2021 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✓ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1 \rightarrow 1s^2\ 2s^2\ 2p^6$ (octet)

C× $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ (not octet)

D× [Ar] $3d^2\ 4s^1$ (not ground state; ground state is [Ar] $3d^1\ 4s^2$) → [Ar] (octet)

$\Rightarrow$ **B**

2

	${}^{1}_{1}H_3\,{}^{16}_{8}O^+$	${}^{2}_{1}H_3\,{}^{16}_{8}O^+$	${}^{2}_{1}H_2\,{}^{16}_{8}O$	${}^{16}_{8}O\,{}^{1}_{1}H^-$
p	$1\times3+8$ $=11$	$1\times3+8$ $=11$	$1\times2+8$ $=10$	$8+1$ $=9$
e	$1\times3+8-1$ $=10$	$1\times3+8-1$ $=10$	$1\times2+8$ $=10$	$8+1+1$ $=10$
n	$0\times3+8$ $=8$	$1\times3+8$ $=11$	$1\times2+8$ $=10$	$8+0$ $=8$

$\Rightarrow$ **A**

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

${}_{n+2}\mathbf{S}$ forms a stable ion which is isoelectronic with ${}_{n}\mathbf{R}^-$. Hence ${}_{n+2}\mathbf{S}$ must have **lost** 1 electron, to form ${}_{n+2}\mathbf{S}^+$, 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 iso-electronic, ${}_{n+2}\mathbf{S}^+$ with a higher nuclear charge will have a smaller ionic radius as the effective nuclear charge experienced by the valence e^-s is higher.

B× ${}_{n}\mathbf{R}^- + e^- \rightarrow {}_{n}\mathbf{R}^{2-}$ will be endothermic due to repulsion of the incoming e^-; ${}_{n+2}\mathbf{S}^+ + e^- \rightarrow {}_{n+2}\mathbf{S}$ will be exothermic due to attraction of the incoming e^-.

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.

D× ${}_{n+2}\mathbf{S}^+ - e^- \rightarrow {}_{n+2}\mathbf{S}^{2+}$ will be more endothermic than ${}_{n}\mathbf{R}^- - e^- \rightarrow {}_{n}\mathbf{R}$ since the e^- is being removed from positively charged ${}_{n+2}\mathbf{S}^+$.

$\Rightarrow$ **A**

4 **A**× Polar single covalent bonds involves unequal sharing of bonding electrons.

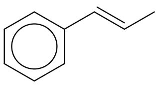
B× Single covalent bonds are also formed in atoms without a complete octet, *e.g.* BF_3 with 6 outer shell electrons around B, or with an expanded octet, *e.g.* PF_5 with 10 outer shell electrons around P.

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 sp^2 hybridised C (33%) compared to sp^3 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_{sp^3}–H bond.

$\Rightarrow$ **D**

5 1× There are no H bonded to F, O or N in cinnamaldehyde $\Rightarrow$ 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✓ All carbon atoms in cinnamaldehyde are sp^2 hybridised, thus all the bond angles are the same at 120°.

$\Rightarrow$ **B**

6 **A**× $S_2O_3^{2-}$ to $S_4O_6^{2-}$ is an oxidation as the oxidation number of S increases from +2 to +2.5.

B✓ Br_2 is unable to oxidise C*l*⁻. Hence Br_2(g) dissolves in water to give orange Br_2(aq).

C× Although C*l*₂ molecules possess lone pairs on C*l*. However, C*l* 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.

$\Rightarrow$ **B**

7 **A**✓ $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ (Brønsted-Lowry acid-base reaction)

B✓ $NH_3 + BH_3 \rightarrow H_3N{\rightarrow}BH_3$ (Lewis acid-base reaction)

C✓ $AlCl_3 + Cl_2 \rightleftharpoons [Cl{\rightarrow}AlCl_3]^- + Cl^+$ (Lewis acid-base reaction)

D× Both A*l*C*l*₃ and BH_3 are electron-deficient species, capable of acting as Lewis acids only.

$\Rightarrow$ **D**

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

no. of O atoms $= 1\ mol \times 2 \times N_A = 2N_A$

B× $n_{Cl_2} = \dfrac{(1.5\times101325)\times(1\times10^{-3})}{8.31\times273}$
$= 0.0670$ mol

no. of C*l*₂ molecules $= 0.670\ mol \times N_A$
$= 0.670N_A$

C✓ $n_{CaSO_4} = \dfrac{68.05}{40.1+32.1+16.0\times4}$
$= 0.500$ mol

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

no. of ions $= 0.500\ mol \times 2 \times N_A = 1.00N_A$

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

no. of C atoms $= 1\ mol \times 2 \times N_A = 2N_A$

$\Rightarrow$ **C**

9 pH of the period 3 chloride in water:

no hydrolysis	– NaC*l* : 7
slightly hydrolysis	– MgC*l*₂ : 6.5
extensive hydrolysis	– A*l*C*l*₃ : 3
complete hydrolysis	– SiC*l*₄, PC*l*₅ : 2

$\Rightarrow$ **C**

10 **A**× 6 P–P bonds are broken. So

$$\Delta H_r = \frac{1}{4}(6\times\text{B.E.(P–P)}) = \frac{3}{2}\text{B.E.(P–P)}$$

B✓ Phosphorus exists as P_4(s) under standard condition.

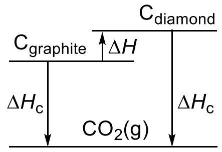
C× Phosphorus exists as P_4(s) under standard condition.

D× Enthalpy change of vapourisation is the energy required to transform one mole of a liquid substance into its gases state: $P_4(l) \rightarrow P_4(g)$

$\Rightarrow$ **B**

11 $\Delta H = \Delta G + T\Delta S = +3.08 + 298 \times \dfrac{-3.3}{1000}$
$= +2.10\ kJ\ mol^{-1}$

1✓



2× Graphite is more stable than diamond. C–C bonds in graphite are stronger than in diamond.

3× Since ΔS is negative, $-T\Delta S$ is always positive. Hence ΔG increases (less spontaneous) with temperature.

$\Rightarrow$ **A**

12 Since $[A] \ll [B]$,

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

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

When [B] is doubled, $t_{\frac{1}{2}}$ 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].

3× 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 $K_c = \dfrac{[C]^2}{[A]^2[B]} = x$

For the new equilibrium,

$$K_c' = \frac{[A][B]^{\frac{1}{2}}}{[C]} = \frac{1}{\dfrac{[C]}{[A][B]^{\frac{1}{2}}}} = \frac{1}{\left(\dfrac{[C]^2}{[A]^2[B]}\right)^{\frac{1}{2}}} = \frac{1}{\sqrt{x}}$$

$\Rightarrow$ **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 $\Rightarrow$ eqm shifts to the side with more gaseous particles.

3× Equilibrium constants are only affected by changes in temperature.

$\Rightarrow$ **D**

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

$n_{\mathrm{CH_3CO_2H}} = \dfrac{20}{1000} \times 1.00 = 0.0200 \text{ mol}$

$\mathrm{CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O}$

$$[\mathrm{CH_3CO_2H}] = \frac{0.0200 - 0.0100}{\frac{20+20}{1000}} = 0.250 \text{ mol dm}^{-3}$$

$$[\mathrm{CH_3CO_2Na}] = \frac{0.0100}{\frac{20+20}{1000}} = 0.250 \text{ mol dm}^{-3}$$

$$\mathrm{pH} = \mathrm{p}K_\mathrm{a} + \lg\frac{[\mathrm{CH_3CO_2Na}]}{[\mathrm{CH_3CO_2H}]} = -\lg(1.8 \times 10^{-5}) = 4.74$$

$\Rightarrow$ **C**

17 Given solubility of AgC*l* and AgBr are *x* and *y* mol dm^{-3} respectively,

$K_{\mathrm{sp}}(\mathrm{AgC}l) = [\mathrm{Ag^+}][\mathrm{C}l^-] = x^2 \text{ mol}^2 \text{ dm}^{-6}$
$K_{\mathrm{sp}}(\mathrm{AgBr}) = [\mathrm{Ag^+}][\mathrm{Br^-}] = y^2 \text{ mol}^2 \text{ dm}^{-6}$

In a solution saturated with **both** AgC*l* and AgBr, let the solubility of AgC*l* and AgBr be x' and y' mol dm^{-3} respectively.

$[\mathrm{Ag^+}] = x' + y'$, $[\mathrm{C}l^-] = x'$, $[\mathrm{Br^-}] = y'$

$K_{\mathrm{sp}}(\mathrm{AgC}l) = [\mathrm{Ag^+}][\mathrm{C}l^-] = (x'+y')(x') = x^2$
$K_{\mathrm{sp}}(\mathrm{AgBr}) = [\mathrm{Ag^+}][\mathrm{Br^-}] = (x'+y')(y') = y^2$

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

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

2✓ $[\mathrm{Br^-}] = y' = \dfrac{y^2}{x'+y'} = \dfrac{y^2}{\sqrt{x^2+y^2}} < y$

3✓ $[\mathrm{Ag^+}] = x' + y' = [\mathrm{C}l^-] + [\mathrm{Br^-}]$

$\Rightarrow$ **D**

18 **A×** There are no chiral centres in 2-methyl-*N*-phenylpropan-1-imine.

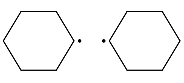
B× π bonds are formed by side-on overlap of unhybridised p orbitals. The C–N σ bond is formed by head-on overlap between sp^2 hybrid orbitals of C and N.

C× N forms 2 σ bonds and possesses 1 lone pair. Hence it is sp^2 hybridised.

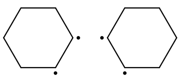
D✓ The lone pair on N in 2-methyl-*N*-phenylpropan-1-imine is in a sp^2 hybrid orbital, while that in NH$_3$ is in a sp^3 hybrid orbital. Due to the larger s-character of sp^2 hybrid orbital (33%) compared to sp^3 hybrid orbital (25%), the lone pair is closer to the nucleus (s orbitals are closer to nucleus than p orbitals) and less available for donation.

$\Rightarrow$ **D**

19 **A✓**

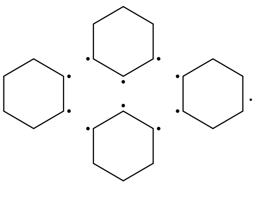


B×

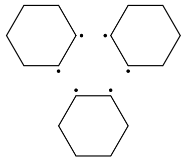


•——• (2 C fragment needed)

C✓

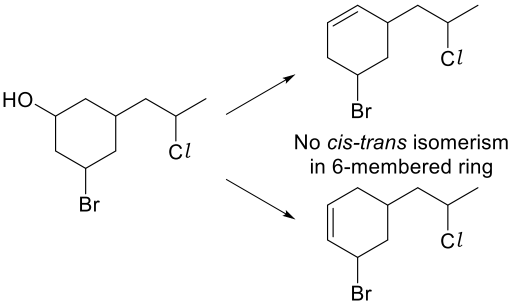


D✓



$\Rightarrow$ **B**

20 Dehydration upon heating with conc. H$_2$SO$_4$,



No *cis-trans* isomerism in 6-membered ring

$\Rightarrow$ **A**

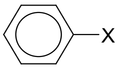
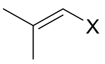
21 **A×** The alkyl group is an activating group. Hence alkylbenzene will react faster.

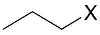
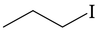
B✓ Anhydrous A*l*X$_3$ and FeX$_3$ can be used in Friedel-Crafts alkylation to generate the carbocation.

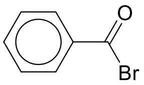
C✓ Due to the bulky alkyl group, the 2-position is sterically hindered and hence the CH$_3$CO– group will preferentially go to the 4-position.

D✓ It is an electrophilic substitution:
Ar–**H** + RCOC***l*** → Ar–COR + **HC*l***

$\Rightarrow$ **A**

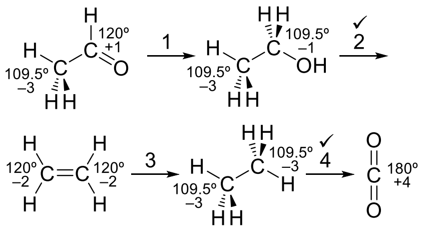
22  and  are resistant to nucleophilic substitution as the lone pair of electrons on X is delocalised into the benzene ring and C=C respectively, imparting partial double bond in the C–X bond, making cleavage difficult.

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

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

$\Rightarrow$ **A**

23



$\Rightarrow$ **B**

24 Since heptan-2-one is formed from **W** via *oxidation* with acidified K$_2$Cr$_2$O$_7$, **W** must be the secondary alcohol, heptan-2-ol.

Heptan-2-one can be *reduced* back to heptan-2-ol using NaBH$_4$, LiA*l*H$_4$ or H$_2$.

Iodoform reaction on the methyl ketone, heptan-2-one leads to lost of the methyl carbon as CHI$_3$, resulting in a *step-down reaction* to give 6-carbon hexanoic acid.

$\Rightarrow$ **D**

25 **A✓** $\mathrm{C_6H_5COC}l \xrightarrow[\text{r.t.}]{\mathrm{H_2O}} \mathrm{C_6H_5CO_2H}$

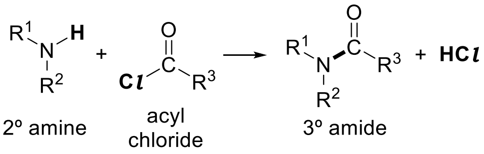
B✓ $\mathrm{CH_2{=}CHCH(CH_3)_2} \xrightarrow[\text{heat}]{\mathrm{KMnO_4,\ H_2SO_4}}$
$\mathrm{(CH_3)_2CHCO_2H + CO_2}$

C× $\mathrm{(CH_3)_2CHC}l \xrightarrow[\text{heat}]{\mathrm{CN^-(alc)}} \mathrm{(CH_3)_2CHCN}$
$\xrightarrow[\text{heat}]{\mathrm{H_2SO_4(aq)}} \mathrm{(CH_3)_2CHCO_2H}$

D✓ $\mathrm{CH_3CH_2CN} \xrightarrow[\text{heat}]{\mathrm{H_2SO_4(aq)}} \mathrm{CH_3CH_2CO_2H}$

$\Rightarrow$ **C**

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



$\Rightarrow$ **A**

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

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

1× Addition of KI(aq), ppt AgI(s), causing [Ag$^+$] to ↓
$\Rightarrow \mathrm{Ag^+} + e^-$ É Ag shifts left
$\Rightarrow E(\mathrm{Ag^+|Ag}) < E^\ominus(\mathrm{Ag^+|Ag})$
$\Rightarrow E_{\text{cell}} < E^\ominus_{\text{cell}}$

2× Addition of H$_2$O to Ag$^+$/Ag half-cell causes [Ag$^+$] to ↓
$\Rightarrow \mathrm{Ag^+} + e^-$ É Ag shifts left
$\Rightarrow E(\mathrm{Ag^+|Ag}) < E^\ominus(\mathrm{Ag^+|Ag})$
$\Rightarrow E_{\text{cell}} < E^\ominus_{\text{cell}}$

3✓ Addition of H$_2$O to Fe^{3+}/Fe^{2+} half-cell causes [Fe^{3+}] and [Fe^{2+}] to ↓ by the same extent.
$\Rightarrow \mathrm{Fe^{3+}} + e^-$ É $\mathrm{Fe^{2+}}$ is not affected
$\Rightarrow E(\mathrm{Fe^{3+}|Fe^{2+}}) = E^\ominus(\mathrm{Fe^{3+}|Fe^{2+}})$
$\Rightarrow E_{\text{cell}}$ is not affected

$\Rightarrow$ **C**

28 Electrolysis of saturated NaC*l* leads to the discharge of C*l*$_2$ at the anode:

$$2\mathrm{C}l^- \rightarrow \mathrm{C}l_2 + 2e^-$$

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

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

$n_{\mathrm{C}l_2} = \dfrac{1}{2} n_{e^-} = 0.1399 \text{ mol}$

$\Rightarrow$ **D**

Answer Key

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