

Checking Dani's Study Guide: Eight Claims About Molecules and Crystals

Learning target: I can find the errors in a classmate's statements about molecules and extended structures, explain the mistaken idea behind each one, and rewrite each statement correctly.

Error analysis

About 35 min

Individual

MS-PS1-1 · practice

writing

independent practice

Standards connections

MS-PS1-1 (practice): Each error targets a mistaken idea that shows up in student models for this PE: treating salt as a molecule, ignoring structure, reading model colors as real, or confusing a ratio with a count. Diagnosing and rewriting the statements strengthens the ideas students will put into their own models.

Purpose: practice · **Time:** about 35 minutes · **Format:** individual

Answers with reasoning

Dani's study guide — **1.** Table salt is made of NaCl molecules, and each molecule has one sodium atom and one chlorine atom. **2.** Butane and isobutane have the same formula, C_4H_{10} , so they are the same substance with two names. **3.** In a ball-and-stick model the oxygen is red because real oxygen atoms are red. **4.** Hydrogen peroxide, H_2O_2 , is just water with a little extra oxygen, so it behaves almost the same as water. **5.** A big quartz crystal has a higher ratio of oxygen to silicon than a small one, because it contains more oxygen atoms. **6.** Oxygen gas, O_2 , cannot be a molecule, because a molecule has to contain more than one kind of atom. **7.** A polymer is an extended structure made of small molecule-based units joined one after another in a long chain. **8.** When water freezes, the H_2O molecules settle into a regular repeating pattern, so ice is a crystal built from molecules.

Part A: Diagnose

- Complete the table. For a correct statement, write 'correct' and leave the second column blank.

Answer: 1: incorrect; salt has no molecules, NaCl is a ratio. 2: incorrect; same composition does not mean same structure or same substance. 3: incorrect; model colors are labels, not real colors. 4: incorrect; a different count of atoms makes a different substance with different behavior. 5: incorrect; a ratio does not change with size. 6: incorrect; a molecule can be one element. 7: correct. 8: correct.

Why: Six of the eight are wrong, each for a different reason that Part B unpacks; two correct statements are included so that students must judge rather than assume everything is wrong.

Also acceptable: Accept any short phrase that identifies the right idea for each incorrect statement.

Part B: Explain and rewrite

For each incorrect statement, write two things. (a) **What went wrong:** the mistaken idea behind the statement, and why someone might believe it. (b) **Rewrite:** the statement, corrected, in one or two sentences that Dani could paste back into the study guide.

2. Statement 1 (salt molecules). (a) What went wrong? (b) Rewrite it. Your rewrite must say what the formula NaCl actually describes.

Answer: (a) Dani assumed that every substance comes in molecules and read the formula NaCl as 'one particle with one Na and one Cl.' It is an easy mistake because formulas for molecules do work that way. (b) Rewrite: Solid table salt is an extended structure in which sodium and chlorine alternate in a repeating pattern in all three directions, so there are no separate salt molecules. The formula NaCl gives the ratio, one sodium for every one chlorine, not the contents of a particle.

Why: The rewrite must shift from count to ratio and from particle to pattern.

Also acceptable: Accept 'crystal' in place of 'extended structure.'

- Identifies the molecule assumption as the error
- Rewrite calls salt an extended structure (or crystal) with no molecules
- Rewrite explains NaCl as a 1:1 ratio

3. Statement 2 (butane and isobutane). (a) What went wrong? (b) Rewrite it using the words **composition** and **structure**.

Answer: (a) Dani thought that the formula, which gives the composition, is enough to identify a substance. But a formula does not say how the atoms are connected. (b) Rewrite: Butane and isobutane have the same composition, 4 carbon and 10 hydrogen atoms, but different structures: butane's carbons form a row, while in isobutane one carbon is joined to the other three. Because their structures differ, they are different substances with different properties.

Why: Composition plus structure identifies a molecule; composition alone does not.

Also acceptable: A rewrite that describes isobutane as 'branched' is acceptable; avoid 'triangle,' which wrongly suggests the outer carbons are bonded to each other.

- Identifies 'formula is enough' as the error
- Rewrite uses composition and structure correctly
- Rewrite states they are different substances

4. Statement 3 (red oxygen). (a) What went wrong? (b) Rewrite it so that it says what the colors in a model are for.

Answer: (a) Dani treated a feature of the model as a feature of the real thing. Models use colors so that people can tell the elements apart at a glance; the convention (often red for oxygen, white for hydrogen, black or gray for carbon) is a labeling system. Atoms are far too small to have a color like a painted ball. (b) Rewrite: In a ball-and-stick model, oxygen is usually shown in red so that anyone can tell which spheres stand for oxygen; the color is a label in the model, not a property of real oxygen atoms.

Why: This is the model-versus-reality error; the rewrite should name the purpose of the colors.

Also acceptable: A student who adds that the convention is common but not universal is correct.

- Identifies model-feature-as-real-feature as the error
- Rewrite explains colors as labels for telling elements apart

5. Statement 4 (hydrogen peroxide). (a) What went wrong? (b) Rewrite it. Include the atom counts of both molecules and one way their behavior differs.

Answer: (a) Dani assumed that a small change in composition makes only a small change in behavior. In fact, a different number of atoms in the particle means a different substance, and different substances can behave very differently. (b) Rewrite: Water (2 hydrogen, 1 oxygen) and hydrogen peroxide (2 hydrogen, 2 oxygen) differ by one oxygen atom per molecule, and that makes them different substances: we drink water, while hydrogen peroxide is used as a disinfectant and bleach and must never be drunk.

Why: The rewrite needs both counts and a concrete behavioral difference. Do not accept a rewrite that recommends putting hydrogen peroxide on wounds; current first-aid guidance advises against it.

Also acceptable: Accept 'hydrogen peroxide breaks down and releases oxygen, which water does not' as the behavioral difference.

- Identifies 'small change, small effect' as the error
- Rewrite gives 2 H, 1 O and 2 H, 2 O
- Rewrite names a difference in use or behavior

6. Statement 5 (big crystal, bigger ratio). (a) What went wrong? (b) Rewrite it, and include a worked example with numbers that shows the ratio stays the same.

Answer: (a) Dani confused a ratio with an amount. A bigger crystal does contain more oxygen atoms, but it also contains more silicon atoms in the same proportion, so the ratio is unchanged. (b) Rewrite: Every quartz crystal has one silicon atom for every two oxygen atoms, no matter its size. Example: a small fragment with 50 silicon atoms has 100 oxygen atoms ($100 \div 50 = 2$), and a large crystal with 5,000 silicon atoms has 10,000 oxygen atoms ($10,000 \div 5,000 = 2$); the ratio is 1:2 in both.

Why: The worked example must show two sizes with the same quotient.

Also acceptable: Any pair of sizes with oxygen = $2 \times$ silicon is acceptable.

- Identifies ratio-versus-amount as the error
- Rewrite states the constant 1:2 ratio
- Includes a numerical example with two sizes

7. Statement 6 (oxygen gas). (a) What went wrong? (b) Rewrite it so that it gives the correct definition of a molecule and names one other molecule made of a single element.

Answer: (a) Dani added a rule that is not part of the definition: a molecule needs at least two atoms joined by chemical bonds, but those atoms do not have to be different elements. Dani may have been thinking of compounds, which do contain more than one element. (b) Rewrite: A molecule is a particle in which a definite number of atoms, at least two, are joined by chemical bonds. Oxygen gas, O_2 , is a molecule: two oxygen atoms bonded to each other. Nitrogen gas, N_2 , is another single-element molecule.

Why: The rewrite must give the correct definition and a second single-element example (N_2 , H_2 , Cl_2 or ozone O_3).

Also acceptable: Accept hydrogen gas H_2 , chlorine gas Cl_2 or ozone O_3 .

- Identifies the invented 'more than one element' rule as the error
- Rewrite gives the two-or-more-atoms-bonded definition
- Names a second single-element molecule

Part C: Step back

8. Statements 1 and 5 are both about the same deeper idea. Statements 2 and 4 are both about another. Name the two ideas, and write one sentence Dani could keep on a card to avoid each kind of mistake.

Answer: Statements 1 and 5 are about count versus ratio: a molecule has an exact count, an extended structure has a ratio that does not change with size. Card sentence: 'If there is no particle with an edge, the formula is a ratio.' Statements 2 and 4 are about composition versus structure, and about the fact that any difference in either makes a different substance. Card sentence: 'To identify a substance you need both what the atoms are and how they are connected; change either one and you have a different substance.'

Why: Grouping the errors by underlying idea is the step-back skill. Statement 4 is about composition (a changed count), statement 2 about structure; together they show both parts matter.

Also acceptable: Accept 'particle versus pattern' as the first idea.

- Names count-versus-ratio for 1 and 5
- Names composition-and-structure (or 'any change makes a new substance') for 2 and 4
- Two usable card sentences

9. Statements 7 and 8 are correct. Pick one and explain why it is correct, as if Dani had asked you to double-check it. Use at least one example from the chapter.

Answer: Statement 7 is correct: a polymer such as polyethylene or PVC is built from a small unit repeated again and again in a long chain, and the chain has no fixed length, which makes it an extended structure. Statement 8 is correct: when water freezes, the molecules stay H_2O but arrange themselves in a regular repeating pattern in all three directions, which is what makes a crystal; table sugar is another crystal built from molecules (sucrose).

Why: Either statement can be chosen; the explanation must connect the statement to the definition it satisfies and give an example.

Also acceptable: A student who notes for statement 7 that chemists also call a whole polymer chain one giant molecule is adding an accurate nuance.

- Chooses 7 or 8
- Explains why it fits the definition (repeating chain, or molecules in a repeating pattern)
- Gives an example from the chapter

Teacher notes

Each incorrect statement maps to one of three deep errors: count versus ratio (1, 5), composition and structure (2, 4), and model versus reality (3), plus a definition error (6). Statements 7 and 8 are correct and are there so that students practice judging. Accuracy notes: the particles in salt are charged ions, which the lesson omits because the assessment boundary of MS-PS1-1 excludes the ionic nature of subunits; and statement 7 follows the chapter's classification of polymers as extended structures, while chemists usually also treat one polymer chain as a single very large molecule, so credit students who mention this. For statement 4, do not let the rewrite include first-aid advice; the textbook's remark about using hydrogen peroxide on cuts is outdated, since current guidance recommends washing with soap and water instead. If students use the word 'compound' in q7, confirm that compounds are substances with more than one element and that oxygen gas is a molecule but not a compound.

Scaffold offered to students: Three test questions for every statement

Ask each statement: (1) Is it talking about a particle with an exact count, or a repeating pattern with a ratio? (2) Does it confuse what the atoms are (composition) with how they are connected (structure)? (3) Does it treat a feature of the model, like a color or a stick, as if it were a feature of the real atoms? Almost every mistake in Dani's guide fails one of these three tests. Write the number of the failed test beside each incorrect statement before you begin Part B.

Extension: Write two traps of your own

Write two new statements for Dani's guide that sound reasonable but contain a mistake about this chapter's ideas, and one statement that sounds surprising but is correct. For each, write the correct version and the test question from the scaffold that catches the error. Trade with a partner and see whether they can find the correct statement among your three. Good traps often involve diamond and graphite, ice and liquid water, or the meaning of a chemical formula.