



Answer all the questions below as fully as you can then check your answers

1. What is a nucleophile?

2. Fill in the gap to complete the sentence below:

The C-Br bond in bromoethane is polar because bromine is more _____ than carbon.

3. Which of the following is NOT a nucleophile?

a) OH^-

b) NH_3

c) CN^-

d) H^+

4. What type of halogenoalkane primarily undergoes a $\text{S}_{\text{N}}2$ reaction?

5. Explain why tertiary halogenoalkanes undergo $\text{S}_{\text{N}}1$ reactions rather than $\text{S}_{\text{N}}2$ reactions.

6. Describe the difference between a primary, secondary, and tertiary halogenoalkane.

7. Fill in the gaps to complete the sentence below:

S_N1 reactions involve a _____ rate-determining step where the _____ bond breaks to form a _____ intermediate.

8. Describe and explain the mechanism of an S_N2 reaction using hydroxide ion (OH^-) and bromoethane.

9. Explain two factors that affect the rate of nucleophilic substitution reactions in halogenoalkanes.

10. Compare and contrast the S_N1 and S_N2 mechanisms in terms of reaction steps, intermediates, and factors influencing the rate of reaction.

11. Explain how the polarity and strength of the carbon-halogen bond affect the rate of nucleophilic substitution reactions.

Answers

1. What is a nucleophile?

Answer: A nucleophile is an electron-rich species that donates a lone pair of electrons to an electron-deficient atom, such as the δ^+ carbon in a halogenoalkane.

2. Fill in the gap to complete the sentence below:

The C-Br bond in bromoethane is polar because bromine is more _____ than carbon.

Answer: electronegative

3. Which of the following is NOT a nucleophile?

- a) OH^- b) NH_3 c) CN^- d) H^+

Answer: d) H^+

4. What type of halogenoalkane primarily undergoes a $\text{S}_{\text{N}}2$ reaction?

Answer: Primary halogenoalkanes primarily undergo an $\text{S}_{\text{N}}2$ reaction because the carbon atom is less sterically hindered, allowing the nucleophile to attack easily.

5. Explain why tertiary halogenoalkanes undergo $\text{S}_{\text{N}}1$ reactions rather than $\text{S}_{\text{N}}2$ reactions.

Answer: Tertiary halogenoalkanes undergo $\text{S}_{\text{N}}1$ reactions because the bulky alkyl groups around the central carbon block nucleophilic attack. Additionally, the tertiary carbocation formed during the reaction is more stable due to electron donation from the alkyl groups.

6. Describe the difference between a primary, secondary, and tertiary halogenoalkane.

Answer:

A primary halogenoalkane has the carbon attached to the halogen connected to only one alkyl group and two hydrogen atoms.

A secondary halogenoalkane has the carbon attached to two alkyl groups and one hydrogen atom.

A tertiary halogenoalkane has the carbon attached to three alkyl groups and no hydrogen atoms.

7. Fill in the gaps to complete the sentence below:

S_N1 reactions involve a _____ rate-determining step where the _____ bond breaks to form a _____ intermediate.

Answers: unimolecular, C-X, carbocation

8. Describe and explain the mechanism of an S_N2 reaction using hydroxide ion (OH^-) and bromoethane.

Answer:

- The hydroxide ion approaches the δ^+ carbon in bromoethane from the opposite side of the leaving group (Br^-).
- A transition state forms where the OH^- begins to bond with carbon as the C-Br bond starts to break.
- The C-Br bond fully breaks, and Br^- leaves as the OH^- fully bonds to the carbon, forming ethanol ($\text{CH}_3\text{CH}_2\text{OH}$).
- This is a concerted reaction where bond formation and bond breaking occur simultaneously.

9. Explain two factors that affect the rate of nucleophilic substitution reactions in halogenoalkanes.

Answer:

Bond strength: The C-X bond strength decreases from fluorine to iodine. Weaker bonds (like C-I) are easier to break, increasing the reaction rate.

Steric hindrance: In primary halogenoalkanes, there is less steric hindrance, allowing nucleophiles to approach more easily, leading to faster reactions compared to tertiary halogenoalkanes.

10. Compare and contrast the S_N1 and S_N2 mechanisms in terms of reaction steps, intermediates, and factors influencing the rate of reaction.

Answer:

S_N1 :

The reaction occurs in two steps. First, the C-X bond breaks, forming a carbocation intermediate. Then, the nucleophile attacks the carbocation.

The rate of the reaction depends only on the concentration of the halogenoalkane (unimolecular).

This mechanism is favoured by tertiary halogenoalkanes due to the stability of the tertiary carbocation.

S_N2 :

The reaction occurs in a single, concerted step where the nucleophile attacks the δ^+ carbon, and the C-X bond breaks simultaneously.

The rate depends on both the nucleophile and halogenoalkane concentrations (bimolecular).

This mechanism is favoured by primary halogenoalkanes because there is less steric hindrance.

11. Explain how the polarity and strength of the carbon-halogen bond affect the rate of nucleophilic substitution reactions.

Answer:

Polarity: The C-X bond is polar due to the difference in electronegativity between carbon and the halogen. A more polar bond (like C-F) makes the carbon more δ^+ , which should make it more susceptible to nucleophilic attack. However, this is counteracted by the bond strength.

Bond Strength: The C-F bond is the strongest due to its short length, making it difficult to break. As you go down the group from fluorine to iodine, bond strength decreases, and C-I is the weakest, leading to faster nucleophilic substitution rates in iodoalkanes. Therefore, while C-F is the most polar, its strong bond makes it unreactive, and iodoalkanes react the fastest due to the weak C-I bond.

