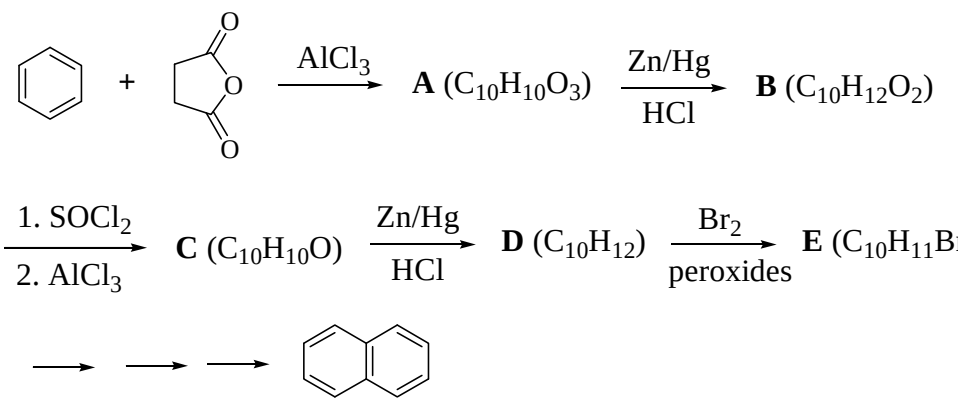
1. Define: (30%)
   (a) absorptivity
   (b) wavenumber
   (c) fluorescence
   (d) phosphorescence
   (e) coupling constants
   (f) chemical shift
   (g) base peak in mass spectrometry
   (h) molecular ion peak in mass spectrometry
   (i) tandem mass spectrometry
   (j) retention time
2. Describe van Deemter equation. (10%)
3. Describe the components of a fluorometer. (10%)
4. Describe Beer's Law. (10%)
5. What is an internal standard and why is it used? (10%)
6. Describe the components of a mass spectrometer. (10%)
7. For a normal-phase separation, predict the order of elution of n-hexane, n-hexanol, benzene. (10%)
8. Which electronic molecular energy levels are most used for absorption spectrometry? (10%)

1. Show the detailed mechanism, using curved arrows, for the dehydration of 1-methylcyclopentanol with phosphoric acid. Show all possible products, indicate which is expected to be the major product, and explain why. (15%)
2. Draw structures of compounds **A** – **E**, formed by reactions in the sequence resulting in the overall conversion of benzene into naphthalene. (20%)



3. Propose structures that are consistent with each set of peaks: (20%)
   (a) C_8H_{10}, 1.25 ppm (t, 3H), 2.68 ppm (q, 2H), 7.23 ppm (m, 5H);
   (b) C_7H_8O, 2.43 ppm (s, 1H), 4.58 ppm (s, 2H), 7.28 ppm (m, 5H); IR peak at 3350 cm^{-1};
   (c) $C_3H_6O_2$, 1.27 ppm (t, 3H), 2.66 ppm (q, 2H), 10.95 ppm (s, 1H); IR peaks at 1715 cm^{-1} and 3500 – 3000 cm^{-1};
   (d) $C_5H_{10}O$, 1.10 ppm (d, 6H), 2.10 ppm (s, 3H), 2.50 ppm (m, 1H); IR peak at 1720 cm^{-1};
   (e) C_8H_9Br, 2.00 ppm (d, 3H), 5.15 ppm (q, 1H), 7.35 ppm (m, 5H)

4. Show the reactions and reagents necessary to accomplish each of the following syntheses. (30%)
   (a) cyclohexane to cyclohexylacetylene
   (b) 1-butene to 3-methyl-1-pentyne
   (c) ethylene to 2-pentyne
   (d) nitrobenzene to *m*-bromophenol
   (e) toluene to benzylamine
   (f) benzene to phenol
   (g) toluene to *p*-nitrobenzoic acid
   (h) cyclohexene to *trans*-1,2-cyclohexanediol
   (i) ethyl bromide to 1-bromobutane
   (j) $CH_3OCH_2CH_2Br$ to $CH_3O(CH_2)_4OH$

5. Three compounds, **A**, **B**, and **C**, have the same molecular formula, C_5H_8. All three compounds decolorize Br_2 / CCl_4. Both **A** and **B** produce pentane when reacted with excess H_2 / Pt. Under the same conditions, **C** absorbs one equivalent of H_2.
   (a) Reaction of **A** with hot $KMnO_4$ gave $CH_3CH_2CH_2COOH$, while similar treatment of **B** produced CH_3CH_2COOH. What are structures of **A** and **B**? (10%)
   (b) Ozonolysis of **C** produced the dialdehyde, $OHC(CH_2)_3CHO$ as a sole product. What is the structure of **C**? (5%)