Build an Atom

PhET Sim Design Document

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Public URL: https://docs.google.com/document/edit?id=1VGGhLUetiwijbDneU-U6BPrjRlkI0rt939zk8Y4AuA4&hl=en&authkey=CMLM4ZUC

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Audience

The high-level goal of this simulation is to enhance students' understanding of atoms and their basic structure. This understanding is an important foundation for the study of chemistry, atomic and sub-atomic physics, many aspects of biology, and other areas of science. The target audience is therefore students who are just beginning to study basic chemistry, physics,

and biology. This will generally be middle school students (grades 6 through 8), though the simulation may also find application with older students that are starting on these subjects or are in need of a review.

Users of this simulation should already understand that all matter is made of atoms, and that there are different kinds of atoms. Some familiarity with the names of elements and with the Periodic Table would be ideal, but not absolutely necessary, since the sim may be able to serve as a sort of roundabout introduction to these ideas for those students that have not yet been exposed to them.

Learning Goals

After using this simulation, a student should be able to:

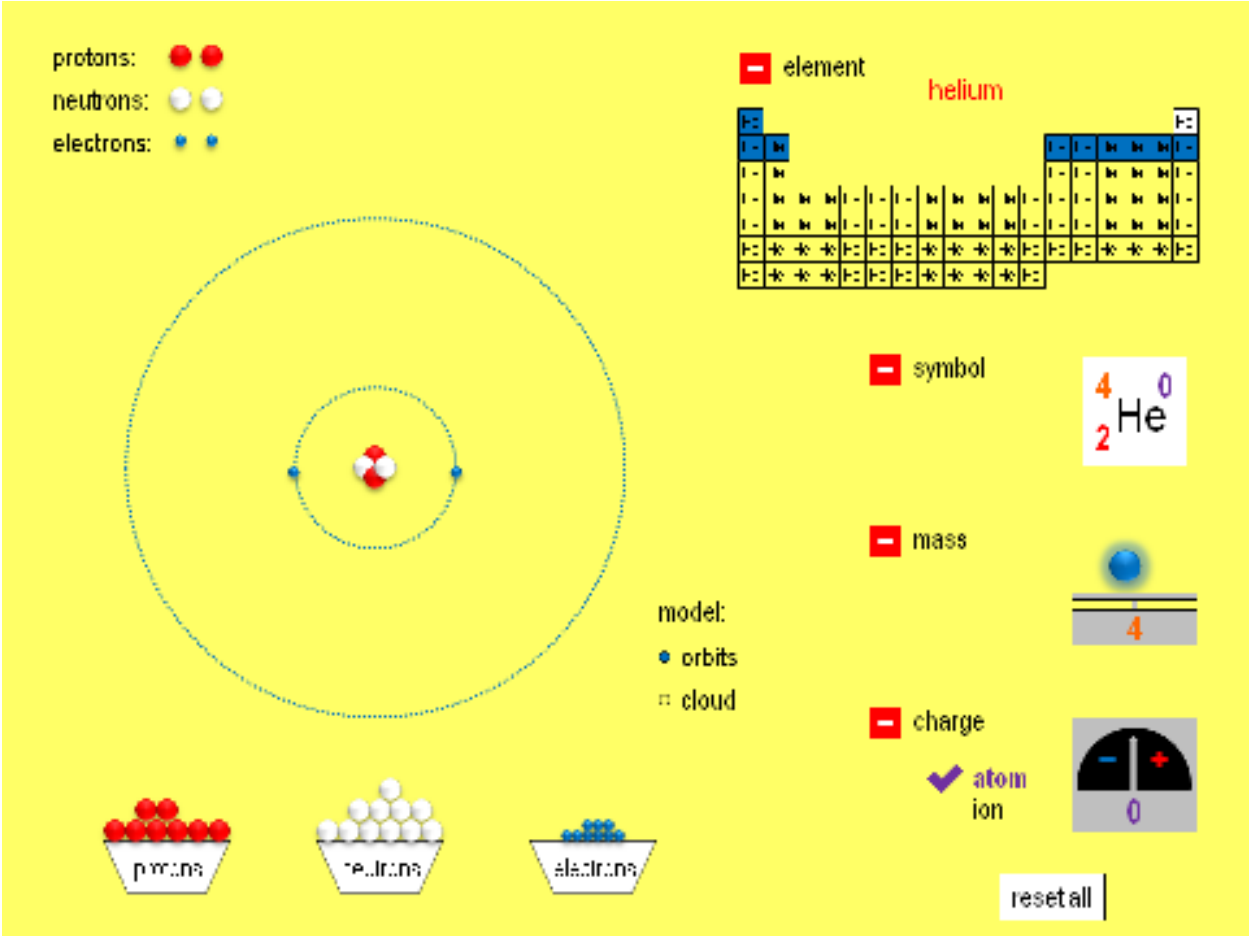
- describe the structure of an atom
- connect protons to element identity
- connect neutrons to nucleus stability
- connect electrons to ionic charge
- describe the mass and charge of the subatomic particles

The student is NOT expected to:

- describe the excited states of an atom
- connect electrons to chemical reactivity
- describe the atomic mass of an element
- understand and use the term “isotope” - sim can be used for this in an activity if desired
- understand trends in atomic size (e.g. Li is actually larger than Be, which is in turn larger than B, and so on for the 2nd row of the periodic table)
- understand the scale of the atom, particularly the relationship between the electron shell size versus the nucleus

Mockup

First Tab - Build Atom



Bucket of particles:
The student can add particles to the model or return particles to the bucket. There is only a limited quantity of each particle:

- Protons: **10**, to limit elements to the first 2 rows
- Neutrons: **13**, to allow all stable isotopes of Ne and one radioactive isotope
- Electrons: **11**, to limit n to 2, and to show that no more than 8 electrons can go in the outer shell. UPDATE: only **10**

Will students know to drag the particles? If not, we could add a “wiggle me” on startup. Will students tire of dragging? If so, we could include an “add” button or a spinner.

Particle	**Charge**	**Mass**
Proton	+1	1
Neutron	0	1
Electron	-1	0

Bohr model:
If the student drags the particle near (need to quantify) the appropriate place in the model:

- Protons and neutrons snap to the center. If the user adds too few/too many neutrons, the nucleus will gyrate - but it will never decay, since the students must add one neutron at a time. UPDATE: if unstable isotope, the word “unstable” will appear under the nucleus; same for “stable”
- Electrons snap to the closest open position. This will allow things to get lopsided, but since they can also remove the electrons, it would be impossible to keep them balanced without moving them around as they are added/removed.
- In order to give students a clue as to where the electrons go, the shell where the next electron would be placed will light up when an electron is dragged near it. Note that this will be the inner shell for the first two electrons and the outer shell for the subsequent 8. UPDATE: no visual cue

Otherwise, the particle will animate back into the bucket.

Electron cloud:
In this view, as more electrons are added to the model, the cloud will become more opaque. If the student clicks in the cloud, an electron will appear under the mouse. The size and shape of the cloud will remain constant (for each electron shell). UPDATE: the size of the cloud is proportional to the number of electrons in the model. The nucleus will behave and look the same as for the Bohr model.

Atomic number & periodic table:
The identity of the atom is determined by the # of protons. Once the student adds a proton, the corresponding element glows. (Should we show the entire periodic table as context for the first 2 rows? UPDATE: yes) If a student moves their cursor over an element, they will get a pop-up of the full name. UPDATE: the name is given, so no need for pop-up. (But in later phase, click on periodic table and get application of element.) The names are translatable, but not the symbols.

Charge:
This is determined by the # of protons - the # of electrons. The meter indicates the magnitude and sign of the charge. If the charge is not 0, the word “ion” will appear in the play area. The color of the word depends on the sign of the charge: positive is red, negative is blue. UPDATE: also include “zero-pairs”

Symbol:
The upper left-hand corner shows the mass number. The lower left-hand corner shows the atomic number. The center shows the symbol of the element. The upper right-hand corner shows the charge of the ion. All four readouts will update as the student adds more particles to the model.

Windows & labels:

All windows can be opened or closed, but all are open by default. UPDATE: the Symbol, Mass, and Charge windows are closed on startup to reduce complexity. The “Show Labels” checkbox removes all readouts in the play area; teachers can use this feature to ask prediction questions.

Mass number & isotopes:
This is determined by the # of protons + the # of neutrons. The scale gives a readout of the mass number. (Will students understand that the blue “fuzzy” represents the atom?) If the isotope is not listed in the table below, the word “unstable” will appear under the nucleus.

www.webelements.com/isotopes.html

The table below lists all stable isotopes for the first 2 rows of the periodic table. (All other isotopes are radioactive.)

Isotope	**Protons**	**Neutrons**	**Mass**	**Abundance %**
1-H	1	0	1	99.99
2-H	1	1	2	0.01
3-He	2	1	3	0.0001
4-He	2	2	4	99.9999
6-Li	3	3	6	7.54
7-Li	3	4	7	92.41
9-Be	4	5	9	100
10-B	5	5	10	19.9
11-B	5	6	11	80.1
12-C	6	6	12	98.93
13-C	6	7	13	1.07
14-N	7	7	14	99.63
15-N	7	8	15	0.37
16-O	8	8	16	99.76
17-O	8	9	17	0.04
18-O	8	10	18	0.20
19-F	9	10	19	100

20-Ne	10	10	20	90.48
21-Ne	10	11	21	0.27
22-Ne	10	12	22	9.25

Second Tab - Game

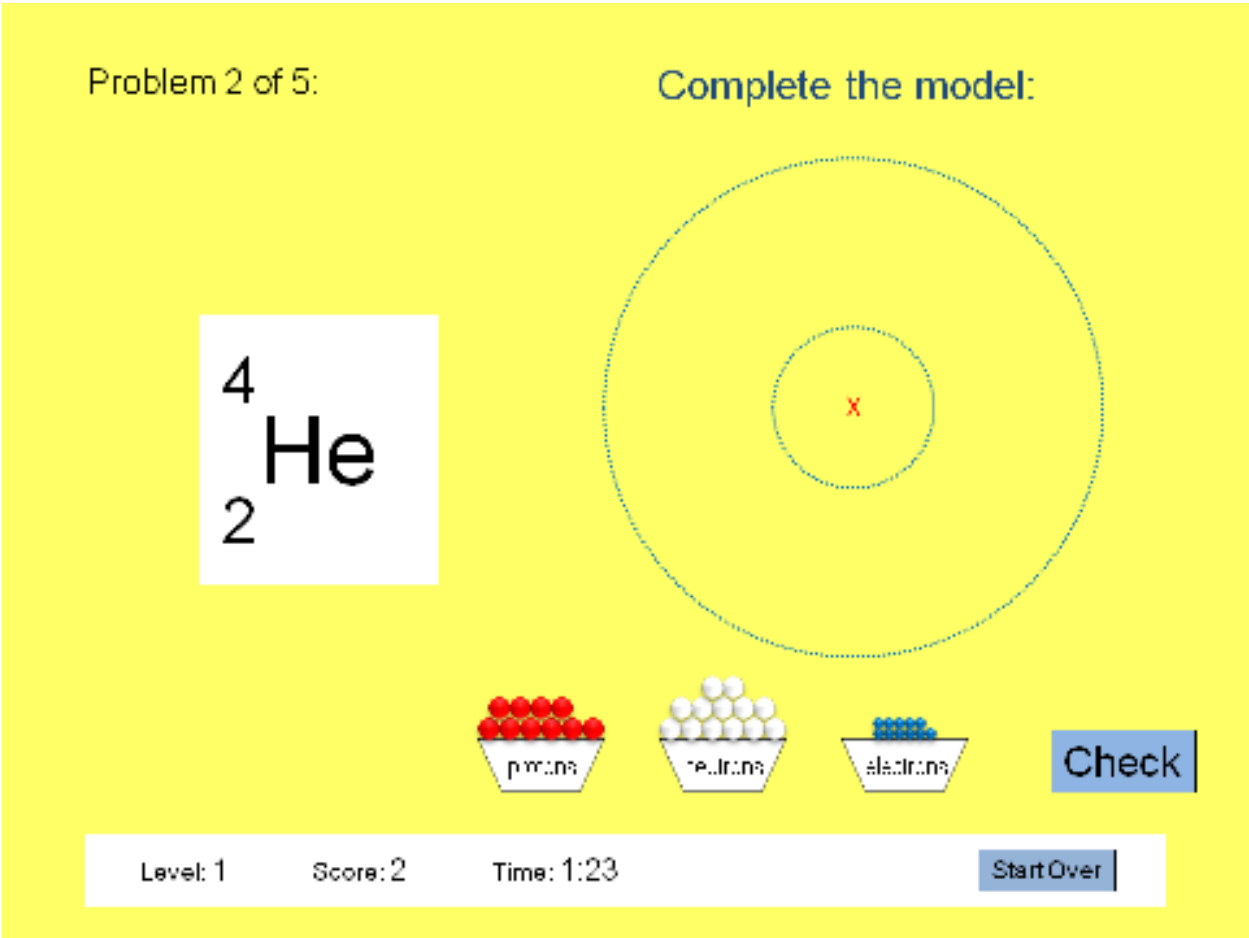
(See the Game tab in the RPAL sim.) The game will give students practice at using the number of protons, neutrons, and electrons to determine the mass number of an atom and the charge of an ion.

The tab will open in “Game Settings” mode; here, the student can select the game level (1, 2 or 3), can elect to turn OFF the timer/sound (both are ON by default), and can click the “Start” button to begin the game. UPDATE: 4 levels

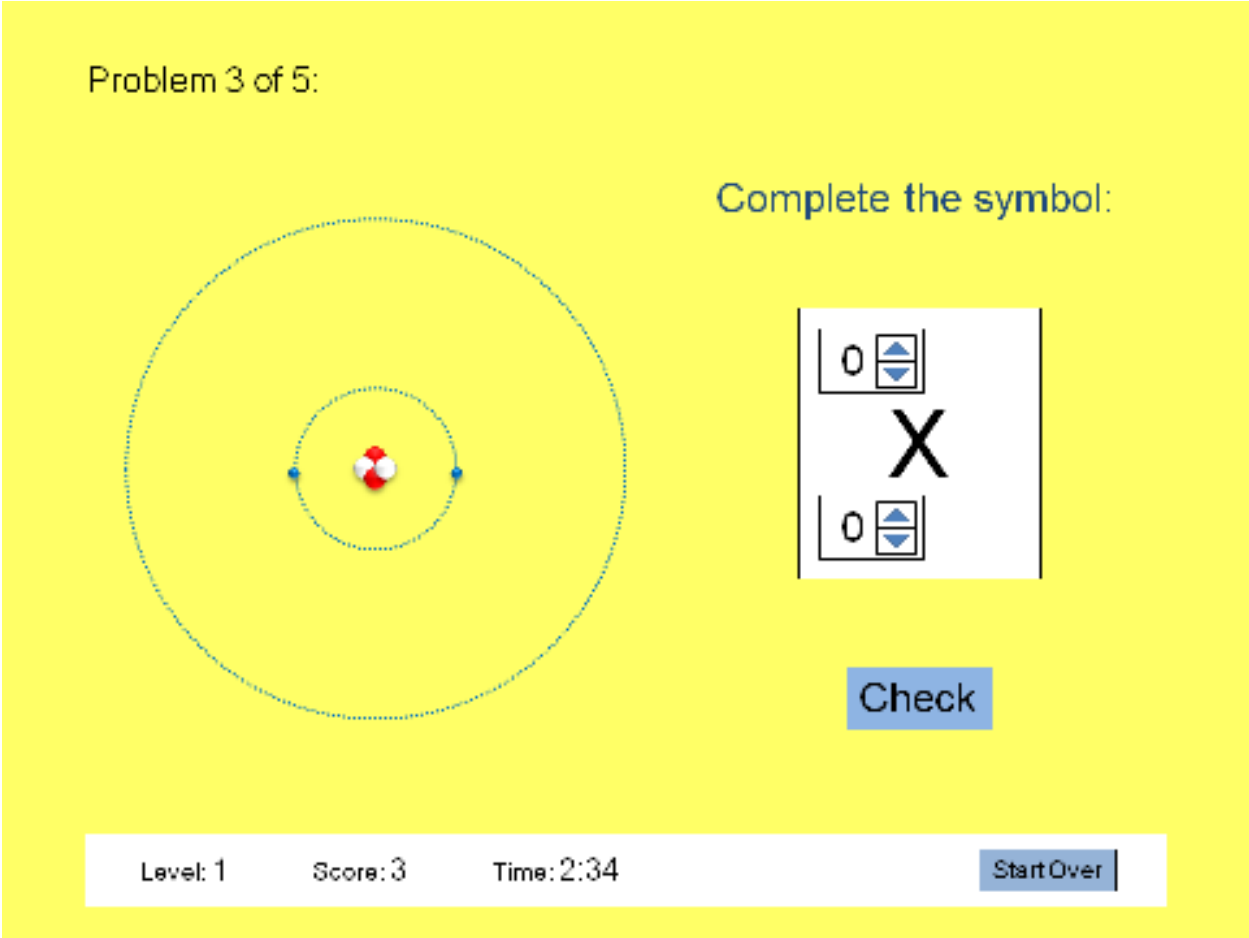
The game will give one representation of an atom (or ion), and ask students to use a different representation to match the one given. In all levels, we will only use the most abundant isotope.

UPDATE: we will include the stable isotopes of H, He, and Li, to ensure a good amount of Bohr model problems in the game. UPDATE: we include *all* stable isotopes for *all* elements. The problem types are defined below:

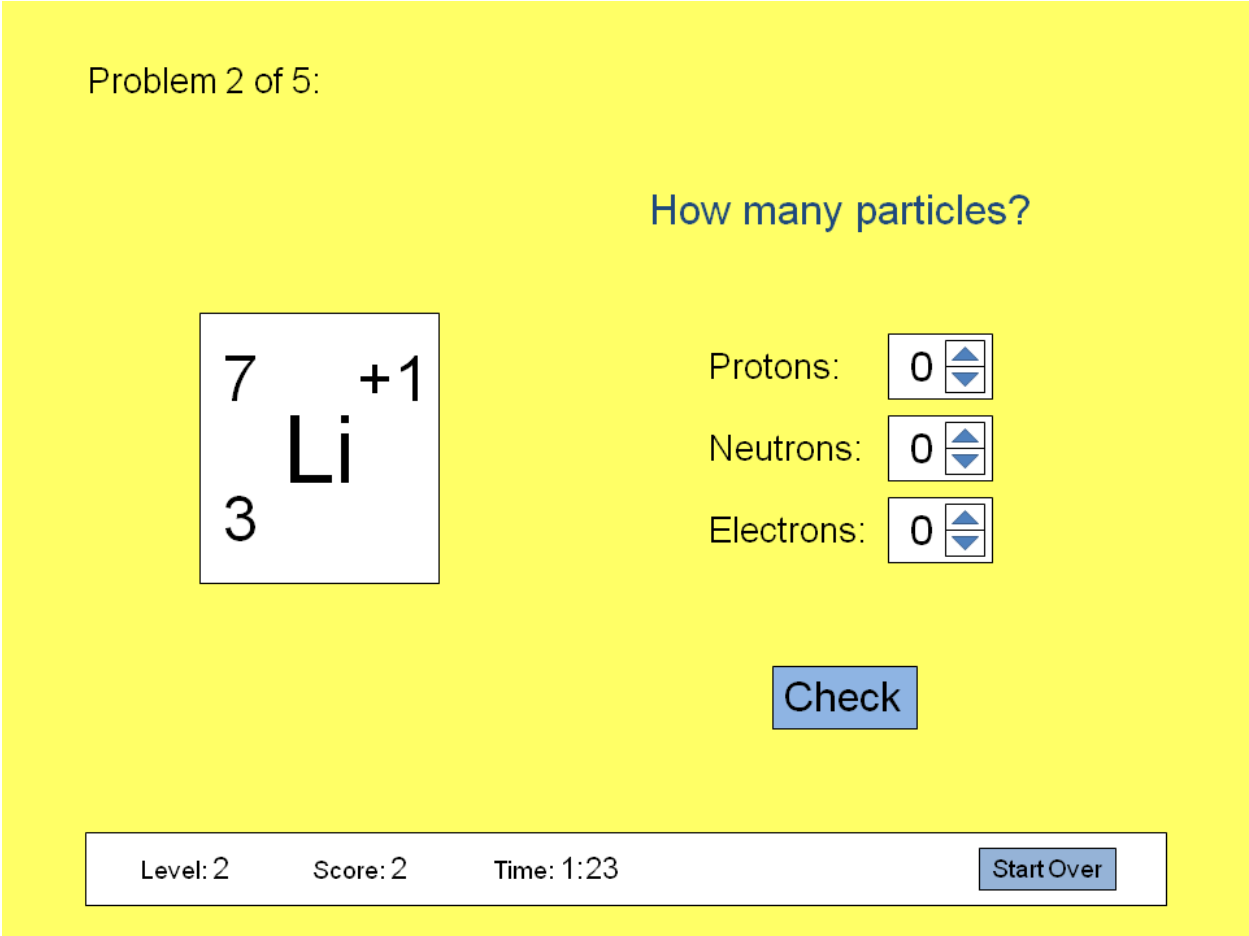
Example of problem type A: given the symbol, drag particles into the model (Level 4 only)



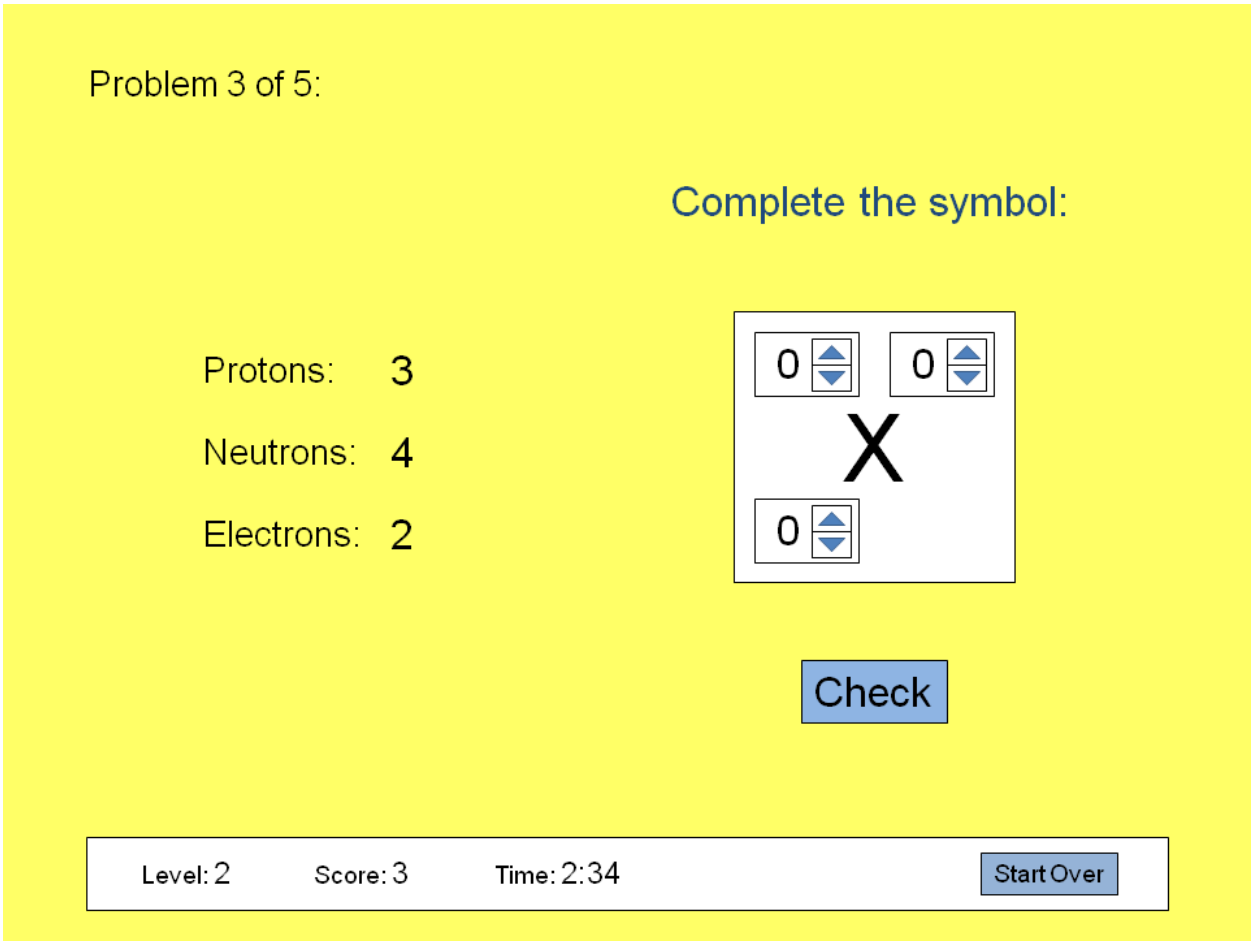
Example of problem type B: given the model, enter values for the symbol (Level 4 only)



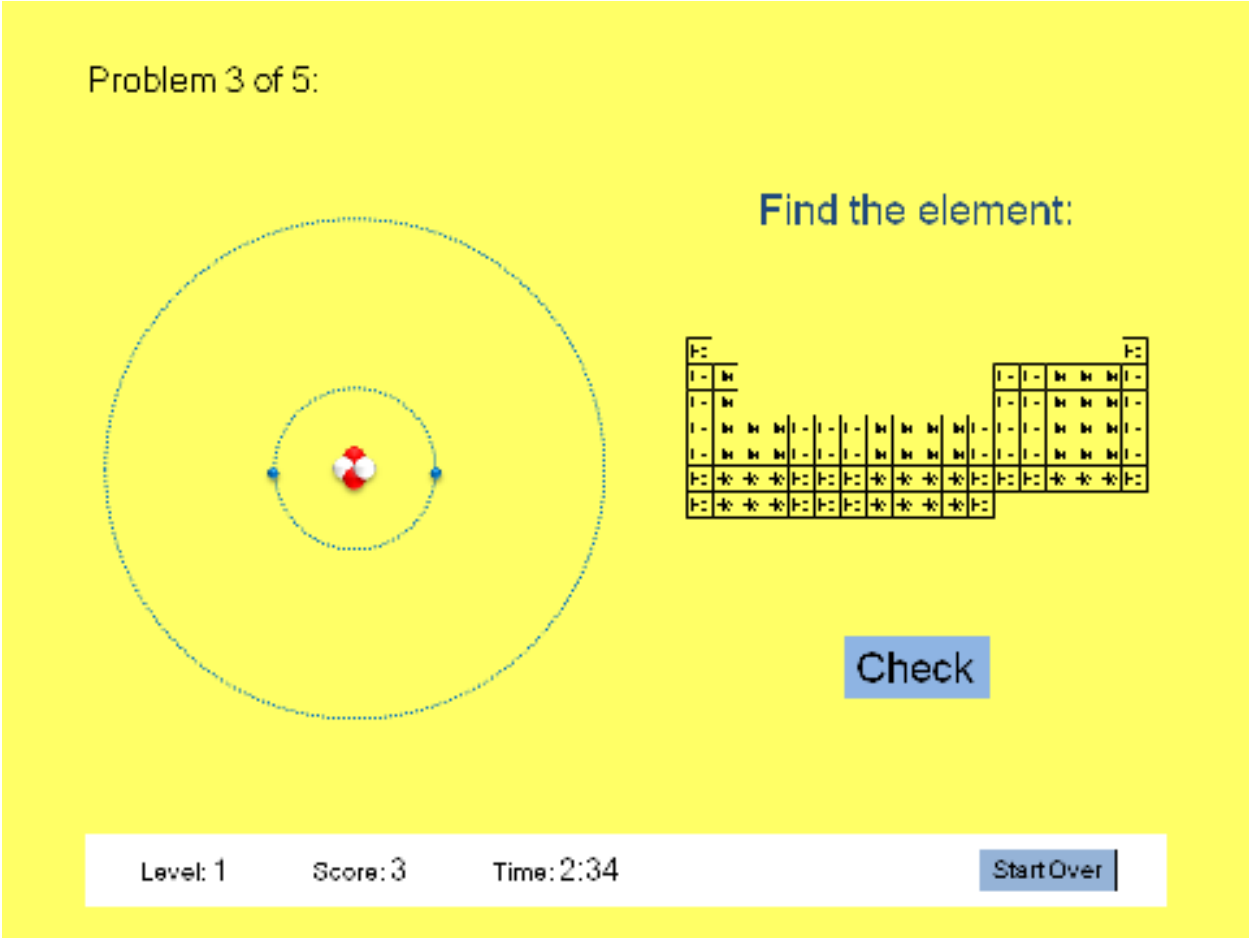
Example of problem type C: given the symbol, enter values for the list (Level 4 only)



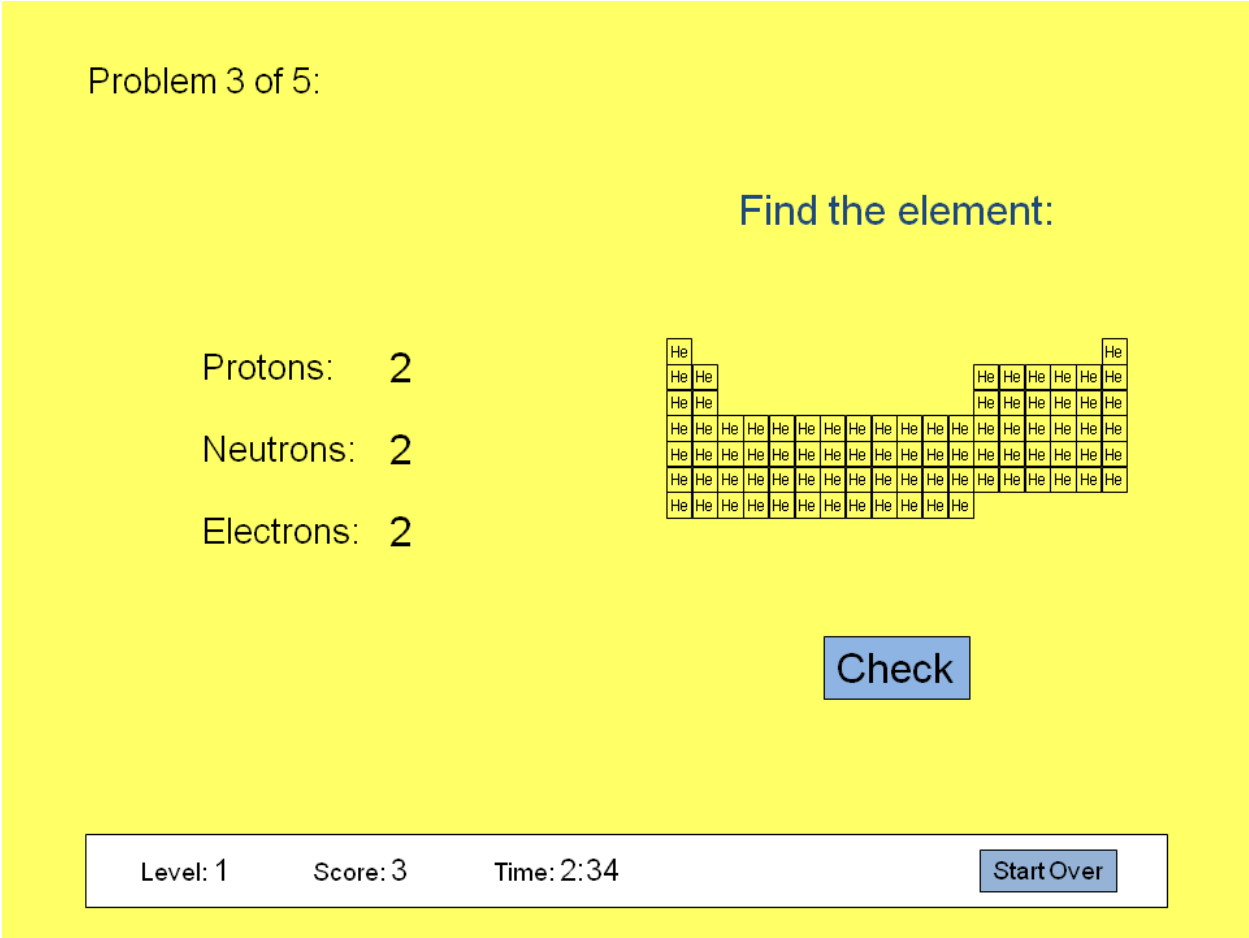
Example of problem type D: given the list, enter values for the symbol (Level 4 only)



Example of problem type E: given the model, select the element in the PT (Level 1 only)



Example of problem type F: given the list, select the element in the PT (Level 1 only)



In level 1, students are given problem types that include the *periodic table* (E and F). Students must understand that the number of protons determines the identity of the atom. They must also decide whether the atom is “neutral” or an “ion”. This level includes atoms and ions in the first 2 rows of the PT.

UPDATE: We added two new levels in the game. In level 2, we do not include the symbol; in level 3, we include the symbol, but students do not need to interpret all 3 numbers at once.

In level 4, students are given problem types that include the *symbol* (A through D). Students must determine: 1) the number of protons from the atomic number, 2) the number of neutrons from the mass number, and 3) the number of electrons from the charge. This level includes atoms and ions in the first 3 rows of the PT, so not all can be made in the 1st tab.

For problems that include the Bohr model, the number of protons is limited to 3, since it could be hard to count the particles otherwise.

For problems in which the student completes the symbol, the element will update as they enter in values for the atomic number, to reinforce that the number of protons determines the identity of the element.

Use the atoms below (up to Ne) in the pool for levels 1&2; use *all* atoms for levels 3&4.

Symbol	**Protons**	**Neutrons**	**Electrons**	**Mass**	**Charge**
1-H	1	0	1 (0, 2)	1	0 (+1, -1)
2-H	1	1	1 (0, 2)	2	0 (+1, -1)
3-He	2	1	2	3	0
4-He	2	2	2	4	0
6-Li	3	3	3 (2)	6	0 (+1)
7-Li	3	4	3 (2)	7	0 (+1)
9-Be	4	5	4	9	0
10-B	5	5	5	10	0
11-B	5	6	5	11	0
12-C	6	6	6	12	0
13-C	6	7	6	13	0
14-N	7	7	7 (10)	14	0 (-3)
15-N	7	8	7 (10)	15	0 (-3)
16-O	8	8	8 (10)	16	0 (-2)
17-O	8	9	8 (10)	17	0 (-2)
18-O	8	10	8 (10)	18	0 (-2)
19-F	9	10	9 (10)	19	0 (-1)
20-Ne	10	10	10	20	0
21-Ne	10	11	10	21	0
22-Ne	10	12	10	22	0
23-Na	11	12	11 (10)	23	0 (+1)
24-Mg	12	12	12 (10)	24	0 (+2)

25-Mg	12	13	12 (10)	25	0 (+2)
26-Mg	12	14	12 (10)	26	0 (+2)
27-Al	13	14	13 (10)	27	0 (+3)
28-Si	14	14	14	28	0
29-Si	14	15	14	29	0
30-Si	14	16	14	30	0
31-P	15	16	15	31	0
32-S	16	16	16 (18)	32	0 (-2)
33-S	16	17	16 (18)	33	0 (-2)
34-S	16	18	16 (18)	34	0 (-2)
35-S	16	19	16 (18)	35	0 (-2)
35-Cl	17	18	17 (18)	35	0 (-1)
37-Cl	17	20	17 (18)	37	0 (-1)
36-Ar	18	18	18	36	0
38-Ar	18	20	18	38	0
40-Ar	18	22	18	40	0

Each level will consist of 5 problems. When a student enters the correct answer, they will see a smiley-face, hear a pleasant sound, and get points added to their score. When a student enters the wrong answer, they will see a frowny-face, hear an unpleasant sound, and get NO points added to their score. Below is a flow-chart:

Enter answer, click “Check”
- If correct: get 2 points, click “Next”
- If wrong: get 0 points, click “Try Again”
  - Enter NEW answer, click “Check”
    - If correct: get 1 point, click “Next”
    - If wrong: get 0 points, click “Show Answer”, then click “Next”

A box at the bottom of the play area will keep track of the current level, the score, and the time (the clock starts at 0:00 and counts UP). The box will also include a “Start Over” button, which will take the student back to the “Game Settings” screen.

After the student has gone through all 5 problems, a “Game Over” box will appear with a summary of the level, the score, and the time. The student can click the “New Game” button to return to the “Game Settings” dialogue and try a new level.

Discussion

This section is intended to capture the feedback that we get on early versions and the decisions that are made in response to it.

06/02/10 - *Uplift & PhET*

Sim on atomic structure:
- build atoms from parts (protons, neutrons, electrons)
- electron cloud
- see what element something is while you're building
- balancing
- where you are in the periodic table
- display mass

- which subatomic particles affect the mass, etc.
- see how mass, charge, atomic number adjust as the atom is changed
- related sim: Periodic Table

09/09/10 *- PhET meeting*

On electrons:
- do we want places for the electrons? or snap to place?
- include option to switch to “cloud” view
    - to emphasize that only a model
    - will the cloud be in shape of orbital? or just round?
    - make the cloud more opaque with more electrons

On neutrons:
- do we need a checkbox for “stable isotope”?

09/16/10 *- PhET meeting*

- where to put electron?
    - Robert wants it to look artificial, so static
- what shape for cloud?
    - sphere - orbitals not learning goal
    - John will prototype electron “fuzz”
- how important is the element name?
    - mouse-over periodic table, or checkbox?
- what to show for mass?
    - stick w/ integers
- how to indicate stable isotope?
    - click on button? Kathy wants more interactive
    - show warning message? e.g., frowny face if unstable, no face when stable; or check mark if stable, no mark if unstable; or write “stable” in green, “unstable” in red?
- do we need to indicate when the atom is an ion?
- do we need more shells?
    - not sure if adds much - try 2 for now
- show more of periodic table?
- Kathy wants non-black background
- if click on element in periodic table, get that atom?
    - Trish says: then why create your own?
- add readouts in play area for # protons, neutrons, etc.
    - because gets crowded for larger atoms
- where to show symbol?
    - mouse-over highlighted atom? or checkbox? or another tab?
    - or different views under “your atom”: readout or symbol
- will students connect green ball on scale w/ atom?
    - try “mini-cloud” view

- do we want a game?
    - e.g., match the atom, or: what do you need to change?
    - will hold off for now
- is excited state an important goal?
    - no, but check w/ Suzanne

09/17/10 - *Suzanne & PhET*

Where to put electrons? In game, spots for the electrons - but in sim, could reject an extra electron. Nice to have open spot, but also gives away the answer. If shell not filled, color it differently than filled shell (or use some other visual)
Rules: atoms are **neutral** - positive & negative must balance. If charged, not an atom - use word "particle" instead?
Do we want game in sim? YES - students like to compete - e.g., who can build B the fastest?
In sim, maybe allow multiple players, or add sound if correct. Limit to first 3 rows
Layers of sim: 1) atoms, 2) isotopes, 3) ions - overload if all together
Students confused by non-integer atomic mass - fill cup w/ different isotopes - get weighted average. Students also confused by percentages - which isotope is most abundant?
Extensions: why does the periodic table end? why do atoms bond the way they do? Good ideas for other sims.
Are symbols a goal in MS? Yes - also Lewis dot structures
How to represent mass & charge? Charge: Use scale instead of meter? NO, may confuse students. Could stack protons & electrons next to each other to see which one is in excess.
Mass: Use scale w/ 4 mass units instead of readout?

09/10 - *PhET email*

JB: Kelly & I just met to discuss the design of Build and Atom, and there were several questions that arose that we thought would be good for the group to discuss at the meeting on Thursday. The questions are listed below. Feel free to respond now, or to wait until Thursday's meeting of the chemistry group.

· Is it okay to position the electrons in whichever slot is closest to where the user drops it? It seems like it is either this or having the electrons "equilibrate" based on some use cases that Kelly and I worked through. We can present details at the meeting.
· Should we show the entire periodic table or just the top of it? I was showing the spec to my wife, who is a Physical Therapist (so has a reasonable science background), and she said that she would not have recognized the top two rows of the periodic table without the rest of it showing.
· Should the names of elements (e.g. Helium) be translatable?
· If we show the entire table, is it okay if only the first rows (the ones that they can build) are interactive and show the name of the chemical on mouseover?

· Should the nuclei of unstable isotopes move/gyrate, or should we keep all configurations still? Kelly and I kind of liked the gyration idea since it would visually convey the idea of instability instead of relying completely on the textual readout.

Cloud view

TL: Here are a couple of cloud view ideas that I liked when I searched the web. One thing I noticed on many of the pics was the representation of the nucleus like in image 1. One thing I liked about image 2 is that it is obviously a cartoon. I attached the images and also included a link.
1 http://www.hk-phy.org/energy/power/nuclear_phy/images/atom.gif
2.http://www.science-class.net/PowerPoints/Atomic Structure_files/slide0026_image015.gif

"Build an Atom" or "Atom Builder"

JB: I was about to set up the Build an Atom sim in SVN, and then I noticed that the title of the spec says "Build an Atom or Atom Builder". We need to choose a title so that I can put the sim into SVN. It is possible to change the name later, but it is best to start out with the ultimate name of the sim so that the name of the SVN project and the name of the simulation match.

I will start down the road of assuming that the name is "Build an Atom". This seems like a superior name to me because it makes it seem like something that the user is going to do, whereas "Atom Builder" sounds like the simulation might be building the atom for you. If anyone feels strongly that the name should be "Atom Builder", please contact me right away so that I don't have to undo too much work.

KL: I like "Build an Atom" too.
RP: I also prefer "Build an Atom".
KP: Me too.
KL: I removed the other name from the Google doc.

Atoms and ions

JB: I was thinking about what Suzanne said in our meeting on Friday about something only being an atom if it is neutral, and decided to go on line and look it up, since I had never heard this before. Here is a sentence for the Wikipedia entry on "Atom":

"An atom containing an equal number of protons and electrons is electrically neutral, otherwise it has a positive or negative charge and is an ion."

I interpret this to mean that an atom is an ion, just a charged one. Do you all read this the same way?

Here is a link to the article if you want more information:

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

TL: In HS and MS, we tend to describe matter as made up of atom, molecules, or ions. But that leaves many structures out like metallic systems, covalent networks, coordinate compounds, just to name a few. So it doesn't bother me that we decided to call ions a type of atom as it is described in many college texts and Wikipedia in this manner. I believe the person that first encouraged this sim is being contacted and she may have an opinion that would effect how we name the sim. "Build Atoms and Ions" may be more conventional for teachers of younger students, but I am ok with "Build an Atom".

RP: While in my everyday discourse I often use the word "atom" to include the possibility of a positive or negative ion, there are certainly many contexts within which the word "atom" implies "neutral atom." If I come across the expression "hydrogen atom transfer reaction" in Google Scholar, I know that the paper will be about neutral atom transfer, not H+ ion transfer (which would be referred to as a "proton transfer reaction".) So I tend to agree with Suzanne that we should change the expression "Your Atom" inside the sim to something else. I'm not sure that Suzanne's suggestion "Your Particle" is the best substitute - like John, I tend to think of "particle" as referring to an elementary particle like an electron or proton, even though no such inference is implied (otherwise we wouldn't have to have the qualifier *elementary*.)

Nevertheless, I think it's perfectly ok to retain the *title* of the sim as "Build an Atom", and would oppose changing it to "Building atoms or ions." The title is basically a tag, not a comprehensive descriptor.

TL: I think I missed the email where the idea of changing "Your Atom" to "Your Particle" . I agree with Robert that particle has the connotation of elementary particles. So to be clear: I vote for "Build an Atom" and "Your Atom" for labels. I think in the Tips we should put a note in the "Modeling" section about our decision to use this nomenclature.

09/23/10 *- PhET meeting*

- need readout of p, n, e (at top of play area)
- Kathy wants “my X” - but what word to use?
- to indicate status:
    - **atom** (w/ check mark)
    - ion
- or at top: H ion, H atom - then need correct name, so keep separate
- show more of the PT (take off atomic #’s) - use diff colors for those you can build
- also show element name next to PT - thus, no mouseover
- what if only put in neutron? nothing
- if nucleus moves, then it needs to fly apart - thus, no movement - write “unstable” under nucleus
- click on PT, get real-world application of element - only for first 10 elements - but wait until phase 2 (need to consider translations)

- do MS students understand the meter? Suzanne wants rows of p & e to help indicate charge:
    protons: 000
    electrons: ooo
- change “isotope” to “mass” - hard to teach vocab w/ sim - not learning goal
- how to take e’s out of cloud? if click in cloud, e will appear under mouse
- Trish is concerned w/ scale - wants smaller nucleus in cloud
- should the orbits/cloud change size? no...
- move symbol closer to PT
- should windows collapse up? or stay in place?
- colors: yellow background (looks more fun), gray neutrons, blue cloud (also on scale)

09/10 *- PhET email*

Excited states

KL: John thought of a user scenario in which a student can create an excited state - they can pull out inner-shell electrons when there are already electrons in the outer shell.

What do we want to do in this situation? One possibility is to make it so that students are not able to move inner-shell electrons when there are one or more electrons in the outer shell. Another is to make an outer-shell electron fall into the spot left by the inner-shell electron. I prefer the first idea, since it demonstrates that inner-shell electrons are hard to remove. What do you think?

KP: I guess I would rather have the electron drop down into the lower shell - to demonstrate that these stay full.

RP: Indeed, this describes an actual physical process, Auger recombination: if you ionize an atom from an inner shell (using, for example, an x-ray laser from Kapteyn/Murnane labs), an outer electron falls back down into the hole, emitting a photon in the process.

TL: I agree with the returning to lower energy level. Anything else would not align with strategies taught in 6-12.

KL: It sounds like we are going to go with the second option - an outer-shell electron will fall into the spot left by the inner-shell electron.

Orbit radius

JB: I am currently setting up the internal scale for the model within the Build an Atom sim, and I decided that I wanted to use the radius of the atoms as the basis for this. However, when I go on Wikipedia, I find two different radii listed that are quite different. One is the covalent radius and the other is the Van der Wals radius. Which one should I use, or is the choice totally arbitrary?

KL: When you say that you want to use the radius of the atoms, do you imply that each atom will have a different radius in the sim? If so, I thought we agreed in our last meeting that we do not want to differentiate the atoms by size.

JB: Sorry, my bad for not being clear. I was planning to use a sort of average value for the inner shell based on the diameter of hydrogen and helium, and then an average of lithium and neon for the size of the outer shell, and then tweak them to make it look good. It doesn't need to be exact, I just want to have some relationship to reality in the model.

RP: In fact there are at least three radii in common use: the van der Waals radius, the covalent radius, and the metallic radius.

The van der Waals radius is the effective radius of an atom that is not involved in a chemical bond, e.g. half the distance between two Neon atoms in solid (frozen) Neon.

The covalent radius is the effective radius of an atom that *is* involved in a chemical bond, e.g. half of the O-O distance in O2. As you would expect it is smaller.

The metallic radius is the effective radius of an atom in a metallic crystal, e.g. half the distance between two Lithium atoms in lithium metal. (Metallic bonding differs from covalent bonding in that the bonding electrons are shared throughout the metal, not just between to atoms.)

It doesn't really matter which we use in principle, but college chemistry textbooks use the metallic and covalent radii when discussing the periodic table (except for the noble gases for which the van der Waals radius is the only relevant number since their atoms don't form chemical bonds with each other) so for consistency we should use the same. In other words, the metallic radius for Li and Be, the van der Waals radius (only choice) for He and Ne, and and the covalent radius for everything else.

The textbook we're using this term uses the following values:
H: 37 pm He: 31pm Li: 152 pm Ne: 71 pm

JB: I just tried using average values for the two sets of numbers that Robert provided at the end of his email (below) as the radius of the shells. This ends up with the shell sizes being quite different in relative scale from what has been drawn in the spec. Please take a look at the attached screenshot and see if you prefer this look or the look of the original spec. If you prefer the latter, I will just tweak the radii of the shells until they look good not worry about having any basis in actual values.

KL: If we want to have some relationship to "reality", then we should use the radius of the orbits for hydrogen, not the radius of the atoms. In the Bohr model, the orbit radius is proportional to n^2, so if the first shell has a radius of 1, then the second shell should have a radius of 4. The actual values are:

r1 = 53 pm
r2 = 212 pm

The ratio of r2 to r1 is 3.3 in your current picture. (I do prefer this look to the one in the original spec.)

UPDATE: we decided on arbitrary values, with a ratio of 3

To flash, or not to flash

JB: I was collaborating with Sam R this morning, and he had an idea about letting the users know where to place protons & neutrons. You might recall that we talked about having some sort of little circle in the center to convey the idea that something needs to go there in case students had no idea. Sam suggested doing what we did in Lac Operon, which was to have a spot light up in the view.

What do you think – would this be worth doing? It isn't trivial to code up, so it would be better to decide that we want to do it or not before moving forward with it.

KL: How about a mixture of the two ideas?

We talked about doing something similar for the electron shells: "In order to give students a clue as to where the electrons go, the shell where the next electron would be placed will light up when an electron is dragged near it."

What if we had the circle in the center light up too? (when a student drags a nucleon)

TL: I'll defer to Kathy since she has so much more experience about sim design and also has to make the cost analysis.

JB: Yes, exactly - we could have the whole shell light up, or just the spot where we want them to put the electron. If they drag to the appropriate shell but don't put it where it needs to go, we just move it there for them.

UPDATE: we decided to hold off on any flash indicator (until we have interview data), and to indicate placement by color - should the circle for the nucleus *disappear* when students drag in a nucleon?

Particle readout

JB: I have one thought/concern now that I see this. The protons, neutrons, and electrons shown at the top look just like the ones that comprise the atom and that sit in the bucket, so there is nothing to cue the user that they are different. Do you have any ideas of what to do in order to

make this difference clear? Maybe grey them out, or put them in a bar graph sort of box or something?

KL: That was my concern when we discussed the feature yesterday - but we concluded that students would eventually discover that they are different.

I like the bar graph idea - are you thinking that the bars would grow upon addition of more particles? Or maybe we could just put a box around all the readouts at the top?

JB: Either. I had tried picturing both and decided that I would need to draw it up to see which one I liked better, so how about you try drawing them and decide which one you think is superior?

KL: I drew them both (see slide 2), and I like the box better than the bar graph look.

JB: I agree. Let's go with that for now, and show it to the group at the next meeting.

Wrong bucket

JB: What do you think should happen if the user drags a particle to the wrong bucket? I'm inclined to just have it pop to the correct bucket (without animation if possible, or with animation if we think it is needed). What say you?

KL: It should definitely go back to the correct bucket. And we should probably animate it, since it would end up in a different place than they were expecting.

09/30/10 - *PhET meeting*

- how to mark the spot for the nucleus?
    - use X instead of O
    - first nucleon will go in the center
- how close do you need to get?
    - for nucleon: inside the inner shell
- do we need to call "orbits" the "Bohr model"?
    - use "model: orbits/cloud"
- will students think the atom on the scale is an electron?
    - use small icon of orbits/cloud instead of cloud
- for teaching tips:
    - no photon is emitted when an electron jumps down a level (see H sim)
- for game: (KL will mockup)
    - in level 3, go beyond 2nd row of PT
    - but in that case, no Bohr model

10/10 - *PhET email*

11th electron

JB: As far as electrons go, where would the 11th electron go if the inner shell maxes out at 2 and the outer one maxes at 8?

SR: I think her point was that the 11th electron should go back in the bucket, signifying to the user that there is no place for it in the 2 shell atom.

RP: I'm a little worried about doing it this way. It's probably ok for high school and later (anyone who has seen the periodic table), but for middle school students who are first encountering atoms - might they conclude that you can't ever have more than 10 electrons?

TL: I agree that providing more electrons than fit in the first two shells might be confusing. Perhaps this is something we could ask the MS specialist?

KL: This sounds like something interviews could inform. We can tell the teachers in Texas to watch for this idea, and I can interview middle school students once we have access to them.

10/07/10 - *PhET meeting*

- talked about colors and readouts
- move readouts closer to play area (idea from Noah: make the element flash)
- display some readouts (e.g., element name) on the model
- no shade on PT for elements you can build, to make the current element more obvious
- game idea from Sam: send score to facebook?
- ask Noah to make pretty icons

10/12/10 - *Feedback on Version 0.00.09*

Version 0.00.09 was circulated within the PhET team and sent out to an external reviewer (Suzanne Brahmia) for feedback. Below is a compilation of the comments that were received.

Comments/Suggestions for Build an Atom

All comments are made with respect to 0.00.09 of the simulation.

Should we have the Atom/Ion indicator? Is an ion an atom?

Noah P said:

Wondering why in the charge box, it selects either atom or ion. My understanding is that an ion is a type of atom. The either / or check mark makes it seem like an ion is not an atom.
Might be better to have nothing in this area, and just show the word "Ion" if it is an ion.
Also kind of odd that if you put in one proton, it gets labeled hydrogen. I'm not sure that a single proton is hydrogen...maybe it is...depends on how this fits your learning goals.

…and then said:

Last I will say about this:

According to Wikipedia: "An ion is an atom or molecule in which the total number of electrons is not equal to the total number of protons, giving it a net positive or negative electrical charge." I haven't found anything on Google to convince me that atom exclusively refers to a neutral particle.

Robert P went through a number of text books and found that some seem to indicate that atoms were neutral while others did not. He summed up with this:

In my experience, practicing chemists don't worry much about this sort of terminological detail. There are certainly some contexts within which the word "atom" automatically implies "neutral atom". For example, the expression "hydrogen atom transfer reaction" invariably means a reaction in which a neutral H atom - the proton together with its electron - moves from one atom to another, e.g. F + HCl -> HF + Cl. If an H^+ ion, rather than a neutral H atom, is transferred, we call it a "proton transfer reaction" (chemists are entirely comfortable with defining a naked proton to be a "hydrogen ion"), or an "acid base reaction". Nevertheless, I don't think that many practicing chemists will have any problem with describing an ion as a "charged atom". I certainly don't - I know that always need adapt my definitions and terminology to the context within which I am working.

Should the sim depict excited states?

Suzanne Brahmia said:

I'm sure you've gone back and forth on excited states. As it stands now, only ground states are allowed. Would it broaden the functionality to provide an option to include excited states (under an options menu)? That way the default would be as is, but for higher levels someone who knows what they are looking for could select that option.

Perhaps this will be covered in the spectroscopy sim we have been kicking around?

Should unstable nuclei wiggle?

Suzanne Brahmia said:

I know, too, that you've talked about wiggling the unstable nuclei. I like this idea, as it gives some urgency to action when the nucleus is unstable. Users, particularly younger ones, won't really understand the word unstable the way we do. If it's connect with a call to action, they may better learn what is meant by unstable nuclei. So I vote for jiggling the unstable nuclei.

Initially we rejected this idea as problematic, because they wouldn’t break apart, and we don’t want to go on that far. Also makes it harder to grab nucleons.

Issue with the charge meter

Suzanne Brahmia said:

The use of a dial gauge for the electrons detracts from the quantized nature of charge at the atomic level. We discussed having piles of paired charges that would cancel each other's effect, and distinguishing the unpaired charged particle as the ionic charge (the net charge.) Is that in the works or has it been nixed?

We would need to sketch out some pictures (or have Suzanne do it) in order to really understand what she is envisioning. We have the paired charges somewhat depicted at the top (I believe her suggestion was the reason that we have this at all), but it sounds like she had something else in mind.

Should there be a pop-up window for stable isotopes?

Suzanne Brahmia said:

As I was making He, there was no distinction between He-3 and He-4, but my instinct felt that He-4 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). So the interaction would go something like this:

- *add protons, the element lights up in the PT add electrons, the scale*
- *balance changes add neutrons until a stable isotope is found, the*
- *unstable indicator stops and an isotope popup window appears add more*
- *neutrons and different isotopes light up in the popup window*

We actually listed the understanding of atomic mass as a non-goal, largely because of the fact that the users would need to understand averages, included very lopsided ones.

Should we require at least one proton before allowing electrons to be added?

John B and Sam R said:

It seems confusing that the user is able to add an electron into an orbital, even before there is any proton present. Should we make it so there has to be a proton before you can add electrons to an orbital? Taking this one step further, we could also make the orbitals invisible until the proton is added. What do you think? Would this be nice internal scaffolding for the sim, or would it make it less graphically inviting (i.e. making it look less like the skeleton of an atom when the sim starts up)?

Trish L and Robert R both thought it made sense to do this.

This was discussed in the 10/14/2010 phet meeting and we decided to defer this as an interview question.

Should we have the game tab in place with a “coming soon” sort of message?

Kathy P said:

We don't usually publish sims that we know are going to add another tab, and I'm wondering if it might actually be worthwhile to hint at this future addition by keeping the tab and saying "Game coming soon ... expected 12/2010".

This was discussed in the 10/14/2010 phet meeting and it was decided that since we have a process for notifying translators of new features, and because it might defer people from using or translating the sim, that we should not add this tab and we should keep the v1.0 version as a single tab sim. Sam R, Chris M, Noah P, and John B were in consensus on this decision.

10/15/10 - *Suzanne & PhET*

- single e- is not an ion
- need a “hide all labels” button for teachers
    - where to put?
- in game, more focus on PT
    - e.g., given Bohr model, click on element in PT, then check
- make word “unstable” wiggle? no, draws too much attention
- make size of word “ion” proportional to charge
    - same for word “unstable”? no, hard to define
- zero-pairs: show that + and - cancel each other in “charge” box

    + + +
    - - - -
- issue w/ unrealistic atoms
    - include word “unstable” under word “ion”? no, hard to define

10/28/10 - *PhET*

Stable/unstable – leave as is on the sim, for the short term just modify activity. We will learn more as interviews are done and more usage occurs in Texas.

Spinners should go to zero if out of range values are manually entered.

Don’t match colors in the SymbolToCounts view, leave as is (i.e. no changes necessary to the sim). Kelly will observe if students use the colors to solve the problems in interviews.

On the game tab, enlarge the symbol a little bit on the symbol nodes. This should make them look a bit more like the symbol presented on the first tab.

For the challenges on the Game tab, add radio button for periodic table to say whether it is “**neutral atom**” or an “**ion**”. Should be like this on all levels game.

Leave the timer running throughout the game, no pauses for correct answers (i.e no changes needed to current version of sim).

Under both the interactive and non-interactive symbol nodes, the name of the element should appear. This applies only to the game tab.

Change the order of the key on the first tab back to Protons, Neutrons, & then Electrons

Random is fine for the choices of the problems, don't worry about having 2 (or more) of the same format in a row, so no changes needed to the current version of the sim.

Add a developer control to allow selection of problem type so that a single problem type can be specified. This is so that Kelly can better test which problem types work best or are more problematic for users.

Note for tips: we use the notation "**-3**" instead of "**3-**" to indicate ions, since MS students are learning about negative numbers.

11/10/10 - *PhET*

Unstable nucleus
- add "Show Stable/Unstable" checkbox (off by default - students pay too much attention to this at first)
- add checkbox for other labels (on by default)

Cloud model
- do not show inner shell (students say it's the nucleus)
- show no change in size for cloud

Game levels
- add another level to game w/out the symbol (students find it hard to interpret the symbol)
- e.g., "What is the mass number?" or "What is the charge?"

11/18/10 - *PhET*

Changes:
- Animation on by default.
- 4 levels total
- New level 2 will have individual questions
- Constraint: Don't do problem combinations where the charge is neutral and we are asking about the charge.
- Ions at every level
- First two levels only first two rows of periodic table
- Last two levels up to 3rd row of periodic table.

11/23/10 - *PhET*

Constrain to have a different problem type each time.

Remove problems with symbol on left side from level 3, but add problems that ask for charge. KL thinks “How many protons?” is trivial, but KP likes.

Enable the Check button for all problems with a spinner - thus, can remove constraint about only asking charge of ions.

Investigate: seems like level 4 has a preference for low atomic numbers.

12/02/10 - *PhET*

On level 4, make the probs that don’t have a schematic use atoms that are heavier than lithium.

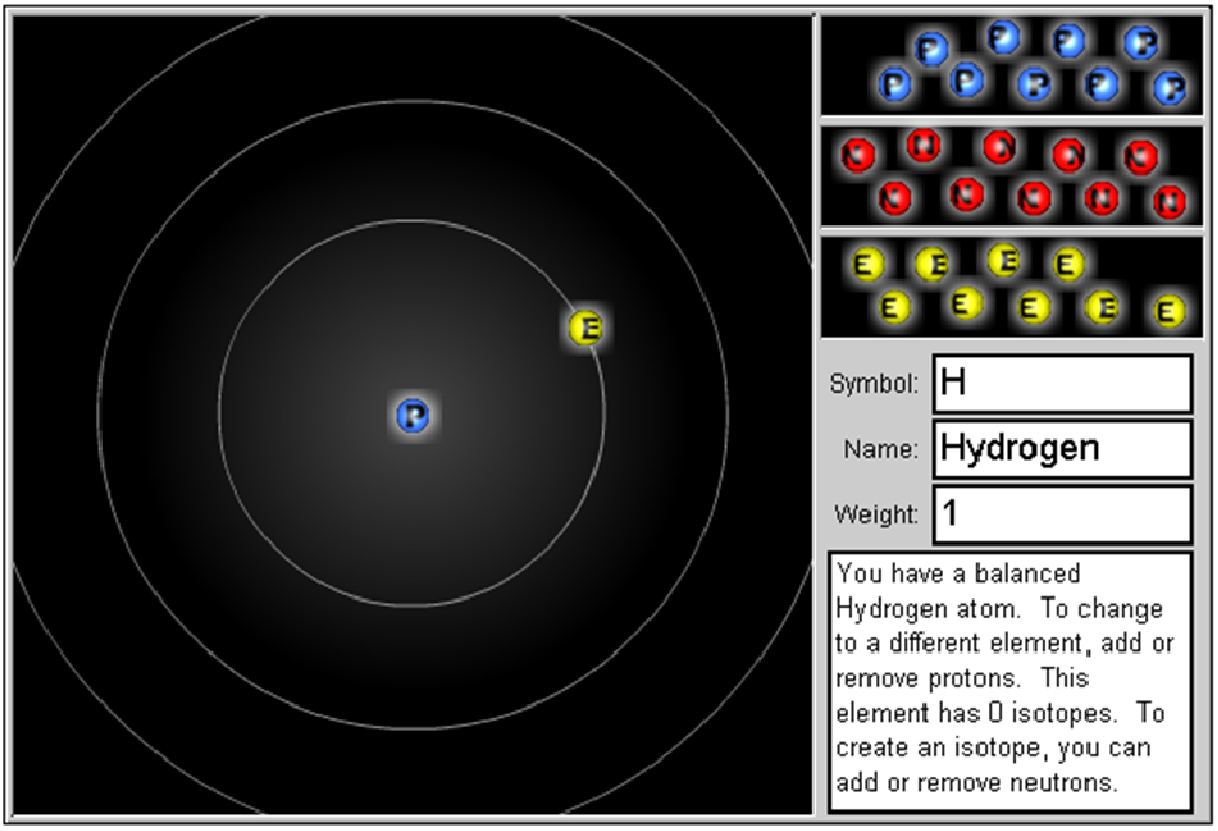
Leave the amount of charge=0 questions as is, i.e. don’t constrain it any further. This came up because Trish commented on it after playing the game, but after discussing it we decided that it was good as it currently is, and we will wait to see if students find it too easy or boring in interviews.

12/13/10 - *PhET*

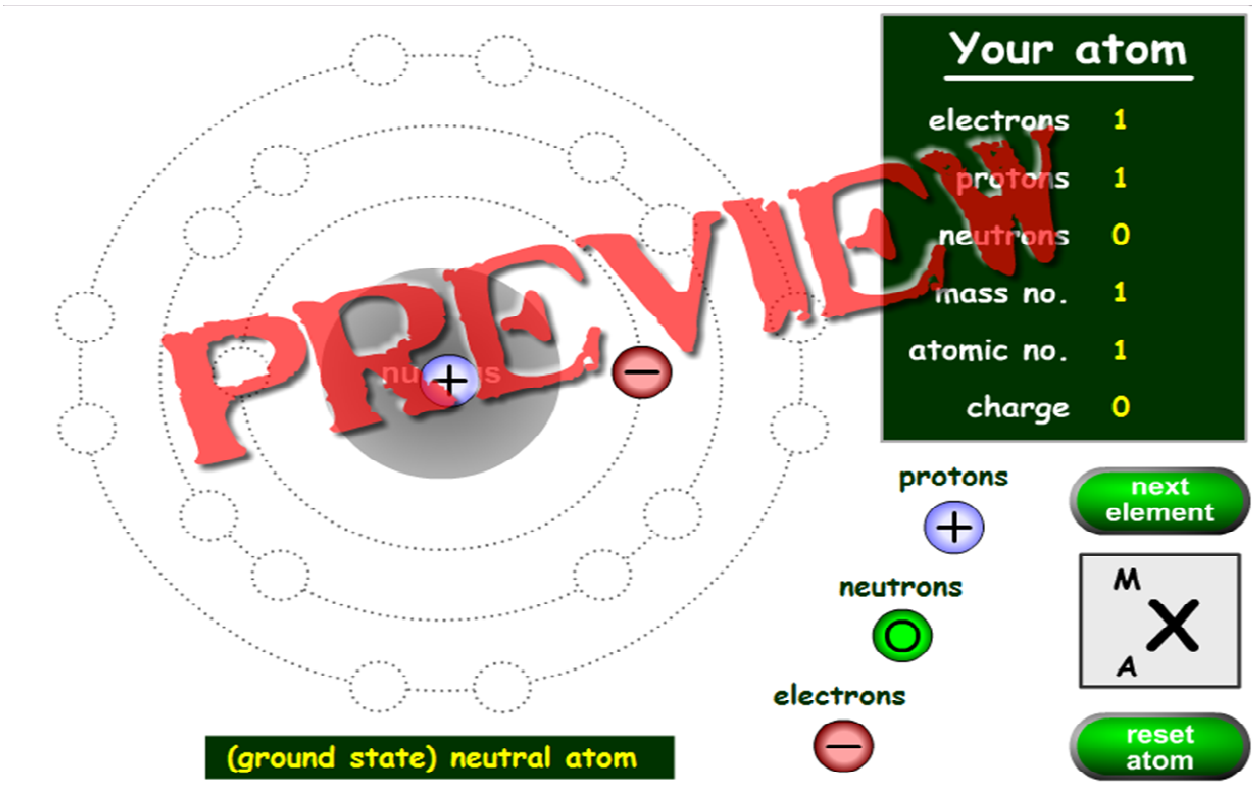
Make ALL non-schem probs at ALL levels heavier than Li

Online Resources

Build Atoms Yourself
www.classzone.com/books/earth_science/terc/content/investigations/es0501/es0501page04.cfm
“One way to find out about the structure of something is to take it apart. Another way is to construct the item from its parts. This interactive model will allow you to build atoms of different elements from a collection of subatomic particles.”



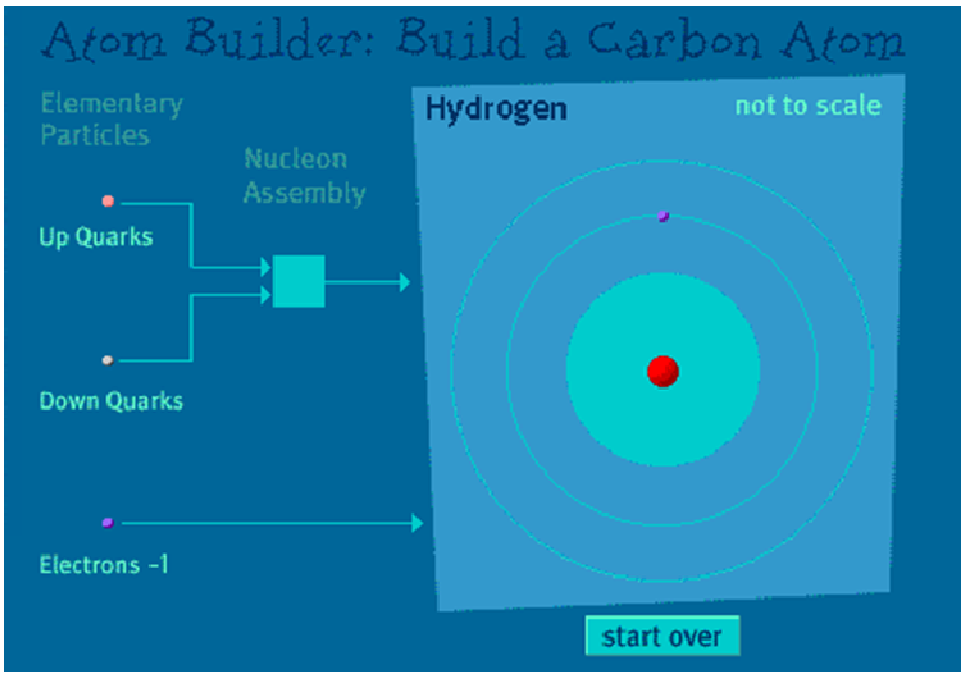
Build Your Own Atom $$
www.echalk.co.uk/Science/chemistry/atomicStructure/atomicStructure.html
"A whole-class resource for teaching atomic structure and electron configuration. Pupils are presented with a mass number and atomic number and must then construct the atom."



Atom Builder

http://www.pbs.org/wgbh/aso/tryit/atom/#

"Here's a chance for you to construct a carbon atom. You'll start with a hydrogen atom, which contains one proton and one electron. Just add protons, neutrons, and electrons. By the way, you must also build each proton and neutron from two types of quarks -- up quarks and down quarks. Finally, some advice: try to keep the particles' charges balanced. You'll have a difficult time if you don't."



Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules
www3.interscience.wiley.com/journal/112752904/abstract
"An understanding of the concepts of atom and molecule is fundamental to the learning of chemistry. Any misconceptions and alternative conceptions that students harbor about these concepts will impede further learning. This article identifies misconceptions related to the fundamental characteristics of atoms and molecules which Grade-12 students hold. Data were obtained by administration of semistructured interviews to a stratified, random sample of 30 students of differing abilities and backgrounds in science. Fifty-two misconceptions were observed and are reported. These are grouped into 11 categories. Six relate to the structure, composition, size, shape, weight, bonding, and energy of molecules; five relate to the structure, shape, size, weight, and animistic perceptions of atoms. Some of the misconceptions identified parallel the historical development of scientific concepts."
NOTE: see appendix for interview guide, table for misconceptions; in pilot study, saw the misconceptions: "electrons have no mass, just a charge", "there is only one kind of atom", and "protons have a mass of one gram"

Why we should teach the Bohr model and how to teach it effectively
http://prst-per.aps.org/abstract/PRSTPER/v4/i1/e010103
"Some education researchers have claimed that we should not teach the Bohr model of the atom because it inhibits students' ability to learn the true quantum nature of electrons in atoms. Although the evidence for this claim is weak, many have accepted it. This claim has implications for how to present atoms in classes ranging from elementary school to graduate school. We present results from a study designed to test this claim by developing a curriculum on models of the atom, including the Bohr and Schrödinger models. We examine student descriptions of

atoms on final exams in transformed modern physics classes using various versions of this curriculum. We find that if the curriculum does not include sufficient connections between different models, many students still have a Bohr-like view of atoms rather than a more accurate Schrödinger model. However, with an improved curriculum designed to develop model-building skills and with better integration between different models, it is possible to get most students to describe atoms using the Schrödinger model. In comparing our results with previous research, we find that comparing and contrasting different models is a key feature of a curriculum that helps students move beyond the Bohr model and adopt Schrödinger's view of the atom. We find that understanding the reasons for the development of models is much more difficult for students than understanding the features of the models. We also present interactive computer simulations designed to help students build models of the atom more effectively."

History

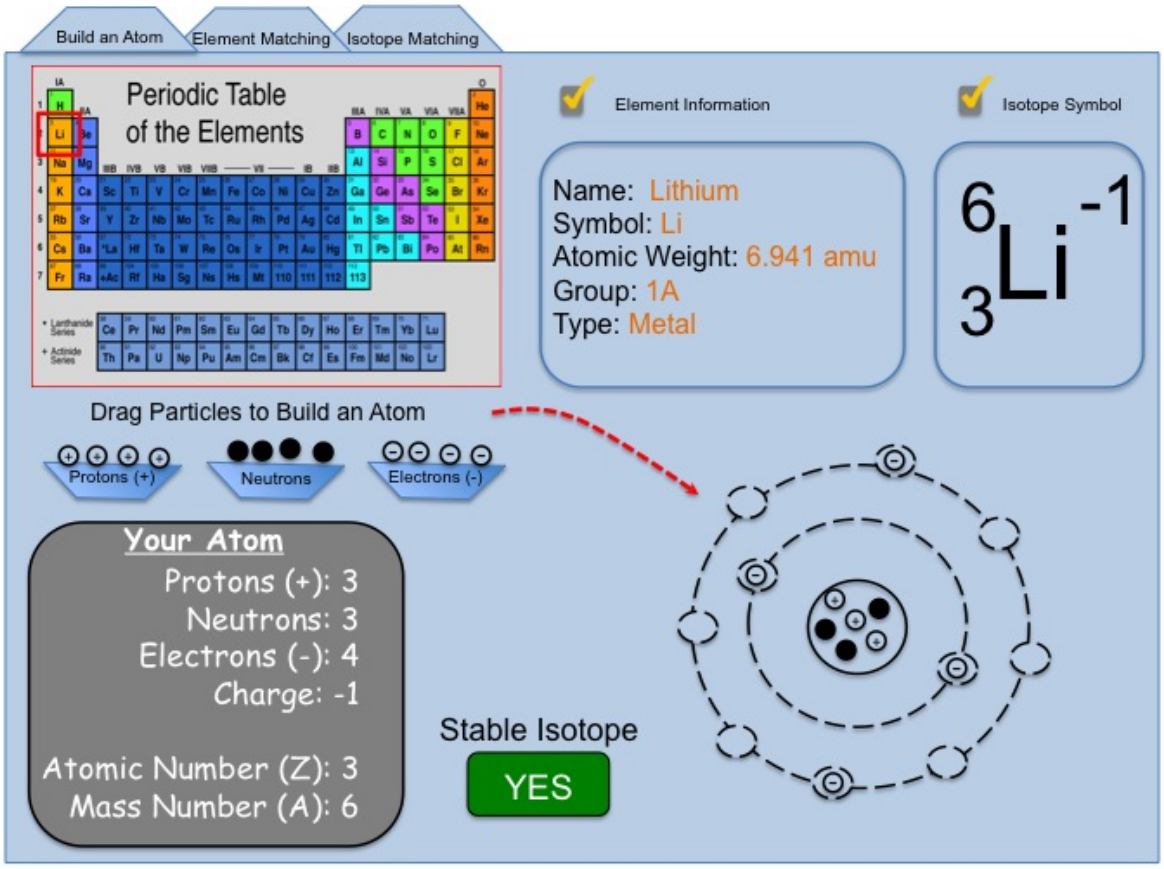
Jack Mockup

Allows user to design an atom by building up number of protons, neutrons, and electrons

- Number of protons added will highlight (bold or animate) the proper element on an embedded periodic table
    - connects idea of protons to element identity
- As neutrons are added, user will vary mass number (isotope), display will show when a stable isotope is achieved
    - connects idea of neutrons to isotope identity
- As electrons are added, user will vary charge of particle
    - connects idea of electrons to ionic charge

Model will consist of a nucleus and several "rings"

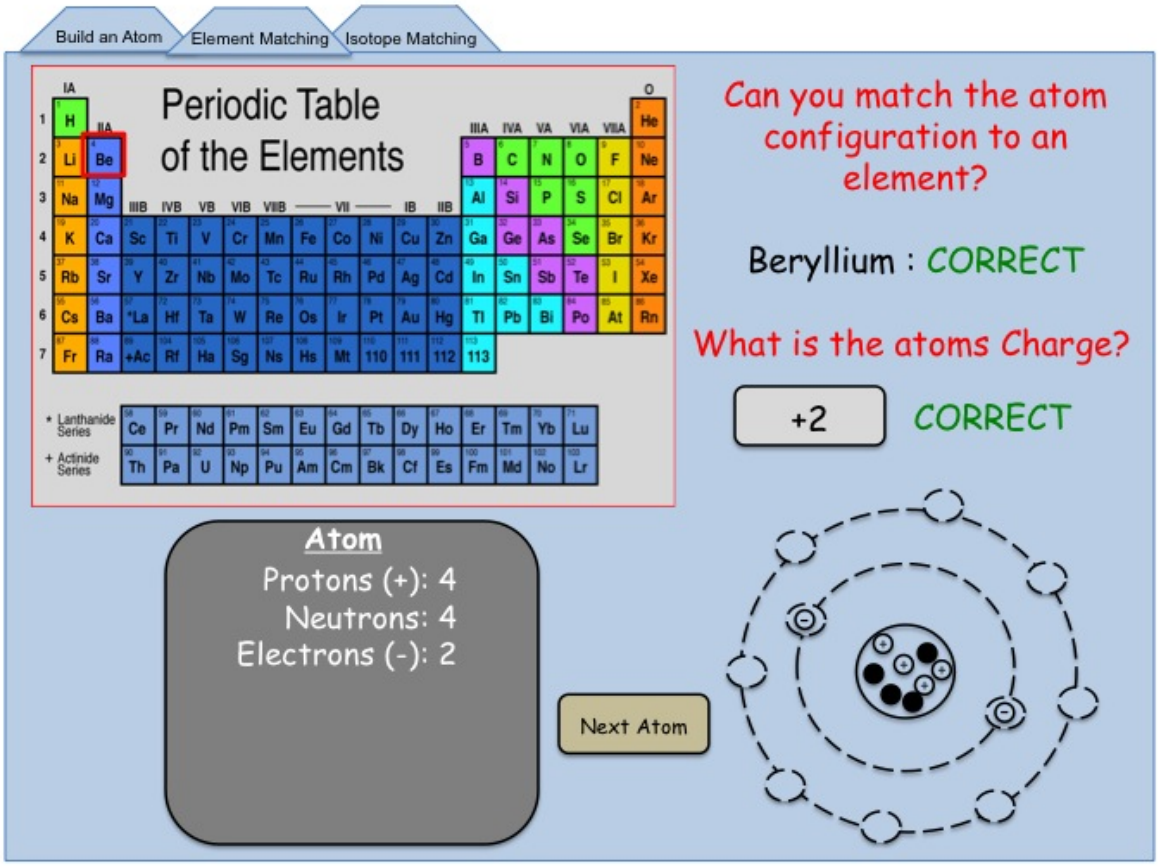
- User can drag protons and neutrons from a bucket into the nucleus
- User can drag electrons from a bucket to the rings
    - Rings will fill based on filling rules, once n=1 is full no more electrons are allowed and must start filling n=2



Second Tab

Display an atom (model) with a given number of protons, neutrons and electrons

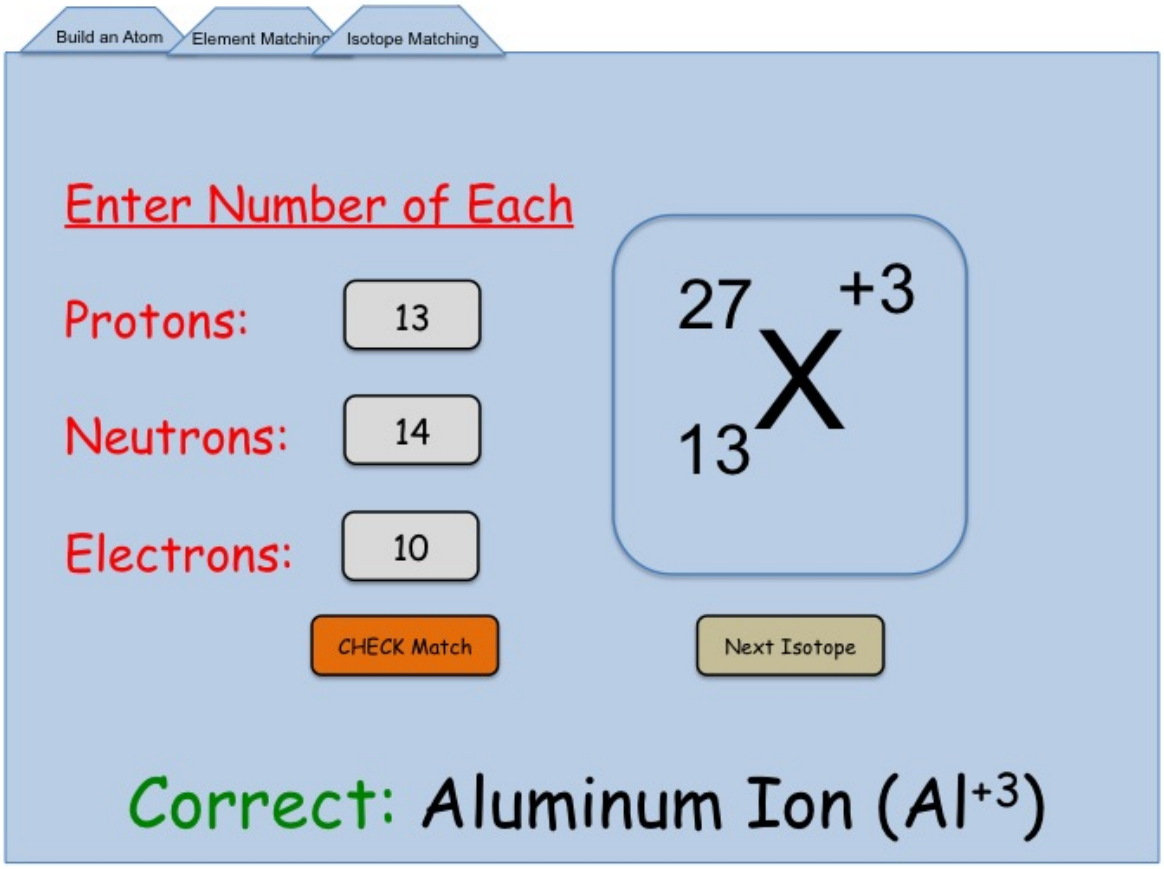
- ask user to identify element and charge



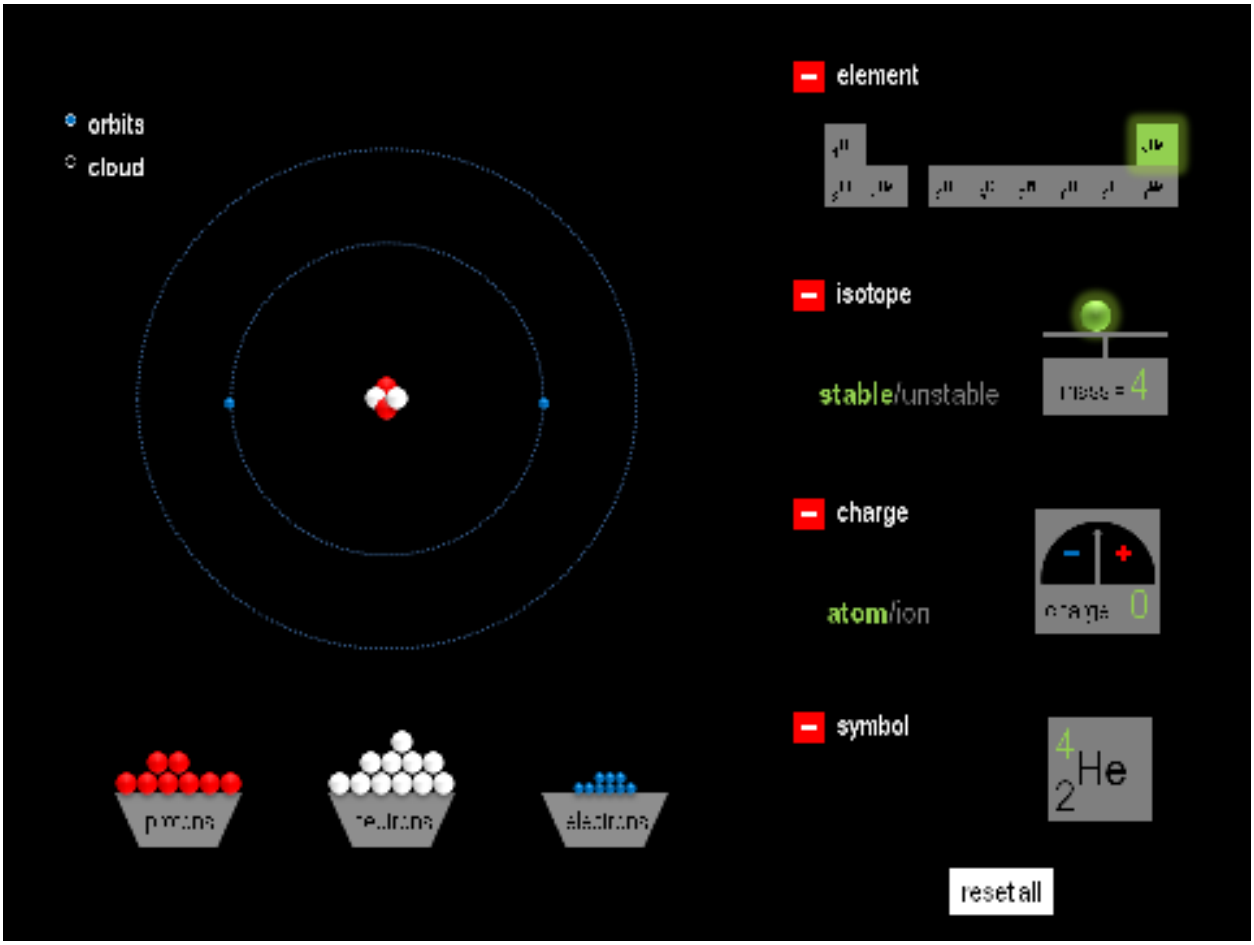
Third Tab

Display an atom (symbol and name) and its charge

- ask user to identify number of protons, neutrons and electrons



Kelly Mockup



Interview and Classroom Feedback

Middle School Classroom

From Tom Hansell:

The focus on "stable" vs. "unstable" nuclei seemed to lack relevance to the students. The word "unstable" pops up when the nucleus is unstable, but that seemed to be hard for them to pick up on. Students generally did not perceive that when no word popped up that the nucleus was stable. If the sim were tweaked and the word "unstable" flashed on and off and the atom literally blew apart after awhile the engagement factor and the understanding of instability would both be enhanced greatly. It would become a challenge to build stable nuclei, and the students love challenges. Obviously, I am suggesting a change to the simulation itself without understanding how difficult that is to accomplish...

For Courtney, I would suggest a break in the middle of the activity that the entire class uses to list stable/unstable nuclei on the whiteboard with teachers help. This "scientific communication" could be monitored by the teacher to identify misunderstanding group by group and allow a

more comprehensive visual check for students in assessing their "rule" hypothesis. Students are easily discouraged when their rule encounters a counterexample. They need to be encouraged in being persistent!!

Also, the "rule" of slightly more neutrons than protons is very subtle to detect.

From Courtney Fadley:

What did you observe working well?

- **Students were very engaged in the lesson. They may not have understood what was going on at all times, but no one seemed to give up. The atoms positioning themselves in the correct location when drug over the atom structure was very helpful. Students learned the position of protons, neutrons, and electrons very well!**
- **After looking over the post-labs, students learned the general rule of atomic mass, which is a VERY hard concept to teach!**

What do you think needs improvement and any ideas about how to improve it?

- **A layer of "lesson" on the sim would make the facilitation of the sim go much more smoothly. During the explore phase of the lesson, students can float the mouse over various items and a description or picture pops up. This layer could be used only during the explore phase, but students could also refer back to it if necessary.**
- **The atom "deconstructing" when it is unstable would be very helpful. Students had a VERY hard time understanding the difference between an atom and an ion, and struggled even more with stable vs. unstable. Maybe layering the activity so that 6th grade students do not have to deal with stable vs. unstable, just neutral atom vs. ion, and then in 8th grade they can develop the concept of unstable more.**

Any observations of the students - what they were saying or doing that struck you as interesting or beneficial or problematic?

- **Many students mixed up the words nucleus and neutron. Having the nucleus labeled would put a stop to that confusion because they will see the words side by side rather than seeing one, and remembering the other.**

Any reflections on the activity - questions that worked particularly well or questions that need restructuring?

- **The format of the pre and post lab confused some students. By the time they got to the end of the page they had forgotten or never realized that the information given at the very top was still related to what they were answering at the bottom. Making the given information about atom more noticeable at the top, and the box for drawing the atom smaller may help students see the connection more. Or simply repeating the given information would be helpful.**

Any thoughts about your facilitation of the activity?

- **Facilitation of the marshmallow activity went very well. Students caught on to the pattern very quickly, and were able to go through “building more complex structures” easily. They built the cube with no hesitation. I feel that most students were able to make the parallel from building complex shapes by adding pieces, to building more complex atoms by adding protons, neutrons, and electrons.**
- **The sim hindered some facilitation with the stable vs. unstable and ion vs. neutral atom. A few times throughout the lesson, I stopped everyone to reiterate those ideas, and I don’t think many students walked away from the lesson with a clear understanding of those objectives.**

Advisory Board Feedback

From Jack Barbera:

I really like the layout and functionality, it all seems to work smoothly.

1) Should the top-right sub-window be labeled "element" or "periodic table"? I would prefer "periodic table" but understand why the other is used.

2) If the "charge" sub-window is closed and the "symbol" window is open, the colored numbers for charge on the isotope symbol are meaningless. Will there be a problem with students misinterpreting a +1 colored RED as indicating that there is an "extra proton" as the protons are colored red? Also, would a -1 colored BLUE indicate a loss of one electron as electrons are colored blue?

The color code makes sense (to me) when the "charge" window is open.

3) Will the model be expandable beyond Ne? That might get tricky with the space allotted.

4) There are no units on the balance! Was there discussion about not putting in that these are Atomic Mass Units (AMU)? Will students try to interpret this as Molar Mass (g/mol), even though there is only one atom on the balance?

5) When I got to level 2 and 3 in the game, on the questions that ask you to enter the Atomic Number, Mass Number, and Charge, I could not get the Chlorine example correct because the Mass Number box will not accept values above 30 (I tried typing it in and using the up arrow button).

6) For game examples with many Protons and Neutrons, it might get hard to count them all. Not a big deal but I was always unsure if there was a "hidden" particle.

7) If this is geared toward middle school science, is the "cloud" model needed? Do students learn beyond the Bohr model? Can middle school science teachers explain the Quantum

Mechanical model for the atom and what the clouds represent? No harm in leaving it, just curious as to why it was included.

I will play with it some more but wanted to get these comments out to spark discussion for everyone.

From Loretta Jones:

Nice job on this sim! I like the fact that it addresses a small set of specific concepts and that it gives students opportunities to play with the particles. I think that the color coding of red for positive and blue for negative will become clear, so that doesn't bother me. How did you decide on the colors? They are the reverse of the conventional colors used for representing charge in electron potential representations of molecules (red for negative and blue for positive). They don't necessarily have to be the same; I'm just wondering how you picked the colors.

Build Atom:
I like the way that the proton and neutron bounce back if they are not sufficiently close to the nucleus. However, if you are watching for changes in symbol, mass, or charge while adding particles, you might miss the fact that they have bounced. Can a sound effect be added? Also, should the program require that the first two electrons be placed close to the inner orbital? Right now, you can place them on the outer one. Although they do move into place, a student might not notice that movement.

When an unstable nucleus is created, the word "unstable" appears, but may not be noticed (it is amazing what students fail to notice). Could a flash of light or a sound effect be added to reinforce the instability? Or could the word flash for a while? Another option would be to simply have the atom blow up when it becomes unstable, so that students learn that they can build the larger atoms only by alternating the protons and neutrons to keep the nucleus stable.

The orbital cloud is a little confusing, because it does not seem to change in size when a neutral atom becomes an ion. There should be a noticeable change in diameter when that happens.

Like Jack, I am concerned about the mass balance. In addition to the lack of units, it seems to imply that electrons are weightless. Can it be relabeled "mass number"? That way, electrons are not counted anyway and units are not needed.

The highlighting of the active element on the periodic chart is very hard to see on my computer. Adding a red border around the element's box might help.

Game:
This is a good game that will get students to think. I would make only one major change. If possible, please reconsider how wrong answers are handled. It would be a good idea to repeat items that students missed until they get them right, giving them either the same atom or a similar one. This approach keeps the focus on the mastery, not the score. As is, a student can

just keep clicking on Check and Show Answer to move rapidly through the game without learning anything. The score is not recorded anywhere, so there isn't a built-in incentive to try harder.

The problem that Jack mentioned he encountered with chlorine in level 2 of the game is true for any element with a mass number greater than 30, although "Show Answer" does give the higher mass number.

Middle School Interviews

S6M
11/08/10 v1.00.06
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.06/

Warm-up:
11 years old, in 6th grade at Centennial Middle
Used PhET sims last year, likes science

Sim:
Build Atom
Clicks on windows, then cloud, nothing happens
Drags in e, tries to put on center X, sees it go to 1st shell
Drags in n, also puts on X, sees word unstable, drags back into bucket
Clicks on windows, closes
Drags in p, sees word Hydrogen
Drags in n to 1st shell, sees it go back to bucket
Drags in another e to 1st shell, sees word -Ion, drags in more e's to 2nd shell (knew that only 2 in 1st shell)
Drags n to 2nd shell, sees it go back to bucket, then drags to X
Drags another n to X, sees word unstable, drags out
Drags in p, sees word unstable, drags out, adds e's
Tries to put 3rd e in 1st shell, sees it go to 2nd shell
Adds more p, tries to see what elements he can get
Adds p and n in order, then takes all back out
Adds only p, looks at periodic table
Clicks on windows again, closes
Tries to move e-in 2nd shell (when full), sees that they go back to same spot
Tries to see what makes the atom stable - is it always same amount of p and n? Needs to be balanced out
Clicks on windows, closes
Puts in all the particles, plays with nucleons, seems not to notice (care?) that it's an ion
Tries to see what happens when same amount of p and n - is it stable?

Ask: what does unstable mean to you? (12:30) The nucleus is loose, the particles (calls them molecules) are unbalanced - tries to think of analogy: it's like a scale with 20 pounds and 20 ounces
Ask: what does ion mean to you? Don't know
Puts in all the particles again
Takes out all e's, clicks cloud, puts in e's
Clicks on windows, closes
Ask: what do you think about the cloud? Says cloud gets smaller and lighter when take out e-, gets bigger and thicker when put in e-, says nucleus (but points to inner ring) is always darker than the outer ring
Ask: what do you think about the windows?
Knows mass is like density - to get density, need mass & volume of an object, and then you divide; if the atom is thick, it makes up something like steel, and if it's light, it makes up something like paper
Not sure about charge - whether it's balanced or neg or pos
Also not sure about the symbol
Puts particles back before he clicks on game tab (did not need to prompt him)
<u>Game</u>
L1: turns off sound & timer
Back to the 1st tab to find answer, then back to game for all problems
Has no problem with how game works
Smiles when gets correct :)
Not aware that neutrons are not important for this level
Gets 9/10 in about 5 mins
Ask: can you do it again without going back?
L1: says he has never done anything with element table in class
Gets H atom correct
Ask: what do you need to know to answer? What you need to add
Tries to count the elements - says H has 1 of each, Li has 2 of each, Be has 3 of each, etc.
Picks C because it is #5 (uses # of neutrons instead of protons)
Ask again: what do you need to know to answer? (KL: stop at 30 mins)
Remembers Li from earlier
Gets 8/10 (went back to 1st tab on last problem)
L2: gets S first (can't make in sim!)
Makes He, looks at symbol
Puts in 16 neutrons, ...
Opens symbol window, closes
Says neg charge on one side of PT, pos charge on other side
Clicks on charge window, keeps open!
Says if take away e, gets more pos; if add p gets more pos
Can tell me what the symbol numbers are
Plays around, sees effect on symbol
Says # in left is either mass or the # of particles (but says molecules)
In game, tries to add up to 40

Back to 1st tab to figure out answer

Follow-up:
Spent 57 mins on sim
Did not do post-lab, ran out of time

Notes:
Did not need to be told to drag the particles
Did not keep windows open, always took out the particles - wanted to put the sim back the way he found it
Knew only 2 e in inner shell, 8 e in outer shell (even used the word shell)
Did not know where n went at first - sim helped him learn the structure of an atom
Tried to figure out what made the atom unstable - said p and n need to balance
Did not seem to notice (or care?) when it was an ion
Knew mass has something to do with density; gave equation D=M/V
Had no problem with how game works
Quick to say he understood

S6F
11/09/10 v1.00.06
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.06/

Warm-up:
11 years old, in 6th grade at Casey Middle
Used Density sim this year, likes social studies

Sim:
Adds particles to the model
Says need equal # of p, n, e
Clicks on game after 2 mins!
L1: back to 1st tab
Only fills in nucleus at first, then does e's
Gets 9/10 in about 5 mins
Says if unequal # of p, n, e, then it's an ion
Tries to put more than 2 e's in 1st shell
L1: gets 9/10 in about 6 mins
Says the element depends on p, n, e
Says the mass is how much it weighs
Says e's lower charge, p's make it higher, n's do nothing
Clicks cloud, back to orbits
Takes out particles to see what element it is
Not sure about unstable - at first thought same # of p, n, e
Ask: ion? Maybe when not equal # of each?

Says if add e, -ion; then if add p, equal; if add another p, +ion
Clicks cloud, back to orbits
Ask: symbol? This is mass, this is charge, not sure about this (atomic #)
Later says it's # of protons
L2: gets wrong, back to 1st tab
Gets atomic # correct
Ask: charge? The # of electrons?
Knows mass is related to neutrons
Uses 1st tab again
Tries w/out help, gets close!
Gets 4/10 in about 9 mins
Ask: cloud? If add e's, cloud gets bigger & darker

Follow-up:
Spent 51 mins on sim
Did not do post-lab, ran out of time

Notes:
Very quiet, had to prod her to talk
Went to the game tab after 2 mins!

S8M
11/10/10 v1.00.09 (stability not shown on startup)
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.09/

Warm-up:
13 years old, in 8th grade at Platt Middle
Never used PhET sims, likes language arts

Sim:
Build Atom
Adds p first, then n
Says if take p's away, makes diff things
Tries to put 3 e's in 1st shell
Says 3p, 6n, 5e makes lithium
Puts in all particles, takes out n's, then e's
Clicks cloud - asks: what does that do? (had no p's or n's at the time)
Says 8p, 6n, 10e makes oxygen
Tries to see if e's change output
Says you need exactly 8 p's, but you can have X n's, and it will still be oxygen
Keeps 1p in, adds all n's - says every n has to touch the p
Says H is 1p and many n's
Says the p changes the outcome

Says can put many n's, do not do anything
Asks me: can I make all of these elements? Tries - only makes 10 of them
Asks: what do these things do? (the windows)
Says the e's equalize - if 3p, 3e, charge is 0
Opens symbol, closes
Says if 2p, 3e, neg charge (says meter is more helpful)
Puts in same # of p, e
Sees that mass # incr w/ neutrons, not sure why
Says it's the overall # of things that make up the atom (not incl e's)
Says when add n, only black # changes
Says blue # is charge
Says when more p than e, pos charge
Says the e's don't change mass #
(After 25 mins, point out stable checkbox and game tab)
Says need 2p, 2n to make it stable - the e's don't change stability
<u>Game</u>
L1: counts p & n at first
Goes back to 1st tab - asks: does it matter where the e's are?
Skips He when counting atomic #, but knows the more p's, the farther right on table
Gets 3/10 in 4 mins
L1: just guessing at first - goes back to 1st tab when wrong
Sees that goes across PT
Gets 5/10
L1: gets 10/10 in <1 min
L2: gets nucleus correct, no e's
Gets all correct but charge
For mass #, adds in e's - says not sure why 24 - oh, e's don't count
Gets all correct except e's - says all even
Tries to put in 31 n's, not possible
Get 2/10
L2: Gets charge wrong, then gets correct
Gets 8/10
Says p & e are same, the overall # minus the p's is the n's
Says atomic # is equal to the e's, the rest are n's
Ask: how to make sim better? Wants to know what symbol #'s mean

Follow-up:
Spent 49 mins on sim
Did not do post-lab, ran out of time

Notes:
Spoke under his breath
Saw that p's change the element, but you can put in many n's and it stays the same (!)

Saw when same # of p & e, charge is 0; when more e than p, neg charge; and when more p than e, pos charge
Saw that n's change mass #, but not e's
Had to point out stable/unstable checkbox and game tab
Did not spend much time on stability, but saw that e's don't change stability
In level 1, figured out that elements go *across* the table, got perfect score in <1 min
In level 2, figured out that e's don't count for mass #, the mass # minus the p's equals the n's, and the p's are equal to the e's
Wanted to know what symbol numbers mean

S5M
11/11/10 v1.00.10 (unstable nucleus wiggles)
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.10/

Warm-up:
10 years old, in 5th grade at Crest View Elementary
Never used PhET sims, likes math

Sim:
Build Atom
Puts in p's
Opens windows, closes
Tries to put p,e in diff places
Makes unstable atom, takes n out
Clicks cloud, puts in e's
Tries to make it stable
Says e's make cloud bigger
Says n's make nucleus stable
Says if too many of one, it's unstable
Tries to put p,n in diff places
Takes e's out of cloud - says makes charge less "minus"
Says you can make it "plus"
Says it tells you what it is
Puts all e's in orbits
Not sure what symbol means
Says if take e away, it fills in the space
Tries to make it stable so "it won't shake"
Puts in everything - says it changes names
Oh, made it stable! Says if put in all except 1n, it's stable
Takes out all e's, clicks cloud
Says the mass # changes if take away red or gray
Says can change symbol if take away... (trails off)
Says if symbol changes, so does element

Says it (charge) tells you which is winning - the red or blue dots
Says the n's balance out the red - with all except 1n, it equals out
Says orbits are like sun & planets
Tries to put back in diff buckets
Says it has initials for everything (H & He)
Says just 1n is unstable
Asks me: can I press reset all?
Says if only e's, mass # is 0 - the blue don't count as weight
Says if 1 more n than p, usually stable
Tests if only n's, never stable
Says it won't let you put p's and n's on the outside, only in the middle
Says don't get what this is based on - what does it relate to?
Cleans up the sim
<u>Game</u>
Prompt to open game tab (after 20 mins; sound was off)
Starts on level 2! Has no idea
Starts over on level 1
L1: gets H correct
Knows it's an ion, because more red than blue
Hard to find element
Gets 5/10 in 3 mins
L1: gets 8/10
Says he memorized ones with small #'s
Says you can try in 1st tab to see what it is
L1: gets 8/10
Tries level 2
Says he likes to be able to check answers

Follow-up:
Spent 37 mins on sim
Did not do post-lab, ran out of time

Notes:
Noticed *everything* we hoped - great at thinking aloud
Tried to put the particles in different places - learned that p & n go in the center
Called p, n, and e red, gray and blue dots
Tried to make it stable - figured out if 1 more n than p, usually stable
Saw that p & n change the mass #, but the e's don't count as weight
Said the charge tells you which is winning - p or e
Did not figure out the symbol
Asked for permission to press reset all - did not uncheck labels
Had to prompt to open game tab
Knew how to tell if atom or ion, but had to memorize to find the element
Wanted to know what the sim *related* to

S4F
11/11/10 v1.00.10 (unstable nucleus wiggles)
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.10/

Warm-up:
9 years old, in 4th grade at Hackberry Hill Elementary
Never used PhET sims, likes writing

Sim:
Build Atom
Puts in e
Tries to put in n, falls back
Puts in p
Clicks cloud, then back to orbits
Not sure what to do
Unchecks boxes (first to do so!)
Opens windows, closes
Clicks reset all
Tries to put p, n, e on X - sees particles move into place
Asks herself: What if put p on unstable? Stable!
Builds up nucleus
Makes Ne, clicks reset
Puts in only e's - says they only go on outside
Asks herself: if put in p, it's He - why? If put in n, it's still He
Maximizes sim
Sees that symbol changes when you take out particles
Wants to stop it from shaking
Says she thinks it's about balancing out
Says if put in n, still neutral
Says you have to build an atom, make it stable & neutral
Game
Prompt to open game tab (after 20 mins)
L1: no clue
Knows it's not these down here (on PT), only these (top 2 rows)
Prompt her to use 1st tab
Knows where e's go now
Thinks it's got to be equal # of p & n - but sees that rule does not work for He
So that's 1p & 2e's - probably one of the first ones
Builds in 1st tab
Gets 3/10 in 10 mins
Says she does not like timer - feels pressure
Says she does not understand when it's unstable

Likes mass & charge
Says she gets all #'s in symbol except mass #

Follow-up:
Spent 30 mins on sim
Did not do post-lab (no point)

Notes:
Asked her own questions, but mumbled
Only student to uncheck boxes, press reset button
Said you have to build an atom, make it stable & neutral
Learned where e's go in the orbits
Tried to figure out when unstable - thought it had to be equal # of p & n, but saw that rule did not work for He
Had to prompt to open game, did not like the timer

S7M
11/12/10 v1.00.10 (unstable nucleus wiggles)
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.10/

Warm-up:
12 years old, in 7th grade at Southern Hills Middle
Used PhET sims before, likes PE, geography

Sim:
Build Atom
Puts in n, then p, then e
Tries to put 3 e's in 1st shell - later only on 2nd shell
Puts in all particles
Says the p,n,e make diff elements
Takes out e's only, then nucleons
Wonders if he can make more elements
On prompt: opens windows
Keeps only charge open, builds atom
Puts in all e's, takes out p's
Says every e makes charge lower - counts as neg
Says every time take e out or add p, charge higher
Keeps mass open
Says if take out p or n, mass lowers
Opens symbol - knows what #'s mean
Tell him to click cloud
Game
L2: on model problem, adds too many nucleons

On symbol, gets mass # wrong
Types in the # when large
Gets 4/10 in 6 mins
L3: gets parts of the answer correct each time
Gets 3/10 in 3 mins
L1: gets 1st problem wrong, figures out
Gets 7/10 in 2 mins
Back to 1st tab
Puts e's into cloud, then takes out
L2: gets 8/10 in 2 mins
L3: tries to beat time
Gets 8/10 in 2 mins
L1: gets 10/10 in 1 min
Back to 1st tab
Says # in upper left is the # of p's and n's
Says # in lower left is # of p's
Says # in upper right is charge
Ask: cloud? The field
Says the # of p's is the atomic # on PT (knew vocab!)
Ask: stable? Not sure
Means it works to make an element - it has to balance out (the p's and n's)
Ask: ion? If more pos than neg charge

Follow-up:
Spent 46 mins on sim
Did not do post-lab

Notes:
Tried to get him to talk, but very quiet
Had to prompt to open windows, cloud model, game tab
If take out e's or add p's, the charge is higher
If take out p's or n's, the mass is lower
Started on level 2 in game
Played each level twice, figured out all #'s on symbol
Not as sure about stable, said the p's and n's must balance

S5F
11/23/10 v1.00.12 (new levels in game, BUG!)
http://www.colorado.edu/physics/phet/dev//build-an-atom/1.00.12/

Warm-up:
10 years old, in 5th grade at High Peaks Elementary
Previous interview on Density sim, likes art

Sim:
<u>Build Atom</u>
Says more familiar (than Density), learning about atoms in school
Puts in all e's, then some p's & n's
Takes out some e's (BUG!), clicks cloud, then orbits
Opens windows, closes
Makes stable B, clicks cloud, adds e's
Makes unstable Ne, then adds more n's
Un-checks the labels, the re-checks, clicks reset
Tries to put e's in diff places
Says you make diff atoms, and make stable
Says when unstable, needs more or less e's!
Makes stable B, adds e's to cloud
Resets, adds all e's, then p's & n's in order
Ask about boxes
Not sure how 3 & 4 & 9 (in symbol) fit together
Says you get 9 when add p's & n's, so maybe mass #
<u>Game</u>
Prompt her to open game
Turns off timer
L1: guesses on first problem
Says "I get it!" - this is a memory game - can build atom over here (1st tab)
Gets 7/10
L2: builds in 1st tab again
On last problem, gets mass # w/out help
Gets 10/10
Says the boxes (in 1st tab) are handy for the game
Likes that you can turn off timer - don't like pressure

Follow-up:
Spent 20 mins on sim

Notes:
Did Density interview first, got antsy toward the end
Not afraid to reset sim
Figured out mass #, but thought e's make atom stable
Built atoms in 1st tab to get answers for game
Turned off the timer

NP did another interview with MS student on v1.00.12