

# ORGANIC CHEMISTRY REACTION MECHANISMS WORKSHEET

International Baccalaureate Diploma Programme – Higher  
Level

Topic: Reaction Mechanisms

Duration: 150 minutes | Total Marks: 70

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## SECTION A: MULTIPLE CHOICE QUESTIONS [20 marks]

Select the correct answer (A, B, C, or D) for each question. Each question is worth 1 mark.

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1. Which of the following is the correct definition of a nucleophile?

- A) A species that accepts electron pairs
  - B) A species that donates electron pairs
  - C) A species that accepts protons
  - D) A species that donates protons
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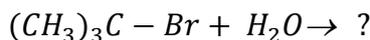
2. In an SN2 reaction, what is the stereochemical outcome?

- A) Retention of configuration
  - B) Racemization
  - C) Inversion of configuration (Walden inversion)
  - D) No change in stereochemistry
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3. Which factor favors an SN2 reaction over an SN1 reaction?

- A) Tertiary alkyl halide
  - B) Polar protic solvent
  - C) Primary alkyl halide
  - D) Weak nucleophile
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4. In the reaction of 2-bromo-2-methylpropane with water, what is the major product?



- A)  $(CH_3)_3C-OH$  (major product)
  - B)  $(CH_3)_2CH-CH_2OH$  (major product)
  - C)  $(CH_3)_3C-OH$  (minor product) and  $(CH_3)_2CH-CH_2OH$  (major product)
  - D) Racemic mixture
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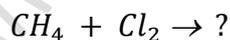
5. Which statement best describes the mechanism of an  $S_N1$  reaction?

- A) Single step with nucleophilic attack from the back side
  - B) Two-step mechanism: carbocation formation followed by nucleophilic attack
  - C) Three-step mechanism involving radical intermediates
  - D) Single step with simultaneous bond breaking and formation
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6. In free radical substitution of alkanes, what is the role of UV light?

- A) To stabilize the carbocation intermediate
  - B) To break the C-H bond homolytically, generating radicals
  - C) To activate the nucleophile
  - D) To increase the polarity of the solvent
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7. What is the first step in the free radical substitution of methane with chlorine?



- A)  $Cl_2 \rightarrow 2Cl\cdot$  (initiation)
  - B)  $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$  (propagation)
  - C)  $Cl\cdot + CH_4 \rightarrow CH_3\cdot + HCl$  (propagation)
  - D)  $CH_3\cdot + Cl\cdot \rightarrow CH_3Cl$  (termination)
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8. In electrophilic addition to alkenes, which carbocation is most stable?

- A) Primary carbocation
  - B) Secondary carbocation
  - C) Tertiary carbocation
  - D) All carbocations have equal stability
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9. According to Markovnikov's rule, in the addition of HBr to propene, where does the Br attach?



- A) To the less substituted carbon (Br-CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>3</sub>)
  - B) To the more substituted carbon (CH<sub>3</sub>-CHBr-CH<sub>3</sub>)
  - C) Equally to both carbons
  - D) The product is a mixture with no preference
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10. What type of mechanism is involved in the bromination of benzene?

- A) Nucleophilic substitution (S<sub>N</sub>2)
  - B) Free radical substitution
  - C) Electrophilic aromatic substitution
  - D) Electrophilic addition
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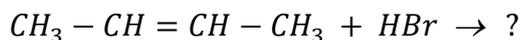
11. In electrophilic aromatic substitution, what is the electrophile in the nitration of benzene?

- A) NO<sub>2</sub>
  - B) NO<sub>2</sub><sup>+</sup>
  - C) NO<sub>3</sub><sup>-</sup>
  - D) HNO<sub>3</sub>
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12. Which intermediate is formed in the electrophilic aromatic substitution of benzene?

- A) Carbocation (arenium ion)
  - B) Carbanion
  - C) Radical cation
  - D) Benzylic anion
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13. In the addition of HBr to but-2-ene, which product is the major product?



- A) CH<sub>3</sub>-CHBr-CH<sub>2</sub>-CH<sub>3</sub>
  - B) CH<sub>3</sub>-CH<sub>2</sub>-CHBr-CH<sub>3</sub>
  - C) Both products in equal amounts
  - D) The reaction does not occur
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**14. What is the stereochemistry of the product in the addition of Br<sub>2</sub> to an alkene (anti addition)?**

- A) Syn addition (both Br on same side)
  - B) Anti addition (Br on opposite sides)
  - C) Random stereochemistry
  - D) No stereoisomers formed
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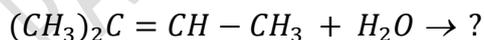
**15. Which factor increases the rate of an S<sub>N</sub>2 reaction?**

- A) Increasing the size of the leaving group
  - B) Increasing the concentration of the nucleophile
  - C) Using a polar aprotic solvent instead of a polar protic solvent
  - D) Both B and C
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**16. In a carbocation rearrangement, which type of shift is most common?**

- A) Electron shift
  - B) Hydride shift or methyl shift
  - C) Proton shift
  - D) Nucleophile shift
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**17. What is the major product of the hydration of 2-methylbut-2-ene via carbocation mechanism?**



- A) (CH<sub>3</sub>)<sub>2</sub>CH-CH<sub>2</sub>-OH (major)
  - B) (CH<sub>3</sub>)<sub>3</sub>C-OH (major)
  - C) (CH<sub>3</sub>)<sub>2</sub>C(OH)-CH<sub>2</sub>-CH<sub>3</sub> (major)
  - D) (CH<sub>3</sub>)<sub>2</sub>CH-CH(OH)-CH<sub>3</sub> (major)
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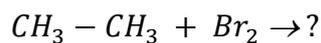
**18. In the S<sub>N</sub>1 reaction of 1-bromo-1-methylcyclohexane with water, which product is formed?**

- A) 1-Hydroxy-1-methylcyclohexane only
  - B) 1-Hydroxy-1-methylcyclohexane and 1-methylcyclohexene (Hofmann product)
  - C) 1-Methylcyclohexene only
  - D) No reaction occurs
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**19. Which statement about carbocation stability is correct?**

- A) Primary > Secondary > Tertiary
  - B) Tertiary > Secondary > Primary
  - C) All carbocations have equal stability
  - D) Stability depends only on solvent polarity
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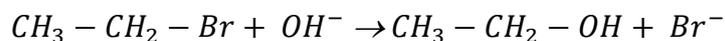
**20. In the free radical substitution of ethane with bromine, what is the major product?**



- A) Bromoethane only
  - B) 1,2-Dibromoethane only
  - C) Mixture of bromoethane, 1,2-dibromoethane, and higher brominated products
  - D) No reaction occurs
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**SECTION B: STRUCTURED QUESTIONS****QUESTION 1: NUCLEOPHILIC SUBSTITUTION MECHANISMS [10 marks]****Background:**

Consider the following reaction:



(a) Identify the type of nucleophilic substitution mechanism (SN1 or SN2) that occurs with a primary alkyl halide and a strong nucleophile in an aprotic solvent. [2 marks]

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(b) Draw the complete mechanism for this reaction, showing all electron movements using curly arrows and all intermediates. [3 marks]

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(c) Explain the stereochemistry of the product. Would the product be optically active or inactive if the starting material were optically active? [2 marks]

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(d) How would the rate of reaction change if:

(i) The concentration of  $OH^-$  is doubled [1 mark]

(ii) The solvent is changed from aprotic to protic [2 marks]

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**QUESTION 2: SN1 VS. SN2 MECHANISTIC DIFFERENTIATION [10 marks]****Background:**

Compare the following two reactions:

**Reaction A:**  $(\text{CH}_3)_3\text{C-Cl} + \text{H}_2\text{O} \rightarrow (\text{CH}_3)_3\text{C-OH}$  (major) +  $(\text{CH}_3)_2\text{C=CH}_2$  (minor)

**Reaction B:**  $\text{CH}_3\text{-CH}_2\text{-Cl} + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{-CH}_2\text{-OH}$

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(a) Identify the mechanism for Reaction A and Reaction B. Justify your answer by discussing the nature of the alkyl halide in each case. [3 marks]

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(b) For Reaction A, draw the complete SN1 mechanism, including:

- The carbocation intermediate
  - The nucleophilic attack
  - The deprotonation step [4 marks]
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(c) Explain why  $(\text{CH}_3)_3\text{C-OH}$  is the major product and  $(\text{CH}_3)_2\text{C=CH}_2$  is the minor product in Reaction A. [2 marks]

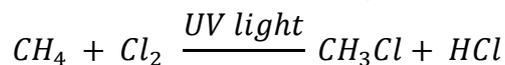
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(d) What is the stereochemical outcome in Reaction A? Would you expect a racemic mixture? Explain. [1 mark]

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**QUESTION 3: FREE RADICAL SUBSTITUTION [10 marks]****Background:**

The free radical substitution of methane with chlorine proceeds as follows:



(a) Identify the three stages of a free radical substitution mechanism and write equations for each stage using the chlorination of methane as an example. [3 marks]

Stage 1 (Initiation):

Stage 2 (Propagation):

Stage 3 (Termination):

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(b) Explain why UV light is necessary for this reaction to proceed. [2 marks]

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(c) In the free radical substitution of ethane with bromine, why is the major product bromoethane ( $\text{C}_2\text{H}_5\text{Br}$ ) rather than dibromoethane ( $\text{C}_2\text{H}_4\text{Br}_2$ )? [2 marks]

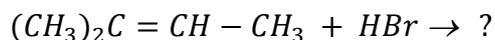
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(d) Draw the propagation steps for the free radical substitution of ethane with bromine, showing all radical intermediates and electron movements. [3 marks]

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**QUESTION 4: ELECTROPHILIC ADDITION TO ALKENES [10 marks]****Background:**

Consider the addition of HBr to 2-methylbut-2-ene:



**(a) Draw the structure of the major product and explain your answer using Markovnikov's rule and carbocation stability. [3 marks]**

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**(b) Draw the complete mechanism for this reaction, showing:**

- The formation of the carbocation intermediate
  - The relative stability of all possible carbocations
  - The nucleophilic attack by bromide ion [4 marks]
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**(c) Explain why the tertiary carbocation is more stable than the secondary carbocation in this case. [2 marks]**

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**(d) If HCl were used instead of HBr, would the product be the same? Explain your reasoning. [1 mark]**

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**QUESTION 5: ELECTROPHILIC AROMATIC SUBSTITUTION AND CARBOCATION  
REARRANGEMENT [10 marks]****Background:**

Consider the nitration of benzene and the hydration of 2-methylbut-1-ene:

**Reaction 1:**  $C_6H_6 + HNO_3 \rightarrow C_6H_5NO_2 + H_2O$  (in presence of concentrated  $H_2SO_4$ )

**Reaction 2:**  $(CH_3)_2CH-CH=CH_2 + H_2O \rightarrow (CH_3)_2CH-CH(OH)-CH_3$  (major product)

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(a) For Reaction 1, identify the electrophile and draw the mechanism for electrophilic aromatic substitution, showing the arenium ion intermediate. [3 marks]

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(b) In Reaction 2, a secondary carbocation is initially formed. Draw the mechanism showing the hydride shift that produces the more stable tertiary carbocation. [4 marks]

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(c) Draw the structure of the major product in Reaction 2 and explain why the hydride shift occurs. [2 marks]

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(d) What is the name of the rearrangement process described in Reaction 2? [1 mark]

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