

# Anglo-Chinese Junior College

JC2 Preliminary Examination

Higher 2



A Methodist Institution  
(Founded 1866)

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## CHEMISTRY

Paper 1 Multiple Choice

**9729/01**

17 September 2025

1 hour

Additional Materials:      Multiple Choice Answer Sheet  
   Data Booklet

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### 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.

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This document consists of **16** printed pages.

- 1 The most common oxidation state of americium, Am, in aqueous solution is +3.

Recently,  $\text{Cu}^{3+}$  has been shown to quantitatively oxidise  $\text{Am}^{3+}(\text{aq})$  in dilute  $\text{HNO}_3$ , while itself is reduced to  $\text{Cu}^{2+}$ .

In an experiment,  $20.0 \text{ cm}^3$  of  $0.0120 \text{ mol dm}^{-3} \text{ Am}^{3+}(\text{aq})$  was found to require  $24.00 \text{ cm}^3$  of  $0.0300 \text{ mol dm}^{-3} \text{ Cu}^{3+}$  for complete oxidation.

What is the formula of the americium-containing species formed?

- A  $\text{Am}_2\text{O}_2^{2+}$   
**B  $\text{AmO}_2^{2+}$**   
 C  $\text{AmO}^{2+}$   
 D  $\text{AmO}^+$

$$n(\text{electrons}) = n(\text{Cu}^{3+}) = 7.20 \times 10^{-4}$$

$$\text{change in oxidation state of Am} = (7.20 \times 10^{-4}) / (20.0 \times 0.0120 / 1000) = +3$$

$$\text{Initial oxidation state of Am} = +3 + 3 = +6$$

Correct option is  $\text{AmO}_2^{2+}$

- 2 Use of the Data Booklet is relevant to this question.

The table shows the fifth, sixth, seventh, eighth, ninth and tenth ionisation energies of an element ( $Z \leq 20$ ) in the Periodic Table.

	5th	6th	7th	8th	9th	10th
ionisation energy / $\text{kJ mol}^{-1}$	7975	9590	11343	14944	16964	48610

What can be inferred about the element from the above data?

- A It is in the third period of the Periodic Table.  
 B It is in Group 2 of the Periodic Table.  
**C It is likely to form an ionic compound when reacted with oxygen.**  
 D Its 6<sup>th</sup> and 7<sup>th</sup> electrons are removed from different subshells.

**C:** There is a large electronegativity difference between the Group 1 element and oxygen (Group 16). Hence, the compound formed will be ionic in nature.

**A:** There is insufficient data to conclude that the element lies in the third period. Since  $Z \leq 20$ , this Group 1 element can be in the fourth period.

**B:** The largest increase in successive ionisation energies (IE) occur between 9<sup>th</sup> and 10<sup>th</sup> IE. This implies that the 10<sup>th</sup> electron is removed from an inner shell. Since  $Z \leq 20$ , only s and p subshells exist. Hence, each shell can only accommodate up to a maximum of 8 electrons. This would imply that the 2<sup>nd</sup> to 9<sup>th</sup> electron also lies in another inner shell. There will be only one electron in the valence shell. This element therefore belongs to Group 1 (either Na or K).

**D:** As a Group 1 element, the 6<sup>th</sup> and 7<sup>th</sup> electrons are removed from the same p-subshell.

- 3 Particle **R** has a proton number  $n$  and forms a stable monoatomic ion of charge  $-1$ .

Particle **S** has a proton number of  $(n+2)$  and it forms a stable monoatomic ion which is isoelectronic with the ion of **R**.

Which statement is correct?

- A** Ion of **S** has a smaller ionic radius than ion of **R**.
- B** **R** has a larger atomic radius than **S**.
- C** Ion of **S** requires less energy than ion of **R** when an electron is removed from each particle.
- D** Ion of **R** releases more energy than ion of **S** when an electron is added to each particle.

${}_n\text{R}$  gains 1 electron to form stable  ${}_n\text{R}^-$ , which has  $(n+1)$  electrons  
 $\Rightarrow$  **R** is in Group 17.

${}_{n+2}\text{S}$  forms a stable ion which is isoelectronic with  ${}_n\text{R}^-$ . Hence  ${}_{n+2}\text{S}$  must have **lost** 1 electron, to form  ${}_{n+2}\text{S}^+$ , which has  $(n+2)-1 = (n+1)$  electrons  
 $\Rightarrow$  **S** is in Group 1 of the *next period*.

**A✓** Since  ${}_n\text{R}^-$  and  ${}_{n+2}\text{S}^+$  are iso-electronic,  ${}_{n+2}\text{S}^+$  with a higher nuclear charge will have a smaller ionic radius as the effective nuclear charge experienced by the valence  $e^-$ s is higher.

**B✗** As **S** is an element in the next period, with one additional filled principal quantum shell, **S** has a larger atomic radius despite the higher nuclear charge.

**C✗**  ${}_{n+2}\text{S}^+ - e^- \rightarrow {}_{n+2}\text{S}^{2+}$  will be more endothermic than  ${}_n\text{R}^- - e^- \rightarrow {}_n\text{R}$  since the  $e^-$  is being removed from positively charged  ${}_{n+2}\text{S}^+$ .

**D✗**  ${}_n\text{R}^- + e^- \rightarrow {}_n\text{R}^{2-}$  will be endothermic due to repulsion of the incoming  $e^-$ ;  ${}_{n+2}\text{S}^+ + e^- \rightarrow {}_{n+2}\text{S}$  will be exothermic due to attraction of the incoming  $e^-$ .

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

- A** The electronegativity increases.
- B** The volatility increases.
- C** The enthalpy change of reaction with hydrogen becomes less exothermic.
- D** The reactivity as reducing agents increases.

**A:** Electronegativity decreases down any Group.

**B:** IDID gets stronger down Group 17. Volatility should decrease.

**C:** 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 less exothermic.

**D:** Halogens are usually oxidising agents, not reducing agents.

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

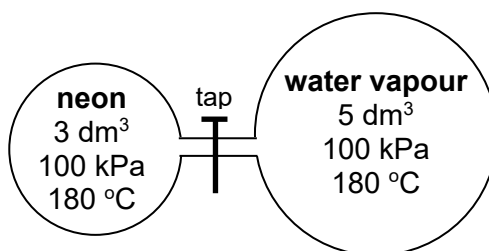
Which sequence is correct in terms of increasing radius?

- A  $\text{Rb}^+ < \text{Sr}^{2+} < \text{As}^{3-} < \text{Se}^{2-}$   
**B  $\text{Sr}^{2+} < \text{Rb}^+ < \text{Se}^{2-} < \text{As}^{3-}$**   
 C  $\text{As}^{3-} < \text{Se}^{2-} < \text{Sr}^{2+} < \text{Rb}^+$   
 D  $\text{Se}^{2-} < \text{Sr}^{2+} < \text{Rb}^+ < \text{As}^{3-}$

All ions are isoelectronic, but different number of protons.

	$\text{Sr}^{2+}$	$\text{Rb}^+$	$\text{Se}^{2-}$	$\text{As}^{3-}$
Proton / Electron Ratio	$38 \div 36$	$37 \div 36$	$34 \div 36$	$33 \div 36$
Attraction	Strongest			Weakest

6 Two bulbs are connected as shown in the diagram below. The bulbs are connected by a narrow tube of negligible volume.



When the tap is opened, the two gases mix. The connected bulbs were then allowed to cool to room temperature.

What was the final pressure, in kPa, in the connected bulbs?

- A 13.9  
**B 24.3**  
 C 37.5  
 D 64.7

When the connected bulbs were allowed to cool to room temperature, water vapour condensed to give liquid water, which occupy negligible volume. Hence, we only need to consider the amount of neon gas present in the connected bulbs.

$$PV = nRT$$

$$100000 \times (3 \times 10^{-3}) = n \times 8.31 \times (180 + 273) \rightarrow n = 0.07969 \text{ mol (amount of neon)}$$

When the tap is opened, and the total volume is  $8 \text{ dm}^3$ ,

$$PV = nRT$$

$$P \times (8 \times 10^{-3}) = 0.07969 \times 8.31 \times 293$$

$$P = 24254 \text{ Pa}$$

$$= 24.3 \text{ kPa}$$

- 7  $(\text{CH}_3)_2\text{S} \cdot \text{BCl}_3$  is a solid that is commonly used in laboratories as a convenient source of  $\text{BCl}_3$ . When heated, it reversibly decomposes to  $(\text{CH}_3)_2\text{S}$  and  $\text{BCl}_3$ .

Which statement is true?

- A** The dative bond is formed using the 2p orbitals of boron and sulfur.
- B**  $(\text{CH}_3)_2\text{S}$  and  $\text{BCl}_3$  act as the Lewis acid and Lewis base respectively in the formation of  $(\text{CH}_3)_2\text{S} \cdot \text{BCl}_3$ .
- C** The dative bond is from boron to sulfur.
- D** The C-S-C bond angle decreases when the solid decomposes.
- A** The dative bond is formed using the hybrid  $\text{sp}^3$  orbitals of boron and sulfur.
- B**  $(\text{CH}_3)_2\text{S}$  and  $\text{BCl}_3$  act as the Lewis base and Lewis acid respectively in the formation of  $(\text{CH}_3)_2\text{S} \cdot \text{BCl}_3$ .
- D** The C-S-C bond angle decreases when the solid decomposes.
- C** The dative bond is from sulfur to boron.

- 8 The compound  $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$  is a superconductor.

In this compound, the oxidation number of bismuth is +3, strontium and calcium is +2 and oxygen is -2.

What are the possible oxidation numbers of the three copper atoms in  $\text{Bi}_2\text{Sr}_2\text{Ca}_2\text{Cu}_3\text{O}_{10}$ ?

- A** +1, +1, +2
- B** +1, +2, +3
- C** 0, +1, +3
- D** 0, +2, +3

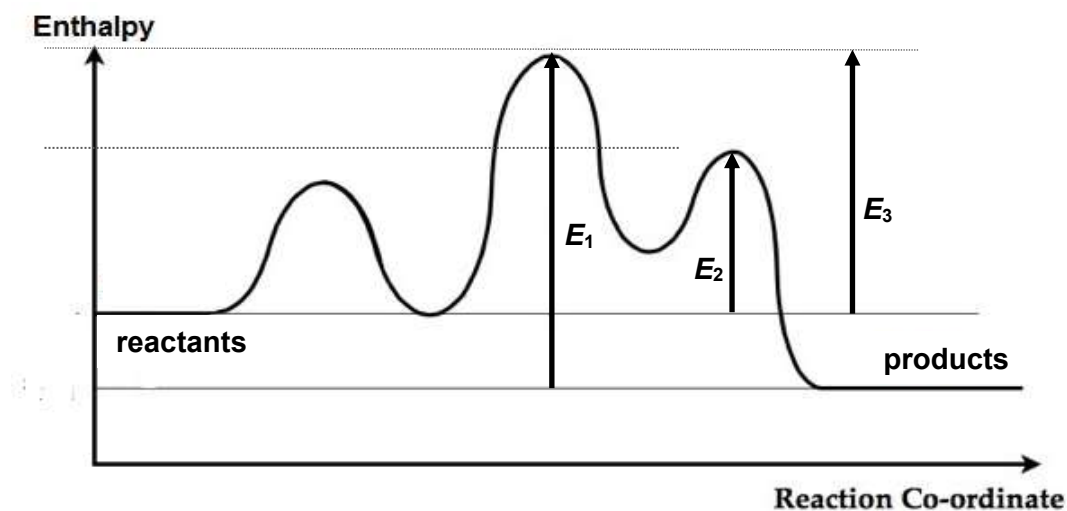
Transition elements have variable oxidation states.

Let the sum of oxidation numbers of the three Cu atoms be x.

$$2(+3) + 2(+2) + 2(+2) + x + 10(-2) = 0$$

$$x = +6$$

- 9 The energy profile diagram below represents a certain three-step reaction.



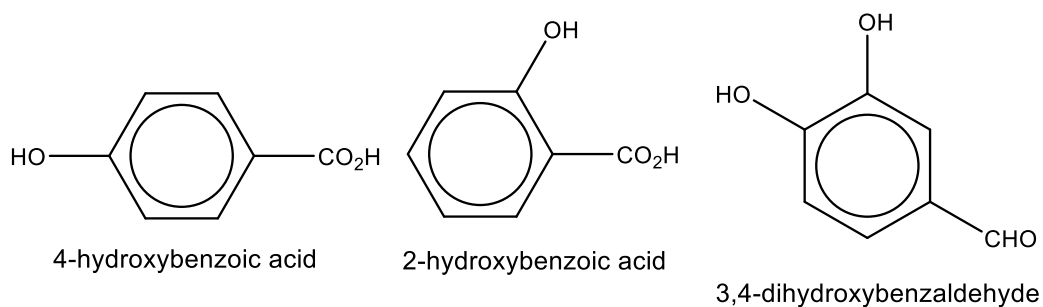
Which statements are correct about the above reaction?

- 1  $E_3$  is the activation energy of the second step.
- 2  $\Delta H$  can be obtained by subtracting  $E_2$  from  $E_1$ .
- 3 There are equal number of intermediates and transition states.

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

- 1  $E_3$  is the activation energy of the second step.
- 2  $\Delta H$  can be obtained by subtracting  $E_3$  from  $E_1$ .
- 3 There may not be equal number of intermediates and transition states.

- 10 4-hydroxybenzoic acid (A), 2-hydroxybenzoic acid (B) and 3,4-dihydroxybenzaldehyde (C) share the same molecular formula.



All three compounds combust exothermically. Their standard enthalpy changes of formation are tabulated below.

	standard enthalpy change of formation / $\text{kJ mol}^{-1}$
4-hydroxybenzoic acid	-481
2-hydroxybenzoic acid	-493
3,4-dihydroxybenzaldehyde	-392

Which statements are correct?

- 1 2-hydroxybenzoic acid and 3,4-dihydroxybenzaldehyde are chain isomers.
- 2 The magnitude of the standard enthalpy change of combustion decreases in the order  $C > A > B$ .
- 3 The thermodynamic stability decreases in the order  $B > A > C$ .

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

Statement 1: They are functional group isomers.

To verify statements 2 and 3, it is best to represent both the enthalpy changes of formation and combustion in the same energy level diagram. With this combined energy level diagram, it is clear that statements 2 and 3 are true.

- 11 A 0.483 g sample of glycine ( $M_r = 75.0$ ) was placed in a bomb calorimeter and then ignited in the presence of excess oxygen. The temperature rose by 0.54 °C.

In a separate experiment using the same calorimeter, the combustion of 0.986 g of benzoic acid ( $M_r = 122.0$ ) gave a temperature rise of 2.14 °C. The enthalpy change of combustion of benzoic acid is  $-3054 \text{ kJ mol}^{-1}$ .

What is the enthalpy change of combustion, in  $\text{kJ mol}^{-1}$ , of glycine?

- A  $-615 \text{ kJ mol}^{-1}$   
B  $-967 \text{ kJ mol}^{-1}$   
C  $-2423 \text{ kJ mol}^{-1}$   
D  $-3812 \text{ kJ mol}^{-1}$

In the experiment with benzoic acid,

No. of moles of benzoic acid combusted =  $0.986 / 122 = 0.008082$

$q = -\Delta H_c \times \text{no. of moles of benzoic acid} = 3054 \times 0.008082 = 24.68 \text{ kJ}$

Heat capacity of the bomb calorimeter =  $24.68 / 2.14 \text{ kJ } ^\circ\text{C}^{-1}$

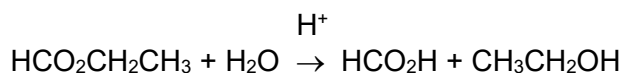
In the experiment with glycine,

No. of moles of glycine combusted =  $0.483 / 75 = 0.00644$

$q = (24.68 / 2.14) \times 0.54 = 6.228 \text{ kJ}$

Enthalpy change of combustion of glycine =  $-6.228 / 0.00644 = -967 \text{ kJ mol}^{-1}$

- 12 Ethyl formate undergoes a slow acid-catalysed hydrolysis in water.



The rate law is found to be

$$\text{rate} = k[\text{HCO}_2\text{CH}_2\text{CH}_3][\text{H}^+]$$

When  $0.1 \text{ mol dm}^{-3}$  of HCl is reacted with  $0.4 \text{ mol dm}^{-3}$  of ethyl formate, the half-life was found to be 62 min.

Another reaction was carried out with  $0.3 \text{ mol dm}^{-3}$  of HCl and  $0.4 \text{ mol dm}^{-3}$  of ethyl formate.

How long does it take for the concentration of ethyl formate to fall to  $0.050 \text{ mol dm}^{-3}$ ?

- A 31 min      **B 62 min**      C 93 min      D 124 min

When  $[\text{HCl}] = [\text{H}^+] = 0.1 \text{ mol dm}^{-3}$ ,

$t_{1/2} = 62 \text{ min}$ .

When  $[\text{HCl}] = [\text{H}^+] = 0.3 \text{ mol dm}^{-3}$  (increased by 3 times),

$t_{1/2} = 62/3 \text{ min}$ .

For [ester] to fall to  $0.050 \text{ mol dm}^{-3}$ , three  $t_{1/2}$  are required.

Time taken =  $3 \times (62/3) = 62 \text{ min}$

- 13 The decomposition of phosphorus pentachloride is reversible.



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

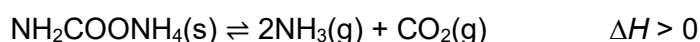
What happens to the values of  $k_1$ ,  $k_{-1}$ ,  $K_c$  and the equilibrium position if an inert gas is introduced into the reaction vessel at constant temperature and pressure?

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

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

At a constant pressure, the position of equilibrium shifts towards the direction of the greater amount of gas.

- 14 Ammonium carbamate,  $\text{NH}_2\text{COONH}_4$ , undergoes thermal decomposition.



A vessel containing only  $\text{NH}_2\text{COONH}_4$  is heated to  $250^\circ\text{C}$ . The reaction reached equilibrium at time  $t_1$ . Subsequently both the temperature and volume of the vessel are decreased, and the reaction established a new equilibrium at time  $t_2$ .

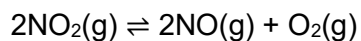
Which statements are correct?

- 1 At  $t_2$ ,  $P_{\text{NH}_3} : P_{\text{CO}_2}$  is 2 : 1.
- 2 The rate of the forward reaction at  $t_1$  is the same as that at  $t_2$ .
- 3 The degree of decomposition of  $\text{NH}_2\text{COONH}_4$  at  $t_1$  is smaller than that at  $t_2$ .
- 4 Decreasing the volume of the vessel at constant temperature has no effect on the equilibrium partial pressures of  $\text{NH}_3$  and  $\text{CO}_2$ .

**A** 1 and 4      **B** 2 only      **C** 1 and 3      **D** 2 and 3

Statement 1	Correct. As there are no addition of any reactant or product to the system, the mole ratio of $\text{NH}_3 : \text{CO}_2$ should always stay the same at 2 : 1 (following the stoichiometric ratio of the balanced equation). Since $p \propto n$ , $P_{\text{NH}_3} : P_{\text{CO}_2}$ is also 2 : 1 at $t_2$ .
Statement 2	Incorrect. Since the temperature at $t_1$ is higher than that at $t_2$ , the rate of the forward (and backward) reaction at $t_1$ is greater than that at $t_2$ . (Recall that at higher temperatures, a greater proportion of the reactant molecules have energy greater than or equal to the activation energy for reaction. Hence, the frequency of effective collisions increases resulting in an increase in rate of reaction.)
Statement 3	Incorrect. By Le Chatelier's Principle, a decrease in temperature will favour the backward exothermic reaction and a decrease in volume (or increase in total pressure) will favour the backward reaction which reduces the number of gas particles.  Hence at $t_2$ , the degree of decomposition of $\text{NH}_2\text{COONH}_4$ is smaller than that at $t_1$ .
Statement 4	Correct. Decreasing the volume of the vessel will cause the total pressure (and partial pressures of $\text{NH}_3$ and $\text{CO}_2$ ) to increase. By Le Chatelier's Principle, the equilibrium position will shift left to reduce the number of gas particles and the partial pressures of $\text{NH}_3$ and $\text{CO}_2$ will decrease.  Since the equilibrium constant ( $K_p = (P_{\text{NH}_3})^2(P_{\text{CO}_2})$ ) remains unchanged (as temperature is constant) and the $P_{\text{NH}_3} : P_{\text{CO}_2}$ stays the same at 2 : 1, the equilibrium partial pressures of $\text{NH}_3$ and $\text{CO}_2$ at $t_2$ will be the same as that at $t_1$ .

- 15 Nitrogen dioxide can decompose to form nitrogen monoxide and oxygen.



When 2.50 mol of nitrogen dioxide was allowed to undergo decomposition in a 0.8 dm<sup>3</sup> container, 0.528 mol of oxygen was present at equilibrium.

What is the numerical value of the equilibrium constant,  $K_c$ , for this reaction?

A 3.54

B 2.83

C 0.353

D 0.282

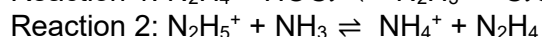
	$2\text{NO}_2(\text{g})$	$\rightleftharpoons$	$2\text{NO}(\text{g})$	+	$\text{O}_2(\text{g})$
Initial $n / \text{mol}$	2.50		0		0
Change in $n / \text{mol}$	-1.056		+1.056		+0.528
Eqm $n / \text{mol}$	1.444		1.056		0.528

$$K_c = \frac{\left(\frac{1.056}{0.8}\right)^2 \left(\frac{0.528}{0.8}\right)}{\left(\frac{1.444}{0.8}\right)^2}$$

$$= 0.35296$$

$$= 0.353 \text{ mol dm}^{-3}$$

- 16 The position of equilibrium lies to the right in each of these reactions.



Which statement can be deduced from the information given above?

- A The order of acid strength is  $\text{HOC}/ < \text{N}_2\text{H}_5^+ < \text{NH}_4^+$ .
- B  $\text{N}_2\text{H}_4$  is the Bronsted–Lowry acid in Reaction 1.
- C  $\text{N}_2\text{H}_5^+$  and  $\text{NH}_3$  are a conjugate acid–base pair in Reaction 2.
- D  $\text{N}_2\text{H}_4$  is a weaker base than  $\text{NH}_3$ .**

**Option A: Incorrect**

Since the POE lies to the right for both reactions,  $\text{HOC}/$  is a stronger acid than  $\text{N}_2\text{H}_5^+$  from Reaction 1 as it prefers to donate a proton. Likewise for Reaction 2 where  $\text{N}_2\text{H}_5^+$  is a stronger acid than  $\text{NH}_4^+$ .

**Option B: Incorrect**

They do not differ by just one proton.

**Option C: Incorrect**

Since the POE lies to the right for both reactions,  $\text{HOC}/$  is a stronger acid than  $\text{N}_2\text{H}_5^+$  from Reaction 1 as it prefers to donate a proton. Likewise for Reaction 2 where  $\text{N}_2\text{H}_5^+$  is a stronger acid than  $\text{NH}_4^+$ .

**Option D: Correct**

$\text{N}_2\text{H}_4$  is indeed a weaker base than  $\text{NH}_3$  because in Reaction 2, the POE lies to the right.

- 17 The value of  $\text{p}K_w$  at 80 °C is 13.94.

What is the pH of an aqueous solution of  $0.05 \text{ mol dm}^{-3} \text{ Ba(OH)}_2$  at 80 °C?

- A 12.64
- B 12.94**
- C 13.44
- D 13.94

$$\text{pH} = \text{p}K_w - \text{pOH} = 13.94 + \log(0.10) = 12.94$$

- 18 The table below shows the numerical values of the solubility products (measured at 25 °C) for some salts.

Salt	CdCO <sub>3</sub>	FeS	CoCO <sub>3</sub>	CuS
$K_{sp}$	$1.0 \times 10^{-12}$	$6.0 \times 10^{-19}$	$1.0 \times 10^{-10}$	$8.0 \times 10^{-37}$

Which statement can be deduced from the information given above?

- A CuS is more soluble than FeS.  
 B CdCO<sub>3</sub> is more soluble than CoCO<sub>3</sub>.  
**C The solubility of these four salts will be increased at lower pH.**  
 D The  $K_{sp}$  value of CuS will decrease as less of it can dissolve when copper(II) nitrate is added to a saturated solution.

- C** At higher  $[H^+]$   
 $H^+(aq) + CO_3^{2-}(aq) \rightarrow HCO_3^-(aq)$   
 $CdCO_3(s) \rightleftharpoons Cd^{2+}(aq) + CO_3^{2-}$   
 $[CO_3^{2-}]$  decreases, and the position of equilibrium shifts to the right. Hence solubility increases.  
 This is similar for the other three salts.  
 $H^+(aq) + S^{2-}(aq) \rightarrow HS^-(aq)$
- A Units are different. We need to calculate solubility from  $K_{sp}$  values.  
 CuS is less soluble than Ag<sub>2</sub>S.
- B Units are the same. Hence we can compare the  $K_{sp}$  values.  
 CoCO<sub>3</sub> is more soluble than CdCO<sub>3</sub>.
- D The  $K_{sp}$  value remains constant if temperature remains constant.  
 However, the solubility of CuS will decrease in this case.

19 The solubilities of AgCl and AgI are  $x$  and  $y$  mol dm<sup>-3</sup> respectively at 298 K.

Which statements are correct about a solution saturated with both AgCl and AgI?

- 1  $[Ag^+] = x + y$
- 2  $[Ag^+] = [I^-] + [Cl^-]$
- 3  $[I^-] < y$

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

Given solubility of AgCl and AgI are  $x$  and  $y$  mol dm<sup>-3</sup> respectively,

$$K_{sp}(AgCl) = [Ag^+][Cl^-] = x^2 \text{ mol}^2 \text{ dm}^{-6}$$

$$K_{sp}(AgI) = [Ag^+][I^-] = y^2 \text{ mol}^2 \text{ dm}^{-6}$$

In a solution saturated with both AgCl and AgI, let the solubility of AgCl and AgI be  $x'$  and  $y'$  mol dm<sup>-3</sup> respectively.

$$[Ag^+] = x' + y', \quad [Cl^-] = x', \quad [I^-] = y'$$

$$K_{sp}(AgCl) = [Ag^+][Cl^-] = (x' + y')(x') = x^2$$

$$K_{sp}(AgI) = [Ag^+][I^-] = (x' + y')(y') = y^2$$

$$(x' + y')(x') + (x' + y')(y') = x^2 + y^2$$

$$(x' + y')^2 = x^2 + y^2$$

1 ✗

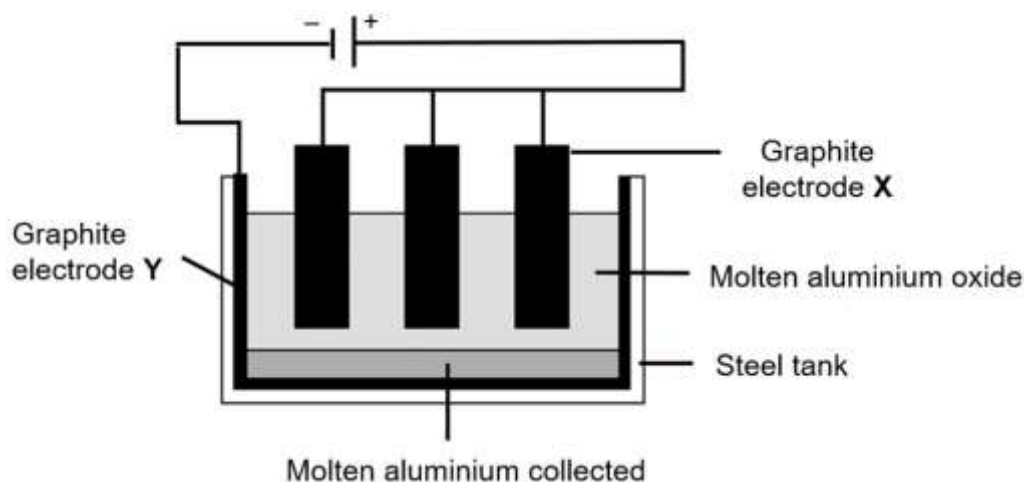
$$[Ag^+] = x' + y' = \sqrt{x^2 + y^2} < x + y$$

3 ✓  $[I^-] = y' = \frac{y^2}{x' + y'} = \frac{y^2}{\sqrt{x^2 + y^2}} < y$

2 ✓  $[Ag^+] = x' + y' = [Cl^-] + [I^-]$

⇒ **D**

20 Aluminium is extracted from its ore by electrolysis.



Which statements are correct?

- 1 Aluminium ions migrate to electrode X.
- 2 Oxygen gas is produced.
- 3 Electrons move from electrode X to electrode Y via the external circuit.

**A** 2 and 3

**B** 1 only

**C** 1 and 3

**D** 1 and 2

Option 2 is correct.

Electrode X is the positive electrode i.e. the anode, anions (i.e.  $O^{2-}$ ) migrate here and oxidation takes place.  $O^{2-}$  is oxidised to  $O_2(g)$ .

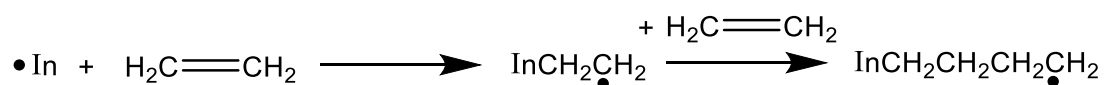
Option 3 is correct.

Electrons move from negative terminal of the battery to electrode Y, and electrode X to the positive terminal of the battery. Thus, electrons move from electrode X to electrode Y.

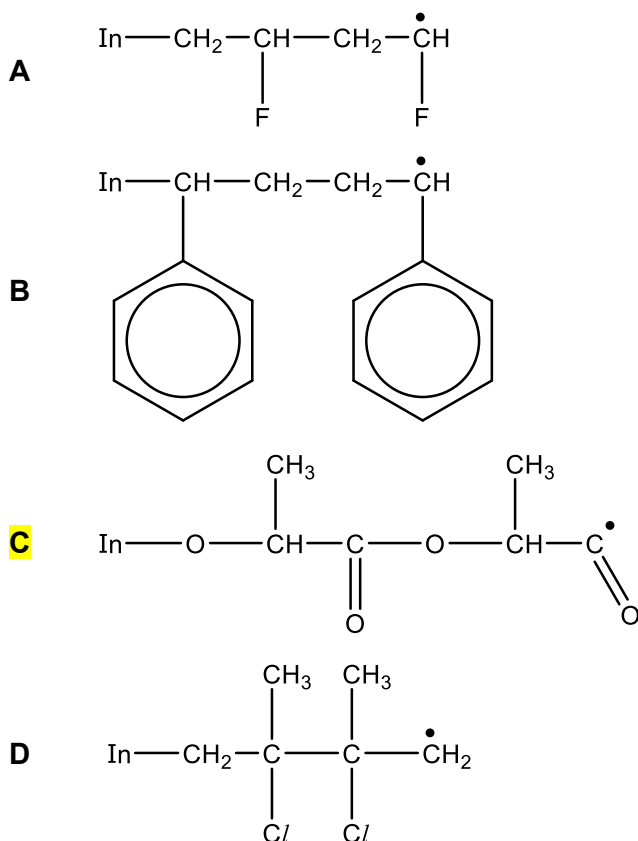
Option 1 is incorrect.

Electrode Y is the negative electrode i.e. the cathode, cations (i.e.  $Al^{3+}$ ) migrate here and reduction takes place.

- 21 Free radical addition is a mechanism used in the synthesis of some addition polymers. Alkene monomers will polymerise in the presence of a radical initiator ( $\text{In}^\bullet$ ). For instance, the synthesis of polyethene begins as such.



Which chain could **not** have arisen from free radical addition?



For free radical addition to occur, students must recognise that an alkene is needed as the monomer.

**A** uses fluoroethene,  $\text{H}_2\text{C}=\text{CHF}$

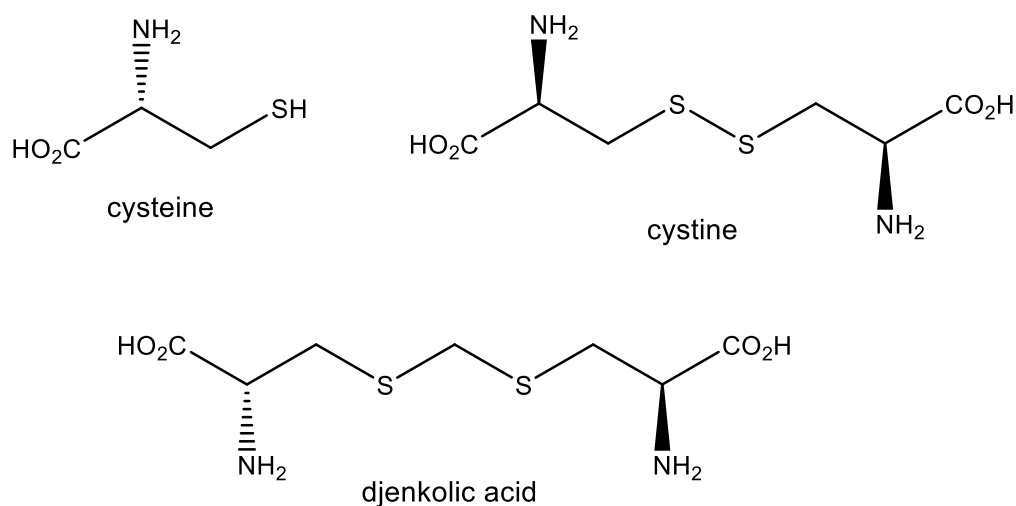
**B** uses phenylethene,  $(\text{C}_6\text{H}_5)\text{CH}=\text{CH}_2$

**D** uses 2-chloropropene,  $\text{H}_2\text{C}=\text{C}(\text{CH}_3)\text{Cl}$

There is no known monomer that can reasonably give rise to the structure in **C**. More accurately, it should be formed as a condensation polymer of lactic acid, 2-hydroxypropanoic acid.

- 22** Cysteine and cystine are important biochemicals in which the former is biosynthesised from the latter. Cysteine is a naturally occurring  $\alpha$ -amino acid, while djenkolic acid is a non-protein amino acid found in the djenkol beans of the Southeast Asian plant.

The three  $pK_a$  values of cysteine are 1.71, 8.33 (belonging to the thiol, -SH), and 10.78.



Which statement about cysteine, cystine and djenkolic acid is true?

- A** Cystine is a *meso* compound, hence it is non-chiral.
- B** Cysteine exists solely in its zwitterionic form at pH 5.02.
- C** Cystine and cysteine share the same empirical formula.
- D** There are four stereoisomeric forms of djenkolic acid because there are two chiral atoms in djenkolic acid.

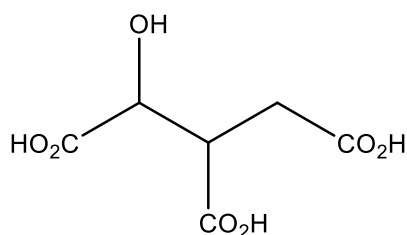
**A** is not true because there is no internal mirror plane in this stereoisomer of cystine.

**B** – 5.02 is indeed the isoelectric point of cysteine.

**C** – not true. 2 times cysteine – 2H = cystine.

**D** – not true. There are only 3 stereoisomers of djenkolic acid, which includes the one in the question. A pair of enantiomers (one of which is in the question) and the *meso* compound.

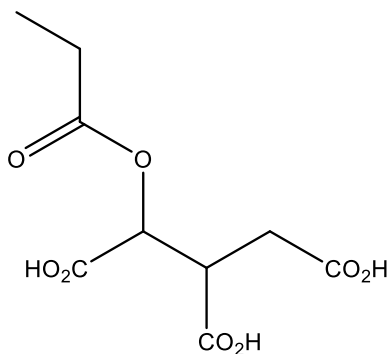
- 23 Isocitric acid is a naturally occurring compound found in fruit juices, vegetables, and other biological systems. It plays an important role in the citric acid cycle.



Which compound, on reaction with isocitric acid in the presence of concentrated sulfuric acid, will produce an organic product of molecular formula  $C_9H_{12}O_8$ ?

- A methanoic acid
- B propan-2-ol
- C methanol
- D propanoic acid**

The product is formed via esterification reaction between propanoic acid and the alcohol in isocitric acid.



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

A sample of an ester is hydrolysed by heating under reflux with aqueous sodium hydroxide. The two organic products of the hydrolysis are separated, purified and weighed.

Which ester would produce a 3:1 mass ratio of the two products obtained?

- A propyl methanoate
- B ethyl ethanoate
- C butyl methanoate
- D methyl propanoate**

Methanol (molar mass  $32 \text{ g mol}^{-1}$ ) and sodium propanoate (molar mass  $96 \text{ g mol}^{-1}$ ) are the basic hydrolysis products from methyl propanoate. Indeed the mass ratio of the product is  $96 / 32 = 3$ .

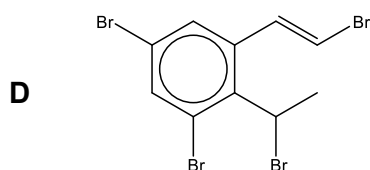
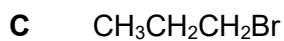
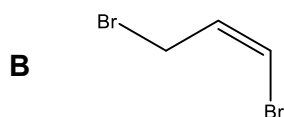
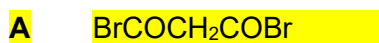
Propanol (molar mass  $60 \text{ g mol}^{-1}$ ) and sodium methanoate (molar mass  $68 \text{ g mol}^{-1}$ ) are the basic hydrolysis products from propyl methanoate. The mass ratio of the product is  $68 / 60$ .

Ethanol (molar mass  $46 \text{ g mol}^{-1}$ ) and sodium ethanoate (molar mass  $82 \text{ g mol}^{-1}$ ) are the basic hydrolysis products from ethyl ethanoate. The mass ratio of the product is  $82 / 46$ .

Butanol (molar mass  $74 \text{ g mol}^{-1}$ ) and sodium methanoate (molar mass  $68 \text{ g mol}^{-1}$ ) are the basic hydrolysis products from butyl methanoate. The mass ratio of the product is  $74 / 68$ .

- 25** 0.04 mol of each of the following compounds was heated with KOH(aq), followed by addition of dilute HNO<sub>3</sub> and AgNO<sub>3</sub>(aq).

Which compound will produce the highest mass of AgBr(s)?



Per mole of each compound:

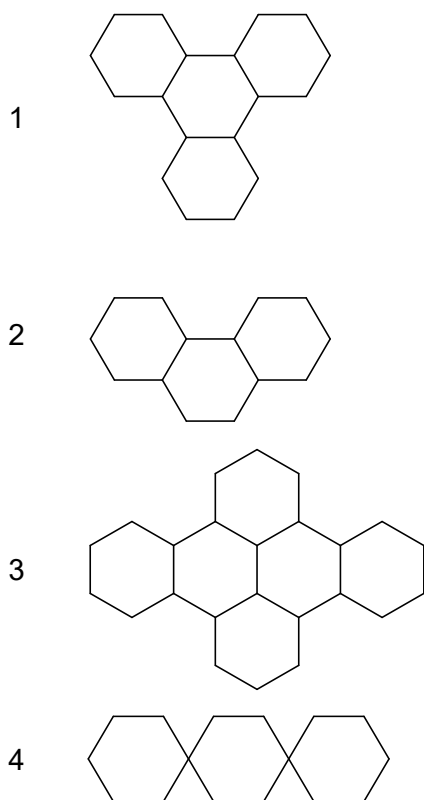
**A:** two moles of bromide formed.

**B:** one mole of bromide formed.

**C:** one mole of bromide formed.

**D:** one mole of bromide formed.

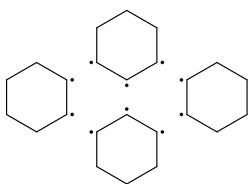
- 26 Which pair of compounds will **not** form when cyclohexane is reacted with excess bromine gas in the presence of ultraviolet light?



- A 1 and 2      B 2 and 4      C 1 and 3      D 1 and 4

1 is formed by three cyclohexyl radicals.

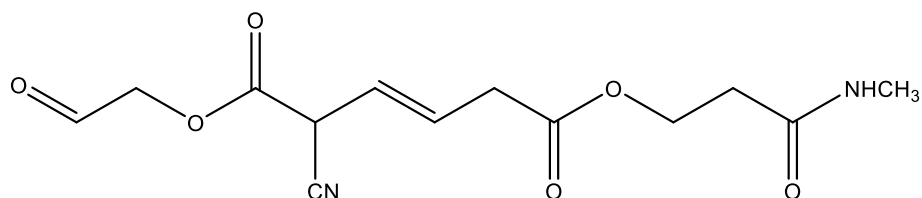
3 is formed by four cyclohexyl radicals.



- 27 Esters can be reduced by  $\text{LiAlH}_4$  in dry ether to give two alcohols as shown below.



Which product may be formed when the following compound is reacted with excess  $\text{LiAlH}_4$  in dry ether?



- A  $\text{H}_2\text{NCH}_2\text{CH}(\text{CH}_2\text{OH})\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$   
 B  $\text{NCCH}(\text{CO}_2\text{H})\text{CH}=\text{CHCH}_2\text{CO}_2\text{H}$   
 C  $\text{HOCH}_2\text{CH}_2\text{NHCH}_3$   
 D  **$\text{HOCH}_2\text{CH}_2\text{OH}$**

The products formed are, in order of fragments from the above compound,

- Ethane-1,2-diol (option D)
- $\text{HOCH}_2\text{CH}(\text{CH}_2\text{NH}_2)\text{CH}=\text{CHCH}_2\text{CH}_2\text{OH}$
- $\text{HO}(\text{CH}_2)_3\text{NHCH}_3$

- 28** Chymotrypsin is an enzyme that hydrolyses protein into smaller peptides and amino acids. It specifically hydrolyses the peptide bond on the carboxylic end of Phe.

The structure of tetrapeptide **X** and  $M_r$  of selected amino acids are given below.

tetrapeptide **X**: Val–Lys–Phe–Arg

amino acid	$M_r$
Val	117
Lys	146
Phe	165
Arg	174

What are the  $M_r$  of the two fragments obtained when tetrapeptide **X** is hydrolysed by chymotrypsin?

- A** 174 and 392  
**B** 174 and 428  
**C** 245 and 321  
**D** 263 and 339

Answer: A

By convention, a polypeptide chain is drawn from the amino end (N-terminus) at the left end to the carboxyl end (C-terminus) at the right end.

N→C N→C N→C N→C

Tetrapeptide **X**: Val—Lys—Phe—Arg

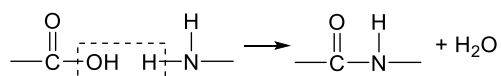
Since chymotrypsin digested **X** at the carboxylic acid end of Phe, then the two fragments obtained are Val–Lys–Phe and Arg.

$M_r$  of Val–Lys–Phe

$$117 + 146 + 165 - 2(18) = \mathbf{392}$$

$M_r$  of  
Arg  
**174**

1 H<sub>2</sub>O ( $M_r = 18$ ) is lost when 2 amino acids form a peptide. 2 H<sub>2</sub>O are lost when 2 amino acids form 2 peptide linkages



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

Which statement is true?

- A  $\text{CoF}_3$  is stable in water because  $2\text{Co}^{3+} + 2\text{F}^- \rightarrow \text{F}_2 + 2\text{Co}^{2+}$  is a non-spontaneous reaction.
- B It is possible to prepare aqueous iron(III) iodide.
- C  $\text{Cr}_2\text{O}_7^{2-}$  is the oxidised form of  $\text{CrO}_4^{2-}$  because it contains more oxygen atoms.
- D The oxidation of iron(II) to iron(III) can be prevented at lower pH.

Option A: False

$\text{CoF}_3$  actually undergoes redox with water itself. It reacts with water to make hydrofluoric acid, oxygen, and  $\text{CoF}_2$ . The  $E_{\text{cell}} = 1.89 - 1.23 = +0.66 \text{ V} > 0$

Option B: False

$\text{Fe}^{3+}$  undergoes redox with iodide in aqueous medium.

$E_{\text{cell}} = 0.77 - 0.54 = +0.23 \text{ V} > 0$

Option C: False

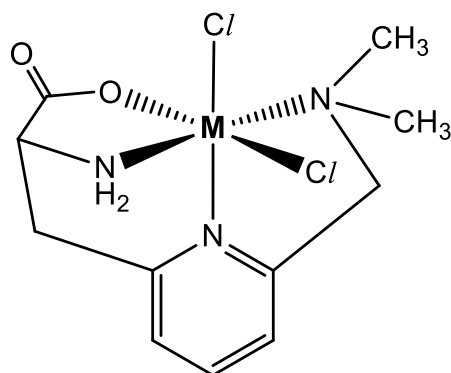
The oxidation states of Cr in both are +6.

Option D: True

The standard reduction potential of  $\text{Fe}^{3+}/\text{Fe}^{2+}$  is positive, while that of  $\text{Fe}(\text{OH})_3/\text{Fe}(\text{OH})_2$  is negative.

In alkaline medium, it is easy to oxidise  $\text{Fe}(\text{OH})_2$  to  $\text{Fe}(\text{OH})_3$ . However in acidic or neutral medium it is not as easy to oxidise  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$ .

30 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 coordination number of the complex is 6.
- C** The complex contains a tetradentate ligand.
- D** The complex contains a ligand which is an  $\alpha$ -amino acid.

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.

Coordination number is the number of dative bonds around M which is equal to 6 in the complex.

Option C: True.

Option D: True