



# Chemistry Higher level Paper 1

4 November 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]**.

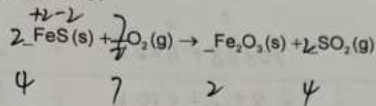
Caption

C 1. How many moles of phosphate ions,  $\text{PO}_4^{3-}$ , are there in 103.39 g of  $\text{Ca}_3(\text{PO}_4)_2$ ?  
 $M_r = 310.18$

- A. 0.11
- B. 0.33
- C. 0.67
- D. 2.00

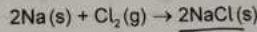
$$\frac{103.39}{310.18} \times 2 = \frac{2}{3}$$

D 2. What is the sum of the coefficients for the balanced equation of the combustion of iron(II) sulphide using the smallest whole numbers?



- A. 6
- B. 7
- C. 14
- D. 17

D 3. What is the yield of sodium chloride, in grams, when 4.60 g of sodium reacts with 1.14 dm<sup>3</sup> of chlorine gas at STP?  
Molar volume = 22.7 dm<sup>3</sup> mol<sup>-1</sup>



- A. 1.17
- B. 2.92
- C. 5.84
- D. 11.7

$$n(\text{Na}) = \frac{4.6}{23} = 0.2 \text{ mol}$$

$$n(\text{Cl}_2) = \frac{1.14}{22.7} = 0.05 \text{ mol}$$

$$n(\text{NaCl}) = 0.2 \text{ mol} \quad m = 0.2 \times (23 + 35.5) = 11.7$$

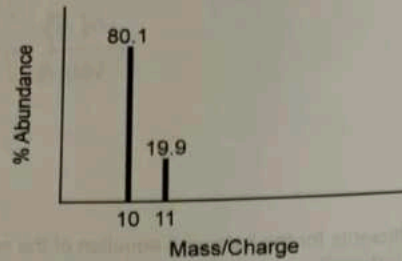
B 4. What is the pressure, in Pa, inside a 3.0 dm<sup>3</sup> cylinder containing 64 g of O<sub>2</sub> at 25.0°C?  
 $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$ ;  $PV = nRT$

- A.  $\frac{2 \times 8.31 \times 25}{3.0}$
- B.  $\frac{2 \times 8.31 \times 298}{3.0 \times 10^{-3}}$  ✓
- C.  $\frac{2 \times 8.31 \times 298}{3.0}$
- D.  $\frac{4 \times 8.31 \times 298}{3.0 \times 10^{-3}}$  ✓

$$PV = nRT \quad n = \frac{64}{2 \times 16} = 2 \text{ mol}$$

$$P = \frac{2 \times 8.31 \times 298}{3.0 \times 10^{-3}}$$

5. What is the A, of the element as determined from its mass spectrum below?



- A. 10.0  
B. 10.2  
C. 10.5  
D. 10.8

$$10 \times 0.8 + 11 \times 0.2$$

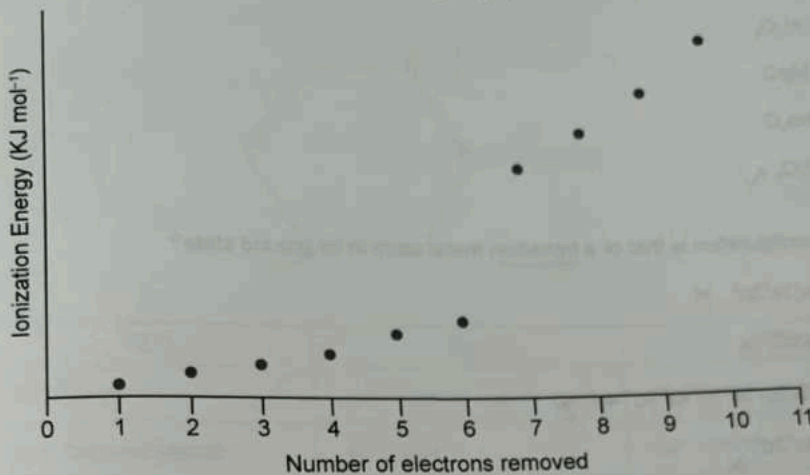
$$= 8 + 2.2 = 10.2$$

6. What is correct for the wavelength and energy of the radiation of the ultraviolet and visible regions of the electromagnetic spectrum?

	Ultraviolet region	Visible region
A.	Lower wavelength and higher energy	Higher wavelength and lower energy
B.	Lower wavelength and lower energy	Higher wavelength and higher energy
C.	Higher wavelength and lower energy	Lower wavelength and higher energy
D.	Higher wavelength and higher energy	Lower wavelength and lower energy

D

7. The graph represents the first ten ionization energies (IE) of an element.



What is the element?

- A. Cl
- B. Ne
- C. O
- D. S

D<sup>8</sup>.

$[\text{Co}(\text{H}_2\text{O})_6]^{3+}$  is blue while  $[\text{Co}(\text{CN})_6]^{3-}$  is pale yellow. Which statement correctly explains the difference in colour?

- A. The ligand in  $[\text{Co}(\text{CN})_6]^{3-}$  is weaker and absorbs light of higher frequency.
- B. The oxidation state of cobalt is different in each complex.
- C. The different colours are due to the different charges on the complex.
- D. The ligand in  $[\text{Co}(\text{CN})_6]^{3-}$  causes larger 3d orbital splitting and absorbs light of higher frequency.

12. A

9. Which of these period 3 oxides forms a solution with  $\text{pH} < 7$  when added to water?

- A.  $\text{Al}_2\text{O}_3$
- B.  $\text{MgO}$
- C.  $\text{Na}_2\text{O}$
- D.  $\text{P}_4\text{O}_6$  ✓

10. Which configuration is that of a transition metal atom in its ground state?

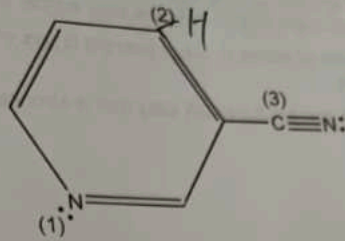
- A.  $[\text{Ne}]3s^23p^6$  ✗
- B.  $[\text{Ar}]3d^0$  ✗
- C.  $1s^22s^22p^63s^23p^64s^23d^{10}4p^2$  ✗
- D.  $[\text{Ar}]4s^13d^5$  ✓

11. Which types of intermolecular force exist between  $\text{CH}_4$ ,  $\text{CH}_3\text{OH}$  and  $\text{CH}_3\text{Cl}$  molecules?

	$\text{CH}_4$	$\text{CH}_3\text{OH}$	$\text{CH}_3\text{Cl}$
A.	London dispersion only	London dispersion, H-bonding, dipole-dipole ✓	London dispersion, dipole-dipole
B.	London dispersion, H-bonding ✗	London dispersion, H-bonding, dipole-dipole	London dispersion, H-bonding, dipole-dipole
C.	London dispersion only	London dispersion, dipole-dipole	London dispersion only
D.	London dispersion, H-bonding ✗	London dispersion only	London dispersion, dipole-dipole

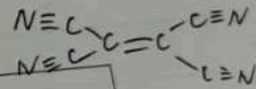
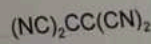


12. What is the molecular geometry and hybridization of the numbered atoms in the molecule shown below?



	N(1)	C(2)	C(3)
A.	sp <sup>2</sup> / bent ✓	sp <sup>2</sup> / trigonal planar ✓	sp / linear ✓
B.	sp <sup>2</sup> / trigonal planar	sp <sup>2</sup> / bent	sp <sup>2</sup> / bent
C.	sp <sup>3</sup> / tetrahedral	sp <sup>2</sup> / trigonal planar	sp / bent
D.	sp / bent	sp <sup>3</sup> / tetrahedral	sp <sup>3</sup> / linear

13. How many sigma ( $\sigma$ ) and pi ( $\pi$ ) bonds are present in the molecule below?

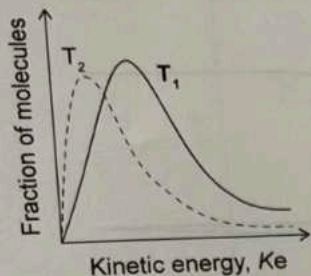


	$\sigma$	$\pi$
A.	7	5
B.	9 ✓	5
C.	9 ✓	9 ✓
D.	13	5

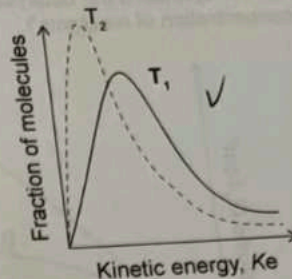
17. Which of the diagrams represents the Maxwell-Boltzmann distribution of kinetic energy of molecules of the same sample of a gas at two temperatures,  $T_1$  and  $T_2$ , when  $T_1 > T_2$ ?

B

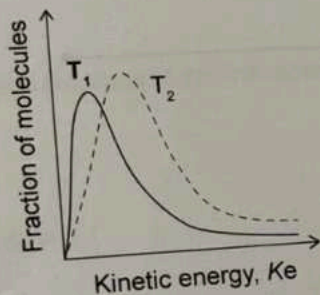
A.



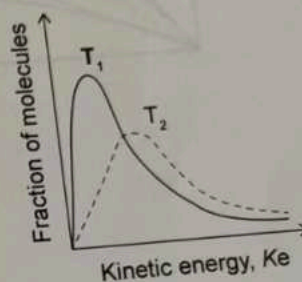
B.



C.



D.



18.

What is the enthalpy change, in  $\text{kJ mol}^{-1}$ , when 107 g of solid ammonium chloride,  $\text{NH}_4\text{Cl}$ , are added to water to form  $50.0 \text{ cm}^3$  of solution, producing a maximum decrease of  $28^\circ\text{C}$ ?  
 $M_r \text{ NH}_4\text{Cl} = 53.5$   
 Specific heat capacity of water =  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$

A.  $\Delta H = \frac{-50.0 \times 4.18 \times (28 + 273)}{2 \times 1000}$  X

B.  $\Delta H = \frac{-50.0 \times 4.18 \times 28}{2 \times 1000}$  X

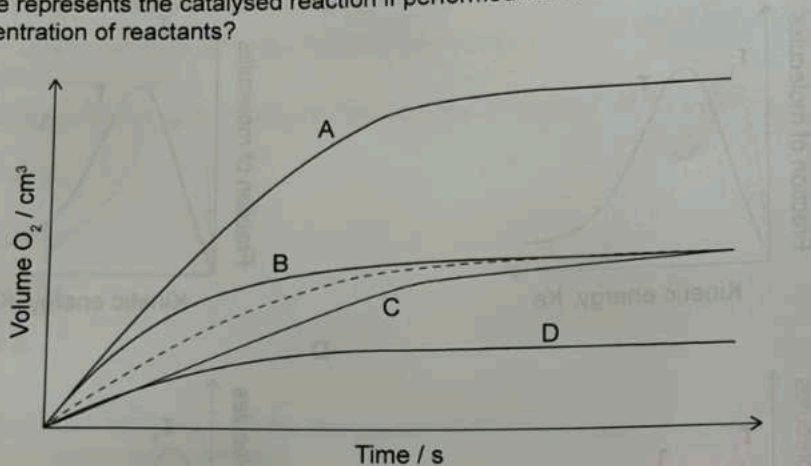
C.  $\Delta H = \frac{50.0 \times 4.18 \times (28 + 273)}{2 \times 1000}$

D.  $\Delta H = \frac{50.0 \times 4.18 \times 28}{2 \times 1000}$  ✓

19. The non-catalysed decomposition of  $H_2O_2$  was monitored giving the dotted line in the following graph.

B

Which curve represents the catalysed reaction if performed at the same temperature and using the same concentration of reactants?



18. What is the enthalpy change in  $kJ mol^{-1}$  when 10g of acid anhydrous chloride  $AlCl_3$  are added to water to form 50  $cm^3$  of solution producing a maximum decrease of  $20.0^\circ C$ .  
 $M_r AlCl_3 = 133.5$   
 Specific heat capacity of water =  $4.18 J g^{-1} K^{-1}$

A  $\Delta H = \frac{-80.0 \times 4.18 \times (28 - 20)}{5 \times 1000}$  X

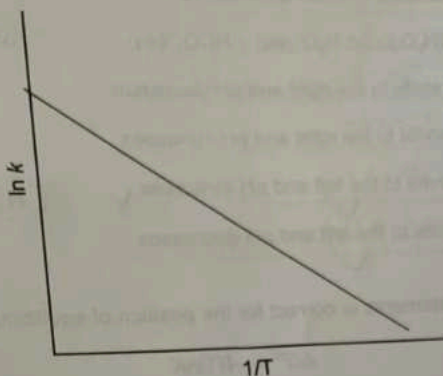
B  $\Delta H = \frac{-80.0 \times 4.18 \times 28}{5 \times 1000}$  X

C  $\Delta H = \frac{50.0 \times 4.18 \times (28 - 20)}{5 \times 1000}$  X

D  $\Delta H = \frac{20.0 \times 4.18 \times 28}{5 \times 1000}$  ✓



20. The rate constants of a reaction at different temperatures were plotted giving the following graph.

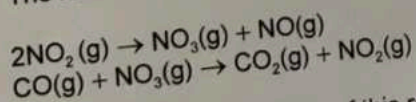


What does the slope of the line represent?

$$\ln k = \frac{-E_a}{RT} + \ln A$$

- A.  $-E_a/RT$  ✓  
 B.  $-E_a$   
 C.  $\ln A$   
 D.  $-E_a/RT$

21. The reaction between carbon monoxide and nitrogen dioxide follows the two-step mechanism:

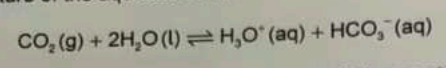


Slow step  
Fast step

What is the rate expression of this reaction?

- A. Rate =  $k[\text{NO}_2]^2$  ✓  
 B. Rate =  $k[\text{NO}_2]^2[\text{CO}][\text{NO}_3]$   
 C. Rate =  $k[\text{CO}][\text{NO}_3]$   
 D. Rate =  $k[\text{NO}_2]^2[\text{CO}]$

22. Carbon dioxide dissolves in water as shown in the equation below. What will happen if the temperature of the aqueous solution is increased?



$$\Delta H^\ominus = -19.3 \text{ kJ mol}^{-1}$$

- A. The equilibrium shifts to the right and pH decreases.
- B. The equilibrium shifts to the right and pH increases.
- C. The equilibrium shifts to the left and pH increases. ✓
- D. The equilibrium shifts to the left and pH decreases. ✓

$[\text{H}^+] \downarrow$  pH  $\uparrow$

23. Which of the following statements is correct for the position of equilibrium of a reaction?

$$\Delta G^\ominus = -RT \ln K$$

- I. It will always shift to the right when temperature increases. ✗
- II. If  $\Delta G^\ominus < 0$ , then  $K > 1$  and products are favoured over reactants.
- III. If  $\Delta G^\ominus = 0$ , then  $K=1$  and [reactants] and [products] are approximately equal.

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

$$[\text{H}^+] = 10^{-5}$$

$$[\text{H}^+] = 10^{-10}$$

24. The pH of an aqueous solution Z is 5 and the pH of an aqueous solution X is 10. What is the ratio of their  $\text{H}_3\text{O}^+$  concentrations?

- A.  $[\text{H}_3\text{O}^+]$  is 2 times lower in X than in Z.
- B.  $[\text{H}_3\text{O}^+]$  is 5 times lower in X than in Z.
- C.  $[\text{H}_3\text{O}^+]$  is  $1 \times 10^2$  times lower in X than in Z.
- D.  $[\text{H}_3\text{O}^+]$  is  $1 \times 10^5$  times lower in X than in Z.

25. Using the data provided in the table, which of the conjugate bases is the strongest? *weak acid. Ka*

A.

Acid	$K_a$
HClO ✓	$2.9 \times 10^{-8}$ ✓
$C_6H_5COOH$	$6.3 \times 10^{-5}$
$H_3PO_4$	$7.3 \times 10^{-3}$
$H_2SO_3$	$1.3 \times 10^{-2}$

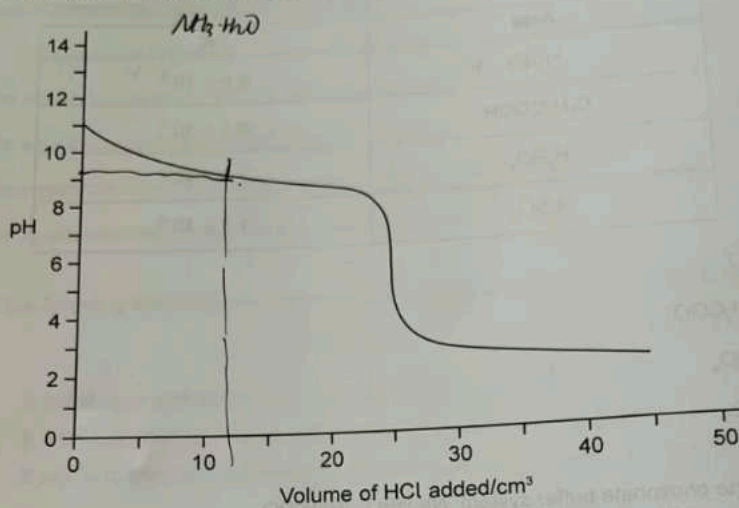
- A.  $ClO^-$   
 B.  $C_6H_5COO^-$   
 C.  $H_2PO_4^-$   
 D.  $HSO_3^-$

26. Consider the phosphate buffer system,  $Na_2HPO_4 / NaH_2PO_4$ .  
 What is correct when a small amount of a strong base is added to the buffer?

- A.  $OH^-$  react with  $Na^+$  to form NaOH. ✗  
 B.  $[H_2PO_4^-]$  increases.  
 C.  $[HPO_4^{2-}]$  increases. ✓  
 D.  $OH^-$  react with  $H_2PO_4^-$  to form  $PO_4^{3-}$ . ✗

27. A 25 cm<sup>3</sup> sample of a weak base was titrated with hydrochloric acid, HCl.

B



What is the  $pK_b$  of the base?

- A. 2  
B. 5  
C. 9  
D. 11

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3 \cdot H_2O]}$$

Half-equivalent point

$$pK_b = p[OH^-] = 14 - pH = 14 - 9 = 5$$

28. In which reaction does  $H_2$  act as an oxidizing agent?

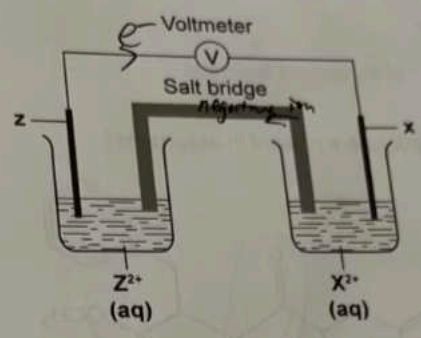
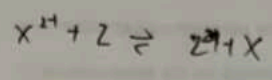
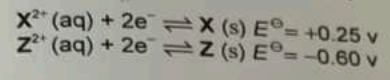
B

- A.  $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$   
 B.  $2Na(s) + H_2(g) \rightarrow 2NaH(s)$   
 C.  $Cl_2(g) + H_2(g) \rightarrow 2HCl(g)$   
 D.  $H_2CCH_2(g) + \overset{0}{H_2}(g) \rightarrow \overset{+1}{H_3}CCH_3(g)$

decrease



29. A voltaic cell is constructed from half-cells using metals X and Z as electrodes. What will occur when this cell produces electricity?



- A. Positive ions flow through the salt bridge to Z half-cell.
- B. Electrons flow from X half-cell to Z half-cell.
- C. The concentration of  $X^{2+}$  increases.
- D. Mass of electrode Z decreases.

30. Which statement is correct for a reaction in a voltaic cell, for which both  $\Delta H^\ominus$  and  $\Delta S^\ominus$  are positive?

$\Delta G^\ominus = -nFE^\ominus$

$\Delta G = \Delta H - T\Delta S$

$T \uparrow, \Delta G \downarrow, E \uparrow$

- A.  $E^\ominus$  cell will increase with an increase in temperature.
- B.  $E^\ominus$  cell will decrease with an increase in temperature.
- C.  $E^\ominus$  cell will not change when the temperature increases.
- D.  $\Delta G^\ominus > 0$  for all temperatures.



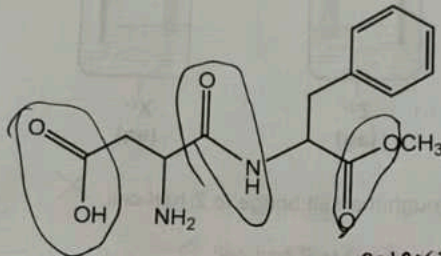
31. Which statement is correct for the value of  $E^\ominus$  of the standard hydrogen electrode (SHE)?

B

- A. It was determined experimentally.
- B. It depends on the temperature.
- C. It was arbitrarily set.
- D. It depends on the  $E^\ominus$  of the second electrode.

32. Which of these functional groups are present in aspartame?

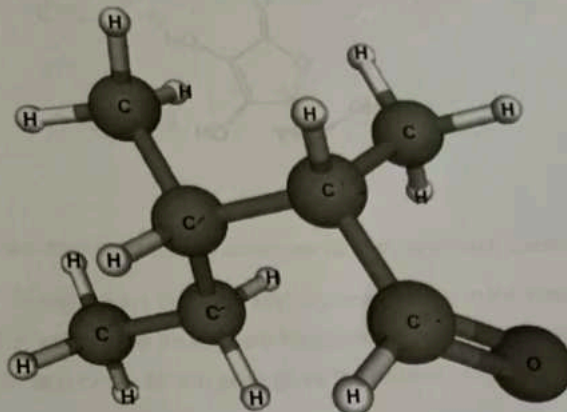
B



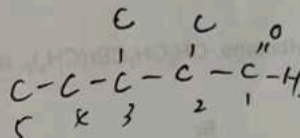
- A. Carboxyl, secondary amino and ether ~~X~~
- B. Carboxyl, secondary amino and ester ✓
- C. Ether, primary amino and secondary amino ~~X~~
- D. Ester, primary amino and carboxyl ~~X~~

33. What is the IUPAC name of this compound?

A



- A. 2,3-dimethylpentanal
- B. 2,3-methylpentanal
- C. 2-methyl-3-ethylbutanal
- D. 3-ethyl-2-methylbutanal



34. Which of the following compounds can react with acidified potassium dichromate to give an acid?

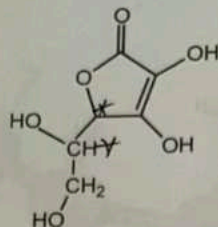
✓

- A.  $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
- B.  $\text{CH}_3\text{COCH}_3$
- C.  $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_2\text{OH})\text{CH}_2\text{CH}_3$  ✓
- D.  $\text{CH}_3\text{C}(\text{CH}_3)(\text{OH})\text{CH}_3$

Compound	Reaction mechanism
A. $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$	Sw2
B. $\text{CH}_3\text{COCH}_3$	Sw1 ✓
C. $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_2\text{OH})\text{CH}_2\text{CH}_3$ ✓	Sw1 ✓
D. $\text{CH}_3\text{C}(\text{CH}_3)(\text{OH})\text{CH}_3$	Sw2

35. How many optical isomers exist for ascorbic acid?

B

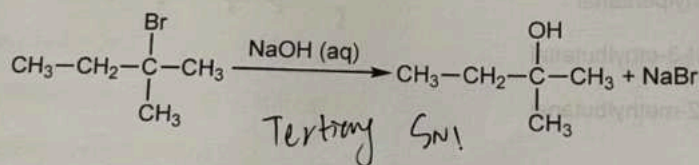


37.

- A. 2
- B. 4
- C. 5
- D. 6

36. 2-bromo-2-methylbutane,  $\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2$ , reacts with a warm solution of NaOH to form an alcohol.

B



What is the reaction mechanism and rate expression?

	Reaction mechanism	Rate expression
A.	$\text{S}_{\text{N}}2$	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2][\text{OH}^-]$
B.	$\text{S}_{\text{N}}1$ ✓	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2]$
C.	$\text{S}_{\text{N}}1$ ✓	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2][\text{OH}^-]$
D.	$\text{S}_{\text{N}}2$	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2]$



