Build-a-Bohr Lab
Name: __________________

In this activity, you will visit a computer simulation at the website: http://scratch.mit.edu/projects/beckerr/867623. (You can either type in this web address or do a google search for “scratch beckerr”.) In this simulation, you will have a chance to build your own atoms – deciding for yourself how many protons and neutrons to put in the nucleus and then seeing what’s stable and what’s not. You will find out what happens to an unstable nucleus, and you will also see how electrons organize themselves in distinct energy levels around the nucleus.

Read through all the questions on this lab worksheet first, then just start exploring and see what you uncover!

1. Which particles (protons, electrons or neutrons) determine what type of element an atom is? __________

2. What two subatomic particles are found in the nucleus? __________ __________

3. What particle exists in specific energy levels around the nucleus? __________

4. What charges do the three particles have? Protons: _____ Neutrons: _____ Electrons: _____

5. The mass number is always equal to the number of __________ plus the number of __________

6. Generally speaking, there are three types of nuclei: a) those that are too unstable to exist for any time at all, b) those that are somewhat unstable, but they last for a while and then change into something more stable, and c) those that are stable just as they are. Using isotope symbols, list four examples of each type. Make sure you use a different element for each of the twelve examples you give. Three have been done for you:

   a) $^7\text{He}$ __________ __________ __________
   b) $^{16}\text{N}$ __________ __________ __________
   c) $^{23}\text{Na}$ __________ __________ __________

7. Multiple choice:
   _Among the first twelve to fourteen elements, nuclei with the same number of protons and neutrons are
   a) never stable  b) rarely stable  c) usually stable  d) always stable
   __ Nuclei which are unstable because they have more protons than neutrons are most likely to become more stable by undergoing:  a) alpha decay  b) beta decay  c) electron capture  d) proton emission  e) positron absorption
   __ Nuclei which are unstable because they have more neutrons than protons are most likely to become more stable by undergoing:  a) alpha decay  b) beta decay  c) electron capture  d) proton emission  e) positron absorption
   __ Very large nuclei which simply have too many protons all repelling each other are likely to become smaller and more stable by undergoing:  a) alpha decay  b) beta decay  c) electron capture  d) proton emission  e) positron absorption
   __ An alpha particle is actually the same thing as...
   a) a hydrogen-1 nucleus  b) a helium-4 nucleus  c) a lithium-7 nucleus  d) an electron  e) a neutron
   __ A beta particle is the same thing as... (same choices as above)
   __ A proton is the same thing as... (same choices as above)

8. T or F
   __ When a nucleus is unstable, it just has to undergo one type of decay to become stable.
   __ The charge on the nucleus is always positive.
   __ A neutral atom must have the same number of electrons as it has protons.
   __ Uranium-235 nuclei undergo several changes and eventually end up right back where they started.
   __ Radioactive radon gas is actually present in the air we breathe.
   __ An alpha particle is comprised of two protons and two electrons.
   __ When a nucleus undergoes electron capture, a proton gets converted into a neutron.

9. Define radioactivity? ________________________________

What causes an atom to be radioactive?
Protons Neutrons and Electrons

10. Fill in the following table. Note: the top five are all ones you can actually build in the Build-a-Bohr program. The bottom five require that you really understand the concepts and can apply them to problems beyond the program. A periodic table will prove helpful.

<table>
<thead>
<tr>
<th></th>
<th>element symbol</th>
<th>atomic number</th>
<th>mass number</th>
<th>charge</th>
<th># of protons</th>
<th># of neutrons</th>
<th># of electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>14 _7 N</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>6</td>
<td>5</td>
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<td>b)</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>c)</td>
<td>lithium</td>
<td>7</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d)</td>
<td>23 _11 Na^1+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>e)</td>
<td>magnesium</td>
<td></td>
<td></td>
<td>2+</td>
<td>20</td>
<td>22</td>
<td>20</td>
</tr>
<tr>
<td>f)</td>
<td></td>
<td>80</td>
<td>202</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g)</td>
<td>33 _16 S^2-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i)</td>
<td>barium</td>
<td>137</td>
<td></td>
<td></td>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>j)</td>
<td></td>
<td>59</td>
<td>3+</td>
<td></td>
<td>32</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

11. How many protons are there in a_{3}^{29}F^{1-} particle? _____ How many neutrons are there in a_{19}^{39}K^{1+} particle? _____

12. The only difference between a_{24}^{52}Cr^{2+} particle and a_{24}^{52}Cr^{3+} is the number of ____________

13. The only difference between a_{24}^{52}Cr^{2+} particle and a_{24}^{52}Cr^{3+} is the number of ____________

14. The only difference between a_{24}^{52}Cr^{2+} particle and a_{25}^{53}Mn^{3+} is the number of ____________

Ions:
Simply put ions are particles which have positive or negative charges—like Mg^{2+} or F^{1-}. Neutral particles (ones that have a charge = 0) are called “atoms.” Neutral atoms can bond together small clusters called “molecules.”

15. Which four particles in the table above would be considered ions: _____________________________

16. Among protons, neutrons and electrons; which two affect the charge of a particle? _______________ _____________

17. Considering your answer above, what must be true of all ions? __________________________________________

Isotopes:
Although they use the term “isotope” in the simulation, they never really define it. Consider the following statements to see if you can figure out what the term means.

“Some isotopes of carbon are stable, some are radioactive, and others can’t exist at all. Fluorine has only one stable isotope: fluorine-19. Nitrogen-12 and nitrogen-13 are considered isotopes. Nitrogen-12 and carbon-12 would not be considered isotopes.

Define isotope: ___________________________________________________________________________

Fill in the blanks below:
18. Isotopes are particles of the same ____________ that have different _____________. Another way of thinking about it is that isotopes are particles with the same number of _____________ but different number of ______________.
Atomic radii:

19. When you have built a Bohr diagram for a stable lithium atom, measure its radius in cm: __________
   (The radius is the distance from the center nucleus out to the outermost occupied level.)

20. Do the same thing for beryllium: __________ and boron: __________ and carbon: __________

21. Find these four elements in the periodic table. What do you notice about the size of the atomic radius as you go left to right across a period in the periodic table? ____________________________

22. Why do you think the atomic radius does this? (Hint: think about what causes the electrons to be attracted to the nucleus in the first place.) ____________________________

23. Now measure the atomic radius for the Bohr diagram for sodium (which is just below lithium on the PT): __________

24. Do the same thing for magnesium (which is just below beryllium): __________

25. What do you notice about the size of the atomic radius as you go top to bottom down a group in the periodic table? ____________________________

26. Why do you think the atomic radius does this? ____________________________

27. Based on the patterns you observed, which would be bigger? (Circle your choice.) K or Ca   Ca or Mg   Sr or Kr

28. The actual radius of a lithium atom is 152 pm (pm = picometer, which is a trillionth of a meter!). Use the measurements you made above to set up proportions to determine the radius (in pm) of
   Be: __________    C: __________    Na: __________

Historical figures:

29. You met several important historical figures at the Build-a-Bohr workshop. For each of the following, specify what contribution they made.
a) Ernest Rutherford

b) Niels Bohr

c) Marie Curie

d) John Dalton

e) JJ Thomson

f) James Chadwick

30. What element did Marie Curie discover ____________. What was it named after? ____________

31. What objection did John Dalton have to the Build-a-Bohr workshop?
**Band of Stability:**

32. Consider the table at right. Each box represents an atom you could have built. Look at the key below. Leave the top square blank; use a regular pencil to color in the second square down then go find four different colored pencils, and use each to color in just one of the four bottom squares — you choose the order.

- □ = nonexistent (left white)
- □ = stable (dark grey = regular pencil)
- □ = radioactive (undergoes beta decay)
- □ = radioactive (undergoes proton emission)
- □ = radioactive (undergoes alpha decay)
- □ = radioactive (undergoes electron capture)

Now use this coloring key to start filling out the grid at right. For example the very first square in the lower left-hand corner corresponds to a nucleus containing one proton and zero neutrons, which (according to the program) is stable, so use a regular (grey) pencil to color this in. The square right above it corresponds to a one proton - one neutron combination, which is also stable, so color it grey too. The square above that represents a one proton - two neutron combination which is an unstable (radioactive) nucleus that undergoes beta decay, so color it with the color you chose to represent radioactive beta decay. While you’re at it, the nucleus it decays into (a two proton - one neutron combination) turns out to be stable, so go ahead and color that square (the second one up in the second column) grey and use a pen to draw an arrow from the beta decay square into this grey square to show how the one decays into the other. (This first arrow has been drawn in for you to serve as an example.) All the rest of the nuclei represented in the first column are too unstable to exist for even an instant so leave them all blank (white). You are done with the first column — and part of the second column. Complete the first seven columns (and finish the whole table for extra credit!) You can either use the Build-a-Bohr program over and over or simply get the information directly from: [http://www.webelements.com/isotopes.html](http://www.webelements.com/isotopes.html). Most of the squares will be left blank, and each time you find one that decays into something else, make sure to fill that square in too and draw an arrow. The chart you have just made will show a dark stripe tilting upward (with a slope of about 1). This stripe is known as the **band of stability**, and it is a quick way of showing what proton-neutron combinations are stable, and how the unstable (radioactive) combinations tend to decay — either directly or in steps—into stable ones.

**Nuclear Equations:**

The nuclear decay events described above are often written as equations like: \( ^{27}_{12}\text{Mg} \rightarrow ^{27}_{13}\text{Al} + ^{0}_{-1}\beta \)

33. Complete the following equations by filling in the boxes.  

34. Write the following equations from scratch:

- a) \( ^{40}_{21}\text{Sc} \rightarrow + ^{0}_{-1}\beta \)  
- b) \( ^{243}_{95}\text{Am} \rightarrow + ^{4}_{2}\alpha \)  
- c) \( + ^{1}_{0}\text{n} \rightarrow ^{14}_{7}\text{N} + ^{1}_{1}\text{p} \)  

a) sulfur-31 undergoing electron capture:

b) iron-59 undergoing beta decay:

c) francium-217 undergoing alpha decay:
Large, Unstable Nuclei:
35. In the program you learned what happens to large unstable nuclei like uranium-235: they tend to undergo a series of mostly alpha decays (to make them smaller) and beta decays (to keep their neutron:proton ratio from getting to high. Find the square in the grid at right that represents uranium-235. This unstable nucleus undergoes alpha decay, so color it in according to the key you developed on the previous page. Then draw an arrow to show what it decays into. This alpha decay arrow should take you down two and back two on the grid: Then find out what kind of decay the new nucleus undergoes, color it in accordingly, draw an arrow on to the next, and so forth for the entire decay series to end up eventually as a stable (colored in grey) lead-207 nucleus.

36. The program shows the correct equations for each of the steps in this decay series. These steps are often combined into one single equation that shows all the alpha and beta particles that are emitted all together, as shown below. What numbers belong in the spaces?

\[ \frac{235}{92}U \rightarrow \frac{207}{82}Pb + ____^4_2\alpha + ____^0_1\beta \]

Notice how the mass numbers on top all up. Show this equality:

Notice how the atomic numbers (actually charges) on bottom all add up? Show this equality:

37. Uranium-235 isn’t the only big nucleus that undergoes a decay series. Here are some others. See if you can fill in the blanks and boxes:

a) \[ \frac{232}{90}Th \rightarrow \underline{ } + 6^4_2\alpha + 4^0_1\beta \]

b) \[ \frac{249}{98}Cf \rightarrow \underline{ } + 10^4_2\alpha + 5^0_1\beta \]

c) \[ \underline{ } \rightarrow \frac{207}{82}Pb + 4^4_2\alpha + 3^0_1\beta \]

d) \[ \frac{244}{94}Pu \rightarrow \frac{208}{82}Pb + ____^4_2\alpha + ____^0_1\beta \]

Isotopic Composition:
38. Based on the Build-a-Bohr program, which isotopes of lithium are stable? ______________. Now find lithium on the periodic table. What atomic mass is associated with lithium (that’s the number posted below the symbol)? _________ This atomic mass is the average of the two stable isotopes. The reason the average is not simply 6.5 (half-way between 6 and 7) is because there is a lot more of one isotope than the other. Which isotope (Li-6 or Li-7) is there more of? ______

How do you know this? ______________ __________________________

38. Which isotopes of boron are stable? ______________ What is boron’s atomic mass? _________ So which isotope of boron is more abundant (in other words, which is there more of)? ______________

The percentages of these two isotopes would be about...(circle your choice) a) 60-40  b) 80-20  c) 90-10  d) 99-1
39. Which isotopes of nitrogen are stable? ____________ Which of these is more abundant? ________
The percentages of these two isotopes would be about...(circle your choice) a) 60-40  b) 80-20  c) 90-10  d) 99-1
40. Which isotopes of fluorine are stable? ____________ Explain how this answer is consistent with the average atomic mass for fluorine?

Finally... Bohr Diagrams:
41. Using the circles below as nuclei, Draw a Bohr diagrams for each of the following elements: Make sure to include the charge on the nucleus. Don’t worry about relative size! (The second one is done for you.)

H  N  Ne  Al  S

42. What’s wrong with each of the following Bohr diagrams

N  Na  F  C

43. You may have noticed that the electrons not only occupy specific energy levels, but they also end up paired up. These spaces that each hold a pair of electrons are called “orbitals.”

How many total orbitals are there in the 1st energy level? ____ In the 2nd level? ____ In the 3rd?* ____ In the 4th?* ____
* You’ll need to see U-235 decay into Pb-207 to reveal a Bohr diagram that shows the 3rd and 4th level in their completely filled state.

Do you see a pattern to the numbers above? ____________________________________________ Use this pattern to predict how many orbitals there would be all together in the 5th level? ____ The 6th? ____ The 10th? ____

44. Which of these statements best describes the way in which electrons fill orbitals within a level:
   a) one electron goes in each orbital and then they start to pair off.
   b) the electrons go two to an orbital and then on to the next orbital in the level.
   c) the electrons go one in each level, out to the third level, then they go back and add a second to each level.
   d) electrons fill the levels and orbitals in a completely random and unpredictable manner.