1. (2 pts) Which is the best leaving group for nucleophilic substitution?
   a) –OH  b) –Br  c) –Br  d) –Cl  e) –F

2. (2 pts) Which statement corresponds to an S_N1 reaction?
   a) takes place in one-step
   b) the concentration of the nucleophile has no effect on the rate
   c) a primary alkyl halide reacts faster than a secondary alkyl halide
   d) only inversion of configuration is observed at any chiral center that undergoes this type of substitution
   e) a polar, aprotic solvent is the best solvent to use in this type of substitution reaction

3. (4 pts) The methoxide ion (CH_3O^-) is a better nucleophile when it is dissolved in dimethyl sulfoxide (DMSO) compared to when it is dissolved in methanol (CH_3OH).
   Briefly explain why this is the case.
   The CH_3O^- is a better nucleophile in DMSO vs CH_3OH because DMSO is a polar, aprotic solvent while CH_3OH is a polar, protic solvent. Nucleophiles work better in polar, aprotic solvents because these types of solvents - like DMSO - cannot hydrogen bond to the charged nucleophile and decrease its nucleophilicity. On the contrary, polar, protic solvents, like CH_3OH, can hydrogen bond to the charged nucleophile and cause its electron density to be less available for nucleophilic substitution.

4. (4 pts, 2 each) Which reaction in each pair is faster? (Circle your answer)
   a) S_N2 reactions:
   ![S_N2 reaction](image)

   b) S_N1 reactions:
   ![S_N1 reaction](image)
5. (1 pt) **True** or **False** E1 elimination must take place through an anticoplanar transition state.

6. (1 pt) **True** or **False** The conjugate base of a nucleophile tends to be a better nucleophile than the acid itself.

7. (5 pts) a) Draw the transition state structure(s) for the following S_N2 reaction.

   \[
   \text{Br} + \text{CN} \rightarrow \text{CN} + \text{Br}^{-}
   \]

   [Diagram of S_N2 reaction]

   b) What happens to the rate of this reaction (i.e. by what factor will the rate increase or decrease by) when the concentration of the alkyl halide and \text{CN} are **both** increased by a factor of two?

   \[
   \text{rate} = k[C_r][C_{\text{CN}}] \quad \text{The rate will increase by a factor of 4.}
   \]

8. (6 pts, 3 each) Give the major E2 elimination product obtained from the following alkyl halides. Be sure to show stereochemistry where appropriate.

   a)

   \[
   \text{CH}_3 \text{CH} = \text{CH}_2 \text{CH}_3 + \text{HO}^- \rightarrow \text{CH}_3 \text{CH} = \text{CH}_2 \text{E}^+ \text{Cl}^- \text{S}_{\text{N2}} \text{ product is major product.}
   \]

   b)

   \[
   \text{CH}_3 \text{CH}_2 \text{CH} = \text{CH}_3 + \text{HO}^- \rightarrow \text{CH}_3 \text{CH} = \text{CH}_3 \text{E}^+ \text{Cl}^- \text{E2 elimination product most highly stereochemically pure.}
   \]