"Polymer Shrinking Madness! Exploring Shrinking Properties and Chemical Makeup through Mass Spectrometry" (Teacher Page)

1. Each pair of students should receive one polystyrene sheet and one polyethylene salad container.

Polystyrene: Grafix KSF50-WIJ 8-1/2-Inch by 11-Inch Shrink Film, Printable, White Inkjet, 50-Pack
Polyethylene: SafePro 8x8x3 Clear Hinged Lid Plastic Container, (CASE OF 50), Polyethylene Terephthalate Square Cold Clamshell Container

Both the polystyrene and polyethylene samples used for this lab can be ordered online. The above sources are the ones used to collect data for this particular lesson plan. If any other sources of polystyrene or polyethylene are used, preliminary data should be collected by the instructor to determine amount of shrinkage of the plastics. Both of these samples exhibit shape memory. They were heated, stretched, and cooled to maintain their shapes. When the samples are heated again in the drying oven, they revert back to their original shapes (before stretching).

2. Students will need to figure out the amount that each sample shrinks before attempting to create their final geometric shapes. Using the above samples of polystyrene and polyethylene, the amount of shrinkage was determined by placing the samples on parchment paper in a 325 F drying oven.

Polystyrene:	Circle:	Area before: 50.24 cm^2	Polyethylene:	Circle:	Area before: 50.24 cm^2
		Area after: 7.06 cm^2			Area after: 33.16 cm^2
		Shrink rate: 7.11x			Shrink rate: 1.51x
	Rectangle:	Area before: 14cm^2		Rectangle:	Area before: 14 cm^2
		Area after: 2.63 cm^2			Area after: 9 cm^2
		Shrink rate: 5.33x			Shrink rate: 1.55x
	Triangle:	Area before: 20.63 cm^2		Triangle:	Area before: 20.63 cm^2
		Area after: 3 cm^2			Area after: 14.62 cm^2
		Shrink rate: 6.87x			Shrink rate: 1.41x
	Average shrink rate:	6.44x		Average shrink rate:	1.49x

The student instruction page encourages them to create circles, triangles or trapezoids. Shapes can be modified as a way to differentiate this activity.

Helpful area formulas: Circle= πr^2 Triangle= ½bh Trapezoid= ½(b_1+b_2)h

3. Safety: Students must use forceps and heat resistant gloves when removing their polystyrene or polyethylene from the drying oven. If a field trip is taken to the mass spectrometer laboratory, safety goggles should be worn at all times.

4. Cost to produce each shape:

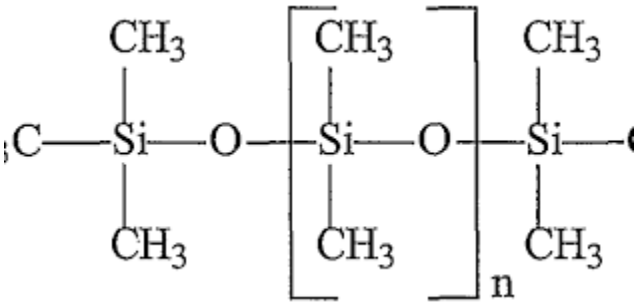
a) PET- The polyethylene used in the collection of this data had an average shrink rate of 1.49x. The usuable surface area of the PET salad containers was approximately 698 cm^2. If the desired shape is to have a surface area of 25 cm^2, the students will have to start with a shape of approximately 37.25 cm^2. This would allow 18 shapes to be produced from the PET container if waste is kept to a minimum. The cost per container is $.52, so the cost per shape would be around $.03.

b) PS- The polystyrene used in the collection of this data had an average shrink rate of 6.44x. The usuable surface of the PS sheets was 602 cm^2. If the desired shape is to have a surface area of 25cm^2, the students will have to start with a shape of approximately 161 cm^2. This would allow 3 shapes to be produced from the polystyrene sheet if waste is kept to a minimum. The cost per sheet is $1.36, so the cost per shape would be around $.45.

5. Interpretation of the mass spectrum of polystyrene

a) Interpretation of PDMS mass spectrum to be done together in class before the lab activity

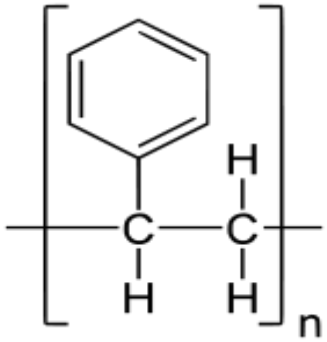
1) The mass spectrum of a sample of PDMS (polydimethylsiloxane) is attached and should be reviewed with the students prior to the lab. The repeating unit of this polymer has a molar mass of 74g/mol. The separation of peaks every 74Da can be seen on spectrum #1.



2) The two series of peaks being offset by 28 Da in spectrum #2 is due to the different termination units of the polymer chains. Students will need help with this concept. The difference is due to some polymers having an ethoxy termination group (O-CH_2CH_3, MM=29Da) and others having a hydroxyl termination group (O-H, MM= 1 Da).

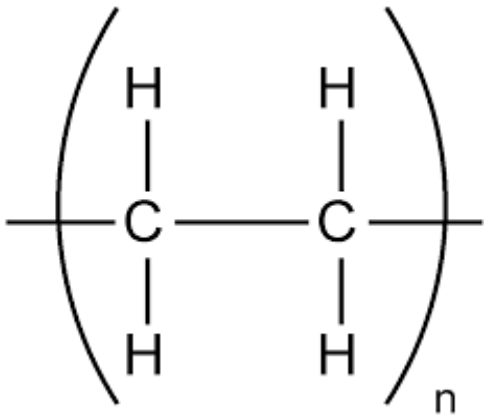
3) The 1 Da separation of peaks in spectrum #3 is due to the existence of isotopes in the PDMS polymer chain. The common isotopes responsible for this would be C-12, C-13 and Si-28 and Si-29.

b) Polystyrene has a repeating unit molar mass 104.12g/mol with the structure (C_8H_8). Students should identify the mass spectrum with the 104Da peak separation as polystyrene.



The formula and the repeating unit molar mass is included on the attachment for teacher reference. If making student handouts the identity of the polymer should be deleted. The end group units have also been included. Students will need help to determine the identity of the end groups.

Polyethylene has a repeating unit molar mass of 28.05 g/mol with the structure (C_2H_4). Students should find that the provided mass spectrum (or the one determined on the field trip) does not have a repeating unit with this molar mass.



As with the attached spectrum of PDMS, the third slide of the polystyrene mass spectrum shows peaks offset by 1 Da. This shows the existence of isotopes in the sample. Isotopes of carbon, hydrogen and the silver ions used in the ionization process can be observed. A slide showing two different samples of polystyrene is also attached. The repeating unit molar mass is consistent, but the polymers have very different molar masses. This slide can be used to explain to students that polymer chains may vary in length substantially.