

Sink, Float, Sort: How a Recycling Plant Tells Plastics Apart

Learning target: I can explain, with evidence from a passage, how a recycling plant uses density and other properties to identify look-alike plastics, and why one property is rarely enough.

Reading with evidence

About 35 min

Individual

MS-PS1-2 · practice

MS-PS1-3 · supports

reading

writing

Standards connections

MS-PS1-2 (practice): The passage shows density, melting behavior and solubility being used as identifying properties of real substances, the same properties the PE's assessment boundary names. Students practice reading and interpreting property information before they analyze data themselves.

MS-PS1-3 (supports): Background only: the passage mentions that plastics are synthetic materials made from natural resources and that recycling them affects society. It does not gather information about how they are made.

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

Answers with reasoning

Sink, Float, Sort

[1] A bale of mixed plastic arrives at a recycling plant looking like one kind of stuff: a crushed tangle of bottles, tubs, trays and lids. It is not one kind of stuff. The bale holds at least six different substances, each a different plastic, and a factory that melts them together gets a weak, streaky material that nobody wants to buy. Plastics are synthetic materials made from natural resources such as oil and natural gas, and each kind has its own set of properties. The plant's job is to use those properties to pull the tangle apart, substance by substance.

[2] The first clue is printed on the item. Since 1988, a plastics industry group has stamped most containers with a small triangle and a number from 1 to 7. A 1 means PET, the clear plastic of soda bottles. A 2 means high-density polyethylene, the cloudy plastic of milk jugs. A 5 means polypropylene, used for yogurt tubs and caps. The code is helpful but weak. Labels wear off, lids get separated from bottles, and a sorting line moving thousands of pieces a minute cannot stop to read each one. The plant needs properties it can test on every piece automatically.

[3] The oldest and cheapest test uses density. Shredded flakes drop into a tank of water. Polyethylene has a density of about 0.95 g/cm^3 and polypropylene about 0.90 g/cm^3 , both lower than water's 1.00 g/cm^3 , so their flakes float and are skimmed off the top. PET, at about 1.38 g/cm^3 , sinks and is collected from the bottom. The tank does not care about the shape, color or size of the flake. A tiny chip of PET and a large one sink just the same, because density belongs to the substance, not to the piece.

[4] Density also shows where the method fails. Polyvinyl chloride, PVC, the plastic of blister packs and pipes, has a density of about 1.38 to 1.41 g/cm³, nearly the same as PET. In the water tank they sink side by side. This matters because PVC and PET behave very differently when heated: PET melts cleanly at about 250 °C, while PVC begins to break down near 150 °C and gives off hydrogen chloride gas, which corrodes equipment and spoils the batch. A few PVC flakes in a ton of PET can ruin it. When two substances share a property, a plant has to test a second property to tell them apart.

[5] A second test uses light. A near-infrared sorter shines invisible light, just beyond red, onto the flakes and reads the pattern each flake reflects. Every plastic reflects its own pattern, a kind of fingerprint, so the machine can flag PVC among PET and blow it aside with a puff of air. Even this test has a blind spot. Black plastic, colored with carbon black, swallows nearly all the infrared light and reflects almost nothing, so the sorter cannot read it. Black trays often end up in the trash for that reason.

[6] Chemists in the plant's lab use a third property when the machines disagree: solubility. A flake of PET will not dissolve in water or ordinary alcohol, but it dissolves in certain strong solvents in which polyethylene stays solid. A questionable flake dropped into a small dish of the right solvent settles the argument. Like the water tank, this test gives the same answer for a big flake and a small one, because solubility is also a property of the substance.

[7] Notice what the plant never does. It never sorts by mass, because a heavy flake of polypropylene and a light flake of PET are both ordinary. It never sorts by color, because a blue PET bottle and a blue polyethylene jug are different substances in the same disguise. Every reliable test on the line measures something that stays the same for every piece of a substance no matter its size or shape: density, melting behavior, the infrared fingerprint, solubility. And no single test is trusted alone. The water tank, the light sorter and the lab each catch what the others miss, which is how a careful scientist identifies any unknown: several properties, compared against a table of known substances, until one answer is left.

Questions: cite the passage

1. According to paragraph 1, why can't the plant simply melt the whole bale together? Quote the phrase that describes the result.

Answer: The bale holds at least six different substances, and melting them together produces a material no one will buy. Quote: 'a weak, streaky material that nobody wants to buy' (paragraph 1).

Why: The point is that different substances have different properties and do not combine into a useful material.

Also acceptable: Accept 'at least six different plastics' for substances.

- States that the bale contains several different substances
- Quotes or closely paraphrases the result

2. Paragraph 2 calls the number code 'helpful but weak.' Give two reasons from the paragraph that it is weak.

Answer: Any two: labels wear off; lids get separated from their bottles; the sorting line moves thousands of pieces a minute and cannot stop to read each one (paragraph 2).

Why: The paragraph gives three reasons; students need two.

Also acceptable: Accept 'not every item has a code' as a reasonable inference from 'most containers'.

- Two distinct reasons from paragraph 2

3. Using the densities in paragraph 3, a flake of PET with a volume of 2.0 cm^3 and a flake of polypropylene with a volume of 2.0 cm^3 are weighed. Calculate the mass of each and the difference between them. Show your work.

Answer: PET: $1.38 \text{ g/cm}^3 \times 2.0 \text{ cm}^3 = 2.76 \text{ g}$. Polypropylene: $0.90 \text{ g/cm}^3 \times 2.0 \text{ cm}^3 = 1.80 \text{ g}$. Difference: $2.76 \text{ g} - 1.80 \text{ g} = 0.96 \text{ g}$.

Why: Mass = density $\times$ volume. Rearranging the definition density = mass $\div$ volume is the one calculation in this sheet.

Also acceptable: Accept 2.8 g, 1.8 g and 1.0 g if the student rounds consistently and shows the multiplication.

4. Paragraph 3 says the tank 'does not care about the shape, color or size of the flake.' Explain in your own words why this is true, using the word *substance*.

Answer: Density is a property of the substance, not of the individual flake. Every piece of PET has the same mass per cubic centimeter, so a big piece, a small piece, a blue piece and a clear piece all sink in water the same way. Shape, color and size are properties of the object and do not change the substance's density.

Why: This is the core idea of the lesson applied to the passage.

Also acceptable: Accept 'a small piece has less mass but also less volume, so the ratio is the same.'

- Says density belongs to the substance
- Says size/shape/color are object properties that do not change it

5. Paragraph 4 describes a case where the density test fails. Name the two substances, give the evidence (with numbers) that density cannot separate them, and explain why mixing them up is a serious problem.

Answer: PET and PVC. Evidence: PET is about 1.38 g/cm^3 and PVC about 1.38 to 1.41 g/cm^3 , so both sink in water 'side by side' (paragraph 4). The problem: when heated, PET melts cleanly at about 250°C but PVC breaks down near 150°C and releases hydrogen chloride gas, which corrodes equipment and spoils the batch; even a few PVC flakes can ruin a ton of PET.

Why: Full credit needs both names, the near-equal densities with numbers, and the heating consequence.

Also acceptable: Accept 'they have almost the same density' with at least one number quoted.

- Names PET and PVC
- Cites the overlapping densities with numbers
- Explains the damage from PVC when heated

6. Paragraphs 5 and 6 each describe a test with a limitation. Name each test and its limitation, citing the paragraph.

Answer: Paragraph 5: the near-infrared light sorter reads each plastic's reflected-light fingerprint, but it cannot read black plastic because carbon black absorbs nearly all the infrared light. Paragraph 6: the solubility test dissolves a flake in a chosen solvent, but it is a lab test done by hand on questionable flakes, used only when the machines disagree, so it cannot sort the whole line.

Why: The infrared limitation is stated outright; the solubility limitation (slow, by hand, used as a tiebreaker) must be inferred from 'when the machines disagree' and 'a small dish.'

Also acceptable: For solubility, accept 'it needs strong solvents' or 'it is only used in the lab' as the limitation.

- Names the infrared sorter and the black-plastic blind spot
- Names the solubility test and a sensible limitation

7. Paragraph 7 lists two things the plant 'never does.' State both and explain, using the idea of identifying properties, why those two methods would fail.

Answer: The plant never sorts by mass and never sorts by color. Mass belongs to the individual piece: a heavy flake of polypropylene and a light flake of PET are both normal, so mass cannot tell the substances apart. Color is a disguise shared across substances: a blue PET bottle and a blue polyethylene jug look alike but are different substances. Only properties that stay the same for every piece of a substance can identify it.

Why: Both methods fail because they are not identifying properties.

Also acceptable: Accept 'mass depends on how big the piece is' for the first explanation.

- States both methods
- Explains that mass is an object property
- Explains that color is shared across substances

8. The passage ends by comparing the recycling plant to 'a careful scientist.' Using evidence from at least three different paragraphs, explain what the plant and the scientist do the same way, and why doing it that way leads to a reliable identification.

Answer: Sample response: Both test several properties rather than one and compare the results with what is known. The plant uses density in the water tank (paragraph 3), the infrared fingerprint (paragraph 5) and solubility in the lab (paragraph 6), and the passage says 'no single test is trusted alone' because each catches what the others miss (paragraph 7). The PET and PVC case (paragraph 4) shows why: two substances can share one property, so a second property is needed. A scientist does the same, comparing several measured properties against a table of known substances until only one answer fits. Relying on several identifying properties is reliable because it is very unlikely that two different substances match on all of them.

Why: Full credit requires evidence from three paragraphs, the 'several properties, compared with known values' idea, and a reason why the approach is reliable.

Also acceptable: A student who argues that the plant is less careful than a scientist because it still throws away black plastic is making a thoughtful point; accept it if the three citations and the reliability reasoning are present.

- Evidence from at least three different paragraphs, cited
- States that several properties are tested and compared with known substances
- Explains why using several properties is more reliable than one

Teacher notes

The passage is about 700 words. Its facts are real: resin identification codes were introduced in 1988 by the Society of the Plastics Industry; approximate densities are PET 1.38, PVC 1.38 to 1.41, polystyrene 1.05, high-density polyethylene 0.95, polypropylene 0.90 g/cm³; float-sink tanks and near-infrared sorters are standard equipment; carbon-black plastics defeat near-infrared sorting; PVC decomposes with hydrogen chloride release well below PET's melting temperature, which is why PVC contamination of PET streams is a known problem. The 'strong solvents' in paragraph 6 are not named on purpose; do not have students test plastics in solvents. The q3 calculation rearranges density = mass ÷ volume into mass = density × volume; some students will divide instead, so check the work. Extension solution: the water tank and the solubility test both still work on black flakes because density and solubility belong to the substance and are not changed by the pigment (paragraphs 3, 6 and 7); black PET (1.38 g/cm³) sinks while black polypropylene (0.90) floats, so the water tank alone separates that mix; black PET and black PVC overlap in density and cannot be read by the light sorter, so the memo should send that pair to the lab solubility test or keep it out of the PET stream.

Scaffold offered to students: A property tracker

Before answering, make a four-row chart on scrap paper with the headings Property, Which paragraph, What it tells apart, and Where it fails. Fill one row each for density, melting behavior, the infrared fingerprint and solubility. Questions 3 through 8 can all be answered from your chart plus one quotation.

Extension: Rescue the black tray

Paragraph 5 says black plastic defeats the light sorter, so black trays are often thrown away. Write a short memo to the plant manager that answers three questions with evidence from the passage: Which of the plant's other tests still work on a black flake, and why does color not affect them? If the black flakes are a mix of PET and polypropylene, which single test would separate them completely? Which pair of black plastics would still be impossible to separate with those tests, and what would you tell the manager to do with that pair?