Welcome to Chemistry 154!

Chemistry for Engineering

Reminders

– **Worksheet: Unit 5 Part 2 (questions 7-13)**
  Due Oct. 25th at 11:59pm

– **Achieve Assignment #5** (Due Oct. 25th at 11:59pm)

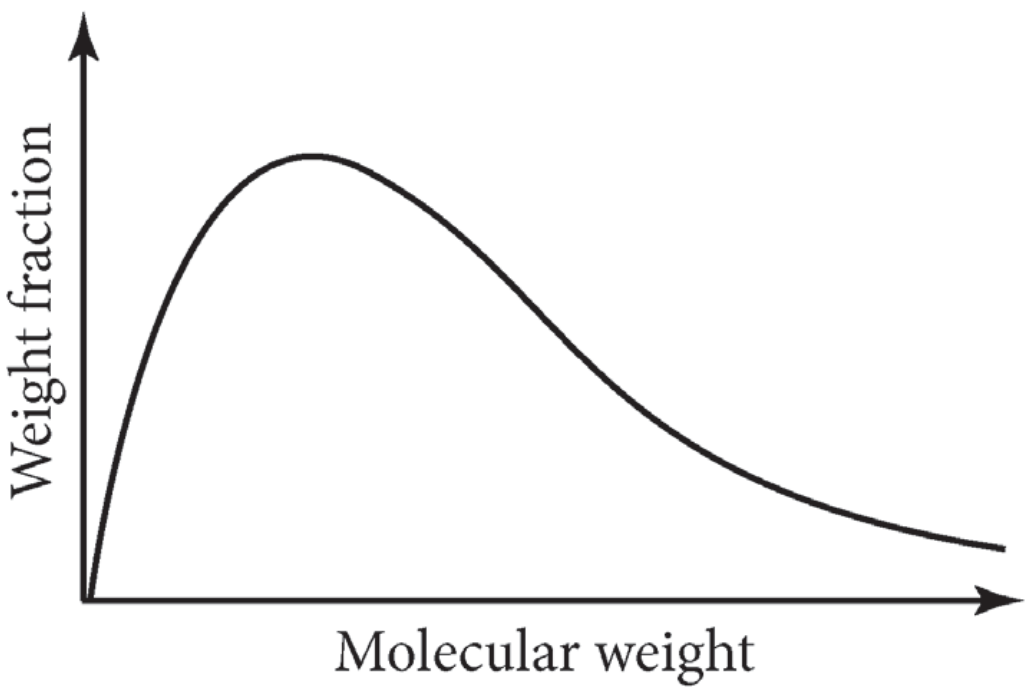
Instructor Office Hours
Monday and Friday 7-8pm via Zoom (All Lectures Site)

Polymers – Learning objectives

- Draw and interpret line bond structures and condensed Lewis structures.
- Describe the growth of polymers through addition and condensation reactions and predict which of these processes is likely to be important for a given monomer.
- Predict the structure of the monomer involved in the formation of a given polymer.
- Identify the type and degree of polymerization and/or the by-products formed for a given polymer and/or monomer.
- Define the terms monomer, polymer, oligomer, molecular weight distribution, degree of polymerization, crosslinking and elastomers.
- Describe how polymer architecture, molecular weight, monomer type, and crosslinking affect polymer properties.

Molecular weight distributions

A synthetic polymer will have a range of chain lengths of differing molecular mass, or a *mass distribution*. Differences in molecular weight affect solubility, strength, viscosity, among other properties.

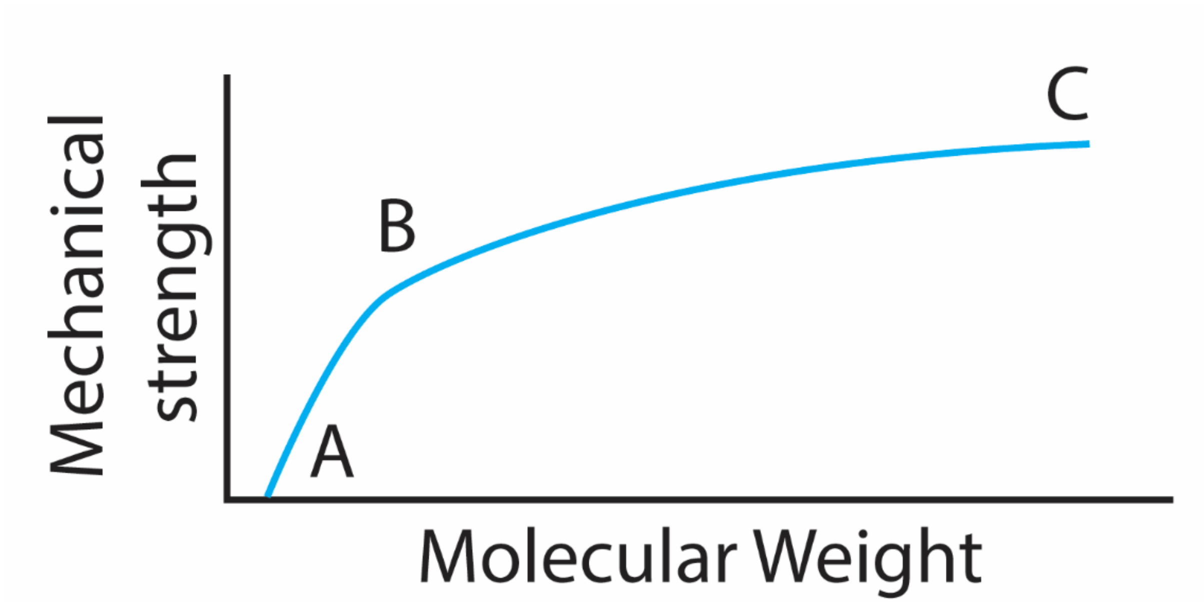


Factors affecting polymer properties

Polymers are versatile materials because their properties can be tailored in a number of ways. For instance, molecular weight, architecture, crosslinking, and composition are some of the factors that can be modified to produce materials with different properties.

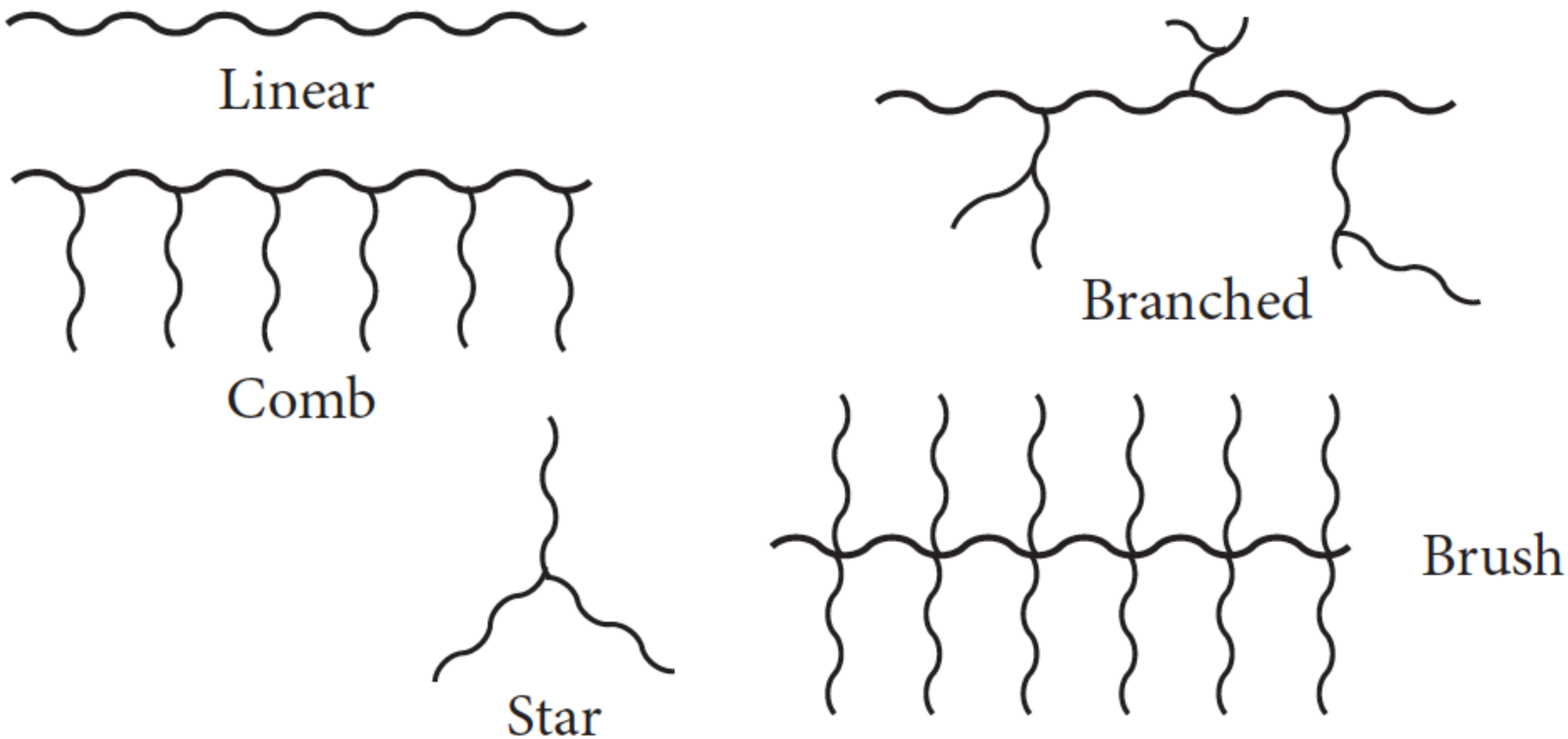
Molecular weight and mechanical strength

When MW is below a certain point, the polymer has no mechanical strength. As MW increases beyond that point, mechanical strength increases rapidly (A-B). At a given chain length, the increase in MW does not significantly change the mechanical strength of the material.



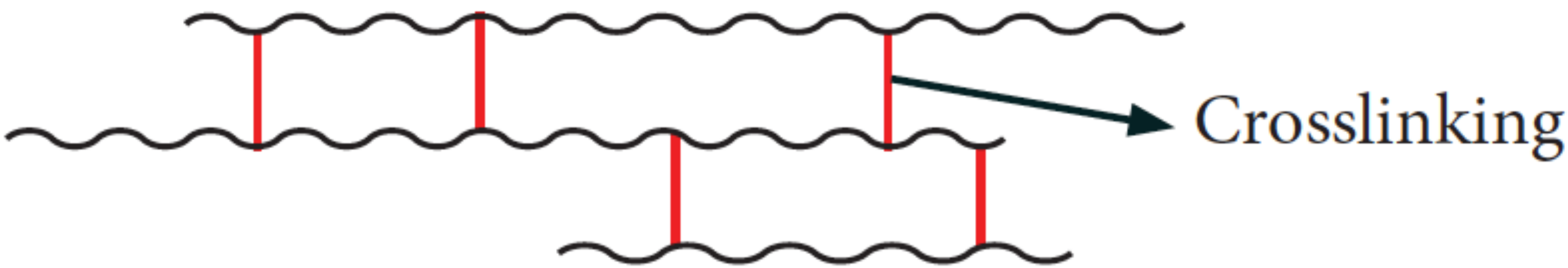
Architecture

Polymers are not always linear, they can also be branched. Branched polymers can have several architectures: star, comb or brush to name a few. Architecture can have significant effects on polymer properties. For instance, branching can enhance chain entanglement that leads to increased viscosity. A polymer’s viscosity is important for polymer processing.



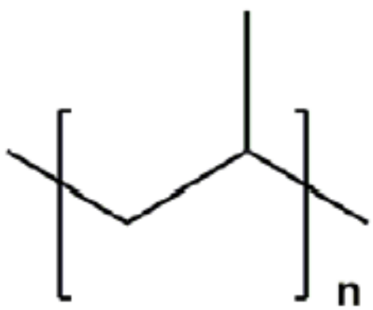
Crosslinking

- When two or more polymer chains are connected via covalent bonds the chains are said to be crosslinked. The molecular weight of a cross-linked polymer is very high.
- Crosslinking has marked effects on a polymer's properties. It improves mechanical strength and increases thermal stability.
- The reversibility of elastomers is due to "light" (occasional) crosslinking between the polymer chains.

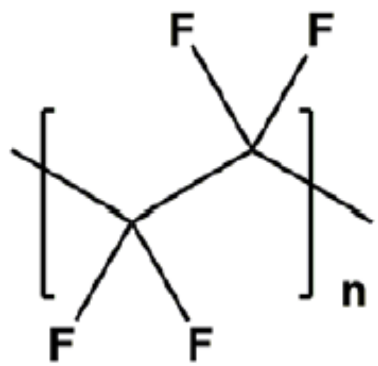


Composition

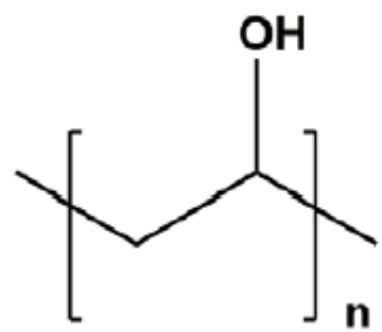
The identity of the monomer will also greatly impact the properties of the polymer. For example, polymers with CH_3 or F side chains are hydrophobic whereas polymers with OH groups are hydrophilic.



Polypropylene
(Hydrophobic)

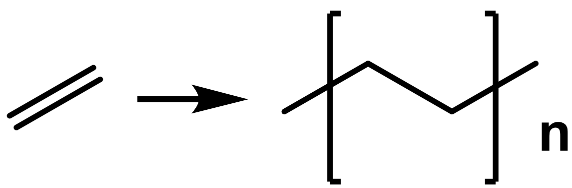


Teflon
(Hydrophobic)

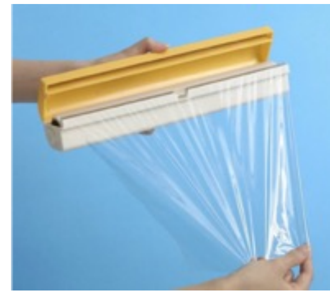


Poly(vinyl alcohol)
(Hydrophilic)

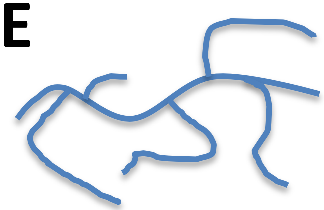
Blueprint question

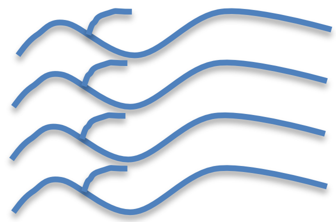


Same monomer,
different properties



Low- density polyethylene
LDPE





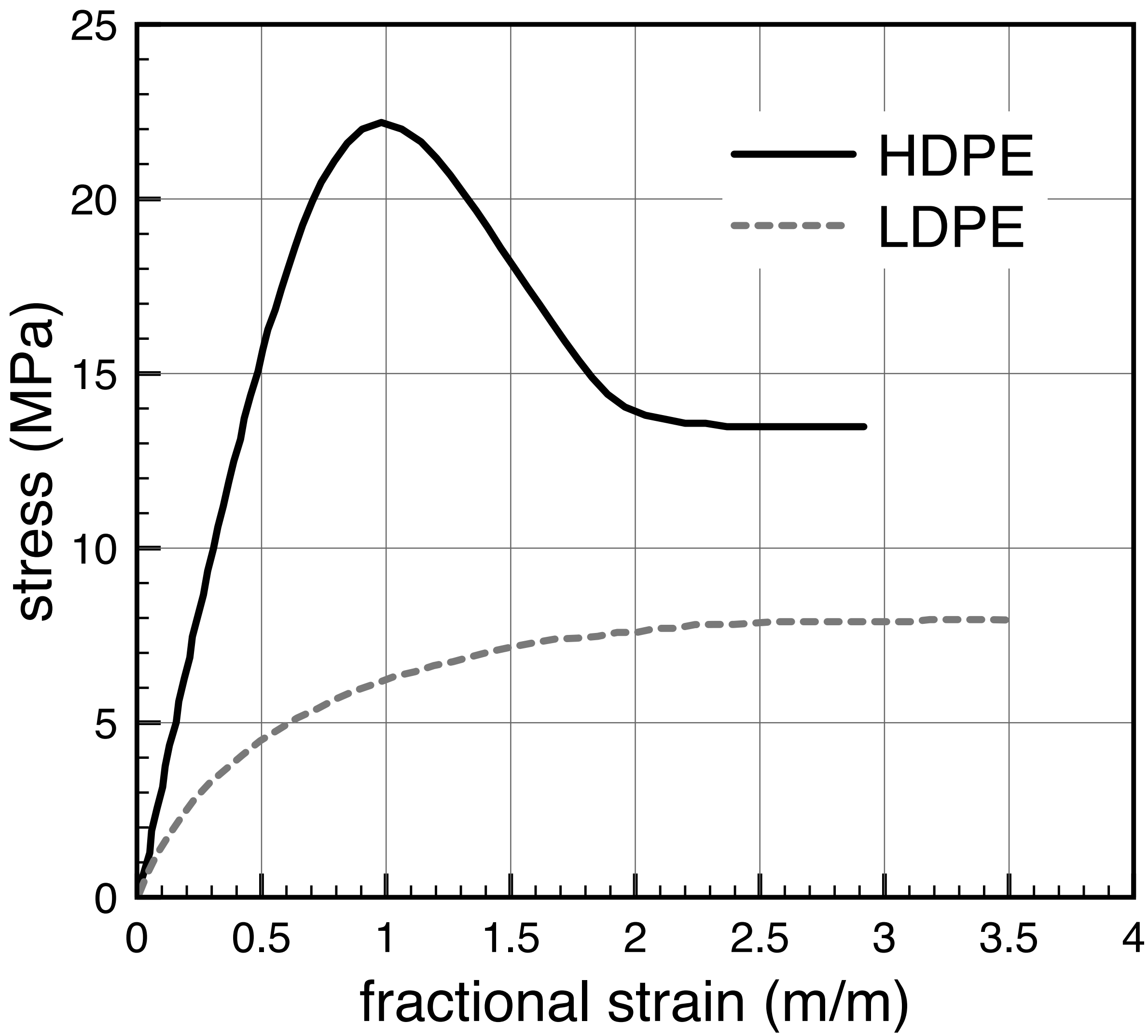
High-density polyethylene
HDPE

Branched structure — Inefficient packing; Flexible

Linear structure — Efficient packing; Strong but less flexible (LDFs)

Thermoplastics, processed using injection molding or thermoforming

HDPE vs. LDPE



HDPE
LDPE
stress (MPa)
fractional strain (m/m)
0
5
10
15
20
25
0
0.5
1
1.5
2
2.5
3
3.5
4

Entropic elasticity

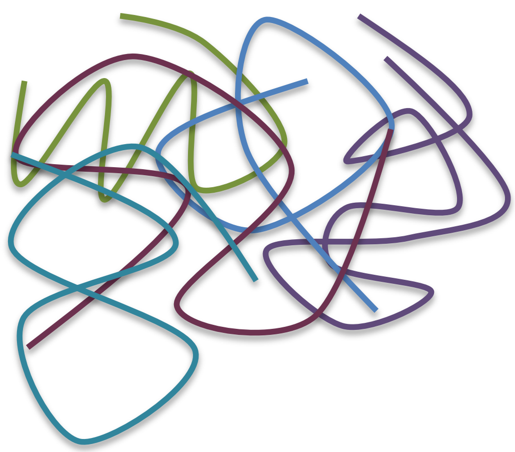
T_g (glass transition)

gradually more viscous (not a true phase transition)

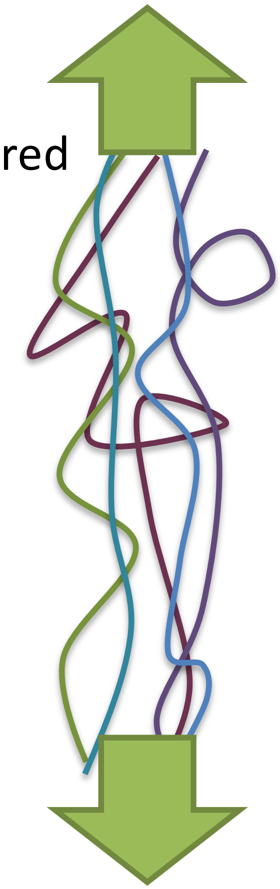
$T<T_g$	$T>T_g$
hard, brittle (but amorphous) state	soft, gummy, elastic state
eg. Lexan, HDPE, hard candy	eg. rubber band, gummy worm
High degree of structural order (eg. crystalline domains) or extensive cross-linking: strong & stiff	Low degree of order…

Entropic elasticity

Disordered chains



Less
disordered
chains

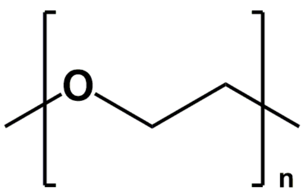


If the polymer chains are relatively disordered, the deformation can come at the expense of uncoiling and ordering the polymer: ***entropic mechanism***! $\Delta S<0$

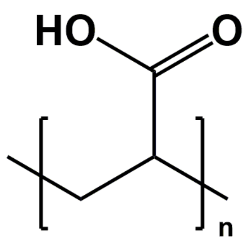
Need proof? Stretch a rubber band against your wrist or lip, it should feel warm: transferring heat to the environment

Worksheet Question #11 – GOOD QUESTION

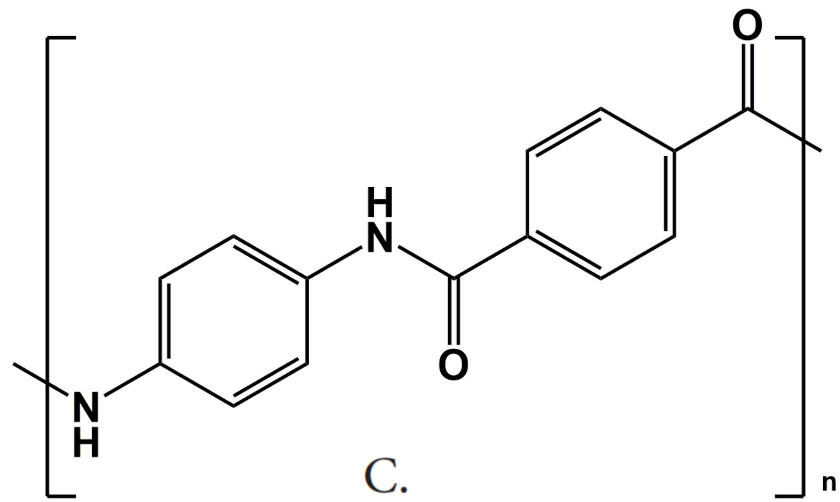
Rank the following polymers in terms of increasing flexibility. Explain your reasoning.



A.
polyethylene glycol
(PEG)



B.
polyacrylic acid
(PAA)



C.
Kevlar

A) A < B < C

B) A < C < B

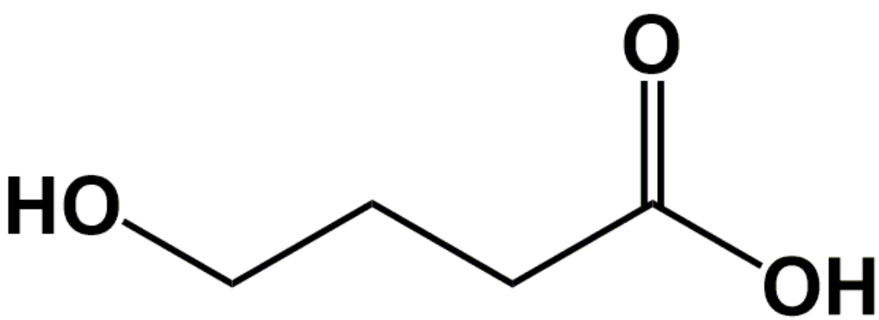
C) B < A < C

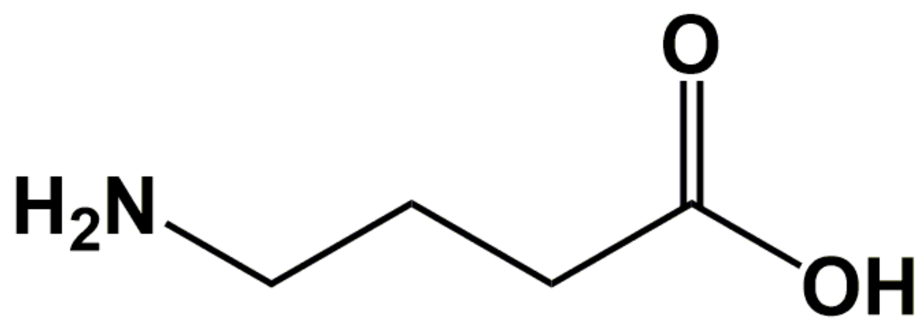
D) C < A < B

E) C < B < A

Worksheet Question #12 – GOOD QUESTION

Which of the following monomers (A or B) produces a polymer with the highest melting point? Briefly explain your reasoning. Assume the molecular weight of the resulting polymer is the same.





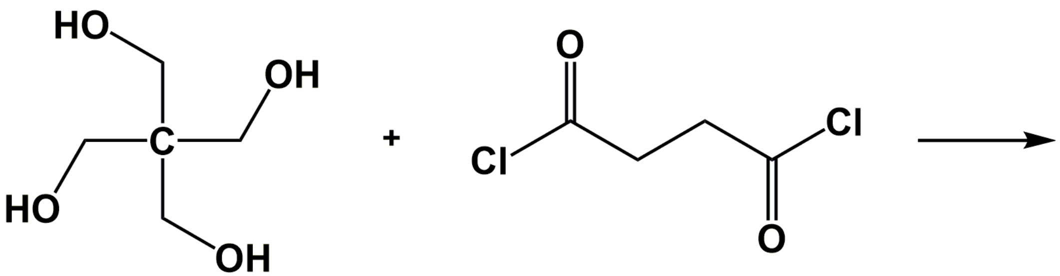
A.

B.

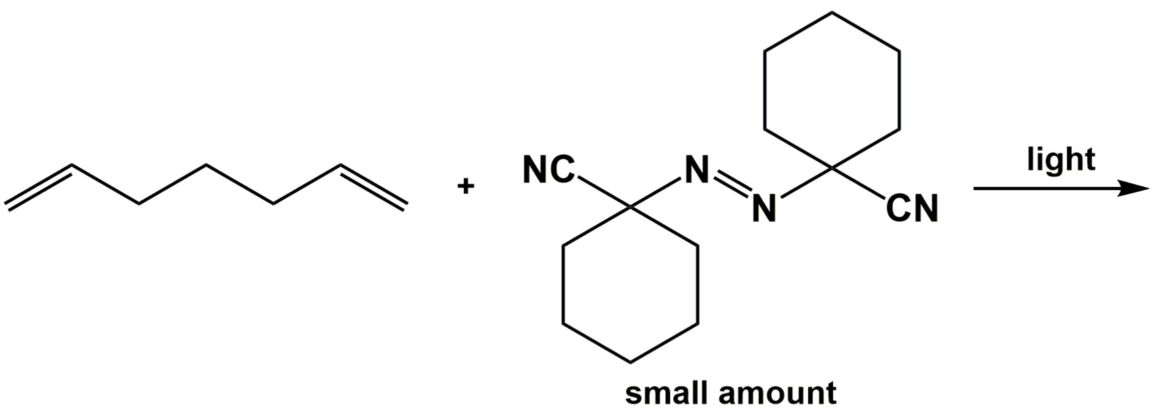
Worksheet Question #13 – GOOD QUESTION

Which of the following reactions produces a branched polymer?

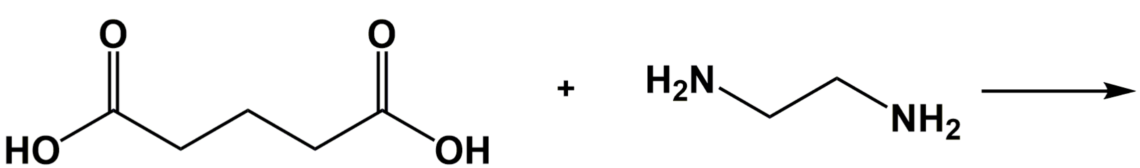
A.



B.



C.



D. Both A + B

E. Both A + C

Unit 6
Gases

Learning Objectives

After mastering this unit you will be able to:

- Use the ideal gas law to calculate changes in the conditions of pure gases and gas mixtures.
- Describe the difference between ideal and real gases, with reference to the postulates of the kinetic molecular theory of gases.
- Use the van der Waals equation to calculate temperature, pressure, volume and number of moles of real gases.

Useful Constants

Pressure

1 atm = 760 mmHg = 760 Torr = 101325 Pa

1 bar = 100000 Pa = 0.986923 atm

Gas constant

$$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 62.37 \text{ L torr mol}^{-1} \text{ K}^{-1}$$

Convert R

Pressure is often reported in a variety of different units.

1 atm = 760 mmHg = 760 Torr = 101325 Pa

100000 Pa = 1 bar

In SI units, the molar gas constant is R= 8.314 J mol^{-1} K^{-1}

Work through the conversion of R to **L atm mol^{-1} K^{-1}** and **L torr mol^{-1} K^{-1}**

Ideal Gas Law (PV = nRT)

Generally gases at high temperatures and low pressures can be described by the ideal gas law.

A gas that follows this relationship is known as an ideal gas.

$$PV = nRT$$

P = Pressure
V = Volume
n = number of moles
R = gas constant
T = Temperature in K

Unless told otherwise in CHEM 154 assume all gases behave ideally.

Clicker Question

A 5.00 L container of unknown gas at 25.0 °C has a pressure of 2.45 atm. The mass of the gas is 32.1 g. What gas is in the container?

$PV = nRT$ $\quad n = \frac{PV}{RT} = 0.5006\ \text{mol}$

$\text{molar mass} = \frac{32.1\text{g}}{0.5006\ \text{mol}} \Rightarrow$ e

a) Cl_2

b) F_2

c) NO_2

d) SO_3

e) SO_2

1 atm = 760 mmHg = 760 Torr = 101325 Pa;

100000 Pa = 1 bar

R = 0.08206 L atm mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1}
= 62.37 L torr mol^{-1} K^{-1}

STP: T = 273.15 K (0 Celsius) , P = 1 atm

Clicker Question

A 50.0 mL canister of Freon-12 (CF_2Cl_2) was heated in boiling water (100.0 °C) until the canister burst. If the canister was not defective, and had a burst rating of 102.05 atm, what minimum amount of Freon-12 was in the canister, assuming no volume change before bursting?

a) 9.63 g
b) 11.5 g
c) 20.2 g
d) 27.5 g
e) 75.0 g

1 atm = 760 mmHg = 760 Torr = 101325 Pa;

100000 Pa = 1 bar

R = 0.08206 L atm mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1} = 62.37 L torr mol^{-1} K^{-1}

STP: T = 273.15 K (0 Celsius) , P = 1 atm

$PV = nRT$

$$\frac{(102.05\ \text{atm})(50\text{mL})}{R\ (100 + 273.15)} = n$$

mass = $n \times$ molar mass

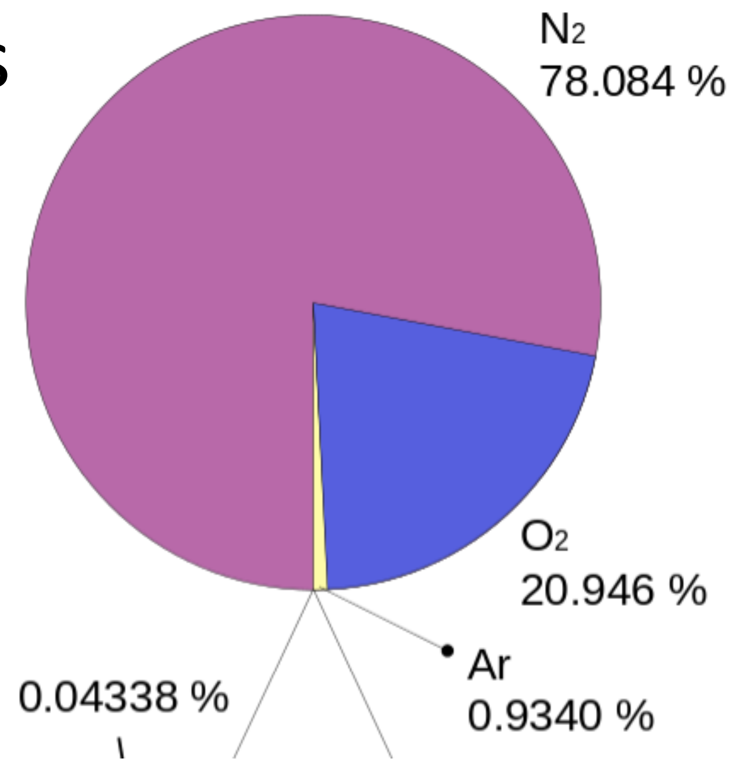
Dalton's Law of Partial Pressures

For a mixture of gases in a container of volume V, the total pressure is the sum of the partial pressures of each gas.

Partial pressure: pressure a gas would exert if it were alone.

$P_{total} = P_1 + P_2 + P_3 + ...$

$P_{total} V = (n_1 + n_2 + n_3 + ...) RT$



Mole fraction

The mole fraction (x) is the ratio of the number of moles of a given component in a mixture to the total number of moles of the mixture

$$x_1 = \frac{n_1}{n_{total}} = \frac{n_1}{n_1 + n_2 + n_3 + \cdots}$$

$$x_1 = \frac{n_1}{n_{total}} = \frac{\frac{P_1 V}{RT}}{\frac{P_{total} V}{RT}}$$

Consequently for ideal gases,

$$x_1 = \frac{n_1}{n_{total}} = \frac{P_1}{P_{total}}$$

$$= \frac{P_1 \cancel{V}}{\cancel{RT}} \times \frac{\cancel{RT}}{P_{total} \cancel{V}}$$

$$= \frac{P_1}{P_{total}}$$

Mole fraction will always be between 0 and 1.

V and T have to be the same in order to cancel.

Clicker Question

A mixture consisting of 4.9 g CO and 8.5 g SO_2, two atmospheric pollutants, exerts a pressure of 0.761 atm when placed in a sealed container. What is the partial pressure of the SO_2 in this mixture?

a) 0.13 atm
b) 0.18 atm
c) 0.33 atm
d) 0.43 atm

1 atm = 760 mmHg = 760 Torr = 101325 Pa;

100000 Pa = 1 bar

R = 0.08206 L atm mol^{-1} K^{-1} = 8.314 J mol^{-1} K^{-1} = 62.37 L torr mol^{-1} K^{-1}

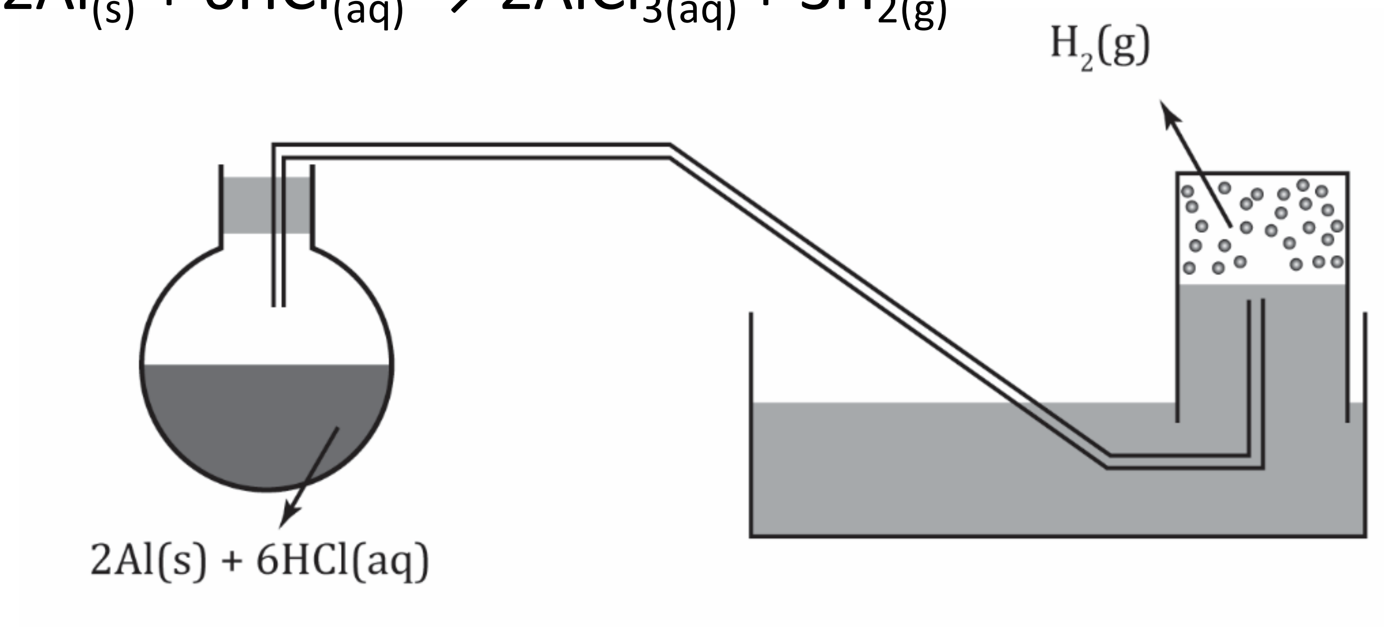
STP: T = 273.15 K (0 Celsius) , P = 1 atm

Worksheet Question #2

The reaction of aluminum with HCl produces hydrogen gas:

35.5 mL of H_2 is collected in a sealed container over water at 26 °C and the pressure is measured to be 755 mmHg, how many moles of H_2 were produced? (The vapour pressure of water at 26 °C is 25.2 mmHg).

$$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$



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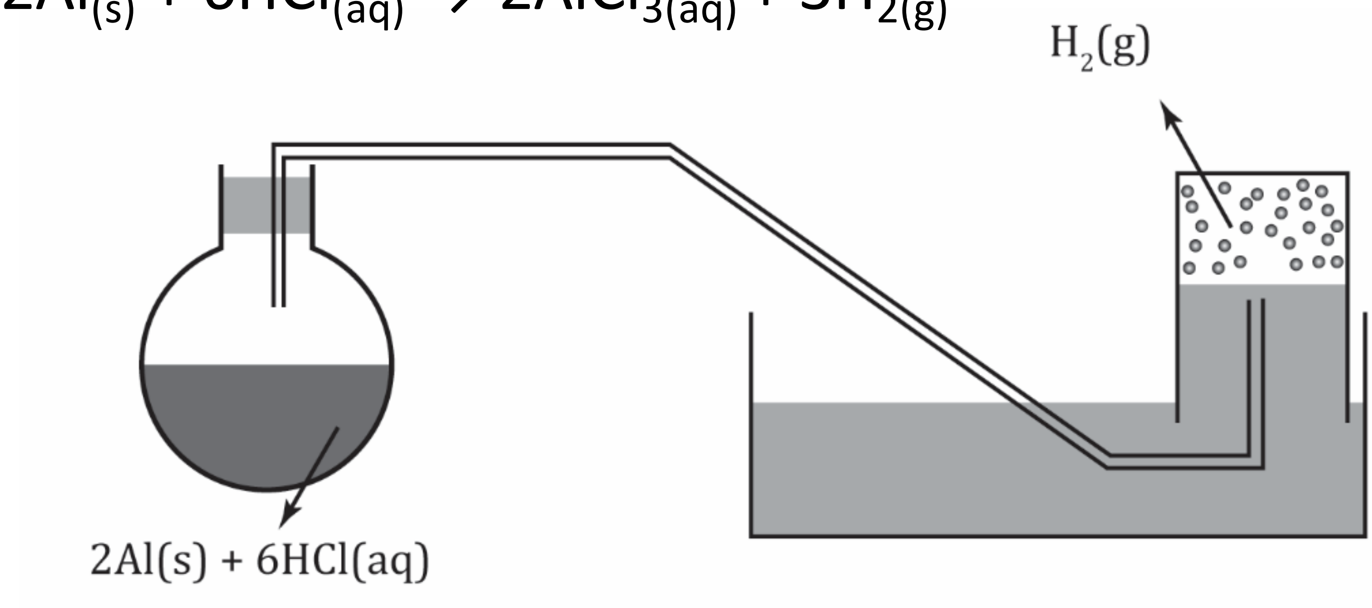
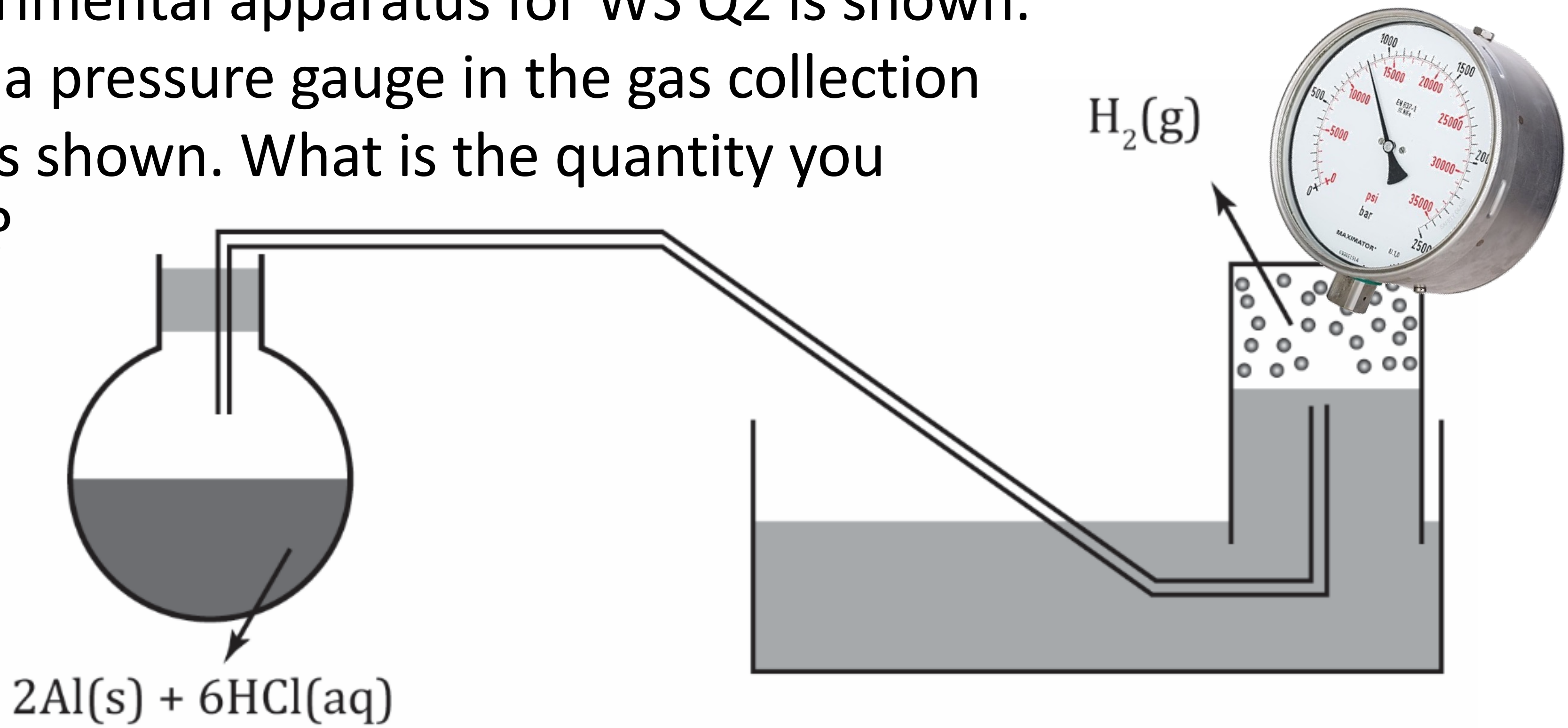


Clicker

The experimental apparatus for WS Q2 is shown. You have a pressure gauge in the gas collection volume as shown. What is the quantity you measure?



A. Total pressure
B. Pressure of the H_2 gas evolved
C. H_2O vapour pressure
D. Atmospheric pressure
E. Unrelated to the experiment, why are you doing this?