Part 3
Acetone test: Of possible resin codes 1 or 6, resin code 6 softens in acetone. The samples that soften in acetone are resin code 6. The samples that did not soften may be resin code 1.
Part 4
Melting test: This sample may have resin code 1. If the sample softens in boiling water, it has resin code 1.

Evaluation

(c) [Sample answer] Repeat the procedure using known resin samples, codes 1 to 6, to confirm test results.

Synthesis

(d) Student answers will vary.
Recycling operation at school
- Types of materials collected: paper, plastic water bottles, plastic pop bottles, glass drink bottles, aluminum cans
- Amounts: approximately four large garbage bags of paper each week, five large garbage bags of each type of bottle and cans each week
- Participation rate: approximately 30% of students recycle
- Problems encountered: "recycling containers" do not keep bottles and cans separate, so bottles and cans need to be sorted by hand; collection containers also contain garbage, sometimes making collected materials unusable
- Destination: collected by city recycling facility; some items are destined for sorting locally, and some items are transported to a large city nearby

(e) Issues related to use of plastics:
- There is a growing demand for petroleum as raw materials for the manufacture of plastics.
- Petroleum, a fossil fuel, is a non-renewable resource that cannot be replaced when the source is exhausted.
- Most plastic products are non-biodegradable; that is, these products, when discarded, occupy large areas of land for an indefinite length of time. Since they do not decompose, the atoms and molecules in plastics are not returned to the environment to be used in other systems.

Suggestions for non-synthetic substitutes:
- cotton fibres instead of polyester
- reusable metal cutlery instead of plastic
- washable glasses instead of Styrofoam cups
- washable cloth diapers instead of disposable synthetic polymers

(f) Student answers will vary. Posters should show types of recycled products, flow charts of recycling resources, benefits to environment, location and dates of collections.
(g) Student answers will vary.
- PET: 56% of recycled PET is made into fibre for carpet and clothing, 13% into strapping, and 14% into food or non-food containers.
- HDPE: 29% of recycled HDPE (mostly from bottles) is made into new bottles. HDPE is also recycled into lawn and garden products, such as flowerbed edging, and into plastic lumber for use in decks, benches, and picnic tables.

(h) Student answers will vary, but may include one of the following careers: recycling truck driver, planner for recycling routes, organizer of recycling facility. Other related fields include environmental enforcement, policy and planning, community relations, and other support services.
Qualifications and training to be a waste systems manager:
- an understanding of environmental issues
- a background in environmental studies or waste management, or a degree in public administration
- courses or qualifications in finance

3.18 POLYMERS

TRY THIS ACTIVITY: SKEWERING BALLOONS

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(a) The intermolecular attractions between polymer chains allow the long molecules to move aside to allow the skewer to push through without breaking, analogous to the noodles moving over each other.

SECTION 3.18 QUESTIONS

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Understanding Concepts

1. carbon–carbon double or triple bonds
2. (a) intermolecular forces: van der Waals forces, electrostatic attractions due to any substituted groups present, and, if crosslinking occurs, covalent bonds.
   (b) Properties of the plastics can be designed and controlled by the type of monomer used, and the type of bonding present in the polymer. The polymers are stronger than the monomers, and can be moulded by various processes, depending on the degree of crosslinking.
   (c) The double bonds in the monomers are replaced by single bonds in the polymers, resulting in the polymer having properties more similar to the less reactive alkanes than to the alkenes of the monomers.
3. The monomer must have more than one double bond for crosslinking to occur between polymer chains (e.g., 1,3-pentadiene).
   $CH_2{=}CHCH{=}CHCH_3$
4. Two functional groups that can undergo condensation reactions, e.g., a carboxyl group, and either a hydroxyl group or an amino group, must be present in the monomer of a condensation polymer.
5. Covalent bonding occurs within a polyamide chain. Van de Waals forces, and hydrogen bonding if N–H bonds are present, occur between polyamide chains.
6. (a) Plastics are typically flexible, lightweight, mouldable, and electrically nonconductive. Plastics also soften when heated.
   (b) Within long polymer molecules, you would expect to find covalent bonds. Intermolecular bonds are van der Waals forces. Covalent bonds between molecules would exist if crosslinking were present.
   (c) Intramolecular bonding: The prevalence of single, rather than multiple, carbon–carbon bonds makes plastics strong and chemically unreactive. Intermolecular bonding: Intermolecular forces and crosslinking make plastics strong, flexible, and mouldable. The more crosslinks there are, the more rigid the plastic is.
7. A polyester is linked by functional groups that form esters: carboxyl groups and hydroxyl groups (e.g., polyester). A polyamide is linked by functional groups that form amides: carboxyl groups and amino groups (e.g., nylon).
8. (a) Covalent bonds: intrachain bonds joining C, H, O, and N atoms.
   (b) Amide bonds: the linkage between the N of the amino group of the amine and the C of the carbonyl group of the acid.
   (c) Hydrogen bonds: interchain attractions between –NH groups and carbonyl groups.

Making Connections

9. (a) $HOOC{-}CH_2CH_2CH_2CH_2{-}COOH + H_2N{-}CH_2CH_2CH_2CH_2CH_2CH_2{-}NH_2$
   $\rightarrow -OC{-}CH_2CH_2CH_2CH_2{-}CONH{-}CH_2CH_2CH_2CH_2CH_2CH_2{-}NH{-}$
   (b) The numbers refer to the number of carbon atoms in the monomers. Nylon 6,6 refers to 6 carbon atoms in each of the two monomers used.

Applying Inquiry Skills

10. (a) An ideal polymer would be able to absorb sufficient water to sustain a plant for several weeks, absorb nutrients dissolved in water, would not be harmful to plants, and could be tailored to specific types of applications (e.g., houseplants, outdoor plants). Also, ideal polymers would degrade after several months into harmless products, and would be inexpensive.
    (b) To test for absorption, place samples of equal mass of each polymer in equal volumes of excess water and excess water with dissolved nutrients. Determine the mass of liquid absorbed. To test for the release of liquid, mix equal swelled masses of each polymer with equal masses of a variety of soil types, and measure the moisture content over a test period. Store the mixture samples over several months and determine the amount of degradation. As a safety precaution, test pH. An appropriate test period would be two weeks.
    Sample answer:
    (i)

Polymer	Mass of polymer	Mass of water added	Mass of polymer and absorbed water
polymer A	50.0 g	100.0 g	70.0 g
polymer B	50.0 g	100.0 g	80.0 g

(ii)

Polymer	Mass of nutrient solution absorbed	% change in concentration of nutrients in excess solution
polymer A	50.0 g	100.0 g
polymer B	50.0 g	100.0 g

(iii)

Polymer	Mass before degradation	Mass after degradation (8 weeks)	pH
polymer A	50.0 g	25.0 g	pH 5.5
polymer B	50.0 g	40.0 g	pH 6.5

Analysis

Polymer A absorbed less fluid than polymer B, and did not absorb nutrients as well as polymer B. Polymer A also degraded to produce acidic substances. Polymer B allowed all nutrients to be absorbed but did not degrade as quickly as polymer A.

11. (a) [Sample answer] The following types of plastic products are accepted: code 1 (bottles for carbonated drinks, containers for peanut butter, salad dressings); code 2 (milk cartons, water bottles, juice bottles, grocery bags); code 4 (dry-cleaning and grocery bags, flexible containers and lids); code 5 (ketchup bottles, margarine containers); code 6 (meat trays, plastic knives, spoons, forks). Code 3 is not accepted by municipal recyclings services because these items are too large for pickup or contain medical hazards in medical tubing, etc. Some construction pipes, siding, window frames, etc., are accepted by nonprofit environmental programs. Students will need to check their local recycling program for specific information. Table headings: SPI resin code; Type of products; Properties; Accepted by Municipal Recycling Organization; Accepted by Other Recycling Organization.

(b) and (c)

Common name of plastic	Monomer	Molecular structure
vinyl	ethene	$[–CH_2–CH_2–CH_2–CH_2–]_n$
Saran wrap	1,1-dichloroethene	$[–CH_2–CCl_2–CH_2–CCl_2–]_n$
acrylic	$CH_2=CH–CN$	$[–CH_2–CH(CN)–CH_2–C(CN)–]_n$
polystyrene	styrene	$[–CH_2–CH(Ø)–CH_2–C(Ø)–]_n$
Polyvinylchloride (PVC)	chloroethene	$[–CH_2–CHCl–CH_2–CHCl–]_n$

12. (a) [Sample answer] Strong, flexible, chemically unreactive, insoluble in polar and nonpolar solvents, not softened by heat, nonbiodegradable

(b) [Sample answer] Presence of F or Cl atoms, controlled degree of crosslinking to obtain desired flexibility and strength, resistance to heat

13. Natural rubber is produced from the sap of the rubber tree, *Hevea brasiliensis*. The sap is collected, exposed to air, and gently heated. Natural rubber is a polymer of 2-methyl-1,3-butadiene (isoprene), $CH_2=C(CH_3)–CH=CH_2$. The polymerization reaction is $n CH_2=C(CH_3)–CH=CH_2 \rightarrow –[CH_2–C(CH_3)=CH–CH_2]_n–$

Charles Goodyear developed the vulcanizing process in which rubber is heated with sulfur. This process produced a more reactive and stable rubber and made it suitable for a wide range of products, such as cushions, mattresses, raincoats, and shoes. Rubber is primarily used in car tires. A filler, such as carbon black, is added for reinforcement. Synthetic rubber was developed and produced in Germany during the First World War, and demand for materials increased research and production of new synthetic rubbers during the Second World War.

14. [Sample answers] This polymer would also be useful as a potting soil additive for moisture retention, as a filter for removing traces of moisture from gasoline and oil, as a time-release drug delivery system, and as material for “grow a dinosaur” type toys.