

Beads Never Vanish: Build Four Reactions and Catch the Fakes

Investigation question: If every atom in the products has to come from the reactants, can a bead model tell a real chemical equation from a fake one, and why does the pile of beads always have the same mass?

Physical model

Groups of 4

1 session

Setup 5 · Activity 45 · Cleanup 5 min

MS-PS1-5 · assesses

MS-PS1-1 · supports

Name _____

Group _____

Date _____

Your role today

- ☐ **Builder:** Threads beads onto bond pieces to build each molecule or formula unit exactly as the card says, and pulls the bonds when the reaction runs.
- ☐ **Atom inspector:** Counts the beads of each color on each side of the arrow, checks that no bead came from the kit and none is left over, and calls a stop when the products cannot be built.
- ☐ **Recorder:** Reads each card aloud as a sentence, fills in the inventory, pattern and mass tables, and writes the group's verdict on every claimed card.
- ☐ **Mass checker:** Counts out the exact reactant beads before building, masses them in the cup, and masses the same beads again after the products are taken apart.

Safety

- Beads are a choking hazard: nothing goes in mouths, and beads are not flicked or thrown. Count the kit back into its bag at the end.
- Cut pipe-cleaner ends can scratch; fold ends over, and tell students not to press a cut end into skin.
- Dropped beads roll and are a slip hazard on hard floors; pick them up at once.
- No chemicals are used. The reactions on the cards are models only; none of them is performed in this lab, and students are not given any procedure for splitting water, burning iron or burning methane.

Procedure

1. Set up the mat with the arrow pointing right. Left of the arrow is the reactant side, right is the product side. Sort the kit by color and have the Atom inspector check the counts against the key.
2. Card R1. The Recorder reads the equation as a sentence ('two water molecules become two hydrogen molecules and one oxygen molecule'). The Mass checker counts out exactly the beads the reactant side needs (coefficient times each subscript), masses them in the cup, and records the mass. These beads, and only these, may be used for the whole card.
3. The Builder builds the reactant molecules on the mat's left side: one bond piece through two beads is one bond. Build each water molecule as an oxygen bead with a hydrogen bead bonded on each side. The

Atom inspector counts the beads of each color on the left and the Recorder fills in the 'reactants' column of the inventory table.

4. Run the reaction: the Builder pulls out every bond piece. The beads do not break, split or change color; only the bonds are gone. Slide the loose beads to the right side of the arrow.
5. Build the products exactly as the card says, using only the beads on the mat. No bead may come from the kit and none may be left over. Count each color on the right and record it under 'products'. Then take the products apart, return the beads to the cup, mass them again and record.
6. Decide the regrouping pattern by counting substances: one reactant into two or more products is break apart; two or more reactants into one product is join; two into two with partners traded is swap; anything else is a mix. Record it with the number of substances on each side.
7. Repeat steps 2 to 6 for cards R2, R3 and R4. For R3 the subscript 2 outside the parentheses multiplies everything inside: build two nitrate groups (one green bead with three red beads bonded to it) and bond both to the blue bead.
8. Claimed cards C1 to C4. For each card, count out and build the reactant side exactly as written, pull the bonds, and try to build the products exactly as written from those beads alone. If you cannot, the Atom inspector names the atom that is missing or left over and the Recorder writes 'fake'. If you can, check the card's claim: count the beads in each molecule you built and ask whether the formula on the card describes the substance the card names. Record the verdict.
9. Make the drawing on the recording sheet for card R4: circles for atoms, labeled, before and after, with the same atoms in both pictures.
10. Return every bead to the kit bag (the Atom inspector counts them back in), then answer the analysis questions on your own before comparing within the group.

Record your observations

Lab 2 recording sheet: Beads never vanish

Two rules of the model — Rule 1: a bond piece can be pulled out at any time. A bead can never be split, swapped for another color or taken from the kit. Rule 2: the products of a card may be built only from the beads that were on the reactant side, with none left over. If you break a rule to make a card work, the card is fake.

Atom key

Symbol	Element	Bead color
H	hydrogen	white
O	oxygen	red
C	carbon	black
Fe	iron	gray
Pb	lead	blue
K	potassium	purple
I	iodine	yellow
N	nitrogen	green

Reaction cards

1 R1: Water split by electricity

$2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2$. Two water molecules become two hydrogen molecules and one oxygen molecule. Build a water molecule as O in the middle with an H on each side.

2 R2: Steel wool burning in air

$4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$. Four iron atoms and three oxygen molecules become two formula units of iron oxide. Iron atoms start alone, with no bonds. Build each Fe_2O_3 unit as two gray beads and three red beads bonded together in any arrangement.

3 R3: Lead nitrate meets potassium iodide

$\text{Pb}(\text{NO}_3)_2 + 2\text{KI} \rightarrow \text{PbI}_2 + 2\text{KNO}_3$. The $(\text{NO}_3)_2$ means two nitrate groups, each one N with three O. Build KI as one purple and one yellow bead bonded. Products: PbI_2 is one blue with two yellow; each KNO_3 is one purple bonded to a nitrate group.

4 R4: Methane (natural gas) burning

$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$. One methane molecule (a black bead with four white beads bonded to it) and two oxygen molecules become one carbon dioxide molecule (O bonded on each side of C) and two water molecules.

5 C1: Claimed. Hydrogen peroxide breaking down

$2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$. Build each hydrogen peroxide as a chain H-O-O-H. The card claims two hydrogen peroxide molecules become two water molecules and one oxygen molecule.

6 C2: Claimed. Water split, short version

$\text{H}_2\text{O} \rightarrow \text{H}_2 + \text{O}_2$. A student says one water molecule becomes one hydrogen molecule and one oxygen molecule.

7 C3: Claimed. Water split, 'fixed' version

$\text{H}_2\text{O}_2 \rightarrow \text{H}_2 + \text{O}_2$. The same student noticed that C2 did not work and fixed it by changing the small 1 after O to a 2. The card still says the reactant is water.

8 C4: Claimed. Iron burning, short version

$2\text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$. A student says two iron atoms and one oxygen molecule become one formula unit of iron oxide.

Atom inventory for the real reactions

Card	Element	Atoms on the reactant side	Atoms on the product side	Same? (yes/no)
R1	H			
R1	O			
R2	Fe			
R2	O			
R3	Pb			
R3	N			
R3	O			
R3	K			
R3	I			
R4	C			
R4	H			
R4	O			

Pattern and bead mass

Card	Substances on the left	Substances on the right	Pattern (break apart / join / swap / mix)	Bead mass before (g)	Bead mass after (g)
R1					
R2					
R3					
R4					

Claimed cards: the verdicts

Card	Can the products be built from the reactant beads alone? (yes/no)	Which atom is missing or left over?	Does each formula describe the substance the card names? (yes/no, and why)	Verdict: real, fake, or mislabeled
C1				
C2				
C3				
C4				

-  Draw card R4 twice: the reactant side (one methane molecule and two oxygen molecules) and the product side (one carbon dioxide molecule and two water molecules). Use labeled circles for atoms and short lines for bonds. Under the drawings, write the count of C, H and O in each picture and one sentence saying why the two piles of beads had the same mass.



1. Which claimed card fooled your group the longest, and what finally gave it away?

2. For card R3, how many red (oxygen) beads did the reactant side need? Which numbers in $\text{Pb}(\text{NO}_3)_2$ told you, and what did you do with them?

Analysis questions

3. In R1, two molecules of water became three molecules (two H_2 and one O_2). Did the number of molecules change? Did the number of atoms change? Explain why counting atoms, not molecules, is the test of whether an equation can be real.

4. Your bead mass before and after each real reaction should have matched. Explain why, using the word atom. Then say what this shows about the mass of the real substances if the reaction ran inside a sealed container.

5. Card C2 claims $\text{H}_2\text{O} \rightarrow \text{H}_2 + \text{O}_2$. Use the beads to explain why it cannot happen as written. Then explain why the student who 'fixed' it on card C3 by writing H_2O_2 has not described water splitting at all.

6. In R2, the product pile had more beads than the iron beads alone. Use this to explain why burned steel wool has more mass than the shiny pad it came from, and say where those extra atoms were before the reaction.

7. Sort R1 to R4 by regrouping pattern using only the number of substances on each side of the arrow. Which card was hardest to sort, and what made it hard?

8. A card you did not build reads $2\text{Fe}_2\text{O}_3 \rightarrow 4\text{Fe} + 3\text{O}_2$ (iron oxide taken back apart into iron and oxygen gas). Without beads, use coefficient $\times$ subscript to count the iron atoms and the oxygen atoms on each side. Would it pass the bead test?

9. What does the bead model get right about a chemical reaction? Name two things it gets wrong or leaves out, and say why that does not matter for counting atoms.
