CHEMISTRY 2500: Organic Chemistry I
MIDTERM-2
Friday, November 23, 2018

Instructions:

- This exam paper consists of 12 questions.
- The exam is worth a total of 56 marks. Most of these marks are for explanation/showing your work rather than for reaching the correct answer. Explain all of your answers fully using diagrams where appropriate (a picture really is worth a thousand words!).
- Marks will be deducted for poorly drawn structures.
- No calculators allowed. No other electronic devices can be present with you during the exam unless authorized by the instructor.
- You may use a molecular model kit.
- There is a 2-hour time limit.
- If your work is not legible, it will be given a mark of zero.
- **Read the questions carefully**. Good luck.

Confidentiality Agreement:

I agree not to discuss (or in any other way divulge) the contents of this exam until they have all been marked and returned. I understand that, if I were to break this agreement, I would be choosing to commit academic misconduct, a serious offense that will be punished. The minimum punishment would be a mark of 0 on this exam and removal of the "overwrite midterm mark with final exam mark" option for my grade in this course; the maximum punishment would include expulsion from this university.

Signature: _____ Date: _____

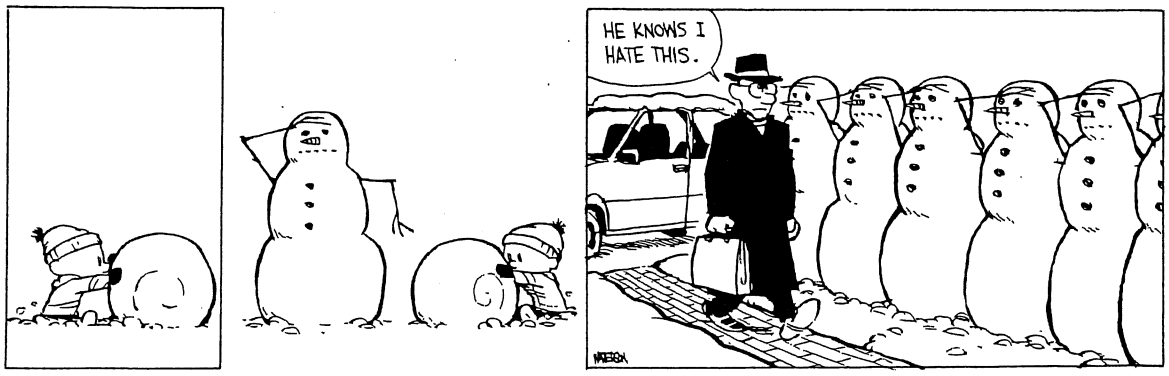
Course: CHEM 2500 (Organic Chemistry I)
Semester: Fall 2018
The University of Lethbridge

KEY

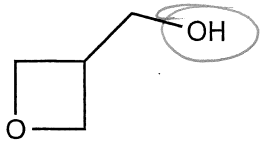
Question Breakdown

Q1	**/6**
Q2	**/4**
Q3	**/4**
Q4	**/4**
Q5	**/4**
Q6	**/5**
Q7	**/5**
Q8	**/4**
Q9	**/6**
Q10	**/5**
Q11	**/5**
Q12	**/4**

Total	**/56**



1. Consider compound X with molecular formula $C_4H_8O_2$: **[6 marks]**

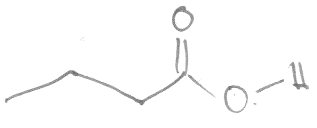


pka ~ 17

Compound X ($C_4H_8O_2$)

(a) Draw a constitutional isomer that is approximately 1 trillion (10^{12}) times more acidic than the compound X.

∴ pka ~ 5 - carboxylic acid.

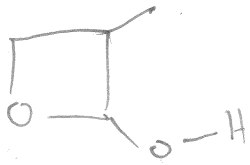


+ other examples.

(b) Draw a constitutional isomer that is less acidic than the compound X.

+ other examples.

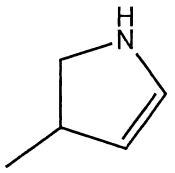
(c) Draw a constitutional isomer that will have approximately the same acidity as the compound X.

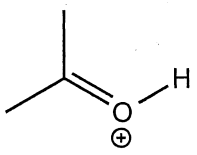


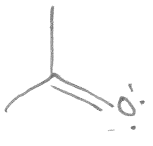
+ other examples.

2.

(a) Draw the conjugate base beside each of the following acids. **[4 marks]**

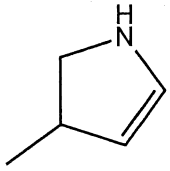




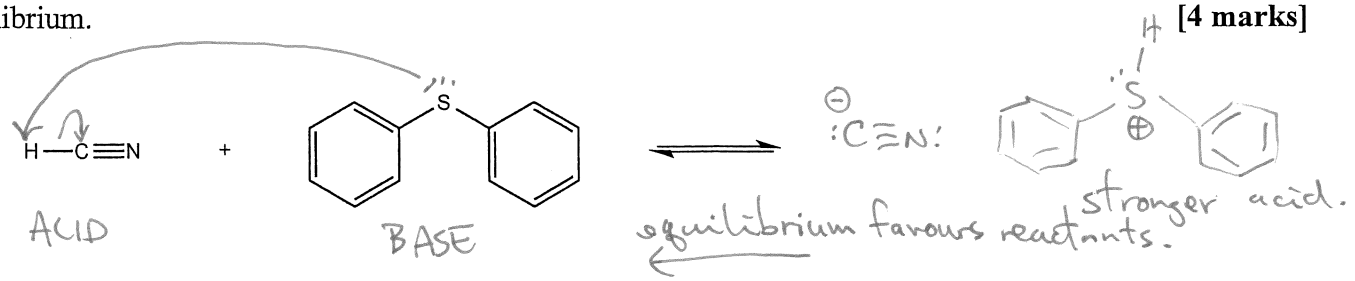


(b) Draw the conjugate acid beside each of the following bases.

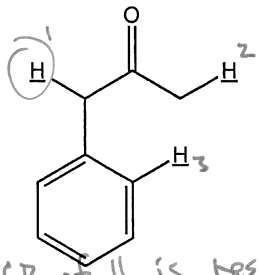
NaOH



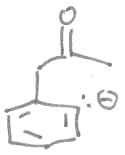
3. For the reactants below, identify the acid and base. Then draw the mechanistic arrows showing a proton transfer reaction. Draw the products of that proton transfer reaction and then predict the position of the equilibrium. **[4 marks]**



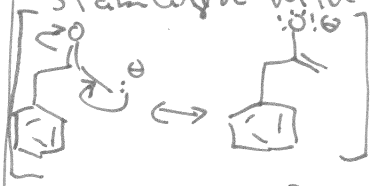
4. The molecule below has three protons which are underlined. Determine which of the three protons is more acidic. Explain your reasoning. **[4 marks]**



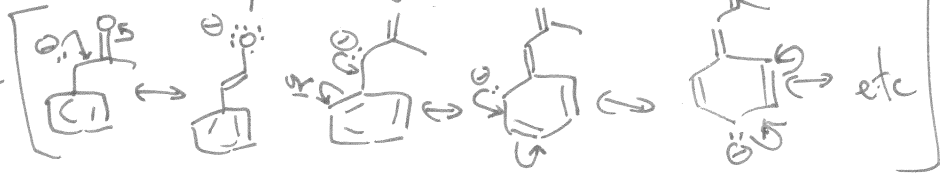
The CB of acid H_3 has no resonance stabilization



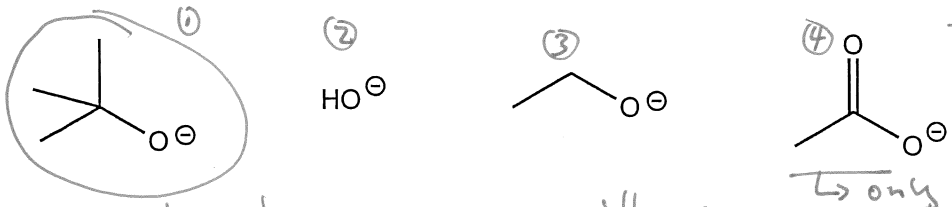
The CB of acid H_2 is resonance stabilized with the oxygen atom.



The CB of H_1 is resonance stabilized with the oxygen atom & the aromatic ring, having the most resonance stabilization makes its CB the most stable and ∴ H_1 the most acidic



5. In the group of compounds below, circle the most basic compound. Explain your reasoning. **[4 marks]**



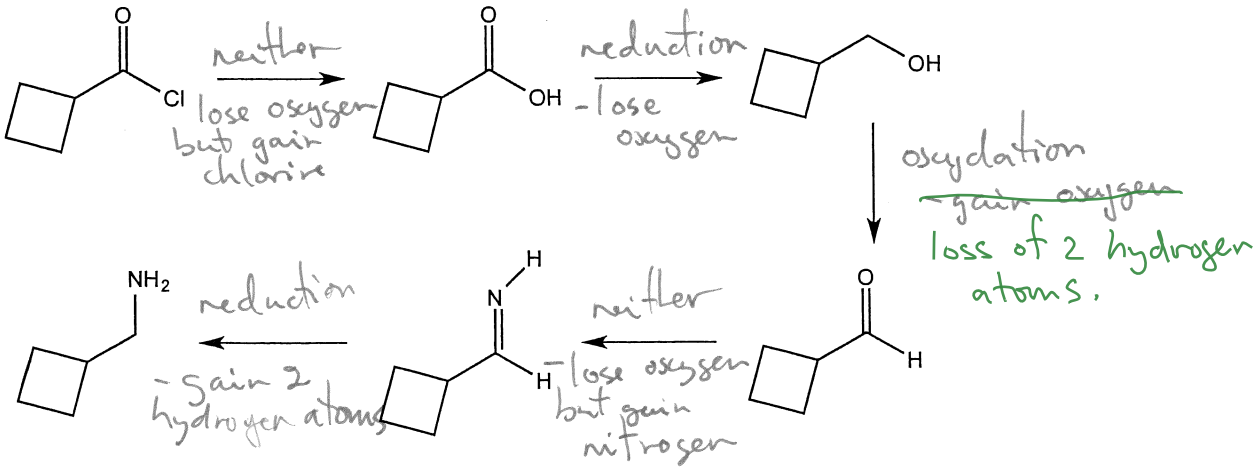
- the more stable the base, the weaker it is.

↳ only molecule with resonance ∴ it is the weakest base.

①, ② & ③ all have negative charge on oxygen with NO resonance stabilization. ① and ③ have alkyl EDGs attached to the oxygen atom adding electron density to the oxygen atom. Since ① has more EDGs attached, it destabilizes the oxygen the most making it the most basic.

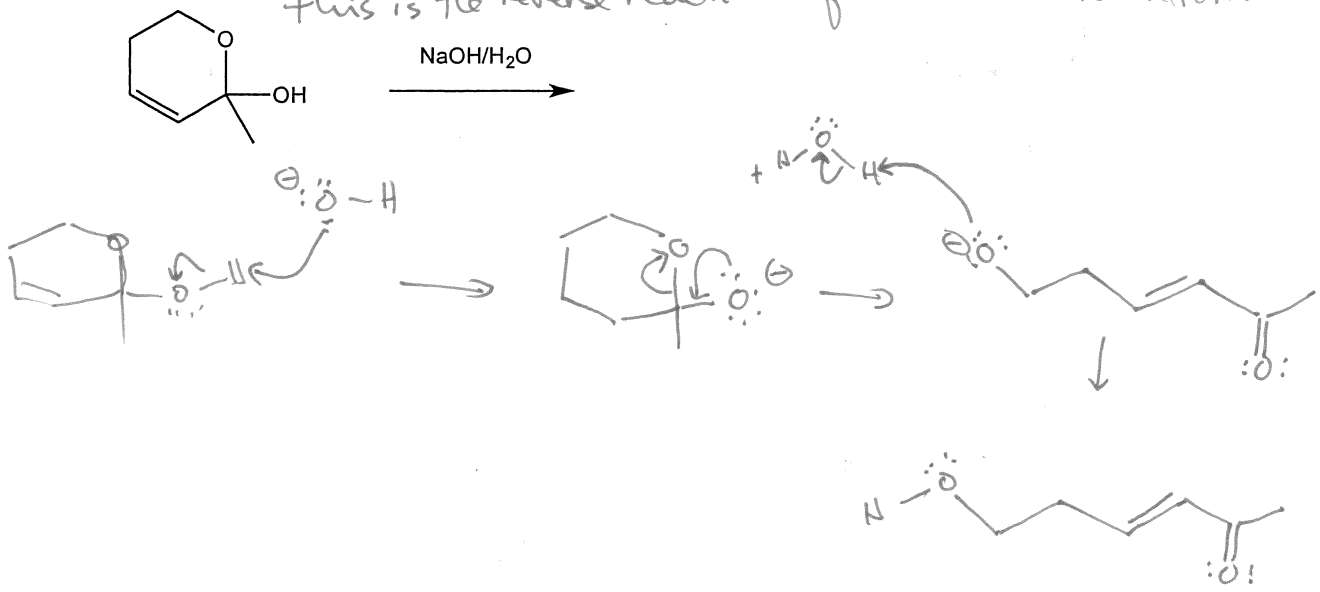
② has no electron donating groups attached.

6. Over each arrow, classify each of the reactions in the following multistep sequence as an oxidation, a reduction, or neither. **[5 mark]**

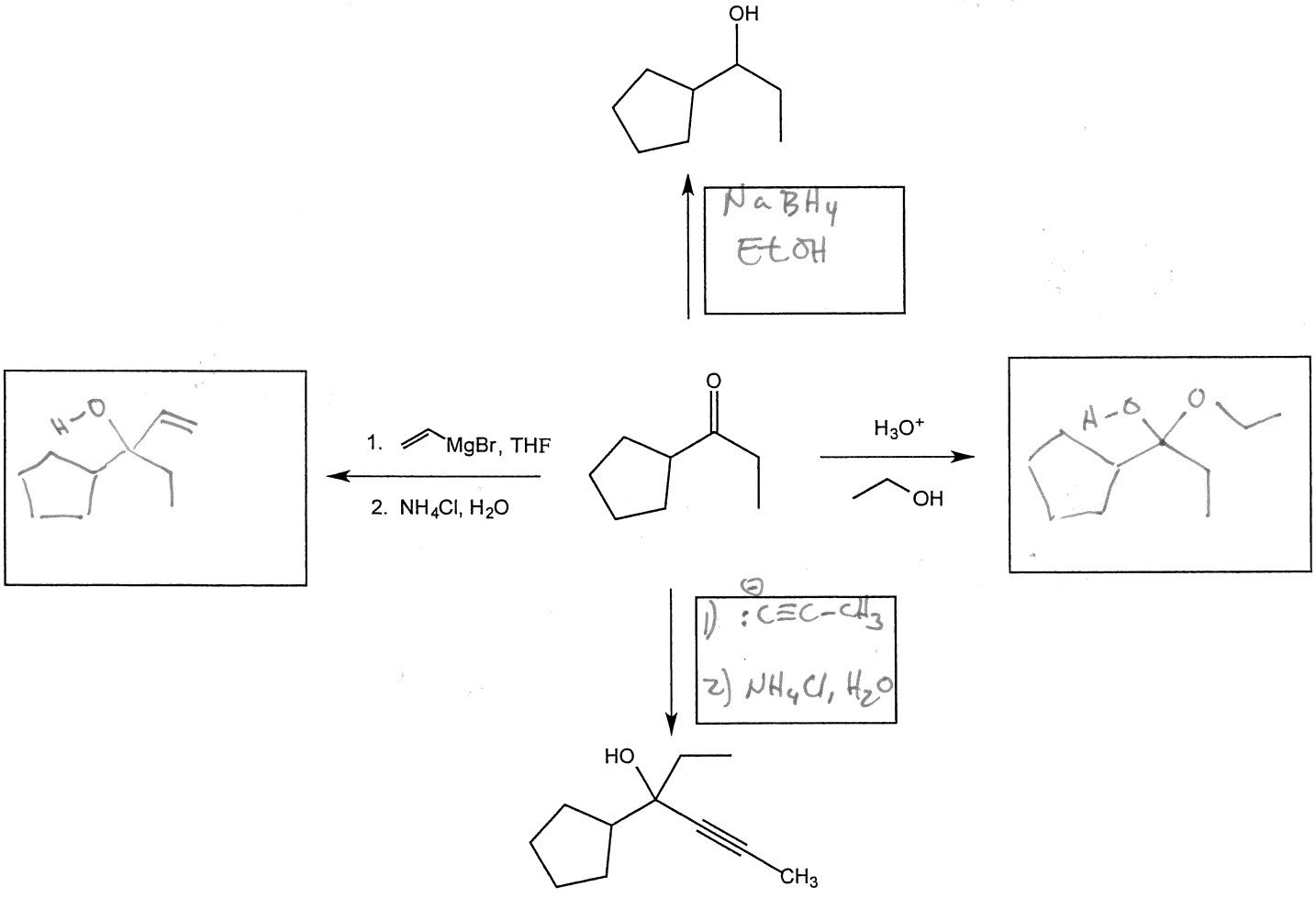


7. The following hemiacetal yields a carbonyl compound when treated with aqueous sodium hydroxide (NaOH). Using curved arrows, draw the mechanism of this reaction and determine the structure of the aldehyde or ketone that results. **[5 marks]**

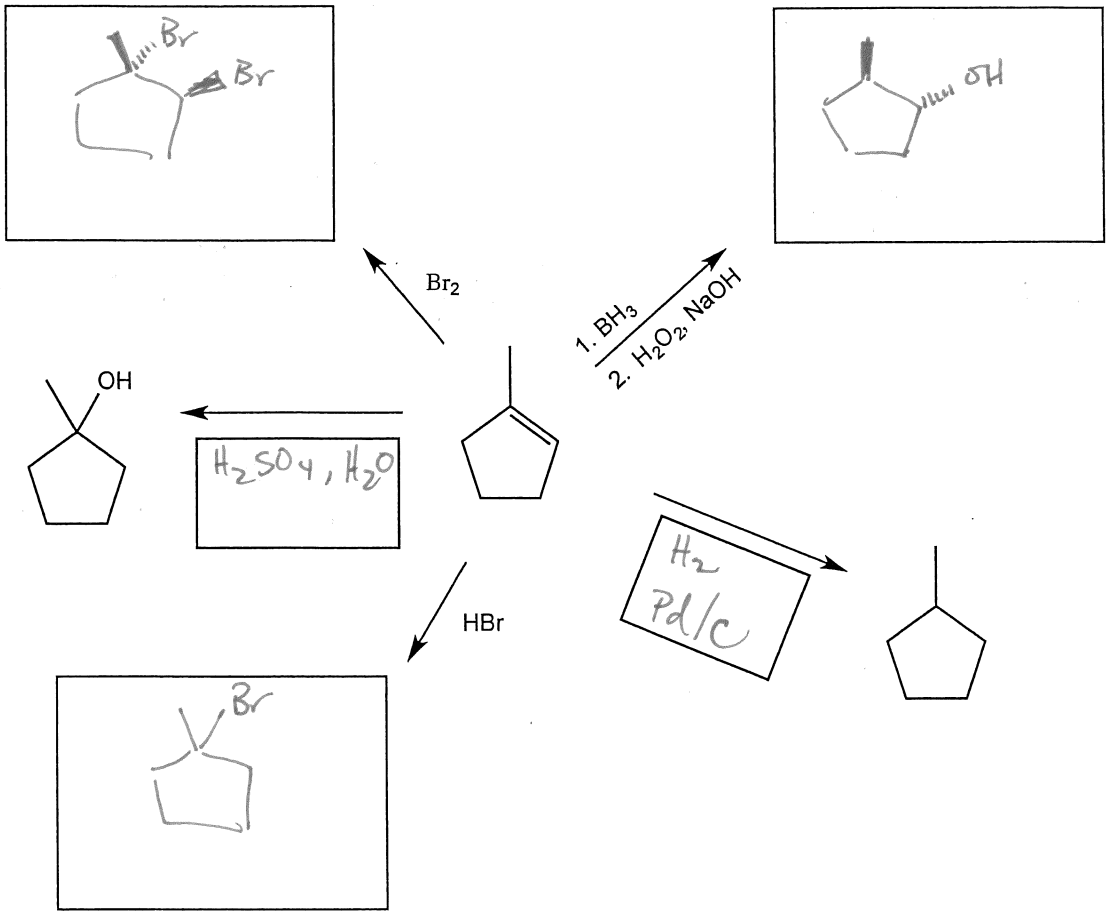
this is the reverse reaction of hemiacetal formation.



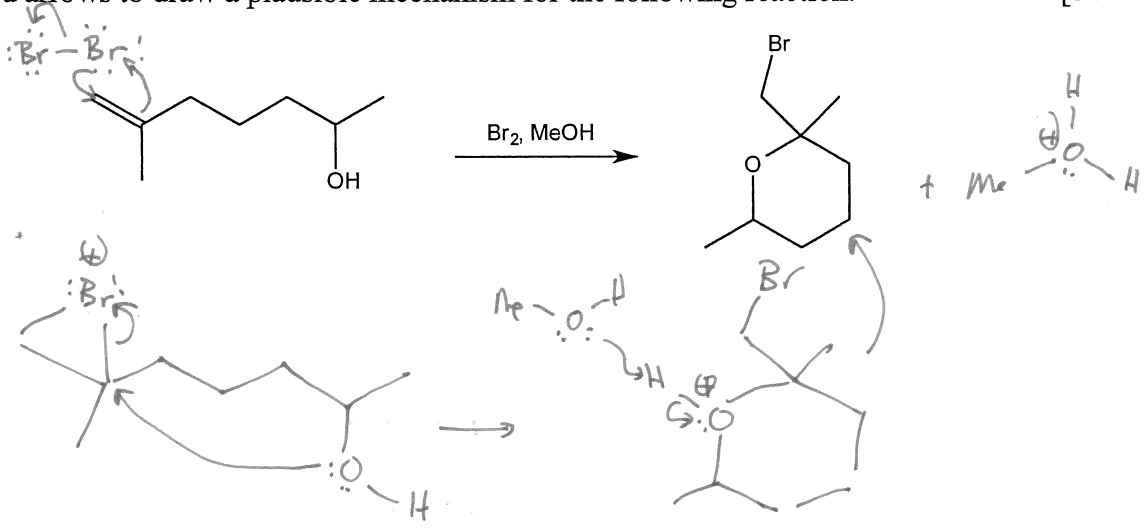
8. For the following reaction sequences, provide the missing reagents or products. **[4 marks]**



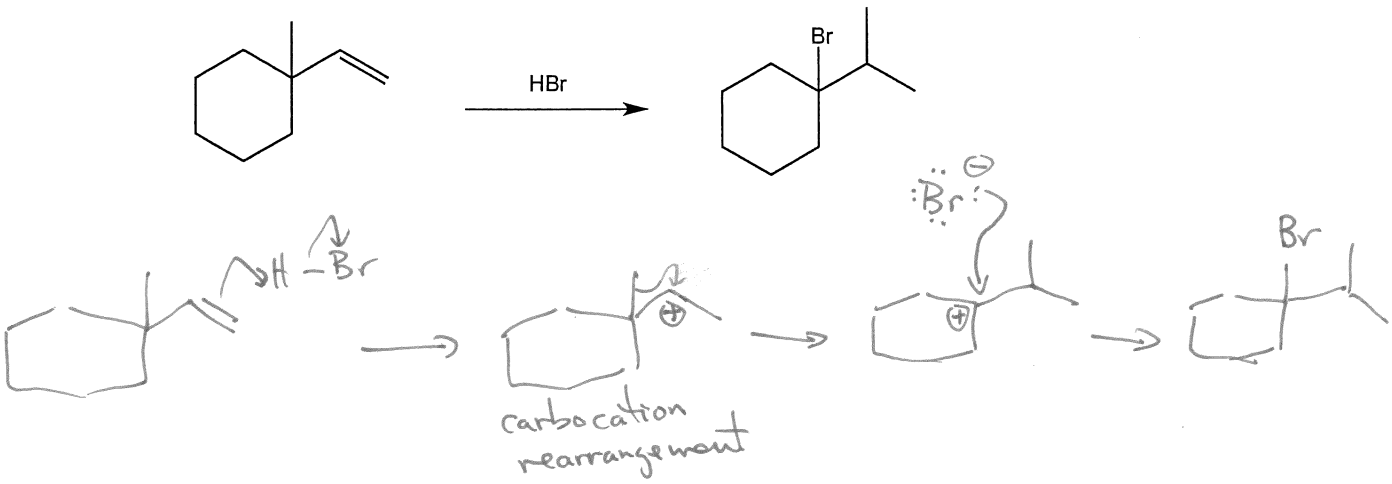
9. For each of the following reactions, fill in the missing reagents or products. For the products, be sure to indicate the correct stereochemistry where necessary. **[6 marks]**



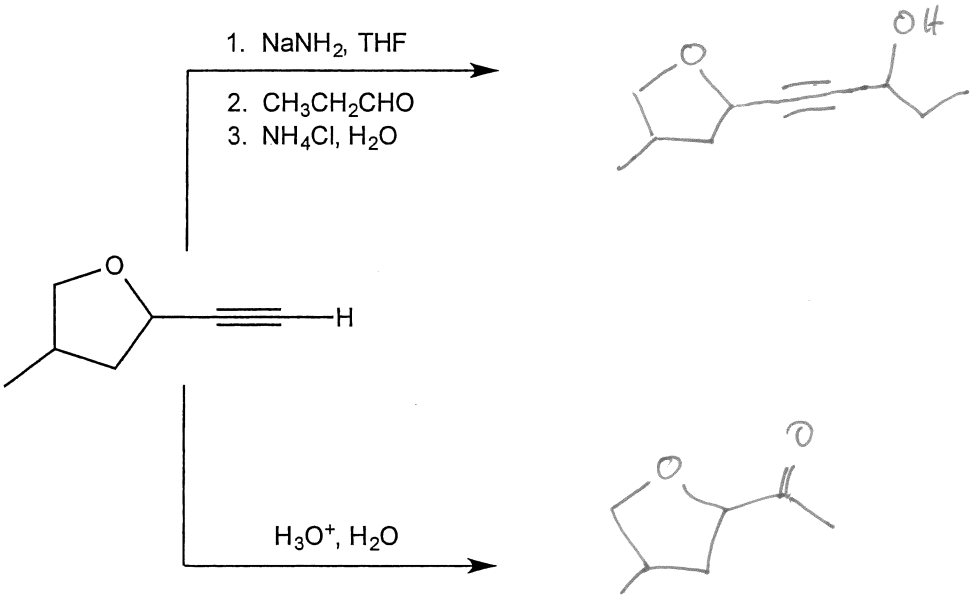
10. Use curved arrows to draw a plausible mechanism for the following reaction. **[5 marks]**

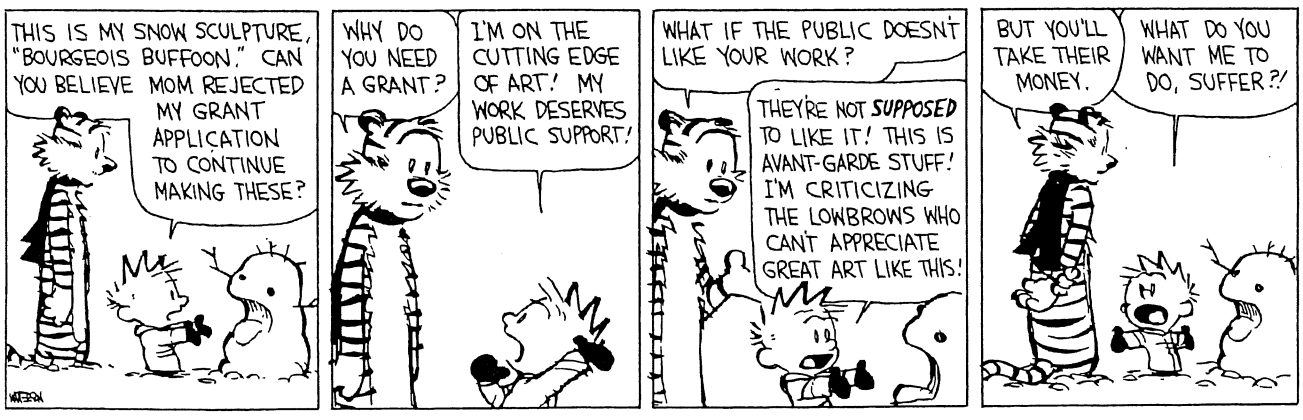


11. Use curved arrows to draw a plausible mechanism for the following reaction. **[5 marks]**

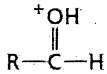
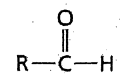
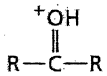
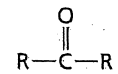
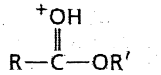
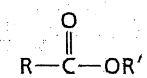
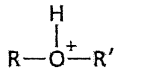
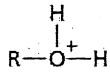
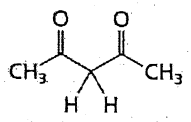
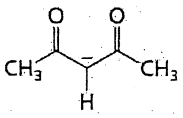


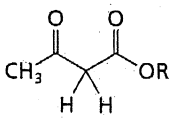
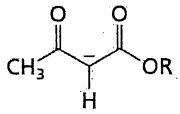
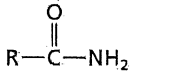
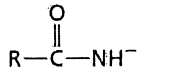
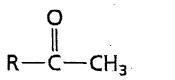
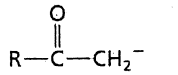
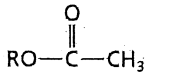
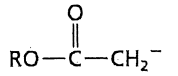
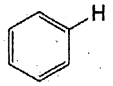
12. Predict the products formed when the given compound is treated with each of the following. **[4 marks]**



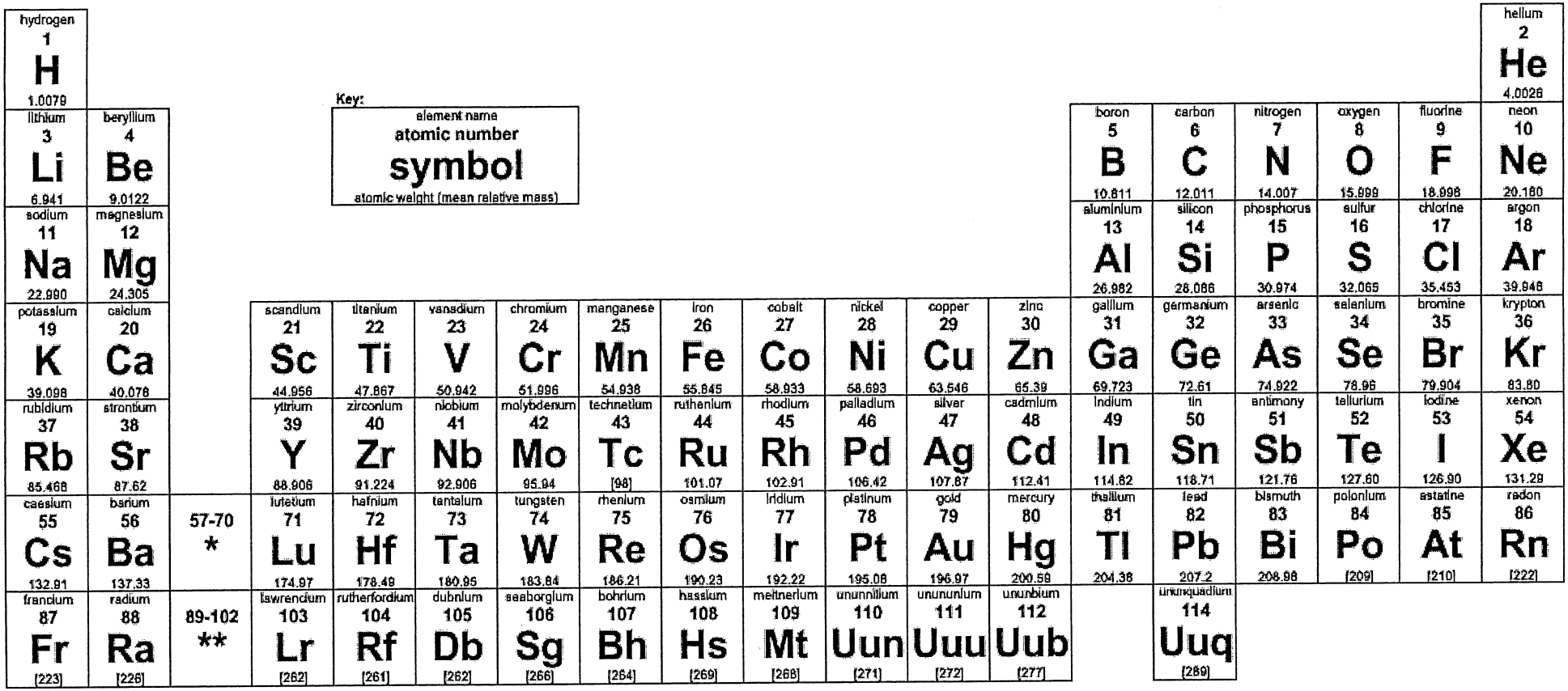


pKa values of molecules and ions commonly encountered in organic chemistry.

Acid	*Conjugate base*	pK_a
$HClO_4$	ClO_4^-	−10
HI	I^-	−9
		−9
HBr	Br	−9
H_2SO_4	HSO_4^-	−7
HCl	Cl^-	−7
		−7
$ArSO_3H$	$ArSO_3^-$	−6.5
		−6
	R—O—R′	−3.5
	R—O—H	−2
H_3O^+	H_2O	−1.7
HNO_3	NO_3^-	−1.4
HSO_4^-	SO_4^{2-}	2
H_3PO_4	$H_2PO_4^-$	2.1
HF	F^-	3.1
HONO	NO_2^-	3.3
$ArNH_3^+$	$ArNH_2$	4
HN_3	N_3^-	4.6
RCOOH	$RCOO^-$	5
H_2CO_3	HCO_3^-	6.4
H_2S	HS^-	7
ArSH	ArS^-	7
		9

Acid	*Conjugate base*	pK_a
HCN	CN^-	9.2
NH_4^+	NH_3	9.2
ArOH	ArO^-	10
$R—CH_2NO_2$	$R—\bar{C}H—NO_2$	10
RNH_3^+	RNH_2	11
RSH	RS^-	11
		11
H_2O_2	HOO^-	11.6
PhNHCOR	$Ph\bar{N}—COR$	13
CH_3OH	CH_3O^-	15.2
H_2O	HO^-	15.7
RCH_2OH	RCH_2O^-	16
$R_2CH—OH$	$R_2CH—O^-$	17
$R_3C—OH$	$R_3C—O^-$	17
		17
$PhCH_2COR$	$Ph\bar{C}H—COR$	17
		20
		24
$R—CH_2CN$	$R—\bar{C}H—CN$	25
$H—C\equiv C—H$	$H—C\equiv C^-$	25
$PhNH_2$	$PhNH^-$	28
H_2	H^-	35
NH_3	NH_2^-	38
$Ph—CH_3$	$Ph—CH_2^-$	40
		43
$CH_2=CH_2$	$CH_2=CH^-$	44
CH_4	CH_3^-	48

Abbreviations: Ar =aryl; Ph =phenyl; R =alkyl.


Key:
element name
atomic number
symbol
atomic weight (mean relative mass)
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
aluminium 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 54.938
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
caesium 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 **
lawrencium 103 Lr [262]
rutherfordium 104 Rf [261]
dubnium 105 Db [262]
seaborgium 106 Sg [266]
bohrium 107 Bh [264]
hassium 108 Hs [269]
meitnerium 109 Mt [268]
ununnilium 110 Uun [271]
unununium 111 Uuu [272]
ununbium 112 Uub [277]
ununquadium 114 Uuq [289]
*lanthanoids
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
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