Supplementary Material #3

21-item Multiple-choice Conceptual Chemistry Questionnaire

Research Article

"Enhancing Chemistry Understanding and Attitudes through an Outreach Education Program on Circular Plastic Economy: A Case Study with Thai Twelfth-Grade Students"

Authors

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Module 3:

Sustainable Polymer

The final module focused on the development of sustainable polymers, exploring biodegradable alternatives and the chemistry behind polymer degradation. Interactive experiments enabled students to comprehend the lifecycle of plastics, and the scientific advancements aimed at mitigating environmental impact.

Experiment #1:

Bioplastic Formulation

Plastic Pollution Overview

Thailand ranks 12th globally (4.8 million tons/year). Driven by food delivery and online shopping.

https://brandinside.asia/plastic-pollution/

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ประเภทพลาสติก	ปี 2562 (ตัน/วัน)	ปี 2563 (ตัน/วัน)	ปริมาณ (ตัน) ที่เพิ่มขึ้น เทียบกับปี62	ร้อยละที่เพิ่มขึ้น เทียบกับปี 62
ขยะพลาสติกรวม	2,120	3,440	1,320	62
ขยะพลาสติกรีไซเคิล	495	660	165	33
ขยะพลาสติกปนเปื้อน	1,630	2,780	1,150	71

https://brandinside.asia/plastic-pollution/

Discussion Questions

- What do you think about the increasing plastic waste?
- Do you think plastic waste management is important to the community?
- If we cannot avoid plastic, what are your proposed solutions?

Bioplastic Synthesis

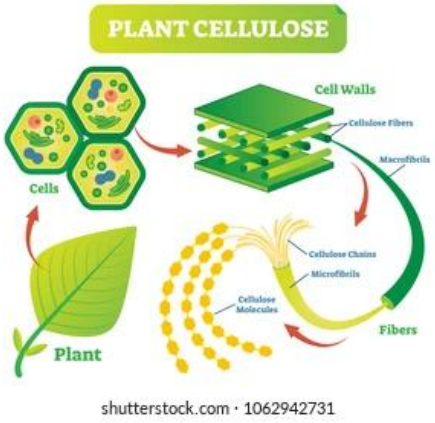
Bioplastic Synthesis: A Case of Thailand

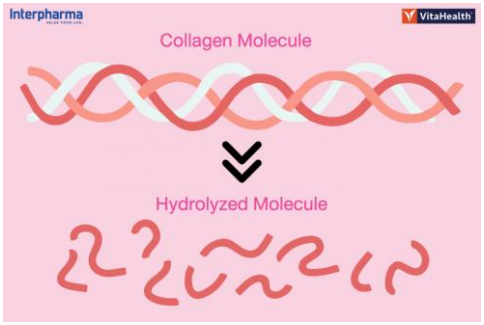
Start with an Open-ended Question:

How is bioplastic produced?

What is Bioplastic?

- Bioplastic refers to plastic made from natural materials, mostly plants, and is biodegradable in the environment.





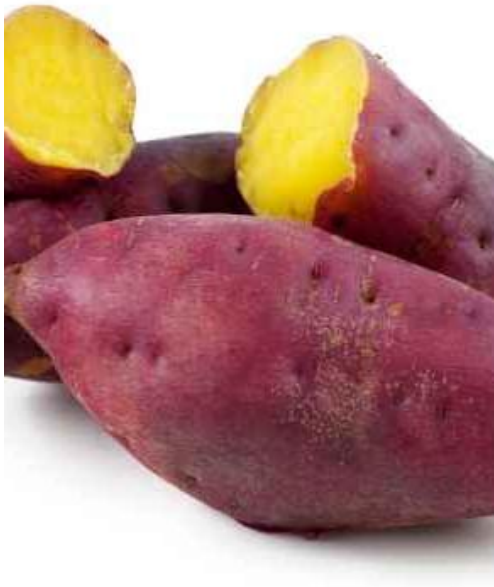
Natural Sources of Bioplastics

Examples include:

- Cellulose
- Collagen
- Starch
- Proteins from beans and corn

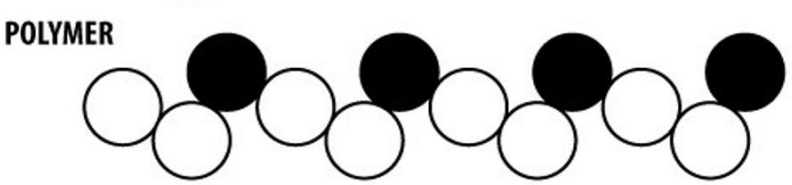
Why Use Starch?

Starch is ideal due to its abundance and low cost, derived from corn, wheat, potatoes, cassava, etc.



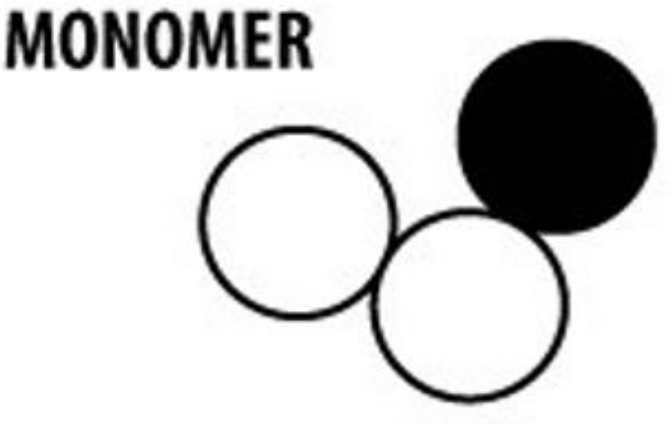
Limitations of Starch-Based Bioplastics

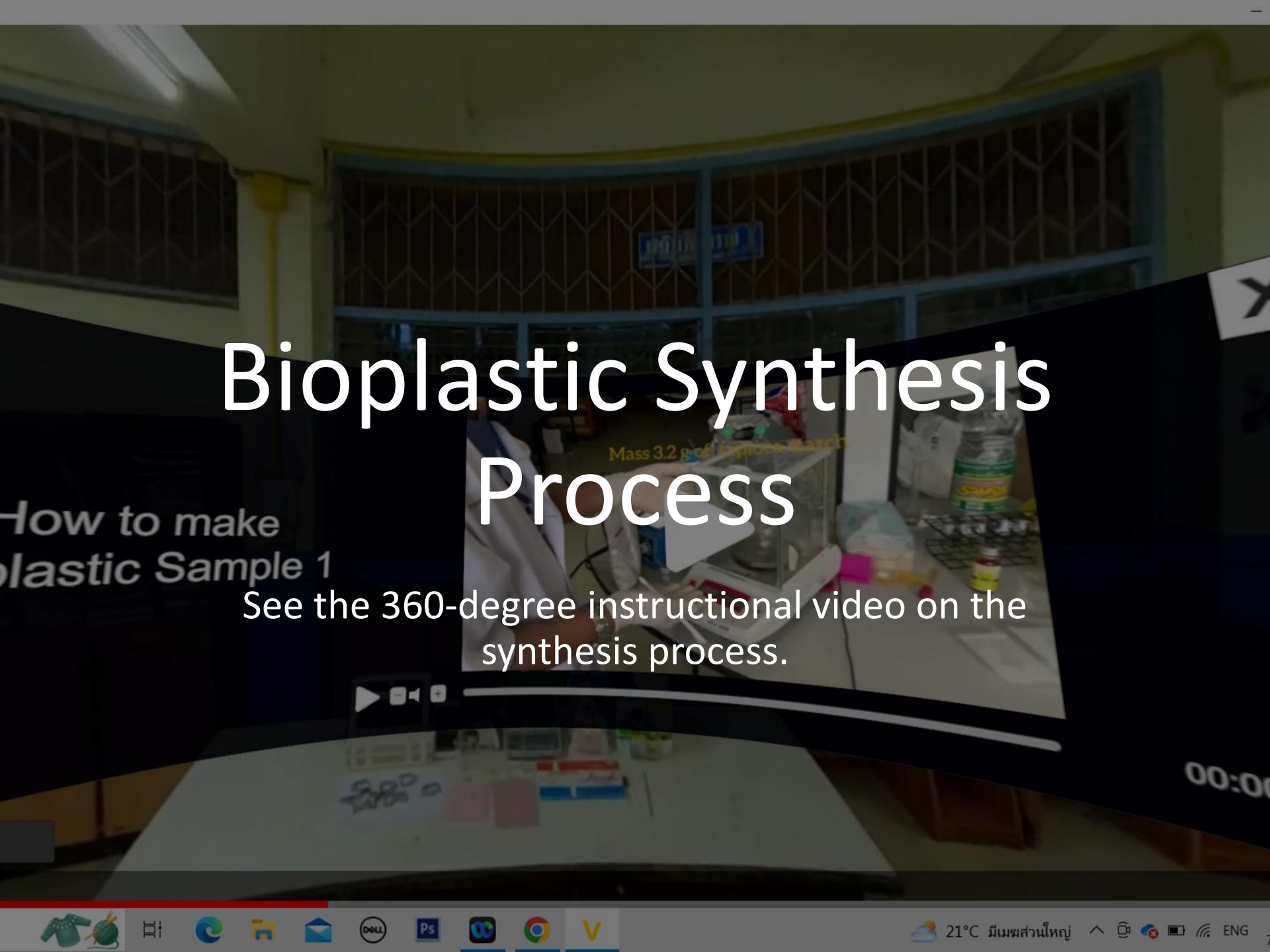
- They swell and deform under moisture. Solution: Use microbes to convert starch to lactic acid.



Lactic Acid to Polymer

Lactic acid (monomer) → Polymerization → Polylactic acid (PLA), a biodegradable polymer.





Bioplastic Synthesis Process

See the 360-degree instructional video on the synthesis process.

Equipment

- Equipment:
- 1. Two chemical spoons
- 2. Two 10 mL measuring cylinders
- 3. 150 mL beaker
- 4. Two stirring rods
- 5. Hotplate

Chemicals

- Chemicals:
- 1. Tapioca starch 3.2 g
- 2. Citric acid 0.5 g
- 3. Distilled water 10 mL
- 4. Vinegar 10 mL

Step 1: Weighing

Weigh 3.2 g of tapioca starch into a 150 mL beaker.

Add 0.5 g citric acid.

Step 2: Mixing

Add 10 mL distilled water and 10 mL vinegar.

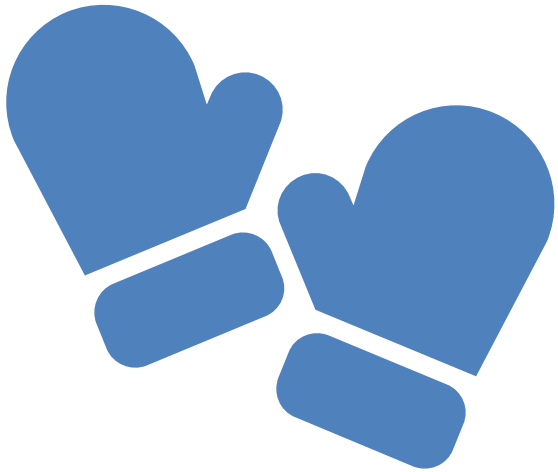
Stir the mixture thoroughly.

Step 3: Heating

5. Place the beaker on a hotplate at low heat (scale 1). Stir continuously (~10-15 mins).
6. Stir the mixture continuously until it starts to thicken (~10–15 minutes). Do not overheat, or the mixture will clump. If it does clump, remove it from the hot plate and stir until smooth.
7. Once thickened, remove the beaker from the hot plate.

Step 4: Coloring

8. Add 1 drop of yellow food coloring and stir until fully mixed.
9. Return the mixture to the **hot plate** and continue heating until the polymer becomes fully translucent (~30 minutes).
10. Pour into molds and let set for 48–72 hours.



Record Your Observations

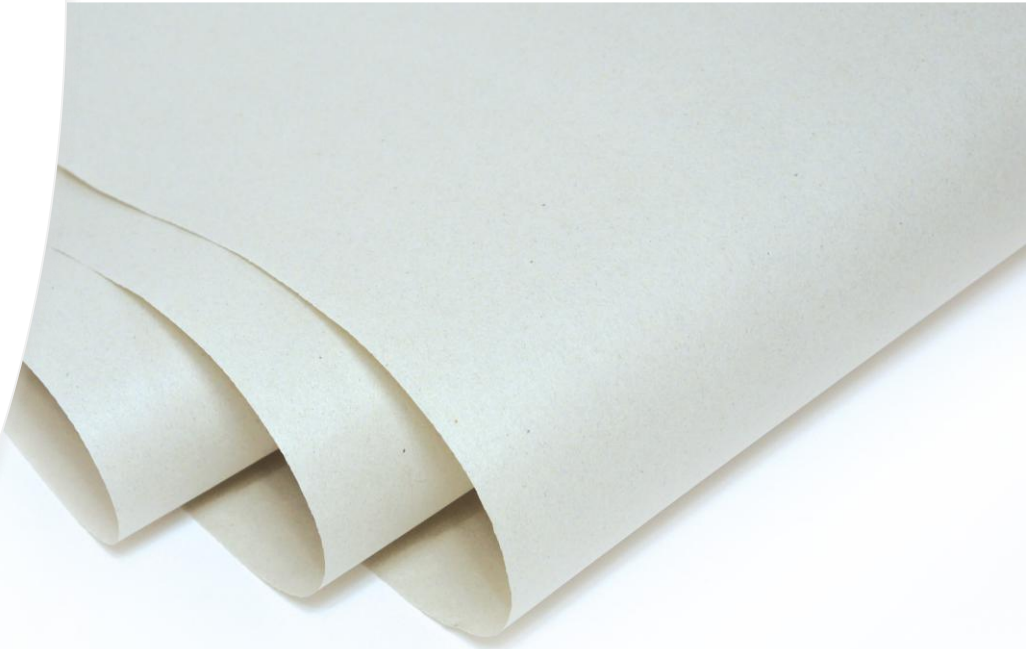
- .....
- .....

Conclusion

- Summarize the outcome of the experiment:
- .....

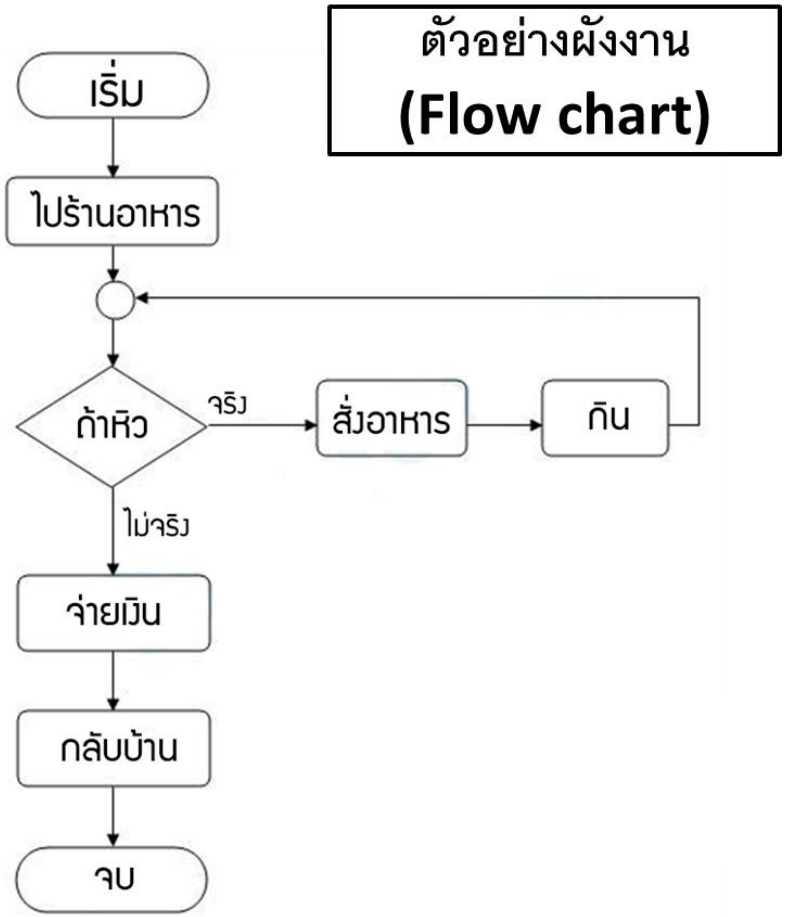
Reflection Activity

Brainstorm ideas on paper using blue or black pen.



Flowchart Task

- Create a flowchart showing the bioplastic synthesis process.
- Example shown as follows.



Conclusion from the Main Question

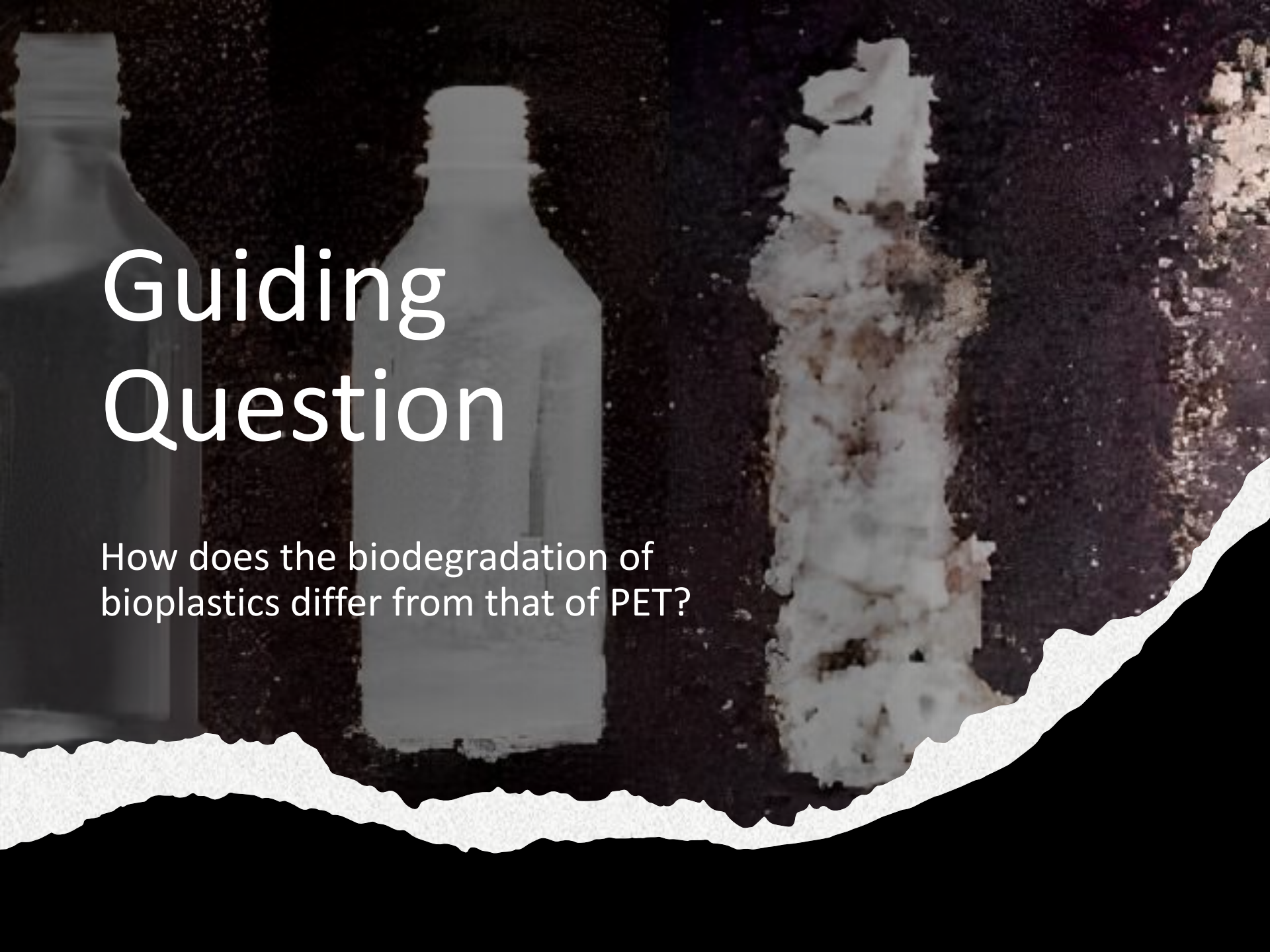
- Summarize your learning based on the initial question:
- .....

Experiment #2:

Biodegradation of Bioplastics

Topic Introduction

- Biodegradation of Bioplastics



Guiding Question

How does the biodegradation of bioplastics differ from that of PET?

Concept of Biodegradable Plastics

- Biodegradable plastics can be decomposed by natural microorganisms, ultimately breaking down into carbon dioxide, water, and biomass.

Conditions for Biodegradation

Occurs under specific conditions:

- Temperature: 50–60°C
- Relative Humidity: 50–60%
- Presence of natural microorganisms

Learning Resource

Watch the 360° video: Biodegradation of Bioplastics

Equipment and Chemicals

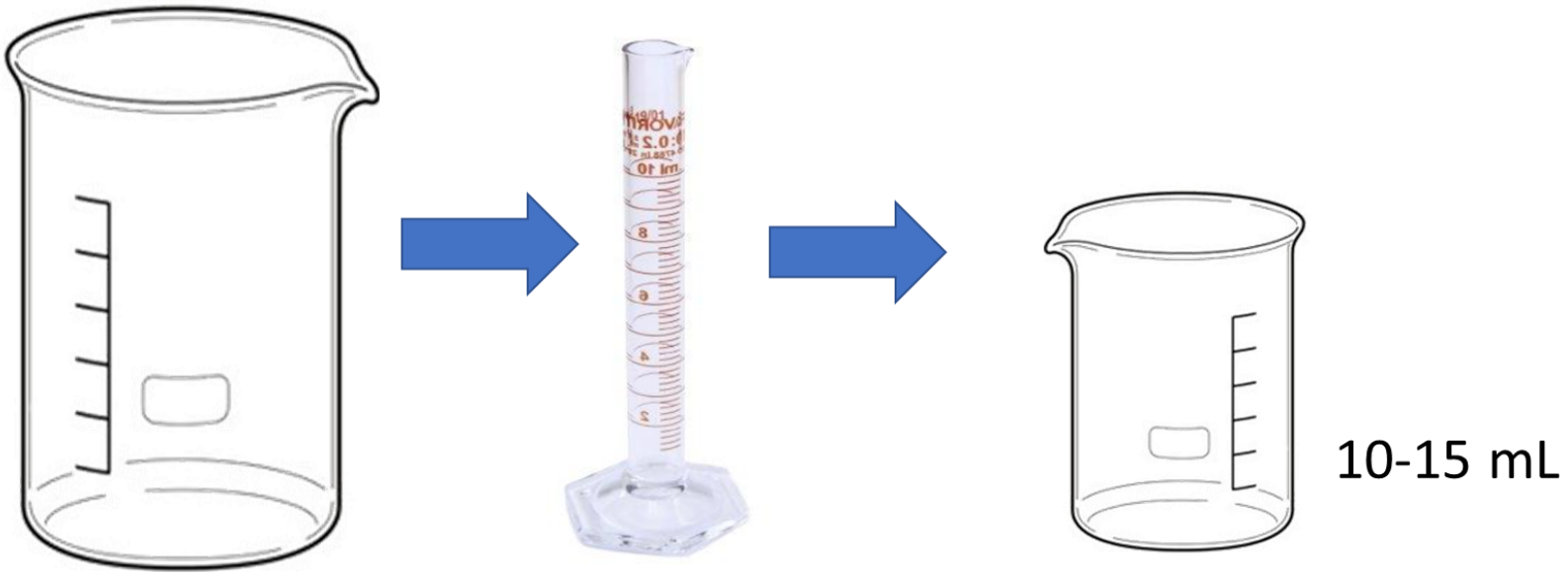
- Equipment: Test tube rack, 100/150 mL beakers, two 10 mL cylinders, four small test tubes, two stirring rods, scale
- Chemical: 1.0 M NaOH solution

Experiment Part 1: PET Degradation (Step 1)

Cut PET into ~0.5 g pieces and place in a small beaker.

Experiment Part 1: PET Degradation (Step 2)

- Add 10–15 mL of 1.0 M NaOH solution into the beaker.



Experiment Part 1: PET Degradation (Step 3-4)

- Let the sample sit for 1 hour while proceeding to other tasks.
- After 1 hour, observe and record the degradation result.

Experiment Part 2: Bioplastic Degradation (Step 1)

- Cut bioplastic samples (~0.1 g) into 3 pieces using scissors.
- Ensure each piece is uniform and weigh each one.

Experiment Part 2: Bioplastic Degradation (Step 2)

- Place one sample into each of the small test tubes.

Experiment Part 2: Bioplastic Degradation (Step 3)

- Add 3.5 mL of 1.0 M NaOH into each test tube.
- Stir each tube for 3 minutes using a glass rod.

Experiment Part 2: Bioplastic Degradation (Step 4)

- Use a smartphone lux meter to measure light intensity every 5 minutes.
- Record the results.

Record Your Observations

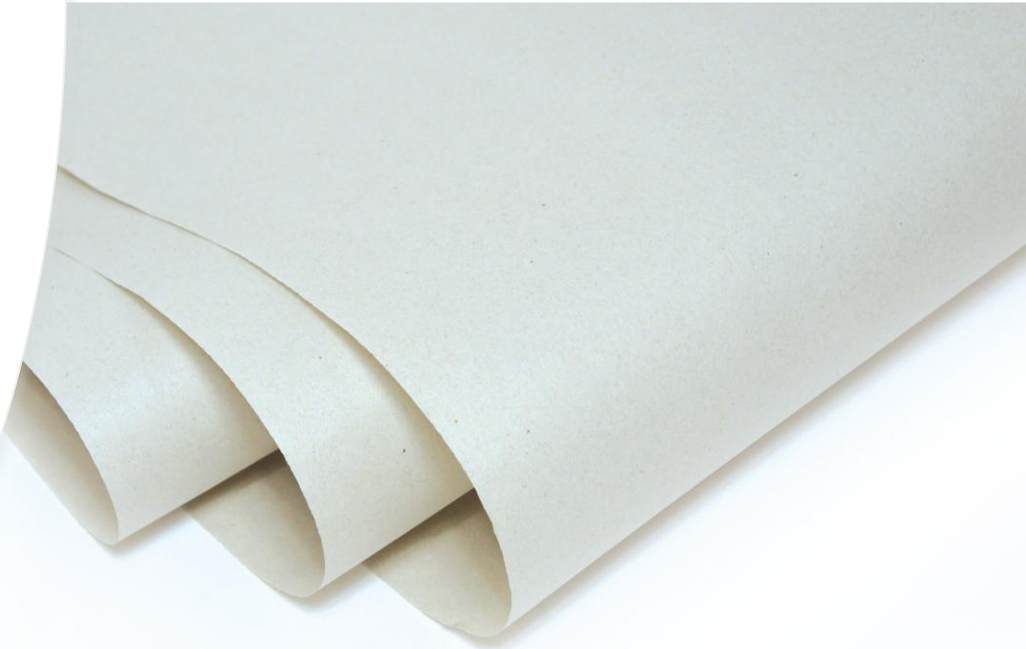
- .....
- .....

Conclusion

- Summarize the outcome of the experiment:
- .....

Reflection Activity

Brainstorm ideas on paper using blue or black pen.



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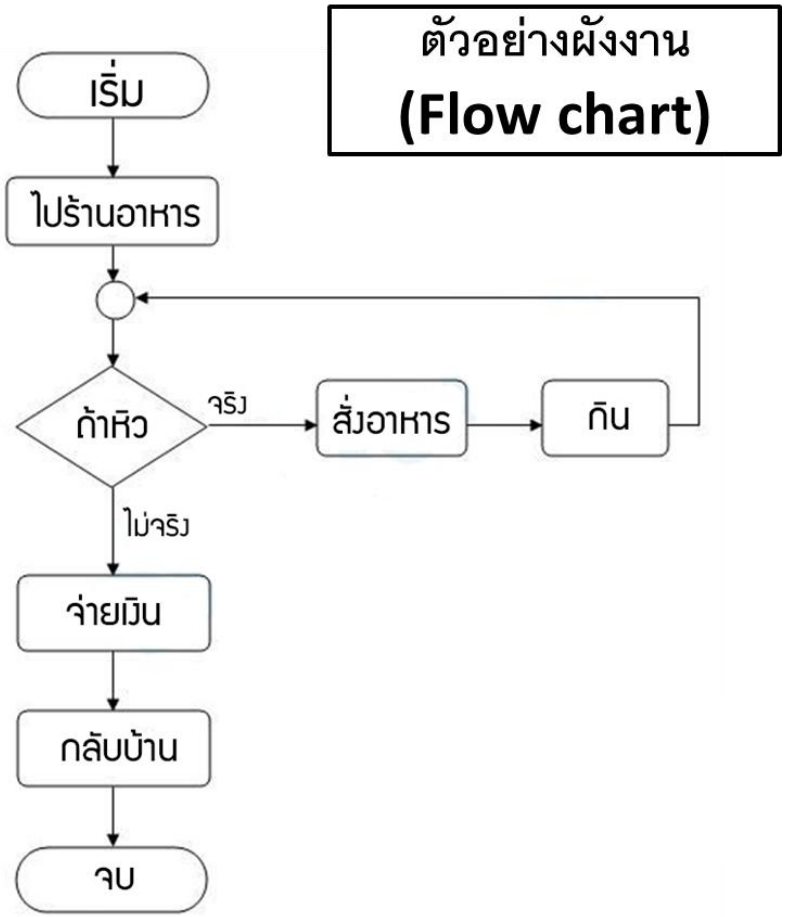


Conclusion from the Main Question

- Summarize your learning based on the initial question:
- .....

Experiment #3:

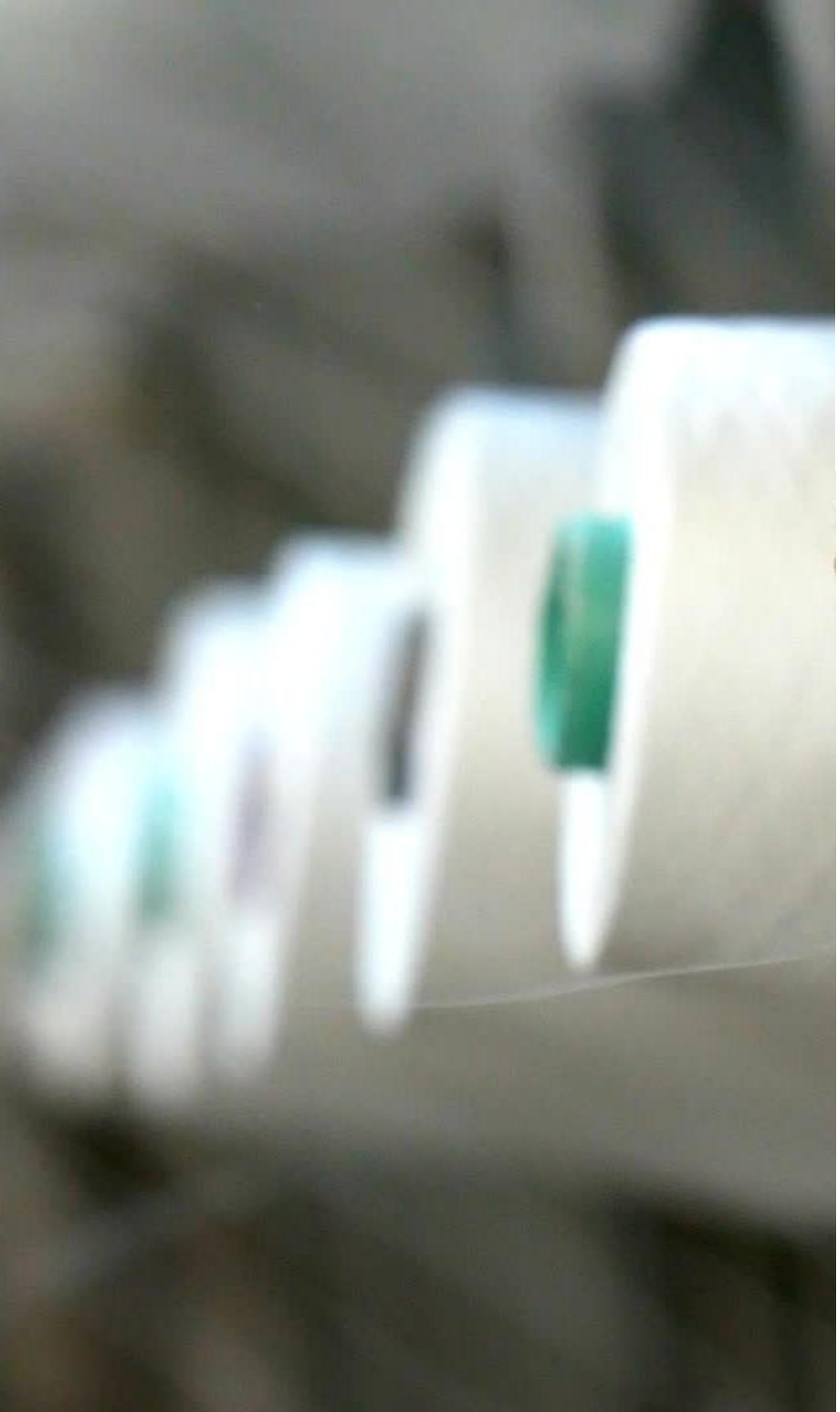
Polymer Classification

How Are Polymers Classified?

How Are Polymers Classified?

Start with an Open-ended Question:

What is the difference between thermoplastic and thermosetting polymers?

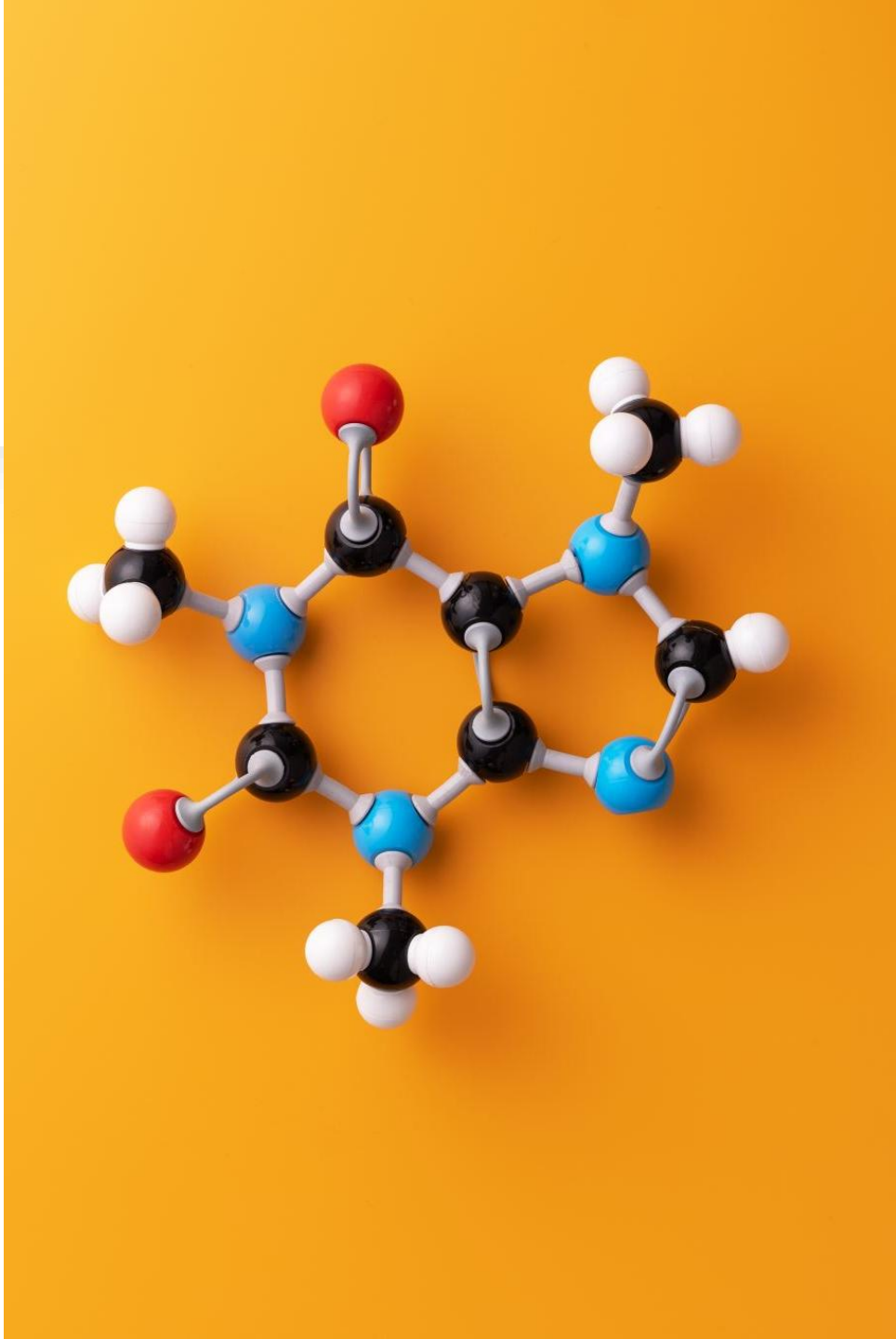


Thermoplastic Polymers

- Thermoplastics soften and melt when heated and harden when cooled.
- They can be remelted and reshaped multiple times.
- Thermoplastics are ideal for manufacturing various products.

Thermosetting Polymers

- Thermosets have a cross-linked molecular structure.
- They degrade when heated and cannot be remelted.
- Cross-linking restricts molecular movement, making reuse difficult.



Equipment

Thermal sensor, smartphone, spatula, pan handle, pot handle,

PET bottle, foam container, yogurt cup, plastic bag, beaker

Experimental Method (1)

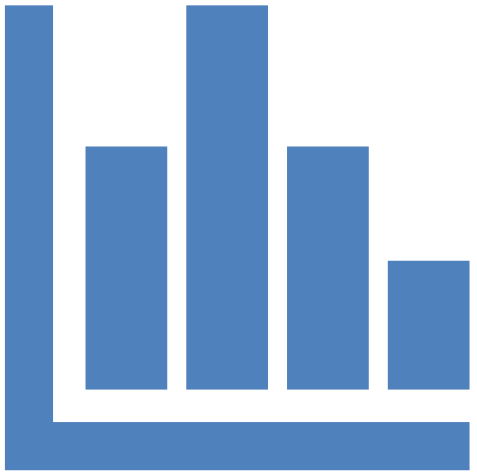
- 1. Download a thermal sensor app on a smartphone.
- 2. Connect the sensor to the phone (see Figures 1 and 2).

Experimental Method (2)

3. Use a gas torch to test the polymer samples provided.

4. Record your experimental results.

Experimental Method (3)



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- .....

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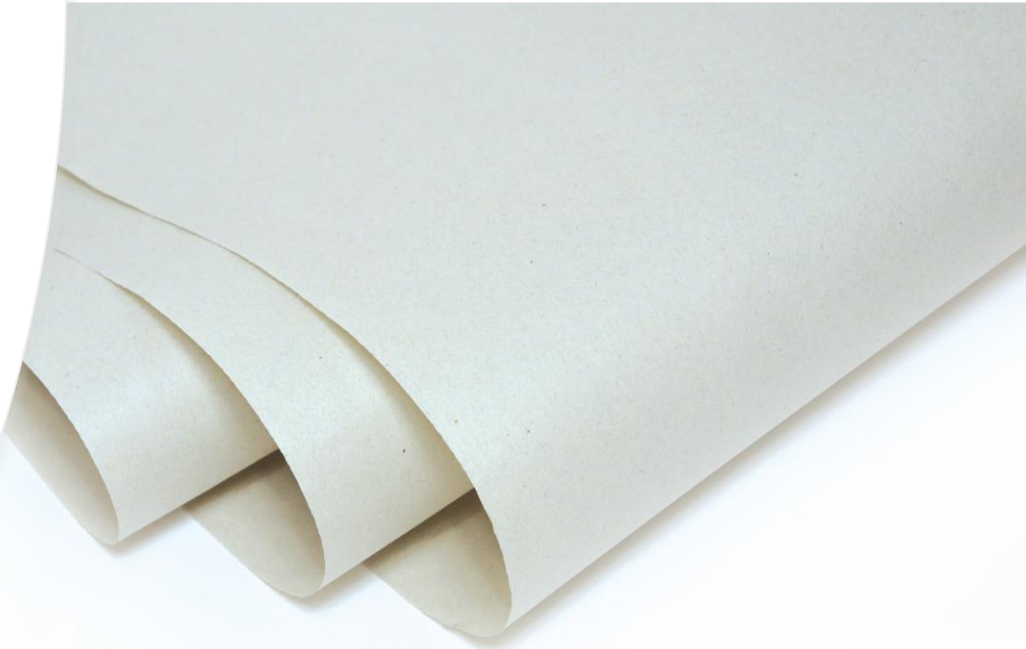

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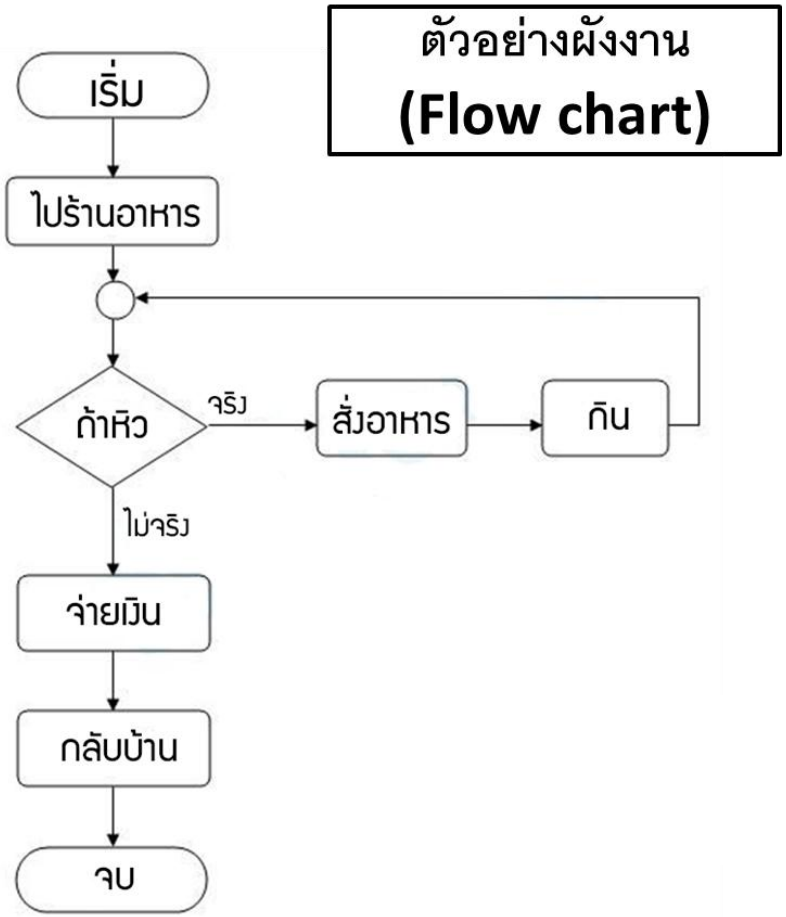

Conclusion from the Main Question

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