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Chemistry

Higher level

Paper 1

8 May 2024

Zone A afternoon | Zone B afternoon | Zone C afternoon

1 hour

Instructions to candidates

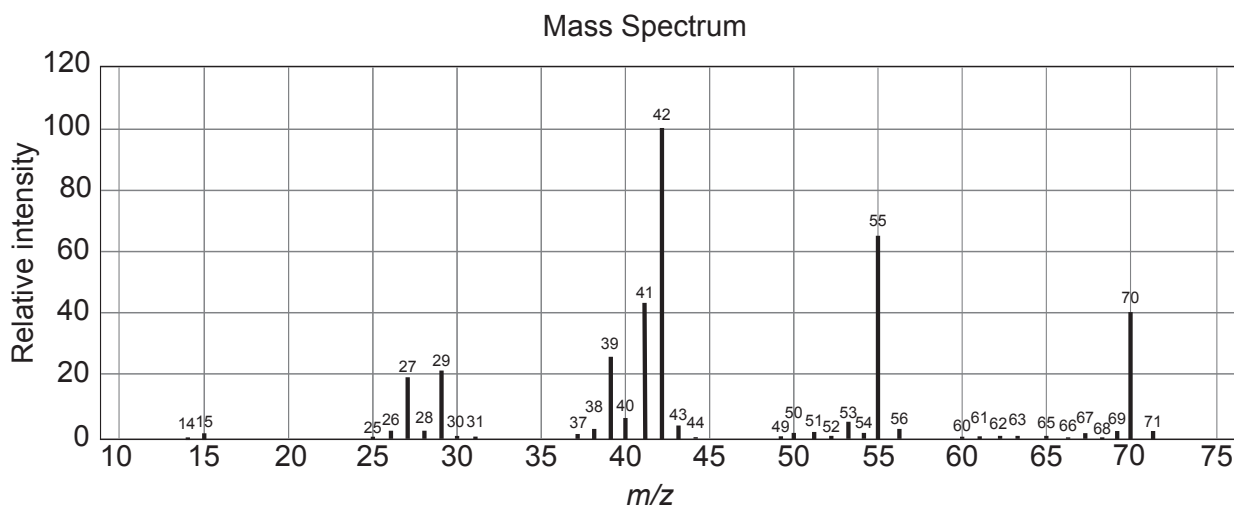
- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is **[40 marks]**.

The Periodic Table

| | | | | | | | | | | | | | | | | | | |
|---|---------------------------|---------------------------|---|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| 1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | 1 H 1.01 | | | | | | | | | | | | | | | | | 2 He 4.00 |
| 2 | 3 Li 6.94 | 4 Be 9.01 | Atomic number Element Relative atomic mass | | | | | | | | | | | | | | | |
| 3 | 11 Na 22.99 | 12 Mg 24.31 | | | | | | | | | | | | | | | | |
| 4 | 19 K 39.10 | 20 Ca 40.08 | 21 Sc 44.96 | 22 Ti 47.87 | 23 V 50.94 | 24 Cr 52.00 | 25 Mn 54.94 | 26 Fe 55.85 | 27 Co 58.93 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.38 | 31 Ga 69.72 | 32 Ge 72.63 | 33 As 74.92 | 34 Se 78.96 | 35 Br 79.90 | 36 Kr 83.90 |
| 5 | 37 Rb 85.47 | 38 Sr 87.62 | 39 Y 88.91 | 40 Zr 91.22 | 41 Nb 92.91 | 42 Mo 95.96 | 43 Tc (98) | 44 Ru 101.07 | 45 Rh 102.91 | 46 Pd 106.42 | 47 Ag 107.87 | 48 Cd 112.41 | 49 In 114.82 | 50 Sn 118.71 | 51 Sb 121.76 | 52 Te 127.60 | 53 I 126.90 | 54 Xe 131.29 |
| 6 | 55 Cs 132.91 | 56 Ba 137.33 | 57 † La 138.91 | 72 Hf 178.49 | 73 Ta 180.95 | 74 W 183.84 | 75 Re 186.21 | 76 Os 190.23 | 77 Ir 192.22 | 78 Pt 195.08 | 79 Au 196.97 | 80 Hg 200.59 | 81 Tl 204.38 | 82 Pb 207.2 | 83 Bi 208.98 | 84 Po (209) | 85 At (210) | 86 Rn (222) |
| 7 | 87 Fr (223) | 88 Ra (226) | 89 ‡ Ac (227) | 104 Rf (267) | 105 Db (268) | 106 Sg (269) | 107 Bh (270) | 108 Hs (269) | 109 Mt (278) | 110 Ds (281) | 111 Rg (281) | 112 Cn (285) | 113 Uut (286) | 114 Uug (289) | 115 Uup (288) | 116 Uuh (293) | 117 Uus (294) | 118 Uuo (294) |
| | | | † | 58 Ce 140.12 | 59 Pr 140.91 | 60 Nd 144.24 | 61 Pm (145) | 62 Sm 150.36 | 63 Eu 151.96 | 64 Gd 157.25 | 65 Tb 158.93 | 66 Dy 162.50 | 67 Ho 164.93 | 68 Er 167.26 | 69 Tm 168.93 | 70 Yb 173.05 | 71 Lu 174.97 | |
| | | | ‡ | 90 Th 232.04 | 91 Pa 231.04 | 92 U 238.03 | 93 Np (237) | 94 Pu (244) | 95 Am (243) | 96 Cm (247) | 97 Bk (247) | 98 Cf (251) | 99 Es (252) | 100 Fm (257) | 101 Md (258) | 102 No (259) | 103 Lr (262) | |

1. What happens as ice melts at 0 °C?
 - I. Molecules gain kinetic energy and temperature increases.
 - II. Added energy overcomes hydrogen bonds between molecules.
 - III. Molecules gain sufficient energy to move from fixed positions.
 - A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

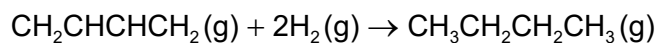
2. What is the molecular formula of the compound with empirical formula CH₂ and the following mass spectrum?



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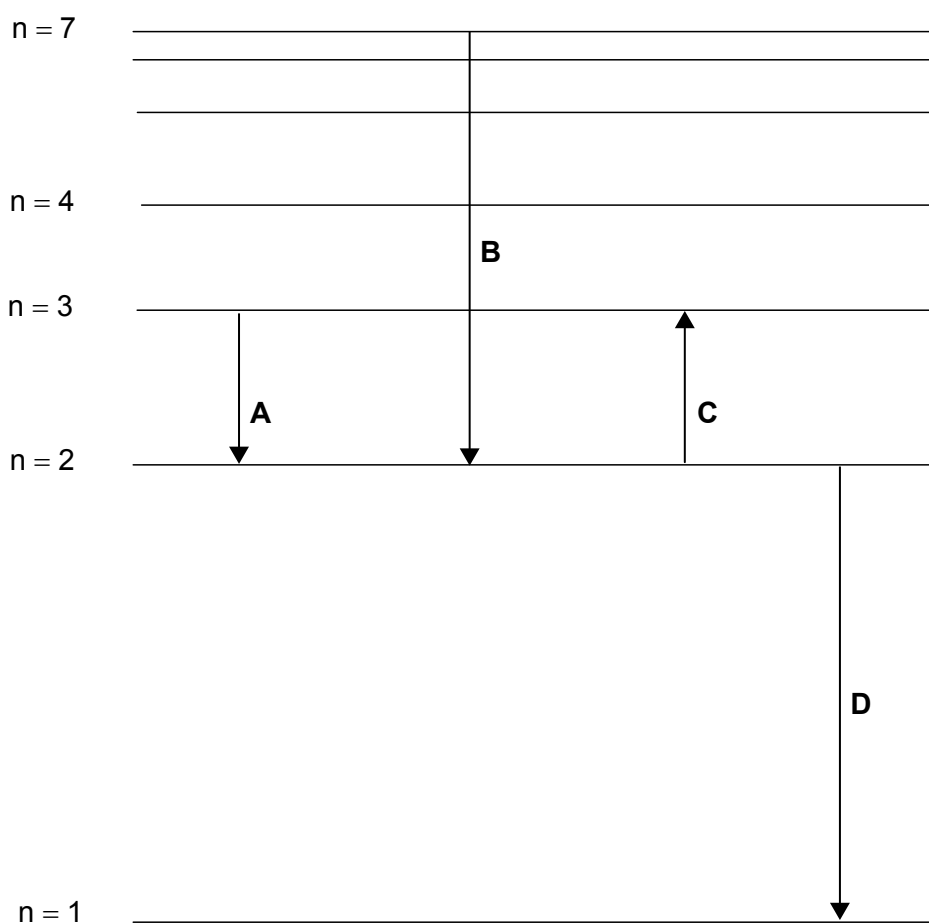
- A. C₂H₄
- B. C₃H₆
- C. C₄H₈
- D. C₅H₁₀

3. Which species are present after 15 dm³ of buta-1,3-diene has reacted with 18 dm³ of hydrogen to produce butane?



- A. 9 dm³ of butane and 6 dm³ of hydrogen
 B. 9 dm³ of butane and 6 dm³ of buta-1,3-diene
 C. 15 dm³ of butane and 3 dm³ of hydrogen
 D. 18 dm³ of butane and 3 dm³ of buta-1,3-diene
4. Which electron transition corresponds to the red line in the hydrogen line emission spectrum?

diagram not to scale



5. Which of the following can be used to determine the group of an element in the periodic table?
- I. successive ionization energies
 - II. electron configuration
 - III. number of occupied energy levels
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III
6. Which element is an actinoid?
- A. Rf
 - B. Ra
 - C. Pr
 - D. Pa
7. Which oxide produces an aqueous solution with the highest pH?
- A. Na_2O
 - B. P_4O_{10}
 - C. NO_2
 - D. CO_2
8. What is the oxidation state of cobalt in the complex ion $[\text{CoCl}_4(\text{NH}_3)_2]^-$?
- A. +2
 - B. +3
 - C. +5
 - D. +6

9. Which type of substance has the following properties?

| Substance properties |
|--|
| high melting point |
| non-conductor of electricity as a liquid |
| insoluble in polar solvents |

- A. ionic
- B. metallic
- C. simple molecular
- D. giant molecular

10. Which species have resonance structures?

- I. CH_2CHCH_3
- II. O_3
- III. NO_3^-

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

11. Which combination best describes NO_2^- ?

| | Number of electron domains around N | Molecular geometry | Bond angle |
|----|--|---------------------------|-------------------|
| A. | 2 | linear | 180° |
| B. | 3 | bent | 105° |
| C. | 3 | bent | 117° |
| D. | 4 | trigonal planar | 120° |

12. What is the molecular geometry of BrF_5 ?
- A. trigonal bipyramidal
 - B. octahedral
 - C. square-based pyramidal
 - D. T-shaped
13. Which gas contributes to ozone depletion?
- A. NO_x
 - B. SO_2
 - C. CO_2
 - D. CH_4
14. How much heat energy, in J, does a 2.00 g block of copper metal at 65.0°C lose when it is dropped into 100.0 cm^3 of water and cools to 15.0°C ?
- The specific heat capacity of copper is $0.385\text{ Jg}^{-1}\text{K}^{-1}$ and the specific heat capacity of water is $4.18\text{ Jg}^{-1}\text{K}^{-1}$.
- A. $2.00 \times 0.385 \times (65.0 - 15.0)$
 - B. $2.00 \times 0.385 \times (65.0 - 15.0 + 273)$
 - C. $100.0 \times 4.18 \times (65.0 - 15.0)$
 - D. $100.0 \times 4.18 \times (65.0 - 15.0 + 273)$
15. What is the correct formula for calculating enthalpy change of reaction, ΔH^\ominus reaction?
- A. ΔH^\ominus reaction = $\sum \Delta H_f^\ominus$ reactants - $\sum \Delta H_f^\ominus$ products
 - B. ΔH^\ominus reaction = $\sum \Delta H_c^\ominus$ products - $\sum \Delta H_c^\ominus$ reactants
 - C. ΔH^\ominus reaction = $\sum \Delta H_{bonds}^\ominus$ reactants - $\sum \Delta H_{bonds}^\ominus$ products
 - D. ΔH^\ominus reaction = $\sum \Delta H_{bonds}^\ominus$ products - $\sum \Delta H_{bonds}^\ominus$ reactants

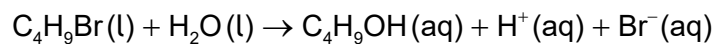
16. Which change represents electron affinity?

- A. $\text{O}_2(\text{g}) \rightarrow 2\text{O}(\text{g})$
- B. $\text{O}(\text{g}) \rightarrow \text{O}^+(\text{g}) + \text{e}^-$
- C. $2\text{O}(\text{g}) + \text{e}^- \rightarrow \text{O}_2(\text{g})$
- D. $\text{O}^-(\text{g}) + \text{e}^- \rightarrow \text{O}^{2-}(\text{g})$

17. Which change results in the greatest decrease in entropy?

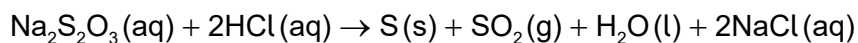
- A. $\text{NaCl}(\text{s}) \rightarrow \text{NaCl}(\text{aq})$
- B. $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$
- C. $\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$
- D. $\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightarrow \text{CO}(\text{g}) + 3\text{H}_2(\text{g})$

18. Which methods could be used to determine the rate of this reaction?

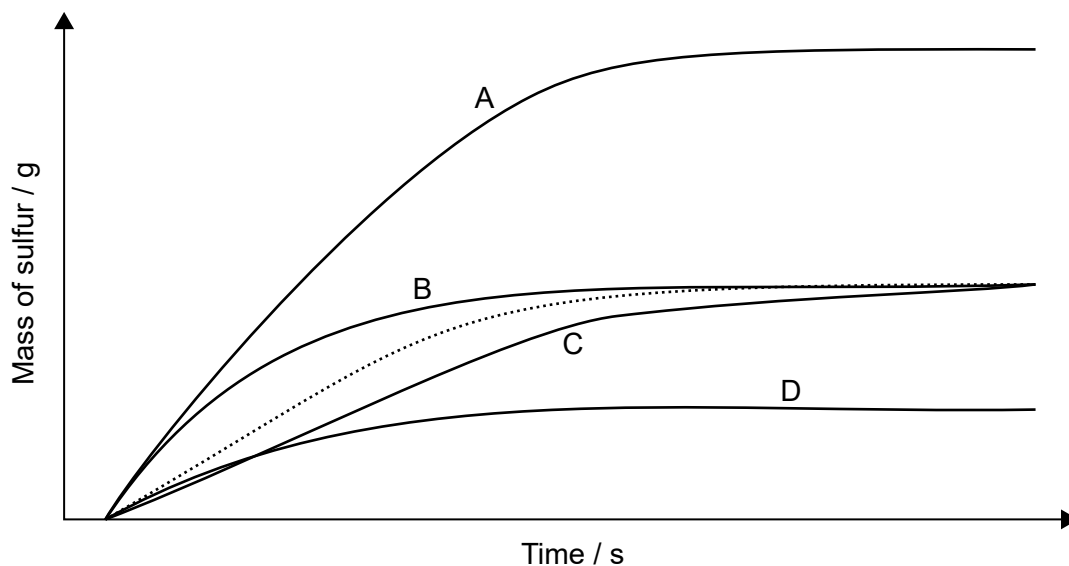


- I. change in pH
 - II. change in electrical conductivity
 - III. change in mass
- A. I and II only
 - B. I and III only
 - C. II and III only
 - D. I, II and III

19. Sodium thiosulfate solution reacts with excess hydrochloric acid.



The dotted line represents the mass of sulfur produced.



Which line represents the change in mass of sulfur per unit time when the concentration of hydrochloric acid is doubled?

20. The reaction between NO_2 and CO gives the following rate data at a certain temperature.

| $[\text{NO}_2] / \text{mol dm}^{-3}$ | $[\text{CO}] / \text{mol dm}^{-3}$ | Rate / $\text{mol dm}^{-3} \text{ sec}^{-1}$ |
|--------------------------------------|------------------------------------|--|
| 0.25 | 0.80 | 1.4×10^{-5} |
| 0.25 | 0.40 | 1.4×10^{-5} |
| 0.50 | 0.40 | 5.6×10^{-5} |

What is the overall order of reaction?

- A. 0
- B. 1
- C. 2
- D. 3

21. Which statement is correct for the components of the Arrhenius equation?

$$k = Ae^{\frac{-E_a}{RT}}$$

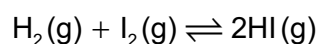
- A. E_a decreases as temperature increases.
- B. A relates to collisions with correct orientation.
- C. k increases as E_a increases.
- D. k is independent of the temperature of the reaction.

22. The equilibrium constant for $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ is $K_c = 0.0059$ at 298 K.

What is the value of the equilibrium constant at 298 K for $4\text{NO}_2(\text{g}) \rightleftharpoons 2\text{N}_2\text{O}_4(\text{g})$?

- A. $\frac{1}{0.0059}$
- B. $\frac{1}{0.0059^2}$
- C. 0.0059
- D. 0.0059^2

23. The value of K_c for the equilibrium between $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ is 51 at 720 K. Which combination is correct?



| | Position of equilibrium | Free energy change at 720 K |
|----|-------------------------|-----------------------------|
| A. | products are favoured | ΔG is positive |
| B. | products are favoured | ΔG is negative |
| C. | reactants are favoured | ΔG is positive |
| D. | reactants are favoured | ΔG is negative |

24. Which two species form a conjugate acid-base pair?



- A. H_3O^+ and H_2O
- B. CaCO_3 and CO_2
- C. CaCO_3 and H_3O^+
- D. H_3O^+ and CO_2

25. Which method can be used to distinguish between $\text{HCl}(\text{aq})$ and $\text{HCOOH}(\text{aq})$ of equimolar concentrations?

- A. measuring the volume of $\text{NaOH}(\text{aq})$ needed to neutralize 20 cm^3 of the acid
- B. measuring the mass loss when reacting with 1.0 g of $\text{NaHCO}_3(\text{s})$
- C. measuring the electrical conductivity of 20 cm^3 of acid solution
- D. measuring the volume of gas produced when reacting with 2.0 g of $\text{Na}_2\text{CO}_3(\text{s})$

26. At 298 K the $\text{p}K_{\text{a}}$ of ethanoic acid is 4.76 and the $\text{p}K_{\text{a}}$ of chloroethanoic acid is 2.87 . Which statement is correct for solutions of these acids with the same concentration?

- A. Ethanoic acid is a stronger acid than chloroethanoic acid.
- B. The K_{a} value of ethanoic acid is greater than the K_{a} of chloroethanoic acid.
- C. The pH of ethanoic acid is lower than the pH of chloroethanoic acid.
- D. The ethanoate ion is a stronger base than the chloroethanoate ion.

27. Which combination would produce a buffer solution?

- A. 25 cm^3 1.0 mol dm^{-3} $\text{CH}_3\text{COOH}(\text{aq})$ and 50 cm^3 1.0 mol dm^{-3} $\text{NaOH}(\text{aq})$
- B. 50 cm^3 1.0 mol dm^{-3} $\text{CH}_3\text{COOH}(\text{aq})$ and 25 cm^3 2.0 mol dm^{-3} $\text{NaOH}(\text{aq})$
- C. 25 cm^3 1.0 mol dm^{-3} $\text{CH}_3\text{COOH}(\text{aq})$ and 25 cm^3 1.0 mol dm^{-3} $\text{NaOH}(\text{aq})$
- D. 50 cm^3 1.0 mol dm^{-3} $\text{CH}_3\text{COOH}(\text{aq})$ and 25 cm^3 1.0 mol dm^{-3} $\text{NaOH}(\text{aq})$

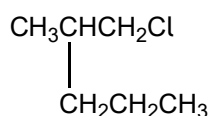
28. In which pair of species does Br have the same oxidation state?
- BrO_4^- and HBrO_3
 - HBr and Br_2O
 - HBrO_2 and Br^-
 - BrO^- and Br_2O
29. Which statement is correct for a voltaic cell?
- Reduction occurs at the negative electrode.
 - Electrical energy is converted to chemical energy.
 - The anode is the positive electrode.
 - Reduction occurs at the cathode.
30. What are the major products of the electrolysis of dilute aqueous magnesium chloride, $\text{MgCl}_2(\text{aq})$?
- magnesium metal and oxygen gas
 - magnesium metal and chlorine gas
 - hydrogen gas and oxygen gas
 - hydrogen gas and chlorine gas
31. Separate 1.00 mol dm^{-3} solutions of $\text{Fe}_2(\text{SO}_4)_3(\text{aq})$ and $\text{CuSO}_4(\text{aq})$ were electrolysed. Which combination of factors would produce the most moles of product at the cathode?

| | Electrolyte | Current / A | Duration of electrolysis / minutes |
|----|---|-------------|------------------------------------|
| A. | $\text{Fe}_2(\text{SO}_4)_3(\text{aq})$ | 2.0 | 45 |
| B. | $\text{Fe}_2(\text{SO}_4)_3(\text{aq})$ | 1.0 | 60 |
| C. | $\text{CuSO}_4(\text{aq})$ | 2.0 | 45 |
| D. | $\text{CuSO}_4(\text{aq})$ | 1.0 | 60 |

32. Which compounds belong to the same homologous series?

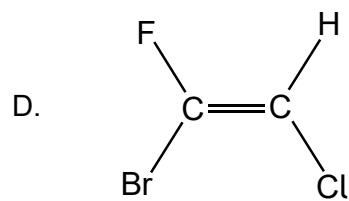
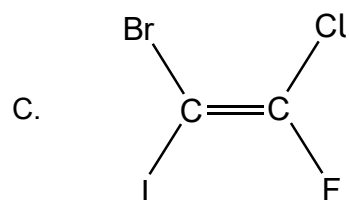
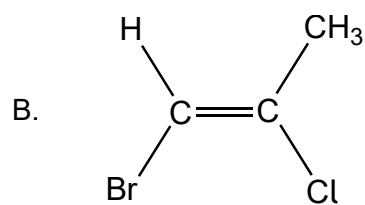
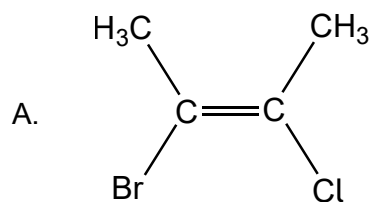
- A. CH_3CH_3 , $\text{CH}_3\text{CH}_2\text{CH}_3$, $\text{CH}_3\text{CHCHCH}_3$
- B. CH_3CHCH_2 , $\text{CH}_3\text{CH}_2\text{CHCH}_2$, $\text{CH}_2\text{CHCH}(\text{CH}_3)_2$
- C. CH_3OH , HCHO , HCOOH
- D. $\text{CH}_3\text{CH}_2\text{CHO}$, $(\text{CH}_3)_2\text{CO}$, CH_3CHO

33. What is the name of this compound?



- A. 1-chloro-2-propylpropane
 - B. 1-chloro-2-methylpentane
 - C. 2-propyl-3-chloropropane
 - D. 1-chlorohexane
34. What is the organic product when CH_3COOH and $(\text{CH}_3)_2\text{CH}(\text{OH})$ are heated together with concentrated sulfuric acid?
- A. $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_3$
 - B. $\text{CH}_3\text{COOCH}(\text{CH}_3)_2$
 - C. $(\text{CH}_3)_2\text{COOCH}_2\text{CH}_3$
 - D. $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$
35. Which reaction would be the fastest under the same conditions?
- A. $(\text{CH}_3)_3\text{CI} + \text{OH}^-$
 - B. $(\text{CH}_3)_3\text{CBr} + \text{OH}^-$
 - C. $\text{CH}_3\text{CH}_2\text{CH}(\text{I})\text{CH}_3 + \text{OH}^-$
 - D. $\text{CH}_3\text{CH}_2\text{CH}(\text{Br})\text{CH}_3 + \text{OH}^-$

36. Why are S_N1 reactions best conducted using protic polar solvents?
- Carbocation is not solvated and is readily attacked by the nucleophile.
 - Nucleophile readily forms a transition state with a negative charge.
 - Carbocation is stabilized by solvent molecules.
 - Nucleophile is solvated and readily forms a bond with the reactant.
37. Which structure is an E-isomer in the E/Z nomenclature system?



38. A 50.0 cm^3 sample of sodium hydroxide solution, $\text{NaOH}(\text{aq})$, weighed 53.894 g at 25°C . What is the density of the solution in g cm^{-3} ?
- A. 1.08
 - B. 1.078
 - C. 1.0779
 - D. 1.07788
39. Which region of the electromagnetic spectrum is used in ^1H NMR spectroscopy?
- A. X-ray
 - B. ultraviolet
 - C. infrared
 - D. radio waves
40. What information do we only get from the splitting pattern in an ^1H NMR spectrum?
- A. number of hydrogen atoms in a particular chemical environment
 - B. number of hydrogen atoms on the adjacent atom(s)
 - C. number of different chemical environments for hydrogen atoms
 - D. ratio of hydrogen atoms in each chemical environment
-

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