

Course Learning Outcomes for Unit VII

Upon completion of this unit, students should be able to:

1. Examine chemistry fundamentals.
 - 1.1 Identify the classifications and physical properties of hazardous materials involved in a gas release incident.
4. Evaluate chemical interactions as they relate to control of potential hazards.
 - 4.1 Identify the toxic gases produced when polymers thermally decompose or burn.
 - 4.2 Determine the chemical reactions, interactions, and incompatibility of common polymers as related to potential emergency response situations.
8. Apply information resources commonly used in emergency response operations.
 - 8.1 Explain the actions an incident commander would take when responding to a gas release incident based on information in the Emergency Response Guidebook (ERG).
 - 8.2 Explain the corrective action plan that should be implemented to prevent reoccurrence of a gas release incident based on information in the ERG.

Course/Unit Learning Outcomes	Learning Activity
1.1	Unit Lesson Chapter 14 Reading Unit VII Case Study
4.1	Unit Lesson Chapter 14 Reading Unit VII Case Study
4.2	Unit Lesson Chapter 14 Reading Unit VII Case Study
8.1	Unit Lesson Chapter 14 Reading Unit VII Case Study
8.2	Unit Lesson Chapter 14 Reading Unit VII Case Study

Reading Assignment

Chapter 14:
Chemistry of Some Polymeric Materials, pp. 606-642

Unit Lesson

In this unit, we will focus our study on the more complex hydrocarbons known as polymers discussed in Chapter 14.

Polymers

Meyer (2014) suggests that a contemporary culture could not long endure without the goods or products that the polymer industry provides. These polymeric products include clothing, household/office, indoor and outdoor gadgets, and furnishings that are manufactured from natural and synthetic polymers.

Polymers are not ordinarily considered hazardous materials since they are stable at ambient conditions; however, most of the products burn and produce toxic gases (Meyer, 2014). Because of their widespread use, it is of benefit to understand why and how they can pose hazards, especially during fires. For this unit, we will study the features and structural characteristics of commonly encountered polymers as well as the hazards that they pose when they burn.

What are polymers? The International Union of Pure and Applied Chemistry (IUPAC) (2017) defines polymers as substances or macromolecules that made up of large molecules that weigh from a few thousand to millions or grams per mole. The structure of a macromolecule is essentially comprised of multiple repetitions of units derived, actually or conceptually, from molecules of low molecular mass.

Polymers can be natural or synthetic, but most of us probably associate polymers with the synthetic ones such as plastic. Examples of natural polymers include protein, starch, cellulose, and DNA that make up most of the structures of living tissue. Synthetic polymers include polyvinyl chloride (PVC), polycarbonate, and polyethylene.

Types of synthetic polymers: Synthetic polymers are often referred to as plastics, and most of them can be classified into the categories of elastomers, thermoplastics, and thermosets:

- Thermoplastics are polymers that soften when heated but return to their original condition on cooling to *ambient temperature* (e.g., polyvinyl chloride (PVC), polyethylene).
- Thermosets are polymers that cannot be remolded once they have solidified, such as polyurethane.
- Elastomers have elasticity like rubber (Polymer Science Learning Center, 2005).

Polymerization is the chemical reaction during which monomers are linked and cross-linked to form polymers. The polymerization reaction is characterized by the macromolecule/polymer that is produced (see Figures 14.1 and 14.2 on pages 608 and 609 of the textbook). According to Meyer (2014), chemists have found when they examined the three-dimensional structure of polymers that the chains of repeating units are invariably cross-linked as shown in Figure 14.3 on page 609 of the textbook.

Note the following information about polymers:

- Intentional cross-linking technique for polymers is used during the production of thermoset plastics to make the polymer denser, stronger, and even elastic.
- Macromolecular chains within polymers can also be folded, coiled, stacked, looped, or intertwined into definite three-dimensional shapes.
- Polymer manufacturers sometimes discover that their products are too stiff and brittle for their intended use. These undesirable features can often be overcome by adding a *plasticizer* to the polymer. This is usually a liquid that manufacturers use to dissolve the polymer.
- These processes are accomplished primarily by unique chemical reactions called *addition* and *condensation*.

For information about addition polymerization, see the example illustration on page 610 in the textbook, which shows how the polymers can be formed by the addition of the same units (starting with the styrene monomer). For more examples of polymers formed by addition polymerization, see Table 14.1 on page 612 in the textbook.

A common example of the condensation polymerization process is the reaction between alcohol and organic acids. In the textbook, the example illustrates that the monomer ethylene glycol can be reacted with succinic acid (an organic acid) to form an intermediate product. This intermediate product has reactive groups that will form more intermediate products that will get more complex as the reactions continue until the end product is formed. In this example, the polymer produced is polyester. See Table 14.2 on page 615 in your textbook for more examples of this type of polymerization reaction.

It is also important to note polymer decomposition and combustion. Most products produced from natural and synthetic polymers are combustible when exposed to an ignition source. According to Meyer (2014), most products often melt and thermally decompose into the monomers from which they were made. This melting is associated with both beneficial and detrimental effects.

Other general features associated with their combustion are discussed on pages 617-618 (e.g., flashover) in your textbook. *Flashover* is the spread of fire from the burning area to other areas physically isolated from the initial source of the fire. Firefighters need to be concerned with this phenomenon. They should also be concerned with the smoke generated and the voluminous amount of toxic gases produced not just from the polymers, but from non-polymeric products that may also burn during a fire.

Vegetable and animal fibers: Many common textiles are produced from naturally occurring vegetable and animal fibers. Cotton and linen are examples of vegetable fibers; whereas, wool and silk are examples of animal fibers. These naturally occurring fibers may be used to produce textiles, or they can be chemically altered to produce synthetic fibers from which the textiles are produced. Vegetable and animal fibers are often mixed with combustible oil such that the DOT regulates their transportation as hazardous materials.

Synthetic polymers that are commonly encountered are discussed in detail in the textbook. They include the following:

- Polyvinyl polymers: These are produced from multiple vinyl compounds. Other examples of this polymer are polyethylene, polypropylene, and polyvinyl chloride.
- Epoxy resins
- Formaldehyde-derived polymers
- Polyurethane: All polyurethane burns when exposed to sufficient heat (Meyer, 2014).
- Heat and fire resistant polymers
- Rubber and rubber products
- Natural rubber
- Synthetic rubbers

Responding to incidents involving the burning of rubber: To understand the substances produced when rubber products burn, we need to recall the general features and constituents of their chemical formulations. According to Meyer (2014),

- As they burn, rubber products vulcanized with sulfur or sulfur-bearing compounds produce carbon monoxide, sulfur dioxide, and water vapor.
- The smoke associated with rubber fires is extraordinarily dense and black.
- To prevent or reduce respiratory concerns or fatalities among firefighters, the use of self-contained breathing apparatus is always warranted (pp. 641-642).

The polymer industry has dramatically altered our way of life, so environmental health and safety (EHS) and fire science (FS) professionals, especially responders, will encounter them virtually everywhere. Because they are stable in ambient conditions, they are not ordinarily considered hazardous materials. However, most polymeric products burn and generate toxic gases on combustion. For these reasons, the burning of polymers is a topic of great concern, especially to firefighters.

References

International Union of Pure and Applied Chemistry. (2013). What are polymers? Retrieved from <https://iupac.org/polymer-edu/what-are-polymers/>

Meyer, E. (2014). *Chemistry of hazardous materials* (6th ed.). Upper Saddle River, NJ: Pearson.

Polymer Science Learning Center. (2005). Elastomers. Retrieved from <http://pslc.ws/macrog/elas.htm>

Suggested Reading

This is an easy to understand webpage that defines elastomers or polymers. If you are having trouble with these concepts, this is a good learning tool.

Polymer Science Learning Center. (2005). Elastomers. Retrieved from <http://pslc.ws/macrog/elas.htm>