HOW TO “TEACH POLYMERS” IN HIGH SCHOOL(?)

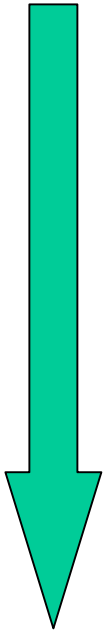
physical properties

- density
- optical properties
- mechanical properties

chemical properties

- chemical reactions (burn tests)
- structure
  - polymers
  - monomers
- nomenclature (names)
- chemical reactions (polymerization)

easiest



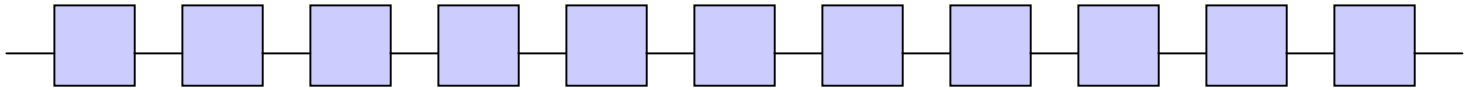
hardest

SAMPLE SOURCES

Polymers used for food applications are usually the best because they contain few pigments or additives

PS	clear plastic cups, should have no haze or color.
PP	microwavable plastic storage containers.
LDPE	resealable lids on coffee cans, 6-pack rings.
HDPE	plastic milk bottles
PETE	2 liter bottles
PVC	plastic pipe, shampoo bottles (usually pigmented)

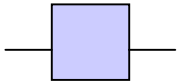
When you compare sample, try to use samples of similar geometries. (especially important for mechanical properties)



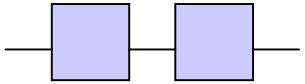
Polymers are chains!

Generic names

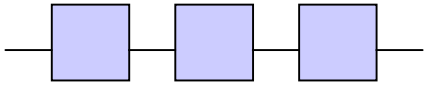
monomer



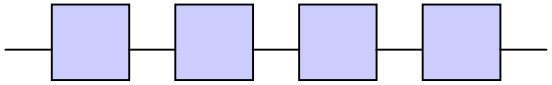
dimer



trimer

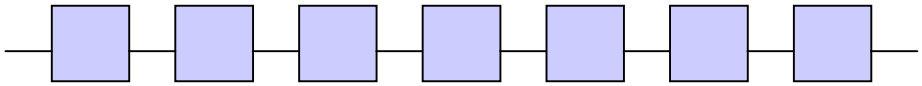


tetramer

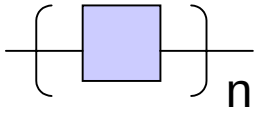


…

oligomer

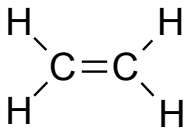


polymer

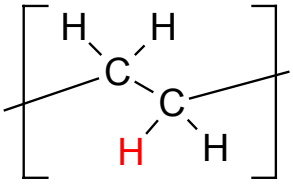


Naming polymers

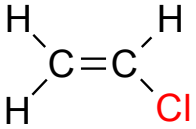
poly(*monomer*)



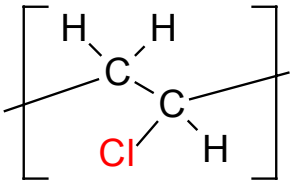
ethylene



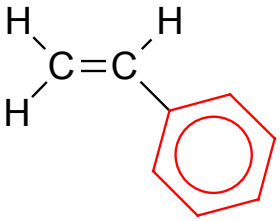
PE



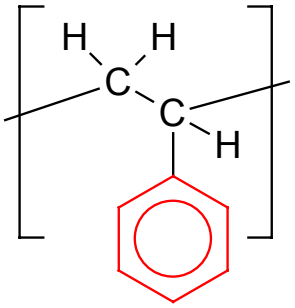
vinyl chloride



PVC



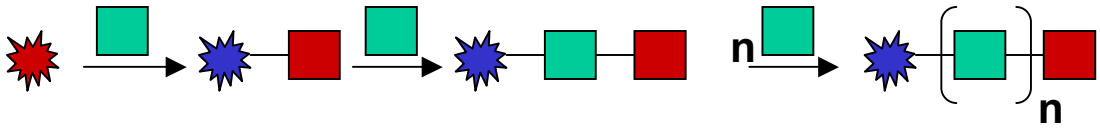
vinyl benzene
(styrene)

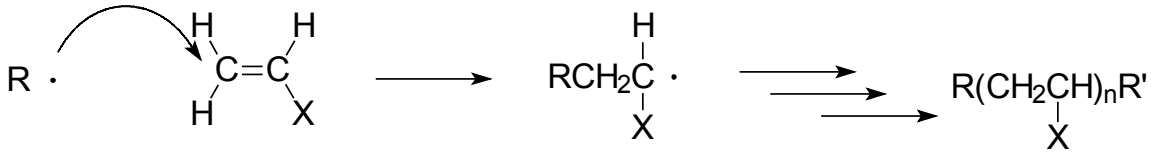


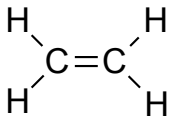
PS

Chain growth

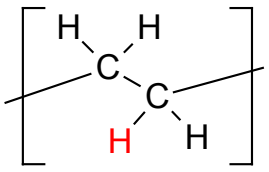
reactive group initiates polymerization, and the group is regenerated as each monomer is added. Chains grow rapidly in length as monomer is consumed.



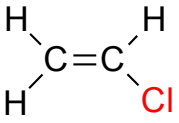




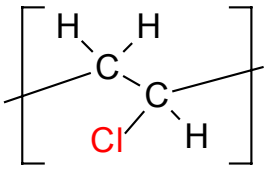
ethylene



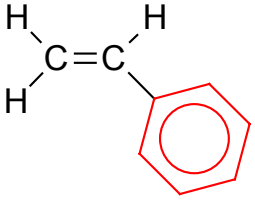
PE



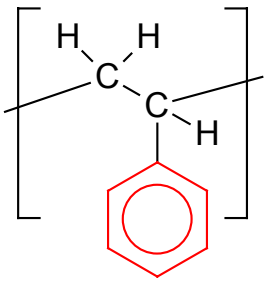
vinyl chloride



PVC



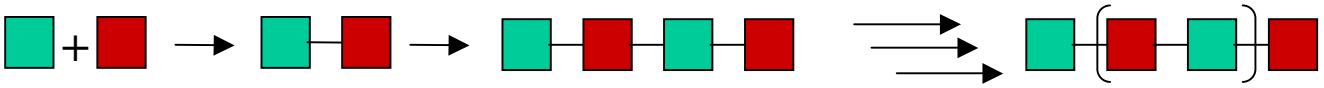
vinyl benzene
(styrene)

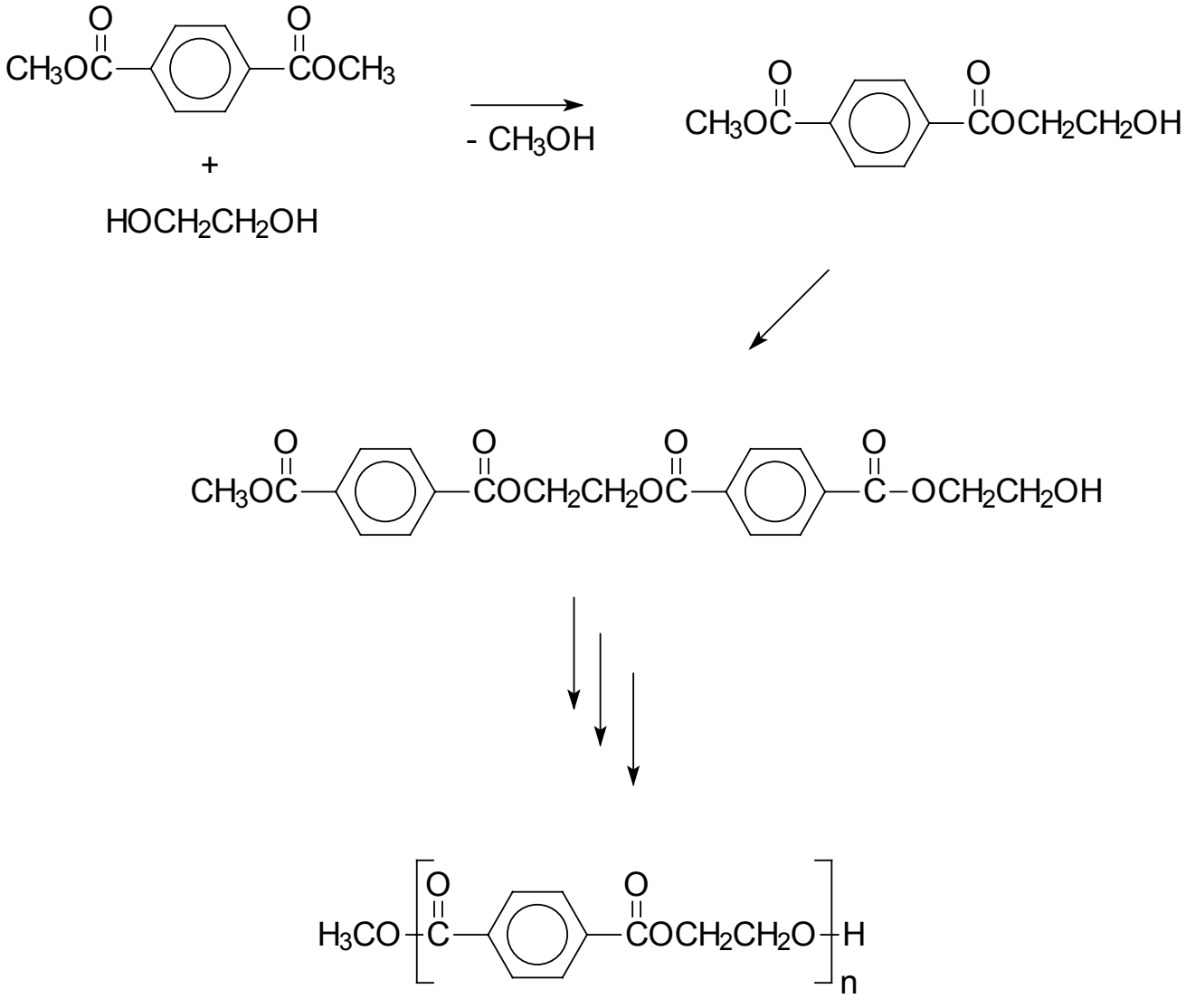


PS

Step growth

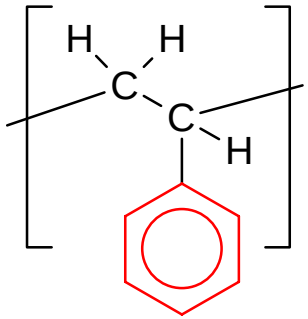
small molecules react to form dimers, dimers form tetramers, etc. Chains gradually lengthen as monomer is consumed.



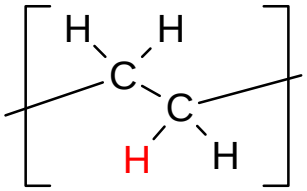


Poly(ethylene terephthalate)

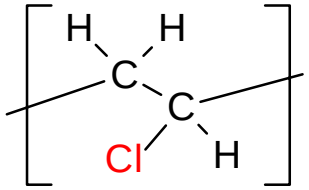
Density



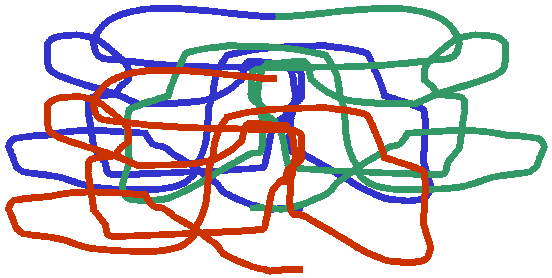
PS

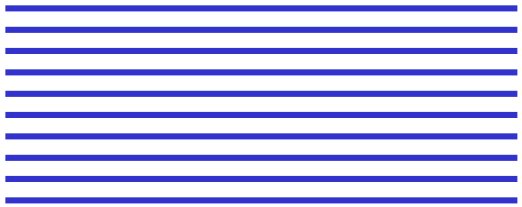


PE



PVC





Materials with high Z atoms have higher densities

PVC vs. PE

Polymers with rings have higher densities

PS vs. PE

Amorphous polymers have low densitites

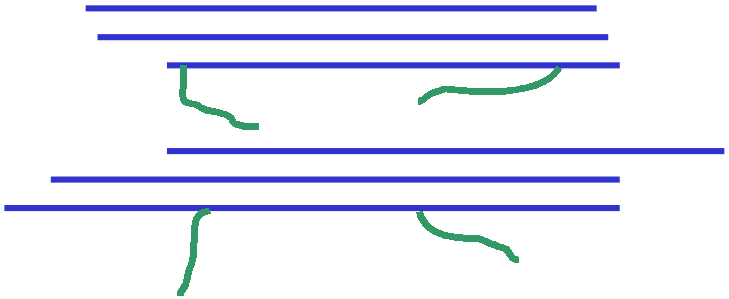
PS, PMMA, LDPE, PVC

Crystalline polymers have high densities

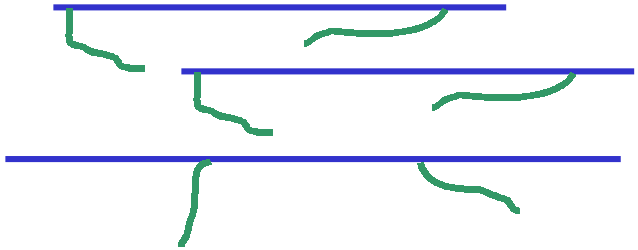
HDPE, PP, (PETE)

More Packing Issues

linear chains, high crystallinity, high density

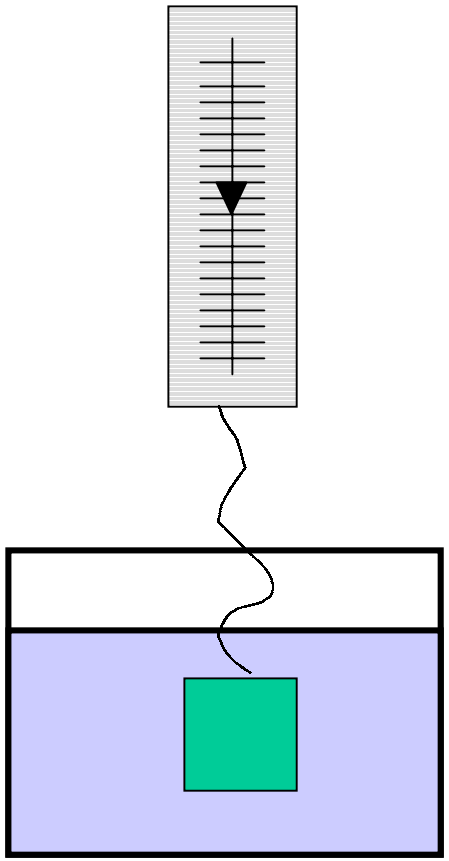


mixture of linear and branched chains, partially crystalline, intermediate density

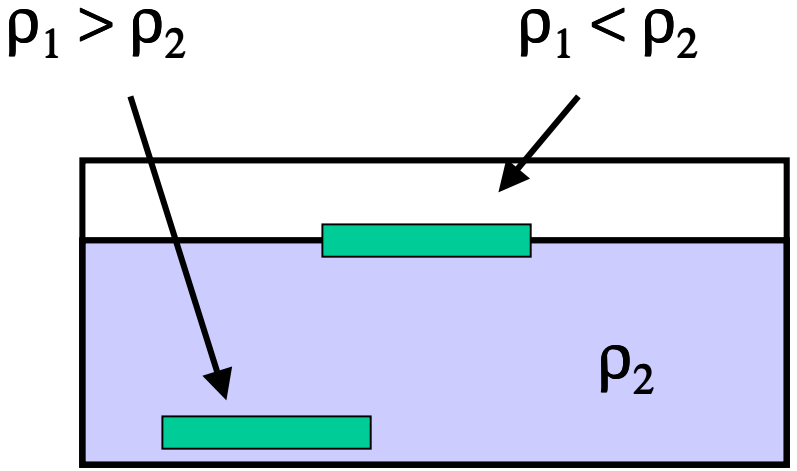


branched chains, amorphous, low density

Measuring Densities



floatation method



water/alcohol mixtures for $\rho < 1$; water salt for $\rho > 1$

hygrometer (supply houses, beer and winemaking)

MECHANICAL PROPERTIES

hard, brittle

typical of glassy polymers, $T < T_g$

PS, PMMA

soft, flexible

amorphous polymers, $T > T_g$

LDPE

tough

crystalline polymers, especially those where $T > T_g$.

example: nylon monofilament, HDPE,

FIBER EXAMPLES

NATURAL

cellulose derivatives (plants)
- •cotton
- •flax
- •hemp

proteins/polyamides (animals)
- •hair
- •wool

SYNTHETIC

polyesters
- •Dacron

polyacrylonitrile
- •Orlon

polyamides
- •nylons
- •Kevlar

FIBER PROPERTIES

(these are generalizations! - each fiber has its own distinctive properties that depends on its diameter, cross-section, roughness, and chemical structure)

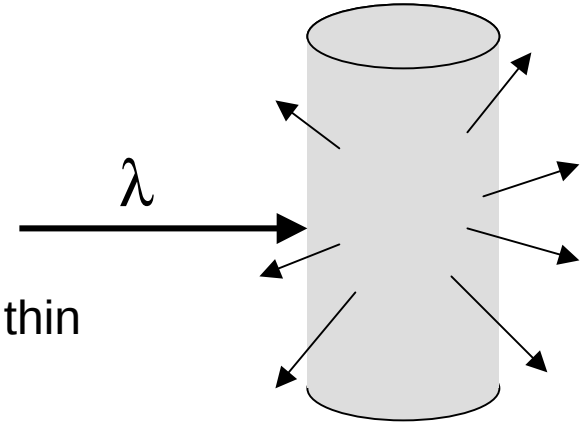
SYNTHETIC	**NATURAL**
•tend to be smooth, cylindrical, with uniform diameters	•Non-uniform diameters, often “crinkly” or rough.
•usually melt before burning	•tend to char rather than melt, proteins burn with a distinctive odor
•resistant to acids and bases	•hydrolyze in either strong acid (cotton, and other cellulosics) or base (proteins)

OPTICAL PROPERTIES OF POLYMER SAMPLES

clear

no absorption or scattering of light (“crystal clear”)

example: clear plastic cups (PS)



milky

white haze to a nearly opaque white color, thin samples appears clearer.

example: HDPE milk bottles

opaque

heavily pigmented often with a definite color other than white.

example: PVC pipe, shampoo bottles

Web-based resources

Macrogalleria (excellent!)

http://www.psrc.usm.edu/macrog//

Polymers Dot Com

http://www.polymers.com/dotcom/home/

National Plastics Center and Museum:

http://npcm.plastics.com/

Q&A posted on Baker home page

http://www.cem.msu.edu/~bakerg/