

Counting Atoms in Fragments: Why a Crystal Has a Ratio, Not a Count

Learning target: I can graph and calculate from atom counts to show that an extended structure keeps a constant ratio at any size, and contrast that with the exact atom count of a molecule.

Data and graphing About 45 min Individual MS-PS1-1 · practice data analysis independent practice

Name

Date

Period

Directions

This sheet has two parts. Part A uses a teaching dataset: a class used a computer model of a quartz crystal, cut off fragments of different sizes, and let the program count the atoms in each fragment. The numbers were invented to be realistic; they are not from a real laboratory. Part B uses real atom counts for molecules. Graph with a ruler, show every calculation, and write units (atoms) on every number.

You will need: This worksheet, Pencil, Ruler, Calculator (optional)

Part A: Fragments of a quartz crystal

Quartz is an extended structure of silicon and oxygen atoms. Five teams each cut a different-sized fragment from the same computer model and recorded the program's atom count. The cuts were made along straight lines through the model, so each fragment's surface contains a few partly attached atoms.

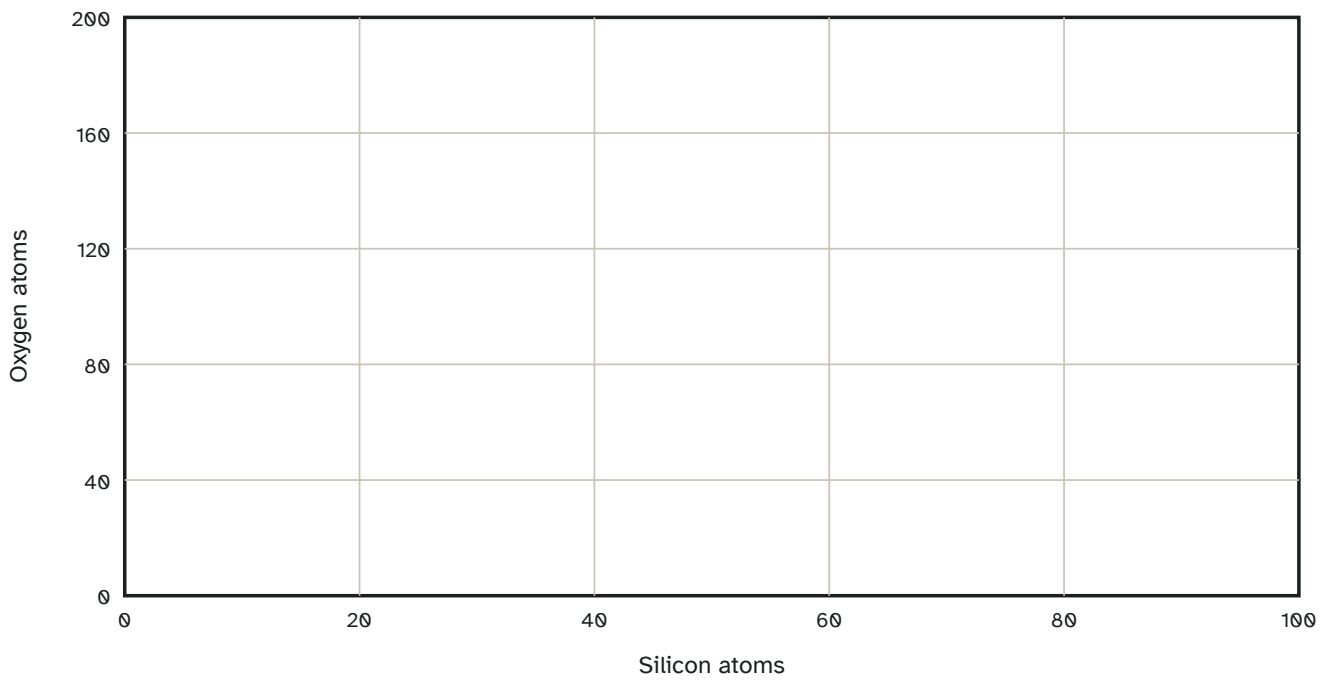
Atom counts in five fragments cut from a quartz model (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Fragment	Silicon atoms	Oxygen atoms
A	10	21
B	25	50
C	40	79
D	60	121
E	100	200

Simulated data for teaching. Realistic for a silicon dioxide model with cut edges.

Oxygen atoms versus silicon atoms in each fragment



1. Complete the table. For each fragment, divide the oxygen count by the silicon count. Show one full division below the table.
- | Silicon atoms | Oxygen atoms | Oxygen ÷ silicon (2 decimal places) |
|---------------|--------------|-------------------------------------|
| A | | |
| B | | |
| C | | |
| D | | |
| E | | |
2. Describe the shape of your graph and where the line meets the left edge. What does this shape tell you about the relationship between the two counts?

3. A sixth team cuts a fragment with 150 silicon atoms. Predict its oxygen count and its total atom count. Show your work.

4. A real grain of quartz contains far more atoms than any model. If a grain holds 2,000,000 oxygen atoms, how many silicon atoms does it hold? Show your work and explain which number from your table you used.

5. Fragments A, C and D give ratios that are not exactly 2.00. Using the description of how the fragments were cut, suggest why. Then use the table to say which fragment is farthest from 2.00 and why that makes sense.

6. The fragments contain 31, 75, 119, 181 and 300 atoms, yet a scientist describes all of them with the same formula, SiO_2 . Explain what the formula of an extended structure describes, and why there is no such thing as 'the number of atoms in quartz.'

Part B: Molecules have exact counts

A molecule is a particle with an edge and an exact number of atoms. The table gives real formulas for eight molecules. In a formula, the small number after a symbol counts that element's atoms in one molecule; no number means one.

Eight molecules and their atom counts (real)

Substance	Formula	Atoms of each element in one molecule
Water	H ₂ O	2 H, 1 O
Ammonia (in some cleaners)	NH ₃	1 N, 3 H
Methane (natural gas)	CH ₄	1 C, 4 H
Methanol (a fuel)	CH ₄ O	1 C, 4 H, 1 O
Carbon dioxide	CO ₂	1 C, 2 O
Vitamin C	C ₆ H ₈ O ₆	6 C, 8 H, 6 O
Caffeine	C ₈ H ₁₀ N ₄ O ₂	8 C, 10 H, 4 N, 2 O
Sucrose (table sugar)	C ₁₂ H ₂₂ O ₁₁	12 C, 22 H, 11 O

7. Complete the table by adding up the atoms in one molecule of each substance. Show one addition below the table.

Formula	Total atoms in one molecule
Methanol	
Vitamin C	
Caffeine	
Sucrose	

8. In vitamin C, what is the ratio of hydrogen atoms to carbon atoms, written in lowest terms? Could a chemist who knew **only** that ratio say how many atoms are in one vitamin C molecule? Explain.

9. A classmate says: 'Quartz has a silicon-to-oxygen ratio of 1:2 and water has a hydrogen-to-oxygen ratio of 2:1, so water must be an extended structure too.' Use the ideas of **count** and **particle edge** to explain the mistake.

10. Look at both parts. Part A needed a graph and five fragments to describe quartz; Part B needed only one row per substance. Explain why describing a molecule's composition takes a count while describing an extended structure's composition takes a ratio, and what each description leaves out.

Reading a ratio from a graph

When a straight line passes through the point (0, 0), the ratio of the two quantities is the same at every point on the line. To find it, pick any point on the line, divide the y-value by the x-value, and you have the number of oxygen atoms per silicon atom. Check it with fragment E: $200 \div 100 = 2$. For q3 and q4, use that ratio as a multiplier (oxygen = $2 \times$ silicon) or a divider (silicon = oxygen $\div 2$).

Where the 1:2 ratio comes from

In quartz every silicon atom is bonded to 4 oxygen atoms, and every oxygen atom is bonded to 2 silicon atoms, so each oxygen is shared between two silicons. Show with a calculation that this sharing forces a ratio of exactly 1 silicon to 2 oxygen. Then imagine a different crystal in which every metal atom is bonded to 6 oxygen atoms and every oxygen is shared by 3 metal atoms; find its ratio. Finally, explain why a cut edge breaks the sharing and makes small fragments drift away from the exact ratio.