2018 JC2 Preliminary Examination
H2 Chemistry 9729
Paper 1 Worked Solution

1 The positive α particles either passes straight through the empty space or are occasionally repelled by the dense positive nucleus. They are not affected by the much smaller electrons and hence does not provide any information about the electrons.

⇒ **C**

2 [O] : $Am^{n+} \rightarrow Am^{2n+} + ne^-$

[R] : $nCu^{3+} + ne^- \rightarrow nCu^{2+}$

So, $Am^{n+} + nCu^{3+} \rightarrow Am^{2n+} + nCu^{2+}$

$n_{Am^{n+}} = \frac{25.0}{1000} \times 0.0100 = 2.5 \times 10^{-4}$ mol

$n_{Cu^{3+}} = \frac{15.0}{1000} \times 0.0500 = 7.5 \times 10^{-4}$ mol

$n_{Am^{n+}} : n_{Cu} = 1 : n = 1 : 3 \Rightarrow n = 3$

Am species formed has O.S. of +6 $\left(AmO_2^{2+}\right)$

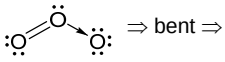
⇒ **D**

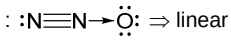
3 OF_2 : 2 b.p. + 2 l.p. ⇒ bent ⇒ 105º

CH_4 : 4 b.p. + 0 l.p. ⇒ tetrahedral ⇒ 109.5º

SF_6 : 6 b.p. + 0 l.p. ⇒ octahedral ⇒ 90º

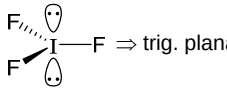
H_2O : 2 b.p. + 2 l.p. ⇒ bent ⇒ 105º

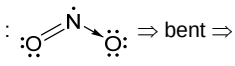
O_3 :  ⇒ bent ⇒ <120º

N_2O :  ⇒ linear ⇒ 180º

PF_3 : 3 b.p. + 1 l.p. ⇒ trig. pyr. ⇒ 107º

BF_3 : 3 b.p. + 0 l.p. ⇒ trig. planar ⇒ 120º

IF_3 :  ⇒ trig. planar ⇒ 120º

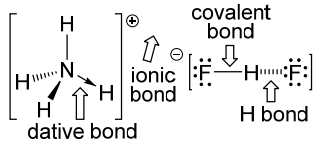
NO_2 :  ⇒ bent ⇒ >120º

SO_2 : 2 b.p. + 1 l.p. ⇒ bent ⇒ <120º

CO_2 : 2 b.p. + 0 1.p. ⇒ linear ⇒ 180º

⇒ **B**

4 Bonding in solid NH_4HF_2:



⇒ **A**

5 At low pressure, gas particles are far apart. IMF between particles causes force they impinge on wall to be smaller and thus pressure is lower than ideal gas ⇒ $pV_{real} < pV_{ideal}$

At higher pressure, gas particles are close together and the volume occupied by particles is significant compared to volume of container. Hence the gas occupies a larger volume than ideal gas ⇒ $pV_{real} > pV_{ideal}$

⇒ **B**

6 ✓Arrhenius acid: Produces H^+(aq) in water

✖ Brønsted-Lowry acid: H^+ donor; $B(OH)_3$ accepts a OH^- and does not donate H^+

✓Lewis acid: Lone pair acceptor; accepts a lone pair fron OH^-

✓Monobasic acid: each mole of $B(OH)_3$ reacts with one mole of OH^-

⇒ **B**

7 $NaCl$: no hydrolysis ⇒ pH = 7

$MgCl_2$: slight hydrolysis ⇒ pH ≈ 6.5

$MgCl_2 + H_2O \ldots Mg(OH)Cl + HCl$

$AlCl_3$: extensive hydrolysis ⇒ pH ≈ 3

$AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$

$SiCl_4$: complete hydrolysis ⇒ pH ≈ 1

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

PCl_5 : complete hydrolysis ⇒ pH ≈ 1

$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

⇒ **A**

8 **A** ✖: Graph is for ionic radii

B ✖: Melting point of Si should be highest due to extensive strong Si–Si covalent bonds within giant molecular structure

C ✓: Nuclear charge increases across period while shielding effect is the same, hence ENC increases across the period resulting in increase in electronegativity

D ✖: Silicon being a metalloid should only have conductivity below that of the metals (Na, Mg, Al)

⇒ **C**

9 $\Delta H_1^{\ominus} = \sum \Delta H_f^{\ominus}(\text{products}) - \sum \Delta H_f^{\ominus}(\text{reactants})$

$= 2\Delta H_f^{\ominus}(NaOH(aq)) + \Delta H_f^{\ominus}(H_2(g)) - 2\Delta H_f^{\ominus}(Na(s)) - 2\Delta H_f^{\ominus}(H_2O(l))$

$= 2\Delta H_f^{\ominus}(NaOH(aq)) + 0 - 0 - 2\Delta H_f^{\ominus}(H_2O(l))$

$= 2\Delta H_f^{\ominus}(NaOH(aq)) - 2\Delta H_f^{\ominus}(H_2O(l))$

$\Delta H_f^{\ominus}(H_2O(l)) = \Delta H_c^{\ominus}(H_2(g))$ as both corresponds to the same reaction:

$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$

⇒ **B**

10 **B** ✖: At 298 K, C is a solid

C ✖: Hydrogen exists as H_2 under std state

D ✖: At 298 K, H_2O is a liquid

⇒ **A**

11 Units for rate is concentration per unit time, in this case, mol dm^{-3} s^{-1}

If k has units of mol^{-2} dm^6 s^{-1}, the reaction must be overall third order:

mol dm^{-3} $s^{-1} = (mol^{-2}\ dm^3\ s^{-1})(mol\ dm^{-3})^3$

⇒ **C**

12 Given $X_2(g) \rightarrow 2X(g)$,

rate $= k[X_2]$, $t_{\frac{1}{2}} = 20$ min

1 ✓: 12.5% X_2 is left after 3 $t_{\frac{1}{2}}$ (60 min).

i.e. 87.5% of X_2 had reacted

$X_2 \xrightarrow{t_{\frac{1}{2}}} \frac{1}{2}X_2 \xrightarrow{t_{\frac{1}{2}}} \frac{1}{4}X_2 \xrightarrow{t_{\frac{1}{2}}} \frac{1}{8}X_2$

50% X_2 25% X_2 12.5% X_2

2 ✓: $n_X = 2n_{X_2\ reacted} = 2 \times \frac{87.5}{100} \times 1 = 1.75$ mol

3 ✓: $n_{gas} = n_{X_2} + n_X = \frac{12.5}{100} \times 1 + 1.75 = \frac{15}{8}$ mol

At constant temperature and volume,

$\frac{p_1}{n_1} = \frac{p_2}{n_2} \Rightarrow p_2 = \frac{p_1}{n_1} \times n_2 = \frac{p}{1} \times \frac{15}{8} = \frac{15}{8}p$

⇒ **D**

13 From the graph,

As pressure increases, % products decreases. Hence, there must be more gaseous particles on the product side, since backward reaction is favoured to decreases the pressure

As temperature increases, % products decreases. Hence the forward reaction must be exothermic, since backward reaction is favoured to absorb heat

⇒ **C**

14 **A** ✖: $n_Q = n_R$; $n_L = n_M = 1.0 - n_R$

Since n_R at eqm can be read from the graph, the partial pressures of **L**, **M**, **Q** and **R** can be obtained. Hence K_p can be obtained.

B ✖: Since the amount of product **R** decreases when temperature is increased, the forward reaction must be exothermic since the backward reaction is favoured to absorb heat.

C ✓: The position of eqm does not provide information about the kinetics of the reaction

D ✖: From the graph, it can seen that it takes a shorter time to plateau at higher temperature, hence eqm is achieved at a faster rate

⇒ **C**

15 pH = 4 ⇒ $[H^+] = 10^{-pH} = 10^{-4}$ mol dm^{-3}

⇒ **X** is fully dissociated, *i.e.* strong acid

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

⇒ **Y** is not fully dissociated, *i.e.* weak acid

pH = 14 ⇒ $[OH^-] = 10^{-pOH} = 10^{-(14-pH)} = 10^0$

$= 1$ mol dm^{-3}

⇒ **Z** is a fully ionised, *i.e.* strong base

⇒ **D**

16 Let the solubility of Ag_3PO_4 be s mol dm^{-3}

$K_{sp} = [Ag^+]^3[PO_4^{3-}]$

A : $K_{sp} = (3s)^3(s) \Rightarrow 27s^4 = K_{sp}$

$s = \sqrt[4]{\frac{K_{sp}}{27}} = 4.26 \times 10^{-5}$

B : $K_{sp} = (3s + 0.10)^3(s) \approx 0.10^3 s$

$s = \frac{K_{sp}}{0.10^3} = 8.89 \times 10^{-14}$

C : $Ag^+ + 2NH_3 \rightarrow [Ag(NH_3)_2]^+$

Formation of complex increases solubility of Ag_3PO_4

D : $K_{sp} = (3s)^3(s + 0.10) \approx (3s)^3\, 0.10$

$s = \sqrt[3]{\frac{K_{sp}}{27 \times 0.10}} = 3.21 \times 10^{-6}$

⇒ **B**

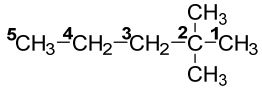
17 **B** ✖: No chiral centre

C ✖: $=CH_2$ ⇒ no *cis-trans* isomerism

D ✖: No chiral centre

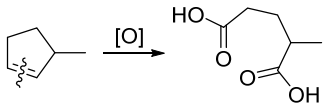
⇒ **A**

18 Structure of 2,2-dimethylpentane:

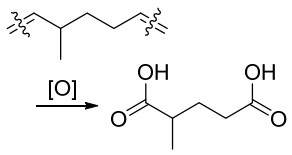


⇒ **C**

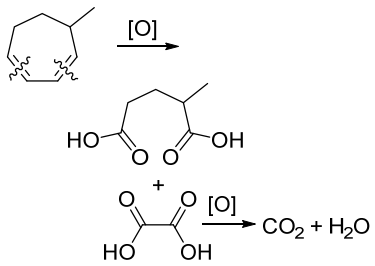
19 **1** ✓:



2 ✓:

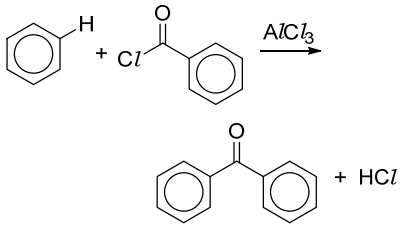


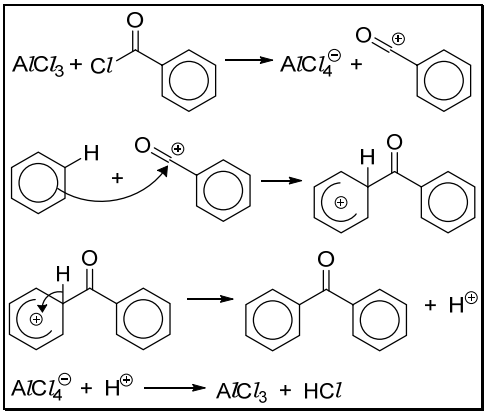
3 ✓:



⇒ **C**

20 Friedel-Crafts acylation, similar to Friedel-Crafts alkyation, using acyl chloride instead of alkyl chloride:





⇒ **D**

21 **A** ✗: Second mechanism is **single-step** S_N2 involving only a **transition state**

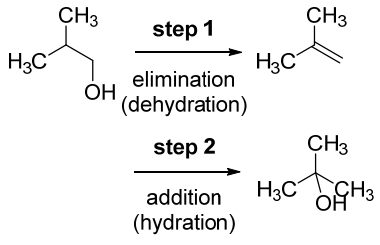
B ✗: Second mechanism is a nucleophilic **substitution** reaction

C ✓: Since both mechanisms involves two reacting species in the rate determining step, both reactions are second order

D ✗: The first mechanism involves addition of the CN^- to a trigonal planar C=O which can take place on both faces with equal chance, hence a racemic product will be obtained

⇒ **C**

22 The reaction involves



⇒ **C**

23 Tollens' reagent, $\left[Ag(NH_3)_2\right]^+OH^-$, only oxidises the –CHO into $–COO^–$ (the salt is obtained and not $–CO_2H$ since Tollens' reagent is alkaline), while itself is reduced to silver metal. Alcohols are **not** oxidised.

⇒ **B**

24 **A** ✗: NH_3 donates a pair of electrons to the electron-deficient acyl carbon, hence a nucleophile

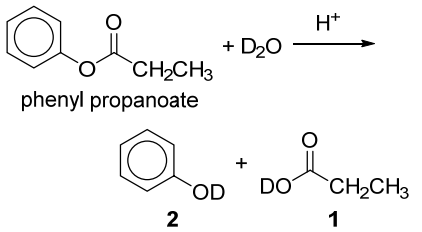
B ✗: The arrow pushing is correct, leading to the regeneration of C=O and expulsion of the Cl^- leaving group

C ✗: The acyl carbon is electron-deficient as it is bonded to two electronegative atoms, O and Cl, hence attracting the NH_3 nucleophile

D ✓: The arrow pushing is wrong as the pair of N–H electrons end up on the H, which will lead to formation of $H^–$ and a doubly positive N instead

⇒ **D**

25

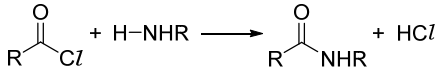


phenyl propanoate

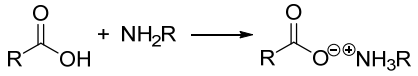
2 **1**

⇒ **B**

26 Amides are made from the reaction between an amine and an acyl chloride:



Amine and carboxylic acid gives an ammonium salt:



⇒ **A**

27 Basicity (availability of lone pair of electrons on N for donation to H^+) :

Generally $R_2NH > RNH_2 > NH_3 > ArNH_2$ as R groups exert electron-donating effect, rendering the lone pair more available for donation, while the lone pair is delocalised into the benzene ring of $ArNH_2$ rendering the lone pair less available for donation.

↓ing basicity ⇒ ↑ing pK_b

So pK_b : $R_2NH < RNH_2 < NH_3 < ArNH_2$

⇒ **B**

28 **W** : Nitrogen in NO_3^- is already in the maximum oxidation of +5 and cannot be further oxidised. Oxidation of H_2O

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

Y : Due to the high concentration of chloride, oxidation of Cl^- occurs instead of H_2O

$2Cl^- \rightarrow Cl_2 + 2e^- \left(4Cl^- \rightarrow 2Cl_2 + 4e^-\right)$

Z : Oxidation of Cu instead of H_2O due to the less positive $E^{\ominus}$. **No gas** evolved

$Cu \rightarrow Cu^{2+} + 2e^-$ $\quad E^{\ominus} = +0.34$ V

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ $\quad E^{\ominus} = +1.23$ V

Since the same amount of charge passes through all three cells, $V_{O_2} : V_{Cl_2} = 1:2$

⇒ **D**

29 **1** ✓: $[R]: Cl_2 + 2e^- \; f \; 2Cl^- \quad E^{\ominus} = +1.36$ V

$[O]: Fe^{3+} + e^- \; f \; Fe^{2+} \quad E^{\ominus} = +0.77$ V

$E^{\ominus}_{cell} = E^{\ominus}_{reduction} - E^{\ominus}_{oxidation}$

$= E^{\ominus}\left(Cl_2|Cl^-\right) - E^{\ominus}\left(Fe^{3+}|Fe^{2+}\right)$

$= +1.36 - (+0.77) = +0.59$ V

As reaction progresses, $[Cl_2]$ ↓es and $[Fe^{2+}]$ ↓es. So $E\left(Cl_2|Cl^-\right)$ ↓es, while $E\left(Fe^{3+}|Fe^{2+}\right)$ ↑es. Hence E_{cell} ↓es.

2 ✓: Addition of $AgNO_3$ causes $AgCl$ to precipitate, hence $[Cl^-]$ ↓es. Thus $E\left(Cl_2|Cl^-\right)$ ↑es, causing E_{cell} to ↑.

3 ✓: Fe^{2+} and Fe^{3+} forms the respective hexacyano complex with $CN^–$:

$\left[Fe(CN)_6\right]^{3-} + e^- \; f \; \left[Fe(CN)_6\right]^{4-} \quad E^{\ominus} = +0.36$ V

Since $E^{\ominus}_{oxidation}$ ↓es , hence $E^{\ominus}_{cell}$ ↑es

⇒ **D**

30 **A** ✗: Oxidations state of Co decreases from +3 in $\left[CoCl(NH_3)_5\right]^{2+}$ to +2 in $\left[Co(OH_2)_6\right]^{2+}$, while that of Cr increases from +2 in $\left[Cr(OH_2)_6\right]^{2+}$ to +3 in $\left[CrCl(OH_2)_5\right]^{2+}$. Hence electron is transferred from Cr to Co

B ✓: Hydration refers to the formation of the aqueous species from the gaseous species, which is not observed in the reaction

C ✗: The Cl^- and NH_3 ligands around the Co ion is replaced by H_2O, while one of the H_2O ligand around the Cr ion is replaced by Cl^-. Hence ligand exchange has taken place

D ✗: The ammonia ligands around Co^{3+} upon replacement by H_2O, reacted with H_3O^+ to give NH_4^+. Hence acid-base neutralisation had taken place

⇒ **B**

Answer Key

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