

Anglo-Chinese Junior College

JC2 Preliminary Examination

Higher 2



A Methodist Institution
(Founded 1866)

CHEMISTRY

Paper 1 Multiple Choice

9729/01

13 September 2023

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

This document consists of **xx** printed pages and **xx** blank page.

1 Which types of chemical bonds listed below are present in solid ammonium nitrate?

- 1 ionic bonds
- 2 dative bonds
- 3 hydrogen bonds

- A 1 only
- B 1 and 2 only**
- C 1 and 3 only
- D 1, 2 and 3

Ans: B

Identify structure to be giant ionic, with covalent bonds within the polyatomic cation, NH_4^+ , and polyatomic anion, NO_3^- . There is a dative covalent bond between N and H in NH_4^+ , and N and O in NO_3^- .

AOA

2 1.00 mol of gaseous molecules **A** take up a volume of 50 dm^3 at a pressure of 2 bar and a temperature of 50°C .

Which statements explain the above observation?

- 1 Gaseous molecules of **A** are in constant rapid random motion.
- 2 Gaseous molecules of **A** have significant molecular volume.
- 3 Gaseous molecules of **A** experience strong intermolecular forces of attraction.

- A 1 only
- B 1 and 2 only**
- C 2 and 3 only
- D 1, 2 and 3

Ans: B

For ideal gas,

$$V_{\text{ideal}} = \frac{nRT}{p} = \frac{1.00 \times 8.31 \times (273 + 50)}{200\,000} = 13.4 \text{ dm}^3$$

$$\therefore V_{\text{observed}} > V_{\text{ideal}}$$

All gases are in constant rapid random motion and exerts pressure as a result.

Since there is a positive deviation ($V_{\text{observed}} > V_{\text{ideal}}$), it is possibly due to significant molecular volume.

Strong IMF would lead to a negative deviation.

AOB

- 3 Two properties relating to silicon and sulfur which are non-metallic elements and their atoms are as follows.

- property 1 – the oxide forms a strong acid in water
- property 2 – no paired 3p electrons

Which properties do silicon and sulfur have?

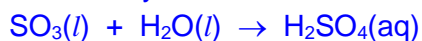
	silicon	sulfur
A	1 and 2	1 only
B	1 and 2	1 and 2
C	2 only	1 only
D	2 only	1 and 2

Ans: **C**

Property 1

SiO₂ does not dissolve in water because of strong covalent bonds between the Si and O atoms in the giant molecular structure.

SO₃ readily soluble to form an acidic solution.



Property 2

Si – 1s²2s²2p⁶3s²3p²

No paired 3p electrons

S – 1s²2s²2p⁶3s²3p⁴

1 paired 3p electrons

AOA

- 4 The Group 2 metals have higher melting points than the Group 1 metals.

Which factors could contribute towards the higher melting points?

- 1 There are smaller interatomic distances in the metallic lattices of the Group 2 metals.
- 2 Two valence electrons from each Group 2 metal atom are available for bonding in the metallic lattice.
- 3 Group 2 metals have the higher first ionisation energy.

A 1, 2 and 3 B 1 and 2 only C 2 and 3 only D 1 only

Ans: B

Recall:

- Energy is needed to overcome the metallic bonds during melting of metals
- Metallic bond strength is dependent on:
(1) charge density,
(2) number of valence e^- contributed to delocalised e^-

Option 1 is correct – As the interatomic distances is smaller in Group 2 metals, the charge density (since radius is smaller) is higher, hence, stronger metallic bond and higher mp.

Option 2 is correct – As Group 2 metals contribute 2 valence electrons to the sea of delocalised electrons, it has stronger metallic bond, and hence, higher mp.

Option 3 is incorrect – Higher first IE relates to metals in gaseous state. Hence, does not explain the mp.

AOA

- 5 Which statement about the trend in the property of the halogens down the group is correct?

- A The electronegativity increases.
- B The reactivity as oxidising agents increases.
- C The enthalpy change of reaction with hydrogen becomes more endothermic.
- D The volatility increases.

Ans: C

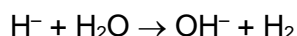
The electronegativity and volatility decrease down the group.

As can be observed from the E^\ominus values, the oxidising strength of the halogens decreases down the group.

Halogens react with hydrogen in the gaseous phase to give hydrogen halides. As reactivity/oxidising power of the halogens decreases down the group, the vigour of the reaction also decreases down the group. Hence, the enthalpy change of reaction with hydrogen becomes more endothermic.

AOA

- 6 Group 1 and Group 2 ionic hydrides react with water.



In an experiment, 1.01 g of a sample of an ionic hydride is dissolved in excess H_2O . The resulting solution required 24.0 cm^3 of a 2.0 mol dm^{-3} HCl solution for complete neutralisation.

What is the formula of the hydride?

- A LiH
- B NaH
- C MgH_2
- D CaH_2**

Ans: **D**

Amt of HCl required = 0.048 mol

Amount of OH^- = 0.048 mol = Amount of H^-

If Group 1 ionic hydride, amount of MH = 0.048 mol and $M_r = 21.0$

If Group 2 ionic hydride, amount of MH_2 = 0.024 mol and $M_r = 42.1$

M_r of $\text{CaH}_2 = 40.1 + 2.0 = 42.1$

AOB

- 7 Two identical iron(II) sulfate solutions were separately titrated with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ and acidified KMnO_4 solutions of equal concentrations.

Which statement describes the required volumes of $\text{K}_2\text{Cr}_2\text{O}_7$ and KMnO_4 solutions needed to completely oxidise the iron(II)?

- A The volume of KMnO_4 solution is 0.83 times that of the volume of $\text{K}_2\text{Cr}_2\text{O}_7$.
- B The volume of KMnO_4 solution is 1.20 times that of the volume of $\text{K}_2\text{Cr}_2\text{O}_7$.**
- C The volume of KMnO_4 solution is 1.82 times that of the volume of $\text{K}_2\text{Cr}_2\text{O}_7$.
- D The volume of KMnO_4 solution is 2.22 times that of the volume of $\text{K}_2\text{Cr}_2\text{O}_7$.

Ans: **B**

6 moles of electrons per mole of dichromate.

5 moles of electrons per mole of manganate(VII).

Let no of moles of Fe^{2+} be x

No of moles of dichromate = $x/6$, no of moles of manganate(VII) = $x/5$

Given the fact that the dichromate and manganate(VII) solutions are of the same concentrations \rightarrow vol of manganate is $6/5$ that of vol of dichromate.

AOB

8 Which reaction represents a standard enthalpy change at 298 K?

- A** $\frac{1}{2}\text{F}_2(\text{g}) \rightarrow \text{F}(\text{g})$
B $\text{C}(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
C $\text{C}(\text{s}) + 4\text{F}(\text{g}) \rightarrow \text{CF}_4(\text{g})$
D $\text{C}_3\text{H}_8(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 3\text{CO}_2(\text{g}) + 4\text{H}_2\text{O}(\text{g})$

Ans: A

A ✓: Standard enthalpy change of atomisation of F_2

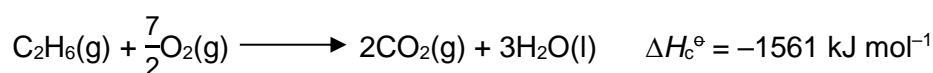
B ✗: At 298 K, C should be a solid

C ✗: Fluorine exists as F_2 under std state

D ✗: At 298 K, H_2O should be a liquid

AOA

9 Ethane undergoes combustion as shown.



Some relevant data are given below.

$$\Delta H_c^\ominus \text{ of C(s)} = -394 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\ominus \text{ of C}_2\text{H}_6(\text{g}) = -85 \text{ kJ mol}^{-1}$$

$$\Delta H_f^\ominus \text{ of H}_2\text{O}(\text{g}) = -243 \text{ kJ mol}^{-1}$$

What is the standard enthalpy change of vaporisation of $\text{H}_2\text{O}(\text{l})$?

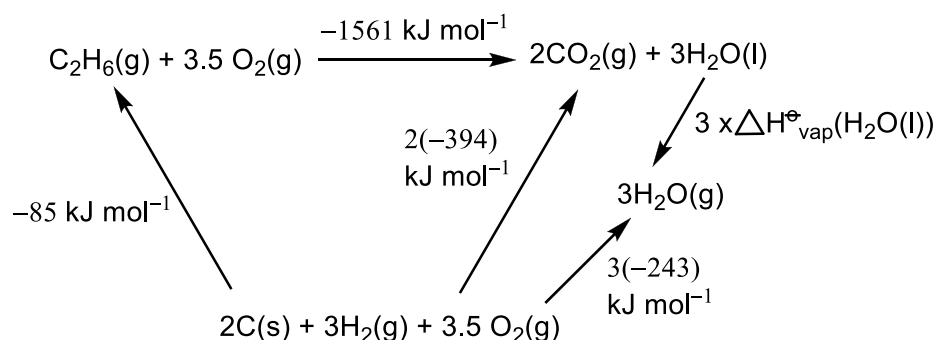
A $+43 \text{ kJ mol}^{-1}$

B -43 kJ mol^{-1}

C $+129 \text{ kJ mol}^{-1}$

D -129 kJ mol^{-1}

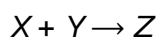
Ans: A



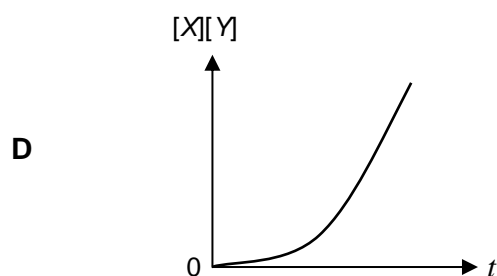
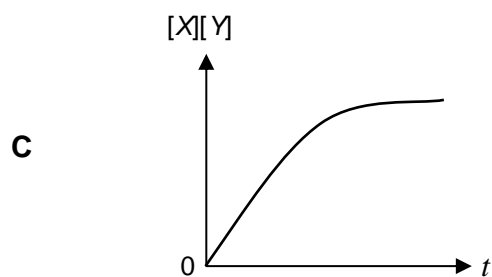
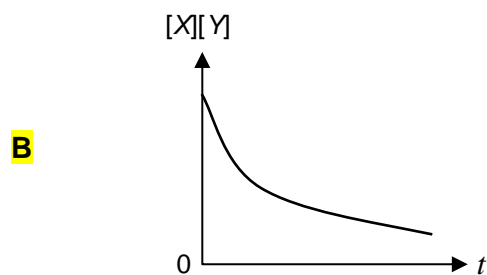
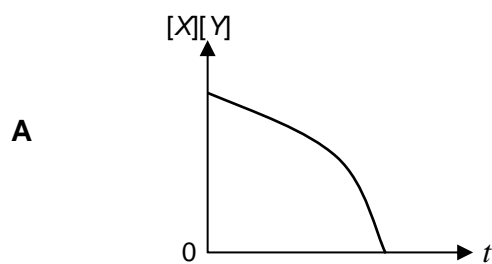
By Hess Law,
 $-1561 - 85 = 2(-394) + 3(-243) - 3 \times \Delta H_{\text{vap}}^\ominus \text{ of H}_2\text{O}(\text{l})$
 $\Delta H_{\text{vap}}^\ominus \text{ of H}_2\text{O}(\text{l}) = \underline{+43 \text{ kJ mol}^{-1}}$

AOB

- 10 The product $[X][Y]$ of the concentrations of X and Y is plotted against time, t , for the following second-order reaction.



Which graph would be obtained?



Ans: **B**
 $X + Y \rightarrow Z$

The question states the reaction is overall 2nd-order. Hence $[X][Y]$ should decrease non-linearly.

AOA

- 11 Two first order reactions were started at the same time. Reaction **I** had an initial concentration of 1 mol dm^{-3} and a half-life of 20 minutes. Reaction **II** had an initial concentration of 4 mol dm^{-3} and a half-life of 10 minutes.

At what time would the concentrations in the two reactions become equal?

- A 15 min
B 35 min
C 40 min
D 50 min

Ans: C

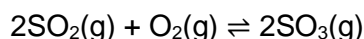
Reaction **I** – $1 \rightarrow 0.5 \rightarrow 0.25$

2 half-lives = $2 \times 20 = 40$ minutes

Reaction **II** - $4 \rightarrow 2 \rightarrow 1 \rightarrow 0.5 \rightarrow 0.25$

4 half-lives = $4 \times 10 = 40$ minutes AOB

- 12 The reaction between sulfur dioxide and oxygen is reversible.



The rate constants of the forward and backward reactions are given as k_1 and k_{-1} respectively.

What happens to the values of k_1 , k_{-1} , K_c and the equilibrium position if an inert gas is introduced into the reaction vessel at constant volume?

	k_1	k_{-1}	K_c	equilibrium position
A	unchanged	unchanged	unchanged	unchanged
B	increases	decreases	increases	shifts to right
C	decreases	increases	decreases	shifts to left
D	unchanged	unchanged	unchanged	shifts to right

Ans: A

Addition of an inert gas does not change the value of rate constant.

At a constant volume, the partial pressures of each gas does not change so the position of equilibrium is unaffected.

AOA

- 13 Malic acid is a dibasic acid which is used in skincare products.

The pK_a values of malic acid are 3.40 and 5.20.

What volume of $0.200 \text{ mol dm}^{-3}$ KOH needs to be added to 20.00 cm^3 of $0.240 \text{ mol dm}^{-3}$ of malic acid to form a buffer solution of pH 5.22?

- A 35.70 cm^3
- B 35.90 cm^3
- C 36.10 cm^3
- D 36.30 cm^3**

Ans: **D**

Recognise that this buffer involves the 2nd pK_a rather than the 1st pK_a .

First equivalence volume = 24.00 cm^3

At 36.25 cm^3 of added KOH,

$$\text{pH} = 5.20 + \lg ([A^{2-}] / [HA^-])$$

$$1.047 = [A^{2-}] / [HA^-]$$

$$x / (24.00 - x) = 1.047$$

$$(24.00/x) - 1 = (1.047)^{-1}$$

$$x = 24.00 / (1 + (1.047)^{-1}) = 12.2755$$

Required volume of KOH = $24.00 + x = 36.28 \text{ cm}^3$, which is closest to option **D**.

AOB

- 14 The indicator bromophenol blue, HIn, changes colour from yellow to blue over a pH range of 3.0 to 4.6.

Which statement is correct?

- A When bromophenol blue is added to pure water at 25°C , $[HIn] > [In^-]$.
- B Bromophenol blue would be a suitable indicator for the titration of a strong base and a weak acid.
- C The In^- ions are yellow.
- D The pK_a of bromophenol blue is around 3.8.**

Ans: **D**

Water has a pH of 7, so the indicator would show blue colour, which means $[In^-] > [HIn]$. Hence option **A** is incorrect.

The end point of the titration between a strong base and weak acid lies above pH 7 and this is way beyond the working range of bromophenol blue. Since bromophenol blue changes colour from yellow to blue over a pH range of 3.0 to 4.6, this implies that the colour of the solution will be yellow and blue for $\text{pH} < 3.0$ and $\text{pH} > 4.6$ respectively. This eliminates option **C** straightaway. (We need to interpret that HIn molecule is yellow while In^- ion is blue.)

Option **D** is a correct option as the colour change of an indicator usually occurs within ± 1 from its pK_a and 3.8 fits a value for its pK_a .

AOB

- 15 The numerical values of the solubility products of zinc carbonate and silver carbonate are 1.46×10^{-10} and 8.46×10^{-12} respectively.

Which statement can be deduced from the information given above?

- A** The units of solubility product for both salts are the same.
B In an aqueous solution containing 0.01 mol dm^{-3} zinc ions and 0.01 mol dm^{-3} silver ions, silver carbonate will be precipitated first.
C In saturated solutions of each salt, the concentrations of carbonate ions are the same.
D Zinc carbonate is a less soluble salt than silver carbonate in water.

Ans: **D**

Option **A** is incorrect

$$K_{sp} = [\text{Zn}^{2+}(\text{aq})][\text{CO}_3^{2-}(\text{aq})]$$

$$\text{Units: mol}^2 \text{ dm}^{-6}$$

$$K_{sp} = [\text{Ag}^+(\text{aq})]^2[\text{CO}_3^{2-}(\text{aq})]$$

$$\text{Units: mol}^3 \text{ dm}^{-9}$$

Option **B** is incorrect

$$K_{sp} = [\text{Zn}^{2+}(\text{aq})][\text{CO}_3^{2-}(\text{aq})]$$

$$1.46 \times 10^{-10} = (0.01) [\text{CO}_3^{2-}(\text{aq})]$$

$$[\text{CO}_3^{2-}(\text{aq})] = 1.46 \times 10^{-8} \text{ mol dm}^{-3}$$

$$K_{sp} = [\text{Ag}^+(\text{aq})]^2[\text{CO}_3^{2-}(\text{aq})]$$

$$8.46 \times 10^{-12} = (0.01)^2 [\text{CO}_3^{2-}(\text{aq})]$$

$$[\text{CO}_3^{2-}(\text{aq})] = 8.46 \times 10^{-8} \text{ mol dm}^{-3}$$

Since carbonate concentration is greater, silver carbonate will not be precipitated first.

Option **C** is incorrect

$$K_{sp} = [\text{Zn}^{2+}(\text{aq})][\text{CO}_3^{2-}(\text{aq})]$$

$$1.46 \times 10^{-10} = x^2$$

$$x = 1.21 \times 10^{-5} \text{ mol dm}^{-3}$$

$$K_{sp} = [\text{Ag}^+(\text{aq})]^2[\text{CO}_3^{2-}(\text{aq})]$$

$$8.46 \times 10^{-12} = (2y)^2(y)$$

$$4y^3 = 8.46 \times 10^{-12}$$

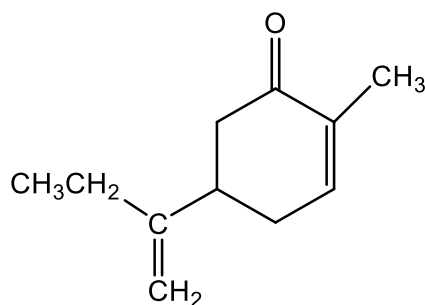
$$y = 1.28 \times 10^{-4} \text{ mol dm}^{-3}$$

The concentration of the carbonate ions is not the same.

From the calculations, x & y is the solubility of each salt. Hence, Zinc carbonate is a less soluble salt than silver carbonate in water.

AOB

- 16 A compound derived from plant essential oil has the following structure.

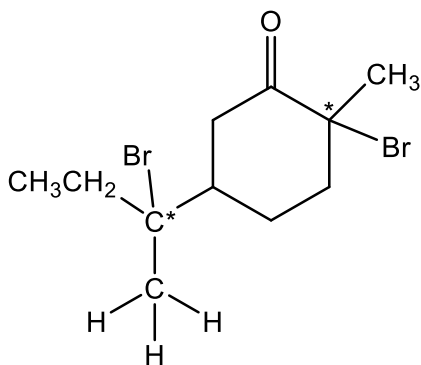


When the compound is reacted with HBr in CCl_4 , how many new chiral centres are formed in the major product in this reaction?

- A 1
B 2
 C 3
 D 4

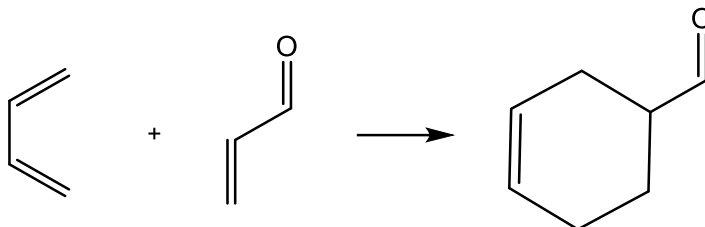
Ans: B

2 new chiral centres are formed in this reaction.

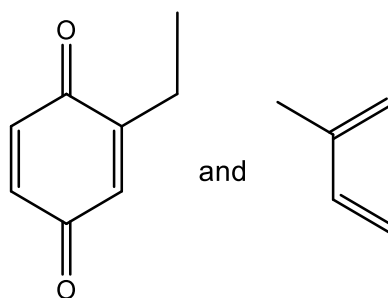


AOA

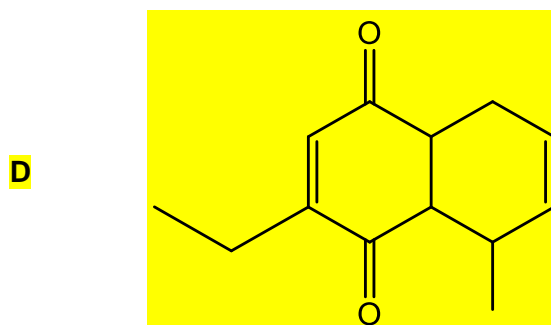
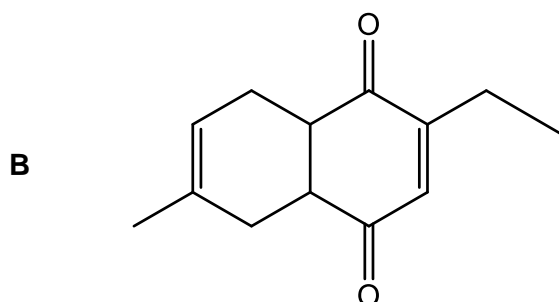
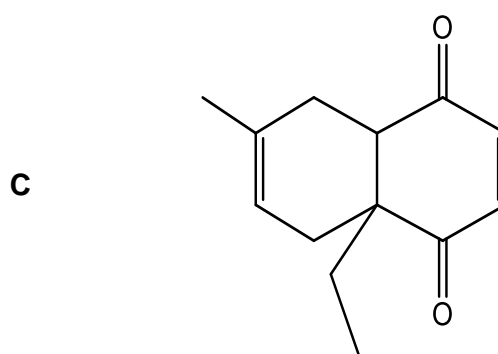
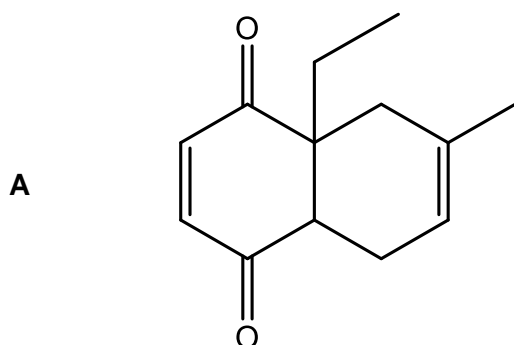
- 17 Unsaturated carbonyl compounds can undergo a useful reaction known as the Diels-Alder reaction with a diene. An example is shown below.



A student reacted the following diene and carbonyl compound together in a Diels-Alder reaction.



Which compound would **not** be formed as a product?

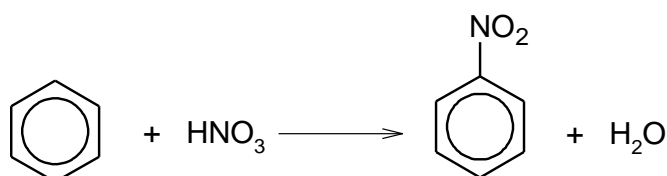


Ans: **D**

The methyl is bonded to the wrong carbon in the cyclohexene ring. It should be bonded to one of the two alkene carbons instead.

AOB

- 18 Nitrobenzene is a yellow liquid with the smell of almonds. It may be prepared by heating a mixture of benzene, concentrated nitric acid and concentrated sulfuric acid under reflux.



Why is concentrated sulfuric acid used?

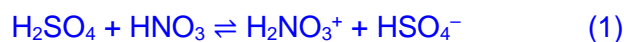
- A** It acts as a Lewis acid catalyst.
B It removes protons from nitric acid, thus forming NO_2^- ions.
C It donates protons to nitric acid, thus forming NO_2^+ ions.

D It acts a dehydrating agent to remove water from benzene and nitric acid.

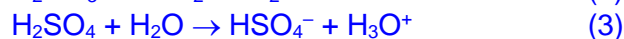
Ans: C

Between both acids, sulfuric acid is the stronger Bronsted acid.

HNO₃ acid acts as a Bronsted-Lowry base and accepts a proton from the Bronsted-Lowry acid H₂SO₄.



The reaction leads eventually to the formation of the **nitronium ion**.



Adding up (1) to (3) gives the overall equation for generation of electrophile.



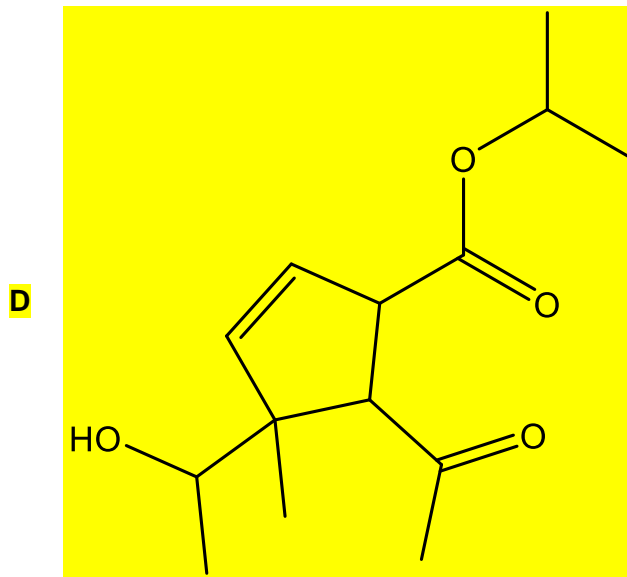
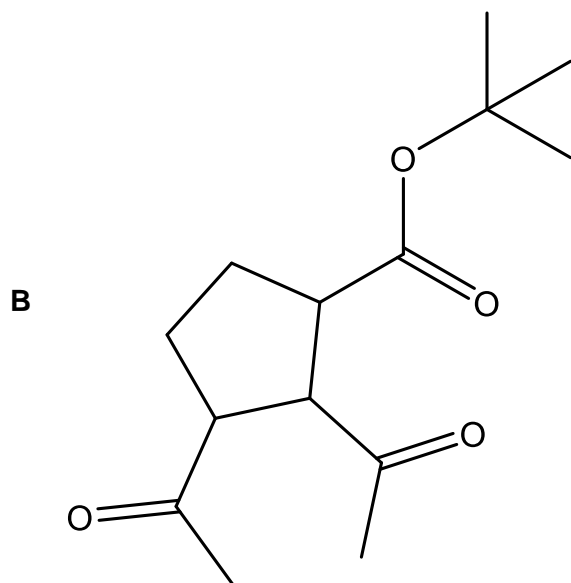
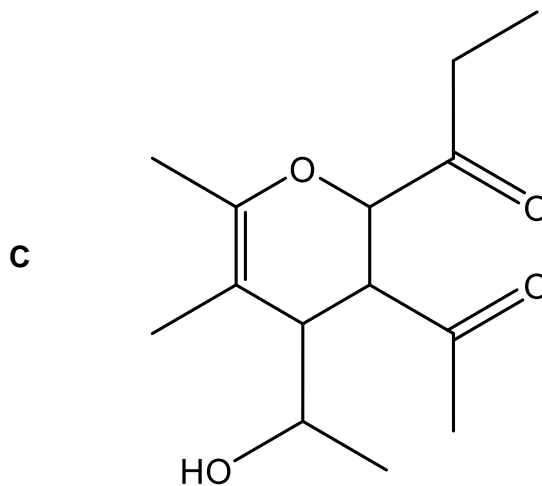
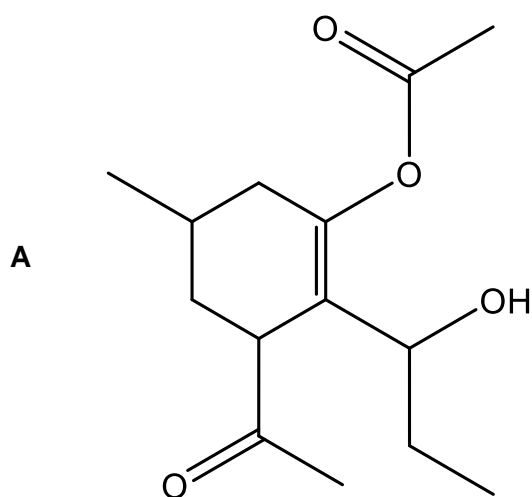
Thus sulfuric acid acts as a Bronsted acid (not a Lewis acid, thus A is incorrect) whereby it donates protons to nitric acid.

AOA

- 19 The same mass of each of the four organic compounds was heated up to 50 °C with excess alkaline aqueous iodine.

The mixture was then filtered, and the filtrate was washed with tetrachloromethane to remove unreacted iodine. The aqueous layer was treated with a dilute acid, followed by aqueous silver nitrate, and the precipitate, if formed, was collected.

Which structure gives the greatest mass of precipitate?



Ans: **D**

The four compounds are constitutional isomers of one another.

Use of same mass of each of them → use of same amount of each of them

A – one mole of iodoform

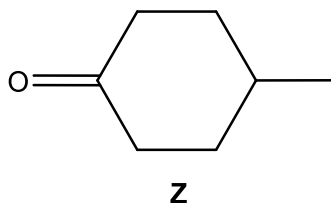
B – two moles of iodoform

C – two moles of iodoform

D – three moles of iodoform

AOB

- 20 The structure of compound **Z** is shown below:



Which statement about compound **Z** is true?

- A** All six carbon atoms in the 6-membered ring in **Z** lie in the same plane.
- B** It reacts with cold HCN in the presence of NaCN to produce a racemic mixture, due to the trigonal planar geometry about the carbonyl carbon.
- C** It changes warm acidified aqueous potassium manganate(VII) from purple to colourless.
- D** There are two sp^2 hybridised atoms in **Z**.

Ans: **D**

Option A: False. Five of the six carbons are sp^3 hybridised and possess tetrahedral geometry.

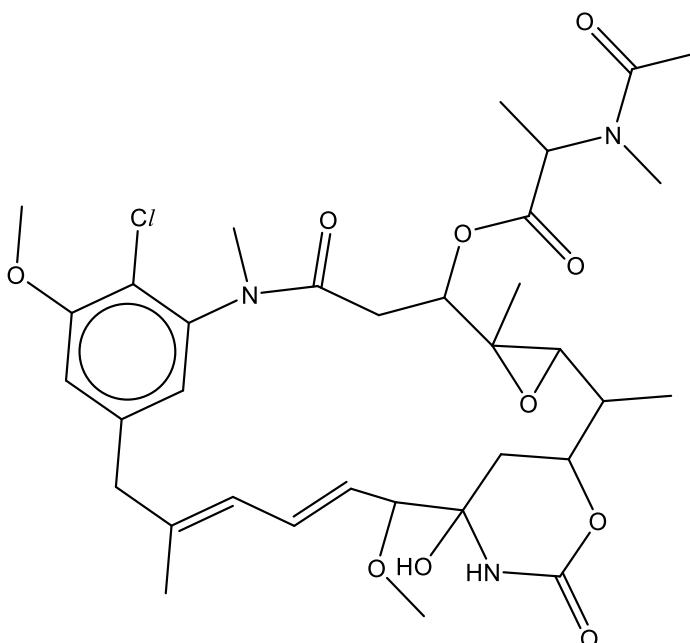
Option B: False. A 1:1 mixture of a pair of stereoisomers is indeed formed (due to the planar nature about the carbonyl carbon) but these stereoisomers are not enantiomers of each other.

Option C: False. No reaction.

Option D: True. Due to the ketone O and ketone C.

AOB

- 21 Maytansine is a potent antitumour agent. It has 34 carbons.



Which statement about maytansine is **false**?

- A** Its molecular formula is $C_{34}H_{46}C/N_3O_{10}$.
- B** 3 moles of CO_2 are formed when 1 mole of maytansine is oxidised by hot acidified $KMnO_4$.
- C** It does not react with 2,4-dinitrophenylhydrazine.
- D** 1 mole of H_2 is formed when one mole of maytansine is reacted with excess sodium.

Ans: **D**

Option **A**: True. Self-evident.

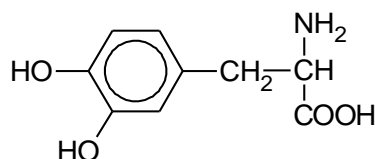
Option **B**: True. 2 moles are from the conjugated diene; the 3rd mole of CO_2 is from the hydrolysis of the non-benzene 6-membered ring.

Option **C**: True. There are only esters and amides; there are no ketones nor aldehydes.

Option **D**: False. Only one OH group $\rightarrow \frac{1}{2}$ mole of H_2 formed.

AOB

- 22** The molecule shown is used in the treatment of Parkinson's disease.



Which statements about the molecule are correct?

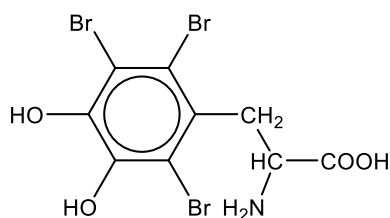
- 1 It is likely to be soluble in water due to zwitterion formation.
- 2 Two Br atoms will be incorporated when aqueous bromine is added.
- 3 One mole of molecule reacts with three moles of sodium hydrogen carbonate solution to form a salt.

- A** 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

Ans: **D**

Option **1** is correct - The carboxylic acid functional group loses a proton to the amine functional group giving a carboxylate group ($-COO^-$). The amine functional group is protonated to an aminium (A cation formed by protonation of an amine) group ($-NH_3^+$). Hence, amino acids are soluble in water and exist as **zwitterions** in aqueous medium.

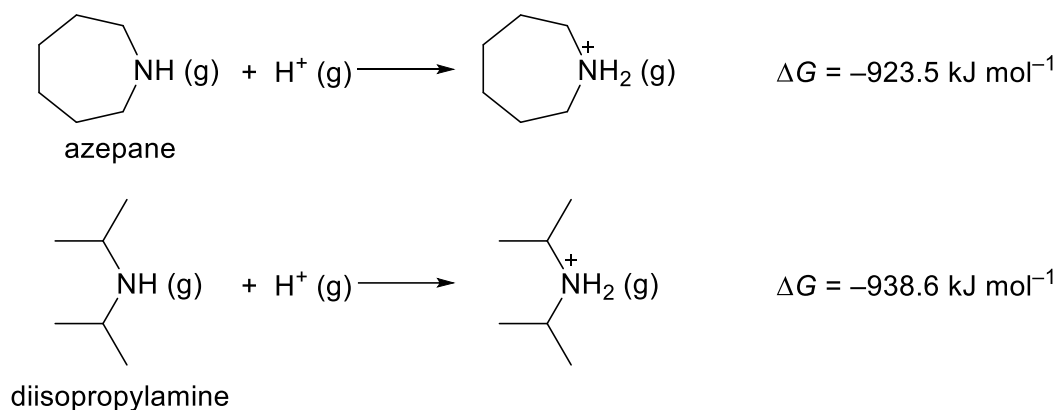
Option **2** is incorrect - Three Br atoms will be incorporated when aqueous bromine is added.



Option 3 is incorrect - One mole of molecule reacts with one mole of sodium hydrogen carbonate solution to form a salt. Phenol do not react with NaHCO_3 .

AOA

- 23 The basicity of gaseous azepane and diisopropylamine is measured by the Gibbs free energy change, ΔG , for the protonation of the two amines in gaseous phase:



The pK_b of azepane and diisopropylamine are 2.93 and 3.43, respectively.

Which statement correctly explains the differences in basicity of the two amines shown?

- A Diisopropylamine is a stronger base in gaseous phase as it has a smaller electron cloud size than azepane.
- B Diisopropylamine is a weaker base in water as the conjugate acid is less readily hydrated due to steric hindrance from the two bulky $(\text{CH}_3)_2\text{CH}-$ groups.**
- C Azepane is a stronger base in water as it has fewer hydrogen atoms compared to diisopropylamine.
- D Azepane is a weaker base in gaseous phase as it is a primary amine, while diisopropylamine is a secondary amine.

Ans: B

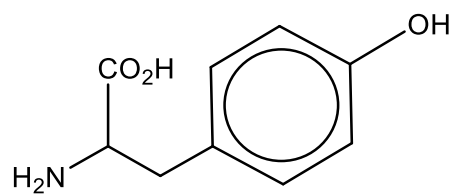
In the gas phase, diisopropylamine is the stronger base (more spontaneous protonation, *i.e.* ΔG is more negative).

In aqueous phase, azepane is the stronger base (smaller pK_b , *i.e.* larger K_b).

This is primarily due to steric hindrance from the two bulky $-\text{CH}(\text{CH}_3)_2$ groups which hinders hydration of the R_2NH_2^+ ion through H-bonding.

AOA

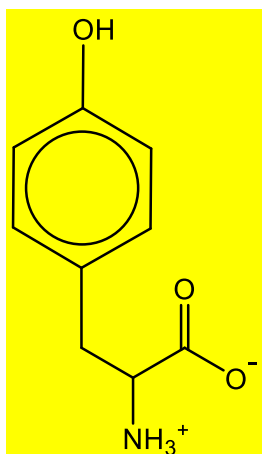
- 24 Tyrosine was first discovered in 1846 by German chemist Justus von Liebig in the protein casein from cheese. It is found in animal sources such as meats.



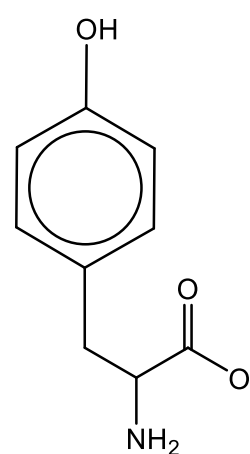
There are three pK_a values associated with tyrosine: 2.20, 9.22, 10.46.

What is the major species present in a solution of tyrosine at pH 5.71?

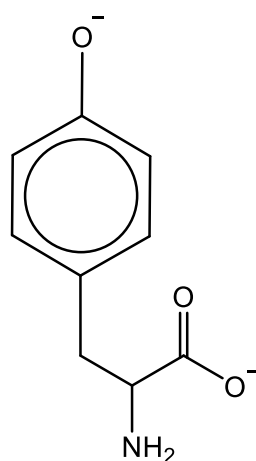
A



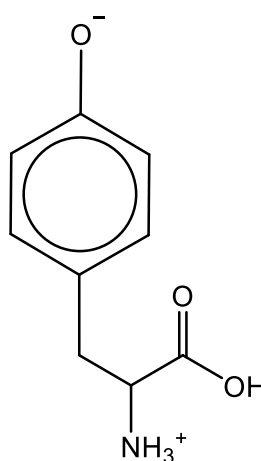
C



B



D



Ans: **A**

Question is asking for the zwitterionic form of tyrosine, which is **A**.

AOB

- 25 J is a synthetic nonapeptide that is found in honeybee venom.

To investigate the sequence of amino acids in J, the nonapeptide was first hydrolysed by two enzymes. The protein fragments were then separated and their sequence determined.

The first enzyme, which hydrolysed the polypeptide chain at the carboxylic end of the amino acid lysine, Lys, yielded the following fragments.

Trp-Ile-Lys
Leu-Arg
Arg-Ile-Ser-Lys

The following protein fragments were obtained from the second enzyme which hydrolysed the polypeptide chain at the carboxylic end of the amino acid isoleucine, Ile.

Ser-Lys-Trp-Ile
Arg-Ile
Lys-Leu-Arg

Which is the correct primary structure of the nonapeptide J?

- A Lys-Leu-Arg-Ile-Ser-Lys-Trp-Ile-Lys
- B Arg-Ile-Ser-Lys-Trp-Ile-Lys-Leu-Arg**
- C Ser-Lys-Trp-Ile-Lys-Leu-Arg-Ile-Ser
- D Trp-Ile-Lys-Leu-Arg-Ile-Ser-Lys-Trp

Ans: B

Option A: Wrong sequence because there is no such "Lys" fragment on using the first enzyme.

Option C: Wrong sequence because there is no such "Ser" fragment on using the second enzyme.

Option D: Wrong sequence because there is no such "Ser-Lys-Trp" fragment on using the second enzyme and no such "Trp" fragment on using the first enzyme.

AOA

26 Use of the Data Booklet is relevant to this question.

Vanadium forms a number of aqueous ions.

Which statements are correct?

- 1 Excess zinc can reduce $\text{VO}_2^+(\text{aq})$ to $\text{V}^{2+}(\text{aq})$ in acidic conditions.
- 2 Excess $\text{Fe}^{3+}(\text{aq})$ can oxidise $\text{V}^{2+}(\text{aq})$ to $\text{VO}_2^+(\text{aq})$ in acidic conditions.
- 3 Excess $\text{Zn}^{2+}(\text{aq})$ ions can oxidise $\text{V}^{2+}(\text{aq})$ ions to $\text{V}^{3+}(\text{aq})$ ions.

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

Ans: A

Solution



Option 1: correct

Excess Zn is the reducing agent which can reduce $\text{VO}_2^+(\text{aq})$ to $\text{VO}^{2+}(\text{aq})$:

$$E_{\text{cell}} = +1.00 - (-0.76) = +1.76\text{V} > 0$$

Excess Zn can further reduce $\text{VO}^{2+}(\text{aq})$ to $\text{V}^{3+}(\text{aq})$:

$$E_{\text{cell}} = +0.34 - (-0.76) = +1.10\text{V} > 0$$

Excess Zn can further reduce $\text{V}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{V}^{2+}(\text{aq})$:

$$E_{\text{cell}} = -0.26 - (-0.76) = +0.50\text{V} > 0$$

Note: Since $E_{\text{cell}} = E_{\text{cat}} - E_{\text{an}} > 0$ for reaction to proceed (Zn is oxidised),

$$E_{\text{cat}} - (-0.76) > 0$$

$$E_{\text{cat}} > -0.76 \text{ for reaction to proceed}$$

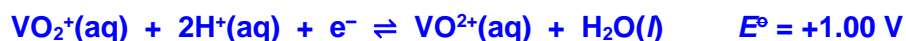
Option 2 is wrong

Since $E_{\text{cell}} = E_{\text{cat}} - E_{\text{an}} > 0$ for reaction to proceed (Fe^{3+} is reduced to Fe^{2+}),

$$+0.77 - E_{\text{an}} > 0$$

$$E_{\text{an}} < +0.77 \text{ for reaction to proceed}$$

Fe^{3+} can oxidise V^{2+} to VO^{2+} but not VO_2^+



$$E_{\text{cell}} = +0.77 - 1.00 = -0.23\text{V} < 0$$

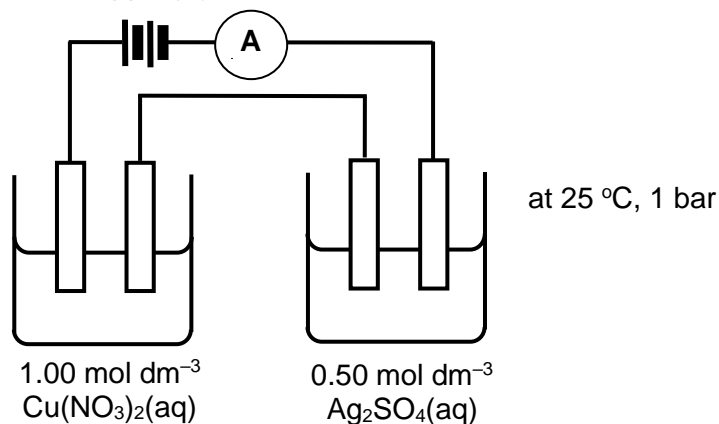
Option 3 is incorrect

Refer to option 1, if Zn is able to reduce V^{3+} to V^{2+} , Zn^{2+} will not be able to oxidise back from V^{2+} to V^{3+} as this is the reverse of the former and E_{cell} will be < 0 .

AOB

27 Use of the Data Booklet is relevant to this question.

Using inert electrodes, a current was passed through two beakers containing aqueous silver(I) sulfate and aqueous copper(II) nitrate, connected in series under standard conditions.



What is the ratio of the mass of copper to silver deposited when current flows?

- A** 0.29 **B** 0.59 **C** 1.70 **D** 3.40

Ans: A

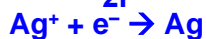
Solution

$$It = n_e F$$

$$n_e \text{ transferred} = \frac{It}{F}$$



$$n_{\text{Cu}} = \frac{It}{2F}$$

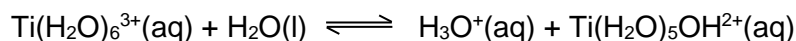


$$n_{\text{Ag}} = \frac{It}{F}$$

$$\frac{\text{mass of Cu formed}}{\text{mass of Ag formed}} = \frac{\text{Ar} \times \text{no. of moles of Cu formed}}{\text{Ar} \times \text{no. of moles of Ag formed}} = \frac{63.5 \times \frac{It}{2F}}{107.9 \times \frac{It}{F}} = 0.29$$

AOB

28 Hexaaquatitanium(III) ion hydrolyses as shown.



Which statements are correct?

- 1 The corresponding hexaaquatitanium(II) ion, $\text{Ti}(\text{H}_2\text{O})_6^{2+}$, is less likely to undergo hydrolysis.
- 2 This hydrolysis is favoured by low pH conditions.
- 3 Titanium undergoes a change in oxidation state.

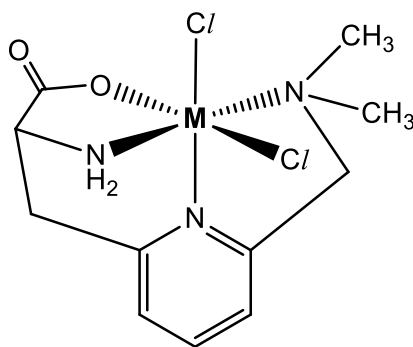
A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

Ans: **D**

- 1 ✓:** $[\text{Ti}(\text{H}_2\text{O})_6]^{2+}$ has a lower charge density, hence the O–H bond is not as polarised as that in $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$, thus less likely to hydrolyse.
- 2 ✗:** Under acidic conditions, $[\text{H}_3\text{O}^+]$ is high, hence position of eqm shifts to the left, suppressing the hydrolysis instead.
- 3 ✗:** The titanium in both $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ and $[\text{Ti}(\text{H}_2\text{O})_5\text{OH}]^{2+}$ are +3 oxidation state.

AOB

29 Which statement regarding the neutral metal complex below is **false**?



- A** The oxidation number of **M** in the complex is +2 because the complex is neutral and there are two chloride ligands.
- B** The complex contains a ligand which possesses a primary and tertiary amine.
- C** The complex contains a ligand which is an α -amino acid.
- D** The complex is octahedral with respect to **M**.

Ans: **A**

Option A: False

The tetradentate ligand is not a neutral ligand, but carries a negative charge on the carboxylate end. The oxidation number of M should be +3 instead.

Option B : True

Option C: True, the primary amine, as mentioned in B, is actually part of the α -amino acid part of the tetradentate ligand.

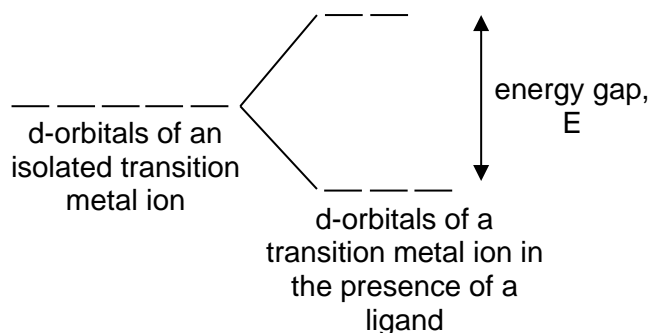
Option D: True

Coordination number is the number of dative bonds around M which is equal to 6 in the complex. Coordination number 6 complexes are octahedral with respect to the central metal species.

AOB

30 Use of Data Booklet is relevant to this question.

The following diagram shows how the d-orbitals are split in an octahedral environment.



Some transition metal ions exhibit the ability to change their electronic configuration from a 'high spin' state to a 'low spin' state.

In a 'high spin' state, the electrons occupy all the d-orbitals singly first, before starting to pair up in the lower energy d-orbitals.

In a 'low spin' state, the lower energy d-orbitals are first filled, by pairing up if necessary, before the higher energy d-orbitals are used.

Which transition metal ion is likely to be able to exhibit both spin states?

A Cu^{2+}

B Cr^{3+}

C Fe^{3+}

D Ni^{2+}

Ans: C

Option A

Cu^{2+} : $[\text{Ar}] 3d^9$

The high spin and low spin configuration are exactly the same. Hence it cannot show a difference between the two spin states.

Option B

Cr^{3+} : $[\text{Ar}] 3d^3$

The high spin and low spin configuration are exactly the same. Hence it cannot show a difference between the two spin states.

Option C

Fe^{3+} : $[\text{Ar}] 3d^5$

The high spin and low spin configuration are different. Hence it can show a difference between the two spin states.

Option D

Ni^{2+} : $[\text{Ar}] 3d^8$

The high spin and low spin configuration are exactly the same. Hence it cannot show a difference between the two spin states.

AOB

1	2	3	4	5	6	7	8	9	10
B	B	C	B	C	D	B	A	A	B
11	12	13	14	15	16	17	18	19	20
C	A	D	D	D	B	D	C	D	D
21	22	23	24	25	26	27	28	29	30
D	D	B	A	B	A	A	D	A	C

