**SN2 / E2 Topics**

1. Strong, nonbulky nucleophiles are best in SN2 reactions (strong decides “2” or “1”)
   
   a. Less bulky is better for SN2 reactions (versus E2)
      
      ![SN2 Reaction Structures](image)
      
      Sterically large potassium t-butoxide mainly produces E2 products, even at 1° RX centers
      
   b. A less basic electron pair donor is better for SN2 reactions (versus E2). A conjugate acid with a lower $pK_a$ is “less basic”.
      
      ![SN2 Reaction Structures](image)
      
   Cyanide is a good SN2 nucleophile at methyl, primary and secondary RX centers, but tertiary RX centers give only E2 reaction. $pK_a$ of conjugate acid $(\text{CN} = \text{H}^-)$ = 9.
      
      A terminal acetylide is a good SN2 nucleophile at methyl and primary, but secondary and tertiary RX centers give mainly or only E2. $pK_a$ of conjugate acid $(\text{RC} = \text{H})$ = 25 (R = carbon or hydrogen)
      
      Carboxylates are good SN2 nucleophiles at methyl, primary and secondary RX centers, but tertiary RX centers give mainly or only E2. $pK_a$'s of conjugate acid = 5
      
      Alkoxides are good SN2 nucleophile at methyl and primary, but secondary and tertiary RX centers give mainly or only E2. $pK_a$'s of conjugate acid = 16-19
      
   Examples of oxygen nucleophiles
      
<table>
<thead>
<tr>
<th>weak nucleophile / bases</th>
<th>strong nucleophile / bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>pK$_a$ (conjugate acid)</td>
<td>pK$_a$ (conjugate base)</td>
</tr>
<tr>
<td>water</td>
<td>H—O—H</td>
</tr>
<tr>
<td>(16)</td>
<td>H—O—</td>
</tr>
<tr>
<td>alcohols</td>
<td>R—O—H</td>
</tr>
<tr>
<td>(16-19)</td>
<td>R—O—</td>
</tr>
<tr>
<td>carboxylic acids</td>
<td>R—C—O—H</td>
</tr>
<tr>
<td>(5)</td>
<td>R—C—O—</td>
</tr>
</tbody>
</table>
      
   ![SN2 Reaction Structures](image)
      
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2. The role of RX in SN2 reactions.
   
   a. The $C_α$ position – Anything that hinders approach of nucleophile slows the SN2 reaction.
      
      ![SN2 Reaction Structures](image)
      
      methyl RX ($≈ 30$)
      
      primary RX ($≈ 1$)
      
      secondary RX ($≈ 1/40$)
      
      tertiary RX ($≈ 0$)
      
      Complete substitution at $C_α$ stops all SN2.
b. The $C_\beta$ position— Anything that hinders approach of nucleophile slows the $S_N2$ reaction.

\[ \text{unsubstituted $C_\beta$ (≈ 1)} \quad \text{monosubstituted $C_\beta$ (≈ 0.4)} \quad \text{disubstituted $C_\beta$ (≈ 0.03)} \quad \text{trisubstituted $C_\beta$ backside of $C_\alpha$ is blocked (≈ 0)} \]

\[ \text{Complete substitution at $C_\beta$ stops all $S_N2$.} \]

\[ \text{The $C_\beta$ position– Anything that hinders approach of nucleophile slows the $S_N2$ reaction.} \]

\[ > >> \]

\[ \text{c. An adjacent pi bond (allyl and benzyl) attached to $C_\alpha$ greatly accelerates $S_N2$ reactions.} \]

\[ \text{The pi bond is parallel to 2p orbital in transition state having excess electron density. This allows the excess charge to be delocalized (resonance), which lowers the activation energy and makes the reaction go faster.} \]

\[ \text{allyl RX $S_N2 \approx x 40$} \]
\[ \text{benzyl RX $S_N2 \approx x 100$} \]

3. Inversion of configuration in $S_N2$ reactions always occurs, but we only “see it” at chiral centers or in rings with “cis/trans” substitution.

a. R/S

\[ \text{“S” configuration} \quad \text{“R” configuration} \]

b. Rings (cis/trans)

\[ \text{(cis ring $\rightarrow$ trans ring) or (trans ring $\rightarrow$ cis ring), May or may not have R/S configurations.} \]
4. The role of solvent in S_N2 reactions

a. Polar, aprotic solvents are best for S_N2 reactions. They tend to strongly solvate cations and keep them away from the electron pair donor (nucleophile). They only weakly interact with the anion nucleophiles. Some more common possibilities are listed below.

\[
\begin{align*}
\text{dimethylsulfoxide (DMSO)} & \quad \text{dimethylformamide (DMF)} \\
\text{acetonitrile (AN)} & \quad \text{hexamethylphosphoramide (HMPA)}
\end{align*}
\]

strong solvent dipole = polar solvent
ox polarized hydrogen atoms = aprotic

Cations tend to be tightly bound to the solvent and anions tend to be unbound and relatively free to react in polar aprotic solvents. Nucleophilic lone pairs are available to react (donate at C_α center).

b. Polar, protic solvents are best for E2 reactions. See point 1 of E2 reactions (next).

5. Common leaving groups (for our course) are stable as anions (which start as neutral) or they are neutral molecules (which start as cations).

\[
\begin{align*}
\text{chloride} & \quad \text{bromide} & \quad \text{iodide} & \quad \text{tosylate} \\
\text{water} & \quad \text{alcohol}
\end{align*}
\]

These can be leaving groups in basic, neutral or acidic conditions.

Water is a leaving group from a protonated alcohol in acid conditions. In a similar way an alcohol is a leaving group from a protonated ether in acid conditions.
1. Strong, bulky bases are best for E2 reactions (often these are polar, protic solvents and their conjugate bases). The conjugate bases are highly basic and have a strong attraction for hydrogen (the target in an E2 reaction). This tendency can be emphasized by introducing steric bulk into the base (electron pair donor) such as the case with potassium t-butoxide. Also used as bases are hindered tertiary amines.

solvent = water methanol ethanol isopropyl alcohol t-buty1 alcohol

Conjugate bases = Potassium t-butoxide mainly produces E2 products, even at 1° RX centers.

Conjugate bases are pretty basic as indicated by moderately high pKₐ of conjugate acids (16-19 range).

2. The role of RX in E2 reactions.

a. The Cₐ position – more substitution here slows S_N2 and makes E2 more competitive. However, you always need a C₇-H (almost always anti).

CH₃ (methyl) 1° < 2° << 3° (only E2 at 3° RX with strong base/nucleophile)

No E2 is possible at methyl.

Anti C₇-H and Cₐ-X is the usual mode for E2 reactions.

b. The C₇ position – more substitution here slows S_N2 and makes E2 more competitive. However, you always need a C₇-H (almost always anti).

The C₇ carbon has no additional groups beyond Cₐ.

The C₇ carbon has one additional group beyond Cₐ.

The C₇ carbon has two additional groups beyond Cₐ.

The C₇ carbon has three additional groups beyond Cₐ. C₇ is fully substituted.

E2 reaction correlates with number of groups at C₇ = 0 < 1 < 2 . (ethyl)

If there are 3 "R": groups on C₇, there is no E2 because there is no C₇-H.
c. An adjacent pi bond is helpful to E2 reactions because the new pi bond can conjugate with the existing pi bond, BUT generally SN2 is helped more (allyl RX and benzyl RX). Tertiary allylic and benzylic still react by E2 (no SN2).

![allyl structure](image1)

![benzyl structure](image2)

3. For us, E2 reactions always attack an anti Cβ-H (relative to the Cα carbon) in competition with SN2. Each Cβ-H must be considered and many outcomes may be possible. A simple beta-CH2 may lead to both E and Z stereoisomers. The major E2 product is decided on the basis of alkene substitution patterns (tetra > tri > di(trans) > di(cis) = di(gem) > monosubstituted alkenes).

a. Open chains must be rotated to the desired conformation for reaction. Look especially at beta CH2's for the possibility of E/Z stereoisomers. Cβ-H and Cα-X are always anti for us in E2 reactions.

![primary RX](image3)

![secondary RX](image4)

![tertiary RX](image5)

b. Two chair conformations rapidly equilibrate in cyclohexane rings. The following is only suggestive, as there are many possibilities for substitution patterns.

![possible E2 approach](image6)

SN2 is difficult when X is equatorial, even if not at a tertiary center.

![SN2 is OK when X is equatorial, but not at tertiary center](image7)

These are only suggestive of the many possible E2 variations in a cyclohexane.

1. In cyclohexanes, the leaving group must be axial to have an anti Cβ-H.
2. If a nonhydrogen group is at one of the Cβ positions, then no E2 can occur at that position.
3. An external Cβ-H is also possible (shown in the example above).
4. The bases role in E2 reactions - strong bases are necessary (most often bulky alkoxides or bulky tertiary amines are used).

Potassium t-butoxide mainly produces E2 products, even at 1º RX centers.

Nitrogen bases used to favor E2 reactions.

5. The role of solvent in E2 reactions (same as #1 in E2 reactions).

a. Polar, protic solvents are best for E2 reactions. Their conjugate bases are highly basic and have a strong attraction for hydrogen (the target in an E2 reaction). This tendency can be emphasized by introducing steric bulk into the base (electron pair donor), such as is the case with potassium t-butoxide.

solvent = water methanol ethanol isopropyl alcohol t-butyl alcohol

Potassium t-butoxide mainly produces E2 products, even at 1º RX centers

6. Common leaving groups (for our course) are stable as anions (which start as neutral) or they are neutral molecules (which start as cations). (Same as point 5 in S_N2 items above.)

These can be leaving groups in basic, neutral or acidic conditions

Water is a leaving group from a protonated alcohol in acid conditions. In a similar way an alcohol is a leaving group from a protonated ether in acid conditions.
Major expected product(s) in $S_N2$ / $E2$ competition.

<table>
<thead>
<tr>
<th>nucleophile</th>
<th>methyl</th>
<th>primary</th>
<th>secondary</th>
<th>tertiary</th>
</tr>
</thead>
<tbody>
<tr>
<td>:N≡C⁻</td>
<td>$S_N2$ (only)</td>
<td>$S_N2 &gt; E2$</td>
<td>$S_N2 &gt; E2$</td>
<td>$E2$ (only)</td>
</tr>
<tr>
<td>$R-\equiv C$</td>
<td>$S_N2$ (only)</td>
<td>$S_N2 &gt; E2$</td>
<td>$E2 &gt; S_N2$</td>
<td>$E2$ (only)</td>
</tr>
</tbody>
</table>

$\text{compare these}$

"**bold**" = different "typical" outcomes

<table>
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<tbody>
<tr>
<td>$\ddots$</td>
<td>$S_N2$ (only)</td>
<td>$S_N2 &gt; E2$</td>
<td>$E2 &gt; S_N2$</td>
<td>$E2$ (only)</td>
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<tr>
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$\text{compare these}$

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</tr>
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</table>

$\text{compare these}$
S\textsubscript{N}1 and E1 Factors

1. We write nucleophiles (H-Nu:) and bases (H-B:) differently. A proton is included and they are written as neutral molecules. Those most often used by us are solvent molecules of polar, protic solvents (water, alcohols and liquid carboxylic acids).

\[
\text{Weak nucleophile bases used in our course:} \quad \text{water} \quad \text{alcohols} \quad \text{carboxylic acids}
\]

2. Role of RX compound – RX needs to stabilize a carbocation carbon.

a. “R” groups on the C\textsubscript{\alpha} carbon are inductively donating and help stabilize positive charge. Tertiary is better than secondary and we will not propose primary or methyl carbocations.

\[
\begin{align*}
\text{very poor} & \quad \text{poor} & \quad \text{OK} & \quad \text{relatively good} \\
\text{= donating inductive effect}
\end{align*}
\]

b. Hyperconjugation stabilizes positive charge. Tertiary is better than secondary and we will not propose primary or methyl carbocations.

\[
\text{Carbocation stabilized by the electrons in an parallel adjacent sigma bond.}
\]

c. Resonance is very good at stabilizing charge (positive, negative, free radicals or neutral conjugate pi systems).

i. Pi bonds allow delocalization of electrons via parallel overlap of adjacent 2p orbitals. Most often these pi electrons are from an alkene or aromatic pi system.
ii. Lone pairs adjacent to empty orbitals can share their electron density to help stabilize positive charge (they also delocalize into neutral pi bonds, like enols and amides). Most often nitrogen or oxygen is the donor atom. (Under very different conditions, carbon can do so when present as a carbanion.)

\[ \text{carbocation next to a lone pair (usually nitrogen or oxygen)} \]

\[ \text{X} = "N" \text{ or } "O" \]

iii. Really poor carbocations – We usually won’t propose these, though there are rare occasions where we do invoke some of them.

\[ \text{Vinyl carbocation has an empty 2p orbital, but on a sp hybridized carbon atom.} \]

\[ \text{Phenyl carbocation has an empty sp}^2 \text{ orbital.} \]

\[ \text{Terminal alkyne carbocation, has an empty sp orbital.} \]

3. Attack of nucleophile/base

a. Attack at C\(_\alpha\) carbon (top and bottom)

If \( R = R \), then we cannot detect top/bottom attack. If \( R_1 \neq R_2 \), then we can detect top/bottom attack because opposite configurations will form at the C\(_\alpha\) carbon, which are enantiomers. We assume racemization, but is not always true.

\[ \text{There are no chiral centers, but top/bottom attack is seen in cis/trans products which are diastereomers.} \]

b. Attack at C\(_\beta\) -H: anything goes (can rotate C\(_\beta\)-H up or down relative to the carbocation 2p orbital).

\[ \text{E and Z possible stereochemistry.} \]
4. Role of solvent – Polar, protic solvent stabilizes charges of both types in first step of the $S_N1$ and E1 reaction possibilities (ionization of the C-X bond).

5. Leaving groups – Same as point 5 in $S_N2$ reactions.

6. Special cases of $S_N1$ and E1 reactions.

   a. Assume mainly $S_N$ product over E product when alcohols (ROH) are mixed with HX acids (H-Cl, H-Br and H-I). $S_N2$ reactions are assumed at methyl and primary alcohols and $S_N1$ reactions are assumed at secondary, tertiary, allylic and benzylic alcohols.

   $$\begin{array}{cccc}
   R & O & H & H \rightleftharpoons X \\
   \text{(X = Cl, Br, I)}
   \end{array}$$

   - $R = \text{methyl} = S_N2$
   - $R = \text{primary} = S_N2$
   - $R = \text{secondary} = S_N1$
   - $R = \text{tertiary} = S_N1$
   - $R = \text{allylic} = S_N1$
   - $R = \text{benzylic} = S_N1$

   b. Assume mainly E1 reactions when alcohols are mixed with concentrated sulfuric acid ($H_2SO_4$) when heated ($\Delta$).

   $$\begin{array}{cccc}
   R & O & H & H \rightleftharpoons S \rightleftharpoons O & H \\
   \Delta = \text{heat}
   \end{array}$$

   - $R = \text{methyl} = \text{not possible}$
   - $R = \text{primary} = \text{difficult, E1}$
   - $R = \text{secondary} = \text{moderate, E1}$
   - $R = \text{tertiary} = \text{relatively easy, E1}$

   Alkenes, with possible rearrangement, more substituted alkenes tend to be the major products formed. This is the only reaction where we will propose E1 as the major product.
Essential clues to make educated guesses about what is occurring.

### Reagents → Reaction Conditions → Products

\[ \text{R-X} + \text{Nu-H} \rightarrow \text{Nu-R} + \text{H} - \text{Nu-H} + \text{X}^\ominus \]  
\[ \text{S_N1} \]

\[ \text{R-X} + \text{B-H} \rightarrow \text{Ca-Cb} + \text{H-B-H} + \text{X}^\ominus \]  
\[ \text{E1} \]

\[ \text{R-X} + \text{Nu}^\ominus \rightarrow \text{Nu-R} + \text{X}^\ominus \]  
\[ \text{S_N2} \]

\[ \text{R-X} + \text{B}^\ominus \rightarrow \text{Ca-Cb} + \text{B-H} + \text{X}^\ominus \]  
\[ \text{E2} \]

- **R** = carbon portion
- **Nu-H** = **B-H**
- **Nu** = **B**
- **Nu-R** substitution products
- **E** elimination products
- **X** leaving group

- methyl = CH3-X
- primary = RCH2-X
- secondary = R2CH-X
- tertiary = R3C-X
- allylic = CH2=CHCH2-X
- benzylic = C6H5CH2-X

- weak electron pair donors = S_N1 / E1
- neutral solvent
- H2O, ROH, RCO2H

- strong electron pair donors = S_N2 / E2
- anions, neutral nitrogen, neutral sulfur

**Typical R-X Structures**

- H3C—X
  - methyl X (unique)
- R—CH2—X
  - primary X (general)
- R—CH—X
  - secondary X (general)
- R—C—X
  - tertiary X (general)
- H2C—CHCH2
  - allylic X (and variations)
- \( \text{benzylic X (and variations)} \)
Templates for predicting SN2 and E2 reactions

**primary RX**

\[ \text{Nu:} \quad \Theta \]

\[ \text{B:} \]

\[ \text{two different perspectives} \]

\[ \Theta : \text{B} \]

\[ \Theta : \text{Nu} \]

**secondary RX**

\[ \text{Nu:} \quad \Theta \]

\[ \text{B:} \]

\[ \text{two different perspectives} \]

\[ \Theta : \text{B} \]

**tertiary RX**

\[ \text{Nu:} \quad \Theta \]

\[ \text{B:} \]

\[ \text{one perspective} \]

**cyclohexane RX**

\[ C_\alpha \text{ is carbon with leaving group and } C_\beta \text{ carbons are attached to } C_\alpha. \]

An axial "X" is necessary for a successful E2 reaction and also works better for SN2. X can be in many possible positions (there are two conformations for each possibility).
Problem: Write a 3D structure of (3S,4S)-3-iodo-4-methoxyhexane. (Draw a 2D structure first.)

1. What is/are the expected product(s) of this compound with sodium cyanide in DMSO (dimethylsulfoxide is the solvent). Show all mechanistic details clearly for how each of the possible products is formed (3D structures, curved arrows, lone pairs and formal charges). Indicate major and minor products.

1. 3D structure

(3S,4S)-3-iodo-4-methoxyhexane

2. mechanisms and products

(3S,4S) (3R,4S) (2E,4S) (2Z,4S)
Problem

a. Write a 3D structure for the given name: (2R,3S,4R) 2-deuterio-3-bromo-4-methylhexane. Draw 2D first.

(2R,3S,4R) 2-deuterio-3-bromo-4-methylhexane

b. What are the expected products if hydroxide is the electron donor? How would the expected products differ if hydroxide were changed to ethoxide (?), t-butoxide (?), water (?) or ethanol(?). Write a separate mechanism showing the formation of each possible product.

Two possible perspectives.

1. Draw $C_\alpha = C_3$ (in this problem). Fill it in with a proper configuration (R or S).

2. Add in groups on $C_\beta$ carbons, with anti $C_\beta$-H and the “other” groups in any manner. If you are lucky, you will have the correct configuration. If you are wrong, then switch the two “other” groups.

3. If there is a strong nucleophile/base, then write out all of the $S_N2/E2$ possibilities. The only $S_N2$ product will form by inversion of configuration. Any $E2$ products require an anti $C_\beta$-H and $C_\alpha$-X conformation. You should draw every possible conformation that allows this, and examine the predicted alkene that forms. This will determine the configuration (E/Z) of any alkene products. More substituted alkenes are generally more preferred products.

4. If there is a weak nucleophile/base (usually $H_2O$, ROH, RCO$_2$H), then write out all of the $S_N1/E1$ possibilities. The first step for both mechanisms is loss of the leaving group which forms a carbocation. If we ignore rearrangement possibilities for now, then there are two choices that can occur ($S_N1$ and $E1$). For $S_N1$ products add the :Nu-H from the top and bottom. If $C_\alpha$ is a chiral center, there will be two different products. It is possible that there are two different products in a ring with cis/trans possibilities and no chiral centers. You will also have to take off the extra proton via an acid/base reaction to get a neutral product. For $E1$ products you will have to remove any $C_\beta$-H (no anti requirement). Make a double bond between all different $C_\beta$-$C_\alpha$’s. Switch the two groups on either of the carbons of each double bond to see if different stereoisomers are formed. The possible outcomes are that the switch produces no change, or E/Z diastereomers are formed. All possible outcomes are predicted results in $E1$ reactions.
**Sₙ/E Worksheet**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Methyl**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Primary**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Secondary**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Tertiary**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**H−Nu:**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**H−B:**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Methyl**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Primary**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Secondary**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**

---

**Tertiary**

**Possibilities:**  
- **SN2**  
- **E2**  
- **SN1**  
- **E1**
Partial Key

a. Write a 3D structure for the given name: (2R,3S,4R) 2-deuterio-3-bromo-4-methylhexane. Draw 2D first.

(2R,3S,4R) 2-deuterio-3-bromo-4-methylhexane

All variations are shown below, which are enantiomers, diastereomers?

(2R,3S,4R) (2S,3R,4S)
(2R,3S,4S) (2S,3R,4R)
(2S,3S,4S) (2R,3S,4R)
(2R,3S,4R) (2S,3S,4R)

How would the problem change if the bromine, deuterio and/or methyl were moved to another position?

b. What are the expected products if hydroxide is the electron donor? How would the expected products change if hydroxide were changed to ethoxide (?), t-butoxide (?), water (?) or ethanol(?). Write a separate mechanism showing the formation of each possible product.

:Nu: Θ
Θ: B:

= hydroxide, ethoxide and many other possibilities.

H—Nu:

= water, ethanol and many other possibilities.

The Cα configuration makes no difference in S_N1/E1 reactions because it is destroyed in the first step of the reaction.
(2R,3S,4R) 2-deutério-3-bromo-4-metilhexano
(2R,3S,4R) 2-deuterio-3-bromo-4-methylhexane

H—Nu:
H—B:

\[ \text{more possibilities} \]

\[ \text{more possibilities} \]

\[ \text{more possibilities} \]

\[ \text{more possibilities} \]
Problem – Predict the possible products (arrow pushing required, lone pairs, formal charges) for the following reactions.

a) 

\[ \text{H} - \text{C} = \text{C} : \]

b) 

\[ \text{H} - \text{O} : \]

c) 

\[ \text{H} = \text{C} - \text{O} : \]

d) 

\[ \text{CH}_3 \text{O} : \]

consider example at top

e) 

\[ \text{H} = \text{N} = \text{C} : \]

"careful"

f) 

\[ \text{O} : \]

(low pK\(_a\))

g) 

\[ \text{O} : \]

(low pK\(_a\))

h) 

\[ \text{H} - \text{S} : \]

(low pK\(_a\))

i) 

\[ \text{H} = \text{C} - \text{O} : \]

(high pK\(_a\) sterically bulky)

j) 

\[ \text{H} = \text{C} - \text{C} - \text{O} : \]

(high pK\(_a\) sterically bulky)

k) 

\[ \text{H} = \text{N} : \]

l) 

\[ \text{F} : \]

m) 

\[ \text{O} : \]

(low pK\(_a\))
Possible Key – predict products

a

In our course $S_N2 > E2$ at primary RX (except t-butoxide).

b

E2 is in competition with $S_N2$. Because hydroxide is strongly basic we expect $E2 > S_N2$. Similar to "c", except for basicity of "O Θ".

c

E2 is in competition with $S_N2$. Because carboxylate is less basic we expect $S_N2 > E2$. Similar to "b", above, except for basicity of "O Θ".

d

"Z" configuration (least = cis)

"E" configuration (most = trisubstituted)
This is a sneaky one. A Cβ carbon is fully substituted so SN2 reaction is greatly inhibited. There is an anti Cβ-H possibility so E2 can occur.

Only the **MAJOR** product is shown on the remaining problems. It is assumed that you can generate all possible products, including the major and minor possibilities.
Bonus problem: Sulfur is a very good nucleophile and not very basic, but at tertiary RX we only see E2.