Second	Midterm	Exam
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Monday, February 21, 2022

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Name
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You may use model kits but no other material with chemical information without instructor approval.

Please do not use ipods or other music players.

hydrogen	ľ		15.5	95%	1550	5	15.75	6	1353	767	5000	100	950	767	650	160	1517 1	helium
1																		2
H																		He
1.0079																		4.0026
lithium	beryllium	1											boron	carbon	nitrogen	oxygen	fluorine	neon
3	_4												5	6	7	8	9	10
Li	Be												В	С	N	0	F	Ne
6.941	9.0122												10.811	12.011	14.007	15.999	18.998	20.180
sodium 11	magnesium 12												aluminium 13	silicon 14	phosphorus 15	sulfur 16	chlorine 17	argon 18
5990														20020		7473	1000	
Na	Mg												ΑI	Si	Р	S	CI	Ar
22.990	24.305												26.982	28.086	30.974	32.065	35.453	39.948
potassium 19	calcium 20		scandium 21	titanium 22	vanadium 23	chromium 24	manganese 25	iron 26	cobalt 27	nickel 28	copper 29	zinc 30	gallium 31	germanium 32	arsenic 33	selenium 34	bromine 35	krypton 36
															_			
K	( 3																	
1.	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.098	40.078		44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63,546	65.39	69.723	72.61	74.922	78.96	79.904	83.80
39.098 rubidium	40.078 strontium		44.956 yttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55,845 ruthenium	58,933 rhodium	58,693 palladium	63,546 silver	65,39 cadmium	69.723 indium	72.61 tin	74.922 antimony	78.96 tellurium	79.904 lodine	83.80 xenon
39,098 rubidium <b>37</b>	40.078 strontium 38		44.956 yttrium <b>39</b>	47.867 zirconium <b>40</b>	50.942 niobium <b>41</b>	51.996 molybdenum <b>42</b>	54.938 technetium <b>43</b>	55.845 ruthenium <b>44</b>	58,933 rhodium <b>45</b>	58.693 palladium 46	63,546 silver 47	65,39 cadmium <b>48</b>	69.723 Indium 49	72.61 tin <b>50</b>	74.922 antimony <b>51</b>	78.96 tellurium <b>52</b>	79.904	83.80 xenon <b>54</b>
39.098 rubidium	40.078 strontium		44.956 yttrium	47.867 zirconium	50.942 niobium	51.996 molybdenum	54.938 technetium	55,845 ruthenium	58,933 rhodium	58,693 palladium	63,546 silver 47	65,39 cadmium	69.723 indium	72.61 tin	74.922 antimony	78.96 tellurium	79.904 lodine	83.80 xenon
39.098 rubidium 37 <b>Rb</b> 85.468	40.078 strontium 38 Sr 87.62		44.956 yttrium 39 <b>Y</b> 88.906	47,867 zirconium 40 <b>Zr</b> 91,224	50.942 niobium 41 Nb 92.906	51.996 molybdenum 42 Mo 95.94	54.938 technetium 43 <b>TC</b> [98]	55.845 ruthenium 44 Ru 101.07	58.933 rhodium 45 <b>Rh</b> 102.91	58.693 palladium 46 Pd 106.42	63,546 silver 47 <b>Ag</b> 107,87	65,39 cadmium 48 Cd 112,41	69.723 Indium 49 In	72.61 tin 50 <b>Sn</b>	74.922 antimony 51 Sb 121.76	78.96 tellurium <b>52</b> <b>Te</b> 127.60	79.904 lodine 53	83.80 xenon 54 <b>Xe</b> 131.29
39,098 rubidium 37 <b>Rb</b> 85,468 caesium	40.078 strontium 38 <b>Sr</b> 87.62 barium	£7.70	44.956 yttrium 39 Y 88.906 lutetium	47.867 zirconium 40 Zr 91.224 hafnium	50.942 niobium 41 Nb 92.906 tantalum	51.996 molybdenum 42 Mo 95.94 tungsten	54.938 technetium 43 TC [98] rhenium	55.845 ruthenium 44 Ru 101.07 osmium	58.933 rhodium 45 <b>Rh</b> 102.91 iridium	palladium 46 Pd 106.42 platinum	63,546 silver 47 <b>Ag</b> 107,87 gold	65.39 cadmium 48 Cd 112.41 mercury	69.723 Indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead	74.922 antimony 51 Sb 121.76 bismuth	78,96 tellurium 52 Te 127.60 polonium	79.904 lodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon
39,098 rubidium 37 <b>Rb</b> 85,468 caesium 55	40.078 strontium 38 Sr 87.62 barium 56	57-70	44,956 yttrlum 39 Y 88,906 lutetium 71	47.867 zirconium 40 Zr 91.224 hafnium 72	50.942 niobium 41 Nb 92.906 tantalum 73	51.996 molybdenum 42 Mo 95.94 tungsten 74	54.938 technetium 43 TC [98] rhenium 75	55.845 ruthenium 44 Ru 101.07 osmium 76	58,933 rhodium 45 <b>Rh</b> 102,91 iridium 77	58,693 palladium 46 Pd 106,42 platinum 78	63.546 silver 47 <b>Ag</b> 107.87 gold 79	65,39 cadmium 48 Cd 112,41 mercury 80	69.723 Indium 49 In	72.61 tin 50 <b>Sn</b> 118.71 lead 82	74.922 antimony 51 <b>Sb</b> 121.76 bismuth 83	78.96 tellurium 52 <b>Te</b> 127.60 polonium 84	79.904 lodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39,098 rubidium 37 <b>Rb</b> 85,468 caesium	40.078 strontium 38 <b>Sr</b> 87.62 barium	57-70 <del>*</del>	44.956 yttrium 39 Y 88.906 lutetium	47.867 zirconium 40 Zr 91.224 hafnium	50.942 niobium 41 Nb 92.906 tantalum	51.996 molybdenum 42 Mo 95.94 tungsten	54.938 technetium 43 TC [98] rhenium	55.845 ruthenium 44 Ru 101.07 osmium	58.933 rhodium 45 <b>Rh</b> 102.91 iridium	palladium 46 Pd 106.42 platinum	63,546 silver 47 <b>Ag</b> 107,87 gold	65,39 cadmium 48 Cd 112,41 mercury 80	69.723 Indium 49 In 114.82 thallium	72.61 tin 50 Sn 118.71 lead	74.922 antimony 51 Sb 121.76 bismuth	78,96 tellurium 52 Te 127.60 polonium	79.904 lodine 53 126.90 astatine	83.80 xenon 54 Xe 131.29 radon
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55 <b>Cs</b> 132.91	40.078 strontium 38 Sr 87.62 barium 56 Ba 137.33	18090 1500000	44.956 yttrium 39 Y 88.906 lutetium 71 Lu 174.97	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95	51,996 molybdenum 42 MO 95,94 tungsten 74 W	54.938 technetium 43 TC [98] rhenium 75 Re 186.21	55,845 ruthenium 44 Ru 101.07 osmium 76 Os 190.23	58,933 rhodium 45 <b>Rh</b> 102,91 iridium 77 <b>Ir</b> 192,22	58,693 palladium 46 Pd 106.42 platinum 78 Pt 195.08	63,546 silver 47 <b>Ag</b> 107,87 gold 79 <b>Au</b> 196,97	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59	69.723 Indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2	74.922 antimony 51 <b>Sb</b> 121.76 bismuth 83	78.96 tellurium 52 <b>Te</b> 127.60 polonium 84	79.904 lodine 53 126.90 astatine 85	83.80 xenon 54 Xe 131.29 radon 86
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55 <b>Cs</b> 132.91 francium	40.078 strontlum 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44,956 yttrium 39 Y 88,906 lutetium 71 Lu 174,97 lawrendum	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51,996 molybdenum 42 Mo 95,94 tungsten 74 W 183,84 seaborgium	54,938 technetium 43 TC [98] thenium 75 Re 186.21 bohrium	55,845 ruthenium 44 Ru 101.07 osmium 76 Os 190.23 hassium	58,933 rhodlum 45 Rh 102,91 iridium 77 Ir 192,22 meitnerium	58,693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium	63,546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium	69,723 Indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 telurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 l 126.90 astatine 85 At	83.80 xenon 54 <b>Xe</b> 131.29 radon 86 <b>Rn</b>
39,098 rubidium 37 <b>Rb</b> 85,468 caesium 555 <b>Cs</b> 132,91 francium 87	40.078 strontlum 38 Sr 87.62 barium 56 Ba 137.33 radium 88	<del>×</del> 89-102	44,956 yttrium 39 Y 88,906 lutetium 71 Lu 174,97 lawrencium 103	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium 104	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium 105	51,996 molybdenum 42 Mo 95,94 tungsten 74 W 183,84 seaborgium 106	technetium 43 TC [98] rhenium 75 Re 186.21 bohrium 107	55.845 ruthenium 44 Ru 101.07 osmium 76 Os 190.23 hassium 108	58,933 rhodlum 45 Rh 102,91 iridium 77 Ir 192,22 meitnerium 109	58,693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium 110	63,546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium 112	69,723 Indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium 114	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 telurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 l 126.90 astatine 85 At	83.80 xenon 54 <b>Xe</b> 131.29 radon 86 <b>Rn</b>
39.098 rubidium 37 <b>Rb</b> 85.468 caesium 55 <b>Cs</b> 132.91 francium	40.078 strontlum 38 Sr 87.62 barium 56 Ba 137.33 radium	*	44,956 yttrium 39 Y 88,906 lutetium 71 Lu 174,97 lawrendum	47.867 zirconium 40 Zr 91.224 hafnium 72 Hf 178.49 rutherfordium	50.942 niobium 41 Nb 92.906 tantalum 73 Ta 180.95 dubnium	51,996 molybdenum 42 Mo 95,94 tungsten 74 W 183,84 seaborgium	54,938 technetium 43 TC [98] thenium 75 Re 186.21 bohrium	55,845 ruthenium 44 Ru 101.07 osmium 76 Os 190.23 hassium	58,933 rhodlum 45 Rh 102,91 iridium 77 Ir 192,22 meitnerium	58,693 palladium 46 Pd 106.42 platinum 78 Pt 195.08 ununnilium	63,546 silver 47 Ag 107.87 gold 79 Au 196.97 unununium 111	65.39 cadmium 48 Cd 112.41 mercury 80 Hg 200.59 ununbium	69,723 Indium 49 In 114.82 thallium 81	72.61 tin 50 Sn 118.71 lead 82 Pb 207.2 ununquadium	74.922 antimony 51 Sb 121.76 bismuth 83 Bi	78.96 telurium 52 Te 127.60 polonium 84 Po	79.904 iodine 53 l 126.90 astatine 85 At	83.80 xenon 54 <b>Xe</b> 131.29 radon 86 <b>Rn</b>

 $^{\star}$ Lanthanide series

\* \* Actinide series

	lanthanum 57	cerium 58	praseodymium 59	neodymium 60	promethium 61	samarium 62	europium 63	gadolinium 64	terbium 65	dysprosium 66	holmium 67	erbium 68	thulium 69	ytterbium 70
l	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dv	Но	Er	Tm	Yb
ı	138.91	140.12	140.91	144.24	[145]	150.36	151.96	157.25	158.93	162.50	164.93	167.26	168.93	173.04
ı	actinium	thorium	protactinium	uranium	neptunium	plutonium	americium	curium	berkelium	californium	einsteinium	fermium	mendelevium	nobelium
١	89	90	91	92	93	94	95	96	97	98	99	100	101	102
١	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No
١	[227]	232.04	231.04	238.03	[237]	[244]	[243]	[247]	[247]	[251]	[252]	[257]	[258]	[259]

1. (30 points) Write the expected product(s) for each of the following reactions. Specify stereochemistry where appropriate, and include all expected organic products.

A. 
$$H_2O$$
 OH OH

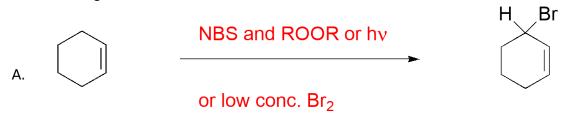
B. 
$$CI_2$$
  $CI_2$   $CI_2$ 

$$\begin{array}{c|c} & OMe \\ \hline & CN \\ \hline & \Delta \end{array}$$

$$\begin{array}{c|c} & & Br_2 \\ \hline & & \\ \hline & FeBr_3 \end{array}$$

$$SO_3$$
 $H_2SO_4$ 
OMe
 $SO_3H$ 
 $SO_3H$ 

2. (25 points) Write (over the arrow) the reagents and/or conditions needed to accomplish the following transformations.



D. 
$$\frac{\text{HNO}_3}{\text{H}_2\text{SO}_4}$$

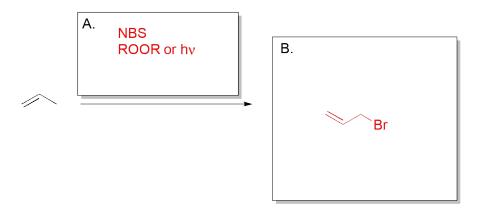
3. (20 points) Write multistep mechanisms (using the correct electron-pushing formalism, and as many steps as needed) for each of the following transformations. Be sure to draw resonance structures for any intermediate so stabilized.

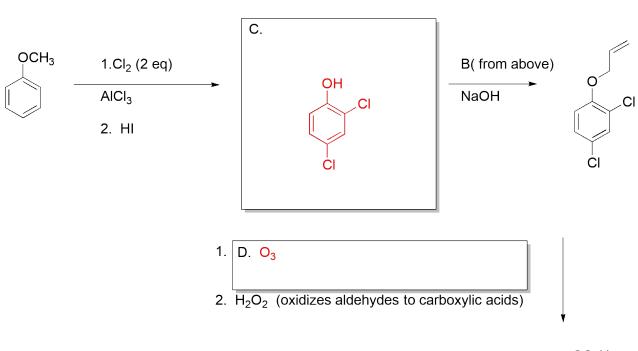
A. 
$$CI_2, H_2O$$
 $CI_2, H_2O$ 
 $CI_2$ 
 $CI_2$ 

В.

$$Br$$
 $H_2SO_4$ 
 $Br$ 
 $H_0SO_3H$ 
 $H_0SO_3H$ 
 $Br$ 
 $HO_3S$ 
 $H$ 
 $HO_3S$ 
 $H$ 
 $HO_3S$ 
 $H$ 
 $HO_3S$ 
 $H$ 
 $HO_3S$ 
 $H$ 

4. (16 points) Using multistep synthesis, show how to make 2,4-dichlorophenoxyacetic acid, sold commercially as the herbicide 2,4-D.





- 5. (9 points) Allyl cations will react with dienes in a concerted, pericyclic reaction very simular to the Diels-Alder reaction.
- A. Sketch in the phase interactions in the two HOMO-LUMO interactions in this reaction. (If the particular p orbital is on a node, leave it completely blank.)



Note that in the allyl cation LUMO, the central p orbital lies on a node (and so does not really participate).

B. Explain why you think an allyl anion would or would not undergo the same reaction.

The allyl anion has two additional electrons. The LUMO of the cation becomes the HOMO of the anion; the LUMO of the anion is now the completely out-of-phase orbital. Since the MO phases don't match between the two molecules, the reaction cannot occur:



## Bond strengths (kcal/mol):

F-F	38
Cl-Cl	58
Br-Br	46
I-I	36
H-F	136
H-Cl	103
H-Br	87
H-I	71
CH₃-H	105
CH <sub>3</sub> CH <sub>2</sub> -H	101
(CH <sub>3</sub> ) <sub>2</sub> CH-H	98.5
(CH <sub>3</sub> ) <sub>3</sub> C-H	96.5
CH₃-F	110
CH₃-Cl	85
CH₃-Br	70
CH₃-I	57
CH <sub>3</sub> CH <sub>2</sub> -F	111
CH₃CH₂-Cl	84
CH₃CH₂-Br	70
CH₃CH₂-I	56
(CH3)2CH-F	111
(CH <sub>3</sub> ) <sub>2</sub> CH-Cl	84
(CH <sub>3</sub> )₂CH-Br	71
(CH3)2CH-I	56
(CH3)3C-F	110
(CH <sub>3</sub> ) <sub>3</sub> C-Cl	85
(CH <sub>3</sub> ) <sub>3</sub> C-Br	71
(CH₃)₃C-I	55

## Typical Heats of Hydrogenation