

From Willow Bark to a White Powder: Proving Something New Was Made

Learning target: I can explain, with evidence from a passage, how chemists use measured properties such as melting point and solubility to prove that a reaction made a new substance, and how doctors judged competing medicines against criteria.

Reading with evidence

About 35 min

Individual

MS-PS1-2 · practice

MS-ETS1-2 · supports

MS-PS1-3 · supports

reading

writing

Standards connections

MS-PS1-2 (practice, the reasoning behind before-and-after property comparisons): The passage shows why a changed melting point or solubility is evidence that a new substance formed and why one changed property is weaker than several. Students practice the reasoning the PE assesses, using reference values rather than a dataset of their own.

MS-ETS1-2 (supports): The passage describes doctors judging salicylic acid and aspirin against the same criteria (reduce fever and pain, cause little harm). It is background for the lesson's engineering strand, not a design evaluation by the student.

MS-PS1-3 (supports): Aspirin is a synthetic material whose story begins with a natural resource, willow bark, changed by chemical processes. The passage gives qualitative background for this Grade 7 PE without asking students to gather information themselves.

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

Answers with reasoning

From Willow Bark to a White Powder

[1] For thousands of years, people chewed willow bark or brewed it into a tea when they had a fever or aching joints. But nobody knew which substance in the bark was doing the work, or how to make more of it. In the early 1800s, chemists in Europe set out to find it. They could boil, filter, evaporate and crystallize, and they could measure a few properties of whatever they ended up with. What they could not do was see a single atom or molecule.

[2] By the late 1820s, chemists had separated a bitter white substance from willow bark and named it salicin. In 1838 an Italian chemist, Raffaele Piria, treated salicin with other chemicals and obtained a different white powder, which he called salicylic acid. Was it truly a new substance, or just salicin cleaned up? A powder's appearance cannot answer that question, because thousands of different substances are white powders. The answer comes from what chemists still do today: measure properties that every pure substance has in its own characteristic amount. Salicylic acid dissolved in water in a different amount than salicin did, and it melted at a different temperature. Different characteristic properties mean a different substance.

[3] Salicylic acid turned out to lower fever and ease pain. Doctors tried it on patients and judged it against two criteria: did it reduce fever and pain, and did it cause harm? It passed the first test but stumbled on the second. It was hard on the stomach, and some patients could not keep taking it. By 1859 a German chemist, Hermann Kolbe, had worked out how to make salicylic acid from cheaper starting chemicals, without any willow bark, and within fifteen years factories were producing it. The supply problem was solved. The side-effect problem was not.

[4] A French chemist, Charles Gerhardt, had already made a related substance in 1853 by reacting salicylic acid with another chemical, but his product was impure and he did not pursue it. In 1897 a chemist at the Bayer company in Germany, Felix Hoffmann, produced a pure form of that substance, acetylsalicylic acid. How could he know his white powder was not just salicylic acid again? The two look identical. Reference values show the difference: salicylic acid melts at about 159 °C, while acetylsalicylic acid melts at about 135 °C, and the two dissolve in water in different amounts. A melting point roughly 24 degrees lower is far more than any error in reading a thermometer.

[5] One changed property is a clue; several that agree make a case. Chemists also know that a lower melting point can come from an impure sample, because impurities make a solid begin melting early and over a wider range of temperatures. A pure substance melts within a degree or two of one temperature. So a careful chemist checks that the new powder melts sharply, at a temperature that stays the same after the powder is purified again, and that a second property, such as solubility, has also changed. Only then is the conclusion earned: a chemical reaction has turned one substance into another.

[6] Bayer began selling acetylsalicylic acid in 1899 under the name Aspirin. Doctors tested it on patients and compared the results with salicylic acid. It lowered fever and pain about as well, and patients tolerated it better. Judged against the same two criteria, the new design was the better solution, and within about twenty years it was one of the most widely used medicines in the world.

[7] The story does not end with a perfect medicine. Aspirin can still irritate the stomach, and today it is not usually given to children and teenagers for fevers because of a rare but serious illness it can trigger. Modern clinical trials are also far more careful than the patient tests of the 1890s: they compare a new medicine with an existing one and are reviewed for safety before they begin. What has not changed is the chemist's basic question. When a flask of one substance becomes a jar of white powder, the only way to know that something new was made is to measure its properties and compare them with what you started with.

Questions: cite the passage

1. According to paragraph 1, what could chemists in the early 1800s **do** to a sample, and what could they **not** do? Why does that matter for the rest of the passage?

Answer: They could boil, filter, evaporate and crystallize samples, and measure a few properties. They could not see a single atom or molecule. It matters because every later conclusion about a 'new substance' had to rest on measured properties, not on looking at the particles.

Why: Paragraph 1 sets up the whole argument: properties are the window when particles are invisible.

Also acceptable: Accept 'they could measure properties but not see atoms' with the connection stated.

- Lists at least two things they could do and the one thing they could not
- Connects it to relying on measured properties

2. Paragraph 2 says a powder's appearance cannot tell you whether it is a new substance. Quote the reason, then name the two properties that settled the question.

Answer: Reason (quoted or close): 'thousands of different substances are white powders.' The two properties: how much dissolved in water (solubility) and the melting temperature (melting point).

Why: Appearance is shared by many substances; solubility and melting point are characteristic.

Also acceptable: Accept 'how much dissolves' and 'what temperature it melts at.'

- Quotes or paraphrases the 'thousands of white powders' reason
- Names solubility and melting point

3. Using the melting points in paragraph 4, calculate how much lower acetylsalicylic acid melts than salicylic acid. Then, using paragraph 5, explain whether that difference could be a thermometer-reading error.

Answer: $159^{\circ}\text{C} - 135^{\circ}\text{C} = 24^{\circ}\text{C}$ lower. It cannot be a reading error: paragraph 5 says a pure substance melts within a degree or two of one temperature, and paragraph 4 says 24 degrees is far more than any error in reading a thermometer. A difference ten times bigger than the normal spread is a real difference.

Why: The subtraction is simple; the judgment compares 24 degrees with the 'degree or two' uncertainty.

Also acceptable: Accept 'about 24 °C' and an answer that compares the difference with 'a degree or two.'

4. Paragraph 3 names two criteria doctors used. State both, and say which one salicylic acid failed, citing the words that tell you.

Answer: Criteria: (1) reduce fever and pain, (2) cause little or no harm. Salicylic acid failed the second: 'It was hard on the stomach, and some patients could not keep taking it.'

Why: The paragraph states both criteria and the stomach side effect.

Also acceptable: Accept 'did it cause harm' phrased as 'side effects.'

- Both criteria
- Identifies the harm criterion as the failure with the stomach evidence

5. Paragraph 5 says a lower melting point is only a clue. Explain why, and describe the **two** extra checks a careful chemist makes before concluding that a reaction produced a new substance.

Answer: A lower melting point alone is only a clue because an impure sample also melts lower and over a wider range, so the powder could be the old substance with something mixed in. Check 1: the new powder should melt sharply (within a degree or two) and at a temperature that does not change after it is purified again. Check 2: a second property, such as solubility, should also differ from the starting substance. When both checks pass, the conclusion that a reaction made a new substance is earned.

Why: This corrects the textbook's jump from one lower melting point to 'a new substance.' Both checks must be present.

Also acceptable: Accept 'repeat the melting point after purifying' as check 1.

- Explains the impurity problem (lower and wider melting)
- Check: sharp melting point that survives re-purification
- Check: a second property also differs

6. Kolbe's work in paragraph 3 solved one problem and left another. Name both problems, and explain why a cheaper way to make the same substance could not fix the second one.

Answer: Solved: the supply problem; salicylic acid could be made from cheaper chemicals without willow bark. Not solved: the side-effect problem (stomach harm). A cheaper way to make the same substance gives the same substance with the same properties, including the property of being hard on the stomach; only a different substance could behave differently.

Why: The point is that properties belong to the substance, not to how it was made.

Also acceptable: Accept 'making it cheaper does not change what it is.'

- Names supply as solved and side effects as unsolved
- Explains that the same substance has the same properties regardless of source

7. Using paragraphs 6 and 7, explain why aspirin was judged the **better** solution and why the passage says it was still not a **perfect** one.

Answer: Better: judged against the same two criteria, aspirin lowered fever and pain about as well and patients tolerated it better (paragraph 6). Not perfect: it can still irritate the stomach and is not usually given to children and teenagers because of a rare serious illness it can trigger (paragraph 7).

Why: Students should see 'better' as relative to criteria and 'perfect' as unreachable.

Also acceptable: Accept the modern-trials point as extra, not as a substitute for the drawbacks.

- Cites criteria-based comparison from paragraph 6
- Cites a remaining drawback from paragraph 7

8. Do you agree with this claim: "A chemist can prove that a new substance formed without ever seeing an atom"? Support your answer with evidence from at least two different paragraphs.

Answer: Agree. Paragraph 1 says chemists could not see atoms but could measure properties. Paragraph 2 says salicylic acid dissolved in a different amount and melted at a different temperature than salicin, which showed it was a different substance. Paragraph 4 gives the numbers for aspirin versus salicylic acid (135 °C versus 159 °C), and paragraph 5 explains the checks that make such a measurement convincing (a sharp melting point that survives purification, plus a second property). Properties identify substances, so comparing properties before and after is proof enough without seeing any atoms.

Why: Full credit needs a position, evidence from at least two paragraphs, and the idea that characteristic properties identify substances. A student who disagrees must still use passage evidence accurately; for example, arguing that properties give strong evidence but that 'proof' needs the extra checks of paragraph 5 is a thoughtful answer.

Also acceptable: A partial-agreement answer that stresses the checks in paragraph 5 is strong.

- Clear position
- Evidence from two or more paragraphs with paragraph numbers
- Reasoning links characteristic properties to identifying substances

Teacher notes

The passage is 694 words long. Its history is deliberately more careful than the textbook's: salicin was isolated in the late 1820s (not 1826), Piria made salicylic acid in 1838, Gerhardt made impure acetylsalicylic acid in 1853, Hoffmann made the pure form at Bayer in 1897, and Bayer began selling Aspirin in 1899; the passage does not say who patented what, because sources disagree. Melting points are reference values (salicylic acid about 158-159 °C; acetylsalicylic acid about 135 °C); the textbook's own example uses 159 °C and 136 °C. Paragraph 7's point that aspirin is not routinely given to children and teenagers refers to Reye's syndrome; keep the discussion to 'medicines are judged against criteria, and none is perfect' and give no dosing advice. The patient tests of the 1890s were not clinical trials in the modern sense, which paragraph 7 states.

Scaffold offered to students: Mark the numbers first

Before answering, list every number in the passage on scrap paper with its paragraph: late 1820s (2), 1838 (2), 1853 (4), 1859 (3), 1897 (4), 1899 (6), 159 °C (4), 135 °C (4), 24 degrees (4), 'a degree or two' (5), 'about twenty years' (6). Questions 3, 5 and 8 can be answered by finding the right number and rereading the sentences around it.

Extension: A third check

Reference values: salicylic acid dissolves about 0.22 g per 100 mL of water at 25 °C; acetylsalicylic acid dissolves about 0.33 g per 100 mL at the same temperature. Calculate how many grams of each would dissolve in 2 liters of water at 25 °C, then write a paragraph explaining why a solubility test must be done at the same temperature for both powders and what could go wrong if one beaker were warmer than the other.