

Twelve Substances, Four Columns: A Molecule and Structure Jigsaw

Learning target: I can teach a classmate the composition and structure of a substance from its card, work with a group to sort twelve substances into molecules, crystals and polymers, and explain which pairs of cards share something and what that teaches.

Collaborative investigation

About 50 min

Jigsaw

MS-PS1-1 · practice

collaboration

discussion

visual modeling

Standards connections

MS-PS1-1 (practice): Students describe the atomic composition and structure of twelve substances and sort them into molecules and kinds of extended structures. Describing and comparing these models in words builds the understanding they need to develop their own models; the sheet does not itself require a drawn model.

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

Answers with reasoning

Twelve substance cards

1 Card 1: Water, H₂O

Two hydrogen atoms each bonded to one oxygen atom; 3 atoms in a particle with an edge. A liquid at room temperature; you drink it.

2 Card 2: Hydrogen peroxide, H₂O₂

Two oxygen atoms bonded to each other, with one hydrogen on each oxygen (H-O-O-H); 4 atoms in a particle with an edge. A liquid used as a disinfectant and bleach; never drunk.

3 Card 3: Oxygen gas, O₂

Two oxygen atoms bonded together; 2 atoms, one element only, in a particle with an edge. The gas your lungs take from the air.

4 Card 4: Ammonia, NH₃

One nitrogen atom with three hydrogen atoms attached; 4 atoms in a particle with an edge. A sharp-smelling gas used in some cleaners and fertilizers.

5 Card 5: Butane, C₄H₁₀

Four carbon atoms joined in a row, carrying ten hydrogen atoms; 14 atoms in a particle with an edge. A fuel in some camp stoves and lighters.

6 Card 6: Isobutane, C₄H₁₀

The same 4 carbon and 10 hydrogen atoms as butane, but one carbon is joined to the other three, which are not joined to each other; 14 atoms. Used as a refrigerant and a spray-can propellant.

7 Card 7: Sodium chloride (table salt)

Sodium and chlorine alternate in a repeating pattern in all three directions; 1 sodium for every 1 chlorine; no particle with an edge. Grains tend to be tiny cubes.

8 Card 8: Quartz, SiO₂

Each silicon atom is bonded to 4 oxygen atoms and each oxygen is shared by 2 silicons, repeating in all directions; 1 silicon for every 2 oxygen; no fixed size. The main mineral in most sand.

9 Card 9: Diamond, C

Carbon atoms only; every atom bonded to 4 neighbors in a rigid network that runs in all directions; no fixed size. The hardest natural material; tips cutting tools.

10 Card 10: Graphite, C

Carbon atoms only; every atom bonded to 3 neighbors in flat sheets of six-sided rings; sheets held together only by weak attractions; no fixed size. Soft and slippery; the pencil core.

11 Card 11: Ice, H₂O

Water molecules, still H₂O, locked into a regular repeating pattern in all three directions with six-sided symmetry; a crystal of any size. Snow crystals tend to show six-sided shapes.

12 Card 12: Polyethylene

One carbon carrying two hydrogens, bonded to the next carbon, repeated in a chain thousands of units long; 1 carbon for every 2 hydrogen; no fixed length. Plastic bags and many bottles.

Part A: Expert round (one set per person)

1. Your expert set: _____. Complete the table for your three cards. Agree with the other experts on your set before you return to your home group.

Answer: Set A: 1 water, molecule, 2 H and 1 O; 2 hydrogen peroxide, molecule, 2 H and 2 O; 3 oxygen gas, molecule, 2 O. Set B: 4 ammonia, molecule, 1 N and 3 H; 5 butane, molecule, 4 C and 10 H; 6 isobutane, molecule, 4 C and 10 H. Set C: 7 salt, crystal of atoms, ratio 1:1; 8 quartz, crystal of atoms, ratio 1:2; 9 diamond, crystal of atoms, one element (ratio not needed). Set D: 10 graphite, crystal of atoms, one element; 11 ice, crystal of molecules, each molecule 2 H and 1 O; 12 polyethylene, polymer, ratio C:H 1:2.

Why: Cards 1-6 describe particles with an edge and exact counts; cards 7-10 are atoms repeating in all directions; card 11 is molecules repeating; card 12 is a chain.

Also acceptable: For card 11, accept 'the molecules have an exact count, the crystal has no fixed size' as the composition entry.

Part B: Home group task

1. Each expert teaches their three cards in one minute each: the category, the composition, and the one feature that decides the category.
2. Lay all twelve cards on the desk and sort them into four columns: molecule, crystal of atoms, crystal of molecules, polymer. Every column must have at least one card. Record the sorting in the group table.
3. Find the four teaching pairs. Each pair is two cards that share something important but differ in one way. Hint: one pair shares the kinds of atoms, one shares the exact composition, one shares a single element, and one shares the very same molecules.
4. For each pair, write one sentence that states what the pair teaches about composition, structure or extended structures.

5. Prepare a one-minute defense of this question from the committee: 'Water and salt are both made of two elements. Why are they in different columns?' Every member must be able to give the defense.

Group record (fill in)

Column	Card numbers	How composition is written (count or ratio)	One feature every card in the column shares
Molecule			
Crystal of atoms			
Crystal of molecules			
Polymer			

2. Group answer: List the four teaching pairs by card number. For each, write what the two cards share and what the pair teaches.

Answer: Pair 1 and 2: same kinds of atoms (H and O), different counts; teaches that a different number of atoms makes a different substance. Pair 5 and 6: identical composition (4 C, 10 H), different structure; teaches that structure alone can make a different substance. Pair 9 and 10: the same single element (carbon), different structure; teaches that how atoms are connected, not just which atoms, decides properties. Pair 1 and 11: the very same molecules (H_2O), separate in liquid water but locked in a repeating pattern in ice; teaches that molecules can be the repeating unit of a crystal.

Why: The four pairs each isolate one variable: count, structure of a molecule, structure of an extended structure, and arrangement of identical molecules.

Also acceptable: Accept the pair 7 and 8 (two crystals of atoms with different ratios) as a fifth pair if the four main ones are also found.

- All four pairs identified by number
- What each pair shares is stated correctly
- Each lesson is correct

3. Group answer: Write the placement the neighboring group challenged, their argument, and how your group answered.

Answer: Any accurate record of a challenge and a response. Typical challenges: 'Ice and water are the same substance, so they belong in one column' (answer: same molecules, but ice is a repeating pattern of them, so it is a crystal of molecules); 'Diamond is one element, so it is not a compound and cannot be a crystal' (answer: a crystal can be one element; what matters is the repeating pattern); 'Polyethylene repeats, so it is a crystal' (answer: it repeats in a line, not in all directions, so it is a polymer).

Why: This item documents the discussion; credit a correct response to any reasonable challenge.

Also acceptable: If the challenge revealed a real error that the group then fixed, credit the record of the correction.

- Names the challenged placement
- States the challenger's argument
- Gives a correct response

Part C: Individual accountability (complete alone)

4. Cards 1 and 11 are both H_2O , yet your group placed them in different columns. Explain why ice is an extended structure while liquid water is a collection of molecules, and what stays the same in both.

Answer: In liquid water the H_2O molecules move around one another freely, so there is no repeating pattern; the substance is a collection of separate molecules. In ice the same molecules are locked into a regular pattern that repeats in all three directions and has no fixed size, which is the definition of a crystal, so ice is an extended structure whose repeating unit is a molecule. What stays the same: every particle is still H_2O with exactly 2 hydrogen and 1 oxygen, and the chemical bonds inside each molecule are unchanged.

Why: The distinction is arrangement, not composition. Students should say explicitly that the molecules survive freezing.

Also acceptable: Accept 'the attractions between molecules hold them in place in ice' as extra, correct detail.

- Liquid water: separate molecules, no repeating pattern
- Ice: the same molecules in a repeating pattern of no fixed size
- States that the molecules and their bonds stay the same

5. A thirteenth card arrives: 'Nitrogen gas, N_2 :' two nitrogen atoms bonded together; most of the air.' Which column does it go in, and which card is it most like? Explain.

Answer: Molecule column. It is most like card 3, oxygen gas: two atoms of a single element bonded together in a particle with an edge and an exact count of 2.

Why: A molecule can be one element; the particle-with-an-edge test decides.

Also acceptable: None.

- Places it with the molecules
- Pairs it with oxygen gas for the same reason

6. Using two of the teaching pairs as evidence, explain the sentence: '**Composition and structure together decide what a substance is.**' Name the cards you use.

Answer: Cards 1 and 2 show that composition matters: water and hydrogen peroxide have the same kinds of atoms, but one extra oxygen per particle makes a different substance with different uses. Cards 5 and 6 show that structure matters: butane and isobutane have identical composition, 4 carbons and 10 hydrogens, yet one has a row of carbons and the other a central carbon joined to three, and they are different substances used for different purposes. So knowing which atoms and how many is not enough, and knowing the arrangement is not enough either; a substance is identified only by both together. (Cards 9 and 10 can be used instead of 5 and 6: the same element, carbon, gives diamond or graphite depending on the arrangement.)

Why: Full credit uses one pair that changes composition and one pair that changes structure, and concludes that both are needed.

Also acceptable: A student who uses 1 and 11 must be careful: that pair shows the same substance in two arrangements of molecules, not two substances, so it supports the sentence less directly.

- Uses a pair that differs in composition (1 and 2)
- Uses a pair that differs in structure (5 and 6, or 9 and 10)
- Concludes that both are required to identify a substance

7. A fourteenth card reads: 'Table sugar: sucrose molecules (12 C, 22 H, 11 O) stacked in a regular repeating pattern in a grain.' Which column does it go in, and which existing card is it most like? Explain your reasoning.

Answer: Crystal of molecules. It is most like card 11, ice: in both, whole molecules with an exact count (sucrose with 45 atoms; water with 3) are the repeating unit, stacked in a regular pattern that continues in all directions with no fixed size.

Why: The repeating unit is a molecule, which places sugar with ice rather than with salt or quartz.

Also acceptable: Accept 'extended structure made of molecules' if the ice comparison is made.

- Places it in the crystal-of-molecules column
- Pairs it with ice and gives the molecule-as-unit reason

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Sorting (group)	All twelve cards in the correct column, each column labeled with how composition is written and a shared feature.	One card misplaced, or one column's shared feature missing or vague.	Two or three cards misplaced, or columns based on use or state of matter rather than structure.	Cards sorted by a feature unrelated to composition or structure, or left unsorted.
Teaching pairs (group)	All four pairs found, with a correct statement of what each shares and what it teaches.	Three pairs correct, or four pairs with one lesson stated vaguely.	Two pairs correct, or pairs chosen for superficial reasons (both liquids, both used in kitchens).	No valid pairs.
Defense (group)	Every member can explain that water is separate molecules with an exact count while salt is a repeating pattern with a ratio and no particle edge, and answers the neighboring group's challenge with evidence from the cards.	Most members can give the defense; the challenge is answered partly.	One member gives the defense; the challenge is not answered.	No defense, or a defense based on 'water is a liquid and salt is a solid.'
Individual accountability (q4-q7)	All four items correct with reasons; q6 uses two pairs and concludes that both composition and structure are needed.	Three items correct; q6 uses one pair well.	Two items correct, or answers without reasons.	One or no items correct.

Teacher notes

Print and cut one card set per home group, or let groups cut the sheet. The four columns are the chapter's taxonomy: molecules; crystals whose unit is an atom (salt, quartz, diamond, graphite); crystals whose unit is a molecule (ice; sugar in q7); and polymers (polyethylene). Expected sorting: molecules 1-6; crystal of atoms 7-10; crystal of molecules 11; polymer 12. The teaching pairs are 1-2, 5-6, 9-10 and 1-11. Watch for groups sorting by state of matter or by 'natural versus made.' Accuracy notes for the teacher: the sodium and chlorine in salt are charged ions, omitted because MS-PS1-1 does not assess the ionic nature of subunits; chemists also treat one polyethylene chain as a single giant molecule, which does not change the sorting; and snow crystals and salt grains 'tend to' show their shapes because many real crystals are irregular.

Hydrogen peroxide's card deliberately avoids first-aid use. Extension answers: carbon dioxide is a molecule (1 C, 2 O), most like water or ammonia; PVC is a polymer with a C:H:Cl ratio of 2:3:1, most like polyethylene.

Scaffold offered to students: The two sorting questions

If the sorting stalls, ask each card two questions in order. First: does the card describe a particle with an edge and an exact count of atoms? If yes, it is a molecule; stop. If no, it is an extended structure, so ask the second question: is the repeating unit an atom, a whole molecule, or a chain link? Atoms repeating in all directions means crystal of atoms; molecules repeating in all directions means crystal of molecules; a unit repeating in a line means polymer. Only cards 7 through 12 need the second question.

Extension: Design the thirteenth and fourteenth cards

Write two new cards in the same style: one for carbon dioxide (CO₂: one carbon atom bonded to two oxygen atoms) and one for polyvinyl chloride (PVC: a chain in which every pair of carbons carries three hydrogens and one chlorine). For each, give the category, the composition as a count or a ratio, and an everyday use. Then write a fifteenth card for a substance you choose, look up its structure in a reliable reference, and explain which column it belongs in and which existing card it is most like.