CHEMISTRY 2500: Organic Chemistry I
MIDTERM-2
Thursday, November 7, 2019

Instructions:

- This exam paper consists of 10 questions.
- The exam is worth a total of 50 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.

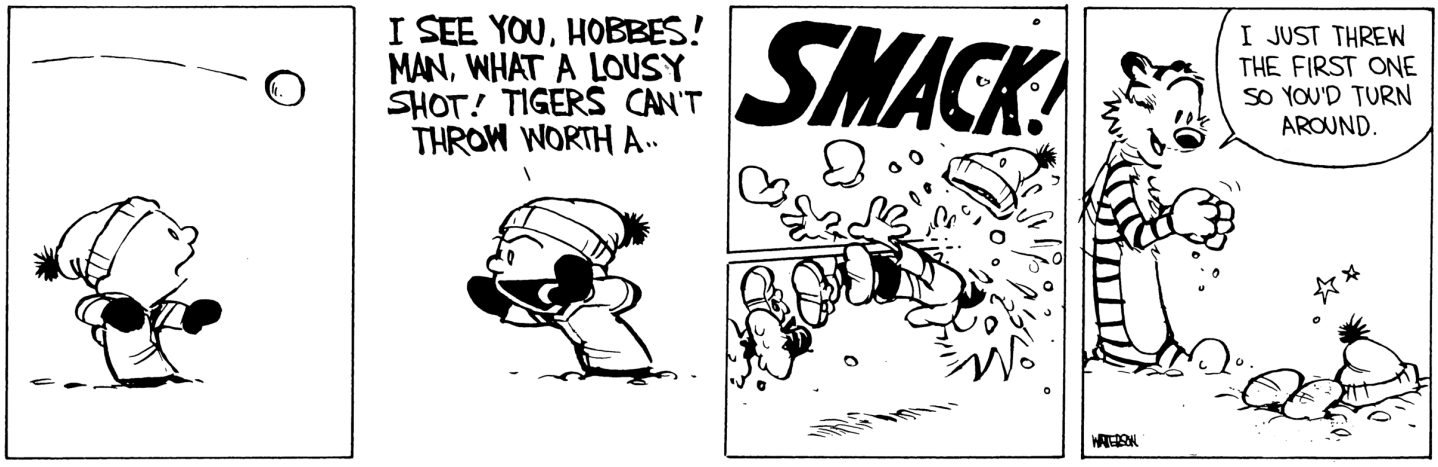
Signature: _____ Date: _____

Course: CHEM 2500 (Organic Chemistry I)
Semester: Fall 2019
The University of Lethbridge

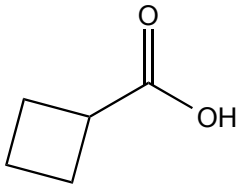
Question Breakdown

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

Total	**/50**



1. Consider the following compound with molecular formula $C_5H_8O_2$: **[6 marks]**



$C_5H_8O_2$

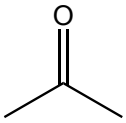
(a) Draw a constitutional isomer that has an approximate pka of 9.

(b) Draw a constitutional isomer that has an approximate pka of 12.

(c) Draw a constitutional isomer that has an approximate pka of 20.

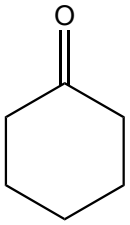
2.

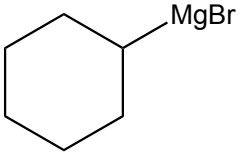
(a) Draw the conjugate base beside each of the following acids. **[4 marks]**



NH_4Cl

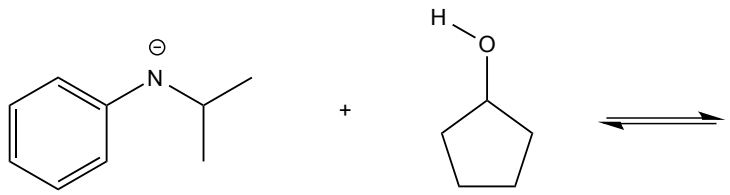
(b) Draw the conjugate acid beside each of the following bases.



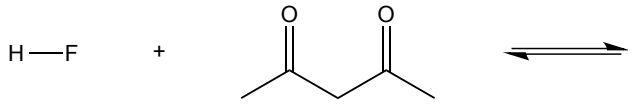


3. For each of the following reactions:
(i) Add all lone pairs and identify the acid and base.
(ii) Draw the mechanistic arrows showing the proton transfer reaction.
(iii) Draw the products of that proton transfer reaction and then predict the position of the equilibrium (reactant or product favoured). **[6 marks]**

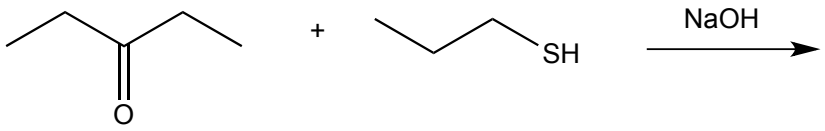
(a)



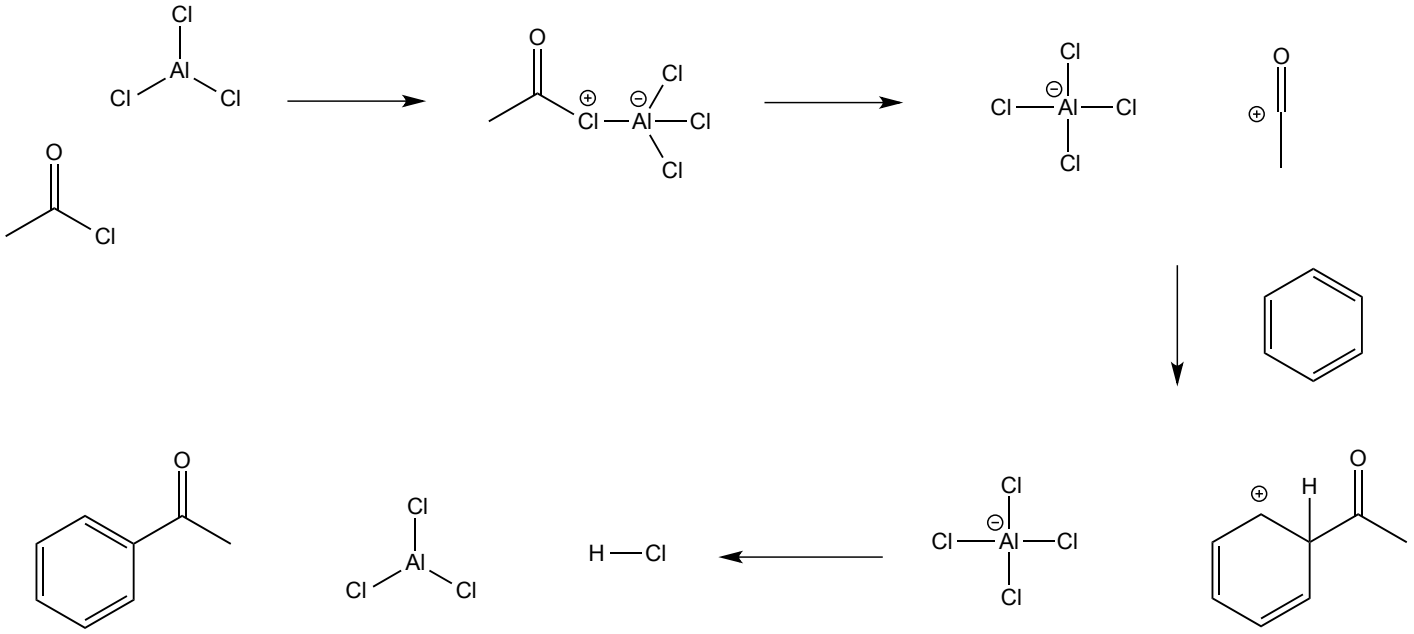
(b)



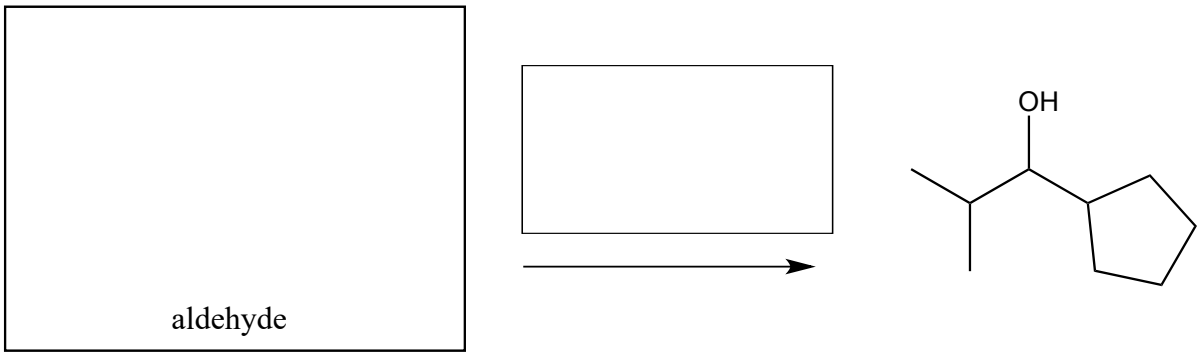
4. Thiols are good nucleophiles and, like alcohols, can react with carbonyl groups to form hemithioacetals. Provide a mechanism using curved arrows to predict the product of the following reaction. Be sure to consider your reaction conditions. **[5 marks]**

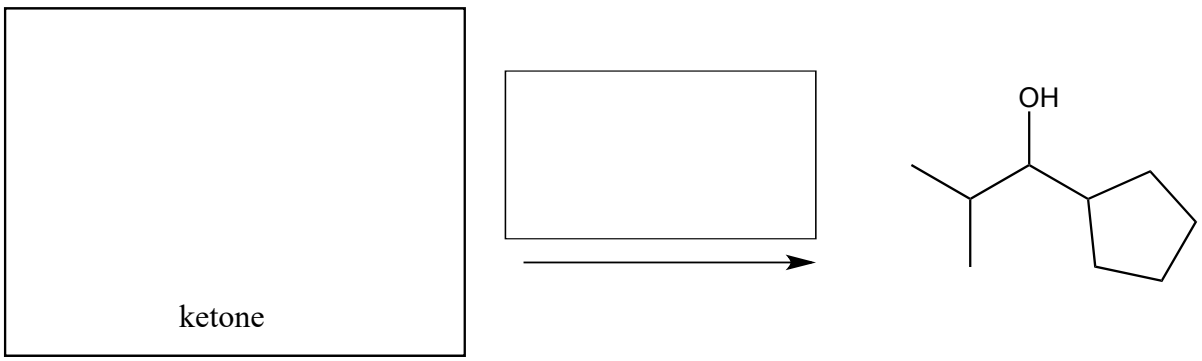


5. Consider the following Friedel-Crafts acylation reaction:
(i) Add all lone pairs.
(ii) Add mechanistic arrows to show the flow of electrons.
(iii) Label each arrow as either Proton Transfer (P.T), Nucleophilic Attack (N.A.), or Leaving Group Loss (L.G.L.) **[5 mark]**

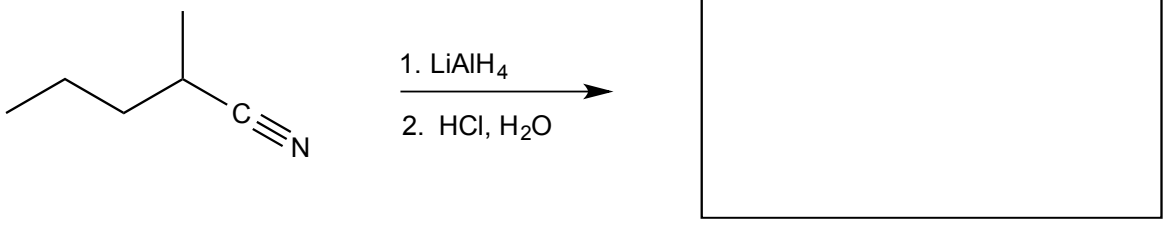


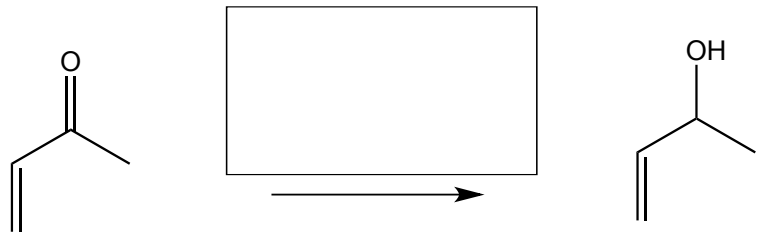
6. Suggest reagents that could be used to synthesize the following molecule in two different reactions; one from an aldehyde and one from a ketone. [**6 marks**]

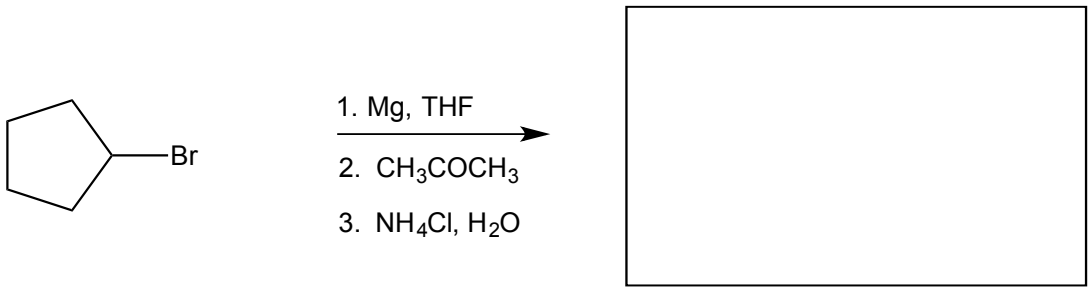


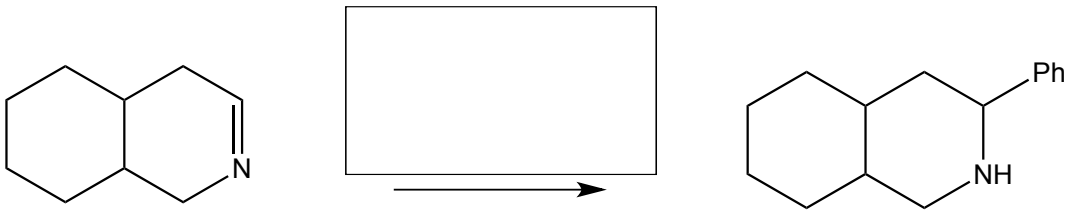


7. For each of the following reactions, provide the missing reagents or products. **[4 marks]**

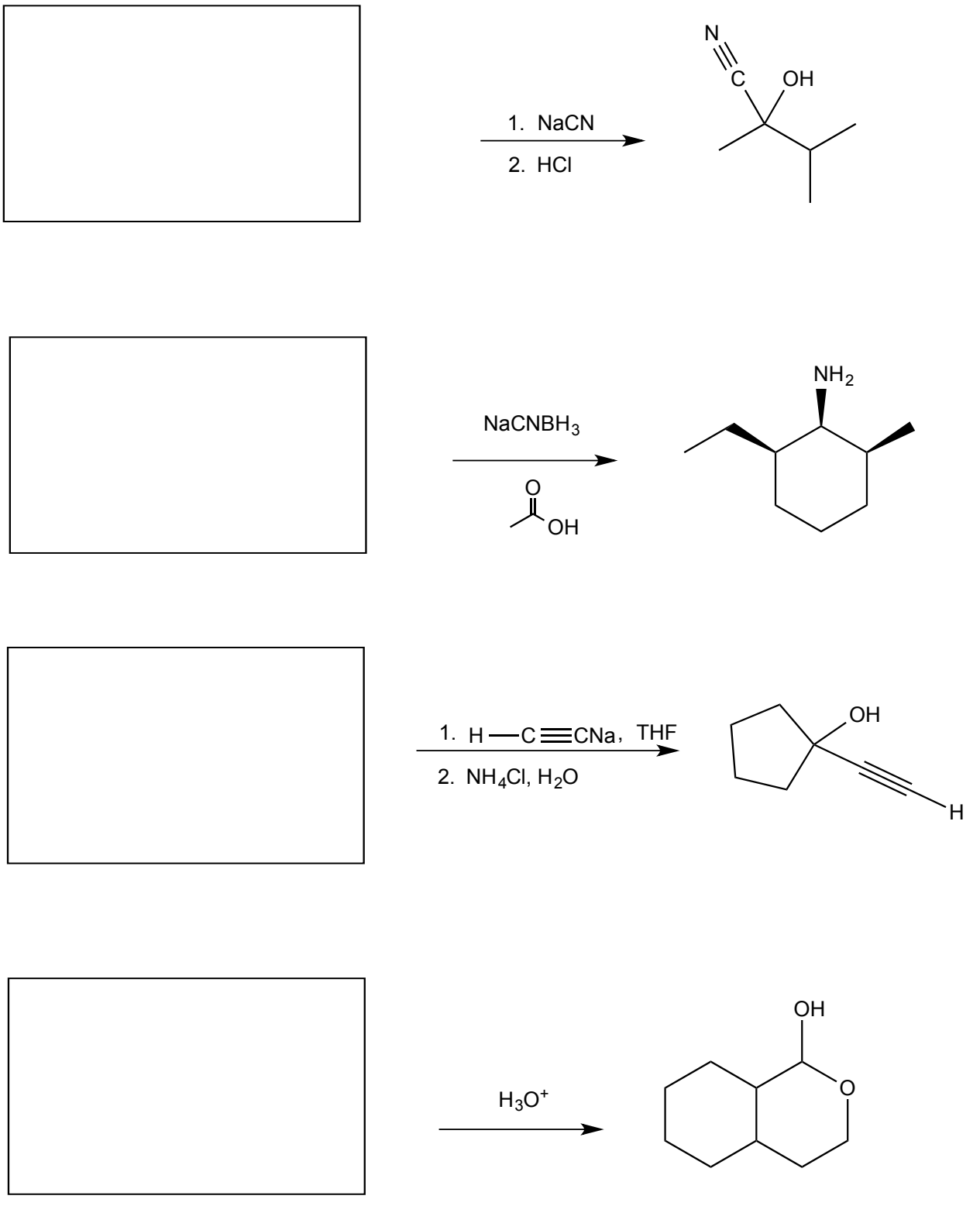




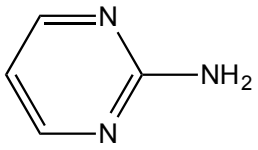


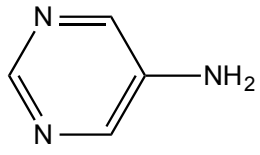


8. For each of the following reactions, fill in the missing organic starting reagents. **[4 marks]**



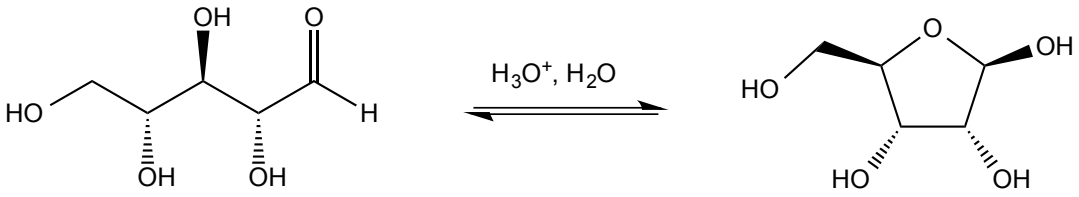
9. Predict which of the following compounds is more acidic and explain your choice. **[5 marks]**

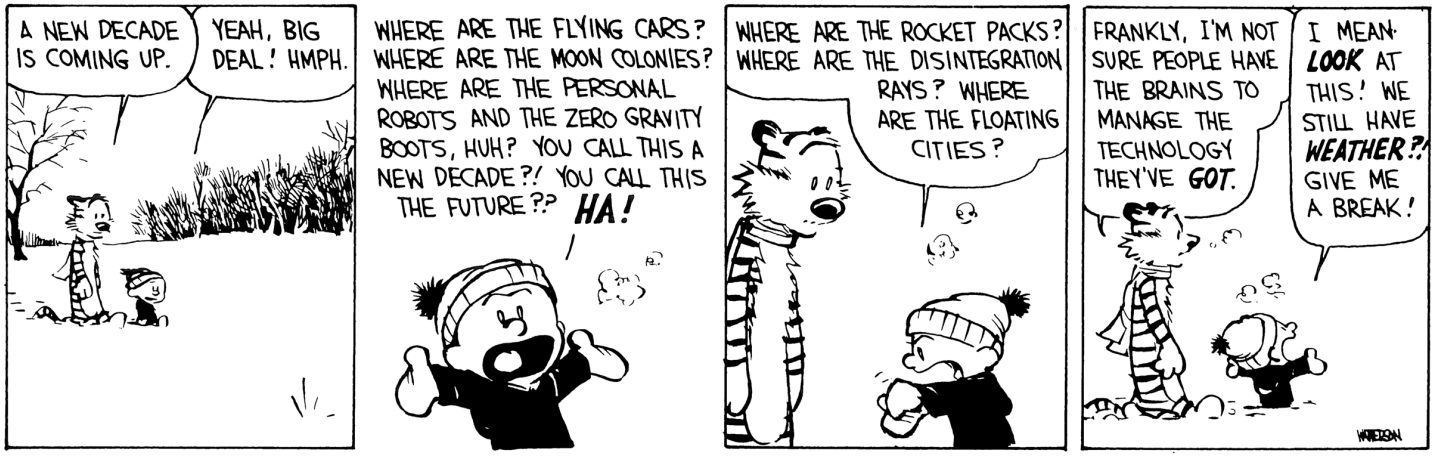




10. Under acidic conditions, D-ribose is converted to the hemiacetal, D-ribofuranose. Use curved arrows to draw a plausible mechanism for the following reaction. Be sure to consider your reaction conditions.

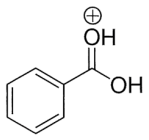
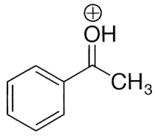
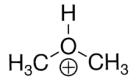
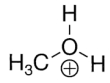
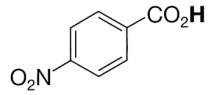
[**5 marks**]

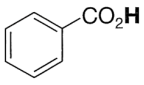
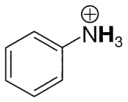
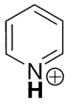
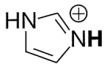
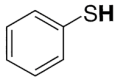
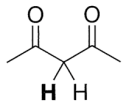
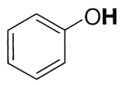
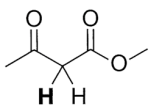


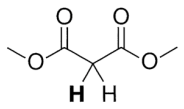
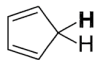
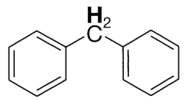
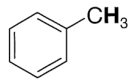
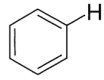


APPENDIX C

pK_a Values[1] of Selected Organic Compounds

Compound	pK_a
HBr	−9
	−8
	−6
HCl	−7
	−3.8
H_2SO_4	−3
	−2.2
CH_3SO_3H	−2.6
H_3O^+	−1.7
HNO_3	−1.3
CF_3CO_2H	−0.2
CCl_3CO_2H	0.6
$CHCl_2CO_2H$	1.3
$CH_2(NO_2)CO_2H$	1.6
H_3PO_4	2.1
CH_2ClCO_2H	2.9
HF	3.2
	3.4
$CH_3OCH_2CO_2H$	3.6
HCO_2H	3.8

Compound	pK_a
	4.2
	4.6
CH_3CO_2H	4.8
	5.2
H_2CO_3	6.4
	6.9
H_2S	7.0
	7.8
$CH_3C(O)OOH$	8.2
	9
NH_4^+	9.2
$H-C\equiv N$	9.4
$^-CO_2CH_2NH_3^+$	9.7
$(CH_3)_3NH^+$	9.8
	10.0
CH_3CH_2SH	10.5
CH_3NO_2	10.3
	11

Compound	pK_a
$CH_2(C\equiv N)_2$	11
H_2O_2	11.6
CCl_3CH_2OH	12.2
	13
$CHCl_2CH_2OH$	12.9
CH_3CHO	13.6
CH_2ClCH_2OH	14.3
	15
CH_3OH	15.5
H_2O	15.7
CH_3CONH_2	15.1
$(CH_3)_3COH$	17
CH_3COCH_3	20
$HC\equiv CH$	24
$N\equiv C-CH_3$	25
	34
H_2	36
NH_3	38
	41
	43
$CH_2=CH-CH_3$	43
$CH_2=CH_2$	44
CH_3CH_3	48

[1] pK_a values obtained in aqueous solutions at 25 °C. pK_a values less than 0 and greater than 15.7 are corrected values from measurements in other solvents.

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]	ununnium 111 **Uuu** [272]	unumbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

Key:

element name
atomic number
symbol
atomic weight (mean relative mass)

*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	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
**actinoids	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]