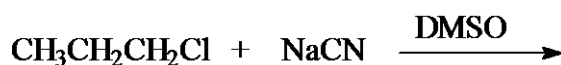
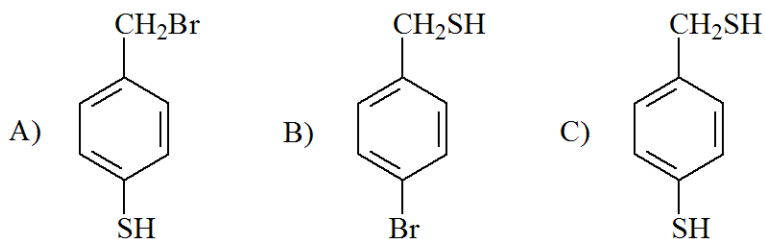
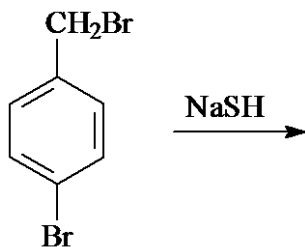


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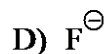
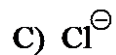
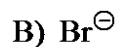
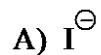
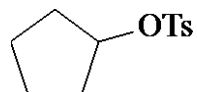
- Which of the following undergoes a substitution reaction with sodium cyanide in DMSO at the fastest rate?
 - $\text{CH}_3\text{CH}_2\text{F}$
 - $\text{CH}_3\text{CH}_2\text{Cl}$
 - $\text{CH}_3\text{CH}_2\text{Br}$
 - $\text{CH}_3\text{CH}_2\text{I}$
- 1-Chloro-4-fluorobutane is reacted with one equivalent of sodium iodide in acetone. During the reaction a precipitate forms. What is the precipitate?
 - $\text{FCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$
 - $\text{ClCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$
 - NaCl
 - NaF
- The rate law for the following reaction is:



- rate = $k[\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}]$
 - rate = $k[\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}][\text{NaCN}]$
 - rate = $k[\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}][\text{NaCN}]^2$
 - rate = $k[\text{NaCN}]$
- Which of the following reacts the fastest by the $\text{S}_{\text{N}}2$ mechanism?
 - CH_3Br
 - $\text{CH}_3\text{CH}_2\text{Br}$
 - $(\text{CH}_3)_2\text{CHBr}$
 - $(\text{CH}_3)_3\text{CBr}$
 - Give the product(s) of the following reaction?



- A
 - B
 - C
 - a mixture of A and B
- Which halide ion reacts the fastest with cyclopentyl *p*-toluenesulfonate in ethanol/water?



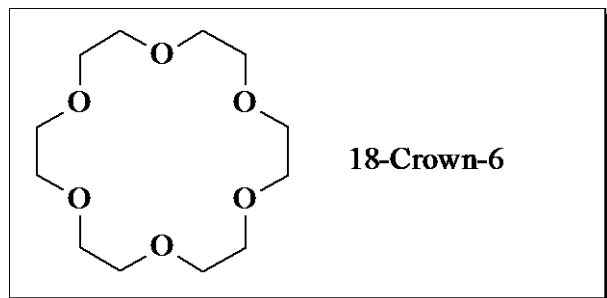
A. A

B. B

C. C

D. D

7. Which one of the following species forms the strongest ion-dipole attraction with 18-crown-6?



8. Identify the major product(s) in the reaction of (R)-2-bromopentane with sodium cyanide in DMSO?

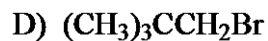
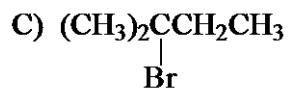
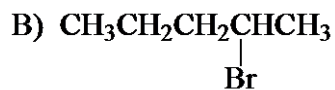
A. (R)-2-cyanopentane

B. (S)-2-cyanopentane

C. racemic mixture of 2-cyanopentane

D. *trans*-2-pentene

9. Which of the following reacts fastest with methanol by the $\text{S}_{\text{N}}1$ mechanism?



A. A

B. B

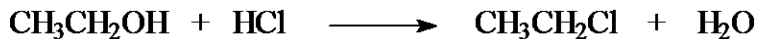
C. C

D. D

10. A pentacoordinate carbon is a transient species in the _____ mechanism.

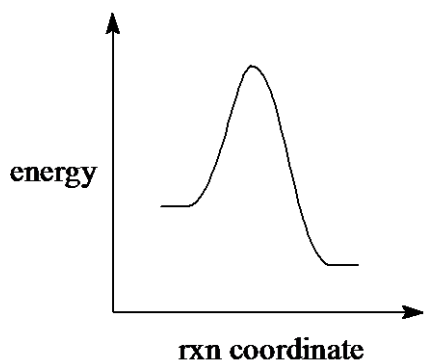
- A. S_N1
- B. S_N2
- C. E1
- D. E2

11. What is the leaving group in the following reaction?



- A. OH⁻
- B. H₂O
- C. CH₃CH₂⁺
- D. Cl⁻

12. Considering the S_N1, S_N2, E1, and E2 mechanisms, the energy diagram shown below corresponds to:

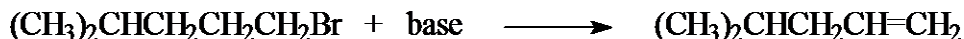


- A. only the S_N1 mechanism
- B. only the S_N2 mechanism
- C. both the S_N1 and E1 mechanisms
- D. both the S_N2 and E2 mechanisms

13. Which of the following is the rate law for the S_N1 mechanism of an alkyl halide with a nucleophile?

- A. rate = k[alkyl halide]
- B. rate = k[nucleophile]
- C. rate = k[alkyl halide][nucleophile]
- D. rate = k[alkyl halide]²[nucleophile]

14. Which of the following bases works best to maximize the E2 product in the reaction shown below?

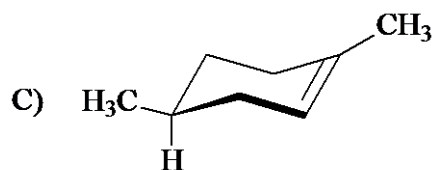
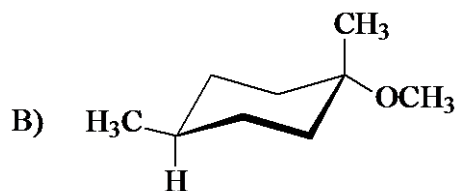
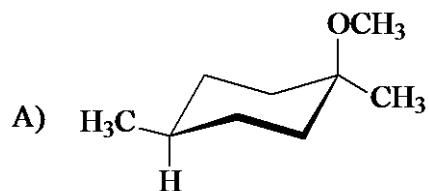
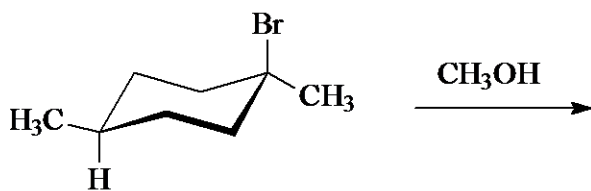


- A. KOCH₂CH₃
- B. NaOCH₂CH₃
- C. NaOC(CH₃)₃
- D. NaOH

15. Which of the following does not correctly describe S_N2 reactions of alkyl halides?

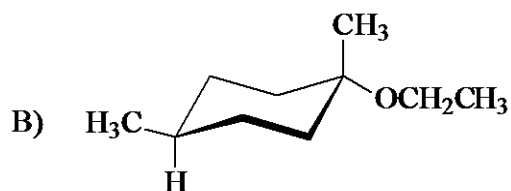
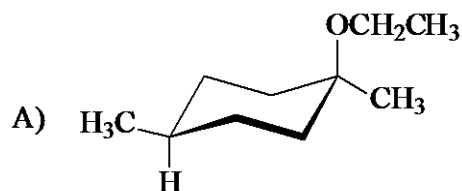
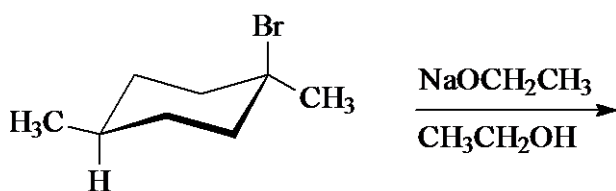
- A. Tertiary halides react faster than secondary halides.
- B. Rate of reaction depends on the concentrations of both the alkyl halide and the nucleophile.
- C. The mechanism consists of a single step with no intermediates.
- D. The transition state species has a pentavalent carbon atom.

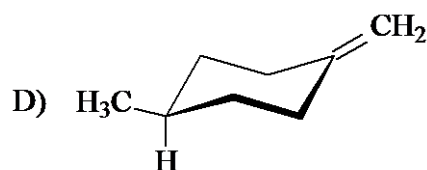
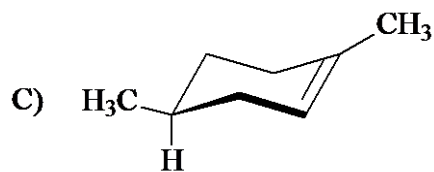
16. Identify the substitution product(s) in the following reaction.



- A. A
 B. B
 C. C
 D. a mixture of A and B

17. What is the major product of the following reaction?





- A. A
B. B
C. C
D. D

18. Starting with 1-hexene, which synthetic sequence below gives 2-cyanohexane?

- A. (1) H_2SO_4 (cat.), H_2O (2) NaCN
B. (1) HBr/peroxide (2) NaCN
C. (1) HBr (2) NaCN
D. (1) Br_2 , H_2O (2) NaCN

19. Which sequence of reactions below gives the highest yield of ethyl isopropyl ether?



- A) (1) $\text{CH}_3\text{CH}_2\text{OH} + \text{Na}$ (2) $(\text{CH}_3)_2\text{CHBr}$
B) (1) $(\text{CH}_3)_2\text{CHOH} + \text{Na}$ (2) $\text{CH}_3\text{CH}_2\text{Br}$
C) (1) $(\text{CH}_3)_2\text{CHOH} + \text{Na}$ (2) $\text{CH}_3\text{CH}_2\text{OH}$
D) (1) $\text{CH}_3\text{CH}_2\text{OH} + \text{Na}$ (2) $(\text{CH}_3)_2\text{CHOH}$

- A. A
B. B
C. C
D. D

20. In the solvolysis of *t*-butyl chloride, a minor product is 2-methylpropene, which results from the:

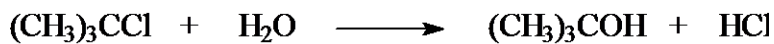


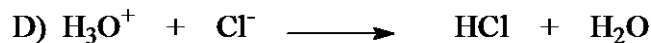
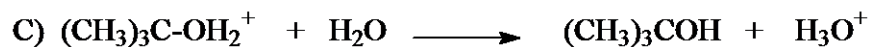
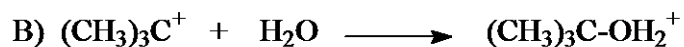
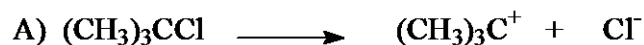
major

minor

- A. E2 mechanism with OH^- acting as the base.
B. E2 mechanism with H_2O acting as the base.
C. E1 mechanism with OH^- acting as the base.
D. E1 mechanism with H_2O acting as the base.

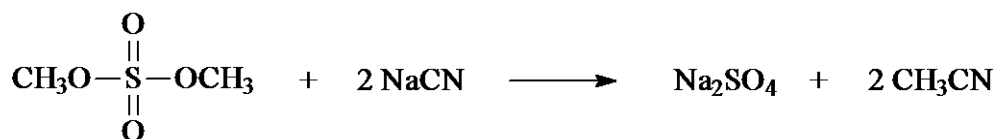
21. What is the rate limiting step in the following reaction?





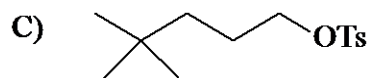
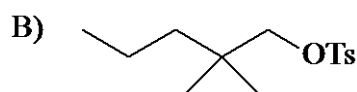
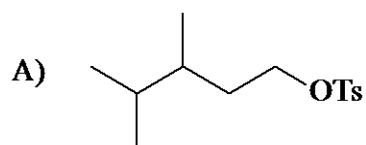
- A. A
B. B
C. C
D. D

22. The mechanism of the following reaction is:



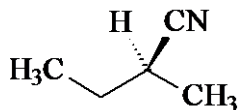
- A. $\text{S}_{\text{N}}1$
B. $\text{S}_{\text{N}}2$
C. E1
D. E2

23. Which of the following reacts the slowest with sodium cyanide, NaCN?



- A. A
B. B
C. C
D. D

24. How would you synthesize the following compound starting with optically pure (R) or (S)-2-butanol?

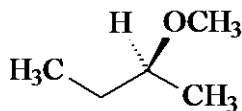


- A) (1) (R)-2-butanol + TsCl (2) NaCN/DMSO
B) (1) (S)-2-butanol + TsCl (2) NaCN/DMSO

- C) (1) (S)-2-butanol + H₂SO₄ (heat) (2) HBr (3) NaCN/DMSO
 D) (R)-2-butanol + NaCN/DMSO

- A. A
 B. B
 C. C
 D. D

25. Starting with optically pure (R) or (S)-2-butanol which method below would give the best yield of the following ether?



- A) (1) (R)-2-butanol + TsCl (2) CH₃ONa
 B) (1) (S)-2-butanol + TsCl (2) CH₃ONa
 C) (1) (R)-2-butanol + Na (2) CH₃I
 D) (1) (S)-2-butanol + Na (2) CH₃I

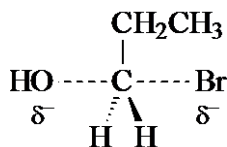
- A. A
 B. B
 C. C
 D. D

26. Which of the following conditions favor the S_N1 mechanism as opposed to the S_N2 mechanism?

- I. tertiary alkyl halide
 II. primary alkyl halide
 III. polar solvent

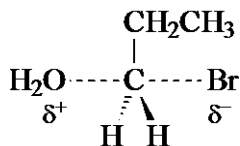
- A. only I
 B. only II
 C. I and III
 D. II and III

27. The species shown below represents the transition state for the:



- A. reaction of 1-propanol with HBr.
 B. reaction of 1-bromopropane with OH⁻.
 C. elimination of HBr from 1-bromopropane.
 D. addition of HBr to propene with peroxides.

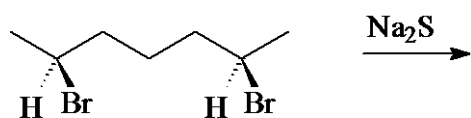
28. The species shown below represents the transition state for the:



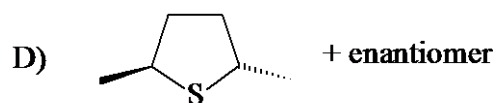
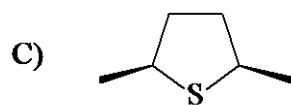
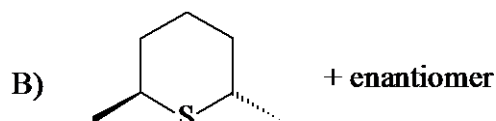
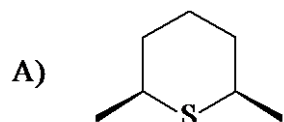
- A. reaction of 1-propanol with HBr.
 B. reaction of 1-bromopropane with OH⁻.

- C. addition of HOBr to 1-propene.
 D. addition of HBr to propene with peroxides.

29. Which of the following is the double substitution product of the reaction below?

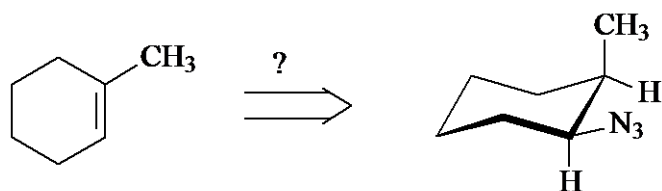


(meso form)



- A. A
 B. B
 C. C
 D. D

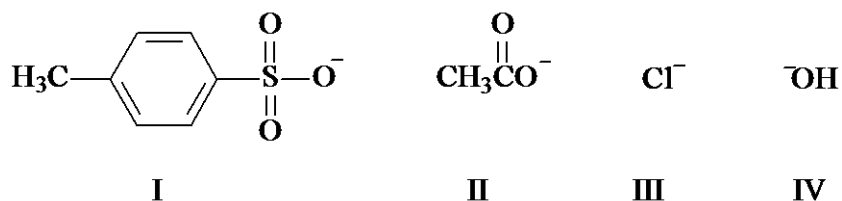
30. Starting with 1-methylcyclohexene, which of the following reaction sequences is the best synthesis of the azide shown below?



- A) (1) HBr (2) NaN₃
 B) (1) HBr, peroxides (2) NaN₃
 C) (1) B₂H₆, diglyme (2) H₂O₂, OH⁻ (3) TsCl, pyridine (4) NaN₃
 D) (1) CH₃CO₃H (2) NaN₃ (3) H₂SO₄, heat (4) H₂/Pt

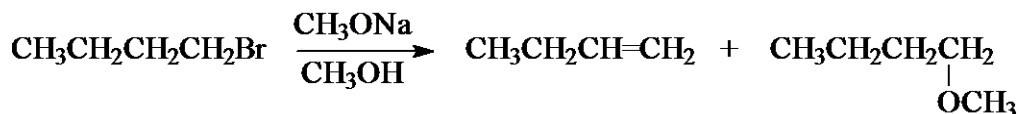
- A. A
 B. B
 C. C
 D. D

31. Rank the following in decreasing order of leaving group ability.



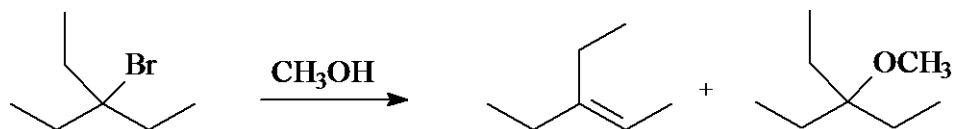
- A. I > III > IV > II
 B. I > III > II > IV
 C. III > II > I > IV
 D. II > I > III > IV

32. Identify the mechanistic pathways, respectively, for the products in the following reaction.



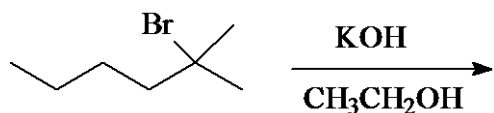
- A. E1, S_N1
 B. E1, S_N2
 C. E2, S_N1
 D. E2, S_N2

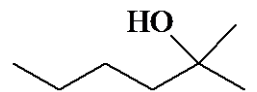
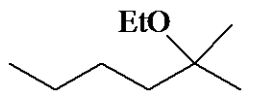
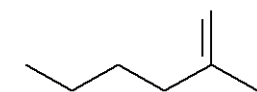
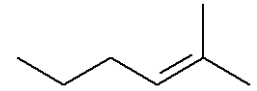
33. Identify the mechanistic pathways, respectively, for the products in the following reaction.



- A. E1, S_N1
 B. E1, S_N2
 C. E2, S_N1
 D. E2, S_N2

34. What is the major product in the following reaction?

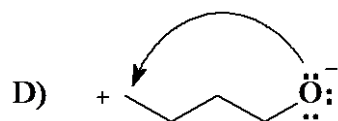
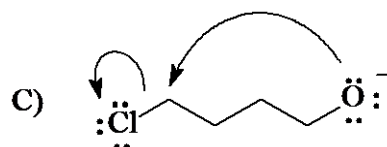
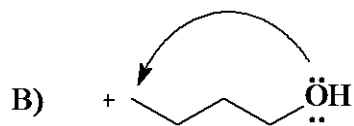
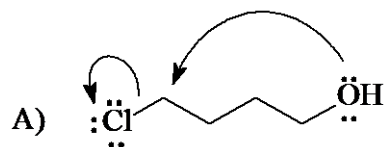
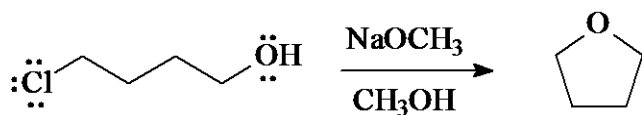


- A) 
 B) 
 C) 
 D) 

- A. A
 B. B

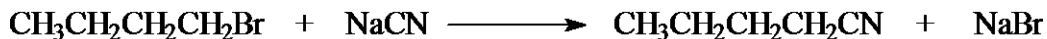
- C. C
D. D

35. Which of the following mechanistic steps is the most likely route for the formation of the cyclic ether shown?



- A. A
B. B
C. C
D. D

36. In which of the solvents below would the reaction shown take place at the fastest rate?

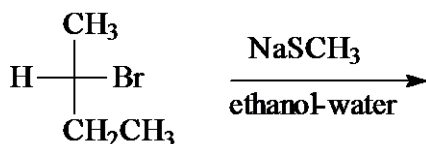


- A. ethanol
B. acetic acid
C. dimethyl sulfoxide
D. water

37. Consider the reaction of each of the following with 1-bromopentane. Which one would have the highest elimination/substitution ratio?

- A. $\text{NaOCH}_2\text{CH}_3$, ethanol, 55°C
B. NaSH , ethanol-water, 25°C
C. $\text{KOC}(\text{CH}_3)_3$, $(\text{CH}_3)_3\text{COH}$, 55°C
D. KCN , DMSO, 40°C

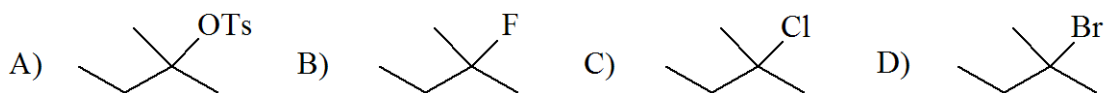
38. Which one of the following correctly depicts the reaction below?



<u>Mechanism</u>	<u>Rate Law</u>	<u>Stereochemistry</u>
A) S _N 1	rate = k [(S)-2-bromobutane]	not stereospecific, but more inversion than retention of configuration
B) S _N 1	rate = k [(S)-2-bromobutane][NaSCH ₃]	stereospecific, retention of configuration
C) S _N 2	rate = k [(S)-2-bromobutane]	not stereospecific, but more inversion than retention of configuration
D) S _N 2	rate = k [(S)-2-bromobutane][NaSCH ₃]	stereospecific, inversion of configuration

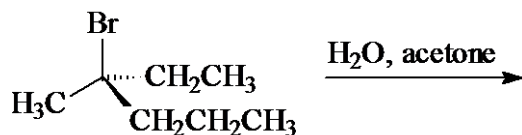
- A. A
 B. B
 C. C
 D. D

39. Which of the following undergoes S_N1 solvolysis in ethanol/water at the fastest rate?



- A. A
 B. B
 C. C
 D. D

40. The major product of the following reaction is an alcohol. Which of the following best describes this reaction?



- A. S_N2 with inversion of configuration
 B. S_N2 with racemization
 C. S_N1 with inversion of configuration
 D. S_N1 with racemization

ACS Review Nucleophilic Substitution KEY

1. D
2. C
3. B
4. A
5. B
6. A
7. B
8. B
9. C
10. B
11. B
12. D
13. A
14. C
15. A
16. D
17. C
18. C
19. B
20. D
21. A
22. B
23. B
24. A
25. D
26. C
27. B
28. A
29. A
30. C
31. B
32. D
33. A
34. D
35. C
36. C
37. C
38. D
39. A
40. D