

Homework 13
Polymer Physics 2023

Due Tuesday April 18 at noon

(Please send one email with a **pdf** attachment to beaucag@uc.edu

The file should be called: **HW 13 Group x Last Name_Name_Name_Name.pdf**)

One of the top groups in polymer membranes is WJ Koros in Chemical Engineering at Georgia Tech. Koros has worked closely with the Department of Energy in separation membranes for CO₂ from flu gas and with Dow on gas phase separations among other topics. He is a member of the National Academy of Sciences (meaning he has reached the top of science in the US). The Koros group recently published a review paper on solid polymer gas separation membranes León NE, Liu Z, Irani M, Koros WJ *How to Get the Best Gas Separation Membranes from State-of-the Art Glassy Polymers* *Macromolecules* **55** 1457-1473 (2023). Another interesting paper is from 2013 and deals with the problem of separation of ethane/ethylene mixed gas streams (Dow Chemical) Rungta M, Zhang C, Koros WK, Xu L *Membrane-Based Ethylene/Ethane Separation: The Upper Bound and Beyond* *AIChE Journal* **59** 3475-3489 (2013). Both papers are rather lengthy and very technical with a bit of science. Reading these should give you a feel for how physics, chemistry and engineering come together in gas separation membranes.

- a) In Rungta's 2013 paper the status of ethane/ethylene separation is spelled out and the conclusion is that the best approach is to pyrolyze (burn) the best solid polymer membranes to improve membrane performance. Most solid polymer separation membranes begin with a plot of selectivity versus flux such as figures 1, 4, 7, 9, and 11. Rungta explains this in equations 1 to 8 including semi-empirical predictive equations for the relationship between selectivity and permeability based on the size of the molecules that are being separated, the energetics of sorption, and the rate of transport. On page 3476-3479 Rungta describes an upper bound for solid polymers in these plots that limits the selectivity to a value of about 10 for very low ethane permeabilities. This is well below the performance necessary for commercialization. Explain, as best you can, the reasoning behind this limit.
- b) Since Rungta demonstrates that it is fruitless to use solid polymers for the ethane/ethylene separation process he explores other membrane types, ruling out all but the pyrolysis method which produces Carbon Molecular Sieve membranes. Describe facilitated transport membranes and explain why they cannot solve the ethane/ethylene separation problem.
- c) Describe a molecular sieve membrane and explain why they cannot solve the ethane/ethylene separation problem.
- d) Describe Rungta's solution using carbon molecular sieve membranes, how these are made, why they are great for separating ethane from ethylene and what data that Rungta presents that shows they can work to solve this problem.
- e) León (2013) gives a comprehensive discussion of solid polymer gas separation membranes with the aim of explaining why plots of selectivity versus permeability are not of great importance to commercialization of these membranes. He lists four items of importance which are listed linking the two columns on the first page. Explain each of these four issues and describe how they can impact the performance of gas separation membranes.