2021 EJC JC2 Prelim Exam H2 Chemistry 9729 Paper 1 Worked Solution

- **1** A × $1s^2 2s^2 2p^3 \rightarrow 1s^2 2s^2$ (not octet)
 - $B\checkmark$ 1s² 2s² 2p⁶ 3s² 3p¹ \rightarrow 1s² 2s² 2p⁶ (octet)
 - $\label{eq:constraint} \begin{array}{l} {\rm C} {}^{\scriptstyle \times} {} \ 1 {s}^2 \ 2 {s}^2 \ 2 {p}^6 \ 3 {s}^2 \ 3 {p}^6 \rightarrow 1 {s}^2 \ 2 {s}^2 \ 2 {p}^6 \ 3 {s}^2 \ 3 {p}^3 \\ (not \ octet) \end{array}$
 - **D**× [Ar] $3d^2 4s^1$ (not ground state; ground state is [Ar] $3d^1 4s^2$) \rightarrow [Ar] (octet)

 \Rightarrow B

2		$^{1}_{1}H_{3}^{16}_{8}O^{+}$	${}^{2}_{1}H_{3} {}^{16}_{8}O^{+}$	${}^{2}_{1}H_{2} {}^{16}_{8}O$	¹⁶ ₈ O ¹ ₁ H⁻			
	р	1×3+8 =11	$\begin{array}{r} 1 \times 3 + 8 \\ = 11 \end{array}$	$1 \times 2 + 8 = 10$	8 + 1 = 9			
	е	$1 \times 3 + 8 - 1$ = 10	$1 \times 3 + 8 - 1$ = 10	$1 \times 2 + 8 = 10$	8+1+1 =10			
	n	$0 \times 3 + 8 = 8$	$1 \times 3 + 8 = 11$	$1 \times 2 + 8 = 10$	8 + 0 = 8			

 $\Rightarrow \mathbf{A}$

3 ${}_{n}\mathbf{R}$ gains 1 electron to form stable ${}_{n}\mathbf{R}^{-}$, which has (n+1) electrons $\Rightarrow \mathbf{R}$ is in Group 17.

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

- **A**✓ Since ${}_{n}\mathbf{R}^{-}$ and ${}_{n+2}\mathbf{S}^{+}$ are isoelectronic, ${}_{n+2}\mathbf{S}^{+}$ with a higher nuclear charge will have a smaller ionic radius as the effective nuclear charge experienced by the valence ers is higher.
- $$\begin{split} \mathbf{B}^{\mathbf{x}} & _{n}\mathbf{R}^{-} + e^{-} \rightarrow _{n}\mathbf{R}^{2^{-}} \text{ will be endothermic} \\ & \text{due to repulsion of the incoming } e^{-}; \\ & _{n+2}\mathbf{S}^{+} + e^{-} \rightarrow _{n+2}\mathbf{S} \text{ will be exothermic} \\ & \text{due to attraction of the incoming } e^{-}. \end{split}$$
- C× 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.
- $$\begin{split} \mathbf{D}^{\mathbf{x}} & _{n+2}\mathbf{S}^{+} e^{-} \rightarrow {}_{n+2}\mathbf{S}^{2+} & \text{will be more} \\ & \text{endothermic than} & _{n}\mathbf{R}^{-} e^{-} \rightarrow {}_{n}\mathbf{R} \\ & \text{since the } e^{-} \text{ is being removed from} \\ & \text{positively charged} & _{n+2}\mathbf{S}^{+} \,. \end{split}$$

 $\Rightarrow \mathbf{A}$

- 4 A× Polar single covalent bonds involves unequal sharing of bonding electrons.
 - B× Single covalent bonds are also formed in atoms without a complete octet, *e.g.* BF₃ with 6 outer shell electrons around B, or with an expanded octet, *e.g.* PF₅ with 10 outer shell electrons around P.
 - **C** × H–H bond (436 kJ mol⁻¹) is stronger than H–C*l* bond (431 kJ mol⁻¹)
 - **D**✓ Due to the larger s-character of sp² hybridised C (33%) compared to sp³ hybridised C (25%), the bonding electrons are closer to the nucleus (s orbitals are closer to nucleus than p orbitals). Hence, the C_{sp^2} -H bond is

stronger than a C_{so³}-H bond.

5 1× There are no H bonded to F, O or N in cinnamaldehyde ⇒ no H bonds between cinnamaldehyde molecules.

2√ The non-polar chain

- of cinnamaldehyde can form strong instantaneous dipole-induced dipole solvent-solute interactions with the non-polar hydrocarbon parts of organic solvents.
- $3\checkmark$ All carbon atoms in cinnamaldehyde are sp² hybridised, thus all the bond angles are the same at 120°.

⇒₿

- **5** $A \times S_2O_3^{2-}$ to $S_4O_6^{2-}$ is an oxidation as the oxidation number of S increases from +2 to +2.5.
 - $\begin{array}{l} \textbf{B} \checkmark \ Br_2 \ \text{is unable to oxidise } C \mathcal{L}. \ \text{Hence} \\ Br_2(g) \ \text{dissolves in water to give orange} \\ Br_2(aq). \end{array}$
 - C× Although Cl₂ molecules possess lone pairs on Cl. However, Cl is not sufficiently electronegative (F, O or N) to form H bonds with the H in water.
 - D× Volatility is related to the ease to vaporisation, which has to do with overcoming intermolecular forces of attraction, and not breaking of covalent bonds.

 $\Rightarrow \mathbf{B}$

- 7 A ✓ NH₃ + H₂O ⇒ NH₄⁺ + OH⁻ (Brønsted-Lowry acid-base reaction)
 - $B \checkmark NH_3 + BH_3 \rightarrow H_3N \rightarrow BH_3$ (Lewis acidbase reaction)
 - **C** ✓ $AlCl_3 + Cl_2 \rightleftharpoons [Cl \rightarrow AlCl_3]^- + Cl^+$ (Lewis acid-base reaction)
 - $D \times$ Both A*l*C*l*₃ and BH₃ are electrondeficient species, capable of acting as Lewis acids only.

 \Rightarrow D

8 A×
$$n_{O_2} = \frac{24 \text{ dm}^3}{24 \text{ dm}^3 \text{ mol}^{-1}} = 1 \text{ mol}$$

no. of O atoms = 1 mol × 2 × $N_A = 2N_A$

$$\mathbf{B} \times n_{Cl_2} = \frac{(1.5 \times 101325) \times (1 \times 10^{-3})}{8.31 \times 273}$$

= 0.0670 mol
no. of Cl₂ molecules = 0.670 mol × N_A
= 0.670 N_A

C ✓
$$n_{\text{CasO}_4} = \frac{68.05}{40.1 + 32.1 + 16.0 \times 4}$$

= 0.500 mol

$$CaSO_4 \rightarrow Ca^{2+} + SO_4^2$$

no. of ions = 0.500 mol $\times 2 \times N_{\rm A}$ = 1.00 $N_{\rm A}$

D×
$$n_{C_2H_4} = \frac{22.7 \text{ dm}^3}{22.7 \text{ dm}^3 \text{ mol}^{-1}} = 1 \text{ mol}$$

no. of C atoms = 1 mol \times 2 \times N_{A} = 2 N_{A}

 \Rightarrow C

9 pH of the period 3 chloride in water:

 10 A× 6 P–P bonds are broken. So

 $\Delta H_{\rm r} = \frac{1}{4} (6 \times \text{B.E.}(\text{P-P})) = \frac{3}{2} \text{B.E.}(\text{P-P})$

- B✓ Phosphorus exists as P₄(s) under standard condition.
- **C**× Phosphorus exists as P₄(s) under standard condition.

 \Rightarrow B

11
$$\Delta H = \Delta G + T \Delta S = +3.08 + 298 \times \frac{-3.3}{1000}$$

= +2.10 kJ mol⁻¹

- 2× Graphite is more stable than diamond. C–C bonds in graphite are stronger than in diamond.
- 3× Since ∆S is negative, -T∆S is always positive. Hence ∆G increases (less spontaneous) with temperature.

 $\Rightarrow \mathbf{A}$

12 Since [A]≪[B],

rate = k'[A], where k' = k[B]

$$t_{\frac{1}{2}} = \frac{\ln 2}{k'} = \frac{\ln 2}{k[B]}$$

When [B] is doubled, $t_{\underline{1}}$ will be halved.

 \Rightarrow B

- 13 1√ Enzymes provide an alternative pathway with a lower activation energy.
 - 2√ When [substrate] is low, there are available active sites for additional substrate molecules to bind to. Hence, rate ∞ [substrate].
 - When [substrate] is high, all active sites are occupied. No available active sites for additional substrate molecules to bind to. Hence rate is constant.

 \Rightarrow B

14 Given
$$K_c = \frac{[C]^2}{[A]^2[B]} = x$$

For the new equilibrium,

$$\mathcal{K}_{c}' = \frac{[A][B]^{2}}{[C]} = \frac{1}{\frac{[C]}{[A][B]^{\frac{1}{2}}}} = \frac{1}{\left(\frac{[C]^{2}}{[A]^{2}[B]}\right)^{\frac{1}{2}}} = \frac{1}{\sqrt{x}}$$

 \Rightarrow C

- 15 1✓ ↓ing the volume ↑es the concentration of the reactants and products, leading to ↑ in rates of both the forward and backward reactions.
 - 2× adding a noble gas at constant pressure will ↓ the partial pressure of all components ⇒ eqm shifts to the side with more gaseous particles.
 - 3× Equilibrium constants are only affected by changes in temperature.

16
$$n_{\text{NaOH}} = \frac{20}{1000} \times 0.500 = 0.0100 \text{ mol}$$

 $n_{\text{CH}_{3}\text{CO}_{2}\text{H}} = \frac{20}{1000} \times 1.00 = 0.0200 \text{ mol}$
 $\text{CH}_{3}\text{CO}_{2}\text{H} + \text{NaOH} \rightarrow \text{CH}_{3}\text{CO}_{2}\text{Na} + \text{H}_{2}\text{O}$
 $[\text{CH}_{3}\text{CO}_{2}\text{H}] = \frac{0.0200 - 0.0100}{20 + 20} = 0.250 \text{ mol dm}^{-3}$
 $[\text{CH}_{3}\text{CO}_{2}\text{Na}] = \frac{0.0100}{20 + 20} = 0.250 \text{ mol dm}^{-3}$
 $p\text{H} = pK_{a} + lg \frac{[\text{CH}_{3}\text{CO}_{2}\text{Na}]}{[\text{CH}_{3}\text{CO}_{2}\text{H}]} = -lg(1.8 \times 10^{-5}) = 4.74$

17 Given solubility of AgCl and AgBr are x and y mol dm⁻³ respectively,

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

In a solution saturated with **both** AgCl and AgBr, let the solubility of AgCl and AgBr be x' and y' mol dm⁻³ respectively.

$$\begin{bmatrix} Ag^{+} \end{bmatrix} = x' + y', \ [Cl^{-}] = x', \ [Br^{-}] = y'$$

$$\mathcal{K}_{sp}(AgCl) = \begin{bmatrix} Ag^{+} \end{bmatrix} \begin{bmatrix} Cl^{-} \end{bmatrix} = (x' + y')(x') = x^{2}$$

$$\mathcal{K}_{sp}(AgBr) = \begin{bmatrix} Ag^{+} \end{bmatrix} \begin{bmatrix} Br^{-} \end{bmatrix} = (x' + y')(y') = y^{2}$$

$$1 \times (x' + y')(x') + (x' + y')(y') = x^{2} + y^{2}$$

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

$$\begin{bmatrix} Ag^{+} \end{bmatrix} = x' + y' = \sqrt{x^{2} + y^{2}} < x + y$$

$$2 \checkmark \begin{bmatrix} Br^{-} \end{bmatrix} = y' = \frac{y^{2}}{x' + y'} = \frac{y^{2}}{\sqrt{x^{2} + y^{2}}} < y$$

$$3\checkmark [Ag^+] = x' + y' = [Cl^-] + [Br^-]$$

 $\Rightarrow \mathbf{D}$

- 18 A× There are no chiral centres in 2-methyl-N-phenylpropan-1-imine.
 - **B**× π bonds are formed by side-on overlap of unhybridised p orbitals. The C–N σ bond is formed by head-on overlap between sp² hybrid orbitals of C and N.
 - C× N forms 2 σ bonds and possesses 1 lone pair. Hence it is sp² hybridised.
 - D√ The lone pair on N in 2-methyl-Nphenylpropan-1-imine is in a sp² hybrid orbital, while that in NH₃ is in a sp³ hybrid orbital. Due to the larger scharacter of sp² hybrid orbital (33%) compared to sp³ hybrid orbital (25%), the lone pair is closer to the nucleus (s orbitals are closer to nucleus than p orbitals) and less available for donation.





20 Dehydration upon heating with conc. H₂SO₄,



- 21 A× The alkyl group is an activating group. Hence alkylbenzene will react faster.
 - $\mathbf{B}\checkmark$ Anhydrous A lX_3 and FeX₃ can be used in Friedel-Crafts alkylation to generate the carbocation.
 - C√ Due to the bulky alkyl group, the 2position is sterically hindered and hence the CH₃CO- group will preferentially go to the 4-position.

$$D \checkmark It is an electrophilic substitution:Ar-H + RCOCl \rightarrow Ar-COR + HCl$$

X are resistant 22 X and

to nucleophilic substitution as the lone pair of electrons on X is delocalised into the benzene ring and C=C respectively, imparting partial double bond in the C-X bond, making cleavage difficult.

Among the X, the C–I bond being the weakest means that ✓^I react the fastest and should give a ppt.

As the acyl carbon in (is Rr

attached highly electronegative O besides Br, it is the most electron-deficient, and hence react the fastest, giving the most ppt.

$$\Rightarrow A$$

 $\Rightarrow A$

24 Since heptan-2-one is formed from W via oxidation with acidified K₂Cr₂O₇, W must be the secondary alcohol, heptan-2-ol.

Heptan-2-one can be reduced back to heptan-2-ol using NaBH₄, LiA*l*H₄ or H₂,

lodoform reaction on the methyl ketone, heptan-2-one leads to lost of the methyl carbon as CHI₃, resulting in a step-down reaction to give 6-carbon hexanoic acid.

$$\Rightarrow \mathbf{D}$$

25
$$\mathbf{A} \checkmark \mathbf{C}_{6}\mathbf{H}_{5}\mathbf{COC}l \xrightarrow{\mathbf{H}_{2}\mathbf{O}} \mathbf{C}_{6}\mathbf{H}_{5}\mathbf{CO}_{2}\mathbf{H}$$

 $\mathbf{B} \checkmark \mathbf{CH}_{2} = \mathbf{CHCH}(\mathbf{CH}_{3})_{2} \xrightarrow{\mathbf{KMnO}_{4}, \mathbf{H}_{2}\mathbf{SO}_{4}} \rightarrow (\mathbf{CH}_{3})_{2}\mathbf{CHCO}_{2}\mathbf{H} + \mathbf{CO}_{2}$
 $\mathbf{C} \nvDash (\mathbf{CH}_{3})_{2}\mathbf{CHC}l \xrightarrow{\mathbf{CN}^{-}(\mathbf{alc})}_{\mathbf{heat}} (\mathbf{CH}_{3})_{2}\mathbf{CHCN}$
 $\xrightarrow{\mathbf{H}_{2}\mathbf{SO}_{4}(\mathbf{aq})}_{\mathbf{heat}} \rightarrow (\mathbf{CH}_{3})_{2}\mathbf{CHCO}_{2}\mathbf{H}$
 $\mathbf{D} \checkmark \mathbf{CH}_{3}\mathbf{CH}_{2}\mathbf{CN} \xrightarrow{\mathbf{H}_{2}\mathbf{SO}_{4}(\mathbf{aq})}_{\mathbf{heat}} \rightarrow \mathbf{CH}_{3}\mathbf{CH}_{2}\mathbf{CO}_{2}\mathbf{H}$

26 Z is a 3° amide which can only be made from an acyl chloride and a 2º amine:

$$\begin{array}{c} R^{1} & H & O \\ N & R^{2} & C t \\ R^{2} & C t \\ P^{0} \text{ amine} \\ \text{chloride} \end{array} \xrightarrow{R^{1}} \begin{array}{c} V \\ R^{1} \\ R^{2} \\ R^{3} \\ R^{2} \\ R^{3} \\ R^{2} \\ R^{3} \\ R^{3$$

⇒ A

27 [**R**]: E^{\leftrightarrow} (Ag⁺ | Ag) = +0.80 V $[\mathbf{O}]: E^{\ominus}(Fe^{3+}|Fe^{2+}) = +0.77 V$

$$E_{\text{cell}} = E(\text{Ag}^+|\text{Ag}) - E(\text{Fe}^{3+}|\text{Fe}^{2+})$$

1× Addition of KI(aq), ppt AgI(s), causing [Ag⁺] to \downarrow $\Rightarrow Aa^+ + e^- \rightleftharpoons Aa$ shifts left

$$\Rightarrow E(Ag^{+}|Ag) < E^{\ominus}(Ag^{+}|Ag)$$

$$\Rightarrow E_{cell} < E_{cell}^{\in}$$

2× Addition of H₂O to Ag⁺/Ag half-cell causes [Ag⁺] to \downarrow ۸ er⁺

$$\Rightarrow Ag^{+} + e^{-} \rightleftharpoons Ag \text{ shifts left}$$
$$\Rightarrow F(Ag^{+}|Ag) < F^{\oplus}(Ag^{+}|Ag)$$

$$\Rightarrow E(Ag^{+}|Ag) < E^{\leftrightarrow}(Ag^{+}|Ag)$$

$$\Rightarrow E_{cell} < E_{cell}^{\ominus}$$

3√ Addition of H₂O to Fe³⁺/Fe²⁺ half-cell causes [Fe³⁺] and [Fe²⁺] to \downarrow by the same extent.

$$\Rightarrow \mathsf{F} \mathsf{e}^{3+} + \mathsf{e}^{-} \rightleftharpoons \mathsf{F} \mathsf{e}^{2+} \text{ is not affected} \\ \Rightarrow \mathsf{E} \big(\mathsf{F} \mathsf{e}^{3+} \big| \mathsf{F} \mathsf{e}^{2+} \big) = \mathsf{E}^{\ominus} \big(\mathsf{F} \mathsf{e}^{3+} \big| \mathsf{F} \mathsf{e}^{2+} \big)$$

$$\Rightarrow E(Fe^{3+}|Fe^{2+}) = E^{\Leftrightarrow}(Fe^{3+}|Fe^{2+})$$
$$\Rightarrow E_{cell} \text{ is not affected}$$

$$\Rightarrow E_{cell}$$
 is not a

 $\Rightarrow C$

28 Electrolysis of saturated NaCl leads to the discharge of Cl_2 at the anode:

$$2Ct \to Cl_{2} + 2e^{-}$$

$$Q = I \times t = 15.0 \times 30 \times 60 = 27000 \text{ C}$$

$$n_{e^{-}} = \frac{Q}{F} = \frac{27000}{96500} = 0.2798 \text{ mol}$$

$$n_{Cl_{2}} = \frac{1}{2}n_{e^{-}} = 0.1399 \text{ mol}$$

$$\Rightarrow \mathbf{D}$$

Answer Key

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