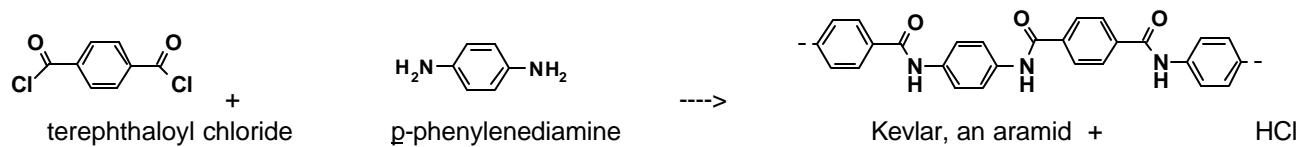
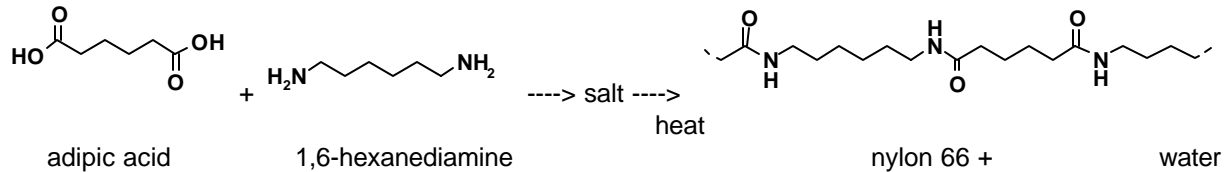


## POLYMERS AND PLASTICS II: CONDENSATION POLYMERS

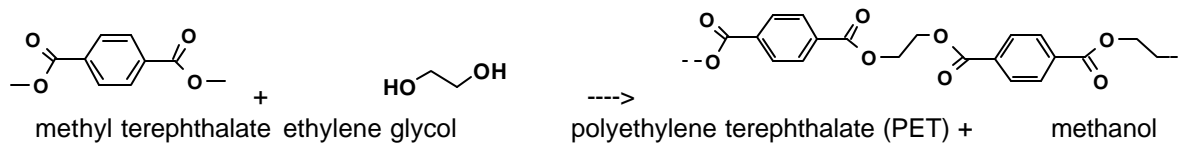
### THERMOPLASTIC POLYMERS

Condensation reactions are probably named for the water that is produced by some; they are substitution reactions in which small molecules (water, ammonia, HCl, etc.) are formed along with the organic product. Most condensation polymers are produced from carboxylic acids and their synthetic equivalents (esters, acid chlorides); the substitution thus occurs by addition (to the carbonyl) plus elimination. Most can be molded by heating to form a thick liquid (they are *thermoplastic*) or made into threads by extrusion of a solution through tiny holes (called spinnerets). They are usually rigid glasses at low temperature and flexible elastomers above  $T_g$ , the glass transition temperature; they may actually melt at a still higher temperature ( $T_m$ ). Their properties and uses are determined partially by whether  $T_g$  is above or below the temperature during use.

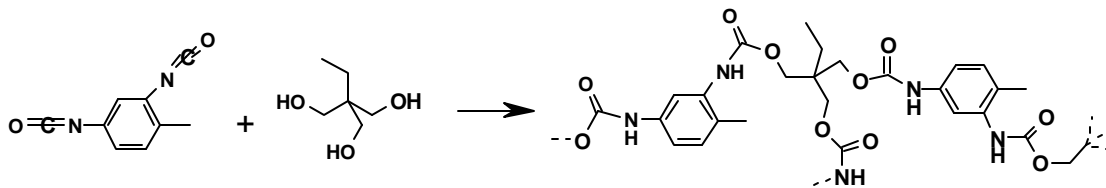
**polyamides:** use: clothing and carpet fibers, spatulas, gears  
source: petroleum -> benzene -> cyclohexene ->



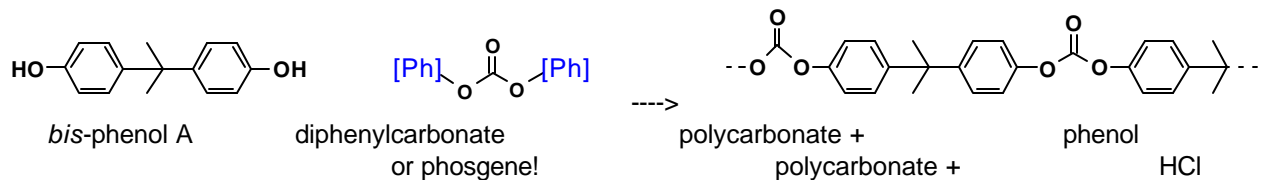
**polyesters:** uses: clothing fibers, bottles,  
source: petroleum -> ethylene and p-xylene ->



**urethanes:** uses: pillow foam, raincoats, insulation  
source: petroleum -> toluene and propene ->



**polycarbonates:** uses: eyeglasses and other high index-of-refraction glass substitutes  
source: petroleum -> propene + benzene ->> phenol ->



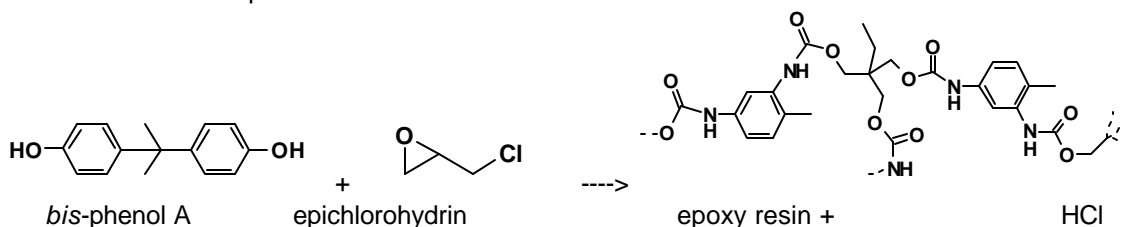
## THERMOSETTING POLYMERS

Other condensation polymers are made from nucleophilic substitution (epoxy) and aldehyde condensation (bakelite). These polymers have three sites of reactivity in one of the monomers, producing highly crosslinked materials that retain the shape into which they polymerize on heating; they are relatively insoluble and decompose on melting. Such materials which cannot be remolded after polymerization are said to be *thermosetting* and are often called resins.

**epoxy:** uses: canoes, auto parts, adhesives

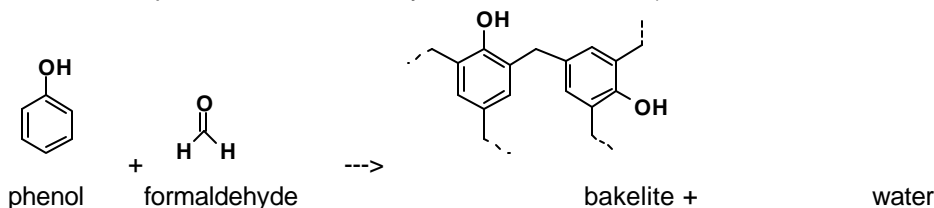
source: petroleum → propene + benzene → phenol

toxicity: Users are often exposed to the monomers, partially prepolymerized; the epoxy component is highly reactive and the catalyst is highly caustic; both irritate tissue. Wear gloves and ensure adequate ventilation.



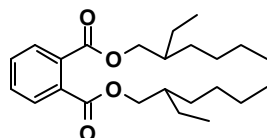
**phenolic resins:** uses: pot handles, electrical and thermal insulation

source: petroleum → benzene → phenol, followed by an aldol condensation in acid or base (note that phenol is the enol of cyclohexa-2,4-dienone)

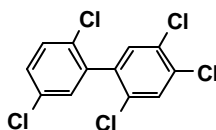


## PLASTICIZERS

Polymers are often too brittle or rigid for a particular application. They are softened by the addition of small molecules called plasticizers that dissolve in the polymer. The plasticizer in polymer is like the sauce on spaghetti, keeping it from setting up. The most common are dibutyl and dioctyl (really di(2-ethylhexyl)) phthalate, relatively non-toxic compounds. Previously polychlorinated biphenyls (PCB's) were used, but like DDT they have long-term toxic and reproductive effects on fish, birds, etc. and have been banned. It is the plasticizers that gum up the windshield of your car when it has been sitting in the sun, and their distillation from the polymeric object leaves it brittle and subject to cracking.



dioctyl phthalate



PCB<sub>3</sub>

## FURTHER READING

L. Mandelkern, *An Introduction to Macromolecules*, Springer Verlag, NY 1972, 1983.

R. B. Seymour, C. E. Carraher, Jr. *Polymer Chemistry: An Introduction*, M. Dekker, NY, 1981.

K. F. O'Driscoll, *The Nature and Chemistry of High Polymers*, Reinhold, NY, 1964.

H. R. Allcock, F. W. Lampe, *Contemporary Polymer Chemistry*, 2nd Ed., Prentice-Hall, Englewood Cliffs, NJ, 1990.

**ORGANIC ENRICHMENT LMS 1993, 1998**