NAME (Print): _____

EID _____

SIGNATURE: _____

Chemistry 320M/328M
Dr. Brent Iverson
2nd Midterm
October 22, 2026

Please print the first three letters of your last name in the three boxes

Please Note: Please take your time. We are giving you three hours to take this exam even though it is really a one hour exam. The idea is to give you enough time to show us what you know, not how fast you can draw structures. Please take all the time you need to draw the best possible structures that you can! Do not be surprised if you are comfortable leaving the exam long before 9 PM. That is to be expected!

In this class students may not wear, access or use smart devices, artificial intelligence (AI) tools, or any other hand-written or external source of information or assistance during examinations.

This applies regardless of whether the device is actively being used or whether any use is observed: **Simply wearing a smart device during a quiz or exam constitutes a violation of this policy,** even if the student does not interact with it and is not seen doing so. Smart devices include, but are not limited to, smartphones, smartwatches, smart glasses, tablets, earbuds or other connected audio devices, and any other electronic device capable of storing, transmitting, receiving, or accessing information.

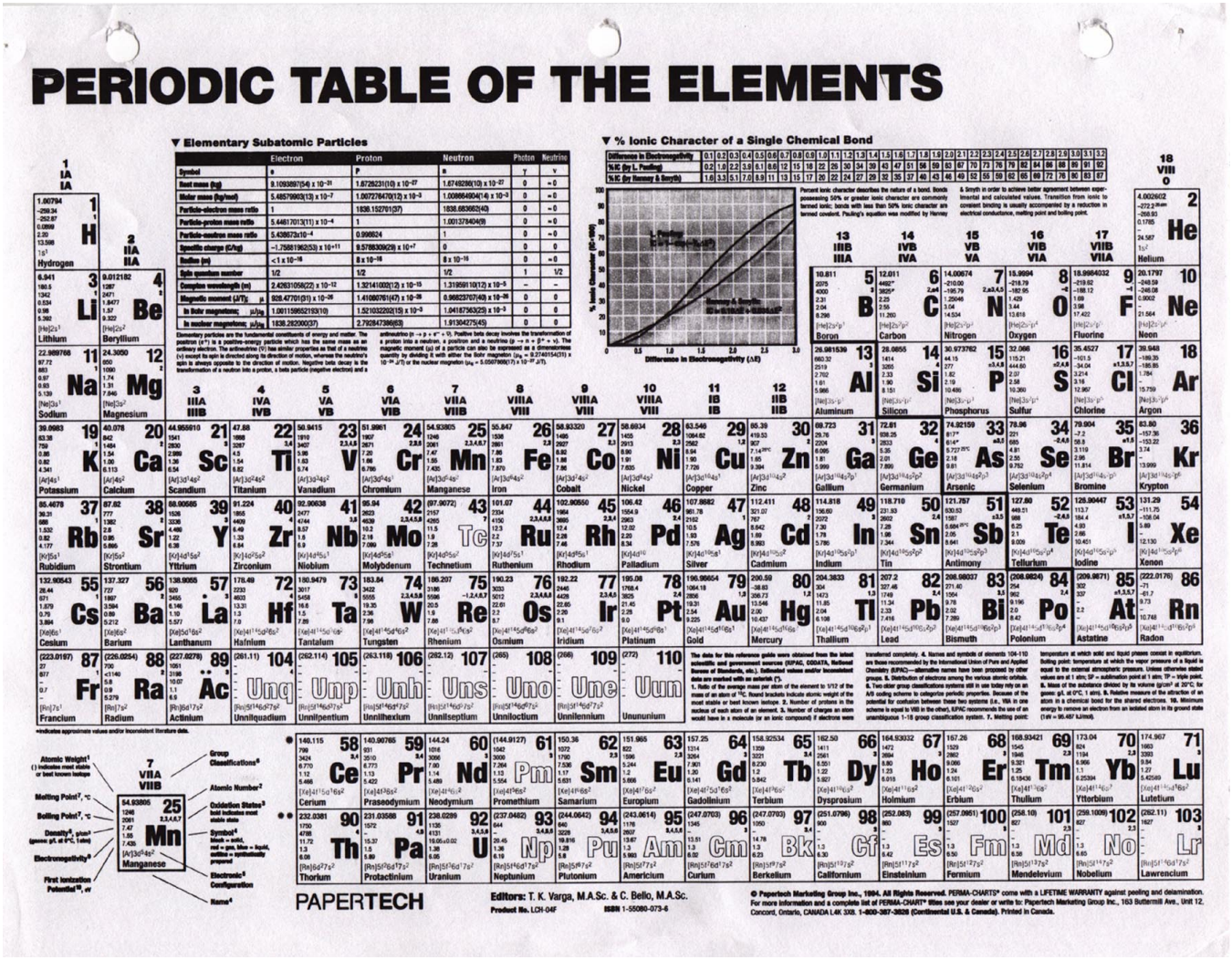
Student Honor Code

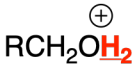
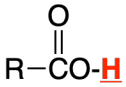
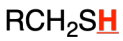
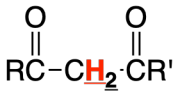
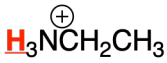
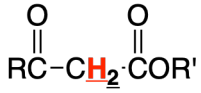
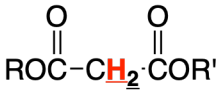
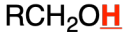
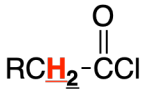
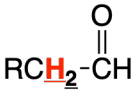
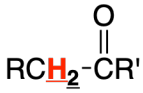
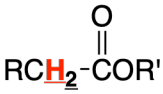
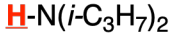
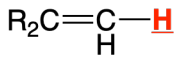
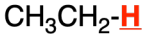
I pledge, as a member of The University of Texas at Austin community, to do my work honestly, respectfully, and through the intentional pursuit of learning and scholarship.

1. I pledge to be honest about what I create and to acknowledge what I use that belongs to others.
2. I pledge to value the process of learning in addition to the outcome, while celebrating and learning from mistakes.
3. This code encompasses all the academic and scholarly endeavors of the University community.

_____

(Your Signature)

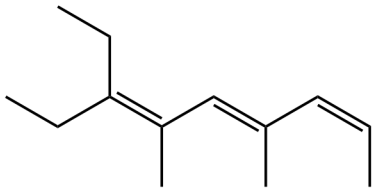


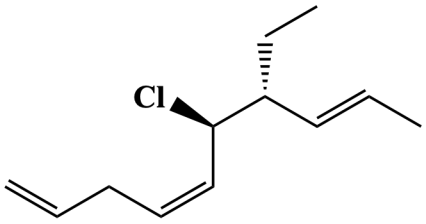
Compound		pK_a
Hydrochloric acid		-7
Protonated alcohol		-2
Hydronium ion		-1.7
Carboxylic acids		3-5
Thiols		8-10
Ammonium ion		9.2
β-Dicarbonyls		10
Primary ammonium		10.5
β-Ketoesters		11
β-Diesters		13
Water		15.7
Alcohols		15-19
Acid chlorides		16
Aldehydes		18-20
Ketones		18-20
Esters		23-25
Terminal alkynes		25
LDA		40
Terminal alkenes		44
Alkanes		51

Signature_____ Pg 1 _____(20)

1. (2 pts) What is the most important question in organic chemistry?

2. (12 pts) Write an acceptable IUPAC name for the following two molecules. Where appropriate, use E and Z or R and S.



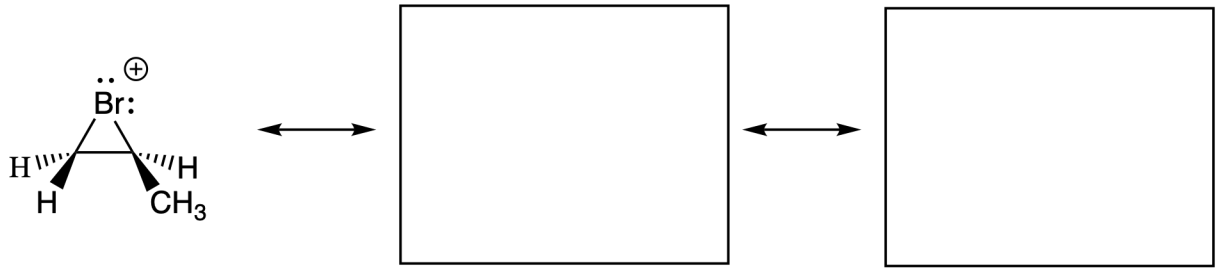


3. (6 pts) Draw the structure that corresponds to the following name:

(4*S*,2*Z*,5*E*)-7,7-dibromo-4,5-diethyl-3-methyl-2,5-nonadiene

4. (9 pts) Amides are best represented as the hybrid of three contributing structures. Draw the second and third important contributing structures in the spaces provided, including all lone pairs and formal charges. For the two structures on the left in each problem, **use arrows to indicate the movement of electrons to give the structures you drew.** You might want to read these directions again to make sure you know what we want.

5. (7 pts**)** Draw the two other most important contributing structures for the bromonium ion. You do NOT need to draw arrows on any of the structures for this problem. **Because this is a mechanism type question, use wedges and dashes to indicate stereochemistry, write "racemic" if appropriate, draw all lone pairs and formal charges. Fill in the circle under the contributing structure that makes the most important (i.e. major) contribution to the overall resonance hybrid.**



○ **Most important (major)** ○ **Most important (major)** ○ **Most important (major)**

6. (24 pts) For set of molecules, one is more stable (lower in energy) because of one or more principles we have discussed. Fill in the circle to indicate which molecule is the more or most stable. Then fill in the circle next to the letter corresponding to the principle or principles (yes there can be more than one!) that explain(s) why the molecule you circled is more stable.

A. Steric Strain B. Angle Strain C. Torsional Strain D. The inductive effect

E. Hyperconjugation F. Delocalization of a charge over more atoms G. Delocalization of pi electron density over more than two atoms ("pi-way")

H. Greater s-character of the orbital containing an electron pair on a negatively-charged atom I. The negative charge is on a more electronegative element J. The negative charge is on a larger atom

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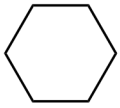
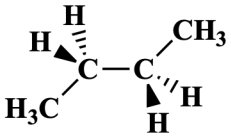


◯ More Stable

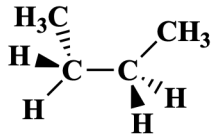
◯ More Stable

The molecule you indicated is more/ most stable upon primarily considering:

◯A. ◯B. ◯C. ◯D. ◯E.
◯F. ◯G. ◯H. ◯I. ◯J.

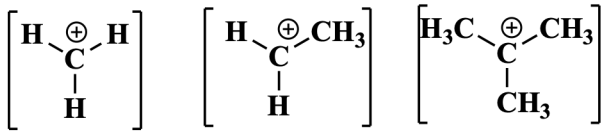


◯ More Stable



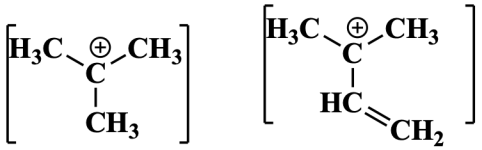
◯ More Stable

◯A. ◯B. ◯C. ◯D. ◯E.
◯F. ◯G. ◯H. ◯I. ◯J.



◯ Most Stable ◯ Most Stable ◯ Most Stable

◯A. ◯B. ◯C. ◯D. ◯E.
◯F. ◯G. ◯H. ◯I. ◯J.

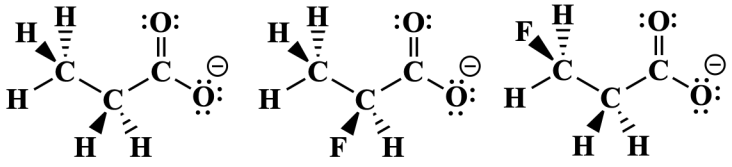


◯ More Stable ◯ More Stable

◯A. ◯B. ◯C. ◯D. ◯E.
◯F. ◯G. ◯H. ◯I. ◯J.

◯ Most Stable ◯ Most Stable ◯ Most Stable

◯A. ◯B. ◯C. ◯D. ◯E.
◯F. ◯G. ◯H. ◯I. ◯J.



◯ Most Stable ◯ Most Stable ◯ Most Stable

◯A. ◯B. ◯C. ◯D. ◯E.
◯F. ◯G. ◯H. ◯I. ◯J.

7. (26 pts) Fill in the circle to indicate the word that best completes these sentences describing mechanims for alkene reactions you have learned..

In mechanisms, arrows are used to indicate the movement of ◯ electrons ◯ atoms

Arrows always start at an electron ◯ source ◯ sink **and always point toward an electron** ◯ source ◯ sink.

In the mechanisms we have seen so far:

The pi bonds of alkenes have been an electron ◯ source ◯ sink .

Carbocations have been an electron ◯ source ◯ sink .

The lone pair of electrons on water have been an electron ◯ source ◯ sink .

A halonium ion intermediate has been an electron ◯ source ◯ sink .

Because a halonium ion can only be attacked from the side behind the halogen atom, the products will always have ◯ anti ◯ syn **stereochemistry.**

Because of the cyclic osmate ester intermediate, the products of the reaction involving OsO_4 ("Ozzy Osbourne") will always have ◯ anti ◯ syn **stereochemistry.**

Due to the four-membered ring transition state, the reactions involving BH_3 will give products with ◯ Markovnikov ◯ non-Markovnikov **regiochemistry and** ◯ anti ◯ syn **stereochemistry.**

The only reaction intermediate we have learned about that can rearrange is a ◯ halonium ion ◯ cabocation **intermediate.**

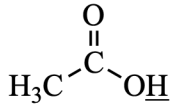
The hydrogenation reaction involves reacting H_2 with an appropriate metal surface. Both H atoms react so fast that the products of the reaction have ◯ anti ◯ syn **stereochemistry.**

8. (2 pts each) Below are a series of definitions. From the list at the bottom of the page, write the letter, i.e. (A), (C), etc., of the word that corresponds best to the following definitions (note you will not use all the letters from down below, there are more words than definitions) I filled in the first one for you.

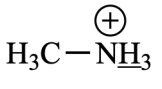
Letter of the word best fitting the definition	
U	Is a great way to stay healthy and deal with the stress of midterms.
____	Contains an electron rich source for a bond forming process. Analogous to a Lewis base
____	Contains an electron deficient atom that serves as the electron sink in a bond forming process (Analogous to a Lewis acid) or possesses a weak bond that breaks to make a stable ion or fragment.
____	Predicts that when HCl adds to an alkene, the Cl atom ends up on the more highly substituted C atom.
____	Describes when a more electronegative element withdraws electron density through sigma bonds.
____	A stabilizing interaction that involves the overlap of adjacent sigma bonds with an empty 2p orbital.
____	A natural product molecule from plants that can be thought of as being derived from various combinations of isoprene units.
____	Involves a net gain of electrons and replaces C-O or pi bonds with C-H bonds..
____	Involves a net loss of electrons and replaces C-H bonds with C-O bonds or pi bonds
____	Stereoisomers that are not enantiomers.

Addition reaction (A)	Anti (B)	Cis (C)	Diastereomers (D)	Electrophile (E)	Enantiomer (F)
Hyperconjugation (G)	Inductive effect (H)	Lewis Acid (I)	Lewis Base (J)	Markovnikov's Rule (K)	
Meso compound (L)	Nucleophile (M)	Oxidation reaction (N)	Reduction reaction (O)		
Regiochemistry (P)	Stereochemistry (Q)	Syn (R)	Terpene (S)	Trans (T)	Running (U)

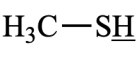
9. (15 pts) Complete the following four structures by adding appropriate numbers of lone pair electrons, H atoms, and formal charges to the atoms in the boxes. You must adjust your answers to indicate the predominant species at each indicated pH value. (You do not have to add anything such as H atoms to atoms not drawn in the boxes.) This problem is testing your understanding of the relationship of protonation state to pH to pKa values for certain functional groups we have discussed. Next, in the space provided, write the overall charge on each structure at the indicated pH. For your reference, here are the relevant pK_a values:



$pK_a = 4.76$

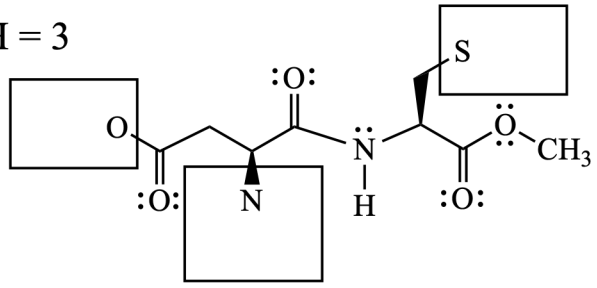


$pK_a = 10.64$



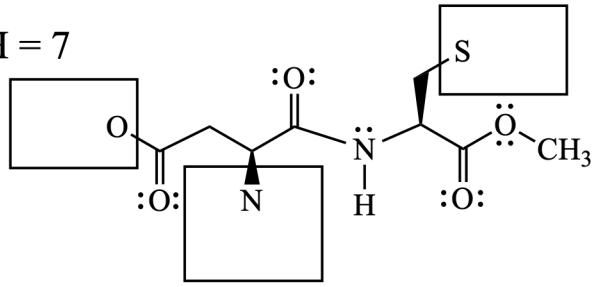
$pK_a = 10$

pH = 3



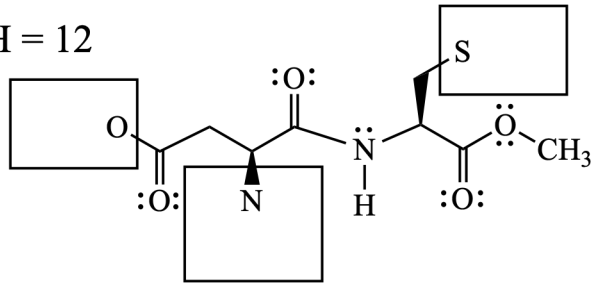
Total charge on molecule:_____

pH = 7



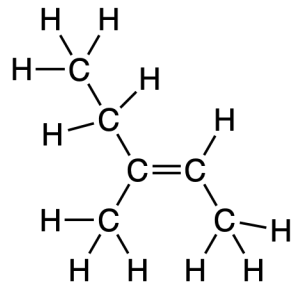
Total charge on molecule:_____

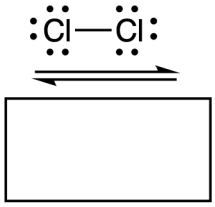
pH = 12

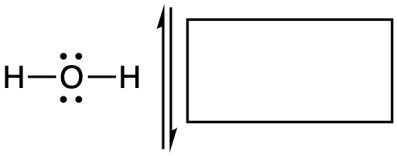


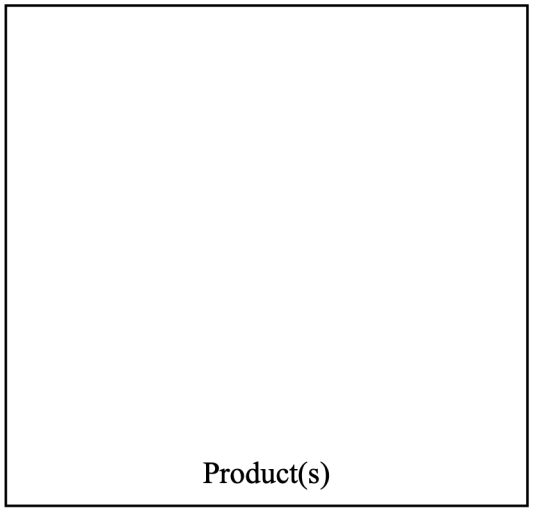
Total charge on molecule:_____

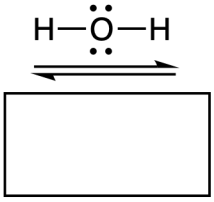
10. (24 pts) Complete the mechanism for the following reaction of an alkene with Cl_2 in the presence of H_2O. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> the products for each step. **YOU ONLY NEED TO DRAW ONE STEREOISOMER OF A CHIRAL INTERMEDIATE OR PRODUCT (using wedges and dashes as appropriate) IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. In the boxes provided under/beside the arrows, write which of the 4 most common mechanistic elements describes each step (make a bond, break a bond, etc.). <u>Be sure to notice the questions at the end.</u>**









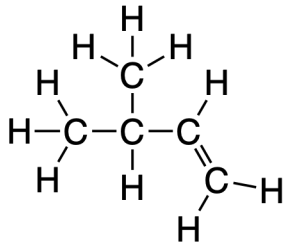


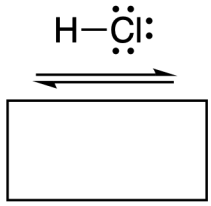
(2 pts) How many total stereoisomers are produced by this reaction? _____

(2 pts) As the reaction proceeds, does the pH of the solution increase, decrease, or stay the same?

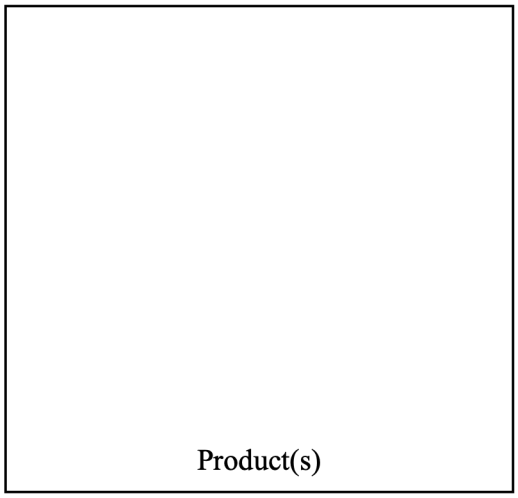
_____

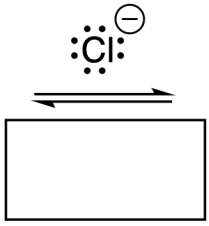
11. (22 pts) Complete the mechanism for the following reaction of an alkene with HCl that includes a rearrangement. **Be sure to show arrows to indicate movement of <u>all</u> electrons, write <u>all</u> lone pairs, <u>all</u> formal charges, and <u>all</u> the products for each step.** Remember, I said <u>all</u> the products for each step. **YOU ONLY NEED TO DRAW ONE STEREOISOMER OF A CHIRAL INTERMEDIATE OR PRODUCT (using wedges and dashes as appropriate) IF A NEW CHIRAL CENTER IS CREATED IN AN INTERMEDIATE OR PRODUCT, MARK IT WITH AN ASTERISK AND LABEL THE MOLECULE AS "RACEMIC" IF APPROPRIATE. In the boxes provided under/beside the arrows, write which of the 4 most common mechanistic elements describes each step (make a bond, break a bond, etc.). <u>Be sure to notice the questions at the end.</u>**





Rearrangement





(2 pts) How many total stereoisomers are produced by this reaction? _____

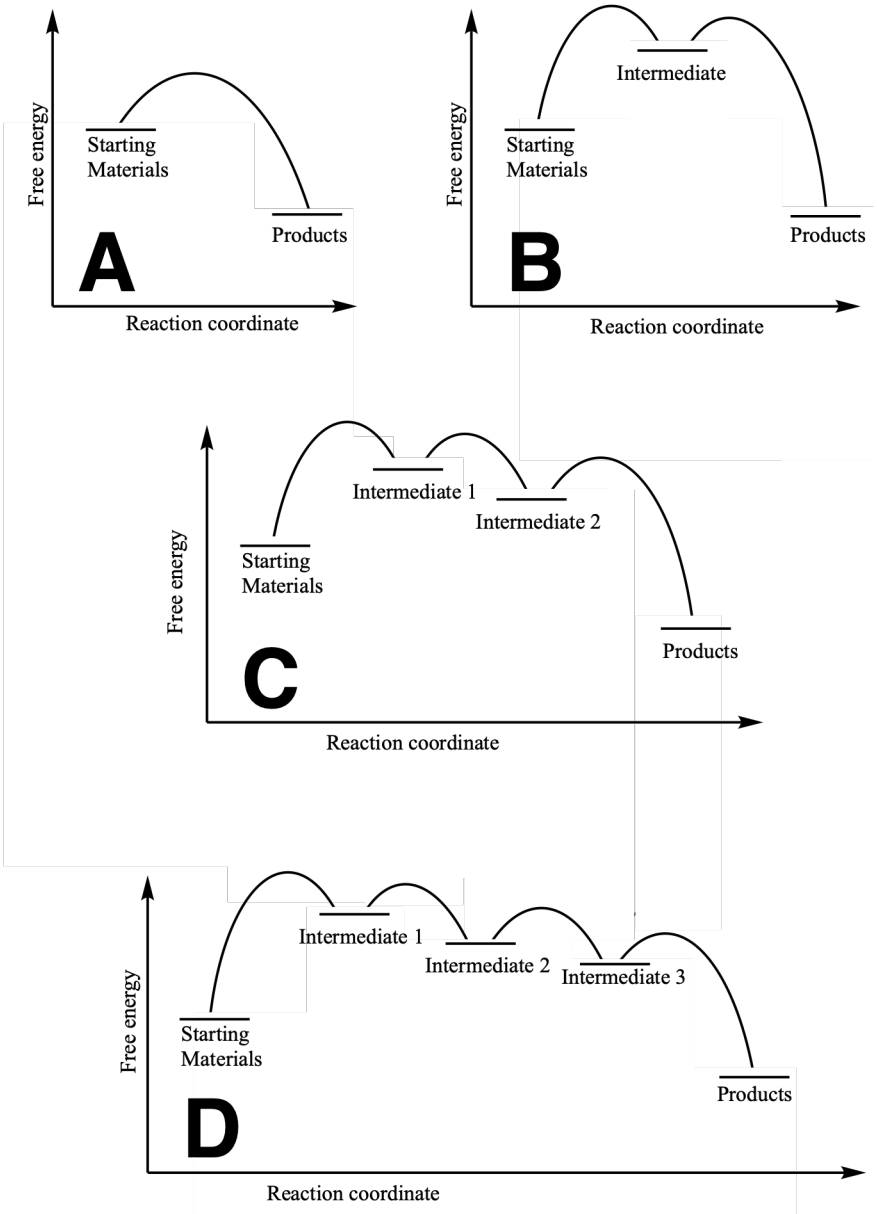
(2 pts) Look as the energy diagrams on page 9. Write the letter of the one that best describes the above mechanism.

_____

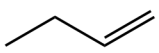
(2 pts) As the reaction proceeds, does the pH of the solution increase, decrease, or stay the same?

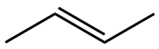
_____

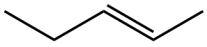
These energy diagrams refer to the mechanism your completed in problem 11 on page 8. This page is not graded.

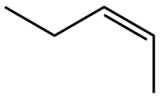


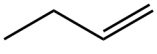
12. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. Draw only the predominant regioisomer product or products and please remember that you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry as appropriate. When a racemic mixture is formed, you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES.

A.  **HBr** →

B.  **H_2O** → **H_2SO_4 (catalytic amount)**

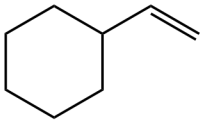
C.  **Br_2** →

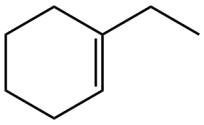
D.  **Cl_2** →

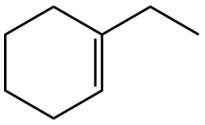
E.  **Br_2** → **H_2O**

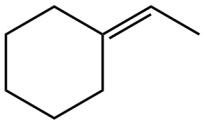
12. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. Draw only the predominant regioisomer product or products and please remember that you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry when appropriate. When a racemic mixture is formed, you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES.

This first one rearranges, draw only the rearranged product(s)

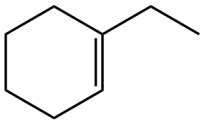
F.  $\xrightarrow[\text{(catalytic)}]{\mathbf{H_2O}\ /\ \mathbf{H_2SO_4}}$

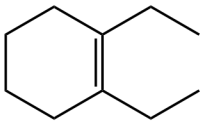
G.  $\xrightarrow[\mathbf{2.\ H_2O_2\ /\ NaOH}]{\mathbf{1.\ BH_3}}$

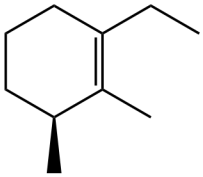
H.  $\xrightarrow[\mathbf{2.\ NaHSO_3\ /\ H_2O}]{\mathbf{1.\ OsO_4}}$

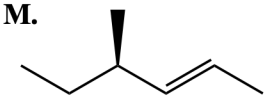
I.  $\xrightarrow[\mathbf{2.\ H_2O_2\ /\ NaOH}]{\mathbf{1.\ BH_3}}$

12. (3 or 5 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. Draw only the predominant regioisomer product or products and please remember that you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry when appropriate. When a racemic mixture is formed, you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES.

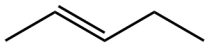
J.  $\xrightarrow[H_2O]{Br_2}$

K.  $\xrightarrow[Pt°]{H_2}$

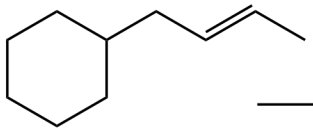
L.  $\xrightarrow[Pt°]{H_2}$

M.  $\xrightarrow{Cl_2}$

12. (9 or 11 pts each) The following reactions all involve chemistry of alkenes. Fill in the box with the product(s) that are missing from the chemical reaction equations. Draw only the predominant regioisomer product or products if relevant and please remember that you must draw the structures of all the product stereoisomers using wedges and dashes to indicate stereochemistry as appropriate. When a racemic mixture is formed, you must write "racemic" under both structures EVEN THOUGH YOU DREW BOTH STRUCTURES.

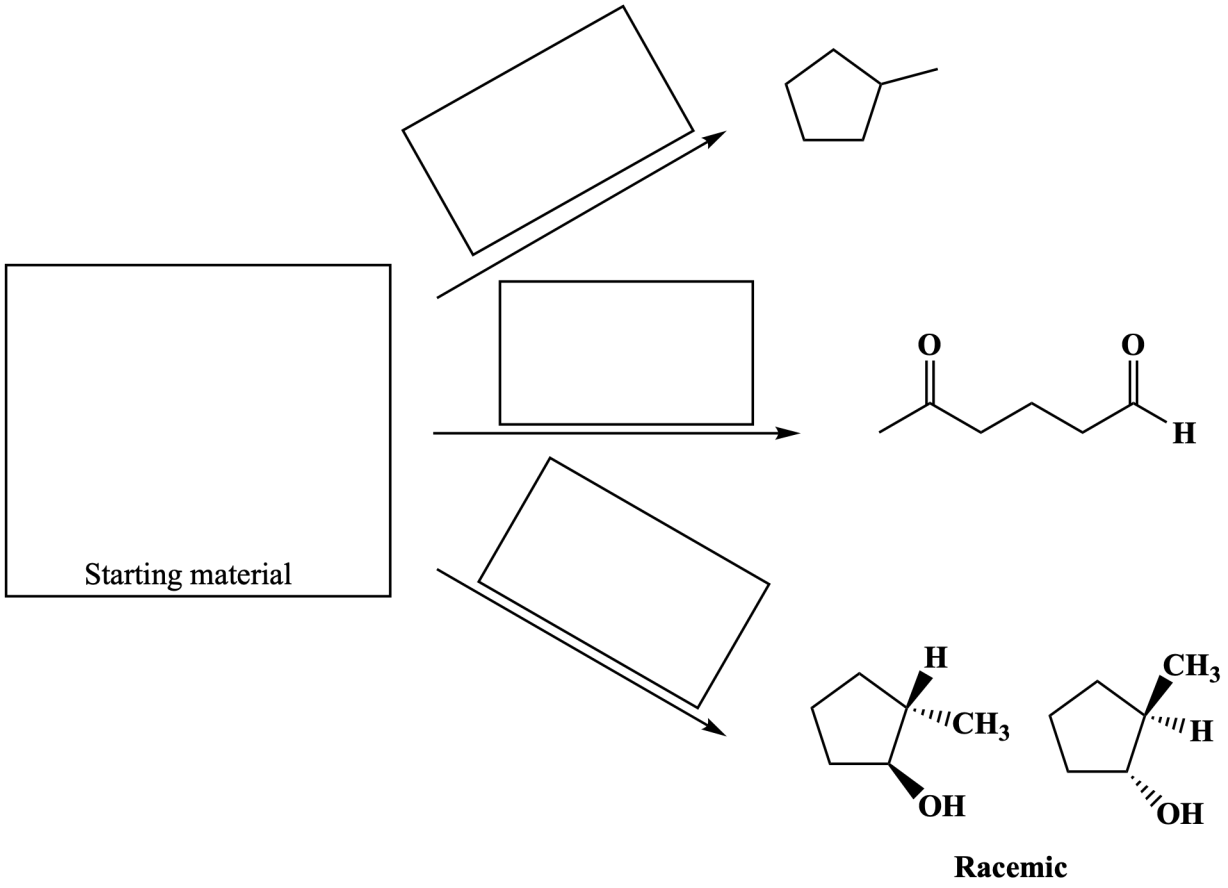
N.  **1. BH_3** → **2. H_2O_2 / NaOH**

(2 pts) Will the product mixture you drew to the right rotate the plane of plane polarized light? _____

O.  **Br_2** → **H_2O**

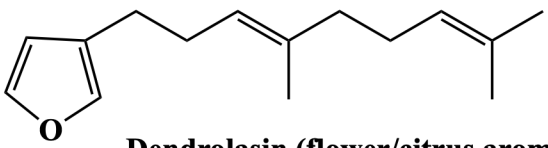
(2 pts) Will the product mixture you drew to the right rotate the plane of plane polarized light? _____

13. (9 pts total) It is important to think about reactions in both directions. To solve synthesis questions you will need to work backwards from a target molecule. All three reactions shown below use the same starting material. **Write the structure of that starting material in the box provided on the left, then write the appropriate reagents in the boxes over each arrow. All** observed products are shown for each reaction.



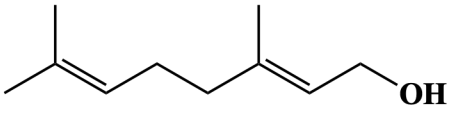
Racemic

14. (4 pts total) For each terpene structure, fill in the circle that correctly indicates how many isoprene units are present in the molecule.



Dendrolasin (flower/citrus aroma)

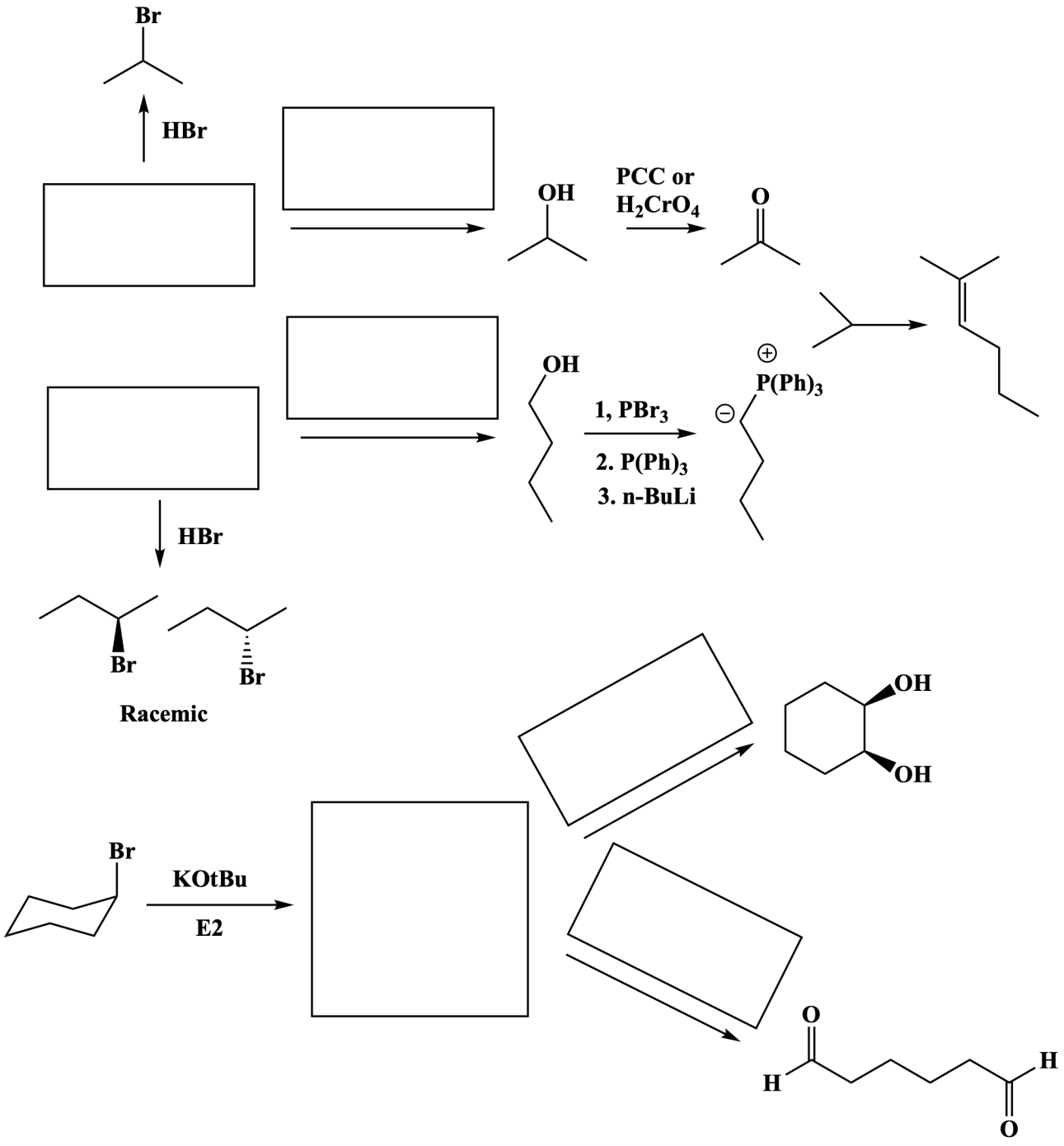
- ○ **Contains 1 isoprene unit**
- ○ **Contains 2 isoprene units**
- ○ **Contains 3 isoprene units**
- ○ **Contains 4 isoprene units**
- ○ **Contains 5 isoprene units**



Geraniol (flower aroma)

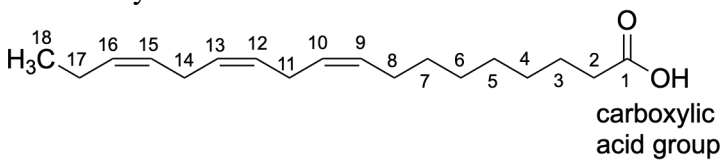
- ○ **Contains 1 isoprene unit**
- ○ **Contains 2 isoprene units**
- ○ **Contains 3 isoprene units**
- ○ **Contains 4 isoprene units**
- ○ **Contains 5 isoprene units**

15. (13 pts total) The point of organic chemistry is synthesis, the conversion of simpler molecules to more complicated ones with enhanced structure and function. Each reaction you are learning should be thought of as a "tool" that allows you to create a desired type of molecule. These tools can be used in an almost infinite number of combinations to create truly interesting molecules. **In the boxes provided, draw the structures of the molecule indicated in this synthesis scheme. FOR THIS ONE, IF STEREOISOMERS ARE CREATED YOU MUST DRAW THEM ALL USING WEDGES AND DASHES. And you must write "racemic" when appropriate. In addition, in the boxes beside the arrows, write the reagents needed to accomplish the reaction indicated.** You will not recognize all of this chemistry, but by the time you finish O Chem II next spring you will!!



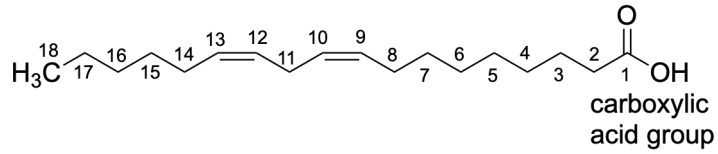
16. (20 pts total) Here is the MCAT style "apply what you know" question based on information from the Linus Pauling Institute's web page. A surprising majority of alkenes in biology are *Z* (cis). These *Z* alkenes are important for everything from being components of membranes in animals to key components of how vision works. In fact, *E* (trans) alkenes are relatively rare in nature.

16.1 For the following molecule, fill in the appropriate circle to indicate the IUPAC name. Note that an 18 carbon chain is referred to as "octadeca" and the carboxylic acid group on the end is indicated by the ending "oic acid". An important point is that according to IUPAC, carboxylic acids are always numbered with a "1" at the carboxylic acid carbon.



◯ (9*Z*,12*Z*,15*Z*)-10,13,16-octadecatrienoic acid
◯ (9*Z*,12*Z*,15*Z*)-9,12,15-octadecatrienoic acid
◯ (9*Z*,12*Z*)-9,12-octadecadienoic acid
◯ (9*Z*,12*Z*)-10,13-octadecadienoic acid

16.2 For the following molecule, fill in the appropriate circle to indicate the IUPAC name.

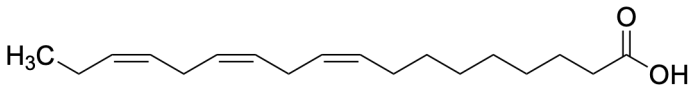


◯ (9*Z*,12*Z*,15*Z*)-10,13,16-octadecatrienoic acid
◯ (9*Z*,12*Z*,15*Z*)-9,12,15-octadecatrienoic acid
◯ (9*Z*,12*Z*)-9,12-octadecadienoic acid
◯ (9*Z*,12*Z*)-10,13-octadecadienoic acid

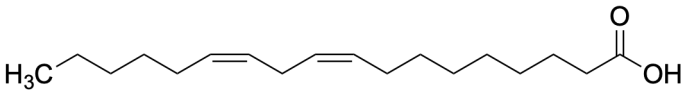
16.3 I am not sure I can explain why, but biochemists never use IUPAC nomenclature. Instead, they use their own system of naming molecules that is based on historical common names, which are not systematic. The common names, used in your biochemistry class for the two molecules I drew above are **α-linolenic acid** (ALA) for the molecule in problem 16.1 and **linoleic acid** (LA) for the molecule in problem 16.2. In addition, these double bonds are never referred to as "Z", they are only called "cis" by biochemists. Furthermore, an alkane molecule with only sp^3 carbons is referred to as "saturated", because each carbon is "saturated" with the maximum number of H atoms. An alkene molecule with a C=C bond is therefore referred to as "unsaturated" because the pi bond replaces bonds to H atoms. Finally, long chain carboxlic acids are referred to as "fatty acids" by biochemists, because they are found in animal fat. Putting all of this together, the above two molecules are called "polyunsaturated fatty acids" by biochemists.

Believe it or not, there is even a third type of nomeclature used for these same molecules!?! This third nomeclature system is based on a paper published in 1964 and is used in the food and food supplement industries. You have probably heard of the omega fatty acids from fish oil. Omega fatty acids belong to the class of polyunsaturated fatty acids (PUFA), which are defined by the presence of two or more Z (cis) double bonds, just like the molecules we have been talking about. Now you know what all of that means! This type of classification actually makes sense because when grouped this way as particular omega fatty acids, the grouped molecules all function the same way in our bodies.

Here is how the "omega" nomeclature works: You assign "1" as the methyl group end (the so-called "omega" end) of the molecule, *not the carboxlic acid end like IUPAC*. With that in mind, you identify the position of the first double bond, counted from the methyl group. **Fill in the circles to indicate how our two molecules, α-linolenic acid and linoleic acid, are classified in the omega system of nomenclature.**



◯ Omega-3 fatty acid (ω3)
◯ Omega-4 fatty acid (ω4)
◯ Omega-5 fatty acid (ω5)
◯ Omega-6 fatty acid (ω6)



◯ Omega-3 fatty acid (ω3)
◯ Omega-4 fatty acid (ω4)
◯ Omega-5 fatty acid (ω5)
◯ Omega-6 fatty acid (ω6)

16.4 α-Linolenic acid and linoleic acid cannot be synthesized by humans because the enzymes needed to introduce a double bond at the omega-6 or omega-3 position are absent, so both must be supplied by the diet and are therefore classified as essential fatty acids. Beyond serving as fuel, these fatty acids act to regulate inflammation, vascular tone and platelet function among other things. Because the omega-6 or omega-3 fatty acids compete for the same functions, the proportion in which the two families are supplied shapes how that shared function occurs. A balanced diet provides both, typically through plant oils, nuts, seeds and oily fish, rather than relying on omega-6 or omega-3 fatty acids alone. **According to this paragraph, why are α-linolenic acid and linoleic acid classified as <u>essential</u> fatty acids?**

◯ They are the only fatty acids that can be incorporated into membrane phospholipids.

◯ Humans lack the enzymes required to introduce a double bond at the omega-6 or omega-3 position.

◯ They cannot be oxidized for energy and must therefore be obtained preformed from the diet.

◯ They are synthesized in the liver but cannot be exported to peripheral tissues in sufficient quantities.

I hope everyone is thinking more about exercise and keeping in shape. Good mental health and good physical health go hand-in-hand. Getting some exercise on a continual basis is the best way to get a positive new outlook! In other words, the absolute best thing you can do for yourself is to go for a walk or run with friends. The weather is now perfect. If you have been hesitating, please give it a try. There are a growing number of neuroscience studies that are uncovering just how this works. Even as the science is advancing, please believe me, this does work.