2019 JC2 Preliminary Examination
H2 Chemistry 9729
Paper 1 Worked Solution

1 From Group 13→18, the number of unpaired electrons ↑es from 1 (Group 13) to 3 (Group 15), then ↓es to 0 (Group 18). Hence, **W**, **X**, **Y** and **Z** cannot be main group elements, *i.e.* they are TM.

W must have been $4d^8\ 5s^2$ and not $4d^2\ 5s^2$ as the number of unpaired electrons ↓es with more electrons added.

⇒ **B**

2 Angle of deflection, $\theta \propto \frac{z}{m}$

For a proton, $^1_1H^+$, $\frac{z}{m} = \frac{+1}{1} = +1$

For particle **X**, $\frac{z}{m} = \frac{-5°}{+15°}(+1) = -\frac{1}{3}$

A : $^3_1\mathbf{A}^-$; **B** : $^5_2\mathbf{B}^-$; **C** : $^6_3\mathbf{C}^-$; **D** : $^9_4\mathbf{D}^{3+}$

⇒ **A**

3 **A** ✖: *trans*-isomer is non-polar (C–C*l* bond dipole cancels), while *cis*-isomer is polar. Hence *cis*-isomer is more soluble in polar H_2O.

B ✓: C=O is more polar than C–C*l* as O is more electronegative. Also, oxygen of C=O can form H-bond with water via its lone pair. ∴ CH_3COCH_3 is more soluble.

C ✖: $CH_3CH_2CH_2CH_2CH(OH)CO_2H$ can form intermolecular H-bond with H_2O, while $CH_3CH_2CH_2CH_2CH(NH_3^+)CO_2^-$ is zwitterionic and forms stronger ion-dipole interaction with H_2O, hence more soluble.

D ✖: 2-nitrophenol can form intramolecular H-bond, while 4-nitrophenol forms intermolecular H-bond with H_2O, hence more soluble.

⇒ **B**

4 **A** ✓: Like graphite, each C is sp^2 hybridised with one unpaired e^- in the remaining p-orbital, which is delocalised, allowing CNT to conduct electricity.

B ✖: Like graphite, the C–C bonds within each molecule is stronger than that in diamond as they result from sp^2-sp^2 overlap. However, between two molecules, there is only weak intermolecular id-id attraction, hence softer than diamond.

C ✖: Like graphite, the high melting point is due to energy required to break the strong intramolecular C–C bond and not to overcome the weak intermolecular id-id attraction.

D ✖: Like graphite, the C–C bonds within each molecule is stronger than that in diamond as they result from sp^2-sp^2 overlap.

⇒ **A**

5 I : H_2SO_4 **oxidises** Br^- to Br_2, itself reduced to SO_2

II : H_2SO_4 **catalyses** the condensation reaction between an acid and an alcohol to give an ester (and water), but making the C=O more electrophilic.

III : Acid-base reaction where H_2SO_4 is the **acid** and NaOH the base, to give salt (Na_2SO_4) and water.

⇒ **D**

6 1 ✖: A more exothermic lattice energy just implies that it takes more energy to vaporise the ionic lattice into gasous ions. No bearing on the decomposition.

2,4✓: CO_3^{2-} is more easily polarised as planar CO_3^{2-} has a larger surface area than the near spherical tetrahedral SO_4^{2-} ion. Hence the C–O bond is more readily weakened, causing $CaCO_3$ to decomposing at a lower temperature.

3 ✖: Due to smaller size of the CO_3^{2-} ion compared to SO_4^{2-}, the charge density is higher. However, higher anionic charge density has no bearing on the decomposition.

⇒ **C**

7 Oxidation state of S in SF_6 is +6, SCl_2 is +2 and S_2Br_2 is +1, which correlates with the ability of the halogen to oxidise S.

⇒ **D**

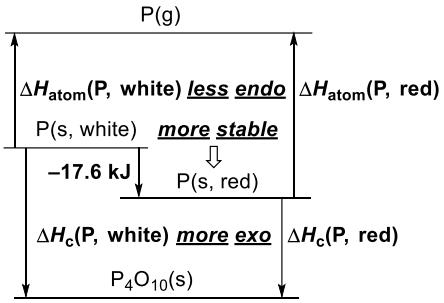
8 Number of ^{13}C atoms $= \frac{0.13}{13} \times L = 0.01L$

Each $^{13}_6C$ atom has 13 – 6 = 7 neutrons

Number of neutrons $= 0.01L \times 7 = 0.07L$

⇒ **B**

9



⇒ **B**

10 $I_2(s) + Cl_2(g) \rightarrow 2ICl(s)$ $\quad \Delta H_1$ --------- (1)

$ICl(s) + Cl_2(g) \rightarrow ICl_3(s)$ $\quad \Delta H_2$ --------- (2)

$$\frac{1}{2}(1) + (2) : \frac{1}{2}I_2(s) + \frac{3}{2}Cl_2(g) \rightarrow ICl_3(s)$$

$$\Delta H_f(ICl_3(s)) = \frac{1}{2}\Delta H_1 + \Delta H_2 = \frac{1}{2}(+14) - 88$$
$$= -81\ \text{kJ mol}^{-1}$$

⇒ **C**

11 Combustion of fuel (hydrocarbon) is an exothermic process, so ΔH is –ve.

Combustion leads to the production of more gaseous CO_2 and H_2O molecules than O_2(g) consumed. Hence, entropy increases, *i.e.* ΔS is +ve.

$\Delta G = \Delta H - T\Delta S$ is –ve for all T.

⇒ **D**

12 **A** ✓: Since HI, a strong acid is produced, although H^+ is a catalyst, the $[H^+]$ ↑es.

B ✖: The rate constant, $k = Ae^{-\frac{E_a}{RT}}$, is independent of concentration.

C ✖: Given rate $= k[H^+][CH_3COCH_3]$. So rate ↑es by 4 × when concentrations of all reactants are doubled.

D ✖: pH 1 ⇒ $[H^+] = 10^{-1} = 0.1$ mol dm^{-3}

pH 2 ⇒ $[H^+] = 10^{-2} = 0.01$ mol dm^{-3}

$[H^+]$ ↓es by 10 ×, rate ↓es by 10 ×

⇒ **A**

13 **A** ✖: Adding Ar at constant volume will not cause a spike in the concentration of all three gases.

B ✖: Decrease in temperature of a large body of gas cannot be achieved instantaneously.

C ✓: As conc $= \frac{\text{amount}}{\text{volume}}$, when volume of container is decreased, the total pressure and conc of all three gases will increase suddenly. By LCP, eqm will shift to the side with fewer gaseous particles (right side), in attempt to bring down the pressure, leading to consumption of N_2 and H_2 to form more NH_3 at the new eqm.

D ✖: Removal of NH_3 will not result in a spike in concentration of all 3 gases.

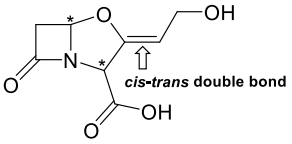
⇒ **C**

14 $\text{pOH} = \text{p}K_w - \text{pH} = -\lg(2.4 \times 10^{-14}) - 7.4$
$= 6.22$

$[OH^-] = 10^{-6.22} = 6.03 \times 10^{-7}$ mol dm^{-3}

⇒ **B**

15

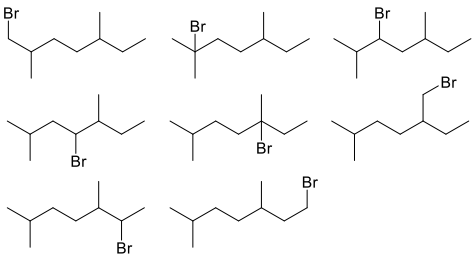


Since there are two chiral centers and one *cis-trans* double bond,

Number of stereoisomers = $2^3 = 8$

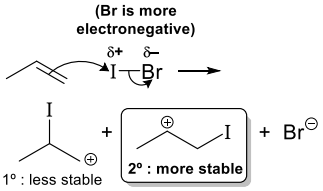
⇒ **D**

16 There are 8 different types of H on the molecule:



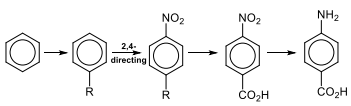
⇒ **C**

17

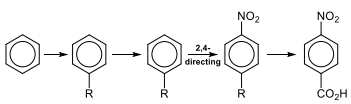


⇒ **C**

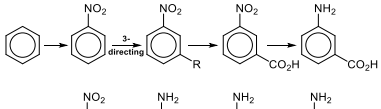
18 **A** ✖:



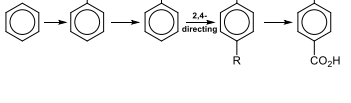
B ✖:



C ✓:

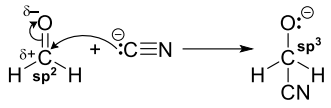


D ✖:

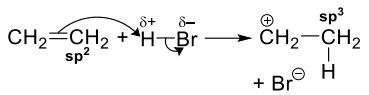


⇒ **C**

19 **1** ✓:

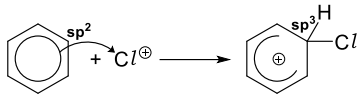


2 ✓:



3 ✗: There is **no intermediate** in S_N2

4 ✓:



⇒ **A**

20 From the rate of formation of ppt (solvolysis), **P** is $C_6H_5CH_2Br$, **Q** is $X–C_6H_4CH_3$, **R** is $C_6H_5CH_2I$, **S** is $C_6H_5CH_2C\mathit{l}$

A ✗: **R** should have the longest C–X bond since it is the weakest and most reactive.

B ✗: Free radical substitution does not work with I_2.

C ✓: **Q** can be $BrC_6H_4CH_3$ formed from $C_6H_5CH_3 + Br_2$ in the presence of $AlBr_3$.

D ✗: Only **P**, **R** and **S** gives benzoic acid upon vigorous oxidation.

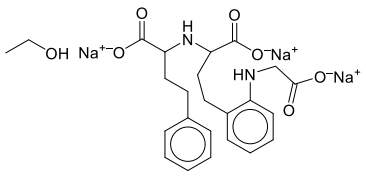
⇒ **C**

21 **A** ✓: hot acidified $K_2Cr_2O_7$ can hydrolyse the ester to release ethanol which can be oxidised into ethanoic acid, reducing orange $K_2Cr_2O_7$ into green Cr^{3+}.

B ✗: $2RCO_2H + Na_2CO_3 \rightarrow 2RCO_2^-Na^+ + CO_2 + H_2O$. 1 mole of benazepril only contains 1 mole of $–CO_2H$.

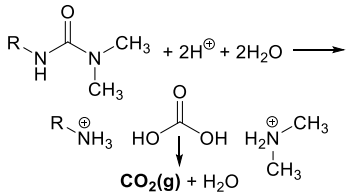
C ✓: $R_2NH + HC\mathit{l} \rightarrow RNH_3^+C\mathit{l}^-$. 1 mole of benazepril contains 1 mole of 2º amine.

D ✓: Benazepril hydrolyses in NaOH to give

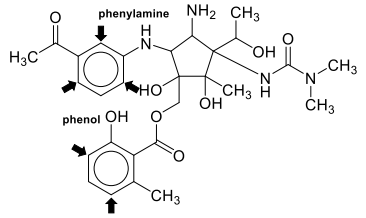


⇒ **B**

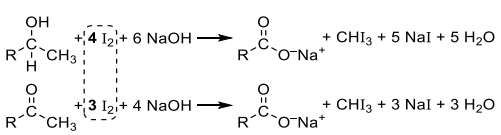
22 **1** ✓:



2 ✓: 5 Ar–H relative (2-, 4-, 6-) to phenol or phenylamine can be substituted by Br: $Ar–H + Br_2 \rightarrow Ar–Br + HBr$

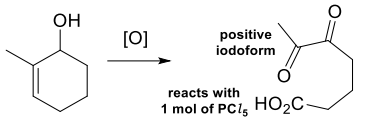


3 ✓: There is one $–CH(OH)CH_3$ and one $–COCH_3$ group in pactamycin.

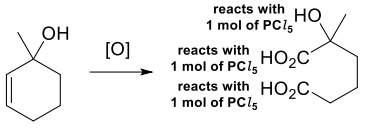


⇒ **A**

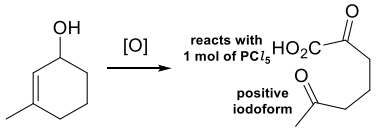
23 **A** ✗:



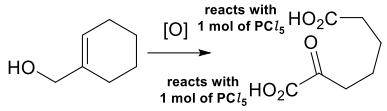
B ✗:



C ✗:

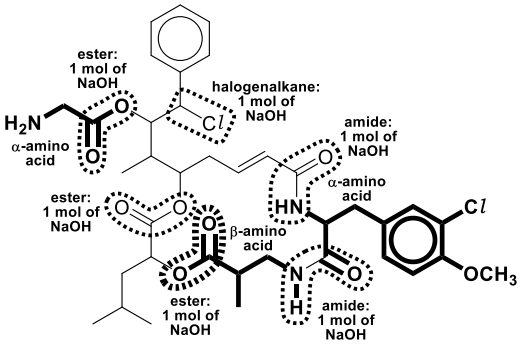


D ✓:



⇒ **D**

24 The ester, amide and halogenoalkane moieties will be hydrolysed by NaOH(aq), giving 2 α-amino acids and 1 β-amino acid:



⇒ **B**

25 **1** ✓: As $HC\mathit{l}$ is a much stronger acid than H_2O, $C\mathit{l}^-$ are less basic than OH^-, hence they are better leaving group, making $RC(=O)–C\mathit{l}$ better acylating agents than $RC(=O)–OH$.

2 ✗: Due to the similarity in size of O and C, lone pair of electrons on O in RCO_2H is much more effectively delocalised into the C=O than that on much bigger $C\mathit{l}$ in $RCOC\mathit{l}$, rendering the C=O carbon in RCO_2H less electrophilic.

3 ✗: While O is more electronegative then $C\mathit{l}$, the C=O carbon in RCO_2H is less electrophilic than that in $RCOC\mathit{l}$ as the lone pair of electrons on O is more effectively delocalised into the C=O of RCO_2H.

⇒ **C**

26 In the gas phase, diisopropylamine is the stronger base (more spontaneous protonation, *i.e.* ΔG is more negative).

In aqueous phase, azepane is the stronger base (smaller pK_b, *i.e.* larger K_b).

This is primarily due to steric hindrance from the two bulky $–CH(CH_3)_2$ groups which hinders hydration of the $R_2NH_2^+$ ion through H-bonding.

⇒ **D**

27 Extraction is dependent on the oxidation of Au to Au(I) by O_2 in alkaline medium:

[R] $O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-$ $E^\ominus = +0.40$ V

For the oxidation to be feasible

$\Rightarrow E^\ominus_{cell} = +0.40 - E^\ominus\left(\mathrm{Au(I)}\middle|\mathrm{Au}\right) > 0$

$\Rightarrow E^\ominus\left(\mathrm{Au(I)}\middle|\mathrm{Au}\right) < +0.40$ V

⇒ **A**

28 The left-hand-side cell is a electrochemical cell, *i.e.* battery source of +1.52 V:

[O]: $Mn \rightarrow Mn^{2+} + 2e^-$ $E^\ominus = –1.18$ V

[R]: $Cu^{2+} + 2e^- \rightarrow Cu$ $E^\ominus = +0.34$ V

$E^\ominus_{cell} = +0.34 – (–1.18) = +1.52$ V

Electrolysis occurs on the right-hand-side:

Cathode (Reduction) :

$E^\ominus\left(Ag^+\middle|Ag\right) = +0.80$ V

$E^\ominus\left(Na^+\middle|Na\right) = –2.71$ V

$E^\ominus\left(H^+\middle|H_2\right) = 0.00$ V

$E^\ominus\left(Zn^{2+}\middle|Zn\right) = –0.76$ V

$E^\ominus\left(H_2O\middle|H_2\right) = –0.83$ V

} Ag is deposited for **A**, while H^+ or H_2O is reduced to $H_2(g)$ for the rest

Anode (Oxidation) :

NO_3^- cannot be oxidised

$E^\ominus\left(O_2\middle|OH^-\right) = +0.40$ V

$E^\ominus\left(S_2O_8^{2-}\middle|SO_4^{2-}\right) = +2.01$ V

$E^\ominus\left(O_2\middle|H_2O\right) = +1.23$ V

$E^\ominus\left(C\mathit{l}_2\middle|C\mathit{l}^-\right) = +1.36$ V

} H_2O or OH^- is oxidised to $O_2(g)$ for all cases

⇒ **A**

29 **1** ✓: $[Ti(H_2O)_6]^{2+}$ has a lower charge density, hence the O–H bond is not as polarised as that in $[Ti(H_2O)_6]^{3+}$, thus less likely to hydrolyse.

2 ✗: The titanium in both $[Ti(H_2O)_6]^{3+}$ and $[Ti(H_2O)_5OH]^{2+}$ are +3 oxidation state.

3 ✗: Under acidic conditions, $[H_3O^+]$ is high, hence eqm shifts to the left, supressing the hydrolysis instead.

⇒ **D**

30 Maximum oxidation state of X = number of 4s + **unpaired** 3d electrons = +(2 + 3) = +5

A ✗: Oxidation state = –2 – (–2)×4 = +6

B ✓: Oxidation state = +2 – (–2) = +4

C ✓: Oxidation state = –1 – (–2)×2 = +3

D ✓: Oxidation state = – (–2)×5÷2 = +5

⇒ **A**

Answer Key

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