

Name _____

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

Please do not use ipods or other music players.

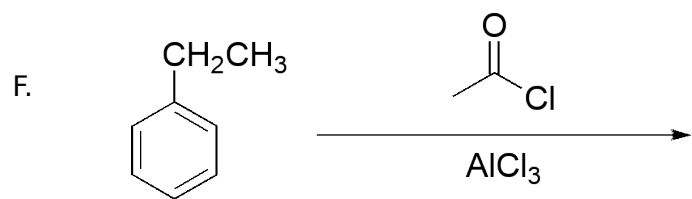
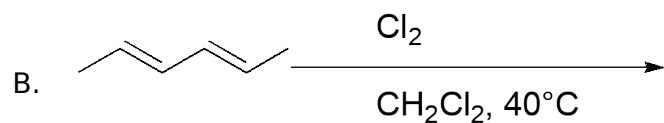
| | | | | | | | | | | | | | | | | | | |
|---------------------------------------|--|---------------------------------------|---|--|--|---|---|--|--|--|---|--|---|--|--|---|--------------------------------------|-----------------------------------|
| hydrogen 1 H 1.0079 | | | | | | | | | | | | | | | | | helium 2 He 4.0026 | |
| lithium 3 Li 6.941 | beryllium 4 Be 9.0122 | | | | | | | | | | | boron 5 B 10.811 | carbon 6 C 12.011 | nitrogen 7 N 14.007 | oxygen 8 O 15.999 | fluorine 9 F 18.998 | neon 10 Ne 20.180 | |
| sodium 11 Na 22.990 | magnesium 12 Mg 24.305 | | | | | | | | | | | aluminum 13 Al 26.982 | silicon 14 Si 28.086 | phosphorus 15 P 30.974 | sulfur 16 S 32.065 | chlorine 17 Cl 35.453 | argon 18 Ar 39.948 | |
| potassium 19 K 39.098 | calcium 20 Ca 40.078 | scandium 21 Sc 44.956 | titanium 22 Ti 47.867 | vanadium 23 V 50.942 | chromium 24 Cr 51.996 | manganese 25 Mn 54.939 | iron 26 Fe 55.845 | cobalt 27 Co 58.933 | nickel 28 Ni 58.693 | copper 29 Cu 63.546 | zinc 30 Zn 65.39 | gallium 31 Ga 69.723 | germanium 32 Ge 72.61 | arsenic 33 As 74.922 | selenium 34 Se 78.96 | bromine 35 Br 79.904 | krypton 36 Kr 83.80 | |
| rubidium 37 Rb 85.468 | strontium 38 Sr 87.62 | yttrium 39 Y 88.906 | zirconium 40 Zr 91.224 | niobium 41 Nb 92.906 | molybdenum 42 Mo 95.94 | technetium 43 Tc [98] | ruthenium 44 Ru 101.07 | rhodium 45 Rh 102.91 | palladium 46 Pd 106.42 | silver 47 Ag 107.87 | cadmium 48 Cd 112.41 | indium 49 In 114.82 | tin 50 Sn 118.71 | antimony 51 Sb 121.76 | tellurium 52 Te 127.60 | iodine 53 I 126.90 | xenon 54 Xe 131.29 | |
| cesium 55 Cs 132.91 | barium 56 Ba 137.33 | 57-70 * | lutetium 71 Lu 174.97 | hafnium 72 Hf 178.49 | tantalum 73 Ta 180.95 | tungsten 74 W 183.84 | rhenium 75 Re 186.21 | osmium 76 Os 190.23 | iridium 77 Ir 192.22 | platinum 78 Pt 195.08 | gold 79 Au 196.97 | mercury 80 Hg 200.59 | thallium 81 Tl 204.38 | lead 82 Pb 207.2 | bismuth 83 Bi 208.98 | polonium 84 Po [209] | astatine 85 At [210] | radon 86 Rn [222] |
| francium 87 Fr [223] | radium 88 Ra [226] | 89-102 ** | lanthanum 103 La [138.91] | cerium 104 Ce [140.12] | praseodymium 105 Pr [140.91] | neodymium 106 Nd [144.24] | promethium 107 Pm [145] | samarium 108 Sm [150.36] | europium 109 Eu [151.96] | gadolinium 110 Gd [157.25] | terbium 111 Tb [158.93] | dysprosium 112 Dy [162.50] | holmium 113 Ho [164.93] | erbium 114 Er [167.26] | thulium 115 Tm [168.93] | ytterbium 116 Yb [173.04] | | |
| | | | actinium 89 Ac [227] | thorium 90 Th [232.04] | protactinium 91 Pa [231.04] | uranium 92 U [238.03] | neptunium 93 Np [237] | plutonium 94 Pu [244] | americium 95 Am [243] | curium 96 Cm [247] | berkelium 97 Bk [247] | californium 98 Cf [251] | einsteinium 99 Es [252] | fermium 100 Fm [257] | mendelevium 101 Md [258] | nobelium 102 No [259] | | |

* Lanthanide series

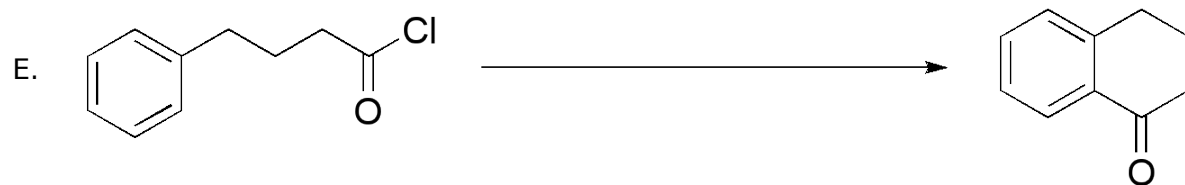
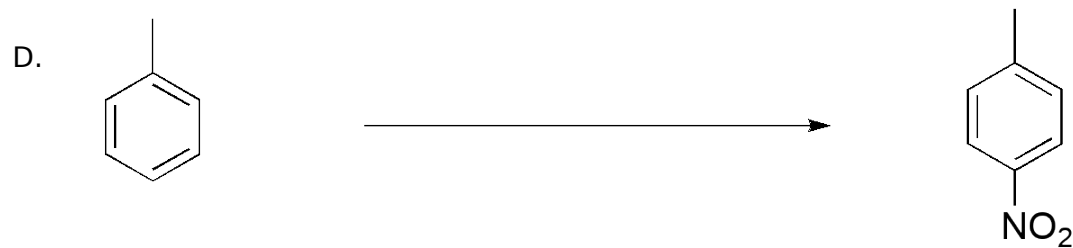
** Actinide series

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

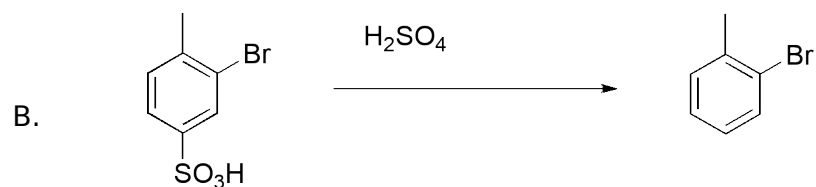
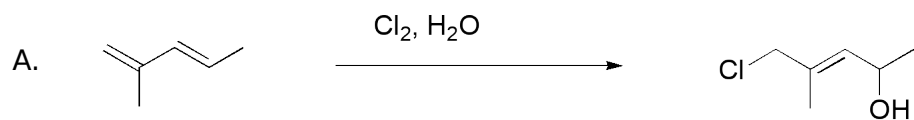
1. (30 points) Write the expected product(s) for each of the following reactions. Specify stereochemistry where appropriate, and include all expected organic products.



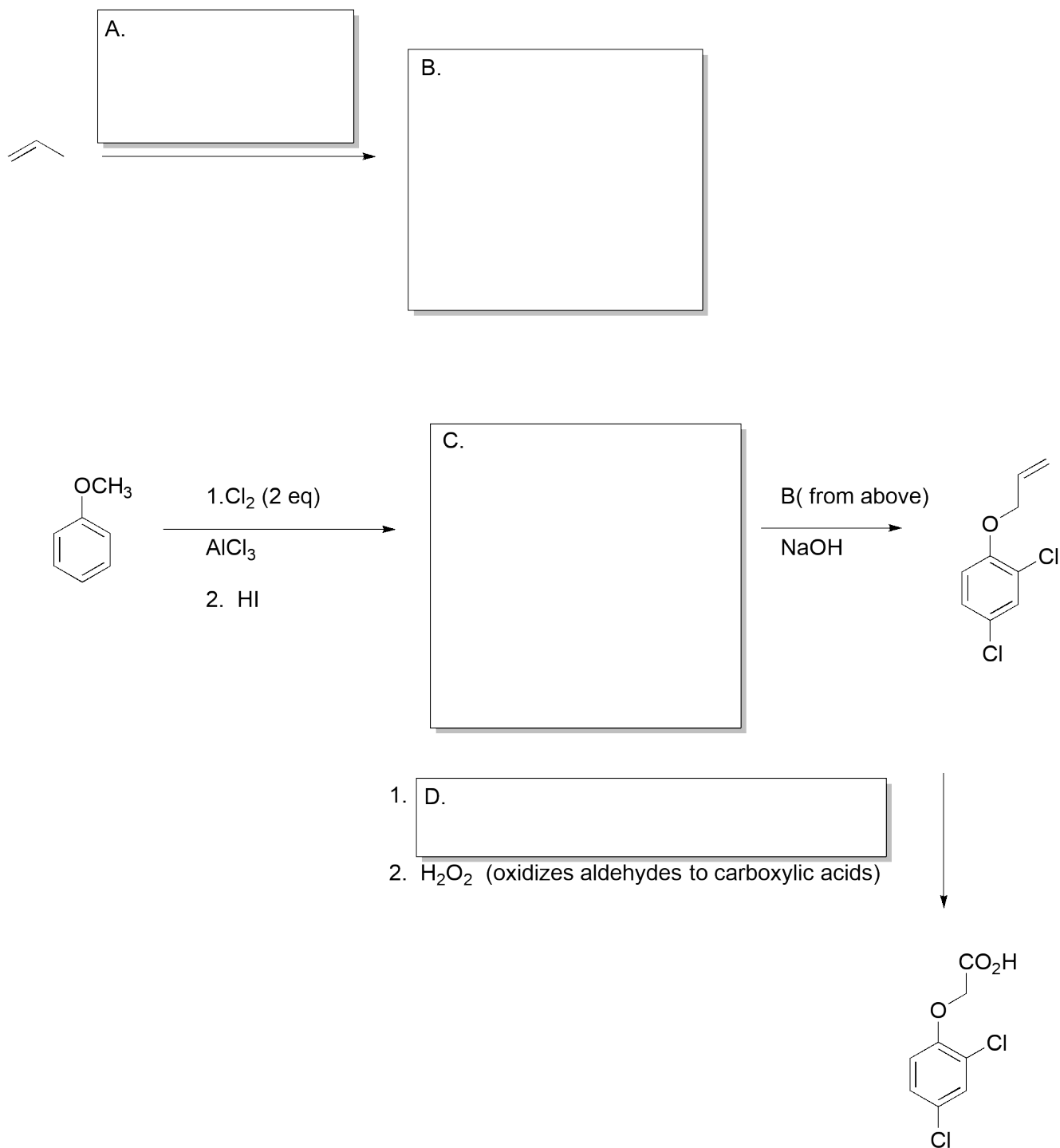
2. (25 points) Write (over the arrow) the reagents and/or conditions needed to accomplish the following transformations.



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.

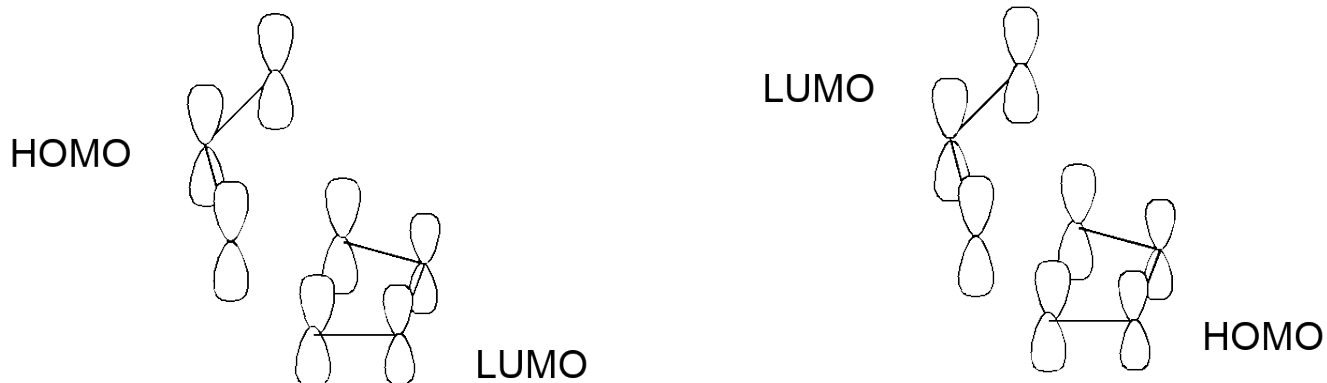


4. (16 points) Using multistep synthesis, show how to make 2,4-dichlorophenoxyacetic acid, sold commercially as the herbicide 2,4-D.



5. (9 points) Allyl cations will react with dienes in a concerted, pericyclic reaction very similar 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.)

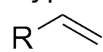

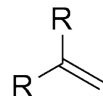

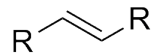
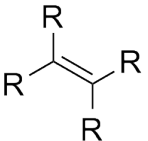


B. Explain why you think an allyl anion would or would not undergo the same reaction.

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 |
| CH ₃ -H | 105 |
| CH ₃ CH ₂ -H | 101 |
| (CH ₃) ₂ CH-H | 98.5 |
| (CH ₃) ₃ C-H | 96.5 |
| CH ₃ -F | 110 |
| CH ₃ -Cl | 85 |
| CH ₃ -Br | 70 |
| CH ₃ -I | 57 |
| CH ₃ CH ₂ -F | 111 |
| CH ₃ CH ₂ -Cl | 84 |
| CH ₃ CH ₂ -Br | 70 |
| CH ₃ CH ₂ -I | 56 |
| (CH ₃) ₂ CH-F | 111 |
| (CH ₃) ₂ CH-Cl | 84 |
| (CH ₃) ₂ CH-Br | 71 |
| (CH ₃) ₂ CH-I | 56 |
| (CH ₃) ₃ C-F | 110 |
| (CH ₃) ₃ C-Cl | 85 |
| (CH ₃) ₃ C-Br | 71 |
| (CH ₃) ₃ C-I | 55 |

Typical Heats of Hydrogenation

| | | | |
|---|----------------|---|----------------|
|  | -30 kcal/mol |  | -28.2 kcal/mol |
|  | -27.9 kcal/mol |  | -26.5 kcal/mol |
|  | -27.4 kcal/mol |  | -26.3 kcal/mol |