Chemistry

Higher level

Paper 1A

Practice paper

Topic: Organic Chemistry

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Specimen paper

1 hour 15 minutes

Instructions to candidates

- Do not open this examination paper until instructed to do so.
- Answer all questions.
- For each question, choose the best answer.
- A clean copy of the chemistry data booklet is required.
- The maximum mark for this paper is [40 marks].

Section A

1. What is the Index of Hydrogen Deficiency (IHD) for aspirin, $C_9H_8O_4$?
   A. 4
   B. 5
   C. 6
   D. 7

2. Which molecule exhibits optical isomerism?
   A. 1-chlorobutane
   B. 2-chlorobutane
   C. 2-chloro-2-methylpropane
   D. 1-chloro-2-methylpropane

3. In the nucleophilic substitution mechanism of a primary halogenoalkane (S_N2), the transition state features:
   A. A fully formed carbocation.
   B. Five partial bonds to the central carbon.
   C. Heterolytic fission of the C-OH bond.
   D. A completely planar molecular geometry at equilibrium.

4. Which reagent and conditions convert nitrobenzene to phenylamine?
   A. Sn and concentrated HCl, followed by NaOH
   B. $LiAlH_4$ in dry ether
   C. H_2 with a Ni catalyst at high pressure
   D. $NaBH_4$ in aqueous methanol

5. Which compound yields a silver mirror when heated with Tollens' reagent?
   A. Propan-2-ol
   B. Propanone
   C. Propanal
   D. Propanoic acid

6. In the high resolution ^1H NMR spectrum of propanone, CH_3COCH_3, how many signals and what splitting pattern are observed?
   A. One singlet
   B. Two singlets
   C. One triplet and one quartet
   D. Two doublets

7. Which species is the electrophile in the nitration of benzene?
A. NO_2^-
B. NO^+
C. NO_2^+
D. HNO_3

8. In the reaction of hydrogen bromide with propene, what is the major product and why?
A. 1-bromopropane, via the most stable primary carbocation.
B. 2-bromopropane, via the most stable secondary carbocation.
C. 1-bromopropane, due to steric hindrance.
D. 2-bromopropane, via a free-radical intermediate.

9. Which solvent favors an S_N1 mechanism over an S_N2 mechanism?
A. Protic polar solvents
B. Aprotic polar solvents
C. Non-polar solvents
D. Liquid ammonia

10. Which fragmentation in a mass spectrum results in a peak at m/z = 29?
A. $[CH_3]^+$
B. $[C_2H_5]^+$
C. $[OH]^+$
D. $[COOH]^+$

11. What is the distinguishing infrared (IR) absorption peak range for a carboxylic acid O-H bond compared to an alcohol O-H bond?
A. It is broad and shifted slightly to lower wavenumbers (2500-3000 cm^{-1}).
B. It is sharp and shifted to higher wavenumbers (3200-3600 cm^{-1}).
C. It lacks any absorption above 1500 cm^{-1}.
D. It appears strictly in the fingerprint region.

12. What specific experimental condition is required to ensure a halogenoalkane undergoes an elimination reaction rather than nucleophilic substitution with NaOH?
A. NaOH dissolved in water at room temperature.
B. NaOH dissolved in hot ethanol under reflux.
C. Excess NaOH in an ice bath.
D. Dilute NaOH with a catalyst.

13. How many stereoisomers exist for 2,3-dibromobutane?
A. 2

B. 3
C. 4
D. 5

14. What occurs when plane-polarized light passes through a racemic mixture?
A. The plane of polarization rotates to the right.
B. The plane of polarization rotates to the left.
C. The light is completely absorbed.
D. The plane of polarization remains unrotated.

15. What is the repeating unit of the polymer formed from the condensation of a dicarboxylic acid and a diol?
A. A polyamide
B. A polyester
C. A polyurethane
D. A polyalkene

16. Which of the following is true for the mechanism of the nitration of benzene?
A. It involves the addition of the nitronium ion without breaking the ring aromaticity permanently.
B. The intermediate is a fully stable neutral molecule.
C. The nucleophile is the concentrated sulfuric acid.
D. It proceeds via a radical mechanism.

17. Which reduction reaction requires the strongest reducing agent, $LiAlH_4$?
A. Ketone to secondary alcohol
B. Aldehyde to primary alcohol
C. Carboxylic acid to primary alcohol
D. Alkene to alkane

18. A compound shows optical isomerism. This indicates the presence of:
A. A carbon-carbon double bond.
B. A chiral carbon atom.
C. An aromatic ring.
D. Hydrogen bonding.

19. Which isomer of C_5H_{12} has the lowest boiling point?
A. Pentane
B. 2-methylbutane
C. 2,2-dimethylpropane

D. Cyclopentane

20. What is the correct IUPAC name for CH_3CH_2COCl?
A. Propyl chloride
B. Propanoic acid
C. Propanoyl chloride
D. Chloropropanone

21. Why are purely S_N2 reactions stereospecific?
A. They involve a planar carbocation intermediate.
B. The nucleophile attacks exclusively from the backside of the leaving group.
C. The leaving group determines the final chirality regardless of entry angle.
D. They produce a racemic mixture.

22. In the electrophilic addition of Br_2 to ethene, what acts as the initial electrophile?
A. A bromide ion, Br^-
B. A polarized bromine molecule passing near the pi bond.
C. A free radical bromine atom, $Br\cdot$
D. The pi bond electrons of ethene.

23. In ^{1}H NMR, what does the integration trace physically represent?
A. The number of neighboring protons.
B. The relative area under a peak corresponding to the number of protons in that environment.
C. The exact electronegativity of the adjacent atoms.
D. The molecular mass of the fragment.

24. A molecule has an IHD of 4. Which structure is most likely present?
A. Four distinct carbon-carbon double bonds.
B. A benzene ring.
C. Two triple bonds.
D. A cycloalkane with three ester groups.

25. What is the name of the intermediate formed during an S_N1 reaction?
A. Carbocation
B. Carbanion
C. Free radical
D. Transition state complex

26. Which functional group is formed when an acyl chloride reacts with ammonia?
A. Primary amine
B. Secondary amide
C. Primary amide
D. Nitrile

27. What happens when a secondary alcohol is heated under reflux with acidified potassium dichromate(VI)?
A. It oxidizes to an aldehyde.
B. It oxidizes to a ketone.
C. It oxidizes to a carboxylic acid.
D. No reaction occurs.

28. Deducing the structure of an organic compound requires distinguishing between conformational and configurational isomers. Which statement is true?
A. Conformational isomers can be separated physically at room temperature.
B. Configurational isomers require bond breaking to interconvert.
C. Conformational isomers are exclusively optical isomers.
D. Configurational isomers arise from rotation around single bonds.

29. What dictates the major product in the hydration of an asymmetric alkene?
A. Le Chatelier's principle
B. Markovnikov's rule
C. Hess's Law
D. The Pauli principle

30. Which organic reagent reacts readily with water to produce a carboxylic acid?
A. An ester
B. An aldehyde
C. An acyl chloride
D. A ketone

31. Which of the following analytical techniques involve the absorption of electromagnetic radiation?
I. Mass spectrometry
II. Infrared spectroscopy
III. ^{1}H NMR spectroscopy
A. I and II only
B. I and III only
C. II and III only

D. I, II and III

32. Which are characteristics of an S_N2 mechanism?
I. It is a one-step concerted process.
II. The rate depends only on the concentration of the halogenoalkane.
III. It causes an inversion of stereochemical configuration.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

33. Which features must a molecule possess to exhibit cis-trans isomerism?
I. Restricted rotation (e.g., a double bond or a ring structure).
II. Two identical groups on the same carbon atom of the double bond.
III. Different groups attached to each of the carbon atoms involved in the restricted rotation.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

34. Which statements are correct about the nitration of benzene?
I. The generating acids are concentrated HNO_3 and concentrated H_2SO_4.
II. The reaction proceeds heavily under reflux conditions at 150 degrees C.
III. The mechanism is electrophilic substitution.
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

35. Which structural features are identifiable utilizing Infrared (IR) Spectroscopy?
I. The exact molecular weight of the compound.
II. The presence of a carbonyl group (C=O).
III. The presence of a hydroxyl group (-OH).
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

36. Which factors stabilize a carbocation intermediate?
I. Inductive effects from surrounding alkyl groups.

II. Decreased steric hindrance.
III. A highly non-polar solvent environment.
A. I only
B. I and II only
C. II and III only
D. I, II and III

37. Which properties are identical for a pair of enantiomers?
I. Boiling point
II. Density
III. Direction of rotation of plane-polarized light
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

38. Which molecules will present a splitting pattern containing a 'quartet' in their high-resolution ^{1}H NMR spectrum?
I. Ethanol
II. Butanone
III. Ethanal
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

39. Regarding the reduction of organic compounds, which pairings are correct?
I. Propanone + $NaBH_4$ -> Propan-2-ol
II. Propanoic acid + $LiAlH_4$ -> Propan-1-ol
III. Propanal + H_2 / Ni -> Propane
A. I and II only
B. I and III only
C. II and III only
D. I, II and III

40. Which structural motifs contribute exactly 1 to the Index of Hydrogen Deficiency (IHD)?
I. A standard cyclic ring.
II. A carbon-oxygen double bond.
III. A carbon-carbon triple bond.
A. I and II only

B. I and III only
C. II and III only
D. I, II and III