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# Chemistry Higher level Paper 1

8 May 2024

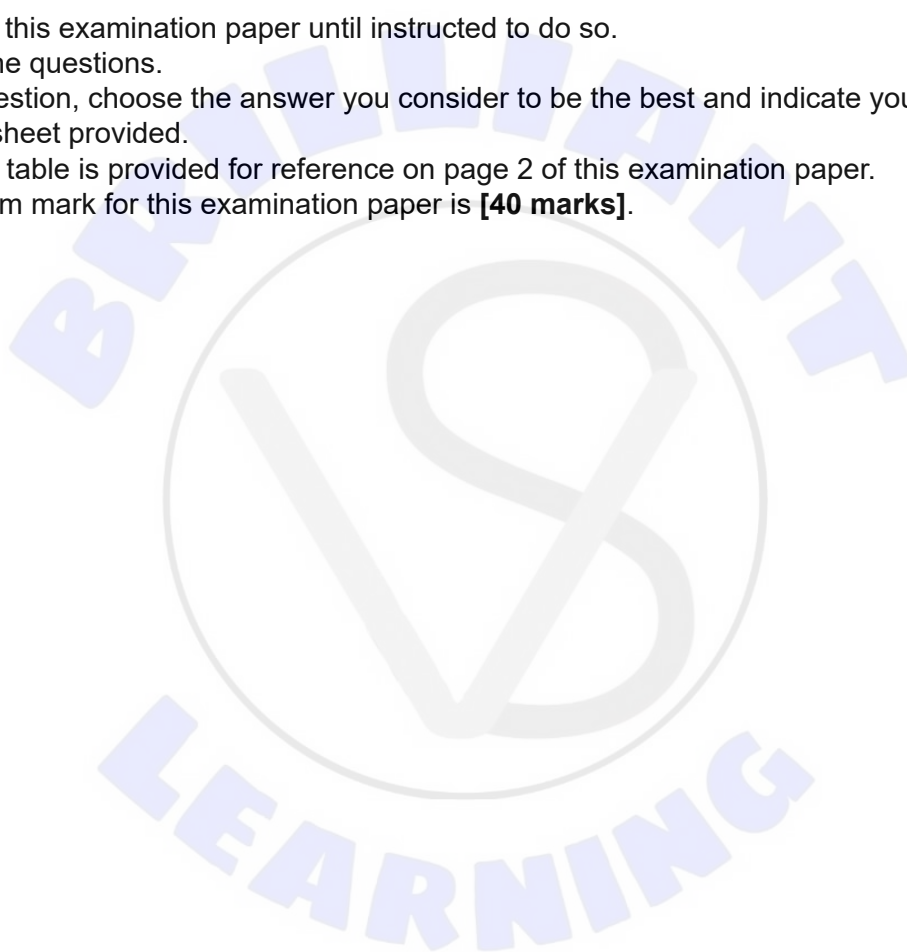
Zone A afternoon | Zone B afternoon | Zone C afternoon

1 hour

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## Instructions to candidates

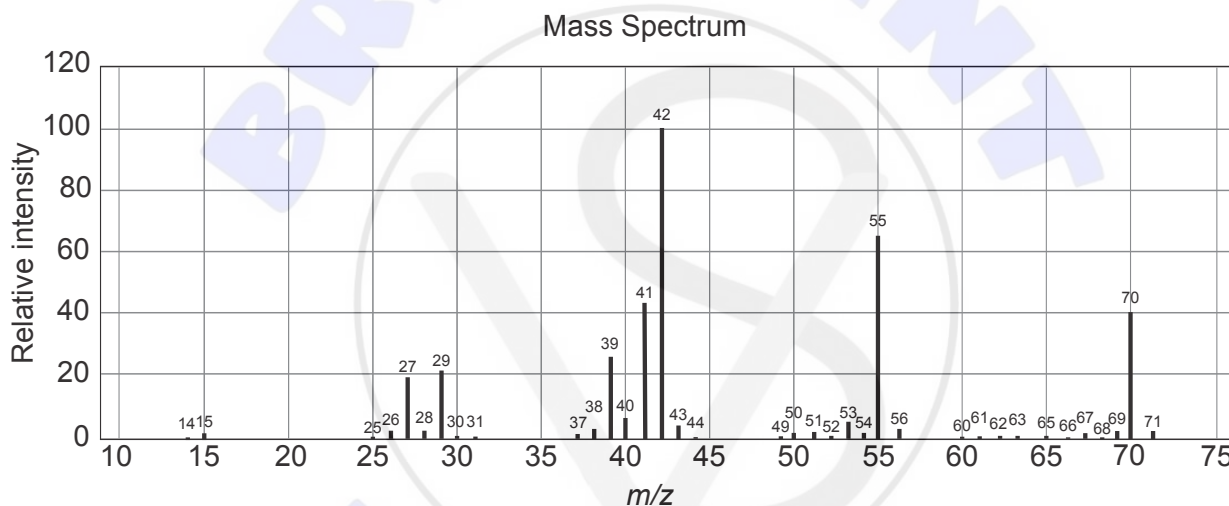
- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The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





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 CH<sub>2</sub> and the following mass spectrum?

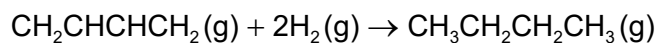


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- A. C<sub>2</sub>H<sub>4</sub>
- B. C<sub>3</sub>H<sub>6</sub>
- C. C<sub>4</sub>H<sub>8</sub>
- D. C<sub>5</sub>H<sub>10</sub>

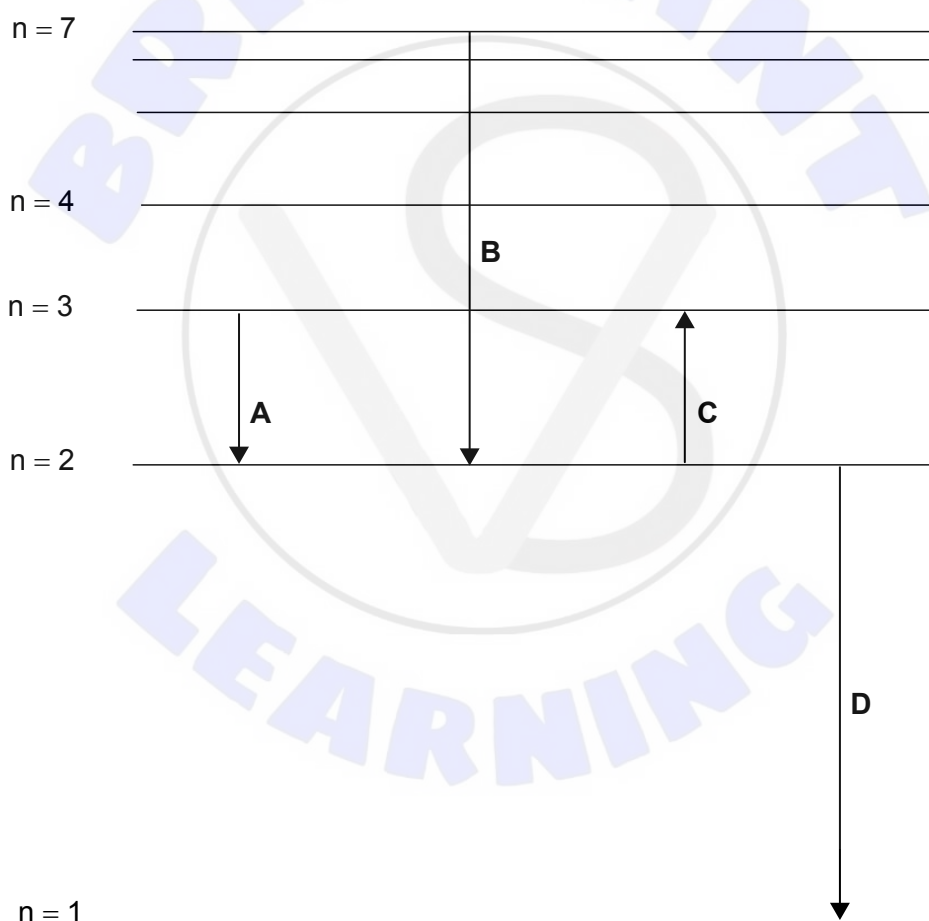
Turn over

3. Which species are present after 15 dm<sup>3</sup> of buta-1,3-diene has reacted with 18 dm<sup>3</sup> of hydrogen to produce butane?



- A. 9 dm<sup>3</sup> of butane and 6 dm<sup>3</sup> of hydrogen  
 B. 9 dm<sup>3</sup> of butane and 6 dm<sup>3</sup> of buta-1,3-diene  
 C. 15 dm<sup>3</sup> of butane and 3 dm<sup>3</sup> of hydrogen  
 D. 18 dm<sup>3</sup> of butane and 3 dm<sup>3</sup> 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.  $\text{Na}_2\text{O}$
  - B.  $\text{P}_4\text{O}_{10}$
  - C.  $\text{NO}_2$
  - D.  $\text{CO}_2$
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

Turn over

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.  $\text{CH}_2\text{CHCH}_3$
- II.  $\text{O}_3$
- III.  $\text{NO}_3^-$

- 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  $\text{NO}_2^-$ ?

	Number of electron domains around N	Molecular geometry	Bond angle
A.	2	linear	$180^\circ$
B.	3	bent	$105^\circ$
C.	3	bent	$117^\circ$
D.	4	trigonal planar	$120^\circ$

12. What is the molecular geometry of  $\text{BrF}_5$ ?
- A. trigonal bipyramidal
  - B. octahedral
  - C. square-based pyramidal
  - D. T-shaped
13. Which gas contributes to ozone depletion?
- A.  $\text{NO}_x$
  - B.  $\text{SO}_2$
  - C.  $\text{CO}_2$
  - D.  $\text{CH}_4$
14. How much heat energy, in J, does a 2.00 g block of copper metal at  $65.0^\circ\text{C}$  lose when it is dropped into  $100.0\text{ cm}^3$  of water and cools to  $15.0^\circ\text{C}$ ?
- 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,  $\Delta H^\ominus$  reaction?
- A.  $\Delta H^\ominus \text{ reaction} = \sum \Delta H_f^\ominus \text{ reactants} - \sum \Delta H_f^\ominus \text{ products}$
  - B.  $\Delta H^\ominus \text{ reaction} = \sum \Delta H_c^\ominus \text{ products} - \sum \Delta H_c^\ominus \text{ reactants}$
  - C.  $\Delta H^\ominus \text{ reaction} = \sum \Delta H_{\text{bonds}}^\ominus \text{ reactants} - \sum \Delta H_{\text{bonds}}^\ominus \text{ products}$
  - D.  $\Delta H^\ominus \text{ reaction} = \sum \Delta H_{\text{bonds}}^\ominus \text{ products} - \sum \Delta H_{\text{bonds}}^\ominus \text{ reactants}$

Turn over

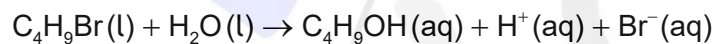
16. Which change represents electron affinity?

- 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?

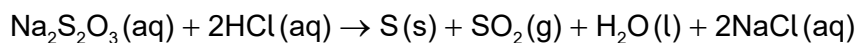
- A.  $\text{NaCl}(\text{s}) \rightarrow \text{NaCl}(\text{aq})$
- B.  $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$
- C.  $\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$
- D.  $\text{CH}_4(\text{g}) + \text{H}_2\text{O}(\text{g})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

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

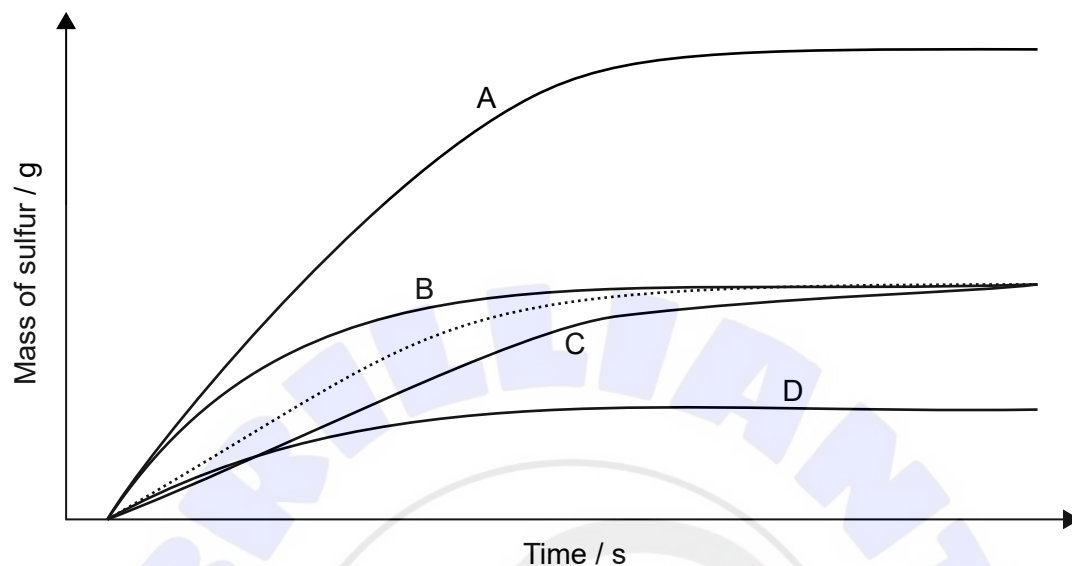


- I. change in pH
  - II. change in electrical conductivity
  - III. change in mass
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

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  $\text{NO}_2$  and  $\text{CO}$  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	$1.4 \times 10^{-5}$
0.25	0.40	$1.4 \times 10^{-5}$
0.50	0.40	$5.6 \times 10^{-5}$

What is the overall order of reaction?

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

Turn over

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

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

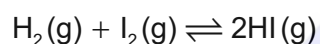
- A.  $E_a$  decreases as temperature increases.
- B.  $A$  relates to collisions with correct orientation.
- C.  $k$  increases as  $E_a$  increases.
- D.  $k$  is independent of the temperature of the reaction.

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  $4\text{NO}_2(\text{g}) \rightleftharpoons 2\text{N}_2\text{O}_4(\text{g})$ ?

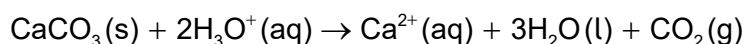
- A.  $\frac{1}{0.0059}$
- B.  $\frac{1}{0.0059^2}$
- C. 0.0059
- D.  $0.0059^2$

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	$\Delta G$ is positive
B.	products are favoured	$\Delta G$ is negative
C.	reactants are favoured	$\Delta G$ is positive
D.	reactants are favoured	$\Delta G$ is negative

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



- A.  $\text{H}_3\text{O}^+$  and  $\text{H}_2\text{O}$
- B.  $\text{CaCO}_3$  and  $\text{CO}_2$
- C.  $\text{CaCO}_3$  and  $\text{H}_3\text{O}^+$
- D.  $\text{H}_3\text{O}^+$  and  $\text{CO}_2$
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  $20\text{ cm}^3$  of the acid
- B. measuring the mass loss when reacting with  $1.0\text{ g}$  of  $\text{NaHCO}_3(\text{s})$
- C. measuring the electrical conductivity of  $20\text{ cm}^3$  of acid solution
- D. measuring the volume of gas produced when reacting with  $2.0\text{ g}$  of  $\text{Na}_2\text{CO}_3(\text{s})$
26. At  $298\text{ K}$  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  $K_{\text{a}}$  value of ethanoic acid is greater than the  $K_{\text{a}}$  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.  $25\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{CH}_3\text{COOH}(\text{aq})$  and  $50\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$
- B.  $50\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{CH}_3\text{COOH}(\text{aq})$  and  $25\text{ cm}^3$   $2.0\text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$
- C.  $25\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{CH}_3\text{COOH}(\text{aq})$  and  $25\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$
- D.  $50\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{CH}_3\text{COOH}(\text{aq})$  and  $25\text{ cm}^3$   $1.0\text{ mol dm}^{-3}$   $\text{NaOH}(\text{aq})$

Turn over

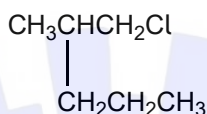
28. In which pair of species does Br have the same oxidation state?
- $\text{BrO}_4^-$  and  $\text{HBrO}_3$
  - $\text{HBr}$  and  $\text{Br}_2\text{O}$
  - $\text{HBrO}_2$  and  $\text{Br}^-$
  - $\text{BrO}^-$  and  $\text{Br}_2\text{O}$
29. Which statement is correct for a voltaic cell?
- Reduction 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  $1.00 \text{ mol dm}^{-3}$  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.  $\text{CH}_3\text{CH}_3$ ,  $\text{CH}_3\text{CH}_2\text{CH}_3$ ,  $\text{CH}_3\text{CHCHCH}_3$
- B.  $\text{CH}_3\text{CHCH}_2$ ,  $\text{CH}_3\text{CH}_2\text{CHCH}_2$ ,  $\text{CH}_2\text{CHCH}(\text{CH}_3)_2$
- C.  $\text{CH}_3\text{OH}$ ,  $\text{HCHO}$ ,  $\text{HCOOH}$
- D.  $\text{CH}_3\text{CH}_2\text{CHO}$ ,  $(\text{CH}_3)_2\text{CO}$ ,  $\text{CH}_3\text{CHO}$

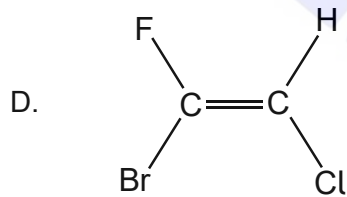
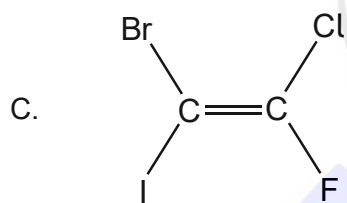
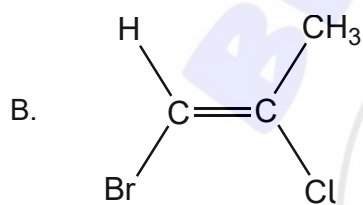
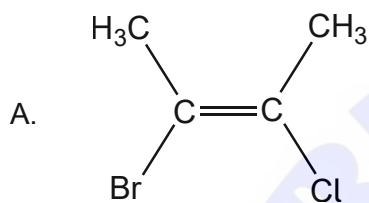
33. What is the name of this compound?



- 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  $\text{CH}_3\text{COOH}$  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.  $\text{CH}_3\text{CH}_2\text{CH}(\text{Br})\text{CH}_3 + \text{OH}^-$

Turn over

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<sup>3</sup> sample of sodium hydroxide solution, NaOH(aq), weighed 53.894 g at 25 °C. What is the density of the solution in g cm<sup>-3</sup>?
- A. 1.08
  - B. 1.078
  - C. 1.0779
  - D. 1.07788
39. Which region of the electromagnetic spectrum is used in <sup>1</sup>H 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 <sup>1</sup>H 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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