#### VICTORIA JUNIOR COLLEGE 2023 JC2 PRELIMINARY EXAMINATION H2 CHEMISTRY PAPER 1 ANSWERS

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

#### 1 D

	No of	No of e⁻	No of
	protons		neutrons
A: Wrong	13	13	27 – 13
For ${}^{27}_{13}Al$			= 14
B: Wrong	17	17 + 1	35 – 17
For <sup>35</sup> <sub>17</sub> C <i>l</i> <sup>-</sup>		= 18	= 18
C: Wrong	16	16 + 2	32 – 16
For <sup>32</sup> <sub>16</sub> S <sup>2–</sup>		= 18	= 16
D: Correct	19	19 – 1	39 – 19
For <sup>39</sup> / <sub>10</sub> K <sup>+</sup>		= 18	= 20

# 2 C

Since central C atom is sp hybridised and there are no unpaired electrons,  $C_2O$  molecule has the following structure:

:c==c==o:

Hence, C<sub>2</sub>O has 3 lone pairs of electrons.

# 3 B (1 and 2 only)

# Option 1: Correct

It shows the structure of diamond which has a giant molecular structure.

# **Option 2: Correct**

It shows the structure of graphite which has a layered giant molecular structure.

# **Option 3: Wrong**

Sodium chloride has a giant ionic structure.

#### **Option 4: Wrong**

lodine has a simple molecule structure. The molecules are held by weak intermolecular forces of attraction. It has a solid lattice structure.

# 4 C

PV = nRT $PV = (m/M_r)RT$ 

$$M_{\rm r} = {\rm mRT/(PV)}$$

Given the same mass of gases in the identical flasks of same volume, hence, m, V and R are constant,  $M_{\rm r} \propto {\rm T/P}$ 

For gas <b>E</b>	For gas <b>F</b>	For gas <b>G</b>
$M_{ m r} \propto t/ m p$	<i>M</i> <sub>r</sub> ∝ t/2p	$M_{ m r} \propto 2t/ m p$

Hence,  $M_r(\mathbf{G}) > M_r(\mathbf{E}) > M_r(\mathbf{F})$ 

# 5 A

# **Option A: Correct**

Real gases behave less ideally at high pressure. At high pressure, real gases behave less ideally as the gas particles are close to each other and size of the particle is not negligible.

#### **Option B: Wrong**

Real gases behave more ideally at high temperature. Intermolecular forces of attraction is negligible at high temperature since gas particles have sufficient kinetic energy to overcome it.

#### **Option C: Correct**

The presence of a catalyst increases the rates of both the forward and backward reactions. It does not have any effect on the ideal behaviour of gas.

#### **Option D: Wrong**

D

Strong covalent bonds between the nitrogen atoms does not explain if the gas is behaving ideally. We should consider the intermolecular attractions between the molecules instead.

#### 6

For element X: Chloride and oxide dissolve to give strong acidic solution  $\Rightarrow$  P or S For element Y: Low conductivity at room temperature  $\Rightarrow$  Si Only 1 chloride with formula SiC $l_4 \Rightarrow$  Si Chloride dissolves giving acid solution  $\Rightarrow$  Si For element Z: Chloride and oxide have high m.p.  $\Rightarrow$  Na or Mg Oxide reacts readily in water  $\Rightarrow$  Na Chloride dissolves giving neutral solution  $\Rightarrow$  Na

# 7

Α

Down Group 2, charge density of cation ( $\propto q^+/r^+$ ) decreases, causing the polarising power of cation to decrease. As a result, there is less distortion (or polarisation) of the anionic charge cloud and so the iodate becomes more stable to heat down the group. This means that iodate is decomposed at a higher temperature.

With the mass of  $Q(IO_3)_2$  being unchanged with time upon heating, that means  $Q(IO_3)_2$  is the most stable to heat. While  $P(IO_3)_2$  is decomposed at a faster rate than  $R(IO_3)_2$ , meaning that  $P(IO_3)_2$  is the least stable to heat.

Hence, order of the Group 2 elements: P, R, Q

# **Option A: Correct**

Down the group, nuclear charge increases. However, the distance between the nucleus and the valence electrons increases due to an increase in number of electron shells. This results in weaker attraction between the nucleus and the valence electrons, less energy is required to remove the valence electron and first ionisation energy (IE) decreases down the group.

Hence, order of first IE of Group 2 elements: P, R, Q, with P having the most endothermic first IE.

#### **Option B: Wrong**

Down the group, with the weaker attraction between the nucleus and the valence electrons, valence electrons are more readily lost and hence reducing strength increases down the group.

Hence, order of reducing power (reactivity) of Group 2 elements: P, R, Q.

Q being the most reactive among all, reacts the most readily with water to give hydrogen gas.

#### **Option C: Wrong**

Melting point of an ionic solid depends on the strength of ionic bond, which is measured by lattice energy as follows:

|Lattice Energy|  $\alpha \left| \frac{q_+ \times q_-}{r_+ + r_-} \right|$ 

Since size of Group 2 cations increases down the group, with P<sup>2+</sup> having the smallest cationic size,  $P(IO_3)_2$  has the most endothermic lattice energy and highest melting point.

#### **Option D: Wrong**

All Group 2 oxides are basic, hence they will react with acids to form salts.

# 8

#### D **Option A: Wrong**

Astatine has more electron shells than bromine. The orbital overlap between hydrogen and astatine atoms will be less effective than the orbital overlap between hydrogen and bromine atoms. Therefore, the bond strength of H-At will be weaker than H-Br implying a lower decomposition temperature.

#### **Option B: Wrong**

Going down Group 17, the oxidising power of halogen decreases. As such, At<sub>2</sub> will not be able to oxidise I<sup>-</sup> to I<sub>2</sub>, which is a brown solution.

# **Option C: Wrong**

Going down Group 17, the solubility product of silver halides decreases. Since the position of astatine is below iodine in the periodic table, when NH<sub>3</sub>(aq) is added, the ionic product of silver astatide will still exceed its solubility product, making silver astatide insoluble in NH<sub>3</sub>(aq).

# **Option D: Correct**

Going down Group 17, the melting point increases due to the stronger instantaneous dipole-induced dipole interactions between the non-polar halogen molecules. Since At<sub>2</sub> has a higher melting point than I<sub>2</sub> which exists as solid at room temperature, At<sub>2</sub> should exist as solid as well.

#### 9 D

Oxidation half equation:  $Tl^+ \rightarrow Tl^{3+} + 2e ---(1)$ Reduction half equation:  $6H^+ + VO_3^- + 3e \rightarrow V^{2+} + 3H_2O ----(2)$ Hence, overall redox equation:  $(1) \times 3 + (2) \times 2$  gives  $3Tl^{+} + 12H^{+} + 2VO_{3}^{-} \rightarrow 3Tl^{3+} + 2V^{2+} + 6H_{2}O_{3}^{-}$ 

Since only VO3- is present at the end of the reaction,  $Tl^+$  is the limiting reagent.

At the end of the reaction, let the amount of VO3- $(aq) = amount of V^{2+}(aq) = a$ 

	3T <i>l</i> + +	2VO <sub>3</sub> - + .	$\dots \rightarrow i$	3T <i>l</i> <sup>3+</sup> +	- 2V <sup>2+</sup> +
I / mol	3a/2	2a			0
C / mol	-3a/2	–а			+a
E / mol	0	а			а

Hence, at the start of the reaction,

amount of Tl+ : amount of VO3-

= 3a/2 : 2a

= 3:4

3 mol of Tl<sup>+</sup> and 4 mol of VO<sub>3</sub><sup>-</sup> are required at the start.

#### 10 В

 $Na(g) \rightarrow Na^{+}(g) + e^{-}$  $\Delta H = W = 1^{\text{st}} \text{IE}$ 

 $Na(g) \rightarrow Na^{2+}(g) + 2e^{-}$  $\Delta H = x$  $\Delta H = x = 1^{st} IE + 2^{nd} IE = w + 2^{nd} IE$ Hence,  $2^{nd}$  IE = x - w (Option B)

# OR

 $Na(s) \rightarrow Na(g)$  $\Delta H = y =$  enthalpy change of atomisation

 $Na(s) \rightarrow Na^{2+}(g) + 2e^{-}$ 

 $\Delta H = z =$  enthalpy change of atomisation + 1<sup>st</sup> IE + 2<sup>nd</sup> IE

 $2^{nd}$  IE = z – enthalpy change of atomisation –  $1^{st}$  IE = z - y - w (This option is not given)

#### 11 С

# **Option A: Wrong**

Six water ligands have been displaced by one edta ligand. As the number of free ligands increases, entropy also increases.

#### **Option B: Wrong**

When gases are mixed at constant pressure, the volume of the mixture increases, leading to more ways to arrange particles. Hence, entropy increases.

#### **Option C: Correct**

A decrease in temperature of liquid ethanol decreases entropy.

# **Option D: Wrong**

A change in state from solid to gas (sublimation) should result in an increase in entropy.

# 12 D

# **Option A: Wrong**

Since the gradient of tangent at t = 0 min (initial rate) increases by two times when the initial [Y] doubles, the reaction is first order wrt Y.

Since the  $t_{1/2}$  of **X** is constant at 20 min, the reaction is first order wrt **X**.

Hence, rate = k[X][Y] and the unit of k is  $mol^{-1} dm^{3} min^{-1}$ .

# **Option B: Wrong**

Based on the rate equation, 1 molecule of **X** and 1 molecule of **Y** are involved in the slow step of the mechanism. The reaction will mostly likely proceed in more than one step as follows:

 $X + Y \rightarrow D$  (slow)

#### $\mathbf{X} + \mathbf{D} \rightarrow \mathbf{Z}$

where **D** is an intermediate Hence, the reaction does not proceed via a single-step mechanism.

# **Option C: Wrong**

rate = k[X][Y], since Y is in excess, hence rate = k'[X] where k' = k[Y]  $t_{1/2} = \frac{\ln 2}{k'} \rightarrow t_{1/2} = \frac{\ln 2}{k[Y]}$ Hence, when [Y] doubles,  $t_{1/2}$  is halved.

# **Option D: Correct**

Since  $t_{1/2} = \frac{\ln 2}{k[Y]}$ , when **[X]** doubles,  $t_{1/2}$  remains the same.

#### 13 B (1 and 2 only) Option 1: Correct:

As temperature increases, since the average kinetic energy of the molecules increases, the fraction of molecules having energy above the activation energy increases.

#### **Option 2: Correct**

As temperature increases, since the average kinetic energy of the molecules increases, there will be more molecules having higher energy and hence the maximum of the curve is displaced to the right.

#### **Option 3: Wrong**

As temperature increases, there will be more molecules having higher energy and lesser molecules having lower energy. Hence, the proportion of molecules of a particular energy does not increase at all energies.

# 14 B

At initial equilibrium,  $K_c = [\mathbf{Y}]/[\mathbf{W}]^2[\mathbf{X}]$   $= (2.00)/(2.00)^2(1.00)$ = 0.50 Assuming z mol of  $\mathbf{Y}$  is added to the equilibrium mixture.

$2W(aq) + X(aq) \Rightarrow Y(aq)$						
Initial conc.	2.00	1.00	2.00 + z			
/ mol dm <sup>-3</sup>						
Change in conc.	+2(0.20)	+0.20	-0.20			
/ mol dm <sup>-3</sup>						
Eqm Conc.	2.40	1.20	1.80 + z			
/ mol dm <sup>-3</sup>						

For the new equilibrium,

С

 $K_c = (1.80 + z) / [(2.40)^2(1.20)] = 0.50$ z = 1.66 mol dm<sup>-3</sup> Since it is 0.50 dm<sup>3</sup> solution, therefore the amount added = (1.66)(0.50) = 0.83 mol

# 15

Upon adding water,  $[H^+] = 10^{-3.2} \text{ mol dm}^{-3}$ Using  $K_a = 1.80 \times 10^{-5}$   $= [H^+]^2/[CH_3CO_2H]$   $1.80 \times 10^{-5} = (10^{-3.2})^2/[CH_3CO_2H]$  $[CH_3CO_2H] = 0.0221 \text{ mol dm}^{-3}$ 

Upon dilution, no. of moles of CH<sub>3</sub>COOH remains unchanged.  $0.0221V = 10 \times 0.100$  $V = 45.2 \text{ cm}^3$ 

Hence, vol. of the final solution with water added =  $45.2 \text{ cm}^3$ 

Vol. of water added = 45.2 - 10=  $35.2 \text{ cm}^3$ 

# 16 B

A buffer is comprised of a weak acid and its conjugate base or a weak base and its conjugate acid.

# **Option A: Wrong**

HCl is a strong acid. HCl and its conjugate base cannot form a buffer solution.

# **Option B: Correct**

 $H_2PO_4^-$  is a weak acid.  $HPO_4^{2-}$  is the conjugate base of  $H_2PO_4^-$ . They can form a buffer solution.

#### **Option C: Wrong**

NaOH is a strong base and it cannot form a buffer solution with NaC*l*.

# **Option D: Wrong**

When 1 mol of  $H_2PO_4^-$  is reacted completely with 1 mol of NaOH,  $HPO_4^{2-}$  is formed. It is a weak acid solution but a buffer solution.

17 C

When  $ZnF_2$  is shaken with water to obtain a saturated solution *L*,

$$\begin{split} &ZnF_2(s) \rightleftharpoons Zn^{2+}(aq) + 2F^{-}(aq) \\ &Let the solubility of ZnF_2 be x mol dm^{-3} \\ &At eqm (when the saturated solution$$
*L* $is formed), \\ &[Zn^{2+}] = x mol dm^{-3}, [F^{-}] = 2x mol dm^{-3} \\ &K_{sp} of ZnF_2 = [Zn^{2+}][F^{-}]^2 \\ &= x(2x)^2 \\ &= 3.20 \times 10^{-2} \\ &4x^3 = 3.20 \times 10^{-2} \\ &x = 0.200 mol dm^{-3} \\ &Hence, [F^{-}] at saturated solution L \\ &= 4.00 \times 10^{-1} mol dm^{-3} \end{split}$ 

When Ba<sup>2+</sup> is added dropwise to *L* containing  $4.00 \times 10^{-1}$  mol dm<sup>-3</sup> of F<sup>-</sup>, BaF<sub>2</sub> just ppt out when ionic product of BaF<sub>2</sub> >  $K_{sp}$  of BaF<sub>2</sub> [Ba<sup>2+</sup>][F<sup>-</sup>]<sup>2</sup> > 1.60 × 10<sup>-7</sup> [Ba<sup>2+</sup>][4.00 × 10<sup>-1</sup>]<sup>2</sup> > 1.6 × 10<sup>-7</sup> [Ba<sup>2+</sup>] > 1.00 × 10<sup>-6</sup> mol dm<sup>-3</sup>

Hence, [Ba<sup>2+</sup>] when BaF<sub>2</sub> just precipitates is  $1.00 \times 10^{-6}$  mol dm<sup>-3</sup>.

#### 18 D

# (A) $\sigma$ bond formed by 1s-2sp overlap H-C=C-CH<sub>3</sub> $\rightleftharpoons$ H<sub>2</sub>C=C=CH<sub>2</sub> (C) sp hydridised carbons

Option **D** is wrong as the C–C single bond in propyne is formed by sp-sp<sup>3</sup> overlap, while that in propane (CH<sub>3</sub>–CH<sub>2</sub>–CH<sub>3</sub>) is formed by sp<sup>3</sup>-sp<sup>3</sup> overlap. The bond length in propyne is shorter as sp orbital has more s character, resulting in more effective overlap.



There are three chiral centres in the molecules as indicated by  $\bigcirc$ No of stereoisomers: 2<sup>3</sup>=8 isomers

#### 20 C

Prop-1-ene reacts with BrC*l* in pure CH<sub>3</sub>OH via electrophilic addition as illustrated in the following steps:



electrophilic addition of  $H_2O$  to propene.



Once the strong electrophile (a carbocation) is formed, it will undergo electrophilic substitution with the benzene.



#### 22 A Option A: Correct

The primary chloroalkane undergoes  $S_N2$  reaction, resulting in the inversion of the spatial configuration of the product from that of the starting organic molecule. Since  $S_N2$  occurs with 100% inversion, the product formed will therefore contain a single enantiomer and not a racemic mixture.

#### **Option B: Wrong**

The tertiary chloroalkane undergoes  $S_N1$  reaction, forming a carbocation intermediate. The OH<sup>-</sup> can then attack the planar carbocation intermediate with equal probability from top and bottom, forming a racemic mixture with two enantiomers.

#### **Option C: Wrong**

CN<sup>-</sup> attacks the planar ketone via nucleophilic addition with equal probability from top and bottom, forming a racemic mixture with two enantiomers.

#### **Option D: Wrong**

The alkene undergoes electrophilic addition, forming planar carbocation intermediate. Br- can then attack the carbocation intermediate with equal probability from top and bottom, forming a racemic mixture with two enantiomers.

# 23 C

**Option A: Wrong** 

There are 4 phenol functional group in Z. Thus, 1 mol of Z reacts with 4 mol of NaOH(aq).

# **Option B: Wrong**

There are 4 phenol functional group and 1 alcohol functional group in Z. 1 mol of Z reacts with 5 mol of sodium to produce 2.5 moles of  $H_2(g)$ .

# **Option C: Correct**



Promote to  $\dot{O}H_{constrainty}$  with  $D_{12}(aq)$  and electrophilic substitution to form 2,4,6-tribromophenol. Hence, when 1 mol of compound Z reacts with  $Br_2(aq)$ , Br can substitute the H atoms labelled a, b, d, e and f. Hence, 1 mol of Z reacts with 5 mol of  $Br_2(aq)$ .

# **Option D: Wrong**

Only alcohol and not phenol will react with  $PCl_5$  to form HCl gas. Hence, 1 mol of **Z** will react with 1 mol of  $PCl_5$  to form 1 mol of HCl gas.

# 24 A



# 25 B (1 and 3 only)

Compound **Y** has the following functional groups: alkene, aldehyde and chloroalkane

Compound **Z** has the following functional groups: secondary alcohol and amide

# **Option 1: Correct**

2,4-DNPH reacts with aldehydes and ketones to give an orange ppt. Compound **Y** containing aldehyde will give an orange ppt while compound **Z** will not.

# **Option 2: Wrong**

Hot acidified  $Cr_2O_7^{2-}$  can oxidise primary alcohols, secondary alcohols and aldehydes. Compound **Y** will get oxidised as it contains an aldehyde. Compound **Z** will also get oxidised as it contains a secondary alcohol.

# **Option 3: Correct**

Hot aqueous NaOH can react with halogenoalkanes, esters, amides and nitriles. Compound **Y** containing chloroalkane will react via nucleophilic substitution to give  $Cl^-$  but this does not give an observable change unless aqueous AgNO<sub>3</sub> is added. Compound **Z** containing amide reacts via hydrolysis to form gaseous NH<sub>3</sub> which can be detected with moist red litmus paper turning blue.

#### 26 B (2 and 4 only) Option 1: Wrong

The surface area decreases from primary (elongated) to secondary to tertiary alcohol (spherical). Hence strength of instantaneous dipole-induced dipole interactions decreases from primary to secondary to tertiary alcohols, leading to decreasing boiling points.

# **Option 2: Correct**

 $CH_3CH_2COCl$  hydrolyses in water to produce a strong acid, HCl. Hence the pH of its aqueous solution is the lowest.  $CH_3CH_2CONH_2$  contains an amide functional group which is neutral.  $CH_3CH(Cl)CH_2NH_2$  contains an amine functional group which is basic and hence its pH value is the highest.

# **Option 3: Wrong**

The carbonyl C in CH<sub>3</sub>COC*l* is bonded to the highly electronegative O and C*l* atoms, making it highly electron deficient due to the electron-withdrawing inductive effect of the two atoms. Hence, it is more susceptible to nucleophilic attack in hydrolysis than CH<sub>3</sub>CH<sub>2</sub>C*l* and C<sub>6</sub>H<sub>5</sub>C*l*. Due to the partial double bond character of C–C*l* bond in C<sub>6</sub>H<sub>5</sub>C*l*, C<sub>6</sub>H<sub>5</sub>C*l* hydrolyses the least readily.

# **Option 4: Correct**

Acidity decreases from ethanoic acid to phenol to ethanol.

Ethanoic acid is the strongest acid among the three, hence its conjugate base, ethanoate ion will be the weakest, with the largest  $pK_b$  value.

Ethanol is the weakest acid among the three, hence its conjugate base, ethoxide ion will be the strongest, with the smallest  $pK_b$  value.

# 27

R

Since there are five peptides, 4 mol is needed for the hydrolysis.

 $M_{\rm r}$  of **X** + 4 × 18 = 2 × 75 + 89 + 2 × 105  $M_{\rm r}$  of **X** = 377

#### **28 C** (2 and 3 only) $Cu^{2+} + 2e^{-} \Rightarrow Cu$ $E^{\circ} = +0.34 \text{ V}$ $Cr_2O_7^{2-} + 14H^+ + 6e^{-} \Rightarrow 2Cr^{3+} + 7H_2O$ $E^{\circ} = +1.33 \text{ V}$

 $Cr_2O_7^{2-}/Cr^{3+}$  half-cell undergoes reduction due to the more positive  $E^0$  value while  $Cu^{2+}/Cu$  half-cell undergoes oxidation.

 $E^{o}_{cell} = E^{o}_{red} - E^{o}_{ox}$ = 1.33 - 0.34 = +0.99 V

#### **Option 1: Wrong**

E.m.f of the electrochemical cell is not affected by the increase in surface area of the Cu electrode.

#### **Option 2: Correct**

Excess NH<sub>3</sub>(aq) added will decrease [Cu<sup>2+</sup>] as Cu<sup>2+</sup> will form a complex ion with NH<sub>3</sub>. As such, position equilibrium of Cu<sup>2+</sup> + 2e<sup>-</sup>  $\rightleftharpoons$  Cu will shift left, oxidation of Cu is favoured and  $E^{o}_{ox}$  becomes less positive, leading to an increase in e.m.f of cell.

#### **Option 3: Correct**

Adding dilute H<sub>2</sub>SO<sub>4</sub> to Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup>/Cr<sup>3+</sup> half-cell will increase [H<sup>+</sup>], position of equilibrium of Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> + 14H<sup>+</sup> + 6e<sup>-</sup>  $\Rightarrow$  2Cr<sup>3+</sup> + 7H<sub>2</sub>O will shift right, reduction of Cr<sub>2</sub>O<sub>7</sub><sup>2-</sup> is favoured and *E*<sup>o</sup><sub>red</sub> becomes more positive, leading to an increase in e.m.f of cell.

#### 29 A

Ligand needs to have a lone pair.  $NH_{4^+}$  does not have a lone pair and thus it does not act as a ligand.

# 30 A

#### **Option A: Wrong**

The complex does not contain five ligands. There is only one polydentate ligand.

#### **Option B: Correct**

The ligand carries two O<sup>-</sup>, as such, manganese exists as  $Mn^{2+}$  in the complex as the complex is electrically neutral. Oxidation number of manganese in this complex is +2.

# **Option C: Correct**

As there are five dative covalent bonds formed into the  $Mn^{2+}$  ion, the coordination number is 5.

# **Option D: Correct**

 $Mn^{2+}$ : [Ar]3d<sup>5</sup>. The two 4s electrons have been removed in the formation of  $Mn^{2+}$  from Mn, resulting in 5 unpaired 3d electrons in manganese in this complex.