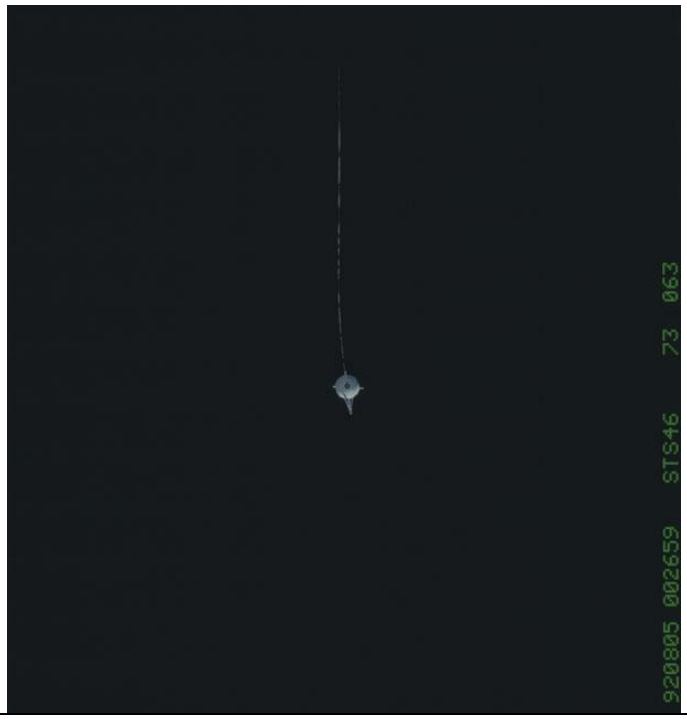
NATIONAL VETERANS MEMORIAL AND MUSEUM

Research Topic- Kevlar

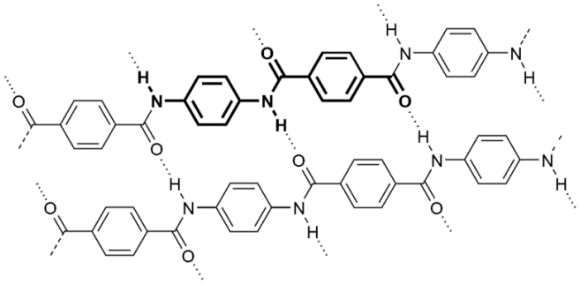
Research Topic	Kevlar and its use in the military
Grade Level	9th -12th Grades
Time Required	1 class period (60 Minutes)
Ohio's Learning Standards S.T.E.M.	Science – Topic: Chemistry as a Human Endeavor. Science has been, and continues to be, advanced by individuals of various races, genders, ethnicities, languages, abilities, family backgrounds and incomes. Every one of us has the ability to advance science for the betterment of the world.
Common Core Standards	CCSS.ELA-LITERACY.RH.9-10.2 Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text. CCSS.ELA-LITERACY.RH.11-12.1 Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.
Objectives	Students will understand the history behind the creation and uses for Kevlar material. Students will learn several scientific terms which are important to know when learning about the creation of Kevlar and other materials.
Research Statement	Kevlar is an important fabric used in military gear which keeps service men and women safe while in field.
Introduction	Kevlar is a heat-resistant and strong synthetic fiber developed at Dupont in 1965 by Stephanie Kwolek. At Dupont, Kwolek was tasked with developing a fiber that could be spun at a lower temperature. During one attempt, a batch dissolved into a milky white, runny liquid solution instead of the usual clear, syrup-thick solution. Instead of discarding it, Kwolek salvaged the solution. The result was the strongest, stiffest fiber that has ever been created: Kevlar.
Supporting Idea I	Kevlar is a synthetic plastic made from the chemical poly-para-phenylene-terephthalamide which is turned into strong fibers. The reason Kevlar works is because, under the right conditions, the molecules arrange themselves end to end, parallel to the length of the fiber, and form strong hydrogen bonds between its molecular chains. During the formation of Kevlar fiber (a polyamide solution): • The amide groups are separated by para phenylene groups. This causes the amide groups to attach to each other on opposite sides of the phenyl group.

	• The separation of amide groups by large phenyl groups causes polymers to nearly always form a trans conformation which causes the groups to become too large to fit on the same side of a bond. • When all monomers connect in a trans conformation, a long straight chain is formed creating an ideal fiber. The reason Kevlar is so strong is because it forms an unusually regular structure created from Hydrogen bonding. Even the weakest form of Kevlar is stronger than steel yet only half as dense.
Supporting Idea II	Kevlar is a well-known component of personal body armor used in combat helmets, ballistic face masks, and ballistic vests. The PASGT helmet and vest used by United States military forces, use Kevlar as a key component in their construction. Other military uses include bulletproof face masks and spall liners used inside armored fighting vehicles to protect the crews from fragments (spalls) generated during impact. Nimitz-class aircraft carriers use Kevlar reinforcement in vital areas. Civilian applications include: high heat resistance uniforms worn by firefighters, body armor worn by police officers, security, and police tactical teams such as SWAT.
Supporting Idea III	Kevlar is not like cotton—it cannot be made by simply combining the right raw materials. It is a proprietary material made only by the DuPont™ chemical company and it comes in two main varieties called Kevlar 29 and Kevlar 49. Kevlar 29 is used in the manufacture of body armor for lightweight military vehicles. It was selected because it is lightweight and withstands attack from RPGs. Kevlar 49 is used for specialist boat hulls and in the aerospace industry. It is popular for boats because it is lightweight and can withstand a considerable amount of force, tensile stress, and impact. Hulls manufactured from traditional materials, such as fiberglass, are limited in their resistance to forces and stress.
Conclusion	It is important to keep our servicemen and women safe when they are in uniform. Kevlar is one of the strongest materials in the world that can protect them against enemy fire. Advancements in the production of such materials is critical to our military.
Resources	Kevlar • Author: Chris Woodford • Published: July 12, 2019. • Link: https://www.explainthatstuff.com/kevlar.html Women in Chemistry: Stephanie Kwolek • Author: Science History Institute • Published: Sep 10, 2012 • Link: https://www.youtube.com/watch?v=L1pepaAdkWA

	• Time: 16:33 Watch In Slow-Motion As Kevlar Fibers Are Put To The Test • Author: Science Channel • Published: June 8, 2017 • Link: https://www.youtube.com/watch?v=ybgMEjl9j-g • Time: 2:41
Visual Thinking Strategies	Visual Thinking Strategies transform the way students think and learn by providing training and curriculum for people to facilitate discussions of visual art that significantly increase student engagement, performance, and enjoyment of learning. https://vtshome.org/about/
Assignment	Have students take 3-5 minutes to look at the images. 1. Ask students to describe what they see in the images. 2. Ask students what more they can tell you about the images. 3. Ask why?
Assessment	Using visual cues, students should observe and discuss people, the way individuals are dressed, the activity of individuals, if individuals look familiar, landscapes, backgrounds, etc. Students should be able to articulate what they see in each image using visual thinking strategies.
Critical Thinking Questions	1. How has technology in body armor evolved over time to keep soldiers safe? 2. Are there any other scientific discoveries you can think of which were discovered by accident?
Images	

Description: A distant view of the STS-46 Tethered Satellite System 1 (TSS-1) satellite extended from the payload bay of Atlantis, Orbiter Vehicle (OV) 104 via its thin Kevlar tether into the blackness of space.
https://nara.getarchive.net/media/s46-73-063-sts-046-sts-46-tethered-satellite-system-1-tss-1-satellite-deployment-415cfa

Golden yellow aramid fiber (Kevlar®). The diameter of the filaments is about 10 µm. Melting point: none (does not melt). Decomposition temperature: 500-550 °C. Decomposition temperature in air: 427-482 °C (800-900 °F). Author: Cjp24
https://commons.wikimedia.org/wiki/File:Aramid_fiber.jpg



The chemical structure of Aramid., Bold: Monomer unit, Dashed: hydrogen bonds. Made by cacycle (taken from english wiki).

https://commons.wikimedia.org/wiki/File:Kevlar_chemical_structure.png

{{Information |Description=Photograph of Stephanie Kwolek, Taken at the Spinning Elements, Chemical Heritage Foundation, Philadelphia, PA, USA. Photograph by Harry Kalish. Please credit: [http://www.chemheritage.org/ Chemical H...]
https://commons.wikimedia.org/wiki/File:Stephanie_Kwolek_at_Spinning_Elements_by_Harry_Kalish.TIF