

**Exam 4** — to supplement Quiz 8a-8b and 8c

**Addition Polymers — Heads and Tails**

The “**spatial rhythm**” is defined (and can be seen) in each **name**:

**Head-to-Tail**, **Head-to-Tail**      **Head-to-Head**, **Tail-to-Tail**  
1      -      3      -      1      2      -      -

Page 379 suggests “arbitrarily thinking of” the carbon-with-H as Head, but this is arbitrary. To make the rhythms 1-3- (not -2-4) and 12-- (not --34), I prefer to define C-with-the-large-group (CH<sub>3</sub>, Cl, ⊗) as **Head** because the names — “Head-to-Tail...” and “Head-to-Head...” — are fixed by tradition, not by me.

**Polymerization** — What is required?

To form a polymer, monomers must react **to-Left** and **to-Right**.

For **addition polymer**, **L-and-R** happens with C=C of alkene.

For **polyester**, use di-acid (**L, R**) plus di-alcohol (**L, R**); {8a}

for **polyamide**, use di-acid (**L, R**) plus di-amine (**L, R**); {8a}

and later, on Quiz 9 — it's after Exam 4, so ignore it now. \*

for **polypeptide**, use amino acids (amine on **L**, acid on **R**).

For **triglyceride** (a non-polymer), use 3 acids plus tri-alcohol.

**Big Six** (p 378): **know** structure & names, properties → uses.

problems of recycling PVC: additives; burning → HCl, dioxin.

**Structures of Monomers** for:

**addition** (p 378 shows similarity of monomers for polyethylene

(HDPE, and LDPE with more branching, → properties ≠)<sup>376</sup>

polypropylene, polyvinyl chloride, polystyrene.

**polyester**: Polyethylene Terephthalic Ester (PETE, aka PET);

p 378: ethylene glycol is 2-C di-alcohol with OH on each C;

terephthalic acid [ph,th] is benzene with symmetric di-acid).

**polyamides**: Nylon-6,6 (p 386, has 6 C in di-acid & di-alcohol),

Kevlar (p 387, benzene with symmetric di-acid & di-amine);

Quiz 8a has repeat-units and rxn-eqtns for PETE & Nylon-6,6.

and later, analogous applications of these ideas for Quiz 9,

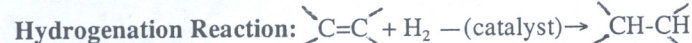
**polypeptides**: variety of **Amino Acids** (amine on left end,

carboxylic acid on right end) with differing R-groups.

**triglycerides** (fats/oils) non-polymer: glycerol, 3-C tri-alcohol

(p 354) plus 3 fatty acids with variety as explained on 452-461,

where one factor is **saturated** (no C=C) vs **unsaturated** (w C=C):



**Catalyst** (over-the-arrow) speeds up reaction but is not reactant

or product in rxn-equation. In rxns: **R•** for **addition polymers**,

**H+** for **condensation** (ester & polyester, amide & polyamide, and

later — after Exam 4 — to make **polypeptides** and **triglycerides**).

For other reactions (catalytic cracking, hydrocracking, adding H across C=Cs), in Chem 108 it's just an undefined “**catalyst**”.

**Writing Condensation Reactions** — a step-by-step strategy uses Steps (0,1,2,3) analogous to Addition Polymerization {8a}.

Step 0: Translate from words (formic acid,...) into structures.

Step 1a: **RED** - find **atoms that leave**: **OH** of COOH, **H** of OH.

**BLUE** - find **atoms that lose bonds**: **C** of COOH, **O** of OH.

**BLUE** - on right side, **bond C** (of C=O) with **O** (of OH), and

**BLACK** - **copy all non-Red/Blue atoms** from left to right.

**RED** - combine “lost” **OH** and **H** to form **HOH** (i.e. H<sub>2</sub>O).

For ester-reaction, stop here; for polyester-reaction, do 1b-2-3.

Step 1b: draw brackets for repeating-unit; **remove remaining**

**Red-atoms** (**OH, H**) so you can draw bonds-across-brackets.

Step 2: **n** di-acids + **n** di-alcohols → **n** repeating-units, **2n** H<sub>2</sub>O.

Step 3: For ester or polyester, H<sup>+</sup> (a catalyst) **over-the-arrow**.

• Use same steps if **alcohol** (-OH) is replaced by **amine** (-NHx); replace **H** (of OH) by **H** (of NH<sub>2</sub>), and **O** (of OH) by **N** (of NH<sub>2</sub>); and product (ester or polyester) is now **amide** or **polyamide**.

If “given product, find reactants”, use blue+black/red **back-logic**: find **blue atoms** (C=O, OH), **un-bond blue**, copy black, add red.

and later — for Quiz 9,

• Use same steps if di-acid/di-amine (for polyamide) is replaced by amino acids (for **polypeptide**); the main differences are the monomer & repeating unit (both have an R-group that can vary), and for Step 2 only **n** H<sub>2</sub>O is produced, instead of **2n**.

• **carbohydrates**: name from C<sub>n</sub>(H<sub>2</sub>O)<sub>n</sub> of **CH<sub>2</sub>O** monomers.

• **saccharides** (mono/di) **dissolve in water** (very polar) due to functional groups — ethers (polar) and alcohols (very polar) — but are **non-electrolytes**, don't form ions or conduct electricity.

• **flowchart** in Slide 38 (Lec 33) is a great overview, showing **monosaccharides** (glucose, fructose), **disaccharides** (sucrose,...), and **polysaccharides** (starch, cellulose), with **1, 2, n** monomers.

• Humans more easily digest disaccharides or polysaccharides with **α-linkages** (rings on ≈ same plane), not **β-linkages** (w rings on different planes); in Slides 34-40, maltose (α) vs lactose (β), starch (α) vs cellulose (β).

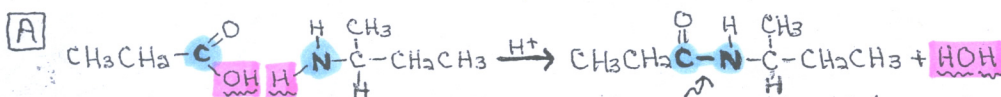
• **HFCS** (**glucose, fructose**) vs **sucrose** (**glucose-and-fructose**)  
**mixture of monosaccharides**      **MOLECULE disaccharide**

**Energy-Math for Energy Lab**: Know calculations from E-Lab and in Exam 3 of 2011 (Part 4, #4), Exam 4 of 2012 (Part 2, #4): Heat Absorbed = (\_\_\_ g H<sub>2</sub>O)(T<sub>f</sub>-T<sub>i</sub>, deg)(4.184 J/g-deg) = \_\_\_ J; Exp Heat of Rxn = (\_\_\_ Abs-Heat in J) / \_\_\_ g fuel) = J / g of fuel; find Efficiency (p 11-5); use Efficiency (p 11-4) to get corrected Heat of Rxn = \_\_\_ J / g fuel, and {1000 J = 1 kJ} in \_\_\_ kJ / g fuel.

\* This handout is for Exam 4, so why does it include ideas from after it? To emphasize the unity of ideas & chemistry; a wide range of applications — using condensation reactions in industry and biology — are minor variations on the same basic themes.

- (A. On Quiz 8c, do #7b except with amine instead of alcohol.  
B. What reactants will form the product of Problem A?

C. Write reaction-equation to make **Kevlar**. (above, or pg 387)



**B** separate here, add red (OH, H)

