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VICTORIA JUNIOR COLLEGE 2024 JC2 H2 CHEMISTRY PRELIM EXAM PAPER 1 ANSWERS

1	Α	7	ပ	13	в	19	Α	25	D	
2	В	8	Α	14	Α	20	В	26	Α	
3	В	9	С	15	С	21	D	27	D	
4	D	10	D	16	D	22	С	28	D	
5	С	11	Α	17	D	23	Α	29	D	
6	В	12	В	18	в	24	С	30	С	

# 1 A

Since there are 4 valence electrons in the Group 14 elements, the electronic configuration of the valence shell at its ground state should be ns<sup>2</sup>np<sup>2</sup>. This corresponds to the electrons with four highest energy.

# 2 B

Element X has the highest  $6^{th}$  ionisation energy, it means that the sixth electron removed from X is from its next inner shell. Hence, X has five valence electrons and X is in Group 15. As W, X, Y and Z are four consecutive elements in the Periodic Table, W is in group 14. Hence, the formula of the fluoride of W is WF<sub>4</sub>.

# 3 B (1 and 2 only)

## **Option 1: Correct**

Lone pair electrons on oxygen in CH<sub>3</sub>OCH<sub>3</sub> is donated to the vacant orbital of boron in BF<sub>3</sub> to form the dative bond.

# **Option 2: Correct**

The bond angle around B changes from  $120^{\circ}$  in BF<sub>3</sub> (3 bond pairs, trigonal planar) to  $109.5^{\circ}$  in J (4 bond pairs, tetrahedral).

## **Option 3: Incorrect**

In  $CH_3OCCH_3$ , there are 2 bond pairs 2 lone pairs around O (bent). In Q, there are 3 bond pairs and 1 lone pair around O (trigonal pyramidal).

# 4 D

### Option A: correct statement

Since O is more electronegative than N, the  $H_2O$  molecule has a greater dipole moment than the  $NH_3$  molecule, which results in stronger permanent dipolepermanent dipole (pd-pd) interactions between  $H_2O$  molecules. Hence, more energy is required to overcome the stronger pd-pd between  $H_2O$  molecules.

### **Option B: correct statement**

Since O is more electronegative than N, the hydrogen bonds formed between  $H_2O$  molecules are stronger than that between  $NH_3$  molecules. More energy is required to overcome the stronger hydrogen bonding between  $H_2O$ molecules.

### **Option C: correct statement**

The extent of hydrogen bonds is greater for  $H_2O$  (2 hydrogen bonds per molecule) than  $NH_3$  (1 hydrogen bond per molecule). Hence, more energy is required to overcome the more extensive hydrogen bonds between  $H_2O$  molecules.

# **Option D: Incorrect statement**

Energy is required to overcome the intermolecular force of attractions (hydrogen bonds) between  $H_2O$  molecules and that between  $NH_3$  molecules. Hence, the strength of O-H bonds in water and N-H bonds in  $NH_3$  does not affect the boiling points of  $H_2O$  and  $NH_3$ .

### **5 C** pV = nRT

Since V is the same for both gases,  $\frac{V}{R} = \frac{nT}{p} = constant$ 

 $\frac{n_A T_A}{p_A} = \frac{n_{D_2} T_{D_2}}{p_{D_2}} \text{ where } D_2 \text{ is deuterium gas, } {}^2H_2$ Since,  $n = \frac{m}{M_r}, \frac{m_A}{p_A M r_A} T_A = \frac{m_{D_2}}{p_{D_2} M r_{D_2}} T_{D_2}$  $\frac{18.0}{2 \times p_{D2} \times M r_A} (40 + 273) = \frac{0.6}{p_B \times 2.0 \times 2} (20 + 273)$ 

# 6

 $M_{r_{\Delta}} = 64.1$ 

Ion of V is positively charged as its ionic radius is smaller than its atomic radius. Hence, V could be Na, Mg, A*l* or Si as these elements form cations with 10 electrons.

Ion of Z is negatively charged as its ionic radius is bigger than its atomic radius. Hence, Z could be P, S or Cl as these elements form anions with 18 electrons.

## **Option A: Incorrect**

lons of V and Z have different number of full electronic shells, i.e. 2 and 3 respectively.

## **Option B: Correct**

Electronegativity increases across the period. Z has a greater electronegativity than V as Z has a greater atomic number than V in Period 3.

### **Option C: Incorrect**

lons of Z are negatively charged.

# **Option D: Incorrect**

Number of outer electrons increases across the period. V has fewer outer electrons than Z as V has a smaller atomic number than Z in Period 3.

# 7 C (1 and 3 only)

## **Option 1: Correct**

Down the group, the ionic radius increases, hence, charge density of the metal ion ( $\propto q^+/r_+$ ) decreases. The polarising power of the metal ion decreases. There is less distortion of the anionic charge cloud by the metal ion and the stability of the carbonate to heat increases.

### **Option 2: Incorrect**

Down the group, the ionic radius increases, hence, valence electrons are less strongly attracted by the nucleus and more easily lost. Reducing power of Group 2 elements increases. Hence, reaction between Group 2 elements and water becomes more vigorous down the group.

### **Option 3: Correct**

Down the group, since number of electronic shells increases, valence electrons are further away from the nucleus. Hence, there is weaker electrostatic forces of attraction between the nucleus and the valence electrons. Ability to attract shared electrons in a covalent bond towards itself decreases, so electronegativity decreases.

# 8 A

For Group 17,

 strength of covalent bonds: Cl-Cl > Br-Br > I-I. As atomic radius increases from Cl to I, the extent of orbital overlap between the halogen atoms becomes less effective, leading to weaker covalent bond between the halogen atoms.

- strength of instantaneous dipole–induced dipole interactions:  $I_2 > Br_2 > Cl_2$ . As number of electrons increases from  $Cl_2$  to  $I_2$ , the larger electron cloud size will lead to greater ease of electron cloud distortion and stronger instantaneous dipole–induced dipole interactions.
- strength of oxidising agent:  $CI_2 > Br_2 > I_2$ . Down the group, the distance between the nucleus and valence electrons increases due to increasing number of electronic shells. There is weaker electrostatic forces of attraction between the nucleus and the incoming electron and the ease of gaining electrons decreases, thus oxidising power of halogens decreases down the group.

Hence,  $X_2$  is  $I_2$  which has weaker covalent bonds than  $Y_2$  which is  $Cl_2$ .  $X_2$  ( $I_2$ ) has stronger instantaneous dipole– induced dipole forces than  $Z_2$  which is  $Br_2$ .  $Y_2$  ( $Cl_2$ ) is a stronger oxidising agent than  $Z_2$  ( $Br_2$ ).

### 9

С

Amount of Au =  $10000 \div 197 = 50.76$  mol Amount of O<sub>2</sub> required =  $50.76 \div 4 = 12.69$  mol Volume of O<sub>2</sub> required =  $12.69 \times 24 = 304.6$  dm<sup>3</sup> Volume of air required =  $304.6 \div 20\% = 1520$  dm<sup>3</sup>

### 10 D

Standard enthalpy change of formation is defined as the enthalpy change when one mole of the substance in their specific state is formed from its constituent elements in their standard states under standard conditions of 298 K and 1 bar.

### **Option A: Incorrect**

For the standard enthalpy change of formation LiCl(s), 1 mol of LiCl(s) should be formed from 1 mol of Li(s) and  $\frac{1}{2}$  mol of  $Cl_2(g)$ .

### **Option B: Incorrect**

2 mol of H<sub>2</sub>O is formed. Hence, the option represents  $2 \times \Delta H_{f}^{e}(H_{2}O)$ .

### Option C: Incorrect

For the standard enthalpy change of formation of  $C_2H_6(g)$ , 1 mol of  $C_2H_6(g)$  should be formed from 2 mol of C(s) and 3 mol of  $H_2(g)$ . Carbon should be in solid state and not gaseous state at 298 K.

### **Option D: Correct**

1 mol of NaCl(s) is formed from their constituent elements.

### 11 A

Vigorous reaction occurred shows that the reaction is spontaneous so  $\Delta G < 0$ . Temperature of the solution falls means the reaction is endothermic,  $\Delta H > 0$ .

Since  $\Delta G = \Delta H - T\Delta S$ ,  $\Delta S = (\Delta H - \Delta G)/T$ , since T > 0,  $\Delta G$  < 0 and  $\Delta H$  > 0,  $\Delta S$  must be positive.

### 12 B

The question states that time is measured when a fixed volume of  $O_2$  is produced. Hence, rate  $\propto 1$ /time. Thus, the order of the reaction with respect to  $H_2O_2$  can be determined from the  $[H_2O_2]$  against 1/time graph, which is equivalent to [reactant] against rate of the reaction graph. Thus, Option **B** is correct.

 $[H_2O_2]$  and volume of  $O_2$  are not measured at different time of the experiment to show the progress of reaction. Thus, options **A** and **C** are incorrect.

The fixed volume of  $O_2$  does not show the progress of reaction. Option **D** is incorrect.



With a decrease in the temperature, the Boltzmann distribution curve will shift to the left (as seen by the dotted line). There is a smaller number of molecules with higher energy so n at Y will be lower, while there are a larger number of molecules with lower energy, so n at X will be higher.

### 14 A

 $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$   $\Delta H < 0$  (exothermic)

Increasing the temperature shifts the position of equilibrium to the left to absorb excess heat as the backward reaction is endothermic. Hence, equilibrium yield decreases.

Adding vanadium(V) oxide as catalyst increases both the rate of forward reaction and the rate of backward reaction to the same extent. Hence, equilibrium yield is unchanged.

#### 15 C

Let x mol be the initial amount of  $N_2O_4$ .

	N <sub>2</sub> O <sub>4</sub> (g)	1	2NO2(g)
Initial / mol	х		0
Change / mol	$-\frac{1}{2}x$		+X
Eqm / mol	$\frac{1}{2} x$		Х

At equilibrium,

Total amount of gas  $= \frac{1}{2}x + x = \frac{3}{2}x$  mol Partial pressure of N<sub>2</sub>O<sub>4</sub>  $= (\frac{1}{2}x \div \frac{3}{2}x)(1.0) = \frac{1}{3}$  atm Partial pressure of NO<sub>2</sub>  $= (x \div \frac{3}{2}x)(1.0) = \frac{2}{3}$  atm

$$K_{\rm P} = \frac{({\sf P}_{\rm NO_2})^2}{{\sf P}_{\rm N_2O_4}} = (^2/_3)^2 \div (^1/_3) = ^4/_3$$
 atm

#### 16

A buffer solution maintains a fairly constant pH when small amounts of acid or base are added to it, i.e. the pH changes very slightly.

#### **Option A: Incorrect**

D

The pH of a buffer solution changes very slightly when small amounts of acid or base are added.

### **Option B: Incorrect**

The pH of a buffer solution may change significantly when very large amounts of acid or base are added. This is because not all the acid or base added can be removed by the limited amounts of buffer components.

### **Option C: Incorrect**

The pH of a buffer solution decreases very slightly when small amounts of acid are added as [H<sup>+</sup>] will increase slightly.

#### **Option D: Correct**

The pH of a buffer solution increases very slightly when small amounts of base are added as [OH<sup>-</sup>] will increase slightly.

#### 17 D (1 Only) Option 1: Correct

$$AgCl(s) \rightleftharpoons Ag^{+}(aq) + Cl^{-}(aq) \dots (1)$$
$$Ag^{+} + 2NH_{3} \rightleftharpoons [Ag(NH_{3})_{2}]^{+} \dots (2)$$

When NH<sub>3</sub>(aq) is added to AgC*l*,  $[Ag(NH_3)_2]^+$  is formed because of equilibrium (2).  $[Ag^+]$  decreases and this causes equilibrium (1) to shift to the right. AgC*l* dissolves when its ionic product <  $K_{sp}$ . However, AgI does not dissolve in NH<sub>3</sub>(aq) as its ionic product >  $K_{sp}$  due to its numerically smaller  $K_{sp}$  value than that of AgC*l*.

# **Option 2: Incorrect**

The solubility of AgCl in aqueous NH<sub>3</sub> is not affected by the affinity between NH<sub>4</sub><sup>+</sup> ions and Cl<sup>-</sup> ions.

# **Option 3: Incorrect**

Lattice energy  $\propto \frac{q^+q^-}{r^+ + r^-}$ .

The ionic charges in AgC*l* and AgI are the same. Ionic radius of  $Cl^-$  is smaller than that of I<sup>-</sup>. Hence, lattice energy of AgC*l* is numerically greater than that of AgI. The ionic bonds are stronger in AgC*l* than AgI. However, this does not explain why silver chloride is soluble in NH<sub>3</sub>(aq).

### 18



Since there are 2 chiral centres (labelled with \*) and 1 C=C bond that allows *cis-trans* isomersim, no. of stereoisomers is  $2^{2+1} = 8$ .

### 19 A

In free radical substitution, Cl radicals are formed from homolytic fission of  $Cl_2$  molecules in the initiation stage. Subsequent free radicals produced in the propagation stage are either alkyl or chlorinated alkyl radicals. Any two radicals produced at initiation or propagation stage can react together in the termination stage.

### **Option A: Correct**

Methyl radicals are first produced at the propagation stage. 2 methyl radicals can react together in the termination stage.

### **Option B: Incorrect**

This is a propagation step where free radicals are consumed but new free radicals are formed as well.

### **Options C and D: Incorrect**

Hydrogen radicals are not formed in initiation or propagation. Hence, it will not be used in termination.

### 20 B

### **Option A: Incorrect**

There are five C=C bonds and one aldehyde group in each molecule. 1 mol of 11-*cis*-retinal are reduced by 6 mol of H<sub>2</sub>(g).

### **Option B: Correct**

A condensation reaction is a type of chemical reaction in which two molecules are combined to form a single molecule, usually with the loss of a small molecule such as water. In this case, 1-cis-retinal and  $R-NH_2$  undergo condensation reaction to form rhodopsin and  $H_2O$ .

### **Option C: Incorrect**

Aldehyde can be reduced to primary alcohol. Hence, the product formed does not have a chiral centre.

# **Option D: Incorrect**

Excess hot acidified KMnO<sub>4</sub> will cleave the C=C bonds to form five products. However, HOOC–COOH formed (which are circled) will be further oxidised to CO<sub>2</sub> and H<sub>2</sub>O. Hence, there are two different organic products.



#### 21 D (3 Only) Option 1: Incorrect

 $A/Cl_3$  acts as Lewis acid catalyst (i.e. halogen carrier) to generate the strong electrophile,  $CH_3CH_2^+$  as follows.

 $AlCl_3 + CH_3CH_2Cl \rightarrow CH_3CH_2^+ + AlCl_4^-$ 

The A*l* atom in A*l*C*l*<sub>3</sub> is electron deficient as there are only six valence electrons around it. A*l* in A*l*C*l*<sub>3</sub> have energetically accessible vacant orbitals to accept a lone pair of electrons from CH<sub>3</sub>CH<sub>2</sub>C*l*. However, if water is present, A*l*C*l*<sub>3</sub> will undergo hydrolysis and the vacant orbital will be occupied so it will not be able to act as a Lewis acid catalyst.

### **Option 2: Incorrect**

 $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ 

In the above step, conc  $H_2SO_4$  functions as both a strong acid and a dehydrating agent. In the presence of water,  $H_2O$  receives the proton instead of HNO<sub>3</sub>. Thus, the strong electrophile cannot be generated.

### **Option 3: Correct**

Phenol undergoes multiple substitution with aqueous  $Br_2$  at room temperature without halogen carrier. In this reaction, orange  $Br_2(aq)$  is decolourised and a white precipitate of 2,4,6-tribromophenol is formed.

# 22 C

Formation of Cl• free radical causes the depletion to the ozone layer. F atom is smaller with a more effective overlap of the orbitals of C and F. Hence, C–F bond is stronger and it is not broken as readily as the C–C*l* bond. Fluorine radicals cannot be produced.

# 23 A

### **Option A: Correct**

5 mol of Br<sub>2</sub>(aq) is required to react with 1 mol of catechin to form the following products.



# **Option B: Incorrect**

There are 4 phenolic OH and 1 alcohol in each catechin molecule. 1 mol of catechin reacts with sodium to produce 2.5 mol of  $H_2(g)$ .

### **Option C: Incorrect**

No reaction between catechin and Na $_2CO_3$ . Alcohol and phenol are not acidic enough to liberate  $CO_2$  from Na $_2CO_3$ .

### **Option D: Incorrect**

There are 4 phenolic OH and 1 alcohol in each catechin molecule. Only the phenolic OH reacts with NaOH(aq). Hence, 1 mol of catechin reacts with 4 mol of NaOH(aq).

Orange ppt with 2,4-DNPH  $\Rightarrow$  aldehyde or ketone is present.

No ppt with I<sub>2</sub>/OH<sup>-</sup> (iodoform test)  $\Rightarrow$  CH<sub>3</sub>CO- or CH<sub>3</sub>CH(OH)- group is absent

Hydrogen gas with sodium metal  $\Rightarrow$  –OH group is present There are 5 non-cyclic constitutional isomers with the molecular formula C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>.



### 25 D

 $\begin{array}{rcl} CH_{3}CO_{2}CH_{2}CH_{2}CH_{3} + NaOH \rightarrow CH_{3}CH_{2}CH_{2}OH + \\ CH_{3}CO_{2}^{-}Na^{+} \\ M_{r} \mbox{ of } CH_{3}CH_{2}CH_{2}OH = 60.0 \\ M_{r} \mbox{ of } CH_{3}CO_{2}^{-}Na^{+} = 82.0 \\ \mbox{Percentage by mass of } CH_{3}CH_{2}CH_{2}OH \\ = \frac{60.0}{60.0 + 82.0} \times 100\% = 42.3\% \end{array}$ 

Percentage by mass of CH<sub>3</sub>CO<sub>2</sub>-Na<sup>+</sup> = 100% - 42.3% = 57.7 %

### 26 A

In compound Q, ketones can be reduced to secondary

alcohols, esters can be reduced to alcohols (as given in the question) and amide can be reduced to primary amine.



Hence, a total of three fragments are produced after the reaction of Q with  $\text{LiA}/\text{H}_4$  in dry ether.

### 27 D (2 Only) Option 1: Incorrect

The amine containing  $N_a$  is a tertiary amine. It cannot undergo condensation with ethanoyl chloride.  $N_b$  belongs to an amide functional group which will not react with ethanoyl chloride.

### **Option 2: Correct**

 $N_b$  belongs to an amide functional group. Unlike amines, amides are not basic. The lone pair of electrons on  $N_b$  is unavailable for donation to acids as it is delocalised through interaction with  $\pi$  electrons of the C=O bond. Hence  $N_a$  in the tertiary amine is protonated preferentially.

### **Option 3: Incorrect**

Both carboxylic acid groups and the amide group will be reduced by  $LiAlH_4$ . There will be a loss of three oxygen atoms from methotrexate.



#### 28 D

For electrolysis 1, oxidation of  $Cl^-$  occurs at the anode.  $2Cl^- \rightarrow Cl_2 + 2e^$  $n(Cl_2) = 100/V_m$  mol, where  $V_m$  is the molar volume at the

specific temperature and pressure.  $n(e^{-}) = 200/V_m$  mol

 $Q = 96500 \times 200/V_m$ 

 $I_1 = 96500 \times 200/V_m \div (5 \times 60)$ 

For electrolysis 2, oxidation of H<sub>2</sub>O occurs at the anode.  $2H_2O \rightarrow O_2 + 4H^+ + 4e^$   $n(O_2) = 200/V_m = (300I)/(96500) \text{ mol}$   $n(e^-) = 800/V_m \text{ mol}$   $Q = 96500 \times 800/V_m$   $I_2 = 96500 \times 800/V_m \div (5 \times 60)$ Hence,  $I_2 = 4I_1$ 

### 29 D (1 only)

When left to stand in the atmosphere,  $O_2$  in the atmosphere will be involved in the reaction, if any.  $O_2$  can only be reduced to either  $H_2O$  in acidic medium or  $OH^-$  in alkaline or neutral medium.

### **Option 1: Correct**

A solution of potassium hexacyanoferrate(III),  $K_3[Fe(CN)_6]$  contains  $[Fe(CN)_6]^{3-}$  ion. It can only be reduced since oxidation number of Fe is +3. It cannot react with O<sub>2</sub>.  $[Fe(CN)_6]^{3-}$  is stable in air.

### **Option 2: Incorrect**

A solution of chromium(II) chloride,  $CrCl_2$  contains  $Cr^{2+}$  and  $Cl^-$  ions.

 $\begin{array}{ll} Cr^{3+} + e^- \rightleftharpoons Cr^{2+} & E^{\oplus} = -0.41 \text{ V} \\ Cl_2 + 2e^- \rightleftharpoons 2Cl^- & E^{\oplus} = +1.36 \text{ V} \\ O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^- & E^{\oplus} = +0.40 \text{ V} \\ \text{For oxidation of } Cr^{2+} \text{ with } O_2, \end{array}$ 

 $E^{\circ}_{cell} = +0.40 - (-0.41) = +0.81 \text{ V} > 0$ , i.e. redox reaction is feasible between  $O_2$  and  $Cr^{2+}$ . Hence,  $CrCl_2$  is not stable in air.

## **Option 3: Incorrect**

A mixture of aqueous sodium hydroxide, NaOH and iron(II) sulfate, FeSO<sub>4</sub> forms  $Fe(OH)_2$  precipitate. For oxidation of  $Fe(OH)_2$ :

 $\begin{array}{l} \mathsf{Fe}(\mathsf{OH})_3 + \mathrm{e}^- \rightleftharpoons \mathsf{Fe}(\mathsf{OH})_2 + \mathsf{OH}^- \ E^{\mathrm{o}} = -0.56 \ \mathsf{V} \\ \mathsf{O}_2 + 2\mathsf{H}_2\mathsf{O} + 4\mathrm{e}^- \rightleftharpoons 4\mathsf{OH}^- \qquad E^{\mathrm{o}} = +0.40 \ \mathsf{V} \\ E^{\mathrm{o}}_{\mathrm{cell}} = +0.40 - (-0.56) = +0.96 \ \mathsf{V} > 0, \ \text{i.e. redox reaction} \\ \text{is feasible between Fe}(\mathsf{OH})_2 \ \text{and } \mathsf{O}_2 \ \text{to form Fe}(\mathsf{OH})_3 \\ \mathsf{Fe}(\mathsf{OH})_2 \ \text{is not stable in air.} \end{array}$ 

### 30 C

Ligands are molecules or anions that have at least one lone pair of electrons which can be used for forming dative bond with a transition metal atom or ion.  $A/H_4^-$  does not have lone pair electrons and hence cannot act as a ligand to form complexes.