



Molecules and Extended Structures

Chapter 2 of 29 • The Composition of Matter

Lesson 2: How do a few kinds of atoms build millions of substances?

Angela's Wand • Bring Science Alive! 7th Grade Integrated

Salt cubes and sugar slants

PHENOMENON

Pour a pinch of salt and a pinch of sugar on dark paper and look through a hand lens. Almost every salt grain is a tiny cube with square faces. Sugar grains are angular too, but slanted, like tilted bricks, never square. Both are white, both dissolve, and grains of all sizes keep their family shape. What inside each grain decides its outside shape?

- Notice: what do all the salt grains share, large or small?
- Wonder: if you crushed a grain, would the pieces keep the shape?
- Predict: are the pieces inside salt and sugar the same kind of thing?





What you will be able to do

LEARNING TARGETS

- 1 Explain that atoms bond into molecules, and read a model or formula for which atoms and how many.
- 2 Explain how composition and structure together decide which substance a molecule is.
- 3 Tell a molecule (exact count) from an extended structure (repeating subunit, fixed ratio).
- 4 Build or draw a model of a simple molecule and of an extended structure, and say what each part means.
- 5 Use atomic-level structure to explain patterns you can see, like salt cubes and pencil marks.

Fewer than 100 kinds of atoms, millions of substances



Fewer than a hundred kinds of atoms occur in nature.



Yet chemists have catalogued many millions of different substances.



Twelve notes in an octave build nearly every song you know; order and combination do the work.

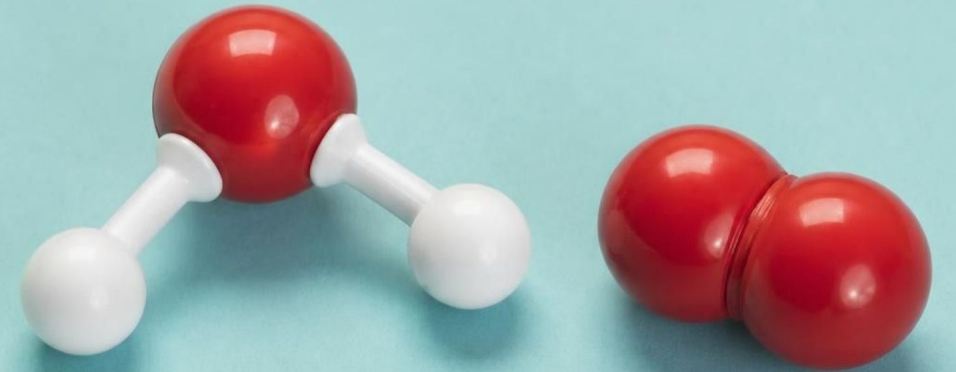


Atoms work the same way: which ones, how many, and how they are joined.



Chemical bonds turn atoms into molecules

When two atoms link strongly, the link is called a chemical bond. A particle made of two or more bonded atoms with a definite count of each is a molecule. One water molecule is always one oxygen atom bonded to two hydrogen atoms: three atoms, two bonds, bent like a boomerang. Oxygen gas is a molecule too, two oxygen atoms bonded to each other.

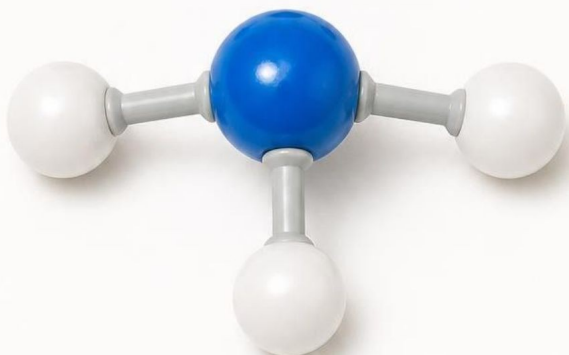




Three words for how atoms join

VOCABULARY IN CONTEXT

- **chemical bond:** A strong connection holding two atoms together inside a particle. *Water has two bonds, each joining one hydrogen atom to the oxygen atom.*
- **molecule:** Two or more bonded atoms with a definite count of each kind; the atoms may be one element or several. *Carbon dioxide, CO_2 , is always one carbon atom bonded to two oxygen atoms.*
- **chemical formula:** Element symbols with small numbers that count the atoms in one molecule; no number means one. *NH_3 (ammonia) is one nitrogen atom and three hydrogen atoms, four atoms in all.*



Reading a ball-and-stick model

Model

Model: What each part of a methane model (CH_4) stands for

Sphere: One atom. Methane has one black sphere (carbon) and four white spheres (hydrogen).

Stick: One chemical bond. Four sticks run from the carbon to the four hydrogens; no stick joins two hydrogens.

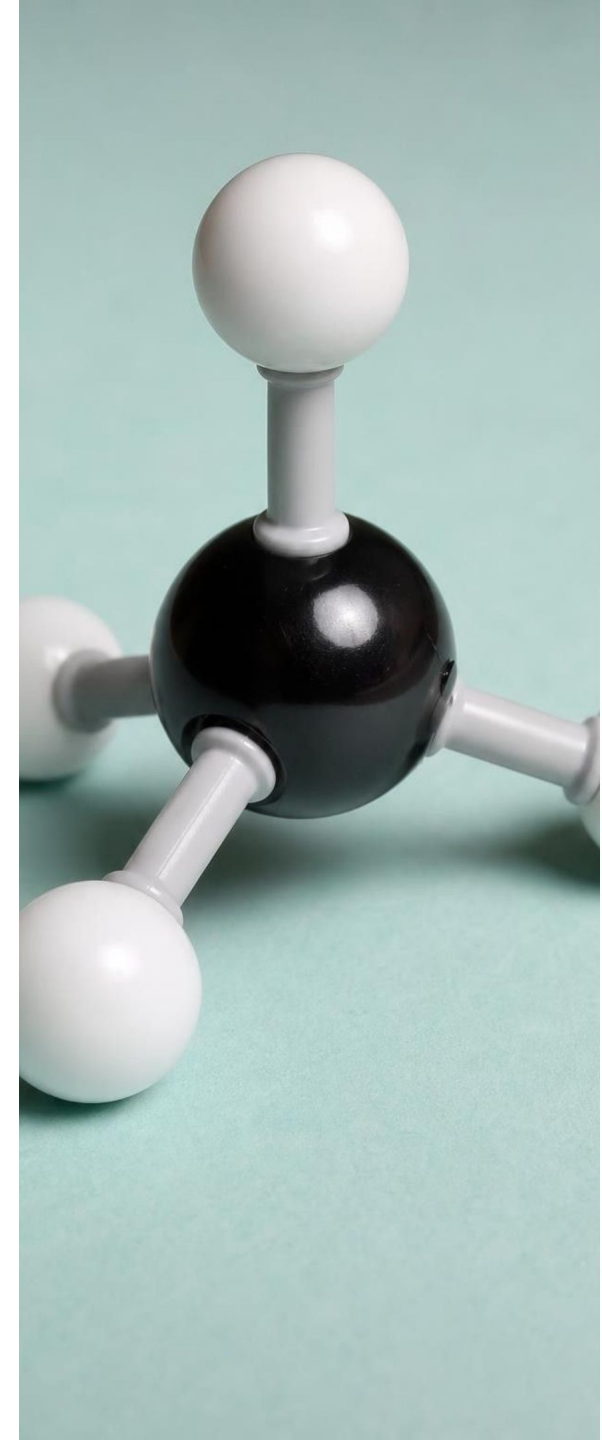
Color key: A shared convention, not real color: white or gray = hydrogen, red = oxygen, black or gray = carbon, blue = nitrogen.

Shape: The hydrogens point to the four corners of a pyramid around the carbon, so methane is three-dimensional, not flat.

Formula from the model: Count spheres of each color: 1 C, 4 H, so CH_4 . The model adds what the formula cannot: who is bonded to whom.

What the model cannot show: Real atoms are not hard balls and bonds are not sticks; the model is about counts and connections, not appearance.

To read any model: count the spheres by color for the formula, then follow the sticks for the structure.



Quick check: read the model

CHECK FOR UNDERSTANDING

A model shows one red sphere bonded to two white spheres, and a second model shows one black sphere bonded to two red spheres. Which pair of formulas is right?

A. H_2O and CO_2

B. HO_2 and C_2O

C. H_2O and C_2O

D. OH_2 and CO



Composition: change the count, change the substance

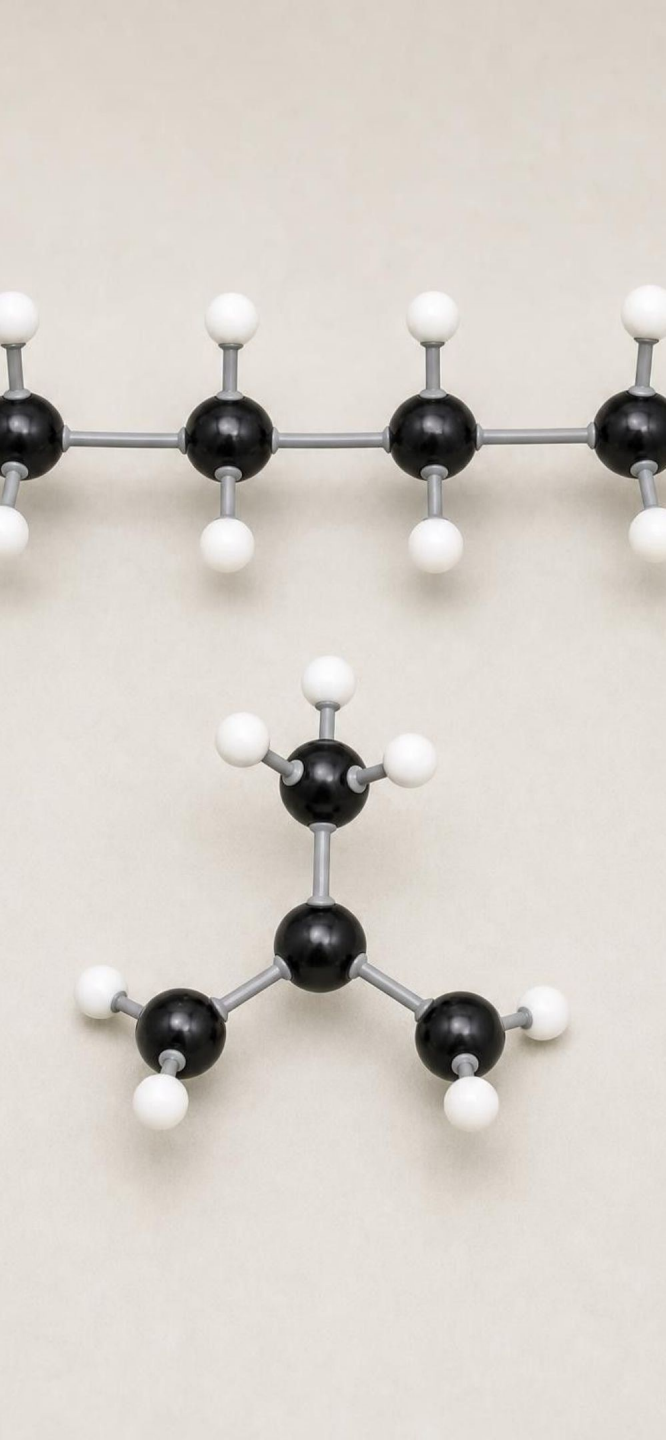
Composition = which elements, and how many atoms of each.

Water, H_2O : 2 hydrogen atoms, 1 oxygen atom. You drink it.

Hydrogen peroxide, H_2O_2 : two hydrogens and two oxygens. A disinfectant; never drink it.

Same two elements, one extra oxygen atom per molecule, completely different substance.





Structure: same atoms, different connections

Model

Model: Butane and isobutane are both C_4H_{10}

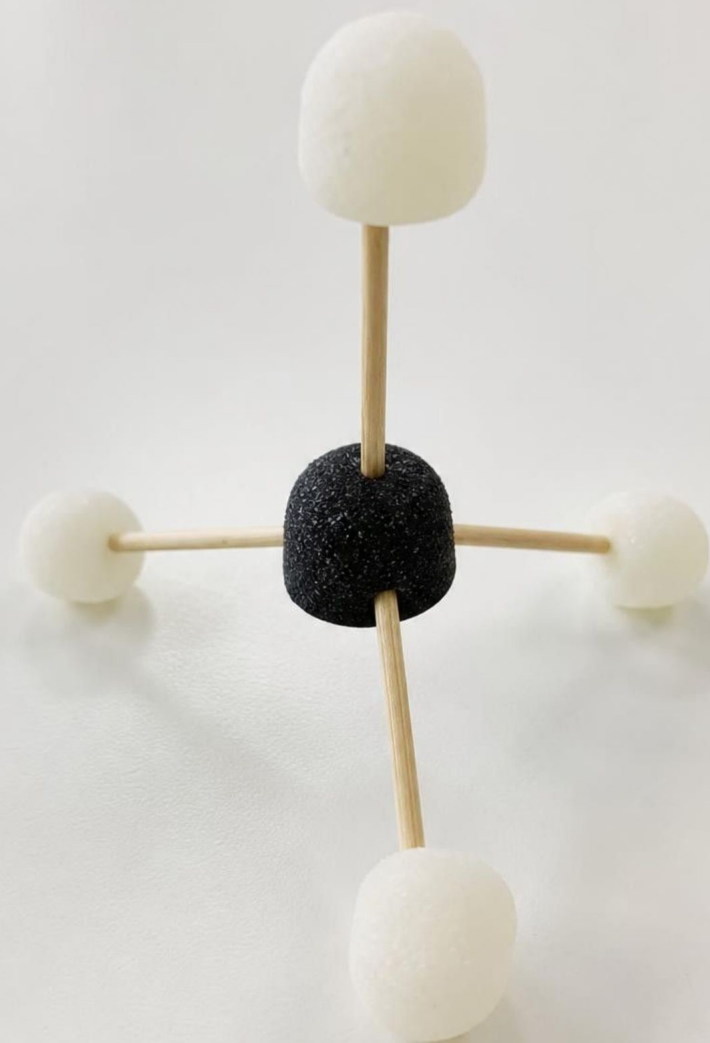
Butane	Isobutane
4 carbon atoms in a row, like a chain of four beads	1 central carbon bonded to 3 other carbons, a branch
Each end carbon holds 3 hydrogens; each middle carbon holds 2	The three outer carbons are not bonded to each other
10 hydrogens in all	Still 10 hydrogens in all
Fuel in camping-stove canisters	Used as a refrigerant and in some fuel blends

A formula gives the count. Only a model or structural drawing shows the connections, and the connections matter.

Composition, structure, model

VOCABULARY IN CONTEXT

- **atomic composition:** Which elements a substance has and how many atoms of each (or their ratio). *Water and hydrogen peroxide differ in composition: H_2O versus H_2O_2 .*
- **chemical structure:** How the atoms are connected and arranged in space. *Butane and isobutane differ in structure: a straight chain versus a branch.*
- **model:** A simplified stand-in that makes the important features of something too small to see easy to notice. *A drawing of circles and lines, a gumdrop build or a computer image can each model methane.*



Quick check: same formula, same substance?

CHECK FOR UNDERSTANDING

Two bottles are labeled $C_{12}H_{22}O_{11}$. One is table sugar, the other is malt sugar, and they taste different. What must be different about their molecules?

A. The number of carbon atoms

B. The elements they contain

C. How the atoms are connected

D. Nothing; the labels must be wrong





Discuss: is a formula enough to name a substance?

Think, pair, share

- True for many small molecules: H_2O is only ever water.
- Fails when two substances share a formula, like butane and isobutane.
- A model or structural drawing shows the connections a formula leaves out.
- Properties (melting point, smell, how it burns) can also tell them apart.

A classmate says 'If I know the formula, I know the substance.' When is that true, and when does it fail? What extra information settles it?

Molecules stop. Some structures keep going.

- A molecule has a definite size: every water molecule is exactly 3 atoms.
- An extended structure repeats one small subunit over and over, with no set size.
- Table salt: sodium and chlorine particles alternate in every direction, as far as the grain goes.

So a formula like NaCl is a ratio,

1 sodium : 1 chlorine,

not a count of a molecule.

A grain with 100 of each and a grain with 10,000 of each are both NaCl.



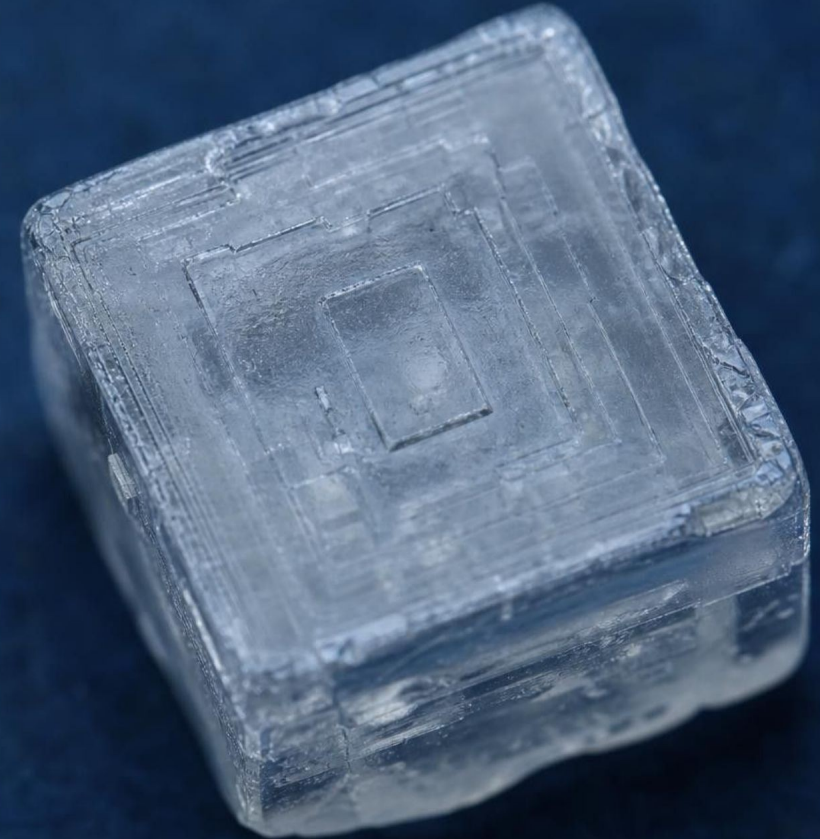
A slice of a salt crystal

MODEL

Model: One layer of table salt: sodium (Na) and chlorine (Cl) alternate like a checkerboard

Na	Cl	Na	Cl
Cl	Na	Cl	Na
Na	Cl	Na	Cl
Cl	Na	Cl	Na

Shade the squares in two colors, alternating: every Na touches only Cl, every Cl touches only Na. The next layer sits on top with colors swapped, so the pattern repeats in all three directions. Any slice has equal numbers of each, 1:1.



Quick check: ratio or count?

CHECK FOR UNDERSTANDING

Quartz is silicon and oxygen in a 1:2 ratio. A quartz grain contains 300 silicon atoms. How many oxygen atoms does it hold, and does a grain with 3,000 silicon atoms have a different ratio?

A. 150 oxygen; yes

B. 300 oxygen; no

C. 600 oxygen; no

D. 600 oxygen; yes, a bigger ratio





Crystals: three kinds of building blocks

A crystal is a solid whose pattern repeats in all three directions.

Built from atoms of one element: diamond (carbon only), graphite (carbon only).

Built from atoms of several elements in a ratio: salt (1:1), quartz (1:2).

Built from whole molecules stacked in a pattern: ice (water molecules), table sugar (sucrose).

Strong bonds hold the atoms inside each molecule; weaker attractions hold the molecules to each other.

Polymers: a chain of repeating units

Model

Model: Polyethylene, the plastic in grocery bags, is one unit repeated thousands of times



Unit 1: one carbon
carrying 2 hydrogens
→ (C-C bond)

Unit 2: the same
→ (C-C bond)

Unit 3: the same
→ (C-C bond)

... thousands more
identical units ...
→ (C-C bond)

Last unit: the chain
ends

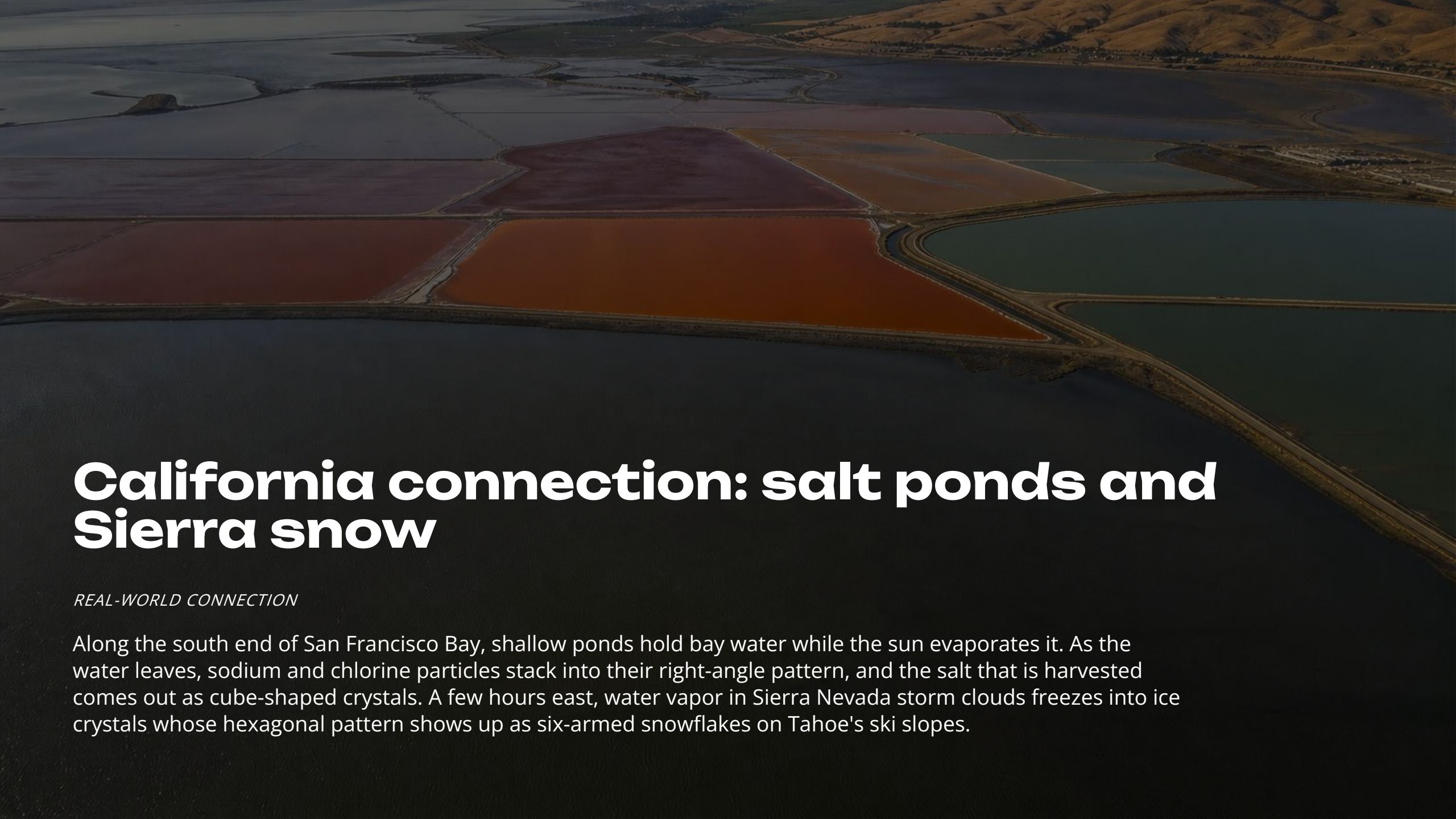
Every unit is the same, so the ratio is fixed (1 C : 2 H) while the chain length is not. The whole chain is one very long molecule.

Words for structures that keep going

Vocabulary in context

- **extended structure:** A structure built by repeating one subunit with no fixed size, so it has a constant ratio of elements. *A grain of salt of any size is sodium and chlorine in a 1:1 ratio.*
- **crystal:** A solid whose atoms or molecules repeat in a regular pattern in all three directions. *Diamond, quartz, salt, ice and sugar are all crystals.*
- **polymer:** An extended structure made of many small units linked into a long chain. *Polyethylene bags, PET bottles and PVC pipes are polymers.*





California connection: salt ponds and Sierra snow

REAL-WORLD CONNECTION

Along the south end of San Francisco Bay, shallow ponds hold bay water while the sun evaporates it. As the water leaves, sodium and chlorine particles stack into their right-angle pattern, and the salt that is harvested comes out as cube-shaped crystals. A few hours east, water vapor in Sierra Nevada storm clouds freezes into ice crystals whose hexagonal pattern shows up as six-armed snowflakes on Tahoe's ski slopes.



THINK, PAIR, SHARE

Discuss: one element, two jobs

Graphite and diamond are both pure carbon. One leaves a mark on paper, the other tips drills that cut through stone. What could be different inside them, if the atoms are identical?

Graphite sheets versus the diamond network

MODEL · MODEL: TWO WAYS TO CONNECT CARBON ATOMS

Graphite	Diamond
Each carbon bonded to 3 neighbors in a flat sheet of hexagons	Each carbon bonded to 4 neighbors pointing in different directions
Sheets stacked like pages, held by weak attraction only	One rigid network in all three directions, no sheets
Sheets slide and peel off under friction: a pencil mark	Nothing can slide; scratching it means breaking bonds
Soft, gray, slippery	Hardest natural material; tips saws and drills for stone and glass

Same atoms, different bonding pattern, opposite behavior. Structure, not composition, does the explaining here.



Task: molecule or extended structure? Read the fragment counts

Apply it · Simulated data for practice.

A lab broke each sample into fragments and counted the atoms in three fragments. For each sample decide: molecule (fixed count) or extended structure (fixed ratio), and write the formula or ratio.

Sample	Fragment 1	Fragment 2	Fragment 3	Your call
A	2 H, 1 O	2 H, 1 O	2 H, 1 O	
B	6 Na, 6 Cl	20 Na, 20 Cl	150 Na, 150 Cl	
C	4 C, 10 H	4 C, 10 H	4 C, 10 H	
D	10 Si, 20 O	48 Si, 96 O	300 Si, 600 O	
E	12 C, 22 H, 11 O	12 C, 22 H, 11 O	12 C, 22 H, 11 O	
F	30 C, 60 H	200 C, 400 H	5,000 C, 10,000 H	



Quick check: why six arms?

CHECK FOR UNDERSTANDING

Snow crystals tend to have six arms. Which statement best explains why?

- A. Snow freezes in six separate steps
- B. Water molecules lock into a hexagonal repeating pattern, and growth follows that pattern
- C. Each snowflake is made of exactly six water molecules
- D. Cold air is shaped like a hexagon





MISCONCEPTION CHECK

True or false? Salt is made of NaCl molecules

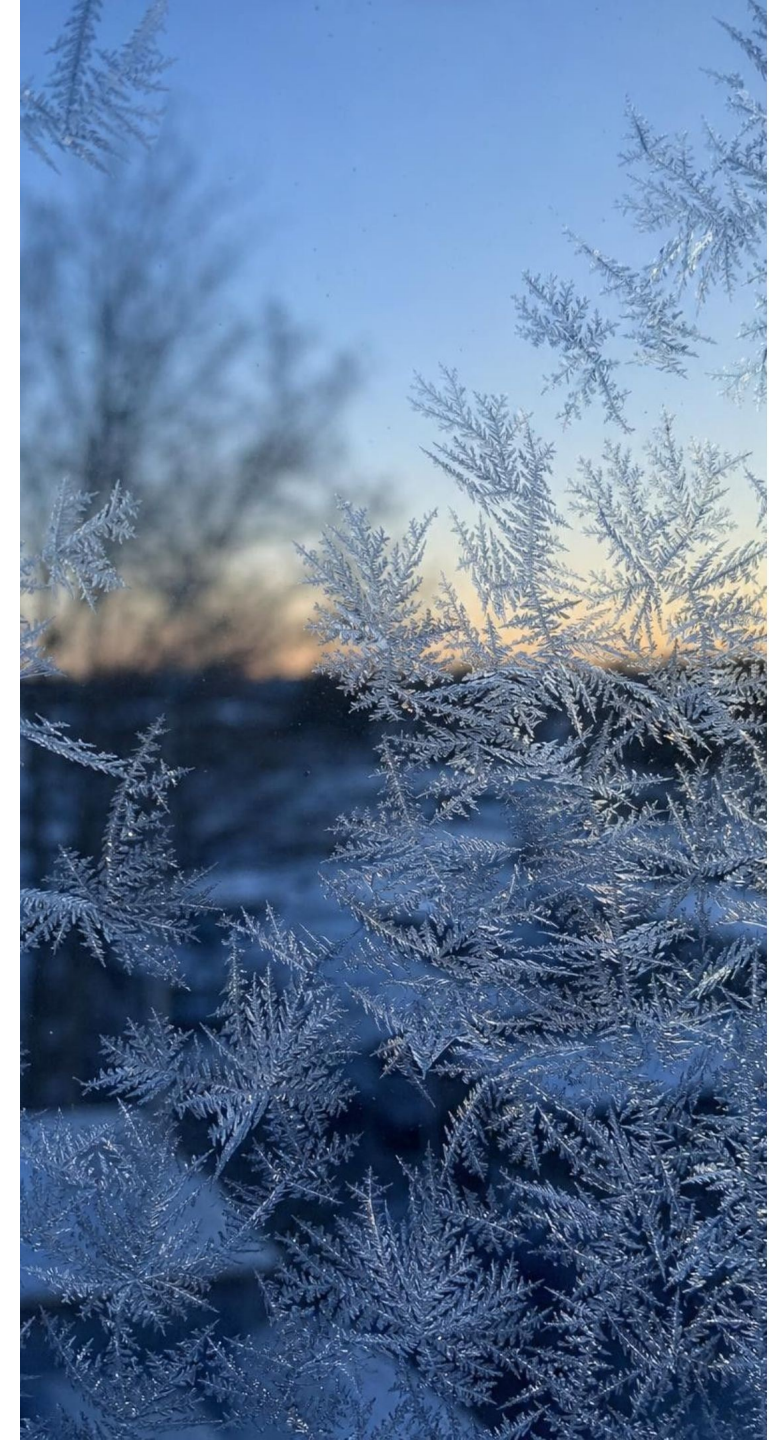
"A grain of table salt is a pile of NaCl molecules, and each molecule is one sodium atom bonded to one chlorine atom."

True or false? Explain your reasoning.

Putting it together

PUTTING IT TOGETHER

- Fewer than 100 kinds of atoms make millions of substances by bonding in different ways.
- Composition and structure together decide the substance: C_4H_{10} names two.
- Crystals repeat in all directions; polymers repeat along a chain.
- A molecule has a definite count of atoms; a formula like H_2O is that count.
- An extended structure repeats a subunit with no set size; $NaCl$ and SiO_2 are ratios.
- Atomic-level structure shows up as patterns you can see: cubes, snowflakes, pencil marks.





Exit ticket

EXIT TICKET

- 1 Write the formula for a molecule with 1 nitrogen atom and 3 hydrogen atoms, and say how many bonds it has.
- 2 A fragment has 40 Na and 40 Cl; another has 90 Na and 90 Cl. Molecule or extended structure? One reason.
- 3 Butane and isobutane are both C₄H₁₀. In one sentence, why are they different substances?
- 4 Why are salt grains cubes? Answer with the word 'repeating'.