

Molecules and Extended Structures: Mastery Check

Learning target: I can read and build models of molecules and extended structures, state a substance's composition as a count or a ratio, and explain how composition and structure decide what a substance is and how it behaves.

Retrieval and mastery check

About 35 min

Individual

MS-PS1-1 · assesses

independent practice

writing

Standards connections

MS-PS1-1 (assesses): Items ask students to read compositions from formulas, identify molecules and extended structures, draw a ball-and-stick model of ammonia, and explain why an extended structure's composition is a ratio. Together they produce evidence toward the PE within its assessment boundary: no charges, bonding energies or complete descriptions of large structures are required.

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

Answers with reasoning

Part A: Retrieval (12 items)

1. Which of these is a molecule? 1 pt

Answer: B. One particle of water, H_2O .

Why: Water comes in particles with an exact count of three bonded atoms. Salt, diamond and quartz are extended structures with no separate particle.

Also acceptable: None.

2. Hydrogen peroxide has the formula H_2O_2 . In one molecule: hydrogen atoms ____ oxygen atoms ____ total atoms ____ 1 pt

Answer: Hydrogen 2, oxygen 2, total 4.

Why: The subscripts count atoms of each element in one molecule; $2 + 2 = 4$.

Also acceptable: None.

3. True or false: Oxygen gas, O_2 , is not a molecule, because both of its atoms are the same element. Explain. 1 pt

Answer: False. A molecule is a particle in which at least two atoms are joined by chemical bonds; the atoms can be the same element. O_2 is two bonded oxygen atoms, so it is a molecule.

Why: The definition requires bonded atoms, not different elements. Single-element molecules include O_2 , N_2 and H_2 .

Also acceptable: Accept 'nitrogen gas N_2 is also a molecule' as the explanation.

- Marks false
- Gives the two-or-more-bonded-atoms definition or a single-element example

4. Which statement about solid table salt, NaCl, is correct?

1 pt

Answer: B. Sodium and chlorine alternate in a repeating pattern in all directions, one for one, with no separate molecules.

Why: A is the molecule misconception; C confuses ratio with amount; D confuses a three-dimensional crystal with a chain.

Also acceptable: None.

5. Quartz has one silicon atom for every two oxygen atoms. A quartz fragment contains 350 silicon atoms. How many oxygen atoms does it contain, and how many atoms in total? Show your work.

2 pts

Answer: Oxygen: $350 \times 2 = 700$ oxygen atoms. Total: $350 + 700 = 1,050$ atoms.

Why: The 1:2 ratio means two oxygens per silicon; the total adds both.

Also acceptable: Full credit for 700 and 1,050 with work; one point if the oxygen count is right and the total is missing.

6. Butane and isobutane both have the formula C_4H_{10} . State what is the same about them, what is different, and whether they are the same substance.

2 pts

Answer: Same: composition, 4 carbon and 10 hydrogen atoms (14 atoms). Different: structure; butane's carbons form a row, while isobutane has one carbon joined to the other three. They are different substances with different properties and uses.

Why: Same formula with different structure gives different substances.

Also acceptable: Accept 'branched' for isobutane's structure.

- Same composition (4 C, 10 H)
- Different structure, described
- Different substances

7. Graphite and diamond are both pure carbon. Why does graphite leave a mark on paper while diamond does not?

1 pt

Answer: B. Graphite's carbon atoms are bonded in flat sheets held together only by weak attractions, so the sheets slide off; diamond's atoms are bonded in all directions.

Why: A treats atoms as having hardness; C describes pencil cores, not pure graphite, and is not the cause; D is false (graphite's bonded atoms are actually slightly closer, 142 pm versus 154 pm).

Also acceptable: None.

8. Label each substance as **molecule**, **crystal** or **polymer**: ice _____ PVC pipe _____ ammonia (NH_3) _____ diamond _____

2 pts

Answer: Ice: crystal. PVC pipe: polymer. Ammonia: molecule. Diamond: crystal.

Why: Ice is water molecules locked in a repeating pattern, a crystal; PVC is a chain of repeating units; ammonia is a 4-atom particle; diamond is a crystal of carbon atoms.

Also acceptable: Accept 'extended structure' for ice, PVC or diamond only if the more specific label is also given; half credit for two of four correct.

9. In a ball-and-stick model, the oxygen spheres are red. What does the red color tell you, and what does it **not** tell you about real oxygen atoms? 1 pt

Answer: The red tells you which spheres stand for oxygen, so you can read the model's composition and structure. It does not tell you that real oxygen atoms are red; atoms are far too small to have a color like a painted ball, and the colors are a labeling convention of the model.

Why: Colors in a model are labels, not properties of atoms.

Also acceptable: None.

- Color identifies the element in the model
- Real atoms are not red

10. Caffeine has the formula $C_8H_{10}N_4O_2$. How many atoms are in one caffeine molecule? What is the ratio of hydrogen atoms to carbon atoms, in lowest terms? Show your work. 2 pts

Answer: Total atoms: $8 + 10 + 4 + 2 = 24$ atoms. Hydrogen to carbon: 10:8, which is 5:4 in lowest terms.

Why: Add all four subscripts for the total; divide both parts of 10:8 by 2 for the ratio.

Also acceptable: Accept 1.25 hydrogens per carbon as the ratio.

11. Draw a ball-and-stick model of one ammonia molecule, NH_3 . Nitrogen forms three bonds and hydrogen forms one. Write the letter of each element inside its sphere, add a legend, and write the atom counts beneath the model. 3 pts

Answer: One sphere labeled N in the center with three sticks, each ending in a sphere labeled H; a legend (N = nitrogen, H = hydrogen); counts: 1 N, 3 H, 4 atoms.

Why: Nitrogen forms three bonds and hydrogen one, so the only arrangement is a central nitrogen with three separate hydrogens. The real molecule is a shallow pyramid, but a flat drawing is acceptable.

Also acceptable: Award 2 of 3 points if the model is correct but the legend or counts are missing; 1 point if the hydrogens are chained (H-N-H-H), which breaks the one-bond rule.

- Central N with exactly three sticks
- One H on each stick, no H-H sticks
- Legend and counts (1 N, 3 H)

12. Why is the composition of an extended structure written as a ratio instead of a count? 1 pt

Answer: B. Because it has no fixed size, so only the proportion of its elements stays the same.

Why: A is false (atoms in a fragment can be counted; the count simply differs from fragment to fragment); C is false (salt and quartz have two elements); D is false (the atoms are bonded).

Also acceptable: None.

Part B: Synthesis

13. Write a paragraph (5-7 sentences) answering: **How can fewer than one hundred kinds of atoms make millions of different substances?** Use the words **molecule**, **composition**, **structure**, **extended structure** and **ratio**, and support your answer with two specific examples from this chapter. 6 pts

Answer: Model paragraph: Atoms join to one another through chemical bonds, and the same few kinds of atoms can be combined in an enormous number of ways. Two or more bonded atoms form a molecule, and each molecule has a composition, the kinds and number of atoms, and a structure, the way the atoms are connected. Changing either one makes a new substance: water (H_2O) and hydrogen peroxide (H_2O_2) differ by one oxygen atom, and butane and isobutane share the composition C_4H_{10} but have different structures. Atoms can also repeat in a pattern that never has to stop, forming an extended structure such as a crystal or a polymer, whose composition is a ratio rather than a count, like the 1:1 of table salt or the 1:2 of quartz. Even one kind of atom can make different materials this way, since carbon forms both diamond and graphite depending on how the atoms are connected. Because counts, connections and repeating patterns can all vary, fewer than one hundred kinds of atoms produce millions of substances.

Why: Full credit (6 points): all five terms used correctly (2), the three sources of variety named: counts, connections, repeating patterns (2), two specific chapter examples (1), and a clear concluding answer to the question (1).

Also acceptable: A paragraph that uses the letters-and-words comparison is fine if it is tied to atoms and bonds; a paragraph that explains only molecules and omits extended structures earns at most 4 of 6.

- Uses molecule, composition, structure, extended structure and ratio correctly
- Explains that different counts, different connections and repeating patterns each produce new substances
- Two specific examples from the chapter (for example water and hydrogen peroxide; butane and isobutane; diamond and graphite; salt or quartz)
- Answers the question in a concluding sentence

Teacher notes

Total 24 points: q1-q4, q7, q9 and q12 are 1 point each; q2 is 1 point (all three blanks); q5, q6, q8 and q10 are 2 points each; q11 is 3 points; q13 is 6 points. Items map to the chapter's four sections: molecules and bonds (q1-q3, q9, q11), composition and structure (q2, q6, q10), crystals and polymers (q4, q5, q8, q12) and patterns you can see (q7). Accuracy notes for grading: accept 'extended structure' as a synonym for crystal only where the more specific word is also given in q8; do not expect charges on the salt particles (ions are beyond the assessment boundary); and if a student notes in q7 that pencil 'lead' contains clay, point out that the item asks about pure graphite. Extension answers: propane has one arrangement; pentane has three (a straight row, a four-row with a branch, and a central carbon with four arms); the count of arrangements grows faster than the number of atoms, which is one reason so many substances exist.

Scaffold offered to students: If you get stuck

Skip any item that stalls you and come back to it; the items do not depend on one another. For q5 and q10, write the formula's numbers in a column before you add or multiply. For q11, draw the nitrogen first, then attach exactly three sticks and put a hydrogen on each. For q13, outline four points on scrap paper before writing: atoms join; counts can differ; connections can differ; patterns can repeat without end. Then write one sentence for each point and add your two examples.

Extension: Two more arrangements

Propane has the formula C_3H_8 and pentane has the formula C_5H_{12} . Using the rule that carbon forms four bonds and hydrogen one, draw ball-and-stick models and decide how many different arrangements (structures) each formula allows with no rings. Then explain, in two sentences, why the number of possible substances grows faster than the number of atoms in the formula, and what that says about the 'millions of substances' question in Part B.