here is the link: http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.03/

KL: Thank you for getting this done so quickly. I hope you have a nice vacation!

03/21/11 - *New PhET sim on Isotopes*

KL: We recently designed a new sim on isotopes to complement our sim on atomic structure. We developed the sim primarily for students in grades 6-12, but we think it could also be useful for college students.

The latest version of the new sim is at:
http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.03/
To launch the sim, click on the "production" link next to "Isotopes and Atomic Mass".

We are about to begin interviews with students, but we'd also like to get your opinion as middle school curriculum and chemistry education experts. Can you take a look at the sim and tell us what you think?

SB: Wow! I really like it.

One of our PUM middle school teachers used build an atom with his students, as did the middle school teachers in the school that I teach in (using a traditional curriculum). Both of them love it!

The PUM teacher told me the kids wanted to keep playing and were disappointed that it maxed out with the first few elements. He also asked about isotopes, so I'm eager to pass this link on to him and have him look it over.

I'm attaching a report that a 3rd grade son of a colleague wrote. His son played with the sim by himself, and was really into it! So much so, that he decided to write a report for his teacher just

for fun. Note he made a mistake with the electrons and mass number. But overall, not bad for an unguided 8 year old.

JB: Were you able to use this version for some interviews and, if so, how did they go?

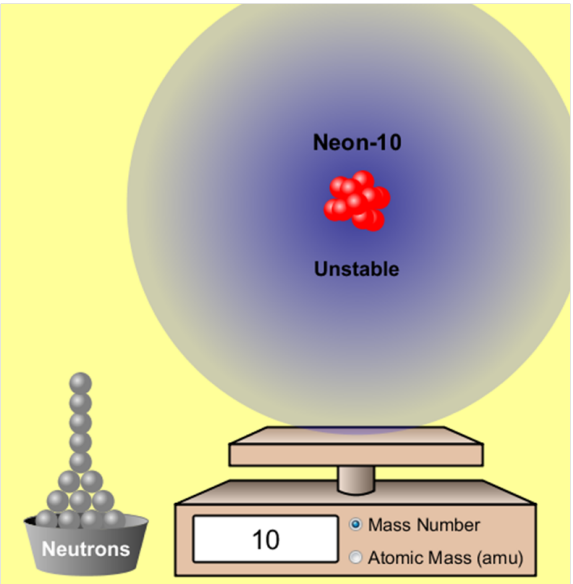
KL: Last week was spring break, so I did not do any interviews. I contacted some chemistry students, and I am waiting to hear back. I should be able to do some interviews this week.

I sent the link to some middle school curriculum and chemistry education experts, but I only heard back from Suzanne. Her feedback was: "Wow! I really like it."

03/30/11 - *Isotope Interviews*

KL: I interviewed a student in the 2nd-semester of chemistry on this version: http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.03/

I noticed a bug when he took out all of the neutrons in Neon (see image), and then tried to add them back in. The sim freezes when you try to put the neutrons back in, but after a while, it unfreezes.



KL: I interviewed another student today on the same version. Both students came in with a lot of prior knowledge on isotopes.

I noticed that it takes a really long time (about 3 seconds) for the nature's mix image to update when you click on a different element (at least on my computer, with Camtasia running). Is it possible to make nature's mix less computer-intensive?

04/01/11 - *Notes from PhET meeting*

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.04/

JB: First couple of interviews on isotopes. Student went to heaviest element and removed all of the neutrons. Fixed right away. The thing that took most time is the pie chart. Labels now work as user is changing the mix. As far as I know it works in all the scenarios and is accurate. I would encourage people to play with this and try to find any problems.
KP: maybe we should go down to 1 decimal place for “my mix”
JB: The reason we have that many is to be the same as for “natures mix”. We also said we wanted it to be uniform between the tabs. So do 1 for “my mix” and 4 for “natures”
A: can you explain my mix?
JB: idea is they can drag things in and then compare it to natures mix
KP: so the one that you saw is when you press the ‘more’ button
A: it kind of seems that the sliders for ‘more’ adding up to 100 is a little confusing
JB: yes, we will watch for interviews to find out if this is an issue

JB: I think pie chart is pretty much done. I have tried to account for all of the different mixes and quantities you can get. I’ve probably only tested the things I can think about and it would be good to have others test. I have also worked on performance of “nature’s mix”. Changed to be able to switch on nature’s mix and made it a lot faster. Kelly’s was taking 3 seconds.
KP: what did you do to make it fast?
JB: code would go through and see a new mix and would update each time. Instead now I am going to add them in bulk then do the update to the pie chart.
KP: if you typed in 100 would it try to add each one?
KL: yes and the student did that yesterday and it was fine

JB: Fixed some issues, where you would pick up the particles and drag them in there. That is fixed now. The only ones you should ever be able to move is these bottom guys. There were several issues with the Mac. Issue with background - problem with average atomic mass being outside of those bounds. Right now with mac it still pushes up against the boundaries. The elements were all buttons before and they looked strange… completely overhauled this and now they are squares. I could go through and make them look more ‘button’ like.
KL: I think it would be good to do that… because students sometimes can’t find it.
KP: it looked good on win7/xp
A: what did it look like before?
JB: more 3 dimensional and like normal buttons… maybe rounded corners and some gradients
KP: maybe coordinate with Chris to look at mac/pc at the same time.
CM: another thing that looked strange is the gradient… it makes it harder to read the button. I wouldn’t worry about texture behind the letters. Probably could take a “+/-“ button.
JB: Internationalization still needs to be done but I am waiting on more interviews before I go ahead with that.
CM: spend anytime with Sam to see why the buttons are no longer centered?

KL: First thing I asked students was what do you know about isotopes. And both students knew

a lot they even gave examples of isotopes. They played with sim for like 6 minutes. They pretty much understood most things and just played around with sim… didn't learn too much.
After they played with sim, I asked them again any new things about isotopes they learned. They used the percentages and learned about the standards.
Both students also recognized they could use 'my mix' to make 'natures mix'. They recognized what we want them to do.
JB: yeah I could imagine there could be a lot of activities you could create with this.
RP: yes it could be good for some college students that haven't had chemistry since high school. It struck me of a concept that students might lose because it doesn't get reinforced.
KL: The reason I said he had a lot of good ideas was because we had the same ideas.
A: maybe for the button issue we could randomly intersperse some other elements as clickable buttons.
KL: The first student said it would be cool to have gold and silver… some that they use often in chemistry.
RP: silver is an interesting one because it turns out to be just about 50% on either side.
JB: if we wanted to have just random ones that had 4 or less isotopes we could stick them on pretty easily.

04/04/11 - *Version 2.01.04*

I looked over the new version of Isotopes and made a few notes:
- use 1 decimal place for % composition in "my mix"
- use same symbol font for % composition and avg atomic mass
- use thinner border around # in % composition
- avg atomic mass does not show when you put in one isotope - it should
- need to talk about sliders and textbox for "more"
- use the same # of decimal places for "natural abundance" in 1st tab and % composition for "nature's mix" in 2nd tab
- tested nature's atomic mass & % composition - some discrepancy, need data source

I also asked Kathy D to find some 8th graders to interview.

04/05/11 - *Version 2.01.05*

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.05/

KL: I checked the values in the sim against the ones in the NIST table. I also updated the table in the G-doc.

I noticed that the 2nd tab leaves off zeros if 0 is the last number - this happens for the mass and the percents in my mix and nature's mix. For an example of both, put in one carbon-12 isotope in my mix and look at the average mass. Or click on nature's mix for Mg and look at the percents. The 1st tab does not have this problem.

I also noticed that we use 5 decimal places for the He abundance in the 1st tab, but only 4 decimal places in the 2nd tab. Either way is fine (I prefer 4) but we need to be consistent.

JB: On the mass, I may have misunderstood, but I thought that you specifically requested that we leave off zeros for the mass when showing nature's mix, since that was the limit of accuracy. Are you thinking that it needs to leave off zeros when showing nature's mix, but show them when depicting the user's mix?

With respect to the pie chart labels, does it need to show the zeros? If so, should it be one decimal digit when on User's Mix and 4 on Nature's Mix?

TL: I tested the periodic table on some computers here at school and they look fine. The dark orange looks nice. I seem to remember that we weren't going to use white because the white boxes are "read-outs", but if it turns out that we need to, I think it is ok.

04/11/11 - *Outside feedback*

LorettaJ: Sorry to take so long responding to your request. You may even have moved on, but here are my thoughts in case they are useful:

First, a sim on isotopes for grades 6-12 is a great idea! It was wise to limit the activity to the first three periods. Even using only the first two periods in the first section is sufficient for the sim.

Isotope section:
Being able to add or take away neutrons allows the user quickly to see the relationship between the number of protons and neutrons and the mass number. Showing both mass number and actual amu is also helpful. Showing the numbers of protons, neutrons, and electrons at the top is a good idea, since it is hard to count the particles in the nucleus and the electrons are shown as a cloud in the model. It is also really cool to be able to see the unstable nucleus quivering as well as to have a statement of instability. The main concern I have about this section is that it isn't clear what the point is. That is, what is the goal for the students that keeps them playing with it? Is that comes in the paper materials? Another point is that the known average atomic mass is never shown. Even though that does come in the next section, it might be nice to have it available here on a button, so that the student can see the relationship between the classroom periodic chart and the numbers in the sim. It might raise some interesting questions for them.

Isotope Mixtures section:
I liked being able to see how different ratios of isotopes affect the atomic mass. That visualization should be very helpful for students. It is helpful to be able to add and take away isotopes and see the ratio change, although I could closely match Nature's mix only by using the "more" option. Even in that option, though, one can't actually match Nature's image, as she always seems to have even more isotopes at her disposal. It really is only the ratio that matters, but it would be satisfying to be able to match Nature.

Overall, a good effort. I'm happy to report that nothing crashed!

KL: Thank you for the feedback! I am still in the process of doing student interviews on this sim,

so your thoughts are not too late!

I find it interesting that one of your concerns is what will motivate students to play with the sim. In interviews so far, this has not been one of our most engaging sims: students only play for about 10 minutes. Then again, all of the college students could define isotopes before using the sim.

I did interview one high school student, and he spent more time on the sim. He also interpreted the electron cloud as a magnetic field.

We do not show the average atomic mass in the Isotope tab because we want to keep the first section about *single* isotopes. But I will bring up your point in our next team meeting.

One of the college students made the same comment about the Isotope mixtures tab: she wanted to be able to match Nature's mix exactly. I will ask our developer if it would be possible to increase the range of the sliders.

JackB: Below are my comments for the Isotopes Sim
Version 2.01.03
Java 1.5.0_26
Mac OS-X 10.5.8

Isotopes Tab:

1. The electron cloud appears to be MUCH larger than what is represented in the "Build an Atom" sim, was this on purpose? Also, the electron are shown in the key as small blue spheres yet they only appear in "cloud form" in the atom. Will this be problematic? It might at least get students to think about what the cloud represents.
2. In reference to Loretta's comment about the average atomic mass, maybe this could be in the box with the natural abundance? This way students can connect the average mass as being dependent on the various isotopes.
3. The size of the electron cloud does not change as you move from H to Ne, was this on purpose? I know that the sim is on isotopes and not the size of atoms but will this give students the idea that this size is static?

Mixtures Tab:

1. I like the addition of the "nature's mix" button, this is a nice visual. Combined with the "average atomic mass" and "percent composition" windows being open it nicely shows why the average mass is what it is.
2. When clicking on periodic table to switch atoms (with nature's mix ON), the sim runs slow. Not sure if this is normal or not. There were a few times when I almost clicked on it a second time, thinking that it did not work.
3. When you get to an atom with a 7-digit average mass (see Boron and higher), the box is not

large enough for all the digits and they spill over.
4. This might be due to the fact that I am on allergy meds but: when I look at the "nature's mix" of an atom, the colored dots seem to move on the black background. I have never experienced this with other sims. I am sure it is some sort of optical illusion or just a side-effect of the meds.
5. With the "my mixture" button clicked, I like the sliders more than the buckets. It is easier to track how the average mass changes as you add more/less of a given isotope.

General Comment:
In your note back to Loretta you mentioned that the sim was not very engaging but that a HS student spent more time with it. If this sim is targeted to grades 6-12, any data you get from a group of college students at CU will be very limited. The real test will be when Trish or another teacher starts using the sim with their students. I guess one thing to keep in mind is that when you are interviewing a college student on a sim designed for grades 6-12, what are your goals for the interview data?

SuzanneB: While the idea of a statistical average may be clear and/or mundane to many college students, isotopes is the first exposure that younger students have to this mathematical concept that involves using very large numbers. The isotopes PhET makes that idea much more accessible to them. I agree with Jack here completely, and would add that not only Trish and her students, but interviews with middle school teachers and their students (8th-9th grade) will likely offer a perspective that the college students interviews don't.

LJ: I agree 100%. Even just sitting and watching a couple of middle school students work on the lesson can be valuable.

KL: Thank you for the comments!

I am going to talk with John, our developer, to see if we can change the size of the electron cloud for each element. The college students said the *blue* electrons in the key helped them understand the *blue* cloud, but it was confusing for the high school student.

I do think we want to keep the ideas of *single* isotopes and *mixtures* of isotopes separate (on different tabs), but I will discuss this with the team tomorrow.

We interview college students because they are easy to access - but those interviews are more about the interface and less about learning. For instance, one student noted that nature's mix was slow to change, so John optimized that feature in a new version. It is much harder to gain access to younger students, so those interviews tend to happen after the college interviews. I have another high school interview today.

The latest version of the sim is at:
http://www.colorado.edu/physics/phet/dev/build-an-atom/2.01.05/

04/14/11 - *Notes from chem meeting*

KL: Here are some of the questions we need to discuss in our meeting today:

From advisory feedback:
- should we show the average atomic mass in the first tab?
- should you be able to match nature's mix exactly?
- should the size of the electron cloud change for each element?
- should we interview more grade 6-12 students?

From interview feedback:
- should we include more elements in the second tab?
- should we allow students to interact with protons?
- how can we help students make sense of isotopes?

Notes from chem meeting:

There was a suggestion to show the avg atomic mass somewhere on the 1st tab.
The group discussed this, and felt that since the first tab is about single isotopes, the avg mass would be confusing. Instead, we will change the name
of the first tab to "Make Isotopes".

Label the atom, just above the isotope name (e.g. Lithium-7) with "Your Isotope:"

Make the size of the electron cloud change as the atomic number changes. Try to match numbers in Wikipedia (whichever radius is desired) at first, and if that makes for too large of a difference, fake the size change (something linear probably).

One comment was that we might want to allow the users to match the proportions nature's mix when doing "my mix". We can't do this exactly due to the very large number of particles that would be required, and we discussed increasing the number of particles allowed so that they could get closer. However, 100 is a nice number of particles to be able to add for each isotope, so we decided to stick with this, at least for now.

There was a question about whether to go beyond the third row of the table in the 2nd tab. This came from students. We're not going to do this because of the number of isotopes that the heavier elements allow, and there isn't any more learning from having more. However, we should explain why it is like this in the teachers' tips.

Dicussed the idea of letting students remove and add back protons, but decided against due to the complications that this would create. Only playing with neutrons is seen as a "productive constraint".

Change "Natural Abundance" to "Abundance in Nature".

John will investigate why the readout on the abundance indicator seems to be right up against the left edge of the container window.

On the 2nd tab, move everything down a touch to make the layout look a little better.

KL: I just had a thought: if we name the first tab "Make Isotopes," maybe we could call the second tab "Mix Isotopes," so both sound like actions.
JB: Sounds great to me. I'll go with it unless others on the team object.
TL: sounds good
KP: Sounds good to me too.
RP: Me three.

04/20/11 - *More interviews*

KL: I interviewed two more students on version 2.03.00 - one in 4th grade, and one in 7th. Below are some interview notes (more detailed notes are in the G-doc). The sim was too abstract for the 4th grader, and the 7th grader did some unproductive (but funny - see attached) things with the sim. I have two more middle school interviews planned for this week and next.

04/20/11 - *New versions*

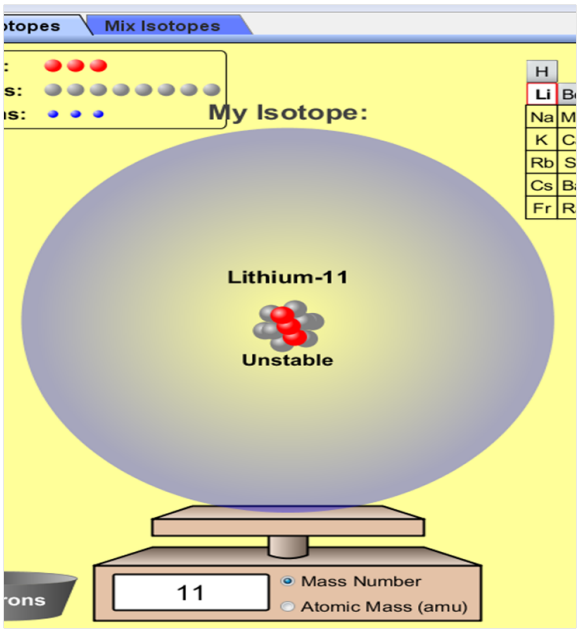
JB: Here is a new version that places the isotope in the correct place. It also include almost all of the changes that were requested at the last meeting, the one exception being the placement of the readout on the abundance indicator on the 1st tab.

The sizing of the atom is based on reality with some amount of scaling. I thought it would be best if you looked at it and we went through a round of tweaking before sharing it with the rest of the group. Let me know what you think, or if you'd like to get together to discuss it.

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.03.01/

KL: This looks good! I attached a picture of the only issue I saw - the label "my isotope" can overlap with the legend for Li if you add all the neutrons.

We can discuss the sizing tomorrow morning. I do think the resizing could draw student's attention away from the nucleus, but we'll see what happens in interviews.



JB: I had the exact same thought about the resizing. I love it from the standpoint that it will teach students a lot, but I think that they might end up playing with the periodic table and comparing the different sizes, and fail to notice the bucket of neutrons.

I think you have an interview today, right? If so, I could leave the resizing as it is so that you can see if it is indeed distracting, or I could tone it down a bit. Please let me know what you think.

KL: Yes, I have an interview today. Let's leave the resizing as is. I can also send this version to the advisory board for feedback, since they were the ones who requested this feature.

JB: Okay. I have written the code so that it is very easy to change the relative sizes but still keep the general relationship the same (e.g. Helium is smaller than Hydrogen, Lithium is the biggest, etc), so just let me know if it needs to change.

JB: The easiest way to fix the issue with the "My Isotope" label is to adjust the scaling so that Lithium doesn't get quite so big. In a separate email conversation, you had recommended leaving the scaling as is for the next interview. Are you okay with the idea of changing it slightly so that this overlap doesn't occur?

KL: The overlap is not a big issue for the interview - so it should be fixed, but it would be fine if the fix is not in time for the interview.

JB: I went ahead and whipped up a new version, since I had to fix something with the abundance indicator on the first tab anyway. I modified the scaling so that the “My Isotope” label should never overlap with the legend. If it looks okay, you might as well use this version in the interview today.

http://www.colorado.edu/physics/phet/dev/build-an-atom/2.03.02/

KL: Thanks, I did use the new version in the interview!

04/22/11 - *Potential changes*

JB: Kelly had mentioned two potential changes to Isotopes, and since we didn't get to discuss this sim yesterday, I thought we could decide on these questions via email. The changes under consideration are:

1. Don't allow users to place isotopes on top of one another in the test chamber on the 2nd tab. Apparently one or more users have done this, and it has the potential to create some confusion with the proportions. Kelly was suggesting that they move apart if this is attempted, sort of like we saw in the Build a Molecule sim yesterday. I'm guessing 1 to 2 hours to implement and test this.

2. Kelly pointed out that it is a little inconsistent to use different size atoms in the first tab but have everything be the same size in the 2nd. Unfortunately, this would be very difficult to change, since we allow the user to interact with 3 rows of the periodic table on this tab, so the variation in size would be quite large. This variation would be difficult to accommodate with the buckets, since the size and placement of the buckets currently relies on the idea that the particles are all the same size. I would have to give this some thought and do some experimenting before I could even give a decent estimate for this one, but it seems to me that it would take a lot of work.

KP: 1. Seems good to me to prevent this.

2. Agreed that it is inconsistent, and could be problematic. Kelly - what is your leaning on this importance given its implementation difficulties? Have interview students gotten confused by this?

More generally - what are opinions and interview findings about of the resizing of the atoms?

KL: I've only interviewed one student (a 7th grader) since the resizing was enabled. I don't think she noticed the inconsistency. When I asked her about the "blue ball" on the 1st tab, she knew that it was the "electron cloud" (her words), but she said that it got bigger or smaller when there are more or less electrons. I am slightly in favor of keeping the atom sizes consistent between tabs, but I am open to other suggestions.

EM: I really like that the size of the atom changes, but perhaps that is not appropriate for this particular sim (seems like it might be distracting since the size change is pretty dramatic). Maybe this can be adapted and reused later as a tab in a sim that demonstrates periodic trends.

In that case, we'll need to figure out a way to show the size changes reasonably accurately, which might have some challenges if more rows of the periodic table are included, but that's a discussion for later.

04/26/11 - *More feedback*

KL: We made some changes to the Isotope sim based on your feedback - the most significant change is that the size of the electron cloud is now different for each element.

The latest version of the sim is at:
http://www.colorado.edu/physics/phet/dev/build-an-atom/2.03.02/

We'd like your thoughts about the resizing. Do you think it distracts from the main learning goal? How do you feel about the inconsistency of atom sizing in the 1st and 2nd tabs?

SueD: Not sure my feedback will be helpful. First, I don't see the size of the electron cloud changing--perhaps I'm looking at an earlier sim.
The size change between tab one and two doesn't bother me.

In most of your sims the learner discovers patterns or rules about how the world works. There are these "Oh, Cool" discoveries. This sim is a bit more difficult. The user is able to see how each individual element works, but doesn't discover predictable patterns across elements. (Are there patterns?)

What messages are you are hoping the young learner takes away? --Here's what I think the messages might be: 1. the number of neutrons can change for some elements but not for others, 2. that the number of neutrons can vary by only a few before instability results, 3. that neutrons and protons together determine the atomic mass, 4. how the symbolic representation is organized.

Perhaps the learning, in this case, is implicit rather than explicit--a middle schooler might end up knowing about isotopes for the first time and associate isotopes with changes in the number of neutrons and with stability and instability.

The isotope sim is solid and clear. The learner will be able to see the differences for various elements. My comments about the quest for discovery results of the high bar you've set with your other sims, not a critic.)

KL: Thank you for the feedback - your comments are very helpful!

Here is the version where the size of the cloud changes:
http://www.colorado.edu/physics/phet/dev/build-an-atom/2.03.03/
(click on the "production" link next to "Isotopes and Atomic Mass")

Your comment on the lack of patterns is one of the difficulties we face in developing sims for chemistry: in many cases, there are no patterns! Chemistry is more of a descriptive science, and sometimes it is impossible to allow students to change a parameter continuously.

The main message is that isotopes are atoms with the same number of protons and different numbers of neutrons. I've done some interviews with middle school students, and it's not clear that this message comes across.

TL: Maybe we should reconsider a macroscopic tab using something like eggs of varying mass and students have to find the average mass of the eggs before they go to the underlying chemistry model. I think the categories on the cartons are like large, xlarge, medium, small.

SueD: The changes in the cloud make the simulation much more dynamic. I found myself "playing" with it in a different way--systematically clicking on each element and watching how the box in the upper left changed.

KL: Do you feel like the cloud resizing is a good change then? Do you feel like it could be distracting for students?

SueD: I think it's a good change.
KL: Great, that really helps!

04/28/11 - *Notes from chem meeting*

- In next interview, try Build an Atom first
- Cloud size change: seems too distracting, probably take it out & put in other sim; but ask Jack again, do one more interview
- Egg analogy: put in sample activity

04/29/11 - *Jack feedback*

JackB: I like the new re-sized electron clouds. I think that it might spark some great questions when students realize that the cloud gets smaller as you add more electrons across a period. It is also a nice visual to see that despite the size-decrease, the atom gains mass.

I know that the group is trying to focus each sim and that the decision was made to not change the electron cloud, however, when students view any simulation, animation, or image we can not restrict what they see or how they interpret it. Something like this may not directly map onto teaching isotopes but might keep students from gaining an alternate conception about electrons.

There could be some interesting studies on what alternate conceptions students at any level gain from any simulation or animation. While we can't address all of them, we should cover the obvious ones.

As far as the inconsistencies between tabs, it does not seem like a problem. It was clear that one tab shows a single atom while the other showed a group of atoms. Have you been finding that it was a problem? Again, something that we (or college students) do not think will be a problem might be for a younger audience.

EM: As I've been going over the PhET look and feel guidelines, one seems particularly appropriate for this issue:

Coherence Principle
Adding interesting but unnecessary material to simulations can harm the learning process in several ways.
· It can distract the user from relevant material.
· It can disrupt the learner's processes of making sense of important information because unnecessary information is in the way.
· It can prime inappropriate bits of knowledge.

It seems that, from PhET guidelines, something as distracting as significant changes in size of the central object that isn't relevant for the goals of the sim should be avoided.

Interviews

Recruited from 2nd semester chem course.

S1M14
03/30/11 v 2.01.03

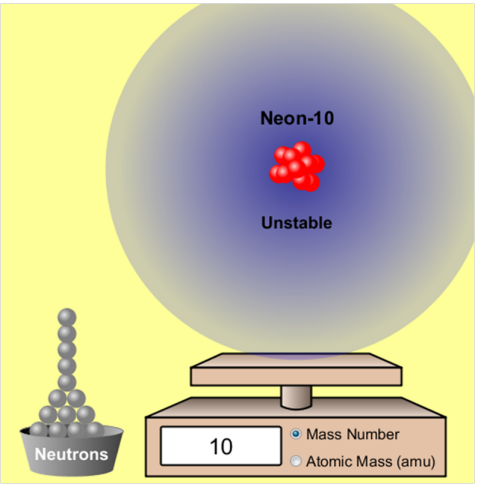
Warm-up:
MCDB major, 2nd year
Took AP chem in HS, in phys 2 and chem 2
Used PhET in phys & chem labs
Isotope = atom w/ diff amounts of neutrons

Sim:
1st tab
Clicks on PT first
Takes out neutrons - says you can't take out protons
Says can you add neutrons, then puts all in
Clicks on Ne, takes out all neutrons
Says can you get to a point where it's nonexistent - says no
Asks if you can use other periods in PT
Opens boxes - says huh
Tries to add neutrons back in, but sim freezes - hits reset
Says the abundance shows you how much there is

2nd tab
Drags one of each isotope into box
Clicks nature's mix, says ok - back to my mix
Clicks on PT
Says is this about finding the correct mass percent
Clicks more (did not use), back to less
Clicks on nature's mix, says it gives you the real # - clicks on diff elements
Clicks my mix, adds one of each isotope
Clicks more (did not use), back to less
Says he gets the gist of it

Follow-up:
Spent 3 mins on 1st tab, 3 mins on 2nd tab before questions
Says the sim is useful for figuring out abundance
Says he likes 2nd tab more
1st tab
Mass buttons: did not notice - says amu gives you more accurate #
Says if take one neutron out, it will be not quite 19 (it's unstable) - oh, there is no such thing
Says the masses will be more different for larger elements
Says mass # = protons & neutrons, atomic mass also has electrons
Cloud: says it's electrons - yes, blue electrons at top (confirms)
Unstable: wanted to see if it became critical - atom splits because forces out of whack
Says we could say "not possible", but you can see in abundance or amu when it does not work
2nd tab
More: (uses now) says you can try to make your mix a similar ratio to nature's mix
Says there could be a **game** where you try to get nature's mix
Says the slider could go higher than 100
Symbols: says can keep bottom # on there - important to know diff representations
Fixed abundance: says at first he was not sure if right - but there will be structure in class, makes sense in sim
Says we could add more common elements like gold, silver, etc.
Standard
Says decimals are because of abundance (give him more prompt)
Adds neutrons to H - says it would be the one w/ only 0's - whole #
Thinks maybe noble gas - clicks on elements - ok, carbon - adds neutrons to C

Notes
- Already knew isotopes are atoms w/ diff amounts of neutrons
- Only spent 6 minutes on the sim before questions
- Found all controls except atomic mass button, did not use more sliders
- Said you could try to make your mix a similar ratio to nature's mix
- Figured out that C is the standard with prompts



S2M13
03/31/11 v 2.01.03

Warm-up:
Physics & astrophys, 1st year
Took AP phys & chem in HS, in phys 3 and chem 2
Used PhET in HS and college phys & chem
Isotope = an atom w/ varying # of neutrons - e.g., carbon-13 has one more neutron - can be more or less n's

Sim:
1st tab
Opens symbol first - says he likes the atomic & mass #'s
Clicks amu, opens abundance
Tries to click potassium - says only goes up to Ne
Puts in n's, takes out n's
Says it's useful for the abundance
2nd tab
Puts in isotopes - says not sure what I'm doing
Says it shows how much you have by % & avg mass
Says you could replicate if you knew actual mass
Clicks nature's mix (NOTE: sim very slow!)
Says there wasn't enough before (to replicate)
Likes that it shows most common isotopes
Clicks more, enters # - likes that can input # instead of drag
1st tab
Clicks reset, says he likes
Says the legend shows how protons & electrons stay the same
Says the red # in symbol is nice b/c it's # of protons
Wants labels for atomic & mass #'s in symbol
2nd tab

Says it's interesting that it does not show C-14 - goes back to 1st tab, makes it - says it does recognize that it exists

1st tab

Maybe include transition elements, but then big nuclei
Maybe include that H-2 is deuterium, H-3 is tritium
Likes how it shakes when unstable
Nods - for C it's exactly 12 (amu)
Likes that can see which ones are stable
Clicks reset

2nd tab

Closes boxes, re-opens
Puts in isotopes, clicks clear box

Follow-up:
Spent 13 mins on sim before questions

1st tab

Cloud: sea of e-s, no particular location - the key shows you blue is e-s
Unstable: if flew apart, could not see mass for long
Mass: mass # = sum of p's & n's, atomic mass = actual mass in amu
Improve: could have larger elements, but legend would be really long

2nd tab

Symbol: can see that even though same atomic #, they have diff mass #
More: if asked for % composition, you can fine tune it
Nature's mix: like that can create your own, and then see the actual - hard to see when only 1, reinforces that not many
Fixed abundance: nature's mix helps show what it really is
Improve: more elements, but might be distracting - more that have no majority
Not sure about purpose of boxes - maybe less distracting if closed

Standard

Goes to 2nd tab, clicks on nature's mix - says avg mass closer to C-12 than C-13
(Rephrase) Says based off C-12 - could find in 1st tab - can see H not exactly 1, etc., C is exactly 12 amu

Notes
- Knew an isotope is an atom w/ varying # of neutrons - gave carbon-13 as an example
- Spent 13 minutes on the sim before questions, used all controls
- Said you could replicate % composition (in my mix) if you know the actual mass
- Noticed that it did not show C-14 in the 2nd tab - went back to the 1st tab to make C-14 to see if the sim did recognize that it exists
- Noticed that C-12 is exactly 12 amu, knew that it is the standard
- Said it was hard to see when only 1 isotope in nature's mix, but it reinforces that not many of that isotope
- Had a lot of good ideas for the sim

S3F15
04/06/11 v 2.01.05

Warm-up:
Psychology, 3rd year
Took regular chem in HS, in chem 2
Used PhET in college chem
Isotope: about the # of neutrons in the atom - had more or less than regular one

Sim:
1st tab
Adds n's
Opens boxes - shows how frequent (the abundance)
Shakes when unstable
Can you remove them? Takes out n's
Clicks on PT - only 1st & 2nd rows
Takes lots of n's out of Ne - says yeah, it's 0 (abundance)
Says interesting to see the abundance of isotope
Not sure what else to do
F is happy the way it is
Spends most time on atomic mass, not mass #
Says sim is for learning isotopes & abundances - resets
Says it shows which ones would rather gain or lose n's
2nd tab
(Point her to tab)
Puts in 1 of each - yep, 50-50
Looks at avg mass - says it makes sense
Clicks nature's mix - visual representation of what's common
Clicks through PT
Back to my mix - not sure what point is - maybe get to avg weight? can make it whatever I want
Clicks more, uses sliders
Tries to get nature's mix for He - uses slider to get 100, types in 1
Clicks clear box
Not sure what else to do other than match

Follow-up:
Spent 10 mins on sim before questions
1st tab
Cloud: guess it's the e- cloud - got a blue dot for e- (in legend)
Unstable: wondered if would fly apart - but would have to chase down the pieces
Mass: did not understand mass # at first - it's the # of p's and n's - atomic mass is weight - p and n are not exactly 1
Better: pretty simple - symbol #'s confusing at first
2nd tab

Symbol: good to associate symbol with word - did not pay attention to symbol in pie chart, but does not hurt
More: thought it would refill the bucket
Nature's mix: disappointing that can't make it - likes that you can type in # - tries to enter large #
Fixed abundance: not sure what purpose (of my mix) - maybe visual representation of composition?
Better: it shows what composition means - wants to be able to make nature's mix
Standard
Isotope: more confident now - it changes weight - 1st tab is what an isotope is
Standard: guess it's the most abundant - but when you click on an element, it gives you the most abundant - makes unstable, notices that atomic mass goes away - can't weigh it when unstable
(Refrase, but still not clear - tell her it's the one with all zeros)

Notes
- Knew isotopes are about the # of neutrons in the atom - more or less than regular one
- Said the 1st tab is for learning isotopes & abundances - it shows which ones would rather gain or lose neutrons
- Had to prompt her to open 2nd tab
- Said you can make my mix whatever you want - maybe the point is to match the avg weight? or a visual representation of composition?
- Tried to match nature's mix for He - used slider to enter 100, typed in 1 - wants to be able to make nature's mix
- Noticed that atomic mass went away when unstable - said you can't weigh it when unstable

Recruited from PhET family and friends.

S4M10
04/07/11 v 2.01.05

Warm-up:
16 years old, in 10th grade at Fairview High
Likes world history, in biology, took physical science in 9th grade
Used PhET in MS
Isotope: no idea

Sim:
1st tab
Opens boxes, puts in neutron, clicks mass buttons
Asks: **is this (the cloud) the field of energy?** (0:40-0:58)
Adds all n's, clicks atomic mass, sees --, takes out n's
Clicks PT, adds n's - says the more n's, the less stable
Resets, adds n's to H, looks at atomic mass
Says the atomic mass grows until it has 3 n's, then not sure what happens

Asks: is natural abundance in the real world?
Puts in n's for H, looks at abundance
Resets, clicks on F, puts in all n's - takes n's out, looks at symbol & abundance
Says he's looking at the relationship between # of n's and %, but not sure what % of
Asks: can I go to next tab?
2nd tab
Puts in some of each isotope, clears box, clicks PT
Says Li-6 has diff effect on % composition than Li-7 - tries to demo, says j/k
Clicks nature's mix & PT - says it shows the % of diff types of He in atmosphere
Back to my mix, puts in some, clears box
Says he's just messing around w/ it
Clicks more, uses sliders
Says he's putting diff types of B in atmosphere, looking for % changes
Tries to get same % for B as natural % using the sliders
Says it looks like less molecules in my mix, but same % and avg mass
Does the same for Si
Back to 1st tab
Says this is just Li-7 (in 1st tab), this has Li-6 and 7 (in 2nd tab) - says this (avg mass) is the atomic mass between the two
Back to 1st tab, clicks through PT
Says this (legend) is the # of p's, n's and e's in the... (did not finish)
Says that's all

Follow-up:
Spent 17 mins on sim before questions
Learn? adding n's makes atom less stable - isotopes are... (did not finish) - when n's added to diff isotopes, make unstable
Isotope? element w/... (did not finish) - if knew more about isotopes, would learn more - would know more about interactions w/ isotopes
Better? wants more explanation of #s in symbol - says this # (atomic #) stays the same when you add n's
Fun if something happened if too unstable - like a rxn or explosion
1st tab
Cloud: the energy - **the magnetic field** - if farther out, it goes back, but if close it attracts it (24:14-25:00)
Legend: did not see hand, so did not try to move
Mass: atomic mass is how dense, mass # is the # of molecules - for example, if add n, the # changes because another molecule - (ask how to get the #) - could be p&n or n&e, since p&e are the same - maybe could take p's out
Abundance: natural abundance in real world - like H w/ 1n is very rare, H w/ 3n's can't exist - rxn would happen
Symbol: top # is # of n's, bottom # is red, so maybe # of p's
2nd tab
Boxes: did not close, but knew you could

Symbol: did not notice
Average mass: if put in one of each (demos w/ 3 isotopes), should be in middle
More: thought you could get more
Nature's mix: how many of each molecule occur in real life
Fixed abundance: nature's mix tells you what it is in reality

Notes
- Could not define the word "isotope" before or after - called the particles & isotopes "molecules"
- Learned the more neutrons you add, the less stable it becomes - said H with 1 n is very rare, H with 3 n's can't exist in real world
- Tried to get same % for B as natural % using the sliders - said it looks like less molecules in my mix, but same % and avg mass
- Asked if the cloud is the field of energy - later said maybe it's the magnetic field - because if you put n farther out, it comes back, but if you put it close it attracts it
- Noticed that the bottom # in symbol (atomic #) stays the same when you add neutrons - said the # is red, so maybe # of p's
- Said the mass number could be the # of p&n or n&e, since p&e are the same - could tell if you could take p's out

S5M7
04/13/11 v 2.01.06

Warm-up:
12 years old, in 7th grade at Centennial
Likes math, in life science
Used PhET at home, used Natural Selection in class
Isotope: no idea

Sim:
(Did not talk for first 5 mins)
1st tab: clicks PT, mass buttons
Tries to drag element into cloud
Adds n's, opens boxes, resets
2nd tab: puts in 2 of each isotope
Clicks PT, nature's mix
Back to my mix, clicks more
1st tab: takes out n's
Clicks PT, opens boxes, resets
Takes out n's, puts them back
2nd tab: resets, nature's mix
(Back-and-forth between tabs, spends about 1 min on each)
1st tab: says would be nice if you could add p's instead of just n's
2nd tab: likes nature's mix & how you can make your own
Says don't understand how to get avg mass - why it goes down when you add more

1st tab: says what is isotope?
Asks is this about how to make an atom stable?
2nd tab: adds 1 of each isotope, says oh
Clicks nature's mix, tries to match
Says he's comparing what you can do w/ nature's mix
Says he wonders if 2 kinds of He, or diff parts of He atom
Is it (% composition) that much in an atom, or % for all atoms?
Likes how it saves what you put in
1st tab: adds n's
Says maybe show + and - for p's and e's - to show how to balance it, why it's unstable
2nd tab: uses sliders to match nature's mix
Says he wonders what the bottom # in % symbol is - says oh, it's the 17th atom in the table
Types in # for slider
1st tab: adds all n's, opens boxes
Clicks PT, adds & removes n's, looks at abundance
Says isotope is how much of the atoms have 2p and 2n in nature - very little look like that (2p and 1n) - gives examples - 19.9% of boron atoms look like that in nature, and 80.1% look like that (17:24-18:24 in Camtasia)
2nd tab: says it shows the % of Mg atoms in nature - but you can make your own
Says all have own atomic mass b/c they have more n's - the avg mass depends on how many of each kind
Asks: **how do you make this?** (the sim) - what program do you use?
Asks: are you going to have all the atoms? says that would be more fun
1st tab: says maybe have e-s circling it - **kids like moving things**

Follow-up:
Spent 24 mins on sim before questions
Says good to use last year, when it was all about atoms
Isotope: how many of one kind of atom (He) vs another kind - depends on how many p's and n's it has
Cloud: says oh, it's the e-s or the outside of atom - the e-s are blue and that's blue
Legend: tried to grab p's - says easy to count p's and n's
Unstable: says it shakes more when you add more n's
Mass: says He-4 has 2p's and 2n's, so mass # is 4 - in mixture, no He-5 b/c unstable - says atomic mass counts the e-s, the whole atom - mass # is only nucleus
Symbol (for H): top # is mass #, bottom # is 1 b/c this is the 1st element
More: you can add more & quicker
Better? more movement - more atoms in PT, but not so big

Notes
- Never stayed on one tab for long, went back-and-forth
- Asked if the sim is about how to make an atom stable
- Knew mass # is only the nucleus, atomic mass is the whole atom - also knew the bottom # in symbol is the atomic #, top # is the mass #

- Tried to match nature's mix for 2 elements
- Did not understand how to get avg mass at first - why it goes down when you add more - later said the avg mass depends on how many of each kind
- Wondered if % composition is that much in an atom, or % for all atoms
- Liked how it saves what you put in the box
- Noticed there are no unstable isotopes in mixture tab
- Said isotope is how many of one kind of atom vs another kind - said it depends on how many p's and n's it has
- Said the sim would be more fun if you could add p's, if we had more atoms in PT, if the e-s circled it, b/c kids like moving things
- Asked how we make the sim - what program we use

Recruited from Boulder area schools.

S6M4
04/15/11 v 2.03.00

Warm-up:
10 years old, in 4th grade at Crestview Elem
Likes art, never used PhET, likes computer games
Isotope: no idea

Sim:
1st tab
Asks: what are you supposed to do?
Opens boxes, clicks mass buttons
Tries to click PT, resets, clicks PT
Says some parts are confusing - not sure what those (the n's) are
Says he's seen the words oxygen, carbon, etc. before
Learn? did not know oxygen has 8 protons
(After 8 mins) Prompt him to use neutron bucket
Adds all n's, clicks PT, takes n's out
On atomic mass, makes unstable, clicks mass #
Counts particles in legend
Takes n's out, puts back in, closes symbol box
Point? to see what happens when take away n's
Mass #? total # of things in here - 7 p's and 7 n's
Abundance? how much there is - did not get until could move n's
Cloud? the electron
2nd tab
(After 20 mins) Prompt him to open 2nd tab
Clicks more, nature's mix
Back to less, adds to box, clicks PT
Adds all of one isotope

Clicks nature's mix, then through PT
On my mix for S, adds all of one isotope, then another, then another
Says he's looking at that (the pie chart)
Clicks more, uses sliders
Puts in one of each "molecule" using the sliders
Says he's looking at avg mass
Types in #s for sliders, resets
Says looking at diff between mine & nature's
About? how many molecules there are
(Weird bucket behavior: isotopes suspended in air)
Puts one isotope on top of another
Learn? diff gases... did not know molecules in the gases
Knows oxygen is a gas
Pie chart? how much of what is in it
Says nature's mix lot diff than mine
Says not sure what avg mass is
Tries to match nature's mix using "less"

Follow-up:
Spent 40 mins on sim before questions
Think? understand when older
Liked seeing diff here (the pie chart)
Isotope? mixture of... molecules - or maybe type of gas
Tries to put all on top of each other in the box

Notes
- Had to prompt him to use the neutron bucket
- Said the point was to see what happens when you take away n's
- Said the mass # is the total # of things in here (the atom)
- Said the cloud was the electron (singular)
- Had to prompt him to open 2nd tab
- Compared nature's mix to his mix
- Tried to put all isotopes on top of one another in the box
- Said an isotope is a mixture of "molecules", or maybe type of gas
- Said he'd understand when he's older

S7M7
04/18/11 v 2.03.00

Warm-up:
12 years old, in 7th grade at Southern Hills
Likes computers, hates math & numbers
Never used PhET sims
Isotope: no idea

Sim:
1st tab
What is this? Adds n's
What's unstable? Is it going to explode?
Clicks PT, removes n's
If remove one, it gets unstable
Maybe there has to be as much p's as n's
What is mass # and "automatic" mass? Mass # is amount of p's and n's
Where's the e-s? Here (in legend), but don't see any
Opens boxes - What's an isotope? Is an isotope an atom?
Says I can add 3 more n's (to oxygen)
What is stable? Heard that nukes come from atoms
Takes out all n's - How do I take away e-s? What do e-s do?
2nd tab
What's this do? Adds to box
Is this oxygen? Says he thinks H & N make oxygen (?)
Says we should add an animal in here (the box)
Clicks more, uses sliders
Says not sure what I'm doing here
1st tab
How do you make it stable?
Can you take away the red things? clicks on legend
2nd tab
Closes boxes, says I'm confused
What's H-1 mean? H-1 and H-2 makes air
What else do you want me to do? Is there a tutorial?
1st tab
What is that table? Can I click on more than one?
Oh, is this a table for all the elements? My mom has one
What happens if add all n's?
Hey, I can throw it (n) in the air & it falls back into the cup (CT 7:48-8:28)
This (He) is diff than O - can add lots (of n's) to O, still stable (demos) - but if add one to "He" it gets angry
2nd tab
Says I'm confused - What happens if I press help?
1st tab
Can I borrow a science book?
Not sure what any of this means - what's the main objective?
What are n's, p's and e-s?
Want to see what happens if add more p's and e-s
Can it explode if add something wrong? Like a nuke - could countdown 5, 4, etc.
Talks about game he wants to buy
About? to see if can make it stable or unstable

What's the scale for?
Says it's boring after 5 mins - should make it explode
Is an isotope a molecule?
Isn't it crazy that an atom can make an explosion? since smaller than my finger?
Could you get radiation from this in real life?

Follow-up:
Spent 17 mins on sim before questions
Cloud? ozone layer, can stop global warming (?)
Asks about bull statue outside
Mass #? 17 p's and n's - when I take one (n) out, it goes down to 16
Atomic mass? the pounds of it
Symbol #? not sure, can I close it? 16-8=8, there must be some math thing
Tries to catch n's in mid-air (20:31-20:54)
Abundance? amount of badness in ozone layer - polluted b/c of BP (?)
Throws all n's in air, tries to make n's collide (22:11-23:10)
Says the isotopes (in 2nd tab) go back too fast
Asks about KFC (the food place)
Tries to make a face w/ these things (the isotopes in box)
Says this one (Mg-25) has 25 atoms, this one has 26
% tells you how many are in there
Avg mass? 25 miles of explosion (?)
Prompt to click nature's mix
Says it looks like a maze - could draw a real picture
Wants a flag to say "these are molecules"
Says it should be more interesting - like a game
Isotope? an atom, I guess
Learn? I made faces on a computer

Notes
- Asked a lot of questions
- Had some form of attention disorder
- Asked: Where are the electrons? Saw them in legend, but no where else. Asked: How do I take away electrons?
- Confused by 2nd tab - wanted more instruction
- Said the sim was boring - wanted unstable to explode
- Found that he could throw neutrons in the air and they would go back to the bucket - tried to catch with mouse in mid-air
- Made faces with the isotopes in the box (see image)
- Talked about how he was going to spend his $10
- Said an isotope is an atom

S8F7
04/20/11 v 2.03.02

Warm-up:
13 years old, in 7th grade at Summit Charter
Likes math & science, learning about energy in class
Used PhET before - wave on string
Isotope: when atom of element has same # of p's, but more or less n's

Sim:
1st tab
Adds n's, clicks amu
Clicks on diff elements
Removes n's, opens boxes, looks at %
Says it shows if stable or unstable & if found in nature
2nd tab
Puts in isotopes, makes a flower
Clicks nature's mix, back to my mix, clicks PT
Says you can see the composition when mix isotopes & how it compares to nature's mix
Clicks more, uses sliders
Clicks nature's mix, PT
On my mix for S, tries to match - same for Ne (uses sliders)
Says trying to see if she can make it close to nature's
Says looking if some isotopes are common, also if some only have one
1st tab
Takes n's out of He, puts back
Clicks through PT, does same
Says to see which other isotopes exist in nature
Clicks amu

2nd tab
Tries to match nature for Mg w/ sliders
Says she uses % to match
Same for Cl

Follow-up:
Spent 15 mins on sim before questions
Think? neat that can match w/ % or avg mass & can find out which isotopes are unstable
Better? not sure what avg mass was at first, but it takes all isotopes together
Learn? how atomic mass is calculated: abundance & mass
Cloud? electron shield - the e- cloud gets bigger or smaller b/c more e-s or fewer
Mass? atomic mass is calculated by abundance & mass - saw that it changed w/ abundance in 2nd tab; mass # is # of p's and n's
Reset? noticed that it stayed when you changed elements (in 2nd tab); reset would clear
Symbol? red # is # of p's; # on top is mass #
Fixed abundance? if something hit earth, the % composition would change
More? at first, thought it would give you more isotopes, but then thought you could add more
Isotope? no change
Standard? maybe H b/c found in lot of places & mass # is 1 and amu is around 1 - can I see if it's any other? (stops on C) - it's C b/c basis of everything & atomic mass is even #; other ones have decimals
Comments? like that p's red, e-s blue, n's neutral color
Fun? puts in middle of other PhET sims - lot of info; others are simple but interesting

Notes
- Already knew that isotopes are atoms with the same # of protons, but more or less neutrons
- Said the 1st tab shows if stable or unstable & if found in nature
- Said the 2nd tab shows the composition when you mix isotopes & how it compares to nature's mix
- Used sliders and % readout to match nature's mix for diff elements
- Learned that atomic mass is calculated from mass & abundance (not correct)
- Said the "electron cloud" gets bigger because more electrons (not correct)
- Said the % composition would change if something hit the earth
- Figured out that C is the standard b/c basis of everything & atomic mass is even #

S9M7
04/29/11 v 2.03 (BAA) v 2.03.03 (IAM)

Warm-up:
12 years old, in 7th grade at Manhattan
Likes mechanical engineering, not doing much in science
Used PhET in elementary school
Isotope: no idea

Atoms:
1st tab
Adds p, e; says still stable; adds n's, says unstable
Adds p, then n, etc.
Says carbon can be stable, resets
Adds p, then lots of n's
Says it's unstable b/c fewer p's than n's
Takes out p's until only n's, resets
Opens boxes, then closes
Says is Li ever stable?
Clicks cloud, adds e's, resets
Asks if it's possible to create all elements: tell him no
Makes neutral, then stable, resets
Adds only p's, resets
Clicks game tab, then back, looks at PT
Says need same # of p's and n's to be stable
Says e's don't change anything but charge; clicks cloud
Says Ne is strange; only atom that can be stable w/ more n's than p's
Says not sure what role e-s play - do not seem to change anything
Goes through each element to see how many n's it needs to be stable
Adds e-s "just for the heck of it"
Clicks cloud, takes out e's, opens mass
Says symbol makes no sense, resets
Ask what he thinks: wants to reset p's, n's and e-s separately
Says boxes did not mean anything to him
Says not fair that can't make all elements
Throws n's in air
Spent 19 mins on sim (did not let him play the game)

Isotopes:
1st tab
Clicks PT, says same atoms
Opens abundance, says useful; lot of H like that
Says n's should go faster when release
On Be, says no point doing that (100%)
Says did not realize could take away what you did not put in; takes out all n's
Says no unstable O that occurs in nature
Says only one (element) that had one (isotope) w/ less n's than start
Says very small seems bigger than 0.0001
2nd tab
Ask if he noticed the tab
Adds to box, clicks nature's mix, says it's funny
Clicks more; says he expected that if this (slider) is 17, this could only go to 83
Says more here (elements in PT)

Asks is there a molecule creator here?
Spells “Hi!” w/ isotopes (see image), says nature disagrees
Clears box, clicks more
Drags isotopes in air, go behind some stuff
Makes exactly 50%
Ask about pie chart: says it’s the % of diff isotopes (says “molecules” too)
Clicks nature’s mix, through PT, closes boxes
Spent 17 mins on sim

Follow-up:
Ask how sims compared: says both not very fun
Says cool to play w/ pie chart, see nature, but nature & I disagree
Notices diff speed of n’s & isotopes; says no “teleporting”
Ask if learned: says could have no less p’s than n’s, but some could have more
(Ran out of time)

Notes
- Used Build an Atom first (but did not play the game)
- Learned that you need about the same # of p’s and n’s to be stable
- Said not sure what role electrons play; do not seem to change anything
- Seemed to learn more about isotopes from BAA sim!
- On 1st tab in Isotope sim, focused on the abundance
- Asked if the 2nd tab was a molecule creator
- Spelled “Hi!” with the isotopes in the box (see image)
- Found a couple of minor bugs: neutrons & isotopes go back to bucket at different speeds, can go behind some things in sim, can left & right click on some things