Objective 11: Apply reactivity principles to Substitution and Elimination reactions. Compare size and strength of nucleophile to predict major product.

Quiz Practice problems

Key ideas:

Substitution and Elimination reactions involve similar structural features in the reactant. Look for the following structural features: alpha carbon, H bonded to a beta carbon, leaving group, and nucleophile.

You want to determine whether the major product is the subsitution product or elimination product.

These factors help you determine the major product:

- Type of substrate: 1^o, 2^o, 3^o RX or ROH or other organic compound with a leaving group.
- Strength of nucleophile: strong or weak – see pK_a table.
- Size of nucleophile: big or small.

In general, the elimination product is favored because it is easier for a nucleophile to react at the H bonded to the beta carbon than at the (crowded) alpha carbon.

2^o and 3^o R-X + strong base favor elimination.

1^o R-X + small, strong bases (e.g., $NaOC_2H_5$) favor substitution.

1^o R-X + large, strong bases (e.g., $NaOC(CH_3)_3$) favor elimination.

1^o and 2^o R-X + weak base favor substitution. Weak Base is a base weaker than OH^-.

3^o R-X without anionic base favor substitution. Use solvent as $Nu:^-$.

Skills:

Identify alpha carbon in a compound.

Identify H bonded to beta carbon in a compound.

Identify alpha carbon as 1^o, 2^o, 3^o.

Identify leaving group in a compound.

Identify leaving group as good or poor.

Describe how to make a poor leaving group into a good leaving group.

Identify a nucleophile as strong or weak.

Identify a nucleophile as big or small.

Given reactants, use curved arrows to show how nucleophile reacts at alpha carbon to form substitution products.

Given reactants, use curved arrows to show how nucleophile reacts at H bonded to beta carbon to form elimination products.

Identify the major product. Give reasons based on substrate type, size and strength of nucleophile.

1. Determine whether the bases (nucleophiles) in Table 1 are strong or weak, big or small.

Table 1. Nucleophile (Base) Strength and Size

Nucleophile	Strength (strong or weak)	Size (big or small)
Cl^-		
OH^-		
H_2O		
CH_3O^-		
CH_3CH_2OH		
$(CH_3)_3CO^-$		
NH_3		
CH_3COO^-		
CN^-		
$HCC:^-$		

Answers:

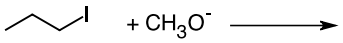
See pK_a table.

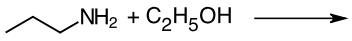
Table 1. Nucleophile (Base) Strength and Size

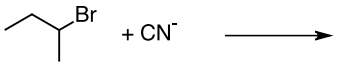
Nucleophile	Strength (strong or weak)	Size (big or small)
Cl^-	weak	small
OH^-	strong	small
H_2O	weak	small
CH_3O^-	strong	small
CH_3CH_2OH	weak	small
$(CH_3)_3CO^-$	strong	big
NH_3	weak	small
CH_3COO^-	weak	big
CN^-	weak	small
$HCC:^-$	strong	small

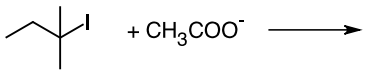
2. For each reaction,
(i) State the type of substrate: 1°, 2°, or 3°.
(ii) Draw the structure of the substitution and elimination product. Use curved arrows to show how each reaction occurs.
(iii) Which product, substitution or elimination, is the major product? Give reasons based on substrate type, size and strength of nucleophile.

Reaction | Substitution Product | Elimination Product



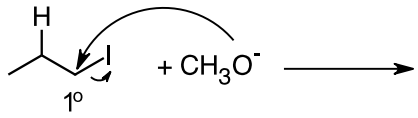


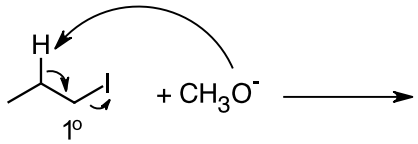




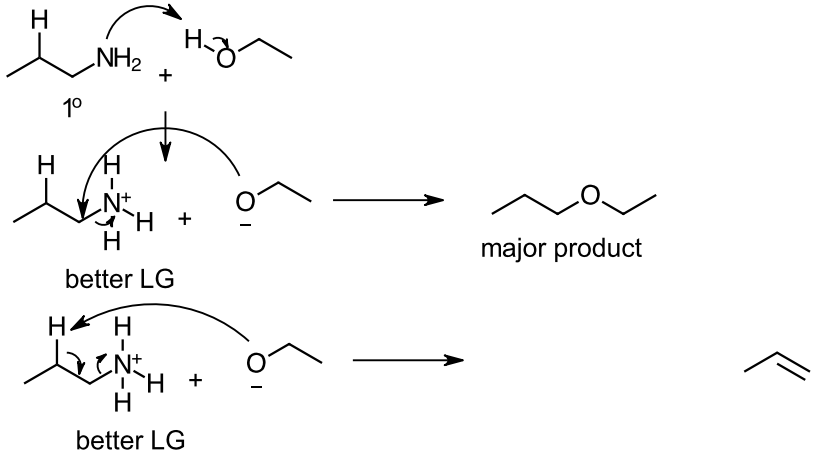
Answers:
(iii) See Objective 11 Slide 10 to identify the factors (substrate type (1°, 2°, 3°) and size (big or small) and strength (strong or weak) of base.
USUALLY, elimination is favored over substitution.

Reaction | Substitution Product | Elimination Product

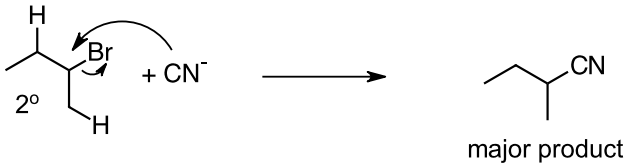




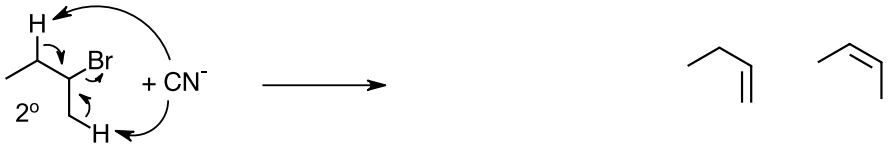
1° RX and small, strong base (CH_3O^-) favors substitution.



1° RX and small, strong base ($C_2H_5O^-$) favors substitution.
You can also state C_2H_5OH, rather than $C_2H_5O^-$, is the nucleophile in the 2nd step. C_2H_5OH is a small, weak base so 1° RX and small, weak base (C_2H_5OH) favors elimination.



major product

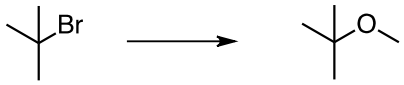


2° RX and weak base (CN^-) favors substitution. A weak base is weaker than OH^-.

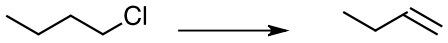
major product

3° RX with anionic base (CH_3COO^-) favors elimination. The more substituted alkene is more stable and is the major product.

3. Identify the nucleophile you would use to produce a high yield of product. Give reasons for your choice.

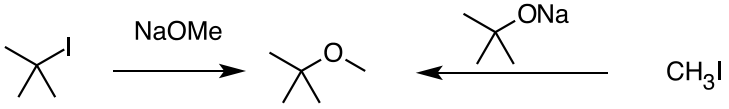


MTBE - common solvent



Answers:
1st reaction: 3° RX without anionic base (CH_3OH) favors substitution. Use CH_3OH as the solvent for your nucleophile.
2nd reaction: 1° RX and large, strong base ($(CH_3)_3CO^-$) favors elimination. Use $(CH_3)_3CO^-$ for your nucleophile.

4. One method works; the other does not. Which one works? Give reasons. (From Klein, "Organic Chemistry", 1st ed., Problem 7.62) Hint: what structural features are in each reactant?



CH_3I

Answers:
In $(CH_3)_3I$, there is one alpha carbon and three beta carbons with 3 H's on each beta carbon.
3° RX with anionic base (CH_3O^-) favors elimination, not substitution.

In CH_3I, there is one alpha carbon and no beta carbons.
1° RX with large, strong base ($(CH_3)_3CO^-$) favors elimination but elimination cannot occur because there are no H's on a beta carbon ==> so substitution occurs.
So the method that works is $CH_3I + (CH_3)_3CO^- \rightarrow (CH_3)_3COCH_3$