

## Sandwiches and Molecules Screens

The simulation is designed to give students a conceptual understanding of limiting reactants, rather than practice at solving algorithmic problems that require mass/mole conversions.

**CHOOSE** your sandwich recipe.

$2 \text{ Bread} + 1 \text{ Meat} + 1 \text{ Cheese} \rightarrow 1 \text{ Sandwich}$

Before "Reaction"

After "Reaction"

**CREATE** custom sandwich recipes to see how the coefficients affect which reactant is limiting.

$3 \text{ Bread} + 2 \text{ Meat} + 0 \text{ Cheese}$

Recipes must use at least 2 items.

Items are stacked for easy comparison.

**CHANGE** the number of "reactants".

**SEE** the number of product sandwiches and leftovers.

**CHANGE** the number of reactant molecules.

$2 \text{ H}_2 + 1 \text{ O}_2 \rightarrow 2 \text{ H}_2\text{O}$

Before Reaction

After Reaction

**CHOOSE** between three reactions.

**HIDE** molecules

Since we show molecules (not moles), there can be left over molecules of the limiting reactant.

## Game Screen

Students are challenged to figure out the missing number of molecules in 5 random questions per level. Each level has one question where the proportions of reactants will not make any products. Students have 2 attempts per question; after 2 incorrect attempts, the sim shows the correct answer.

The screenshot shows the 'Choose Your Level' interface. At the top, it says 'Choose Your Level'. Below this are three level selection cards: Level 1 (a green sphere and a white sphere with a question mark), Level 2 (two red spheres and a white sphere with a question mark), and Level 3 (two blue spheres and a white sphere with two question marks). Each card has a five-star progress indicator. To the right of the cards is a settings menu with three options: 'Show All' (selected), 'Hide Molecules', and 'Hide Numbers'. At the bottom, there is a navigation bar with icons for 'Reactants, Products and Leftovers', 'Sandwiches', 'Molecules', 'Game', and a home icon. The PhET logo is in the bottom right corner.

**LEVEL 1:**  
Find the number of reactant molecules.

Stars keep track of the highest previous score.

**CONTROL** game sounds or enable a timer before starting a level.

**LEVELS 2-3:**  
Find the number of molecules of products and leftovers.  
*Level 2 reactions have one product; Level 3 reactions have two.*

**HIDE** molecules or numbers for more challenge.

## Model Simplifications

- In order to represent all particles as space-filling models, we did not include ionic compounds in the sim.
- On the sandwiches screen, students can investigate “reactions” that have 3 ingredients as an extension, but none of the chemical reactions in this sim have more than 2 reactants.

## Insights into Student Use

### Sandwiches and Molecules Screens

- During many students' initial exploration of these screens, they followed the chemical equation like a recipe, only entering the exact number of reactants that resulted in zero leftovers. Students tended to explore more diverse scenarios in these screens only after starting to play the Game, or after being given one or two challenging cases to compare.

### Game Screen

- Many of the questions in Level 1 (Finding the number of reactant molecules) can be solved by students counting up the total atoms of each element after the reaction and using only these totals to figure out the number of reactant molecules - without ever making reference to the chemical equation. Level 2 and 3 (Finding the number of products and leftovers) cannot be solved this way, and require students to leverage the chemical equation.
- Students may need prompting that they can (and should) return to earlier screens to help them figure out a strategies as they tackle challenging Game questions. Students in interviews who did return to and make use of earlier screens during the Game made quicker conceptual progress and were more positive about their experience in the Game.

## Suggestions for Use

- **Compare coefficients:** Ask students to pick a number of sandwich ingredients to start.  
**Challenge prompt:**  
“Using only these ingredients, can you them to find a Custom sandwich recipe that makes the bread run out first? What about the cheese, or the meat? How are these recipes different?”
- **Compare molecules and moles:** Choose any example that results in leftover molecules of both reactants. Ask students to discuss what result they might expect if the numbers they were given were moles instead of molecules.
- **Compare strategies:** Ask student groups to compare how they figured out the number of leftovers in Level 2 or 3 of the Game. What information did they need?

See all published activities for Reactants, Products and Leftovers [here](#).

For more tips on using PhET sims with your students, see [Tips for Using PhET](#).