

Stockings, Tires and a War: How Synthetic Materials Took Over

Learning target: I can use evidence from a passage to describe where four synthetic materials came from, what problems they solved for society, and what new problems they created.

Reading with evidence

About 40 min

Individual

MS-PS1-3 · assesses

reading

writing

Standards connections

MS-PS1-3 (assesses, gathering information from a text and describing, in words, that synthetic materials come from natural resources and affect society): The passage traces Bakelite, nylon, synthetic rubber and PET back to coal tar and petroleum and describes their effects on daily life, wartime supply and waste. Students answer by citing the text, which is qualitative information-gathering and sense-making as the PE and its assessment boundary describe.

Purpose: build · **Time:** about 40 minutes · **Format:** individual

Answers with reasoning

Stockings, Tires and a War

[1] Until the early 1900s, nearly everything a person wore, built with or rode on came from a plant, an animal or a mine and was used much as nature made it. That changed in 1907. Leo Baekeland, a Belgian-born chemist working in New York, heated phenol, a substance from coal tar, with formaldehyde under pressure. The reaction produced a hard, dark resin that could be molded while hot and then never melted again. He named it Bakelite. Because it did not conduct electricity and did not soften in a warm room, it became the material of radio cases, telephone handsets and light switches.

[2] The next leap came at DuPont, where a team led by Wallace Carothers was studying how small molecules could be linked end to end into enormous chains. In 1935 they made nylon, a polymer that could be drawn into a strong, thin thread. Its building blocks came, through several chemical steps, from coal tar at first and later from petroleum. DuPont announced nylon publicly in October 1938; the first product sold that year was a toothbrush with nylon bristles. Nylon stockings went on sale across the United States in May 1940 and sold out quickly.

[3] Why the rush? Silk stockings snagged and tore easily, and the silk came from silkworms raised mostly in Japan, across an ocean. Nylon stockings were stronger and dried quickly. The trade-off was invisible at the time: the new material came from a resource that cannot be regrown, and a nylon stocking thrown away does not rot the way a silk one does. When the United States entered World War II in December 1941, almost all nylon went to parachutes, ropes and tire cords, and stockings vanished from stores.

[4] Rubber was the greater emergency. Natural rubber is made from latex, the sap of a tree grown on plantations in Southeast Asia. Early in 1942 Japanese forces took control of that region, and the United States lost access to roughly nine tenths of its rubber supply, with only about a year's worth stockpiled.

Chemists already knew that two small molecules, styrene and butadiene, could be joined into long, springy chains that behaved like rubber. Within three years, dozens of new factories were making synthetic rubber from petroleum and grain alcohol, hundreds of thousands of tons a year.

[5] The two wartime substitutes had different fates. During the First World War, sugar had been scarce and many people switched to the synthetic sweetener saccharin, but when sugar returned, most switched back. Synthetic rubber did not go away. It could be made at home, its properties could be adjusted for different jobs, and the factories already existed. Today more than half of the rubber used in the world is synthetic. Natural rubber has not disappeared, though: it stays strong when it is flexed and heated over and over, which is why aircraft tires are still made mostly from the tree-grown kind.

[6] In 1941 two British chemists, John Whinfield and James Dickson, linked two building blocks, today made from petroleum, into a polymer called PET. Spun into fiber in the 1950s, it made shirts that resisted wrinkles. In 1973 a DuPont engineer, Nathaniel Wyeth, patented a way to blow PET into a bottle strong enough to hold the pressure of a fizzy drink, and by the late 1970s soft drinks came in clear, light, shatterproof PET bottles.

[7] Every one of these materials solved a real problem, and every one created a new problem that nobody set out to make. Bakelite cannot be remelted, so it is very hard to recycle. Nylon and polyester do not rot, so a shirt can last for decades or longer in a landfill. Washing polyester sheds tiny fibers into wastewater. Of the PET bottles thrown away in the United States in 2018, fewer than a third, about 29 percent, were collected for recycling. Engineers are now working on the second round of problems: plastics that break down, fibers that shed less, bottles that are easier to collect. The lesson is not that natural materials are good and synthetic ones are bad. It is that every material has a source and an ending, and a fair judgment has to look at both.

Questions: cite the passage

1. According to paragraph 1, what two substances did Bakelite start from, which natural resource did one of them come from, and what did the chemical reaction do to them? Give the paragraph number.

Answer: Bakelite started from phenol, which came from coal tar, and formaldehyde. Heating them together under pressure caused a reaction that produced a hard, dark resin that could be molded while hot and then would not melt again (paragraph 1).

Why: The point is the chain: natural resource (coal tar), chemical reaction (heat and pressure joining phenol and formaldehyde), new material with new properties. Formaldehyde's own source is not named in the passage, so students need only phenol's.

Also acceptable: Accept 'coal tar and formaldehyde' as the two starting substances.

- Names phenol (from coal tar) and formaldehyde
- States that a reaction turned them into a new hard material
- Cites paragraph 1

2. Paragraph 1 names two properties of Bakelite that made it useful in electrical products. Write both properties and explain why each one mattered for a light switch or a radio case.

Answer: It did not conduct electricity, so a switch or socket made of it would not shock the person touching it. It did not soften in a warm room, so a radio case or handset would hold its shape next to warm electrical parts (paragraph 1).

Why: Both properties are stated in paragraph 1; the question asks students to connect a property to a function, which is the structure-and-function thread of the chapter.

Also acceptable: Accept 'it could be molded into any shape' as a third property if the two required ones are also present.

- Both properties named
- Each property connected to a use

3. Trace nylon backward using paragraph 2: what did the chemists do to small molecules, and what natural resources did those small molecules come from?

Answer: The chemists linked small molecules end to end into very long chains, which is what makes nylon a polymer. The small molecules were made, through several chemical steps, from coal tar at first and later from petroleum (paragraph 2).

Why: This is the resource-to-material trace. Students should name both the chain-building step and the two resources.

Also acceptable: Accept 'coal' for coal tar.

- Says small molecules were joined into long chains
- Names coal tar and petroleum as the sources

4. Paragraph 3 gives benefits of nylon stockings and a trade-off that was 'invisible at the time.' List two benefits and the two parts of the trade-off, each with a quote or close paraphrase. Then explain in your own words why people in 1940 might not have noticed the costs.

Answer: Benefits: nylon stockings 'were stronger and dried quickly,' and they did not depend on silk from silkworms raised mostly in Japan (paragraph 3). Trade-off: the material 'came from a resource that cannot be regrown' and 'a nylon stocking thrown away does not rot' (paragraph 3). People in 1940 did not notice because the benefits were immediate and personal (durability, quick drying, availability) while the costs show up years later, in landfills and oil fields far from the shopper, and at that time nobody expected petroleum to run short or stockings to pile up.

Why: Full credit requires both halves of the trade-off and an explanation that costs are delayed or displaced. This previews the chapter's claim that benefits are visible now and costs come later.

Also acceptable: A student who adds that the war made supply, not waste, the urgent problem is reasoning well.

- Two benefits with quotes or close paraphrase
- Both parts of the trade-off (nonrenewable source, does not rot)
- An explanation of why the costs were invisible

5. Using paragraph 4, explain why the loss of Southeast Asia in 1942 forced the United States to make synthetic rubber rather than simply buying natural rubber somewhere else.

Answer: Natural rubber comes from trees grown on plantations in Southeast Asia, and that region supplied roughly nine tenths of what the United States used. Once Japanese forces controlled it, there was no other place growing enough rubber trees to replace it, and the stockpile would last only about a year, so the only fast option was to make synthetic rubber from resources the country already had: petroleum and grain alcohol (paragraph 4).

Why: The answer should connect the single geographic source of the natural resource to the need for a synthetic substitute.

Also acceptable: Accept an answer that says trees take years to grow, so new plantations elsewhere could not help in time.

- Notes that most natural rubber grew in one region
- Notes the stockpile limit or the war need
- Concludes that synthetic rubber made from resources at home was the available substitute

6. Paragraph 5 compares what happened to saccharin after World War I with what happened to synthetic rubber after World War II. State the difference, then give three reasons from the passage that explain why synthetic rubber stayed. Finally, quote the sentence that shows natural rubber still has an advantage.

Answer: Difference: after World War I people switched back from saccharin to sugar, but after World War II synthetic rubber stayed. Reasons: it could be made at home; its properties could be adjusted for different jobs; and the factories already existed. The sentence showing natural rubber's advantage: 'it stays strong when it is flexed and heated over and over, which is why aircraft tires are still made mostly from the tree-grown kind' (paragraph 5).

Why: All three reasons appear in one sentence of paragraph 5. The quote shows students that the passage does not treat synthetic as simply better.

Also acceptable: Accept 'more than half of the rubber used in the world is synthetic' as supporting evidence but not as one of the three reasons.

- States the saccharin-versus-rubber difference
- Three reasons from the passage
- Quotes or closely paraphrases the aircraft-tire sentence

7. Paragraph 7 says about 29 percent of PET bottles thrown away in the United States in 2018 were collected for recycling. If a city threw away 2,000,000 PET bottles that year and matched the national rate, how many bottles were collected for recycling and how many were not? Show your work.

Answer: Collected for recycling: $2,000,000 \times 0.29 = 580,000$ bottles. Not collected: $2,000,000 - 580,000 = 1,420,000$ bottles (or $2,000,000 \times 0.71 = 1,420,000$).

Why: Percent of a total, then the complement. The second number is larger than the first, which is the point the passage makes.

Also acceptable: Accept 580,000 and 1,420,000 with either method shown. If a student uses 'fewer than a third' and computes with $1/3$, accept about 667,000 and 1,333,000 with a note that 29 percent is the figure given.

8. The passage claims that 'every one of these materials solved a real problem, and every one created a new problem.' Choose two of the four materials (Bakelite, nylon, synthetic rubber, PET). For each, name the problem it solved and the problem it created, citing paragraph numbers. Then explain whether you agree with the passage's final sentence that a fair judgment 'has to look at both' the source and the ending of a material.

Answer: Sample: Bakelite solved the need for a moldable material that does not conduct electricity (paragraph 1) and created a material that cannot be remelted and is very hard to recycle (paragraph 7). Nylon solved the problem of fragile silk imported from across an ocean (paragraphs 2 and 3) and created a stocking that comes from a nonrenewable resource and never rots (paragraphs 3 and 7). Synthetic rubber solved the wartime loss of nine tenths of the rubber supply (paragraph 4) and created a material that depends partly on petroleum, a nonrenewable resource (paragraph 4). PET solved the need for a light, shatterproof bottle (paragraph 6) and created a bottle that mostly is not recycled, about 71 percent not collected for recycling (paragraph 7). Agreement: judging only by the source (natural or synthetic) or only by the ending (rots or does not) gives half the picture; silk rots but was scarce, nylon was plentiful but lasts for decades or longer, so a fair judgment needs both.

Why: Full credit requires two materials, a solved and a created problem for each with paragraph numbers, and a position on the final sentence with a reason. A student may disagree with the passage if the argument uses evidence from it.

Also acceptable: A student who argues the costs outweigh the benefits for one material and not another is giving a strong, balanced answer.

- Two materials chosen
- Problem solved and problem created for each, with paragraph numbers
- A clear position on the 'look at both' claim with a reason

Teacher notes

The passage is 698 words and all history is documented: Bakelite was patented by Leo Baekeland in 1907 from phenol and formaldehyde; nylon was first made by Wallace Carothers's DuPont team in 1935, announced publicly in October 1938, sold first in toothbrush bristles in 1938 and in stockings nationwide in May 1940; the United States lost access to about 90 percent of its natural rubber supply when Japan took Southeast Asia in early 1942, and the government program made styrene-butadiene rubber at hundreds of thousands of tons a year by 1944-45, with most of the 1943-44 butadiene made from grain alcohol and the rest from petroleum; PET was first made by Whinfield and Dickson in 1941 and the PET bottle was patented by Nathaniel Wyeth in 1973; the 29 percent PET bottle recycling figure for 2018 is from the U.S. EPA. Two claims are deliberately absent: early nylon stockings cost about what good silk ones did, so the passage does not call them cheaper, and it does not claim synthetic rubber was cheaper than natural rubber after the war. The saccharin-after-World-War-I story is the textbook's own example and is accurate. Keep the debrief balanced: paragraph 5 and paragraph 7 both show that synthetic is neither simply better nor simply worse. If students ask whether nylon is still made from coal, say that today nearly all of it starts from petroleum or natural gas.

Scaffold offered to students: A four-column chart

Before answering, draw a chart with four rows (Bakelite, nylon, synthetic rubber, PET) and four columns: the year it appeared, the natural resource it came from, the problem it solved, the problem it caused. Fill it in from your underlined dates and material names. Questions 1, 3, 5 and 8 can be answered almost directly from the chart; the rest ask you to add the reason behind an entry.

Extension: The third round

Paragraph 7 says engineers are working on 'the second round of problems.' Pick one of the three examples (plastics that break down, fibers that shed less, bottles that are easier to collect) and write a paragraph predicting what new problem that solution might create in turn. Base your prediction on the pattern in the passage: a material's benefits show up right away, and its costs show up later and often somewhere else. Then write one question you would want answered before calling the new solution a success.