For questions 1-4, draw the major product formed by the given mechanism pathway in the corresponding product box. Draw the curved arrows showing formation of this product in the mechanism box.

**Mechanism. Include curved arrows but not transition state structures.**

1. (4) S<sub>N</sub>2:
   \[ \text{Br} \rightarrow \text{CH}_3\text{OH} \]

2. (8) S<sub>N</sub>1:
   \[ \text{Br} \rightarrow \text{CH}_3\text{OH} \]

3. (4) E<sub>2</sub>:
   \[ \text{Br} \rightarrow \text{CH}_3\text{OH} \]

4. (6) E<sub>1</sub>:
   \[ \text{Br} \rightarrow \text{CH}_3\text{OH} \]

5. (2) Complete this statement by writing S<sub>N</sub>2, S<sub>N</sub>1, E<sub>2</sub>, or E<sub>1</sub> in the blank. The **one most likely** mechanism for the reaction shown in questions 1-4 is _________.

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6. (10) Consider the effect on the S$_{N}$2 reaction rate of question 1 when the following changes are made. These changes are not cumulative; part (b) does not also include the change made in part (a). In the blank after each change write 'F' if the change makes the reaction faster, 'S' if the change makes the reaction slower, or 'N' if the change does not cause a significant rate change.

(a) NaOCH$_3$ changed to NaF: __________
(b) NaOCH$_3$ changed to NaOC(CH$_3$)$_3$: __________
(c) Bromine changed to iodine: __________
(d) NaOCH$_3$ changed to NaOCH$_2$CF$_3$: __________
(e) NaOCH$_3$ changed to NaOCH$_2$CF$_3$: __________

7. (2) In the box draw the molecular structure (not just the molecular formula) of a common aprotic solvent that has higher $\varepsilon$ than acetone. If you cannot remember the structure then write the common abbreviation of the solvent's name for one point.

8. (12) Now let's figure out what happens to the reaction rate for question 1 if CH$_3$OH is changed to acetone. In the space after each question, write 'A' if acetone is the correct answer, 'M' if methanol is the correct answer, or 'E' if the solvents are equal in this regard.

(a) Which solvent(s) are protic? __________
(b) Which solvent is more polar? __________
(c) In which solvent are the reactants more stable? _____
(d) In which solvent is the transition state more stable? _____
(e) In which solvent is $\Delta G^\ddagger$ lowest? ______
(f) In which solvent is the reaction fastest? ______

9. (4) Consider this S$_{N}$2 reaction:

If the reaction can occur write the S$_{N}$2 reaction in the product box. If the reaction cannot occur, complete the following explanation by adding no more than ten words: An S$_{N}$2 reaction is not possible because...

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Questions 10–12 concern the following process to convert a benzoic acid into methyl benzoate. $K_2CO_3$ is a mild base.

Benzoic acid $\xrightarrow{\text{K}_2CO_3, \text{aceton}}$ Potassium benzoate $\xrightarrow{\text{CH}_3I, \text{aceton}}$ Methyl benzoate

10. (3) Complete the reaction sequence by writing the molecular structure of methyl benzoate in the methyl benzoate box.

11. (2) Complete this sentence by writing 'better', 'poorer', or 'equal' in the blank: Potassium benzoate is a ____________ nucleophile than benzoic acid.

12. (6) Dimethyl sulfate (structure shown at the right) can also be used to convert potassium benzoate in methyl benzoate. Dimethyl sulfate is cheaper than iodomethane, but is it better? Complete each statement below by adding no more than fifteen words in each case. Make your reasons as different as possible.

(a) The reaction of potassium benzoate with dimethyl sulfate might be faster than the reaction of potassium benzoate with iodomethane because...

(b) The reaction of potassium benzoate with dimethyl sulfate might be slower than the reaction of potassium benzoate with iodomethane because...

13. (3) The reaction written below -- which was discussed in lecture -- produces another E2 product not shown. Write the structure of this second product in the additional product box. Hint: this additional product contains carbon.
14. (9) In the product box write the one major SN1 solvolysis product:

Write the mechanism showing the formation of your major product choice:

Questions 15–18 concern this E2 reaction:

15. (2) In the space below write one or more of the answer choice(s) describing the alkene of product C. Answer choices: cis, trans, E, and Z.

16. (2) In the reactant B box write an appropriate reactant necessary to carry out this E2 reaction. Be specific.

17. (2) Make a clear and precise drawing showing exactly which two bonds of reactant A must be aligned (along with the angle between them) for this E2 to occur.

18. (4) Complete this statement by writing a letter (C or D) in the blank, then add no more than fifteen words of explanation. Be very precise and very specific. Product _____ is the major product of this E2 reaction because this product...
Questions 19–21 concern nucleophilic addition of cyanide ion (a powerful nucleophile) to epoxide $E$. An epoxide is an ether that is part of a three-membered ring. The reaction occurs via an $S_N2$ mechanism.

\[
\begin{align*}
\text{Epoxide } E & \quad \xrightarrow{\text{K}^- \cdot \text{CN}^-} \quad \text{Alcohol } F \\
\text{Alcohol } F & \quad \text{Alcohol } G
\end{align*}
\]

19. (2) What kind of leaving group is an alkoxide ($RO^-$)? Write one of the following leaving group category choices in the space below: excellent, moderate, special circumstances, or never.

20. (4) Complete this statement by writing a letter ($F$ or $G$) in the blank, then adding no more than fifteen words. Be precise and be specific. The major product of this reaction is alcohol _______ because formation of this alcohol...

21. (3) Complete this statement by adding no more than ten words. One factor in this reaction which helps the alkoxide be a better leaving group than an alkoxide normally might be is...

22. (6) In lecture we learned of the three common carbocation fates. Write the name of these fates in the 'Name of Fate' column (one fate per box). In the 'Problem Number' box write one problem or solution number, such as 29(q), in which that fate appears. If a fate does not appear on this exam write '0' in the Problem Number box.

<table>
<thead>
<tr>
<th>Name of Fate</th>
<th>Problem Number</th>
</tr>
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<tbody>
<tr>
<td>Fate #1:</td>
<td></td>
</tr>
<tr>
<td>Fate #2:</td>
<td></td>
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<tr>
<td>Fate #3:</td>
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