

Substances and Their Properties

Chapter 3 of 29 • The Composition of Matter

Lesson 3: How can you tell one substance from another when they look the same?

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



PHENOMENON

Four objects, four stopping points

A jar holds corn syrup, blue-tinted water and vegetable oil in three layers that will not blend. Drop in a steel bolt, a grape, a shaving from a milk-jug cap and a cork. The bolt sinks to the bottom. The grape stops on the syrup. The cap shaving sinks through the oil but floats on the water. The cork stays on top. Nothing holds them up. What decides where each one stops?

- Notice: what is different about the places where the objects stop?
- Wonder: why do the three liquids stay in layers instead of mixing?
- Predict: where would a paper clip stop? An ice cube? A drop of food coloring?





LEARNING TARGETS

What you will be able to do

- Explain what a substance is and tell a pure substance from a mixture.
- Sort properties that describe one object from properties that identify a substance.
- Calculate density and use it to rule a substance in or out.
- Explain melting point, boiling point, solubility and flammability, and which tests change the substance.
- Combine several tests with a reference table to identify an unknown or choose a material.

What is a substance?

- A substance is matter with one fixed makeup throughout: water, oxygen gas, pure copper.
- A single molecule is far too small to see. Trillions of trillions of them together make a sample you can hold.
- A sample at that everyday scale is called macroscopic.
- Invisible gases count too: the oxygen you breathe and the carbon dioxide you breathe out are substances.
- 'Chemical' just means substance. Water and table salt are chemicals; so is everything you eat.



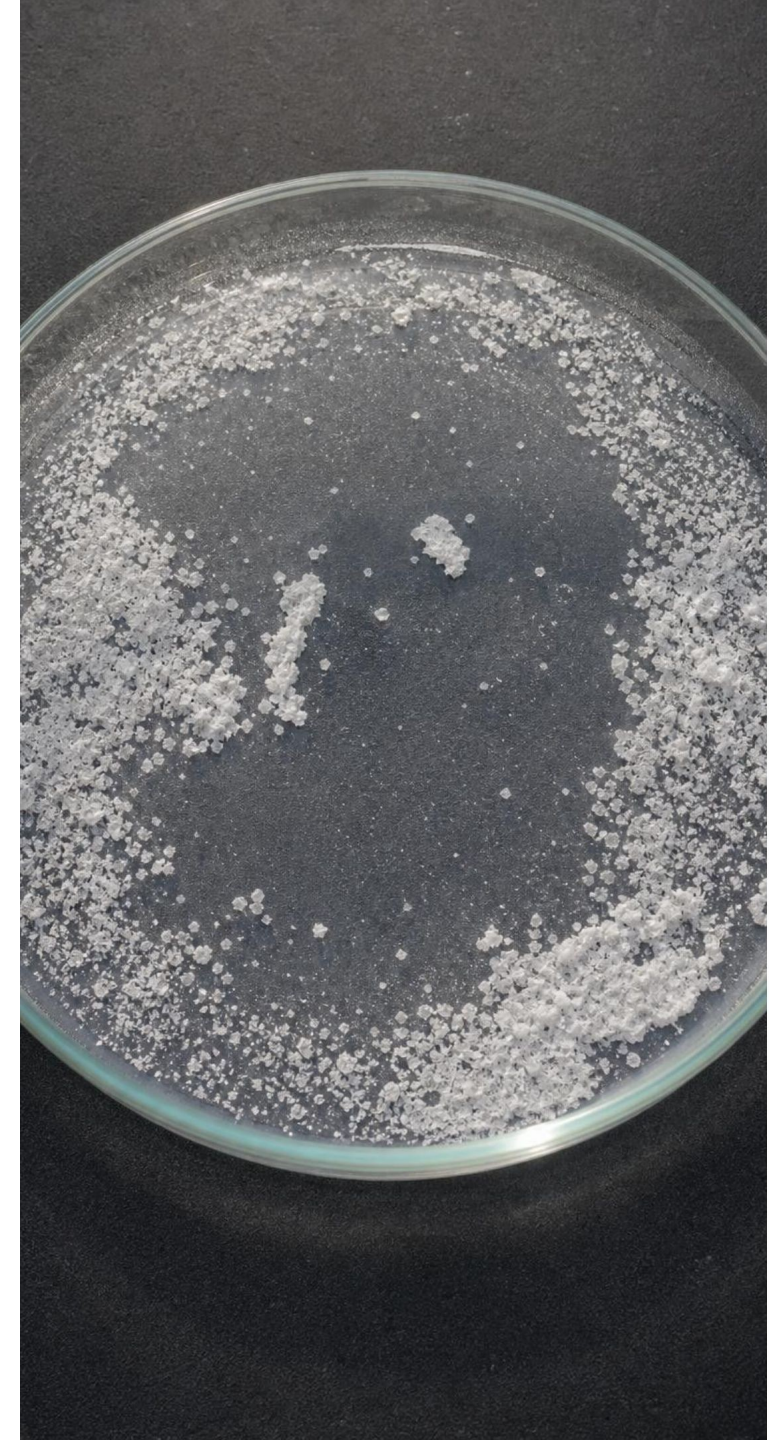
VOCABULARY IN CONTEXT

Three words to keep straight

substance: Matter with one fixed makeup throughout; every pure sample has the same identifying properties. *Every drop of pure water, from any tap on Earth, freezes at 0 °C.*

macroscopic: At the everyday scale you can see and measure, made of trillions upon trillions of particles. *You can measure the density of a copper wire, but not of one copper atom.*

mixture: Two or more substances mingled together, each keeping its own properties. *Seawater is water with dissolved salts; evaporate the water and the salts are left behind.*



Pure substance or mixture?

Model: Two kinds of matter you meet every day

Pure substances (one fixed makeup)	Mixtures (two or more substances mingled)
Water (every molecule is H ₂ O)	Air: nitrogen, oxygen, argon, carbon dioxide and more
Oxygen gas, invisible but one makeup	Seawater: water plus dissolved salts
Pure copper wire	Steel: iron with a little carbon and other elements
Table salt (one repeating extended structure)	Wood: cellulose, lignin and other substances
Sugar crystals	A gold coin: gold mixed with harder metals

Separate a mixture all the way into its parts and each part is a pure substance with its own properties.





CHECK FOR UNDERSTANDING

Quick check: substance or mixture?

Which one of these is a pure substance?

A. Air in a balloon

B. Salt water

C. Carbon dioxide gas

D. Brass (copper mixed with zinc)

Two kinds of properties

- A property is anything about matter you can observe or measure.
- Some properties describe one particular object: its mass, its volume, its shape.
- Cut a copper bar in half and each half has a new mass, a new volume and a new shape.
- Other properties belong to the substance: density, melting point, boiling point, solubility, flammability.
- Both halves of the bar have exactly the same density and melt at exactly the same temperature.
- Only the second kind can tell you what something is made of.





MODEL

Which properties can identify a substance?

Model: Describes one object versus identifies the substance

Describes this one object (changes when you cut it)

Identifies the substance (same for every pure sample)

Mass: a bar has more than a bead

Density: mass per cm^3 at a given temperature

Volume: how much space this piece takes up

Melting point: same for a chip or a block

Shape: a ring, a wire, a coin

Boiling point: at the same air pressure

Temperature right now

Solubility: in a named liquid

Position: on the desk or in a drawer

Flammability: whether it burns (a chemical property)

A detective ignores the left column and measures the right column.

THINK, PAIR, SHARE

Discuss: two gray rings

- Both are gray and shiny, so color is no help.
- Both can be weighed and measured.
- Some tests leave the ring unchanged. Others destroy it.

Two gray, shiny rings look identical. One is silver and one is platinum. Which measurements would you make to tell them apart, and which tests would you refuse to do to someone's ring?





Density: a fair way to compare

$$\text{Density} = \text{mass} \div \text{volume}.$$

Units are grams per cubic centimeter (g/cm^3); $1 \text{ cm}^3 = 1 \text{ mL}$.

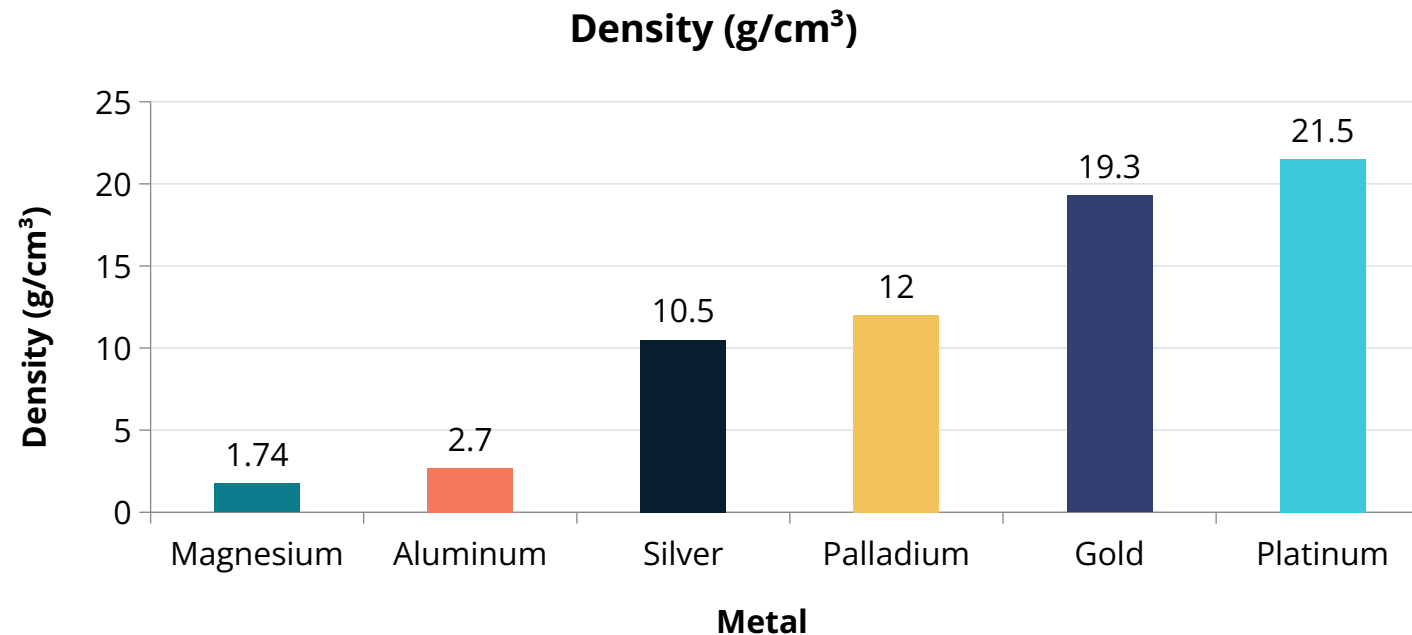
Equal volumes make the comparison fair: a 1 cm^3 cube of silver has about **10.5 g**; platinum about **21.5 g**.

- A big silver spoon has more mass than a tiny platinum bead, yet platinum is twice as dense.
- Cut a sample in half: half the mass, half the volume, the same density.
- Measure a sample's density, compare it to a table of known values, and you can rule substances in or out.

MODEL

Six gray or yellow metals that look alike

Model: Density of six metals (g/cm³, rounded reference values)



Magnesium, aluminum, silver, palladium and platinum are all gray and shiny. Density separates most of them, but silver and palladium are close.



CHECK FOR UNDERSTANDING

Quick check: name the metal

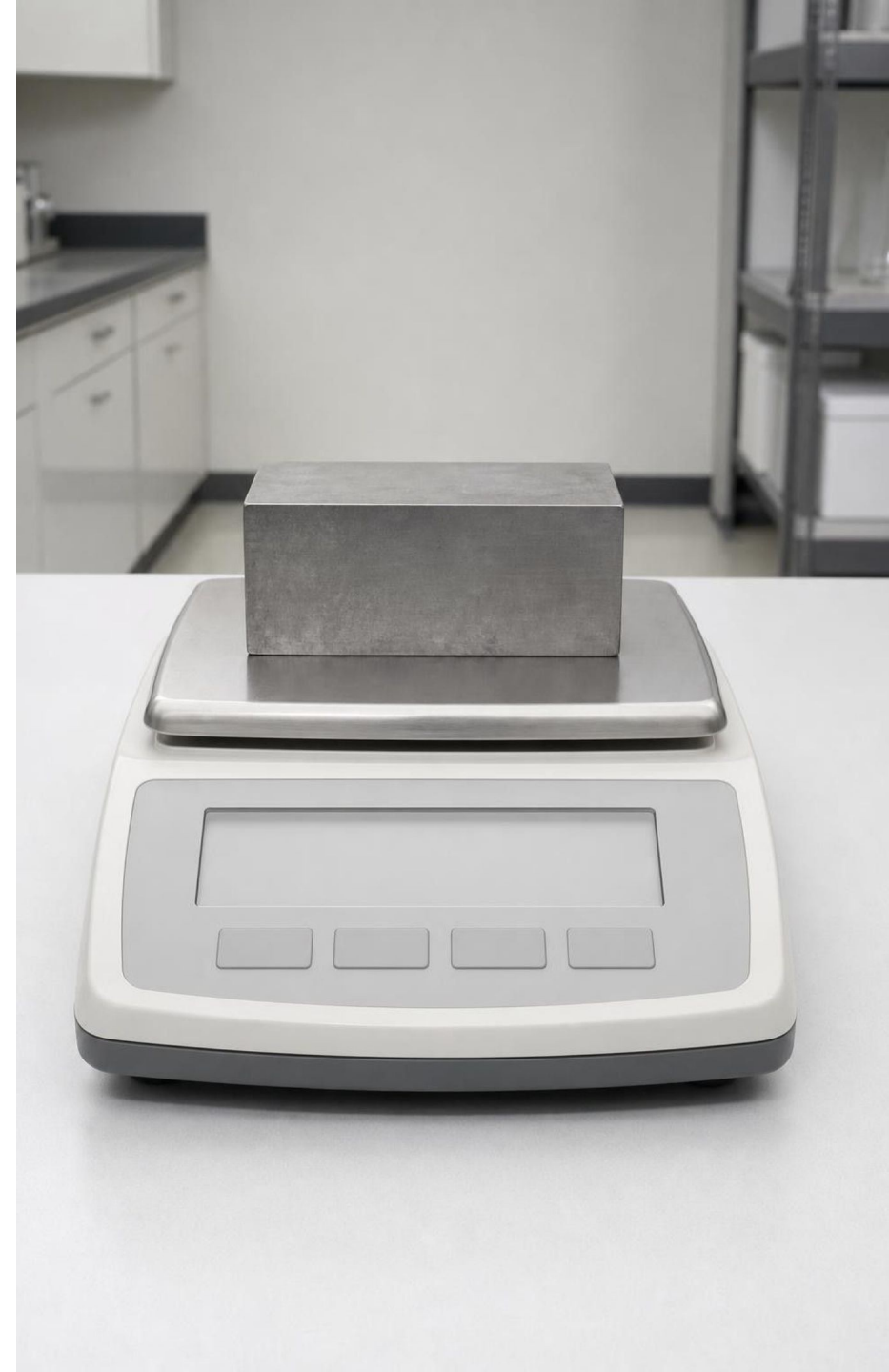
A gray block has a mass of 54.0 g and a volume of 20.0 cm³. What is its density, and which metal on the last slide matches?

A. 0.37 g/cm³; none of them

B. 2.7 g/cm³; aluminum

C. 10.8 g/cm³; silver

D. 1,080 g/cm³; platinum





VOCABULARY IN CONTEXT

The measuring words

density: Mass packed into each unit of volume: $\text{mass} \div \text{volume}$, in g/cm^3 . *A cork at about 0.25 g/cm^3 floats on oil at about 0.92 g/cm^3 .*

melting point: The temperature at which a solid turns to liquid; the same for a chip or a block of the same substance. *A silver chip and a silver bar both begin to melt at about 962°C ; the bar just takes longer.*

boiling point: The temperature at which a liquid boils to gas, listed at sea-level air pressure. *Pure water boils at 100°C at the beach and at about 94°C near Lake Tahoe.*

Melting point and boiling point

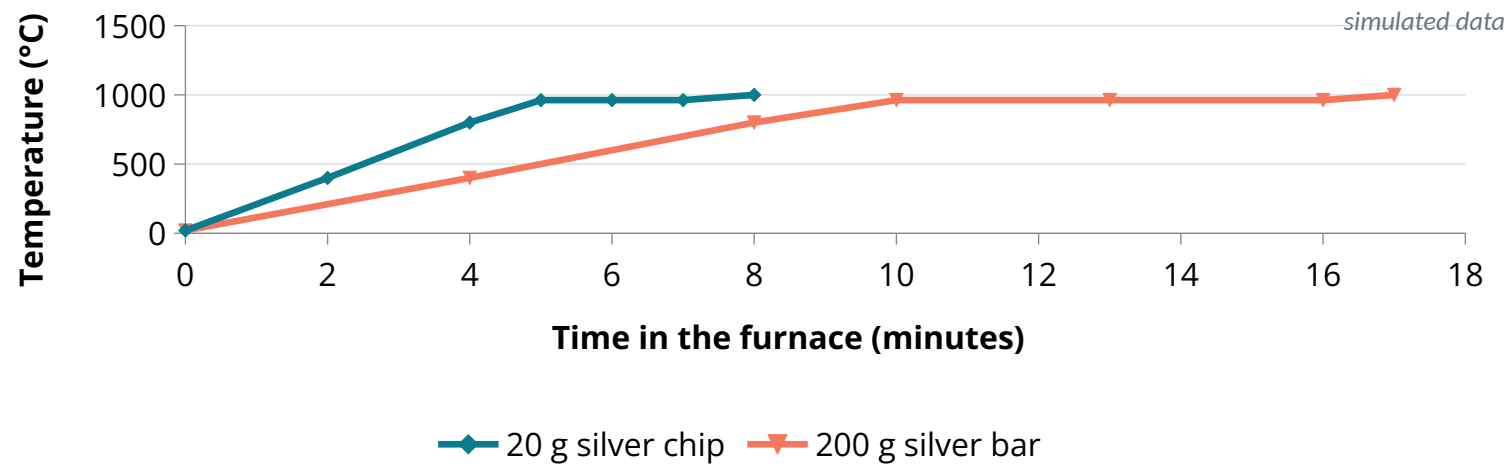
- Heat a solid and watch the thermometer: the temperature where liquid first appears is the melting point.
- Keep heating the liquid: the temperature where it boils is the boiling point.
- A bigger sample needs more energy and more time, but it melts at the same temperature.
- Silver melts near 962 °C and palladium near 1555 °C, so melting point separates these density look-alikes.
- Boiling point depends on air pressure; tables give the sea-level value.



Same melting point, different time

Model: Heating a small and a large sample of silver (teaching data)

x: Time in the furnace (minutes) · y: Temperature (°C)



- **20 g silver chip:** (0, 20), (2, 400), (4, 800), (5, 962), (6, 962), (7, 962), (8, 1000)
- **200 g silver bar:** (0, 20), (4, 400), (8, 800), (10, 962), (13, 962), (16, 962), (17, 1000)

Both curves flatten at about 962 °C while the silver melts. The bar flattens later and for longer, but at the same temperature.





CHECK FOR UNDERSTANDING

Quick check: which statement is true?

A 5 g chip and a 500 g block of the same pure metal are heated in the same furnace. Which statement is true?

A. The block melts at a higher temperature

B. The chip melts at a higher temperature

C. Both melt at the same temperature; the block takes longer

D. They melt at the same time at different temperatures

Solubility: it takes two

- Solubility: how much of a substance can vanish into a given liquid, particle by particle. It names a pair.
- Sugar dissolves in water; flour does not. Both are white powders, so this one test tells them apart.
- Permanent-marker ink will not dissolve in water, but it dissolves in isopropyl alcohol.
- Dissolved is not gone: the particles spread out among the water particles and the mass is still there.
- Oil and water will not dissolve in each other, which is why the jar stays in layers.



MODEL

Where did the sugar go?

Model: Before and after stirring sugar into water

- **Sugar crystal:** particles tightly spaced; Sugar molecules packed in a regular pattern. Visible as a grain.
- **Water:** particles mediumly spaced; Water molecules close together but free to move past one another.
- **Sugar solution:** particles mediumly spaced; Sugar molecules spread out singly among the water molecules. Too small and too separated to see.

The sugar molecules are still there, still sugar, and still counted on the balance. Only their spacing changed.



REAL-WORLD CONNECTION

California connection: salt from the South Bay

Along the southern shore of San Francisco Bay, shallow ponds have been used since the 1800s to make salt from seawater. Bay water is pumped from pond to pond while the sun and wind evaporate the water. The dissolved salt cannot evaporate, so it grows more concentrated and finally crystallizes out, and machines scrape it up. Seawater is a mixture; sunlight pulls it apart into its substances.





Flammability: a property you can only see by changing the substance

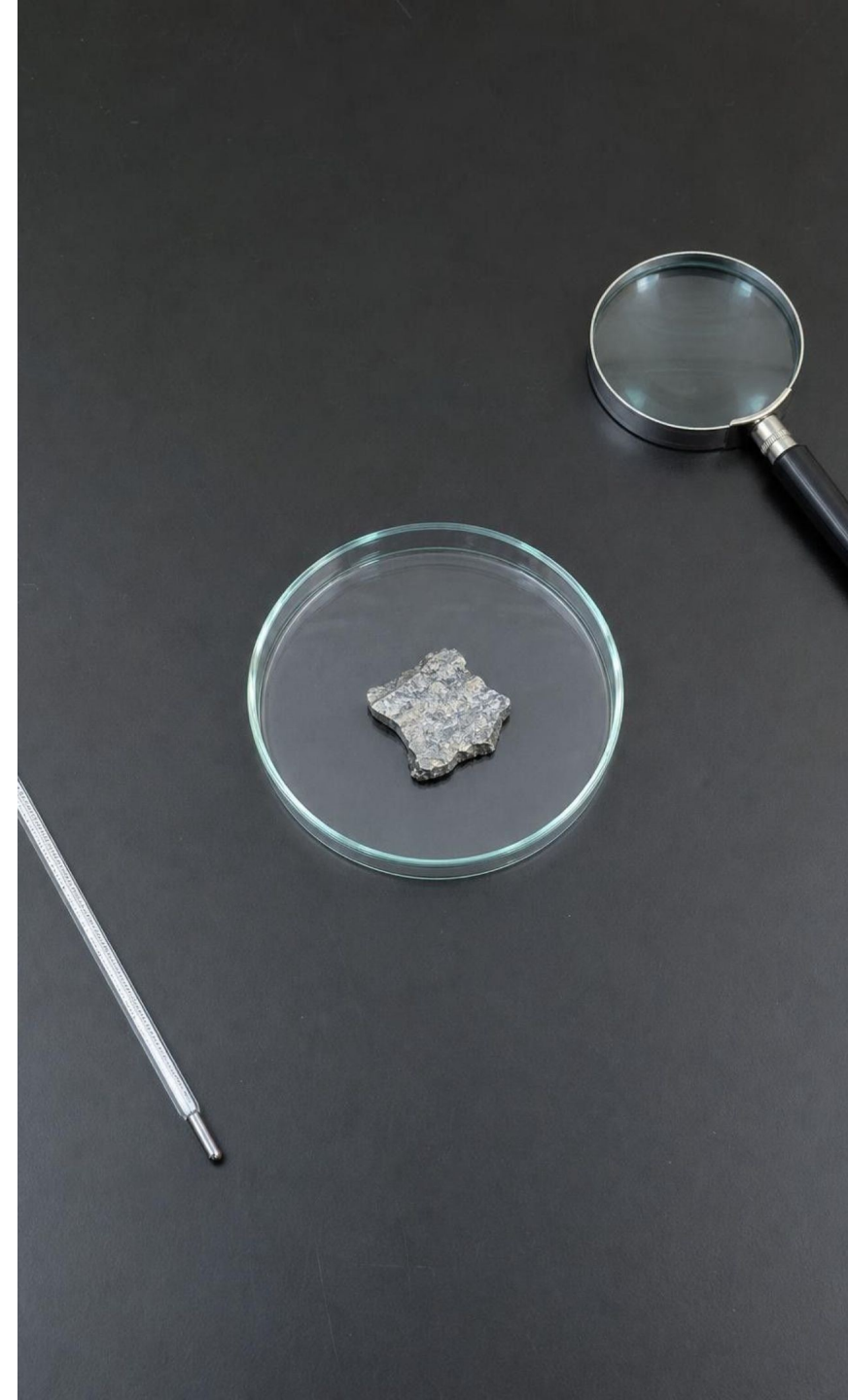
- Flammability is whether, and how easily, a substance burns.
- Burning is a chemical change: magnesium burning in air becomes magnesium oxide, a white powder.
- The sample is used up, so flammability is tested last and never on something you want to keep.
- Water is non-flammable. Gasoline, a mixture of many liquids, is highly flammable.
- A burning splint near a little hydrogen mixed with air gives a pop; such tests help identify gases.

How scientists identify an unknown

Model: From an unknown sample to a name

- 1 Observe safely: color, shine, state, texture → (narrow)
- 2 Measure density: $\text{mass} \div \text{volume}$ → (narrow)
- 3 Test solubility in a named liquid → (narrow)
- 4 If still unsure, measure melting or boiling point → (compare)
- 5 Compare every result with a table of known substances → (decide)
- 6 Name the substance only when all the results agree

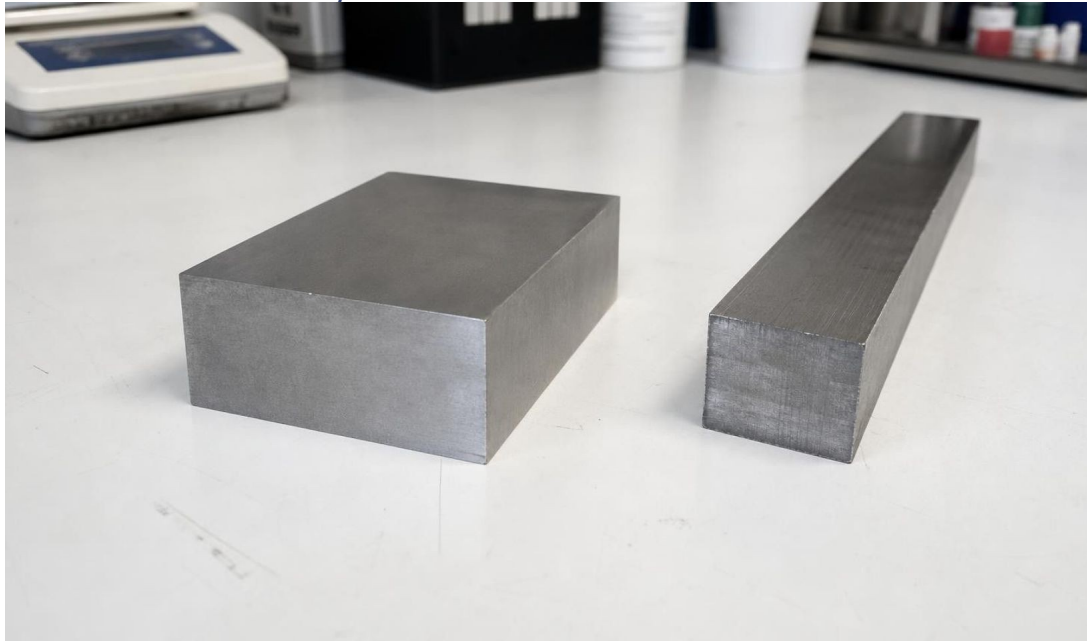
Each test rules some candidates out. The non-destructive tests come first; a test that uses up the sample comes last, if at all.



Task: name the two gray samples

Sample 1: a gray block, mass 87.0 g, volume 50.0 cm³. Sample 2: a gray bar, mass 210 g, volume 20.0 cm³. The class balance and cylinder give densities good to about ± 0.3 g/cm³. A small chip cut from sample 2 begins to melt at about 960 °C. Show each density calculation.

Simulated data for practice.



Metal	Density (g/cm ³)	Melting point (°C)	Appearance
Magnesium	1.74	650	gray, shiny
Aluminum	2.7	660	gray, shiny
Zinc	7.14	420	bluish gray
Molybdenum	10.2	2623	gray, shiny
Silver	10.5	962	gray, shiny
Lead	11.3	327	dull gray

Use the reference table to identify each sample. Which sample needed a second test, and why?

THINK, PAIR, SHARE

Discuss: tests that keep the sample, tests that destroy it

- Density: mass and volume, coin unchanged.
- Solubility: a drop of liquid on the surface, or the whole coin?
- Melting point: the coin becomes a puddle.
- Flammability: the coin becomes something else entirely.

A museum wants to know whether an old coin is silver or a silver-colored alloy without damaging it. Rank the five property tests from safest to most destructive and decide where you would stop.





Most things are mixtures

1 Pure gold is soft; coins and rings are gold alloys, mixed with copper or silver so they do not dent.

2 Air is a mixture: mostly nitrogen and oxygen, with argon, carbon dioxide, water vapor and more.

3 Wood, steel, glass, seawater and gasoline are all mixtures.

4 Each substance in a mixture keeps its own properties, which is how mixtures can be taken apart.

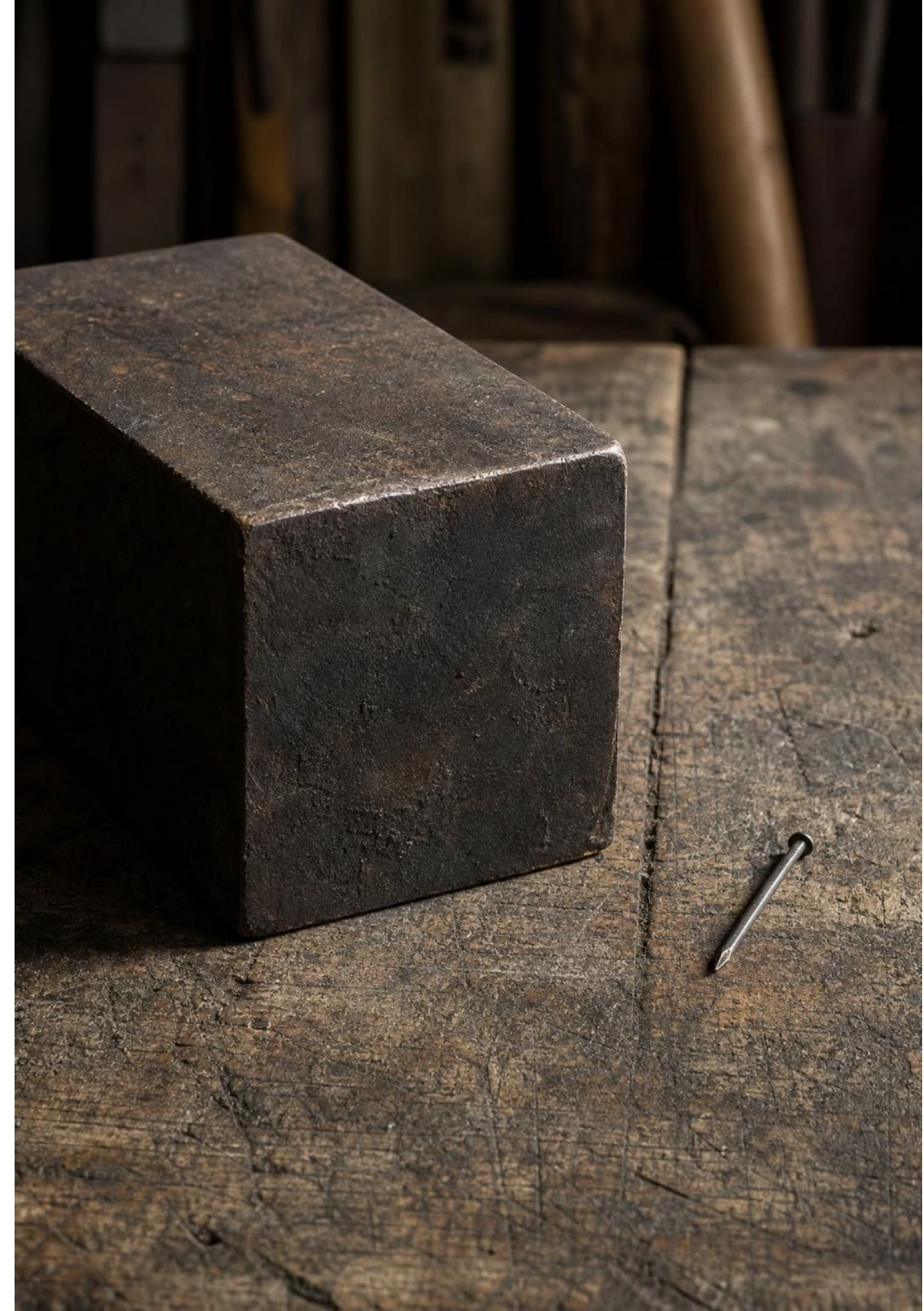
5 The salt ponds, a density jar and a coffee filter are all separation tools.

MISCONCEPTION CHECK

True or false? Bigger means denser

"A large block of iron is denser and has a higher melting point than a small iron nail, because there is more iron in it."

True or false? Explain your reasoning.



PUTTING IT TOGETHER

Putting it together

- A substance has one fixed makeup; most everyday materials are mixtures of substances.
- Mass, volume and shape describe one object; density, melting point and solubility identify the substance.
- $\text{Density} = \text{mass} \div \text{volume}$, the same for every pure sample at the same temperature.
- Melting and boiling point do not depend on amount; boiling point does depend on air pressure.
- Solubility names a pair; dissolved is not gone. Flammability is a chemical property that uses up the sample.
- Identify an unknown with several tests, non-destructive first, compared against a reference table.





EXIT TICKET

Exit ticket

- A sample has a mass of 48 g and a volume of 40 cm³. Give its density with units.
- Name one property that describes an object and one that identifies a substance. How can you tell them apart?
- A white powder vanishes when stirred into water. Did it stop existing? Give one piece of evidence.
- Which of the five identifying properties is a chemical property, and why is it tested last?