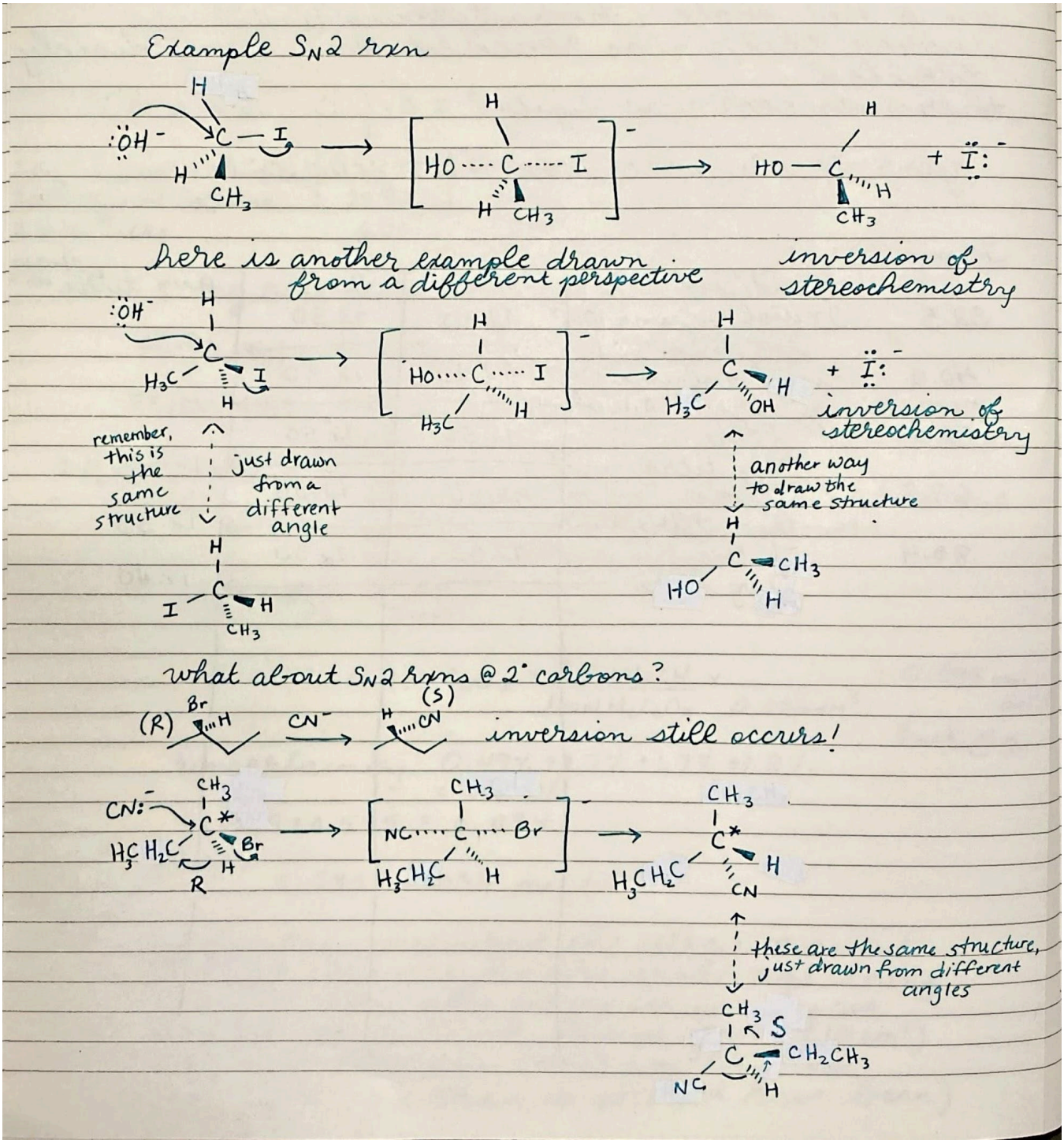
Nucleophilic Substitution Reactions: S_N1 vs S_N2 Mechanisms **Name _____**

Introduction

Nucleophilic substitution reactions are fundamental transformations in organic chemistry where a nucleophile replaces a leaving group in a molecule. Two distinct mechanisms exist for these reactions: S_N1 (Substitution Nucleophilic Unimolecular) and S_N2 (Substitution Nucleophilic Bimolecular). Understanding the differences between these mechanisms is essential for predicting reaction outcomes and designing synthetic pathways.

S_N2 Mechanism proceeds through a single concerted step where the nucleophile attacks the electrophilic carbon from the backside as the leaving group departs. This results in inversion of configuration at the stereogenic center (Walden inversion). The reaction rate depends on both the concentration of the substrate and the nucleophile, making it second-order kinetics.

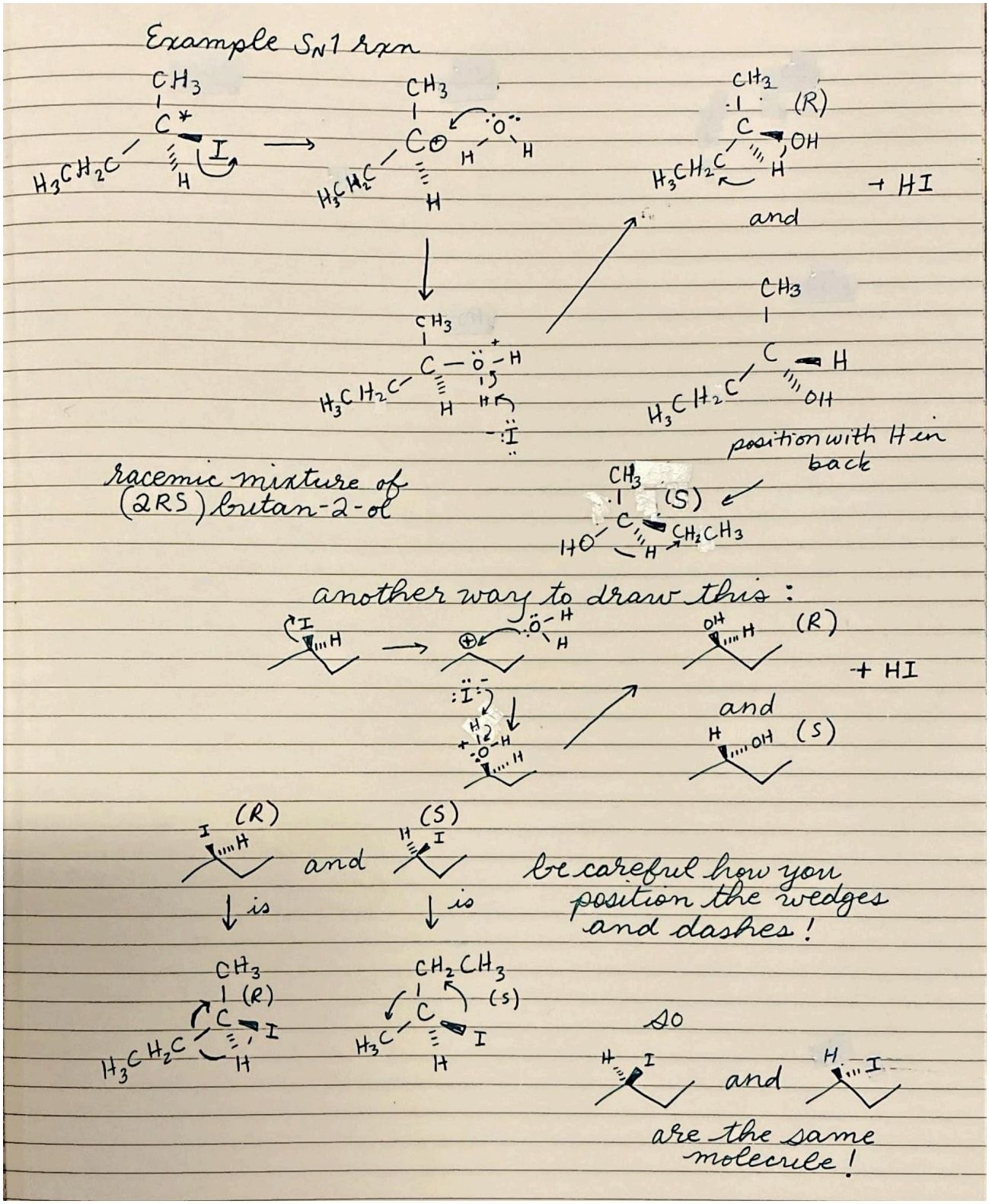
Example S_N2 reaction: $CH_3CH_2I + OH^- \rightarrow CH_3CH_2OH + I^-$



S_N1 Mechanism proceeds through a two-step process. First, the leaving group departs to form a planar carbocation intermediate. Second, the nucleophile attacks the carbocation from either face, leading to racemization (or partial inversion in some cases). The reaction rate depends only on the substrate concentration, exhibiting first-order kinetics.

Example SN_1 reaction: $CH_3CH_2C(CH_3)I + H_2O \rightarrow CH_3CH_2C(CH_3)OH + HI$

The mechanism that predominates depends on several factors including substrate structure, nucleophile strength, solvent polarity, and temperature. Generally, S_N2 is favored by primary substrates, strong nucleophiles, and polar aprotic solvents, while S_N1 is favored by tertiary substrates, weak nucleophiles, and polar protic solvents.



Assignment Questions-Please answer on a separate sheet of paper

1. Draw the complete mechanism for the S_N2 reaction between bromomethane (CH_3Br) and hydroxide ion (OH^-). Include:

- Proper curved arrow notation showing electron movement
- The transition state structure
- All lone pairs

2. Draw the complete mechanism for the S_N1 reaction between 2-bromo-2-methylpropane and water. Include:

- Both steps of the mechanism with curved arrows
- The carbocation intermediate with its geometry
- All lone pairs and formal charges
- The final deprotonation step to form the neutral product

3. Explain why carbocation intermediates are formed in S_N1 reactions but not in S_N2 reactions. What is the hybridization and geometry of the carbocation intermediate?

4. Rank the following alkyl halides in order of decreasing S_N2 reactivity. Justify your ranking.

- $CH_3CH_2CH_2Br$ (1-bromopropane)
- $(CH_3)_2CHBr$ (2-bromopropane)
- $(CH_3)_3CBr$ (2-bromo-2-methylpropane)
- CH_3Br (bromomethane)

5. Rank the same alkyl halides from question 4 in order of decreasing S_N1 reactivity.

6. Explain why tertiary alkyl halides generally do not undergo SN_2 reactions, but readily undergo S_N1 reactions.

7. Classify each of the following as a strong or weak nucleophile:

- OH^-
- H_2O
- CH_3O^-
- CH_3OH
- Br^-
- NH_3

8. Explain why strong nucleophiles favor the SN2 mechanism while weak nucleophiles can participate in S_N1 reactions.

9. For the reaction of 2-bromobutane, predict whether S_N1 or S_N2 will predominate with:

- (a) NaOH in ethanol
- (b) H_2O Justify your predictions.

10. Distinguish between polar protic and polar aprotic solvents. Give two examples of each type.

11. Explain why:

- (a) Polar aprotic solvents favor S_N2 reactions
- (b) Polar protic solvents favor S_N1 reactions

Your answer should discuss how these solvents interact with nucleophiles and stabilize (or destabilize) charged species.

12. Predict the major mechanism (S_N1 or S_N2) for the following reactions:

- (a) CH_3CH_2Br + NaCN in DMF (dimethylformamide - polar aprotic)
- (b) $(CH_3)_3CCl$ + CH_3OH (methanol - polar protic)

13. Starting with (R)-2-bromobutane:

- (a) Draw the product of an S_N2 reaction with OH^- and assign its configuration
- (b) Explain why inversion of configuration occurs in S_N2 reactions

14. Starting with (R)-3-bromo-3-methylhexane:

- (a) Draw the product(s) of an S_N1 reaction with water
- (b) Explain why racemization occurs in S_N1 reactions
- (c) Would you expect exactly a 50:50 mixture of enantiomers? Why or why not?

15. How does the stereochemical outcome differ between S_N1 and S_N2 reactions? Explain the structural reasons for these differences.

16. Write the rate law for:

- (a) An S_N1 reaction
- (b) An S_N2 reaction

Explain what "unimolecular" and "bimolecular" mean in this context.

17. For an S_N1 reaction between $(CH_3)_3CBr$ and water:

- (a) If the concentration of $(CH_3)_3CBr$ is doubled, how does the reaction rate change?
- (b) If the concentration of water is doubled, how does the reaction rate change?
- (c) Explain your answers in terms of the rate-determining step.

18. For an S_N2 reaction between CH_3Br and OH^-:

- (a) If the concentration of CH_3Br is tripled while $[OH^-]$ remains constant, how does the rate change?
- (b) If both concentrations are doubled, how does the rate change?

19. Complete the following comparison table:

Feature	S_N1	S_N2
Number of steps		
Rate law		
Substrate preference		
Nucleophile strength		
Solvent type		
Stereochemistry		
Intermediate formed		
Transition state		

20. Design an experiment to determine whether a nucleophilic substitution reaction proceeds via S_N1 or S_N2 mechanism. Describe what you would measure and what results would indicate each mechanism.