NYLON

OBJECTIVE:

You will understand how nylon is produced from chemicals and will make nylon thread and demonstrate its property of elasticity.

INTRODUCTION:

Nylon is a polymer, a substance made up of repeating chemical units linked together in a long chain. There are many polymers. Some are natural, such as the cellulose in plant fibers and the proteins in wool and silk; others are synthetic (manufactured from artificial materials). Nylon is the first truly synthetic fiber ever developed commercially.

By the 1920s the search was on for synthetic polymers that had special properties and could replace natural polymers. American chemist Wallace Carothers (1896–1937), working with colleagues at the Du Pont chemical company, had by the early 1930s developed several polymers that showed promise as alternatives to natural fibers. Among these were a semisynthetic fiber called rayon and an artificial silk called acetate. In 1935 Carothers' team produced a polymer with many useful properties that could be manufactured relatively quickly, cheaply, and easily. This polymer could be drawn out into fibers that were slightly elastic, resisted other chemicals, and had a tensile strength greater than that of steel. This was nylon, although it took several more years of development before it was mass produced and given that name. Nylon proved to be an amazingly versatile new material. It could be used as a single solid strand (a monofilament) for fishing lines and surgical stitches. Twisted into yarn, it could be used to make many new fabrics. It was rolled into fine transparent sheeting and used to insulate electric wires and to form bristles in brushes. Nylon is unusually resistant to damage. It resists stretching and rubbing and many chemicals, it does not rot easily, and it only burns or melts at relatively high temperatures.

Nylon was first manufactured to make women's stockings, for which it was in great demand and highly prized as superior to silk—from which they were previously made—for its stretchiness and ability to keep its shape. When the US entered World War II in late 1941, nylon production was soon diverted to meet military rather than civil needs. Nylon fabric made parachute canopies and nylon cord reinforced airplane tires, allowing heavier engines and therefore heavier loads of bombs.

Nowadays its uses range from forming the strong, smooth moving surfaces in artificial joints to reinforcing bulletproof vests. It is the first in a vast range of synthetic polymer fibers that have helped revolutionize much of our everyday working and domestic lives. Here you will make a simple nylon thread and test its elastic properties.

TIME NEEDED:

45 minutes

MATERIALS:

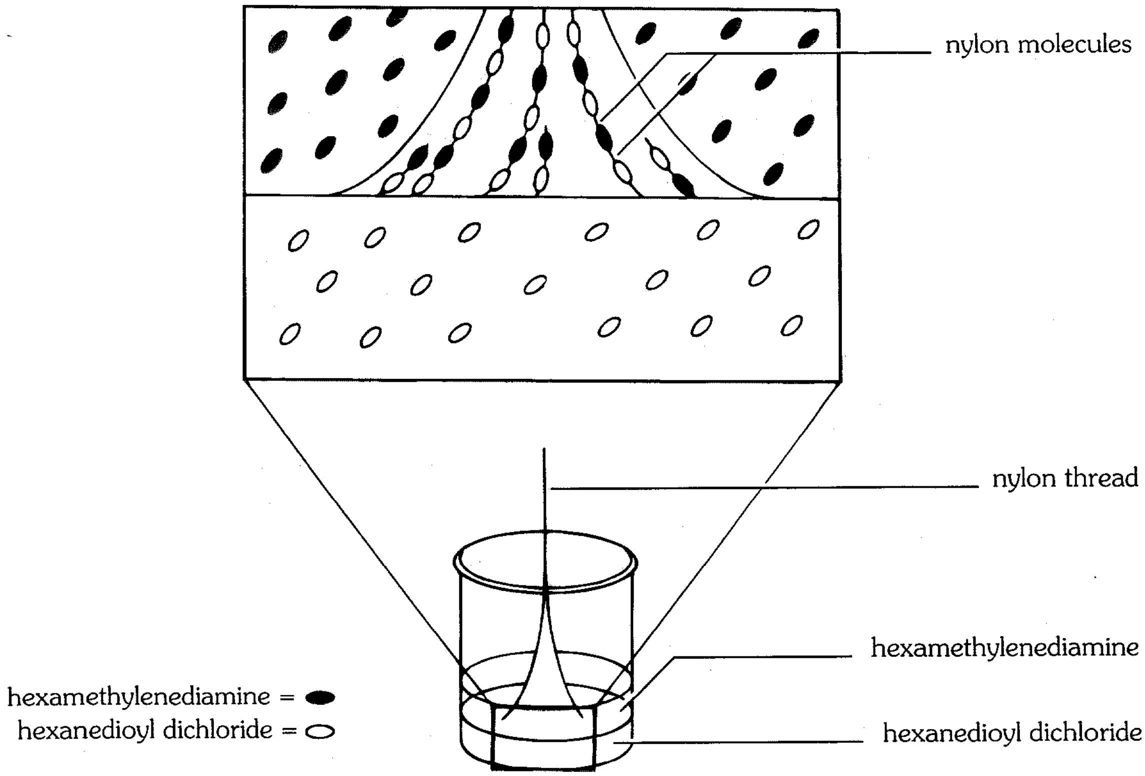
- solution A: in a 10ml measuring cylinder, a freshly prepared solution of 5 ml of sebacoyl chloride (decandioyl chloride) in cyclohexane at a concentration of 5 g in 100 ml solvent
- solution B: in a 10ml measuring cylinder, 5 ml hexamethylenediamine (hexane-1,6-diamine) in water at a concentration of 5 g in 100 ml solvent
- 10ml beaker
- 2 pairs of tweezers
- glass stirring rod 5 mm in diameter and at least 20cm long
- metric ruler
- protective plastic gloves
- safety goggles

Note: You will need a source of running water—e.g., a sink and faucet.

Original Materials:

Carothers used two chemicals—hexanedioyl dichloride and hexamethylenediamine—which reacted with one another to make nylon (see figure 1). You are using sebacoyl chloride instead of hexanedioyl dichloride, which is more expensive and less safe. In Carothers' experiments, the hexanedioyl dichloride sunk below the other chemical. In our investigation, the sebacoyl chloride floats above the other chemical. Figure 1 shows how in Carothers' experiments the two chemicals reacted together to form nylon.

Figure 1



Safety Precautions

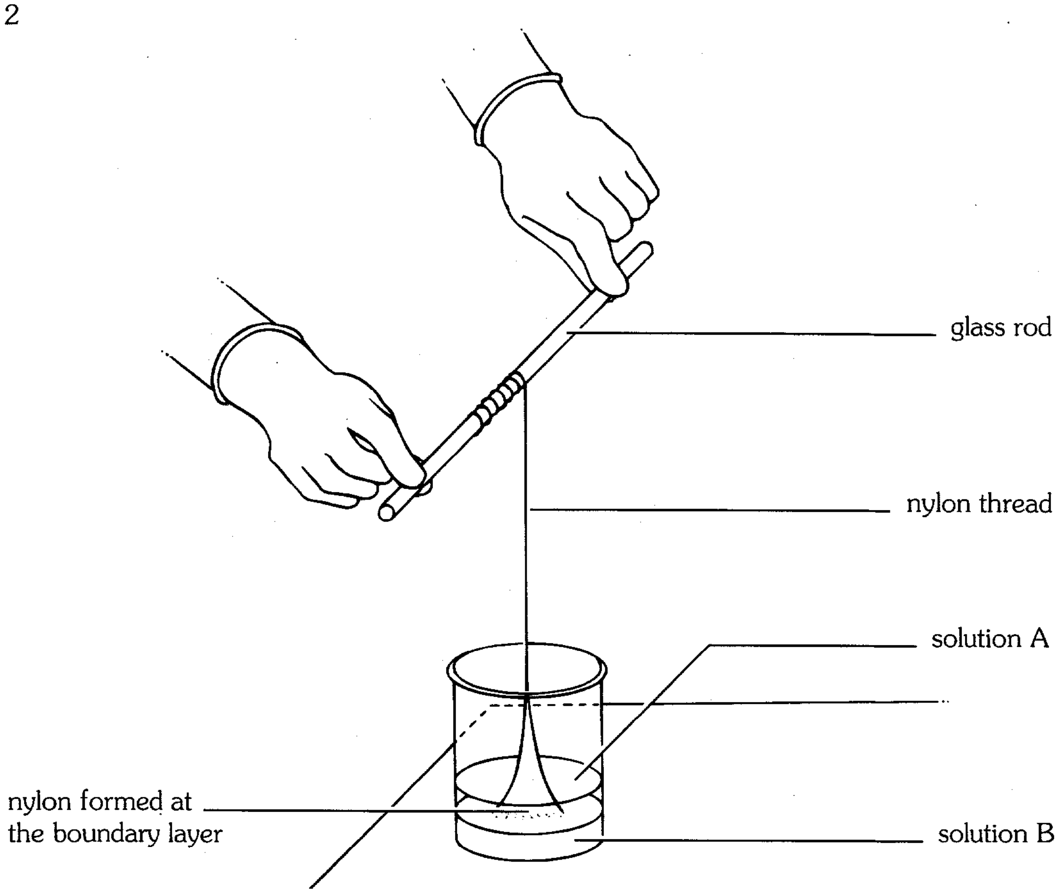
Adult supervision required. Please read and copy the safety precautions at the beginning of this book. You must wear protective gloves and safety goggles throughout this investigation. Care must be taken by the supervising adult to dispose of the reaction mixture safely without possible harm to the environment. The mixture should be treated as a "chlorinated waste" and not poured down the sink. Consult your school's laboratory safety regulations for the environmentally sound disposal method to be used.

PROCEDURE:

Part 1—Making nylon

1. Put on the safety gloves and goggles.
2. Pour 2 ml of solution B into the beaker. Then carefully pour 2 ml of solution A into the beaker. The two solutions should form two layers with as little mixing as possible.
3. Notice the film forming where the two liquids meet. Puncture this film with a pair of tweezers and slowly pull out a thread from the film. This is a nylon thread. Wind the end of the thread around the glass rod as shown in figure 2.
4. When you have collected a meter or so of thread around the glass rod, break off the thread using the tweezers. Wash the nylon in a gentle stream of water from the faucet. The nylon can now be handled with care (although you must continue to wear protective gloves and goggles because the nylon may still contain small amounts of the original materials).

Figure 2

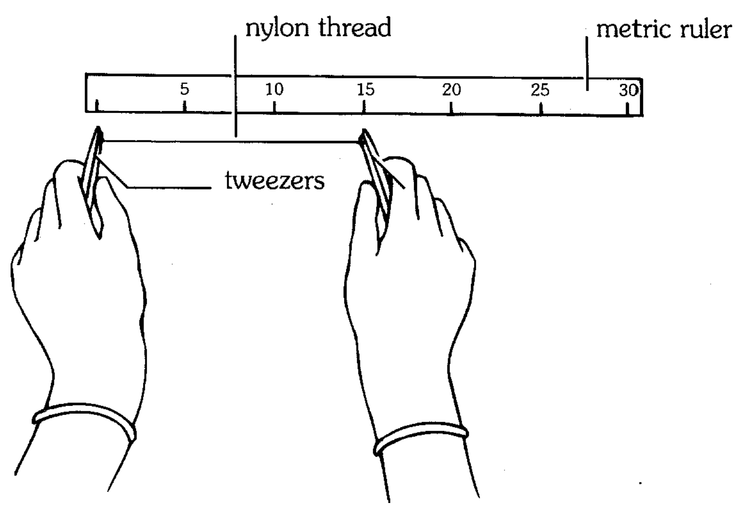


Part 2—Testing nylon's elasticity

5. Using tweezers, break off a 15cm length of nylon thread from around the glass rod.

6. Holding the nylon thread between two pairs of tweezers alongside the ruler as shown in figure 3, gently pull and extend the nylon thread by 1 cm. Then relax the thread and notice whether it returns to its original length. Repeat this at further 1cm intervals, so that the thread is stretched 2 cm, 3 cm, and so on. Record in the first line of the Data Table the stretched length at which the thread first fails to return to its original length (this is called the elastic limit).

Figure 3



7. Now continue gently stretching the nylon thread alongside the ruler until the thread breaks. Record in the first line of the Data Table the length of the thread at the point when it breaks.

8. Repeat steps 5–7 twice more with new 15cm lengths of thread from around the glass rod. It is important that you do this immediately as the thread becomes less elastic and more brittle with time. Record all your findings in the Data Table. You should finish with three readings for the elastic limit and three readings for the breaking length of the thread.

DATA TABLE

Thread	Original length	Elastic limit	Breaking point
1	15cm		
2	15cm		
3	15cm		

ANALYSIS:

1. From the three readings you obtained in steps 5–8, work out the average elastic limit in cm. From this value, calculate the degree of elastic stretch of the thread using the following equation:

$$\frac{(\text{average elastic limit} - \text{original length}) \times 100}{\text{original length}} = \text{degree of elastic stretch (as \%)}$$

2. From the three readings you obtained in steps 5–8, work out the average length to which the thread can be pulled before breaking. From this value, calculate the degree to which the nylon thread can be stretched using the following equation:

$$\frac{(\text{average breaking point} - \text{original length}) \times 100}{\text{original length}} = \text{degree of maximum stretch (as \%)}$$

3. Do some research. In industry, how is the strength and elasticity of nylon thread increased?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES