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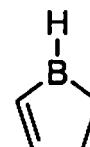
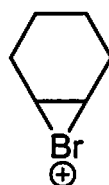
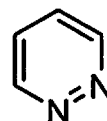
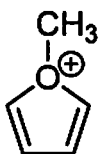
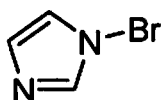
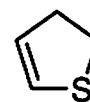
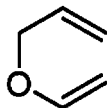
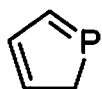
If you do not want your graded exam placed in the box outside my office, then please check here

(1-10) are True/False. (10pts)

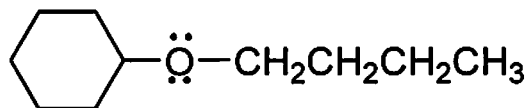
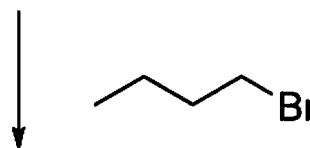
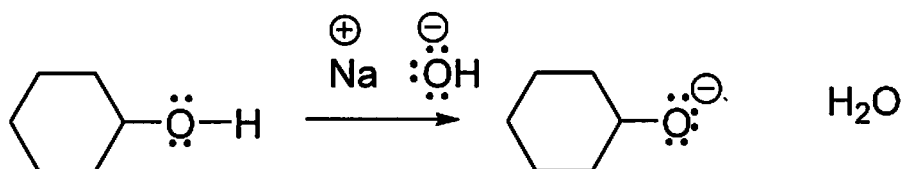
- 1) Woodward and Hoffmann created the rules that predict whether pericyclic reactions proceed thermally or photochemically.
- 2) Normal ethers are unreactive under neutral and basic conditions.
- 3) *Thermodynamic control* means the major product will be the one that is most stable.
- 4) Nitrobenzene undergoes EAS reactions slower than Benzene.
- 5) *Unsymmetrical* epoxides give products with *different* regiochemistry with basic ring opening compared to acidic ring opening.
- 6) For buta-1,3-diene, the lowest energy conformation is the *s-cis* conformation.
- 7) Aromatic species have very stable, delocalized π bonding, and undergo substitution reactions preferentially to addition reactions.
- 8) This is a bonding molecular orbital:


The diagram shows three p-orbitals arranged horizontally. Each orbital is represented by two lobes, one above and one below a central horizontal line. All three orbitals are in phase, with the top lobes shaded and the bottom lobes unshaded, representing a bonding molecular orbital.
- 9) Oxetane is a six membered ring with one oxygen.
- 10) "Conjugation" means three or more, consecutive, aligned and interacting p orbitals.
- 11) Draw 4-Chlorophenol in line angle (*stick figure*) form. (2pts)

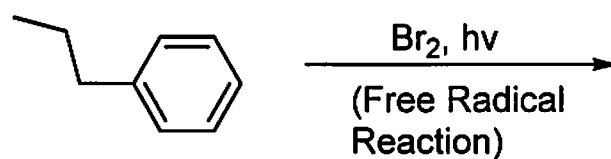
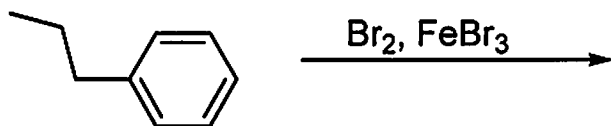
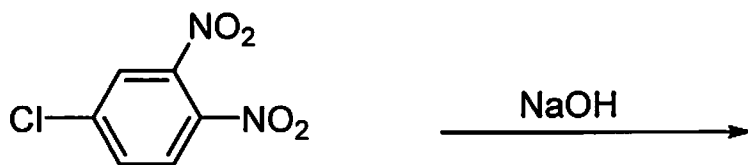
12) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the species are planar). (9pts)



13) (4pts) Draw in the curly arrows to complete this mechanism.

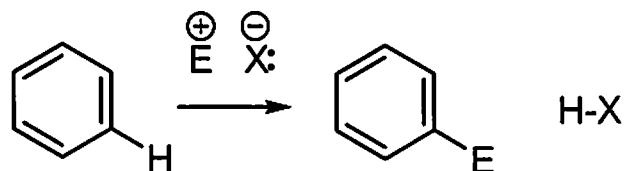


14) Predict the major products in the following reactions (if you believe **no reaction** will occur, indicate this!), paying attention to regio/stereo-chemistry where applicable. (5x2=10pts)

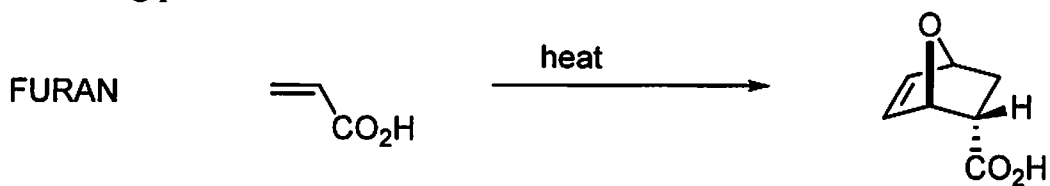


15) (1+1pts) Using the polygon rule, show that Benzene is aromatic.

16) Write the mechanism (i.e. curly arrows) for the following generic Electrophilic Aromatic Substitution. (*You do not need to draw all the resonance structures of the intermediate sigma complex*). (4pts)

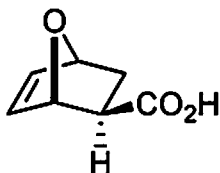


17) (1+2=3pts). Furan reacts in a Diels Alder reaction to generate the following product.



a) Draw the structure of Furan.

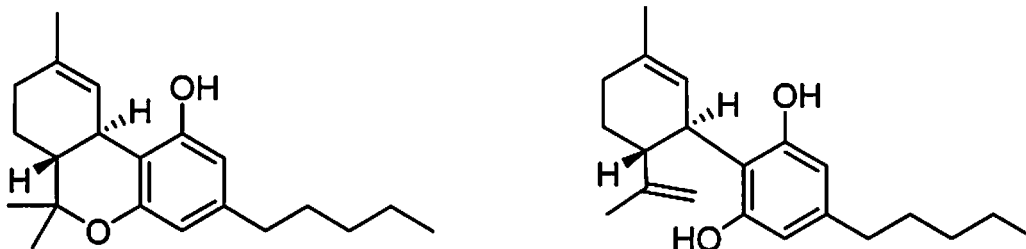
b) The following isomeric product is NOT generated in this reaction. Very briefly explain the difference in the products, and justify why one is produced (and the other is not).



18) “Cannabinoid” refers to compounds that act on cannabinoid receptors in cells that alter neurotransmitter release in the brain. Cannabis (Marijuana) contains at least 100 different cannabinoids.

The primary psychoactive molecule in cannabis is **THC**, which creates the “high” or “stoned” feeling, whereas recent interest has increased in the molecule **CBD** which has zero psychoactivity (i.e. does not get you “high”), but does have positive effects on anxiety, cognition, inflammation, PTSD and pain relief.

The structures of the two above cannabinoids are shown below:

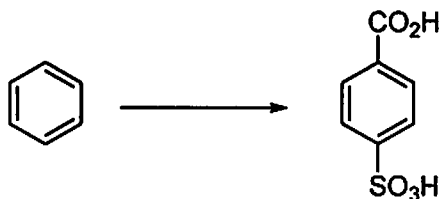


a) THC and CBD are *isomers*. What molecular formula (e.g. $C_xH_yO_z$) do they have in common? (1pt)

b) THC has an **ether** functional group, whereas CBD does not. Circle one of the above structures to identify which isomer is CBD. (1pt)

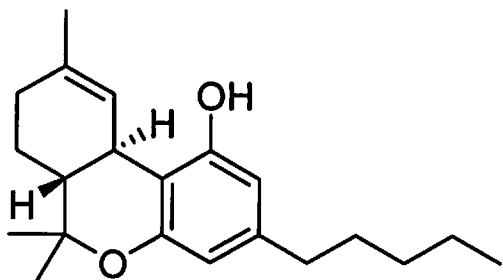
c) Indicate with an arrow, the **aromatic** ring in THC. (1pt)

19) Provide the reagents to achieve the following transformation (but be aware that both the carboxylic acid, and sulfonic acid groups are **META** directing). (3pts)



****BONUS Points (up to 2 points)****

How many chiral centers are in the cannabinoid structure below?



Circle the most acidic Hydrogen in this molecule.

hydrogen 1 H	beryllium 4 Be	scandium 21 Sc	yttrium 39 Y	lanthanum 57 La	actinium 89 Ac	helium 2 He
lithium 3 Li	boron 5 B	titanium 22 Ti	zirconium 40 Zr	cerium 58 Ce	thorium 90 Th	neon 10 Ne
sodium 11 Na	carbon 6 C	vanadium 23 V	niobium 41 Nb	praseodymium 59 Pr	protactinium 91 Pa	argon 18 Ar
potassium 19 K	nitrogen 7 N	chromium 24 Cr	molybdenum 42 Mo	neodymium 60 Nd	uranium 92 U	krypton 36 Kr
calcium 20 Ca	oxygen 8 O	manganese 25 Mn	technetium 43 Tc	promethium 61 Pm	neptunium 93 Np	xenon 54 Xe
strontium 38 Sr	fluorine 9 F	iron 26 Fe	ruthenium 44 Ru	samarium 62 Sm	plutonium 94 Pu	radon 86 Rn
rubidium 37 Rb	neon 10 Ne	cobalt 27 Co	rhodium 45 Rh	europium 63 Eu	americium 95 Am	
cesium 55 Cs	boron 5 B	nickel 28 Ni	palladium 46 Pd	gadolinium 64 Gd	curium 96 Cm	
barium 56 Ba	carbon 6 C	copper 29 Cu	silver 47 Ag	terbium 65 Tb	berkelium 97 Bk	
francium 87 Fr	nitrogen 7 N	zinc 30 Zn	cadmium 48 Cd	dysprosium 66 Dy	californium 98 Cf	
	oxygen 8 O	gallium 31 Ga	indium 49 In	holmium 67 Ho	einsteinium 99 Es	
	fluorine 9 F	germanium 32 Ge	tin 50 Sn	erbium 68 Er	fermium 100 Fm	
	neon 10 Ne	arsenic 33 As	antimony 51 Sb	thulium 69 Tm	madamium 101 Md	
	argon 18 Ar	selenium 34 Se	tellurium 52 Te	ytterbium 70 Yb	noibium 102 No	
	potassium 19 K	bromine 35 Br	iodine 53 I			
	calcium 20 Ca	cadmium 48 Cd	mercury 80 Hg			
	strontium 38 Sr	tin 50 Sn	lead 82 Pb			
	barium 56 Ba	thallium 81 Tl	unnilquadium 114 Uuq			
	cesium 55 Cs	lead 82 Pb				
	francium 87 Fr	thallium 81 Tl				
		unnilseptium 117 Uus				
		unniloctium 118 Uuo				
		unnilnonium 119 Uun				
		ununium 120 Uu				
		unununium 121 Uuu				
		ununbium 122 Uub				
		ununtrium 123 Uut				
		ununquadium 124 Uuq				
		ununpentium 125 Uup				
		ununhexium 126 Uuh				
		ununseptium 127 Uus				
		ununoctium 128 Uuo				
		ununnonium 129 Uun				
		ununnilium 130 Uun				
		ununundecium 131 Uuu				
		ununbium 132 Uub				
		ununtrium 133 Uut				
		ununquadium 134 Uuq				
		ununpentium 135 Uup				
		ununhexium 136 Uuh				
		ununseptium 137 Uus				
		ununoctium 138 Uuo				
		ununnonium 139 Uun				
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		ununundecium 141 Uuu				
		ununbium 142 Uub				
		ununtrium 143 Uut				
		ununquadium 144 Uuq				
		ununpentium 145 Uup				
		ununhexium 146 Uuh				
		ununseptium 147 Uus				
		ununoctium 148 Uuo				
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		ununundecium 151 Uuu				
		ununbium 152 Uub				
		ununtrium 153 Uut				
		ununquadium 154 Uuq				
		ununpentium 155 Uup				
		ununhexium 156 Uuh				
		ununseptium 157 Uus				
		ununoctium 158 Uuo				
		ununnonium 159 Uun				
		ununnilium 160 Uun				
		ununundecium 161 Uuu				
		ununbium 162 Uub				
		ununtrium 163 Uut				
		ununquadium 164 Uuq				
		ununpentium 165 Uup				
		ununhexium 166 Uuh				
		ununseptium 167 Uus				
		ununoctium 168 Uuo				
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		ununtrium 173 Uut				
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		ununpentium 175 Uup				
		ununhexium 176 Uuh				
		ununseptium 177 Uus				
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		ununnonium 179 Uun				
		ununnilium 180 Uun				
		ununundecium 181 Uuu				
		ununbium 182 Uub				
		ununtrium 183 Uut				
		ununquadium 184 Uuq				
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		ununquadium 194 Uuq				
		ununpentium 195 Uup				
		ununhexium 196 Uuh				
		ununseptium 197 Uus				
		ununoctium 198 Uuo				
		ununnonium 199 Uun				
		ununnilium 200 Uun				

* Lanthanide series


** Actinide series

lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	neodymium 60 Nd	promethium 61 Pm	samarium 62 Sm	europium 63 Eu	gadolinium 64 Gd	terbium 65 Tb	dysprosium 66 Dy	holmium 67 Ho	erbium 68 Er	thulium 69 Tm	ytterbium 70 Yb
actinium 89 Ac	thorium 90 Th	protactinium 91 Pa	uranium 92 U	neptunium 93 Np	plutonium 94 Pu	americium 95 Am	curium 96 Cm	berkelium 97 Bk	californium 98 Cf	einsteinium 99 Es	fermium 100 Fm	madamium 101 Md	noibium 102 No
138.91	140.12	140.91	144.24	148	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
174.97	178.49	180.95	183.84	186.21	190.23	192.22	195.08	196.97	200.59	204.38	207.2	208.98	209
1221	1261	1261	1261	1261	1261	1261	1271	1271	1271	1271	1257	1259	1259

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(1-10) are True/False. (10pts)

- 1) Woodward and Hoffmann created the rules that predict whether pericyclic reactions proceed thermally or photochemically. T
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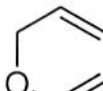
11) Draw 4-Chlorophenol in line angle (*stick figure*) form. (2pts)



12) Indicate which of the following molecules are aromatic, non-aromatic or anti-aromatic. (Assume all the species are planar). (9pts)



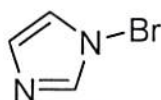
N.A



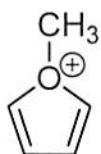
N.A



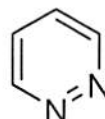
N.A



Aromatic



Aromatic



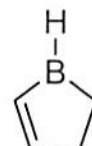
Aromatic



Anti
Aromatic

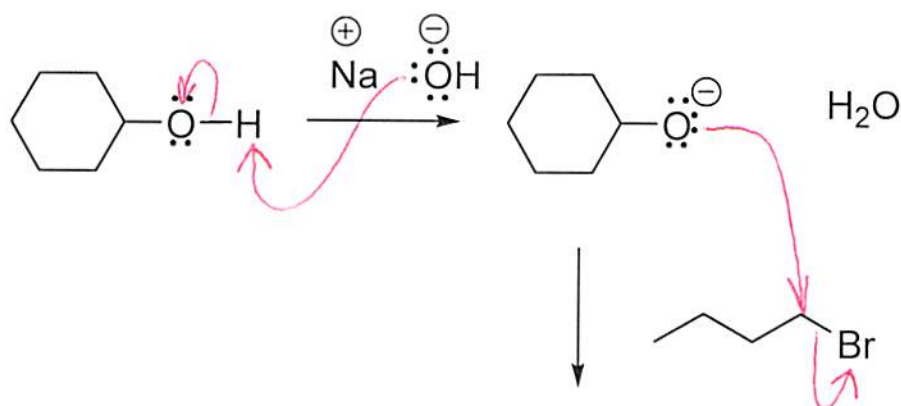


N.A.



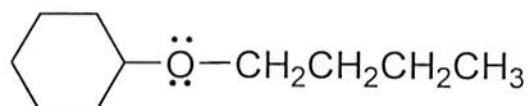
N.A

13) (4pts) Draw in the curly arrows to complete this mechanism.

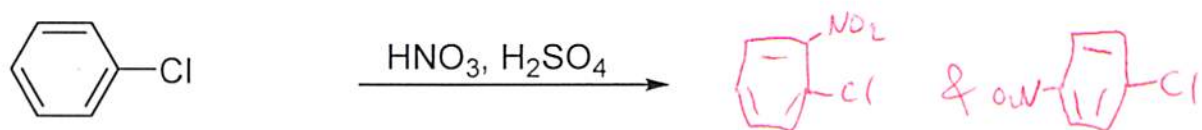
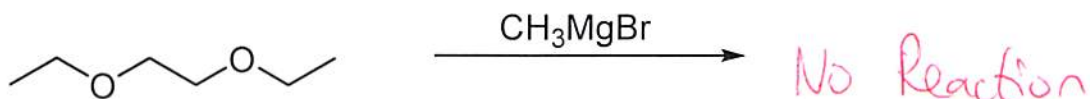
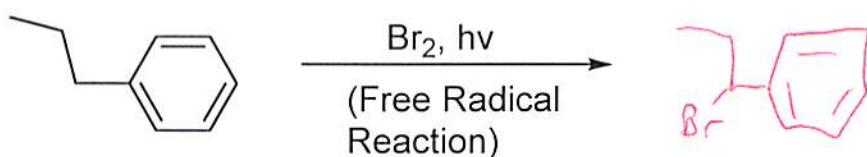
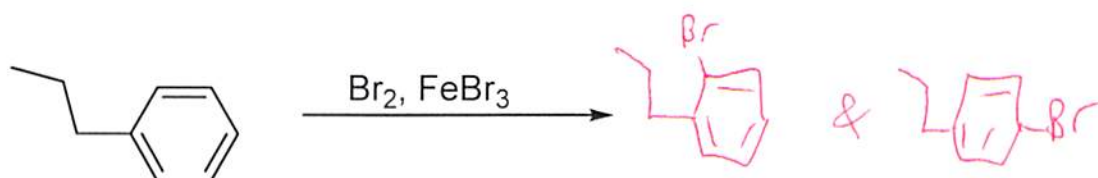
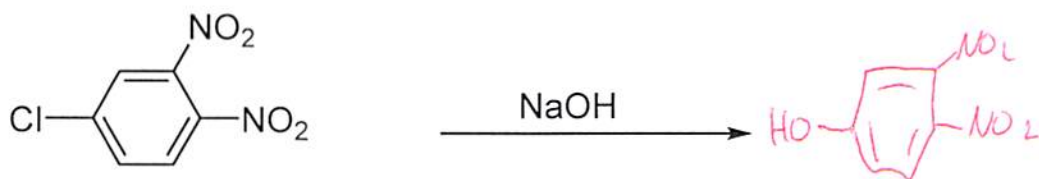


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Na

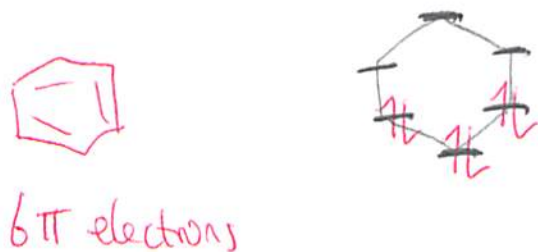
\ominus
Br



14) Predict the major products in the following reactions (if you believe **no reaction** will occur, indicate this!), paying attention to regio/stereochemistry where applicable. (5x2=10pts)

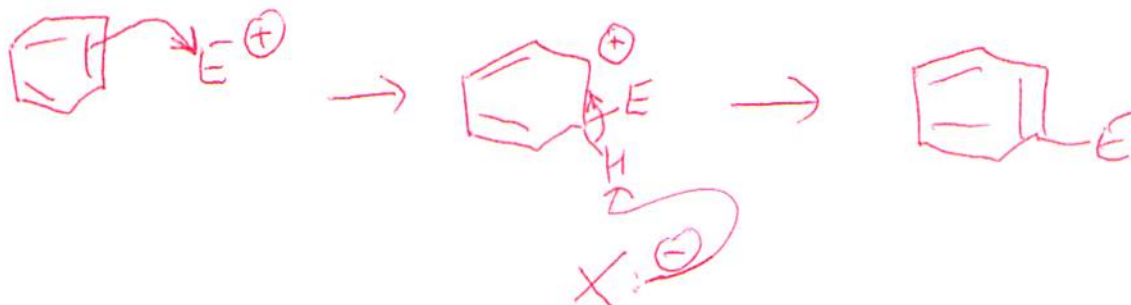
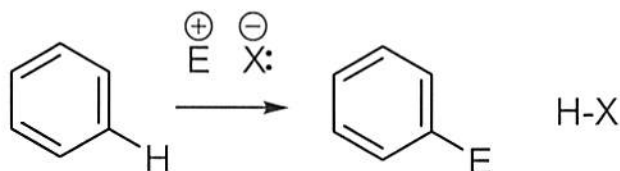


15) (1+1pts) Using the polygon rule, show that Benzene is aromatic.

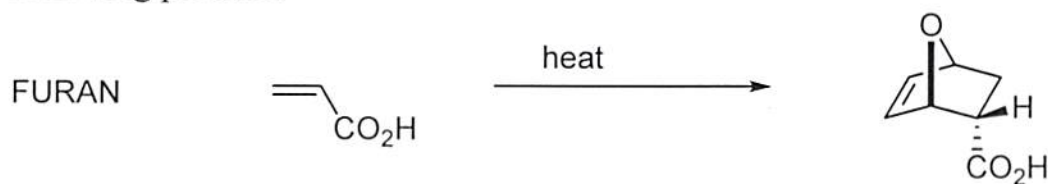


Closed bonding shell \Rightarrow Aromatic.

16) Write the mechanism (i.e. curly arrows) for the following generic Electrophilic Aromatic Substitution. (You do **not** need to draw all the resonance structures of the intermediate sigma complex). (4pts)



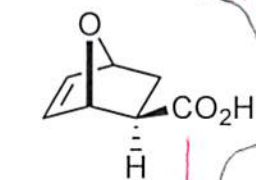
17) (1+2=3pts). Furan reacts in a Diels Alder reaction to generate the following product.



a) Draw the structure of Furan.



b) The following isomeric product is NOT generated in this reaction. Very briefly explain the difference in the products, and justify why one is produced (and the other is not).



EXO

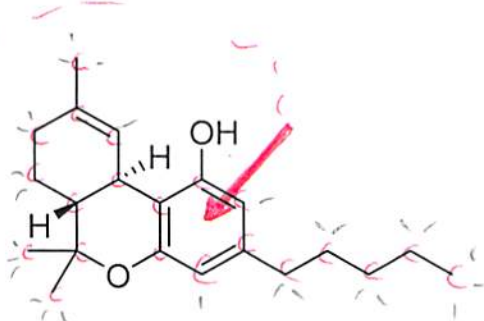
The difference is whether the $-CO_2H$ group is exo or endo.

The 'Endo Rule' states that if the dienophilic substituent has a π bond (like $-C(=O)-OH$) it will prefer to go endo due to favourable secondary orbital overlap.

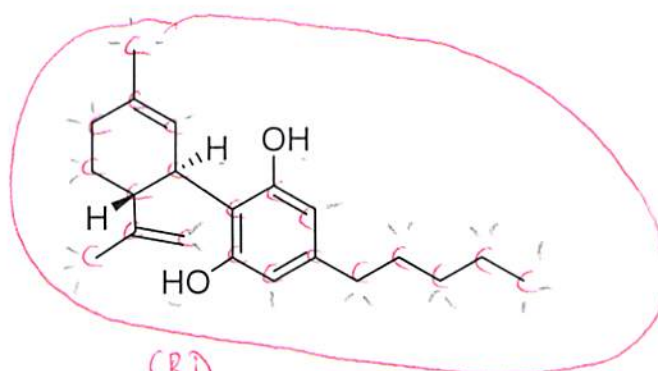
18) "Cannabinoid" refers to compounds that act on cannabinoid receptors in cells that alter neurotransmitter release in the brain. Cannabis (Marijuana) contains at least 100 different cannabinoids.

The primary psychoactive molecule in cannabis is **THC**, which creates the "high" or "stoned" feeling, whereas recent interest has increased in the molecule **CBD** which has zero psychoactivity (i.e. does not get you "high"), but does have positive effects on anxiety, cognition, inflammation, PTSD and pain relief.

The structures of the two above cannabinoids are shown below:



THC



CBD

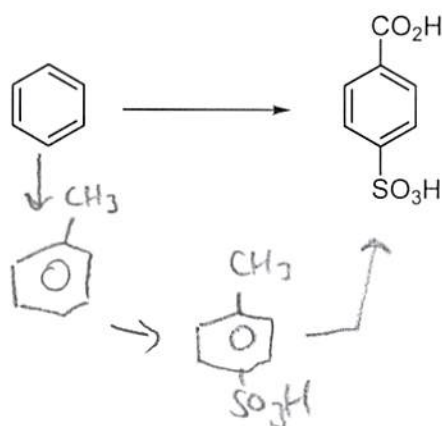
a) THC and CBD are *isomers*. What molecular formula (e.g. $C_xH_yO_z$) do they have in common? (1pt)



b) THC has an **ether** functional group, whereas CBD does not. Circle one of the above structures to identify which isomer is CBD. (1pt)

c) Indicate with an arrow, the **aromatic** ring in THC. (1pt)

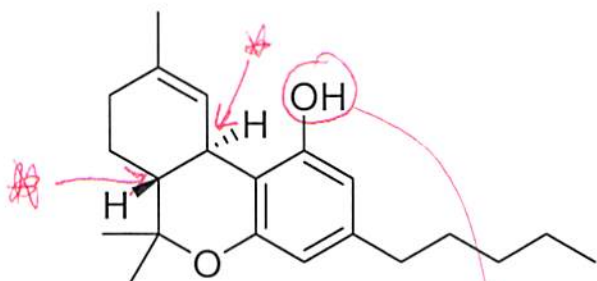
19) Provide the reagents to achieve the following transformation (but be aware that both the carboxylic acid, and sulfonic acid groups are META directing). (3pts)



- ① $CH_3Cl, AlCl_3$
- ② SO_3, H_2SO_4
- ③ $KMnO_4, NaOH; H_3O^+$

****BONUS Points (up to 2 points)****

How many chiral centers are in the cannabinoid structure below?



2

Circle the most acidic Hydrogen in this molecule.

Removal of this proton leads to -ve charge on oxygen which is resonance stabilized by the aromatic ring.