1. (32 points) Circle the letter on the right which corresponds to the answer to each question. There is only one correct answer for each question.

(i) Which of the following terms describes the reactivity of boron tribromide, BBr₃?
   A. Brønsted-Lowry acid and Lewis acid  
   B. Brønsted-Lowry base and Lewis base  
   C. Lewis acid and not a Brønsted-Lowry acid  
   D. Lewis base and not a Brønsted-Lowry base

(ii) What is the equilibrium constant (Keq) at 25 °C for a reaction with a ΔG° value of 0 kcal/mole.
   E. –1  
   F. 0  
   G. 1  
   H. 1x10⁸

(iii) Which of the following is the correct order of increasing acidity (less acidic < more acidic)?
   I. CH₄ < NH₃ < H₂O < CH₃NH₂  
   J. NH₃ < CH₄ < MeOH < HF  
   K. NH₃ < CH₄ < H₂O < MeOH  
   L. H₂O < CH₃CO₂H < H₃O⁺ < HCl

(vi) During which of the following reactions did a rearrangement occur?
   M. t-butanol → 2-methylpropene  
   N. 3,3-dimethyl-2-butanol → 2,3-dimethyl-2-butene  
   O. cyclohexene → 1,2-dichlorocyclohexane  
   P. t-butanol → t-butyl chloride

(v) Which of the following is would react most quickly in an SN₁ reaction with acetic acid?
   Q. methyl fluoride  
   R. ethyl chloride  
   S. isopropyl chloride  
   T. tert-butyl bromide

(vi) Which of the following statements is not true regarding the reaction of 1° alkyl halides with good nucleophiles?
   U. the rate depends on concentration of nucleophile  
   V. alkyl fluorides are unreactive  
   W. large groups near the halide will not effect the rate  
   X. the rate will be faster at higher temperatures

(vii) Which of the following is the most reactive nucleophile?
   Y. tert-butyl cation  
   Z. dimethyl ether  
   AA. dimethylamine  
   BB. water

(viii) Which of the following anions is the strongest base?
   CC. CH₃COO⁻  
   DD. HO⁻  
   EE. NH₂⁻  
   FF. Cl⁻
2. (36 points). Provide the structure of products or reagents for each of the following reactions

(a) 

(\text{S\text{-1-bromo-3-methylhexane}} + \text{I}^-) \rightarrow \text{Product}

(\text{Cl}_{\text{Ph}} + \text{KCN}) \rightarrow \text{Product}

(\text{Br}_{\text{CH}_3}) + \text{HOC} \rightarrow \text{Product}

(\text{H}_2\text{NCH}_2\text{CH}_2\text{CH}_2\text{Br}) + \text{H_2O} \rightarrow \text{Product}, \text{C}_4\text{H}_9\text{N}

(b) Complete the following statements:

(i) Reaction of \((\text{R})\)-1-bromo-3-methylhexane with sodium methoxide produces \((\text{R}) / (\text{S}) / \text{racemic methyl 3-methylhexyl ether}\) \((\text{circle one})\)

(ii) The rate of the above reaction depends on the concentration of alkyl halide / methoxide. \((\text{circle all that apply})\)

(iii) Heating the above reaction will result in a faster / slower reaction \((\text{circle one})\)

(iv) The best solvent for this reaction would be water / DMF / hexane / acetic acid \((\text{circle one})\)
3. (32 points). Conversion of 3-methyl-1-butane to 2-methylhexane requires three synthetic steps. Provide reagents and the structure of the two synthetic intermediates in the following scheme.

(b) *With reference to structure*, explain why the tosylate anion (shown at right) is a much better leaving group in SN2 reactions than the hydroxide anion (HO⁻).

(c) *With reference to structure*, explain why acetonitrile, CH₃CN, is a weaker base than ethylamine, CH₃CH₂NH₂.

(d) A student realizes that protonation of an alcohol makes the -OH into a better leaving group. Therefore, he suggested that reaction of 1-propanol, H₂SO₄ and trimethylamine would provide N,N,N-trimethyl-N-propylammonium hydrogen sulfate according to the following key mechanistic step. However, this process does not yield the product predicted here. Why not?