

Atom Tokens: Taking a Sugar Molecule Apart Without Losing a Piece

Investigation question: When a cell takes one sugar molecule apart with oxygen, where does every atom end up, does the mass change, and how should a model show the energy that is released?

Physical model

Groups of 3

1 session

Setup 5 · Activity 40 · Cleanup 5 min

MS-LS1-7 · assesses

MS-PS1-5 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Builder:** Threads beads onto pipe cleaners to make each molecule according to the molecule mats, and takes molecules apart when the group is ready to rearrange.
- ☐ **Counter:** Keeps the atom inventory table, counts each color before and after every step, and refuses to let the group continue until the counts match.
- ☐ **Weigher and recorder:** Masses the full set of molecules on the balance before and after rearranging, records every value, and writes the group's energy-token decision.

Safety

- Pony beads are a choking hazard for small children; keep them off the floor and count them back into the bags at the end.
- Pipe cleaner ends have a wire core: fold the tips over so they do not scratch, and do not point them toward faces.
- No chemicals, heat or glass are used.

Procedure

1. Lay out the molecule mats. Using the beads and pipe cleaners, build one sugar molecule: 6 black (carbon), 12 white (hydrogen) and 6 red (oxygen) beads. Then build six oxygen molecules, each two red beads on a short pipe cleaner.
2. Counter: fill in the 'before' row of the atom inventory with the number of beads of each color actually on the mats, and the total. Weigher: put every molecule and every pipe cleaner on the tray and record the mass.
3. Now 'run the reaction'. Take the molecules apart and use exactly the same beads to build the products: as many carbon dioxide molecules (one black between two red) and as many water molecules (one red between two white) as the beads allow. No beads may be added and none may be left over. If something does not work out, do not borrow from the spares; figure out what went wrong.
4. Counter: fill in the 'after' row. Weigher: put the full set back on the tray and record the mass again. Record how many carbon dioxide and how many water molecules you made.

5. Scaling step: predict how many oxygen molecules and how many of each product two sugar molecules would need and make. Then build the second sugar with the remaining beads and test your prediction by running the reaction again with both sugars. Record the counts.
6. Now run the model in the photosynthesis direction: starting from six carbon dioxide and six water, rebuild one sugar and six oxygen molecules. Note anything that is the same and anything that feels different about doing it this way.
7. Energy decision: your model so far shows only atoms, but respiration releases energy and photosynthesis stores it. As a group, design a way to show energy in the model that does not use a bead and does not get counted with the atoms. Make it with the index cards and write a one-sentence rule for when it appears on the reactant side and when on the product side.
8. Run the respiration reaction one last time with your energy token in play, then answer the recording-sheet questions and the analysis questions individually.

Record your observations

Lab 2 recording sheet: Atom tokens

Black = carbon (C), white = hydrogen (H), red = oxygen (O). Count beads, not molecules, in the inventory. The Counter signs off each row before the group moves on.

Atom inventory for one sugar molecule

Step	Black (C)	White (H)	Red (O)	Total beads	Mass of the set (g)	Molecules on the mats
Before: 1 sugar + oxygen molecules						
After: carbon dioxide + water						

Scaling up: two sugar molecules

	Oxygen molecules needed	Carbon dioxide made	Water made	Total beads
Prediction				
Result				

-  Draw the 'before' and 'after' sets side by side using circles labeled C, H and O, with the energy token you designed in its correct place. Write the word equation underneath.

1. Describe your energy token and write your group's rule for which side it goes on in respiration and in photosynthesis.

2. Did the balance reading change between before and after? Write the two values and the difference, and explain the result in terms of beads.

Analysis questions

3. Every carbon bead from the sugar ended up in a carbon dioxide molecule and every hydrogen bead ended up in water. Where did the 18 oxygen beads end up? Give the split between the two products and show that it adds to 18.

4. Use the model to explain to a younger student why the mass of the set did not change, and then explain what that means for the sugar in a squirrel's acorn: where is that sugar's mass an hour after the squirrel eats it?

5. Why can energy not be a bead in this model? Give two reasons, one about what beads represent and one about what would happen to the mass if energy were a bead.

6. A cell in a running muscle takes apart 5 sugar molecules in a short time. How many oxygen molecules does it need and how many carbon dioxide molecules does it give off? Show the pattern you used.

7. When you ran the beads in the photosynthesis direction, the atoms worked out exactly the same. List two ways real photosynthesis is not just real respiration run backward, and say which of them your bead model can show.

8. Name one thing about cellular respiration that the bead model shows well and one thing it hides or gets wrong. For the hidden one, say what a better model would need.
