



**Catholic Junior College**  
**JC 2 Preliminary Examinations**  
**Higher 2**

CANDIDATE  
NAME

CLASS

2T

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**CHEMISTRY**

**9729/01**

**Paper 1 Multiple Choice**

**18 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, class and NRIC/FIN number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. 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.

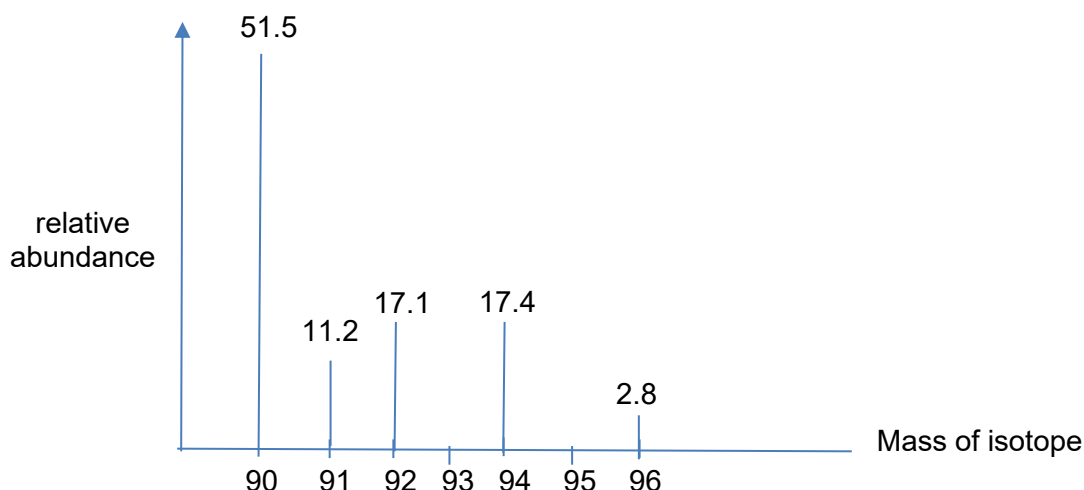
The use of an approved scientific calculator is expected, where appropriate.

**WORKED  
SOLUTIONS**

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**This document consists of 28 printed pages.**

- 1 The relative abundances of all the isotopes present in a sample of zirconium are shown.



What is the relative atomic mass of zirconium calculated from these data?

- A 91.1      **B 91.3**      C 91.6      D 93.1

**Topic: Atomic Structure**

$$A_r \text{ of Zr} = \frac{51.5(90) + 11.2(91) + 17.1(92) + 17.4(94) + 2.8(96)}{100} = 91.3$$

**Answer: B**

- 2 In the interhalogen compound  $\text{ICl}$ , there is a single polar covalent bond.
- Which of the following statement(s) helps to explain the polarity of the  $\text{I-Cl}$  covalent bond?
- 1  $\text{Cl}$  is more electronegative than  $\text{I}$ .
  - 2 The outer shell electronic configuration of both elements is  $s^2 p^6$ .
  - 3 The outer shell electrons are more shielded from nuclear charge in  $\text{I}$  than they are in  $\text{Cl}$ .

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

**Topic: Chemical Bonding**

**Polarity of a covalent bond depends on the electronegativity difference between two atoms.**

**Electronegativity is a measure of the ability of an atom to attract the bonding electrons.**

**Option 1: True;  $\text{Cl}$  is more electronegative than  $\text{I}$ .**

**Option 2: True but does not explain why the bond is polar.**

**Option 3: True; hence the attraction exerted by the nucleus of  $\text{I}$  on the shared pair of electrons is weaker than that of  $\text{Cl}$ .**

**Answer: C**

- 3 In which pairs of compounds does the first molecule have a smaller bond angle than that in the second molecule?

1	NF <sub>3</sub>	CCl <sub>4</sub>
2	H <sub>2</sub> S	H <sub>2</sub> O
3	SF <sub>6</sub>	CS <sub>2</sub>

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

**Topic: Chemical Bonding**

	molecule	shape	bond angle	molecule	shape	Bond angle
1 ✓	NF <sub>3</sub>	trigonal pyramidal	107°	CCl <sub>4</sub>	tetrahedral	109°
2 ✓	H <sub>2</sub> S	bent	92° due to central S atom being less electronegative than O in H <sub>2</sub> O	H <sub>2</sub> O	bent	105°
3 ✓	SF <sub>6</sub>	octahedral	90°	CS <sub>2</sub>	linear	180°

**Answer: A**

- 4 The table shows the boiling point of three alcohols.

	boiling point / °C
pentan-1-ol	138
2-methylbutan-2-ol	129
2,2-dimethylpropanol	114

What is responsible for the differences in boiling point?

- A** different relative molecular mass  
**B** different number of carbon-carbon bonds  
**C** weaker hydrogen bonding between branched chain molecules  
**D** more extensive instantaneous dipoles–induced dipoles attractions between straight chain molecules

**Topic: Chemical Bonding**

- A** False; all three alcohols are isomers with the same relative molecular mass  
**B** False; same number of carbon-carbon bonds in the three isomers  
**C** False; strength of intermolecular hydrogen bonding in the straight chain and branched chain isomers are similar since all three isomers, on average, will form the same number of hydrogen bonds per molecule (since each molecule consist of 1 -OH group).  
**D** True; more extensive instantaneous dipoles-induced dipoles attractions between straight chain molecules (due to larger surface area of contact between the molecules).

**Answer: D**

- 5 Which statements about the behaviour of Group 17 elements from chlorine to iodine are correct?
- A The elements become stronger oxidising agents.
- B The volatility of the elements decreases.
- C The thermal stability of the hydrogen halides increases.
- D The bond energy of H–X bond increases.

**Topic: The Periodic Table**

- A False; the elements become weaker oxidising agents from chlorine to iodine as there is a lower tendency for  $X_2$  to reduce to  $X^-$ .
- B True; The volatility of the elements decreases down the group. As the number of electrons of the halogen molecules increases, the instantaneous dipoles – induced dipoles (id-id) forces of attractions between the halogen molecules increases. Larger amount of energy is required to overcome the stronger id-id forces of attractions, resulting in higher boiling point and hence lower volatility.
- C False; the thermal stability of the hydrogen halides decreases from H-Cl to H-I as the bond energy of H-X bond decreases, hence the ease of breaking H-X bond increases, resulting in lower thermal stability.
- D False; the bond energy of H–X bond decreases from H-Cl to H-I due to less effective overlap of orbitals as the valence orbital used in bonding becomes bigger and more diffused from chlorine to iodine.

**Answer: B**

- 6 0.10 mol of an oxide of nitrogen ( $N_xO_y$ ) is mixed with an excess of hydrogen and passed over a catalyst at a suitable temperature.  
The water produced in this reaction has a mass of 7.2 g.  
The ammonia produced requires 200 cm<sup>3</sup> of 1.0 mol dm<sup>-3</sup> HCl for complete neutralisation.

What is the formula of this oxide of nitrogen?

- A  $N_2O$                       B NO                      C  $NO_2$                       D  $N_2O_4$

**Topic: The Mole Concept and Stoichiometry**

Let the oxide of nitrogen be  $N_xO_y$ .

Amt of water formed when 0.10 mol of the oxide reacted =  $\frac{7.2}{18.0} = 0.400$  mol

No of O atoms in  $N_xO_y$ ,  $y = \frac{0.400}{0.100} = 4$

Amt of  $HCl$  required for neutralisation =  $\frac{200}{1000} \times 1.0 = 0.200$  mol = amt of  $NH_3$  formed.

No of N atoms in  $N_xO_y$ ,  $x = \frac{0.200}{0.100} = 2$

Hence oxide of nitrogen is  $N_2O_4$ .

**Answer: D**

unbalanced equation:  $N_xO_y + H_2 \rightarrow NH_3 + H_2O$

Amounts / mol:            0.1            0.2            0.4

Hence:                       $1N_xO_y + H_2 \rightarrow 2NH_3 + 4H_2O$

where x and y can be derived via inspection

- 7 Sodium thiosulfate is used in the textile industry to remove an excess of chlorine from bleaching processes by reducing it to chloride ions.

One mole of thiosulfate ions,  $S_2O_3^{2-}$ , is able to remove 4 moles of chlorine,  $Cl_2$ , in this process. In this process,  $S_2O_3^{2-}$  is oxidised. What is the resultant sulfur-containing product in this reaction?

**A**  $HSO_4^-$

**B**  $S_4O_6^{2-}$

**C**  $SO_2$

**D**  $S$

**Topic: The Mole Concept and Stoichiometry (Redox)**

Half equation involving chlorine:



Hence, 4 moles of  $Cl_2$  would gain  $8e^-$ .

This means that 1 mole of  $S_2O_3^{2-}$  loses  $8e^-$ . (one S atom loses  $4e^-$ )

Oxidation state of S in  $S_2O_3^{2-} = +2$

Final OS of S in the product =  $+2 - (-4) = +6$

OS of S in

(A)  $HSO_4^-$  (+6) **answer**

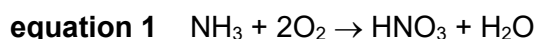
(B)  $S_4O_6^{2-}$  (+2.5)

(C)  $SO_2$  (+4)

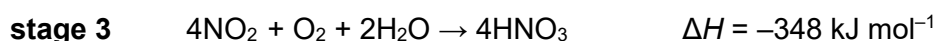
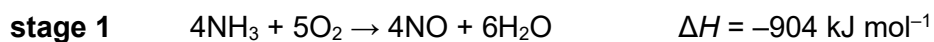
(D) S (0)

**Answer: A**

- 8 Nitric acid is made industrially by the oxidation of ammonia. The overall equation for the process is shown.



The process happens in three stages. The equations and enthalpy changes for these stages are given.



What is the enthalpy change of the process shown in equation 1?

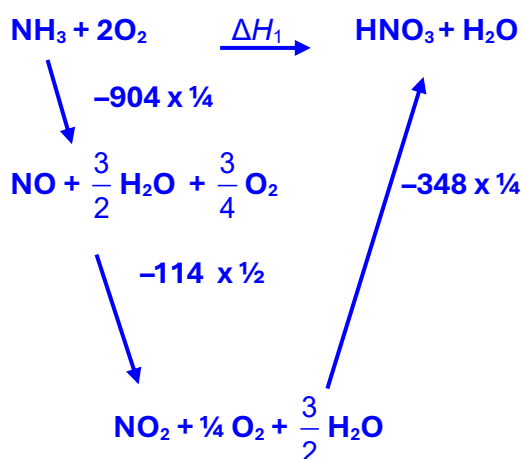
A  $-1480 \text{ kJ mol}^{-1}$

**B  $-370 \text{ kJ mol}^{-1}$**

C  $-341.5 \text{ kJ mol}^{-1}$

D  $+82 \text{ kJ mol}^{-1}$

**Topic: Energetics (Energy cycle and Hess' Law)**



$$\begin{aligned}\Delta H_1 &= -904 \times \frac{1}{4} + -114 \times \frac{1}{2} + -348 \times \frac{1}{4} \\ &= -370 \text{ kJ mol}^{-1}\end{aligned}$$

**Alternative method (Mathematical method)**



Summing up the above 3 equations gives equation 1.

Hence  $\Delta H_1 = -226 + (-57) + (-87) = -370 \text{ kJ mol}^{-1}$

**Answer: B**

- 9 A radioactive element has 2 isotopes, **G** and **H**, with half-lives of 3 days and 6 days respectively. An experiment starts with 4 times as many atoms of **G** as of **H**.

Given that radioactive decay is a first-order reaction, how long will it be before the number of atoms of **G** left equals the number of atoms of **H** left?

- A** 12 days      **B** 15 days      **C** 24 days      **D** 48 days

**Topic: Kinetics (first order reactions and half-life)**

Let the number of atoms of **G** be  $4x$  and the number of atoms of **H** be  $x$ .

Radioactive decay for **G** after 12 days (4 half-lives of 3 days):

$4x \rightarrow 2x \rightarrow x \rightarrow x/2 \rightarrow x/4$

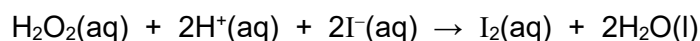
Radioactive decay for **H** after 12 days (2 half-lives of 6 days):

$x \rightarrow x/2 \rightarrow x/4$

**G** goes through 4 half lives (12 days) before it can have the same amount of atoms as **H** at the same time.

**Answer: A**

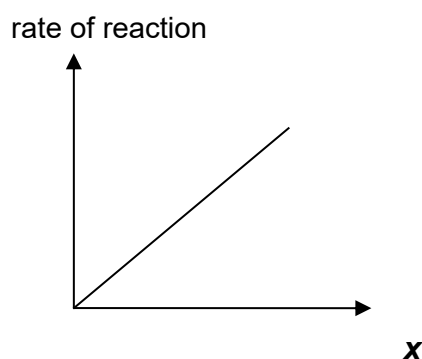
- 10 The kinetics of the reaction between hydrogen peroxide and acidified iodide ions were investigated.



The rate equation was found to be  $\text{rate} = k[\text{H}_2\text{O}_2][\text{I}^-]$

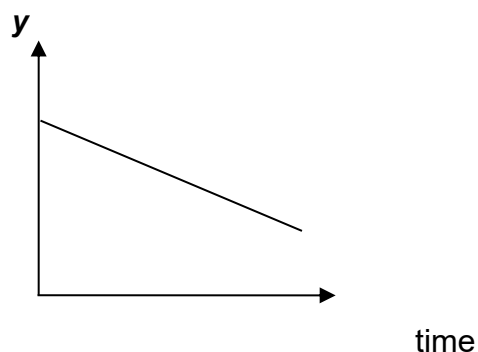
Which of the following shows the correct labelling of the **x**-axis for **Graph I** and **y**-axis for **Graph II**?

**Graph I**



**x-axis for Graph I**

**Graph II**



**y-axis for Graph II**

- |          |                                      |                                      |
|----------|--------------------------------------|--------------------------------------|
| <b>A</b> | $[\text{I}^-]$                       | $[\text{H}_2\text{O}_2][\text{I}^-]$ |
| <b>B</b> | $[\text{H}^+]$                       | $[\text{I}_2]$                       |
| <b>C</b> | $[\text{H}_2\text{O}_2][\text{I}^-]$ | $[\text{H}^+]$                       |
| <b>D</b> | $[\text{H}_2\text{O}_2][\text{H}^+]$ | $[\text{I}^-]$                       |

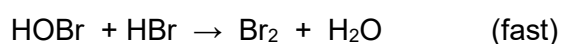
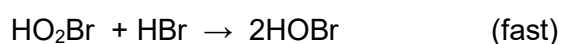
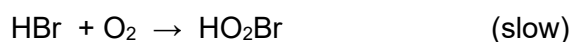
**Topic: Kinetics (shapes of graphs )**

**Graph I :** Rate =  $k \underbrace{[\text{H}_2\text{O}_2]}_y \underbrace{[\text{I}^-]}_x$  (similar to  $y=mx$  graph)

**Graph II :** gradient of the graph shows that rate is independent of [reactant].  $\text{H}^+$  is not involved in the rate equation and thus zero order wrt  $\text{H}^+$ .

**Answer: C**

- 11 The reaction between HBr and  $\text{O}_2$  is thought to occur via a multi-step mechanism:



The overall reaction is  $4\text{HBr} + \text{O}_2 \rightarrow 2\text{Br}_2 + 2\text{H}_2\text{O}$ .

Which statement is correct?

- A The overall order of reaction is 3.
- B  $\text{HO}_2\text{Br}$  is the only intermediate in the reaction.
- C HOBr acts as a catalyst in the reaction.
- D Units of the rate constant is  $\text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$ .**

**Topic: Kinetics (reaction mechanism, units of rate constant)**

**Rate =  $k[\text{HBr}][\text{O}_2]$   $\Rightarrow$  overall order of reaction is 2**

**$\text{HO}_2\text{Br}$  and HOBr are the intermediates in the reaction (they do not appear in the overall equation).**

**HOBr is not a catalyst as it is not regenerated.**

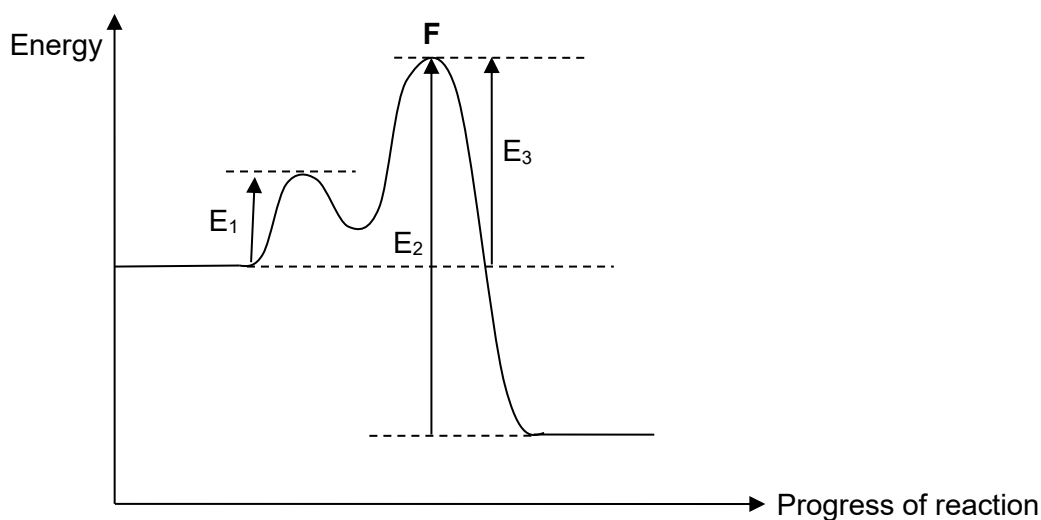
**$k = \text{rate} / [\text{HBr}][\text{O}_2]$**

**units of  $k = \text{mol dm}^{-3} \text{s}^{-1} / (\text{mol dm}^{-3})^2$   
 $= \text{mol}^{-1} \text{dm}^3 \text{s}^{-1}$**

**Answer: D**



- 12 Which of the following statements is true about the following energy profile for a catalysed reaction shown below?



- 1 The reaction is catalysed by a heterogeneous catalyst.
- 2 The enthalpy change of the reaction is  $E_3 - E_2$ .
- 3 F is the intermediate formed.
- 4 The second step of the reaction is the rate determining step.

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

**Topic: Kinetics (energy profile diagram, rate determining step and catalysis.**

**1 is wrong. The profile of the graph matches a two-step reaction. This is characteristic of a homogeneous catalyst which occurs via an intermediate.**

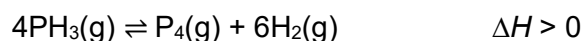
**2 is true. The enthalpy change of the reaction is  $E_3 - E_2$  to give the correct sign and magnitude.**

**3 is wrong as F is the transition state for Step 2 of the reaction, not the intermediate.**

**4 is true. The second step has a larger  $E_a$ , hence it is more likely to be the rate determining step compared to the first step.**

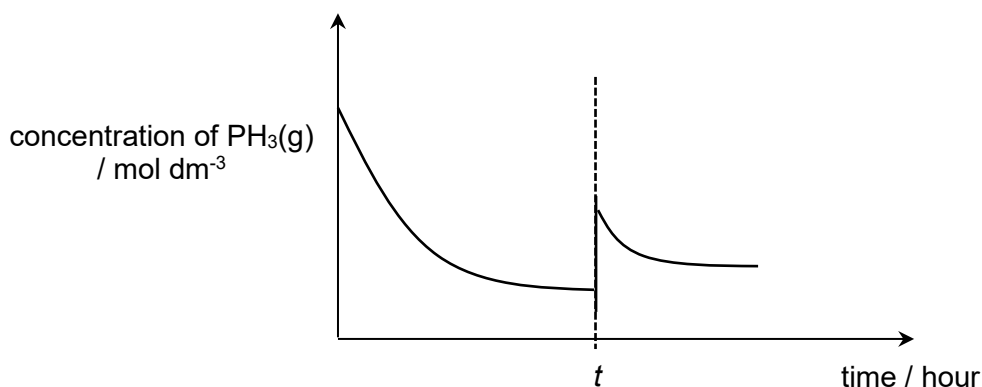
**Answer: B**

- 13 Phosphine,  $\text{PH}_3$ , decomposes to give phosphorus and hydrogen gas.



The graph below shows the change in concentration of  $\text{PH}_3$  over time until the reaction mixture reaches equilibrium at a constant temperature of 400 K.

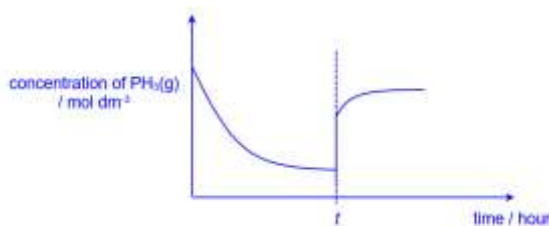
Which of the following is a possible change made at  $t$  hour?



- A reduction of volume of the vessel
- B addition of  $\text{PH}_3$**
- C removal of  $\text{P}_4$
- D addition of a catalyst

**Topic: Chemical equilibrium, Le Chatelier's principle**

**Option A:** The reduction of volume (increase in overall pressure) will cause  $\text{PH}_3$  to have a sharp increase at time  $t$  as shown. However, the increase in overall pressure will result in the position of equilibrium shifting to the left to produce fewer no. of moles of gas. This will increase in concentration of  $\text{PH}_3$  after time  $t$ , and the graph should look like this:



**Option B** is correct as concentration of  $\text{PH}_3$  will increase at time  $t$  and position of equilibrium shifts right leading to a subsequent decrease in its concentration.

**Option C** is wrong as removal of  $\text{P}_4$  will not lead to a drastic increase in concentration of  $\text{PH}_3$  at time  $t$ .

**Option D** is wrong as addition of a catalyst does not lead to a shift in position of equilibrium.

**Answer: B**

14 Which statement about the chemical properties of the oxides in the third period of the Periodic Table is true?

A  $\text{Na}_2\text{O}$  and  $\text{MgO}$  can be mixed in water to give an approximately neutral solution.

**B  $\text{Al}_2\text{O}_3$  is soluble in both  $\text{KOH}$  and  $\text{HCl}$ .**

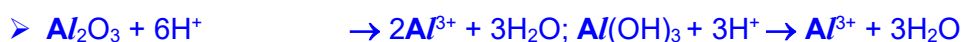
C  $\text{SO}_3$  is insoluble in water.

D  $\text{SiO}_2$  forms a solution of pH 2 when dissolved in water at room temperature.

**Topic: The Periodic Table**

**Option A: False.  $\text{Na}_2\text{O}$  and  $\text{MgO}$  are basic and dissolve in water to give an alkaline solution ( $\text{NaOH}$  and  $\text{Mg(OH)}_2$ ). Moreover,  $\text{MgO}$  is sparingly soluble only.**

**Option B: True.  $\text{Al}_2\text{O}_3$  is amphoteric. It reacts with  $\text{KOH}$  to give  $\text{Al(OH)}_4^-$  and  $\text{HCl}$  to give  $\text{AlCl}_3$ , hence  $\text{Al}_2\text{O}_3$  does dissolve in both  $\text{KOH}$  and  $\text{HCl}$ .**



**Option C: False.  $\text{SO}_3$  dissolves in water to give  $\text{H}_2\text{SO}_4$ .  $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$**

**Option D: False.  $\text{SiO}_2$  giant covalent and hence is insoluble in water, therefore the pH of solution will be 7.**

15 Which one of the following statements about the behaviour of the Group 2 elements from magnesium to barium is correct?

A They become weaker reducing agents.

B The electronegativity increases.

**C The thermal stability of the metal carbonate increases.**

D The enthalpy change of hydration of the ions become more exothermic.

**Topic: The Periodic Table**

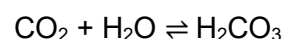
**Option A and B: Incorrect.** Down the group, due to increasing size and an increase in shielding effect (due to increasing number of electron shells), the nucleus has lower attraction for the valence electrons (electronegativity decreases). As a result, the tendency for the element to lose the valence electrons increases, and therefore the reducing power increases.

**Option C: Correct.** Down the group, the size of cation increases, thus charge density decreases, leading to lower polarising power of the cation. As a result, the  $\text{CO}_3^{2-}$  ion is polarised to a smaller extent, C–O bond weakened to a smaller extent and harder to break. Decomposition of the metal carbonate occurs with greater difficulty hence thermal stability increases.

**Option D: Incorrect.** Down the group, the size of cation increases, thus charge density decreases. The hydration energy of an ion is proportional to the charge density of the ion. The ion–dipole attractions formed between the ions and water molecules become increasingly weaker, and thus the hydration energy becomes less exothermic.

**Answer: C**

- 16** The concentration of carbon dioxide in the blood is regulated by the following equilibria.



During exercise, the production of lactic acid decreases the pH of blood. Which statements about these equilibria are correct when this happens?

**1** The positions of both equilibria shift left.

**2**  $[\text{H}^+]$  decreases.

**3**  $\text{HCO}_3^-$  acts as a Bronsted-Lowry acid.

**A** 1 only

**B** 2 only

**C** 1 and 3 only

**D** 1, 2 and 3

**Topic: Chemistry of Aqueous Solutions**

When the pH of blood decreases, the  $[H^+]$  increases. (Option 2 is wrong)

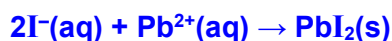


When  $[H^+]$  increases,  $HCO_3^-$  will accept the  $H^+$  ( $HCO_3^-$  is a Bronsted-Lowry base, hence option 3 is wrong). Position of eqm 2 will shift left to decrease the amount of  $H^+$ . This will result in an increase in  $H_2CO_3$ . Subsequently, eqm 1 will respond by shifting left as well. (Option 1 is correct.)

**Answer: A**

- 17 Equal volumes of aqueous KI and  $0.200 \text{ mol dm}^{-3}$  of  $Pb(NO_3)_2$  are mixed together to precipitate  $PbI_2$ . Given that the  $K_{sp}$  value of  $PbI_2$  is  $8.70 \times 10^{-9} \text{ mol}^3 \text{ dm}^{-9}$ , which one of the following could have been the initial concentration of KI?

- A  $8.70 \times 10^{-8} \text{ mol dm}^{-3}$   
 B  $2.95 \times 10^{-4} \text{ mol dm}^{-3}$   
 C  $5.50 \times 10^{-4} \text{ mol dm}^{-3}$   
 D  $1.50 \times 10^{-2} \text{ mol dm}^{-3}$

**Topic: Chemistry of Aqueous Solutions**

For precipitation of  $PbI_2$  to occur, ionic product  $[Pb^{2+}][I^-]^2$  must be greater than the  $K_{sp}$  value of  $PbI_2$ .  $\Rightarrow [Pb^{2+}][I^-]^2 > K_{sp}$

Let  $x$  be  $[I^-]_{\text{initial}}$

$$\frac{0.200}{2} \times \left(\frac{x}{2}\right)^2 > 8.70 \times 10^{-9}$$

$$[I^-]_{\text{initial}} > 5.90 \times 10^{-4} \text{ mol dm}^{-3}$$

Option D is the only one that has a value higher than  $5.90 \times 10^{-4} \text{ mol dm}^{-3}$

**Answer: D**

- 18 Which of the following reactions is ammonia acting as a Brønsted–Lowry base?

- A  $NH_3 + HF \rightleftharpoons NH_4^+ + F^-$   
 B  $NH_3 + CH_3Br \rightarrow CH_3NH_2 + HBr$   
 C  $4NH_3 + [Cu(H_2O)_6]^{2+} \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$   
 D  $NH_3 + BCl_3 \rightarrow NH_3 \cdot BCl_3$

**Topic: Theories of Acids and Bases involving concepts from multiple topics**

- A:**  $\text{NH}_3$  is behaving as a Brønsted–Lowry base as it accepts a proton,  $\text{H}^+$  from  $\text{HF}$  to form  $\text{NH}_4^+$ .
- B:**  $\text{NH}_3$  is behaving as a Lewis base where it donates a pair of electrons to electron deficient C atom in  $\text{CH}_3\text{Br}$  in a nucleophilic substitution ( $\text{S}_{\text{N}}2$ ) reaction.
- C:**  $\text{NH}_3$  is behaving as a Lewis base where it donates a pair of electrons to  $\text{Cu}^{2+}$  in a ligand displacement reaction.
- D:**  $\text{NH}_3$  is behaving as a Lewis base where it donates a pair of electrons to electron deficient B atom in  $\text{BCl}_3$  to form a tetrahedral adduct.

**Answer: A**

**19** Which statement about benzene and cyclohexene is correct?

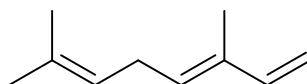
- A** Both are planar molecules.
- B** Both possess delocalised  $\pi$  electrons.
- C** Both decolourise aqueous bromine in the presence of finely divided iron.
- D** Both undergo complete combustion give the same products.

**Topic: Properties of Alkenes vs Arenes**

- A:** Cyclohexene is **not** planar, it has four  $\text{sp}^3$ -hybridised carbon atoms which are tetrahedral about each of them.
- B:** Only benzene has delocalised electrons where the six  $\pi$  electrons are delocalised over the six carbon atoms in the structure. The two  $\pi$  electrons in cyclohexene are localised between two  $\text{sp}^2$ -hybridised carbon atoms.
- C:** Cyclohexene decolorises orange-red aqueous bromine at room temperature in an electrophilic addition reaction but benzene decolorises reddish-brown **liquid** bromine upon warming with  $\text{Fe(s)}$  or  $\text{FeBr}_3\text{(s)}$  under anhydrous conditions.
- D:** Carbon dioxide and water will be formed from complete combustion.

**Answer: D**

- 20 Ocimenes are a group of isomeric hydrocarbons with a sweet herbal scent and are commonly used in perfumes. The structure of one of its isomers is shown below.



$\beta$ -ocimene

Which statements are correct?

- 1  $\beta$ -ocimene has a total of four stereoisomers.
- 2  $\beta$ -ocimene reacts with HBr to produce a major product containing two chiral centres.
- 3  $\beta$ -ocimene undergoes both electrophilic addition and free radical substitution in the presence of excess bromine in the dark.
- 4  $\beta$ -ocimene reacts with cold dilute alkaline potassium manganate(VII) to produce a major product with six  $\text{-OH}$  groups.

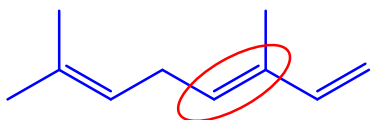
A 1 and 3

**B 2 and 4**

C 1, 2 and 3

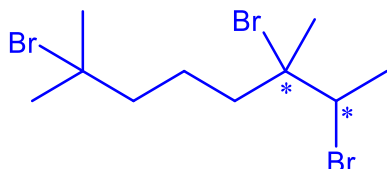
D 1, 2, 3 and 4

**Topic: Alkenes**



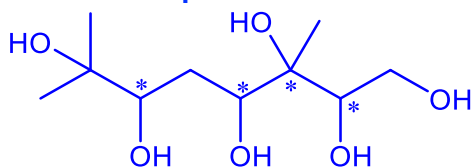
**1: Incorrect.** Only one  $\text{C}=\text{C}$  can exhibit cis-trans isomerism, hence total number of stereoisomers in  $\beta$ -ocimene =  $2^1 = 2$  stereoisomers.

**2: Correct – The major product as shown below has 2 chiral centres.**



**3: Incorrect. Free radical substitution of bromine requires UV light to react with  $\beta$ -ocimene.**

**4: Correct. The product of mild oxidation produces 6  $\text{-OH}$  groups.**



**Answer: B** – similar to 2018/P2/Q3(b(iii)); 2019/P3/Q3(d)(ii); 2013/P3/4(a)

- 21 Methylbenzene reacts with bromine chloride,  $\text{BrCl}$ , in different ways, depending on the conditions used. A reaction is carried out using an excess of methylbenzene in the absence of sunlight and in the presence of an iron-containing catalyst.

What is the main reaction taking place?

- A substitution of one bromine atom into the  $-\text{CH}_3$  side-chain
- B substitution of one chlorine atom into the  $-\text{CH}_3$  side-chain
- C substitution of one bromine atom into the benzene ring**
- D substitution of one chlorine atom into the benzene ring

**Topic: Arenes**

**Electrophilic substitution of the benzene ring with the electrophile  $\text{Br}^+$ , being generated in the presence of an iron-containing catalyst, which then attacks the C atom in the benzene ring.**

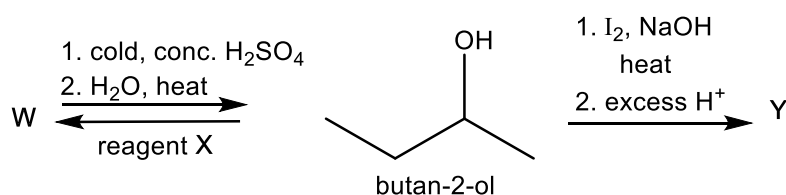
**In absence of sunlight (uv light), FRS of the side-chain cannot take place. So, A and B are incorrect.**

**$\text{Cl}^+$  is not the electrophile as it is more electronegative than Br as can be seen from  $\text{Br}-\text{Cl}$ . So, D can be ruled out.**

$\delta^+ \quad \delta^-$

**Answer: C**

- 22 The diagram shows reactions involving butan-2-ol.

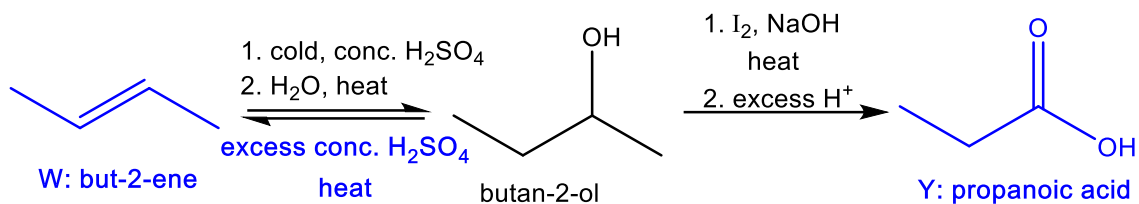


Which row correctly identifies the unknown compounds and reagents?

	W	reagent X	Y
A	2-chlorobut-2-ene	$\text{PCl}_5$	butanoic acid
B	but-2-ene	ethanolic KOH	propanoic acid
C	2-chlorobutane	$\text{PCl}_5$	butanoic acid
<b>D</b>	<b>but-2-ene</b>	<b>conc. <math>\text{H}_2\text{SO}_4</math></b>	<b>propanoic acid</b>



**Topic: Reactions of alcohols**



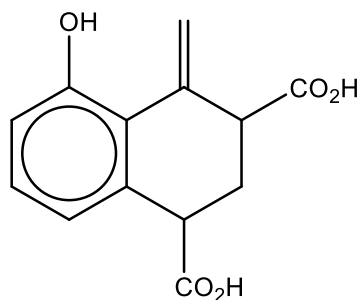
2-chlorobutane is not a possible answer for W as it does not undergo electrophilic addition with steam to form butan-2-ol.

Ethanollic KOH is not a possible answer for reagent X as it is only used for the elimination of halogenoalkane to an alkene.

Mild oxidation with iodine in alkaline media reduces the number of carbon atom by 1 to generate propanoic acid. Hence, butanoic acid is not produced as compound Z.

**Answer: D**

- 23 Compound **A** dissolves in heavy water,  $D_2O$ , to form compound **B**. Compound **B** contains a number of hydrogen atoms which can be replaced by deuterium, D.  
[D, deuterium =  $^2_1H$ ]

Compound **A**

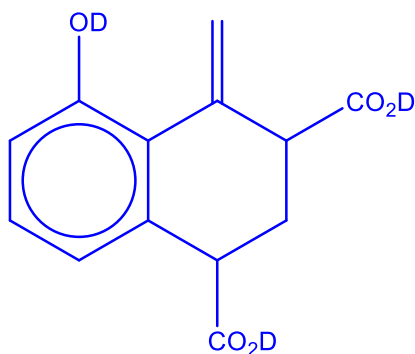
What is the maximum number of deuterium atoms present in one molecule of compound **B**?

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

**Topic: Acidity of Carboxylic Acids and Phenols**

When compound **A** is dissolved in  $D_2O$ , the following reactions will take place:

- proton exchange of the 2 acidic functional groups (phenol and carboxylic acid)

Compound **B**

**Answer: C**

- 24 Methanal, HCHO is the simplest aldehyde.  
Which statements about methanal is correct?

- 1 All four atoms in methanal lie in the same plane.
- 2 The carbon atom in methanal has an oxidation number of 0.
- 3 Complete combustion of 1 mol of methanal requires 1 mol of oxygen gas.

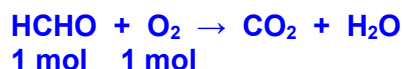
**A** 1, 2 and 3      **B** 1 and 2      **C** 2 and 3      **D** 1 only

**Topic: Carbonyl Compounds**

Methanal is trigonal planar in shape, the central C atom is  $sp^2$  hybridised.



The O.N. of C = 0 since the O.N. of H is +1 and that of O is -2. The molecule is not charged.



**Answer: A (1, 2, 3 are correct)**

- 25 A liquid **P** is sparingly soluble in water. It dissolves readily in cold hydrochloric acid. Evaporation of this solution yields a crystalline solid.  
Which could be **P**?

**A**  $\text{C}_6\text{H}_5\text{COCH}_3$       **B**  $\text{C}_6\text{H}_5\text{CONH}_2$       **C**  $\text{C}_6\text{H}_5\text{NH}_2$       **D**  $\text{C}_6\text{H}_5\text{OH}$

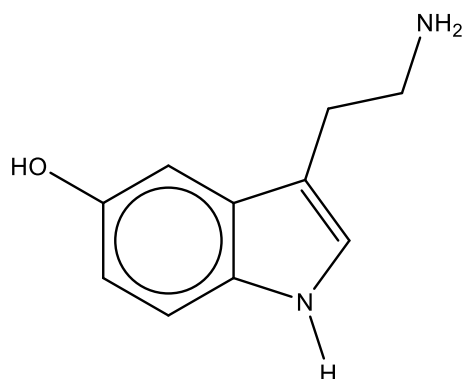
**Topic: Nitrogen compounds**

Liquid **P** is sparingly soluble in water since it contains the hydrophobic phenyl group, - $\text{C}_6\text{H}_5$ . **P** dissolves readily in cold hydrochloric acid, suggesting that it is basic. Only phenylamine is basic, and a very soluble ionic salt,  $\text{C}_6\text{H}_5\text{NH}_3^+\text{Cl}^-$ (aq) is formed as neutralisation takes place. The crystalline solid,  $\text{C}_6\text{H}_5\text{NH}_3^+\text{Cl}^-$ (s) is produced upon evaporation of the aqueous solution.

The ketone, amide are neutral and phenol is acidic so they do not react with cold HCl.

**Answer: C**

- 26 Serotonin is a neurotransmitter molecule.



serotonin

Which one of the following reagents will not react with serotonin?

- A  $\text{CH}_3\text{COC}/$
- B  $\text{HC}/$
- C  $\text{NaOH}$
- D  $\text{PCl}_5$

**Topic: Organic Reactions with different functional groups**

$\text{CH}_3\text{COC}/$  reacts with the amines and phenols to give the corresponding amides and esters.  $\text{HC}/$  undergoes EA reaction with the alkene; it also reacts with the basic amines via neutralisation.  $\text{NaOH}$  reacts with acidic phenol.

$\text{PCl}_5$  does not react with any of the functional groups present in serotonin. In addition, no reaction with phenol due the partial  $\text{C}=\text{O}$  double bond arising as a result of the overlapping of the p-orbital of the oxygen atom with the  $\pi$  orbitals of the carbon atoms of the benzene ring. So, there is no reaction involving cleavage of  $\text{C}-\text{O}$  bond.

**Answer: D**

- 27 A voltaic cell is set up using the  $\text{Mg}^{2+}/\text{Mg}$  and  $\text{Fe}^{3+}/\text{Fe}^{2+}$  half-cells.



Under standard conditions, the cell e.m.f. would be 3.15 V. However, the voltmeter recorded a reading of 3.05 V.

What is the best explanation for this lower e.m.f.?

- 1 a higher concentration of  $\text{Fe}^{3+}$  was used
- 2 a higher concentration of  $\text{Mg}^{2+}$  was used
- 3 a smaller magnesium electrode was used

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

**Topic: Electrochemistry [modified from 2021 CJC Prelim]**

- 1 incorrect – a higher concentration of  $\text{Fe}^{3+}$  would result in an even greater tendency for reduction, so  $E_{\text{Fe}^{3+}/\text{Fe}^{2+}}$  becomes more positive, and cell e.m.f. becomes more positive as well.
- 2 correct – a higher concentration of  $\text{Mg}^{2+}$  shifts the position of equilibrium of  $\text{Mg}^{2+}/\text{Mg}$  to the right.  $E_{\text{Mg}^{2+}/\text{Mg}}$  becomes less negative and cell e.m.f. becomes less positive.
- 3 incorrect – changing the size of the electrode does not shift the position of equilibrium.

**Answer: B**

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

The table below shows the properties of four metals K, Ca, Cr and Ga. Which set of properties belong to Cr?

	melting point / °C	density / g cm <sup>-3</sup>
<b>A</b>	<b>1860</b>	<b>7.19</b>
<b>B</b>	30	5.91
<b>C</b>	63	0.86
<b>D</b>	842	1.55

**Topic: Transition Elements**

	melting point / °C	density / g cm <sup>-3</sup>	Element
<b>A</b>	<b>1860</b>	<b>7.19</b>	<b>Cr</b>
<b>B</b>	<b>30</b>	<b>5.91</b>	<b>Ga</b>
<b>C</b>	<b>63</b>	<b>0.86</b>	<b>K</b>
<b>D</b>	<b>842</b>	<b>1.55</b>	<b>Ca</b>

Transition elements have higher melting points because the 3d and 4s electrons are involved in delocalisation in metallic bonding (due to their proximity in energies). For main group metals, eg For s-block elements, only the s electrons are involved in delocalisation in metallic bonding. Hence, larger amount of energy is required to overcome the stronger electrostatic forces of attraction between the cations and the sea of delocalised electrons in transition elements.

Transition elements are denser than main group metals because transition metals have: Relatively smaller atomic radius, hence a closer-packed structure. Higher relative atomic mass, hence higher mass per unit volume.

**Answer: A**

- 29 Which statement best explains why the  $[\text{TiCl}_6]^{2-}$  complex ion is expected to be colourless?

- A** The 3d subshell of the transition metal ion is empty.  
**B** Electrons from the lower energy level absorb energy outside the visible spectrum.  
**C** There is a large energy gap between the non-degenerate orbitals.  
**D** There is no d-orbital splitting in the transition metal ion.

**Topic: Transition Elements**

The electronic configuration of Ti is  $[\text{Ar}]3d^2 4s^2$ .

The oxidation state of Ti in  $[\text{TiCl}_6]^{2-}$  is +4.

The electronic configuration of Ti in the +4 oxidation state is  $[\text{Ar}]3d^0 4s^0$

The 3d (and 4s) subshells are empty.

The d – d\* electronic transition cannot take place because of the absence of electrons, even though the orbitals are expected to split into two non-degenerate levels.

**Answer: A**

- 30 The cathode of an electrolytic cell is a square piece of copper with dimensions 0.1 m x 0.1 m. The electrolyte is copper(II) sulfate.

Assume that each copper atom occupies a cube of length  $3.0 \times 10^{-12}$  m, the piece of copper has no thickness and that there is a uniform coverage.

How long will it take a current of 4.0 A to cover both sides of the piece of copper with new copper to a total of depth of 1000 atoms?

- A** 178 s      **B** 24.7 h      **C** 49.4 h      **D** 98.9 h

**Topic: Electrochemistry**

The surface area on one side of the copper piece =  $(0.1 \times 0.1) = 0.01 \text{ m}^2$

The surface area of one copper atom on one side =  $(3.0 \times 10^{-12})^2 = 9.0 \times 10^{-24} \text{ m}^2$

Number of copper atoms to cover one side with depth of a single atom

$$= \left( \frac{0.01}{9.0 \times 10^{-24}} \right) = 1.11 \times 10^{21}$$

Total number of copper atoms to cover two sides with depth of 1000 atoms each

$$= (1.11 \times 10^{21} \times 2 \times 1000) = 2.22 \times 10^{24}$$

Amount of copper atoms to be deposited =  $\left( \frac{2.22 \times 10^{24}}{6.02 \times 10^{23}} \right) = 3.69 \text{ mol}$

At the cathode,  $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$

Amount of electrons required =  $(3.69 \times 2) = 7.38 \text{ mol}$

$$Q = (7.38 \times 9.65 \times 10^4) = 7.12 \times 10^5 \text{ C}$$

$$Q = I \times t$$

$$t = \left( \frac{7.12 \times 10^5}{4.0} \right) = 1.78 \times 10^5 \text{ s}$$

$$= \left( \frac{1.78 \times 10^5}{60 \times 60} \right)$$

$$= 49.4 \text{ h}$$

**Answer: C**