

Build the Table, Defend the Blank: An Element Jigsaw

Learning target: I can work with a team to arrange elements into columns by shared behavior and rows by atomic mass, identify where an element is missing, and defend a prediction about it.

Collaborative investigation

About 50 min

Jigsaw

MS-PS1-1 · practice

collaboration

discussion

data analysis

Standards connections

MS-PS1-1 (practice): Sorting elements by behavior and mass rebuilds the logic of the periodic table that students rely on when they choose and label atoms in molecular models; it builds the practice of using patterns without yet modeling molecules.

Purpose: practice · **Time:** about 50 minutes · **Format:** jigsaw

Answers with reasoning

Twelve element cards (real rounded atomic masses)

1 Card 1: Lithium (Li), 7 Da

Soft silvery metal, cut with a knife. Fizzes steadily in water, no flame. Stored under oil. Forms a white salt with chlorine in a one-to-one ratio of atoms (LiCl).

2 Card 2: Neon (Ne), 20 Da

Colorless gas. Does not react with any other element under normal conditions. Glows red-orange when electricity passes through it; used in lighted signs.

3 Card 3: Iodine (I), 127 Da

Gray-black solid that turns into a purple vapor when warmed. Reactive non-metal. Forms a white salt with sodium in a one-to-one ratio of atoms (NaI). Used as an antiseptic.

4 Card 4: Sodium (Na), 23 Da

Soft silvery metal, cut with a knife. Reacts fast with water and can catch fire. Stored under oil. Forms table salt with chlorine in a one-to-one ratio of atoms (NaCl).

5 Card 5: Argon (Ar), 40 Da

Colorless gas. Does not react with any other element under normal conditions. Makes up about 1 percent of air; used to fill light bulbs so the hot wire does not burn.

6 Card 6: Fluorine (F), 19 Da

Pale yellow gas. The most reactive non-metal known. Forms a white salt with sodium in a one-to-one ratio of atoms (NaF), which is added to toothpaste.

7 Card 7: Potassium (K), 39 Da

Very soft silvery metal. Bursts into flame immediately in water. Stored under oil. Forms a white salt with chlorine in a one-to-one ratio of atoms (KCl).

8 Card 8: Krypton (Kr), 84 Da

Colorless gas. Does not react with other elements under normal conditions. Used in some bright white lamps.

9 Card 9: Chlorine (Cl), 35.5 Da

Yellow-green gas with a sharp smell. Reactive non-metal. Forms salts with the soft metals in a one-to-one ratio of atoms. Used in small amounts to keep swimming pools clean.

10 Card 10: Rubidium (Rb), 85.5 Da

Very soft silvery metal. Explodes on contact with water. Stored under oil. Forms a white salt with chlorine in a one-to-one ratio of atoms (RbCl).

11 Card 11: Xenon (Xe), 131 Da

Colorless gas. Does not react with other elements under normal conditions. Used in some car headlights and camera flashes.

12 Card 12: Helium (He), 4 Da

Colorless gas, lighter than air. Does not react with any other element. Used in party balloons and to cool scientific magnets.

Part A: Expert round (one set per person)

1. Your expert set: _____. Each set contains three elements that do NOT belong together. For each of your three cards, write the one behavior that will decide which column it goes in.

Answer: Set A (Li, Ne, I): lithium reacts with water and is stored under oil (soft-metal column); neon does not react (gas column); iodine forms a 1:1 salt with sodium (reactive non-metal column). Set B (Na, Ar, F): same three behaviors in the same order. Set C (K, Kr, Cl): same. Set D (Rb, Xe, He): same.

Why: Each expert set was built to contain one element from each column so that every student handles all three behaviors.

Also acceptable: Any behavior from the card that correctly places the element in its column is acceptable (for example 'cut with a knife' for the metals).

- Identifies the set
- Names a deciding behavior for each of the three cards

Part B: Home group task

1. Lay all twelve cards on the desk. Sort them into columns so that every element in a column shares a behavior. You should end with exactly three columns. Name each column by its shared behavior.
2. Inside each column, order the cards from lowest atomic mass at the top to highest at the bottom.
3. Now line the columns up side by side so that each row contains elements with similar masses (the lightest metal beside the lightest reactive non-metal beside the lightest unreactive gas, and so on). Helium starts a row by itself.
4. Look for a row that has a hole. One element that should exist is not in the deck. Mark the hole with a blank card.
5. Using the masses above and below the hole in its column, and the masses on either side of it in its row, predict the missing element's atomic mass. Then predict its state, its behavior with the soft metals, and what it would look like.
6. Prepare a one-minute defense: why the columns are right, why the hole is where it is, and why your prediction is reasonable. Every member must be able to give the defense.

Group record (fill in)

Row	Soft metals that react with water	Reactive non-metals that form 1:1 salts	Unreactive gases
Row 1			
Row 2			
Row 3			
Row 4			
Row 5			

2. Group answer: Which row and column has the hole? What atomic mass does your group predict for the missing element, and how did you calculate it?

Answer: The hole is in row 4 (the potassium and krypton row) of the reactive non-metal column, between chlorine (35.5 Da) above and iodine (127 Da) below. Column estimate: $(35.5 + 127) \div 2 = 81.25$ Da, about 81 Da. Row check: potassium 39 Da on one side and krypton 84 Da on the other, so a mass between 39 and 84 is consistent; about 80 Da fits both checks. (Real bromine: 80 Da.)

Why: The full table reads: Row 1: (none), (none), He 4. Row 2: Li 7, F 19, Ne 20. Row 3: Na 23, Cl 35.5, Ar 40. Row 4: K 39, [blank], Kr 84. Row 5: Rb 85.5, I 127, Xe 131. Note that each row's masses increase left to right, with the row-4 blank needing a mass between 39 and 84.

Also acceptable: Accept 'between 39 and 84, probably around 80' with the reasoning shown. Accept a group that places helium at the top of the gas column as row 1 with nothing beside it.

- Correct row and column for the hole
- Prediction near 80-81 Da with the averaging calculation

3. Group answer: Write the strongest challenge the neighboring group made to your arrangement or prediction, and how you answered it.

Answer: Common challenges and good answers: 'Why is helium alone in a row?' (there are no lighter soft metals or salt-formers in the deck, and the real table also starts with helium beside hydrogen only). 'Why is potassium (39) before argon (40) if you read across?' (in our layout the metal column comes first, so potassium at 39 is in row 4 and argon at 40 is in row 3; argon belongs with the unreactive gases regardless of its mass). 'How do you know something is missing and not just a bigger jump?' (every other column step is a modest jump, but chlorine to iodine is a jump of 91.5 Da, far bigger than any other step in the column, and the row with potassium and krypton has nothing in the middle).

Why: The quality of the record matters more than which challenge was raised. Look for a specific challenge and a reply that uses the cards.

Also acceptable: Any reasonable challenge and evidence-based reply earns credit.

- Records a real challenge
- Reply uses evidence from the cards or the arrangement

Part C: Individual accountability (complete alone)

4. Explain in your own words why your group did not simply put the twelve cards in one long line by mass. What would have been lost?

Answer: A single line by mass would hide the repeating pattern: the soft metals, the salt-formers and the unreactive gases come around again and again as mass increases. Stacking the look-alikes in columns makes that repetition visible, lets you predict an element's behavior from its position, and makes a missing element obvious as a hole. A line has no holes.

Why: The answer should say that columns reveal the repeating pattern and make gaps visible.

Also acceptable: A student who writes 'you could not see which elements act alike' has the main idea.

- Says a single line hides the repeating behavior pattern
- Says columns allow prediction or reveal the hole

5. The soft-metal column gets more violent with water as mass increases (fizz, flame, immediate flame, explosion). Does the unreactive-gas column show any trend down the column? Use the cards to answer.

Answer: The gases show almost no trend in reactivity: every card says the gas does not react. The only clear trend is atomic mass increasing down the column (4, 20, 40, 84, 131). Their uses change (balloons, signs, light bulbs, lamps, headlights) but that is not a chemical trend.

Why: Students should recognize that some columns show a strong trend and others very little, which is itself a pattern worth stating.

Also acceptable: Accept 'they get heavier but stay unreactive.'

- States that reactivity shows no trend in that column
- Identifies mass as the one thing that increases

6. The missing element is real; it was discovered in 1826 and is a red-brown liquid. Name the three predictions your group made about it (mass, state and behavior), and say which one the real element matches, which one it does not, and why a prediction can be useful even when one part is wrong.

Answer: Predictions: mass about 80–81 Da; state probably a gas (because fluorine and chlorine above it are gases) or possibly a solid (because iodine below is a solid); behavior: a reactive non-metal that forms 1:1 salts with the soft metals. The real element, bromine, has a mass of 80 Da (prediction matches) and forms 1:1 salts such as NaBr (prediction matches), but it is a red-brown liquid, which neither the gas nor the solid guess matches exactly; a liquid is actually in between the gases above and the solid below. A prediction is useful even with one miss because it tells you where to look and what tests to run; the mass and salt-forming predictions would let a chemist recognize bromine as the missing element.

Why: Historical check: bromine was isolated by Antoine Balard in 1826, before Mendeleev's table; in this activity it is withheld only to create a hole. Credit a student who notices that 'liquid' is the in-between state.

Also acceptable: A group that predicted 'liquid' as the in-between state should be praised; the answer then has no miss and the student should explain the in-between reasoning.

- Lists mass, state and behavior predictions
- Correctly identifies which match bromine and which does not
- Explains why a partly wrong prediction is still useful

7. Suppose a thirteenth card arrived: a soft silvery metal, stored under oil, explodes in water, atomic mass 133 Da. Where would it go, and what would that do to the number of rows?

Answer: It belongs in the soft-metal column below rubidium (85.5 Da), starting a sixth row (row 6: this metal at 133 Da, then blanks for a salt-former and a gas that are not in the deck). The real element is cesium.

Why: Behavior places it in the metal column; mass places it below rubidium; the new row has holes to its right that the deck cannot fill.

Also acceptable: Naming cesium is not required.

- Places it in the metal column under rubidium
- States that it starts a new row with two holes

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Column sorting	Three columns, each named by its shared behavior, with all twelve cards placed correctly.	Three correct columns with one card misplaced or one column unnamed.	Columns based partly on mass or appearance rather than behavior; two or more cards misplaced.	Cards sorted by a feature that is not a behavior (color, use) or left in one line.
Row alignment and the hole	Masses increase down every column and across every row; the hole is identified in row 4 of the non-metal column with a clear blank card.	Rows mostly aligned; the hole is found but one row is misaligned (for example, helium placed beside lithium).	Columns ordered by mass but rows not aligned; the hole is noticed only after a hint.	No row alignment and no hole identified.
Prediction and defense	Predicts about 80-81 Da using the column average and checks it against the row neighbors; predicts state and behavior; every member can give the defense and answer a challenge with evidence from the cards.	Prediction and calculation correct; defense given by one or two members, or the challenge is answered without card evidence.	Prediction given without a calculation, or the defense restates the arrangement without reasons.	No prediction, or a prediction unrelated to the surrounding masses.
Individual accountability (Part C)	All four Part C answers are accurate, use the cards as evidence, and show the student understands the group's reasoning, not just its result.	Three of four accurate with evidence; one thin or partly incorrect.	Two accurate; others restate the group result without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the twelve cards; shuffle them before handing a full deck to each home group so that sorting is genuine. The expert sets (1-3, 4-6, 7-9, 10-12) each contain one metal, one gas and one salt-former on purpose. All masses and behaviors are real (rubidium's reaction with water is explosive; krypton and xenon are unreactive under normal conditions, though xenon can be forced to form compounds in the lab, which is beyond this lesson). Bromine is withheld from the deck to create the hole; it was in fact discovered in 1826, before Mendeleev's table, so make clear in the debrief that the hole is a classroom device that reproduces

Mendeleev's reasoning, not his actual gap. Do not demonstrate any of the water reactions in connection with this sheet.

Scaffold offered to students: Column-first, then mass

If the sorting feels overwhelming, use the storage clue: cards that say 'stored under oil' go together, cards that say 'does not react' go together, and everything left over is the third column. Only after the three stacks exist should you look at the masses. Then order each stack by mass before you line the stacks up into rows.

Extension: Mendeleev's harder problem

Your deck had only three kinds of behavior and one hole. Mendeleev's 1869 table had to handle about 60 elements and eight columns, and he left three major gaps. Find out which three elements filled those gaps and in which years, then write a paragraph comparing your group's prediction process to his: what information did you have that he did not, and what did he have to figure out that your deck handed to you?