



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]**.

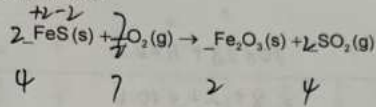
Caption

C 1. How many moles of phosphate ions, 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

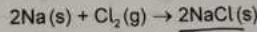
$$\frac{103.39}{310.18} \times 2 = \frac{2}{3}$$

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 dm³ of chlorine gas at STP? Molar volume = 22.7 dm³ mol⁻¹



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

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

$$n(\text{Cl}_2) = \frac{1.14}{22.7} = 0.2 \text{ mol}$$

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

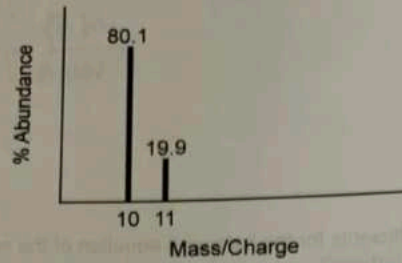
B 4. What is the pressure, in Pa, inside a 3.0 dm³ cylinder containing 64 g of O₂ at 25.0°C? $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$; $PV = nRT$

- 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

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

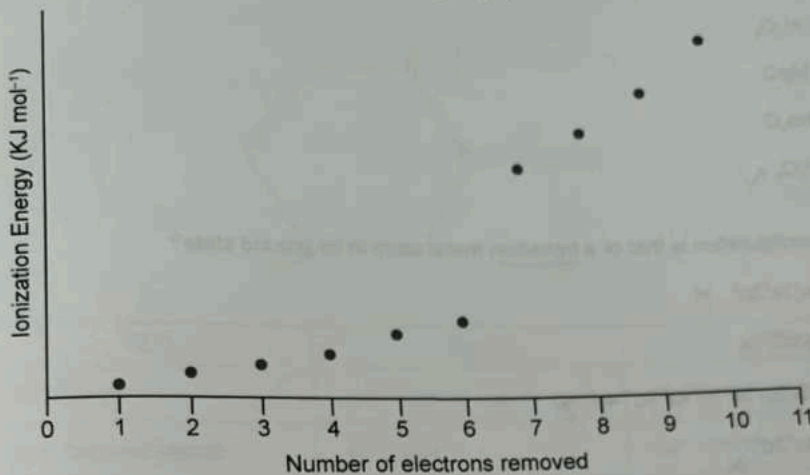
$$= 8 + 2.2 = 10.2$$

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

D⁸.

$[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ 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. Al_2O_3
- B. MgO
- C. Na_2O
- D. P_4O_6 ✓

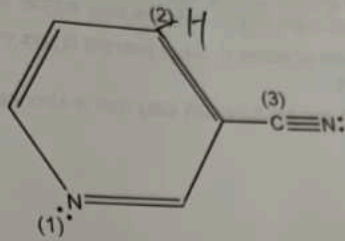
10. Which configuration is that of a transition metal atom in its ground state?

- 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 CH_4 , CH_3OH and CH_3Cl molecules?

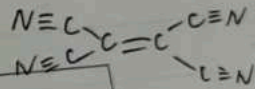
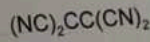
	CH_4	CH_3OH	CH_3Cl
A.	London dispersion only	London dispersion, H-bonding, dipole-dipole ✓	London dispersion, dipole-dipole
B.	London dispersion, H-bonding ✗	London dispersion, H-bonding, dipole-dipole	London dispersion, H-bonding, dipole-dipole
C.	London dispersion only	London dispersion, dipole-dipole	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 ² / bent ✓	sp ² / trigonal planar ✓	sp / linear ✓
B.	sp ² / trigonal planar	sp ² / bent	sp ² / bent
C.	sp ³ / tetrahedral	sp ² / trigonal planar	sp / bent
D.	sp / bent	sp ³ / tetrahedral	sp ³ / linear

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

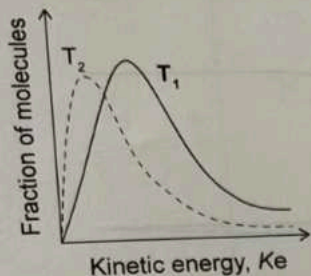


	σ	π
A.	7	5
B.	9 ✓	5
C.	9 ✓	9 ✓
D.	13	5

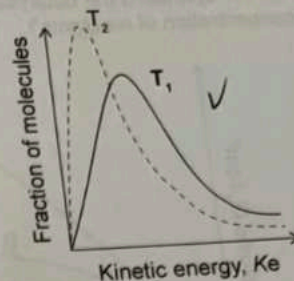
17. Which of the diagrams represents the Maxwell-Boltzmann distribution of kinetic energy of molecules of the same sample of a gas at two temperatures, T_1 and T_2 , when $T_1 > T_2$?

B

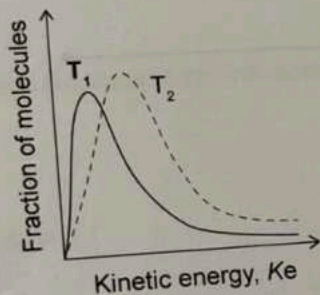
A.



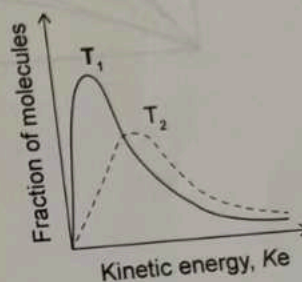
B.



C.



D.



18.

What is the enthalpy change, in kJ mol^{-1} , when 107 g of solid ammonium chloride, NH_4Cl , are added to water to form 50.0 cm^3 of solution, producing a maximum decrease of 28°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

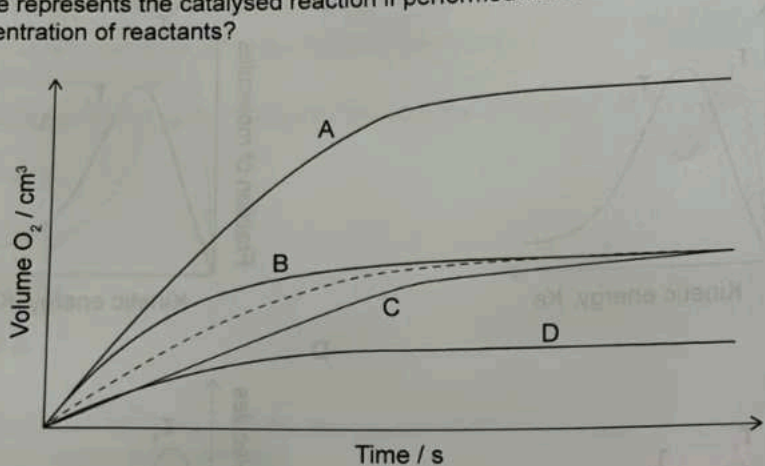
C. $\Delta H = \frac{50.0 \times 4.18 \times (28 + 273)}{2 \times 1000}$

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 $SnCl_4$ are added to water to form 50 cm^3 of solution producing a maximum decrease of $28.7^\circ C$.
M. H. Cl = 23.5
Specific heat capacity of water = $4.18 J g^{-1} K^{-1}$

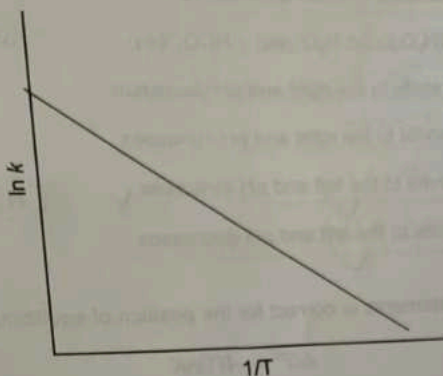
A $\Delta H = \frac{-80.0 \times 4.18 \times (28 - 27.5)}{5 \times 1000}$ X

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

C $\Delta H = \frac{50.0 \times 4.18 \times (28 - 27.5)}{5 \times 1000}$

D $\Delta H = \frac{-50.0 \times 4.18 \times 28}{5 \times 1000}$ ✓

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

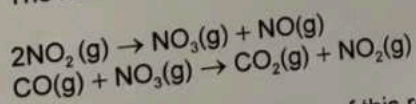


What does the slope of the line represent?

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

- 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:

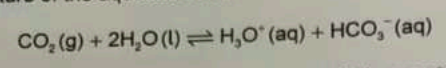


Slow step
Fast step

What is the rate expression of this reaction?

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

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 H_3O^+ 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 1×10^2 times lower in X than in Z.
- D. $[\text{H}_3\text{O}^+]$ is 1×10^5 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 ✓	2.9×10^{-8} ✓
C_6H_5COOH	6.3×10^{-5}
H_3PO_4	7.3×10^{-3}
H_2SO_3	1.3×10^{-2}

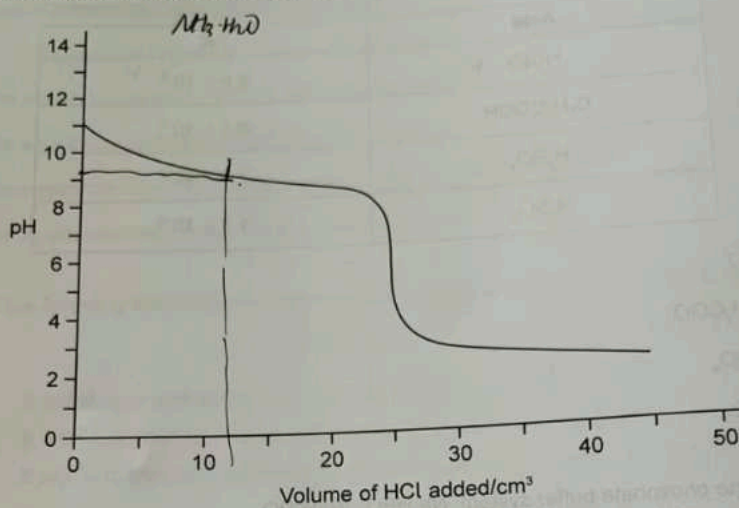
- A. ClO^-
 B. $C_6H_5COO^-$
 C. $H_2PO_4^-$
 D. HSO_3^-

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 cm³ 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

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

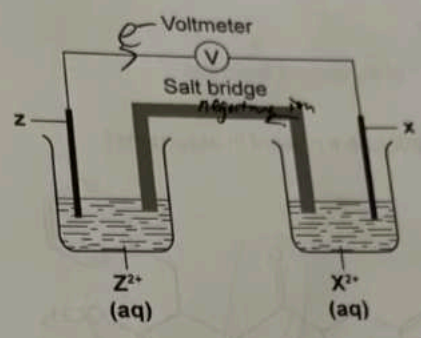
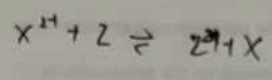
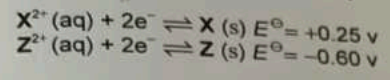
28. In which reaction does H_2 act as an oxidizing agent?

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 ΔH^\ominus and ΔS^\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.

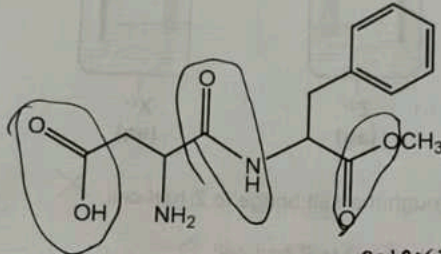
31. Which statement is correct for the value of E^\ominus of the standard hydrogen electrode (SHE)?

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?

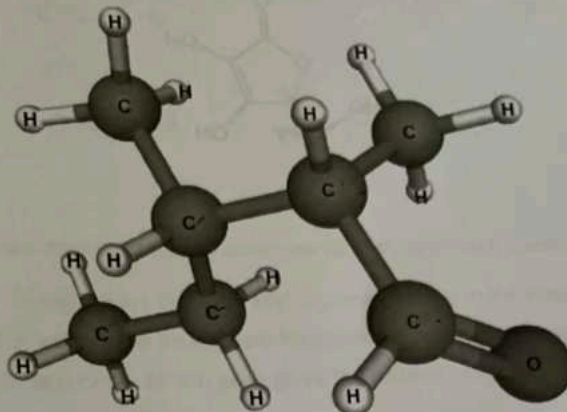
B



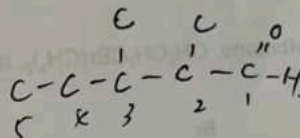
- A. Carboxyl, secondary amino and ether ~~X~~
- B. Carboxyl, secondary amino and ester ✓
- C. Ether, primary amino and secondary amino ~~X~~
- D. Ester, primary amino and carboxyl ~~X~~

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



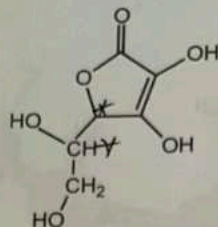
34. Which of the following compounds can react with acidified potassium dichromate to give an acid?

✓

Compound	Reaction mechanism
A. $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$	Sw2
B. CH_3COCH_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

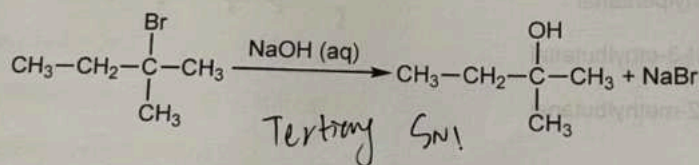


37.

- 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.	$\text{S}_{\text{N}}2$	$\text{rate} = k[\text{CH}_3\text{CH}_2\text{CBr}(\text{CH}_3)_2]$

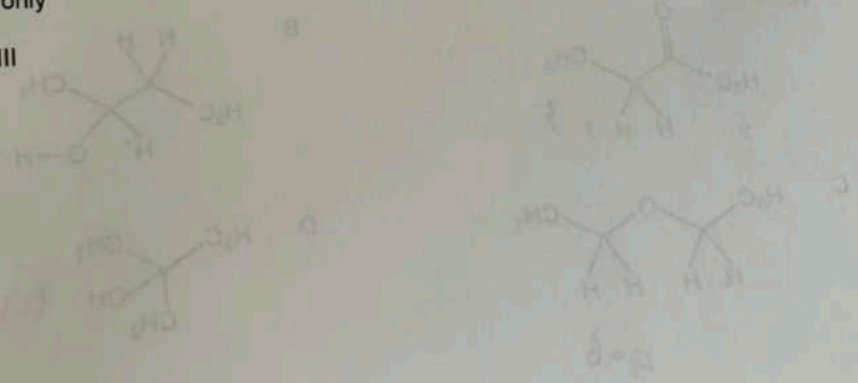
37. Which of the following compounds would give an optically active compound on reacting with LiAlH_4 ?

- A. Propanal $\text{C}-\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{H}$
- B. Butanal $\text{C}=\text{C}-\text{C}-\text{H}$
- C. Butanone $\text{C}-\overset{\text{O}}{\parallel}{\text{C}}-\text{C}-\text{C}$
- D. Propanone

38. Which statements are correct about the molecular ion, M^+ , in a mass spectrum?

- I. The M^+ is **not** always the peak with highest intensity in the mass spectrum. ✓
- II. The M^+ is always the most stable fragment formed during electron bombardment. X
- III. The m/z ratio of the M^+ ion peak gives the relative molecular mass of the molecule. ✓

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



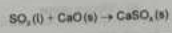
Student perform an investigation to determine the content of ethanol acid in vinegar samples...
of a non-standardized sodium hydroxide solution. Which type of error will occur and how will it affect the quality of the data obtained?
Systematic error and lower accuracy
Systematic error and lower precision
Random error and lower accuracy
Random error and lower precision

14. Which statements are correct for alloys?

- i. The mixture of metallic cations of different sizes increases the strength of the non-directional metallic bonding making the alloy harder than the parent metals.
- ii. The different sizes of atoms in alloys prevent layers of metallic cations sliding over each other easily.
- iii. Adding carbon to iron produces an alloy that is stronger than pure iron.

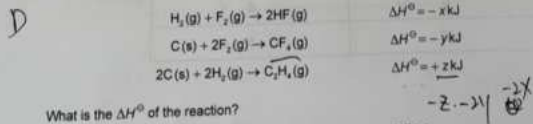
- A. i and ii only
- B. i and iii only
- C. ii and iii only
- D. i, ii and iii

15. What are the signs of ΔH° and ΔS° for this reaction that is non-spontaneous at high temperatures and spontaneous at low temperatures?
 $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

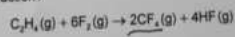


	ΔH° <input checked="" type="checkbox"/>	ΔS° <input checked="" type="checkbox"/>
A.	+	+
B.	-	-
C.	- <input checked="" type="checkbox"/>	+ <input checked="" type="checkbox"/>
D.	+	-

16. Consider the following equations:



What is the ΔH° of the reaction?



- A. $-x - y - z$
- B. $-x - y + z$
- C. $-2x + 2y - z$
- D. $-2x - 2y - z$