HWA CHONG INSTITUTION
2022 C2 H2 CHEMISTRY PRELIMINARY EXAM
SUGGESTED SOLUTIONS (PAPER 1)

Paper 1

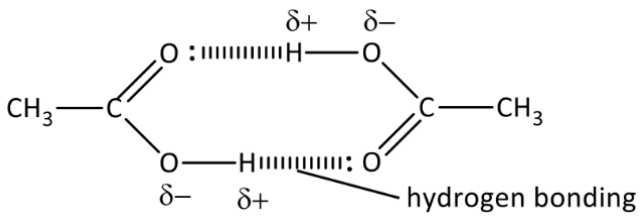
1	2	3	4	5	6	7	8	9	10
C	**B**	**B**	**D**	**D**	**D**	**C**	**A**	**B**	**A**
11	12	13	14	15	16	17	18	19	20
B	**A**	**A**	**B**	**B**	**C**	**C**	**D**	**B**	**A**
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
A	**C**	**A**	**D**	**C**	**A**	**D**	**D**	**C**	**D**

1 C Option D can be eliminated immediately as He contains 2 protons.

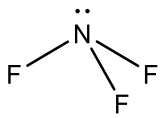
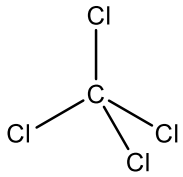
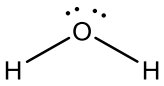
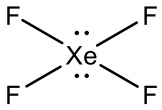
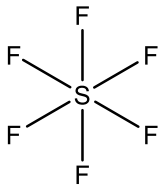
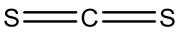
Option	No. of protons	No. of neutrons	No. of electrons
A	1	0	2
B	1	1	3
C	1	2	3

2 B The large drop in the graph suggests that A^+ ion (which has already lost its first electron) has electronic configuration of ns^1. Hence A originally has electronic configuration of ns^2 and is a Group 2 element. Since the graph is showing consecutive elements in the Period Table, B is a Group 13 element.

3 B

Option	Explanation
A	Methanol forms favourable hydrogen bonding between its –OH group and that in water.
B	The hydrogen atom is not bonded to F, O or N atom, hence there is no intermolecular hydrogen bonding for HBr and HC*l*.
C	For 2-aminophenol, the $–NH_2$ and the –OH groups are in close proximity which allows for intramolecular hydrogen bonding. Hence there is less extensive intermolecular hydrogen bonding for 2-aminophenol and less energy is required to overcome the intermolecular forces, leading to a lower boiling point.
D	When ethanoic acid, CH_3CO_2H (M_r = 60), is dissolved in a non-polar solvent (hexane), the molecules form hydrogen-bonded dimers. 

4 D

Option	Explanation	
1	 about 107°	 109.5°
2	 about 104.5°	 90°
3	 90°	 180°

5 D Recall that real gases would deviate from ideal behaviour at high pressures and low temperatures.

Option	Explanation
A	HC*l* is a polar molecule, which will deviate less at higher temperature since the molecules have more kinetic energy to overcome the intermolecular permanent dipole-permanent dipole (pd-pd) interactions.
B	CH_4 is a non-polar molecule with only weak intermolecular dispersion forces. CH_4 will also deviate less at higher temperature since the molecules have more kinetic energy to overcome the intermolecular forces.
C	O_2 is a non-polar molecule with only weak intermolecular dispersion forces, hence should deviate less from ideal behaviour than HC*l*.
D	HF is a polar molecule with stronger hydrogen bonding interactions than the permanent dipole-permanent dipole interactions of HC*l*. Hence HF deviates more from ideal behaviour than HC*l* at the same temperature of 300 K.

6 D An acid-base indicator is a weak aqueous acid whose acid form, HIn, is a different colour from its ionised form (or conjugate base form), In^-. As such, it shows different colours in solutions of different pH.

$$HIn(aq) \rightleftharpoons H^+(aq) + In^-(aq)$$
red yellow

7 C When the metal nitrate decomposes, metal oxide, nitrogen dioxide and oxygen are formed.

$M(NO_3)_2$ d MO + $2NO_2$ + ½O_2

The metal oxide then reacts with the added acid to form salt and water.

MO + 2HC*l* d M$C*l*_2$ + H_2O

The excess HC*l* will undergo neutralisation with NaOH.

HC*l* + NaOH d NaC*l* + H_2O

Amount of NaOH = 0.0780 × 0.0216 = 0.001685 mol = amount of excess HC*l*

Amount of HC*l* used to dissolve residue = 0.0350 × 0.080 = 0.00280 mol

Amount of HC*l* reacted with MO = 0.00280 – 0.001685 = 0.001115 mol

Amount of MO = 0.001115 / 2 = 0.0005575 mol = Amount of $M(NO_3)_2$

M_r of $M(NO_3)_2$ = 0.118 / 0.0005575 = 211.7

A_r of M = 211.7 – 2(14 + 16 × 3) = 87.7

Checking the periodic table, M is Sr.

8 A

Statement	Explanation
1	Down the group, the size of electron cloud and hence polarisability of the halogen molecule increases. More energy is required to overcome stronger intermolecular dispersion forces. Hence, the volatility of halogens decreases down Group 17.
2	Large anions have high polarisability as their electron cloud is less attracted by the nucleus and can be more easily distorted by a cation. Hence, there is a higher degree of covalent character in the silver halide ionic compounds down Group 17.
3	As the atomic radius increases down the group, the bond length of H–X increases and thus bond strength decreases. Hence, the H–X bond energy decreases down Group 17 and less energy is required to break the bond and HX decomposes more readily.

9 B In the experiment with benzoic acid,

No. of moles of benzoic acid combusted = 0.986 / 122 = 0.008082

$q = -\Delta H_c$ × no. of moles of benzoic acid = 3054 × 0.008082 = 24.68 kJ

Heat capacity of the bomb calorimeter = 24.68 / 2.14 kJ $°C^{-1}$

In the experiment with glycine,

No. of moles of glycine combusted = 0.483 / 75 = 0.00644

q = (24.68 / 2.14) × 0.54 = 6.228 kJ

Enthalpy change of combustion of glycine = –6.228/ 0.00644 = –967 kJ mol^{-1}

10 A This decomposition is endothermic since energy is required for breaking the covalent bonds in the OH^- anion.

ΔS is expected to be positive since there is formation of gaseous H_2O, thus statement 3 is wrong.

ΔG can be positive or negative depending on the temperature.

For reactions to be spontaneous, ΔG needs to be negative. As $\Delta G = \Delta H - T\Delta S$, T has to be high so that $|T\Delta S| > \Delta H$. Thus statement 2 is correct.

Similar to Group 2 carbonates, the thermal decomposition of Group 2 hydroxides is dependent on the charge density of the cation. Since Ba^{2+} is larger in cationic radius as compared to Mg^{2+}, the charge density of Ba^{2+} is smaller. Hence its polarising power is weaker and is less able to distort the electron cloud of the hydroxide ion, weakening the O-H covalent bond to a smaller extent. Thus, barium hydroxide will decompose at a higher temperature than magnesium hydroxide.

11 B Comparing the first two sets of experiments, when concentration of bromine doubles while the concentrations of other reactants remain unchanged, the rate of reaction remains the same. Hence, it should be zero order with respect to Br_2.

Comparing the first and third sets of experiments, when concentration of H^+ doubles while the concentrations of other reactants remain unchanged, rate doubles. Hence it is first order with respect to H^+.

Comparing the third and fourth sets of experiments, when the concentration of H^+ doubles and the concentration of propanone increases 4/3 times, the rate of reaction increases by (2 × 4/3) times. Hence it is first order with respect to propanone.

Option	Explanation
A	Rate equation should be rate = $k[CH_3COCH_3][H^+]$.
B	The rate constant value may be obtained by substituting the rate and concentrations from any set of experiments.
C	Rate constant is only affected by temperature or addition of catalyst.
D	Overall order is not 1. Hence half lives may not be the same across different experiments.

12 A Recall Haber process: $N_2(g) + 3H_2 \rightleftharpoons 2NH_3(g)$
The forward reaction is exothermic.

Option	Explanation
A	High temperature will favour the endothermic backward reaction. Hence the yield will decrease but the rate of the reaction will increase.
B	At lower temperature, K_p increases. There will be more NH_3 formed and less N_2 and H_2 present.
C	Higher pressure will favour the forward reaction to produce less number of gaseous molecules. Hence the yield will increase.
D	The presence of catalyst does not affect the yield.

13 A

	CH_3CO_2H +	CH_3CH_2OH	$\rightleftharpoons$	$CH_3CO_2CH_2CH_3$	+ H_2O
initial amt/ mol	0.50	0.50		−	−
change/ mol	−x	−x		+x	+x
eqm amt/ mol	0.50 − x	0.50 − x		x	x

$K_c = (x/V)^2 / ((0.50 – x)/V)^2 = 4.0$
Taking square root on both sides, x = 0.33
Hence amount of $CH_3CO_2H = 0.50 – 0.33 = 0.17$

14 B $pH = -\lg[H^+] = 7$

$pK_w = -\lg[H^+][OH^-] = 14$

$pK_a = -\lg\frac{[H^+][OH^-]}{[H_2O]} = -\lg((10^{-7})^2/(55.6)) = 15.7$

15 B Recall that a buffer should be made up of a weak acid and its conjugate base or a weak base and its conjugate acid.

Option	Explanation
A	This mixture consists of NaC*l*(aq) (a salt) and HC*l*(aq) (a strong acid). Thus this is not a buffer solution.
B	$HCl + NH_3 \rightarrow NH_4Cl$ Since the same volume but a higher concentration of NH_3(aq) is used, NH_3(aq) is added in excess. The resulting mixture consists of NH_3 (a weak base) and NH_4Cl (its conjugate acid) which makes up a buffer solution.
C	H_2CO_3 is a dibasic acid. Twice the volume of NaOH(aq) (a monoacidic strong base) is added to H_2CO_3(aq) of the same concentration. Hence, H_2CO_3 and NaOH are completely neutralised to give Na_2CO_3 and H_2O. This is not a buffer solution.
D	$CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$

	Since a larger volume of the same concentration of NaOH(aq) is used, NaOH(aq) is added in excess. The resulting mixture consists of a strong base and a salt and hence is not a buffer solution.

16 C

$$PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2I^-(aq)$$

Option	Explanation
A	As more I^- is added, the above equilibrium will shift to the left, causing the solubility of PbI_2 to decrease. This is the common ion effect.
B	When even more I^- is added, a soluble complex $[PbI_4]^{2-}$ is formed. The formation of this complex decreases the $[Pb^{2+}]$, causing the above equilibrium to shift to the right. This increases the solubility of PbI_2.
C	At Q, the concentration of I^- is not necessarily twice that of Pb^{2+} as I^- is also contributed by the addition of KI.
D	K_{sp} is only dependent on temperature.

17 C The first step is a reduction reaction as there is a loss of oxygen, and hydrogen is added. The second step is a nucleophilic addition reaction, hence an addition reaction.

18 D This is a recall question on the reagents and conditions for mild oxidation of an alkene functional group, which requires basic or acidic conditions with cold temperature, and $KMnO_4$ as the oxidising agent. Option **D** is preferred over **C** due to the lower temperature used in **D**.

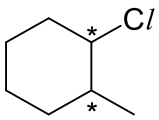
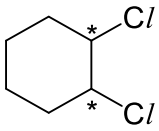
19 B Students should take note that bromine addition occurs on the alkene functional groups, and electrophilic substitution would occur on both the 2 and 4 positions respective to the –OH group, except in options **B** and **D**, where one of the positions is blocked by a methyl group.

20 A

Option	Explanation
A	When $AlCl_3$ reacts as a Lewis acid catalyst, it takes in the electron rich atom. In option A, the I–Cl would become an I^+ electrophile, hence the –I would be substituted onto the benzene ring.
B	The oxidising agent should be potassium manganate(VII), not potassium dichromate.
C	Concentrated nitric and sulfuric acids should be used, not diluted.
D	Iron(III) bromide must be used under anhydrous conditions. In the presence of water, iron(III) bromide is hydrolysed and no longer able to accept the lone pair of electrons from bromine.

21 A Any halogen directly bonded to a benzene ring would not be hydrolysed and remain bonded. The C–F bond is also very strong hence alkyl fluorides do not undergo nucleophilic substitution. Option A would not generate any silver halide.

22 C

Option	Explanation
1	The carbon bonded to the C*l* and CH_3 groups is not chiral.
2	There are two chiral carbons present as indicated with asterisks. This compound exhibits stereoisomerism, and there are 4 stereoisomers in total. 
3	There are two chiral carbons present as indicated with asterisks. This compound exhibits stereoisomerism, and there are 3 stereoisomers in total. 

23 A

Option	Explanation
A	The aluminium hydride ion is negatively charged and would be attracted to the electron deficient carbonyl carbon. But it would be repelled and unable to react with the electron rich alkene functional group.
B	Ethene does not have any delocalised electrons.
C	Adsorption is related to heterogeneous catalysis, but lithium aluminium hydride is not a heterogeneous catalyst.
D	Alkene can be further reduced using hydrogenation reaction. This statement is false.

24 D

Option	Explanation
A	The ketone is the electrophile in this nucleophilic addition reaction.
B	The alkoxide intermediate acquires a proton in the second step of the mechanism, hence it should be a Bronsted acid-base reaction.
C	The shape with respect to the carbonyl carbon changes from trigonal planar to tetrahedral, hence the hybridisation should change from sp^2 to sp^3.
D	The reaction can proceed with just KCN without HCN. The nucleophile is the CN^- ion. The proton in the second step of the mechanism is provided by the dilute sulfuric acid.

25 C The key phrases in the question are ‘ester’ and ‘immediately’ so students should be looking for an alcohol and an acid chloride pair. Option **A** will form an ester but not immediately. Option **B** will not give an ester. Option **D** will just result in an acid-base reaction.

26 A Options **B** and **C** (nitrogen compounds chapter), and **D** (alkyl halide chapter) will all result in products with amine functional groups. Option **A** is a base-catalysed hydrolysis but the nitrogen containing product is ammonia, not a compound with an amine functional group.

27 D

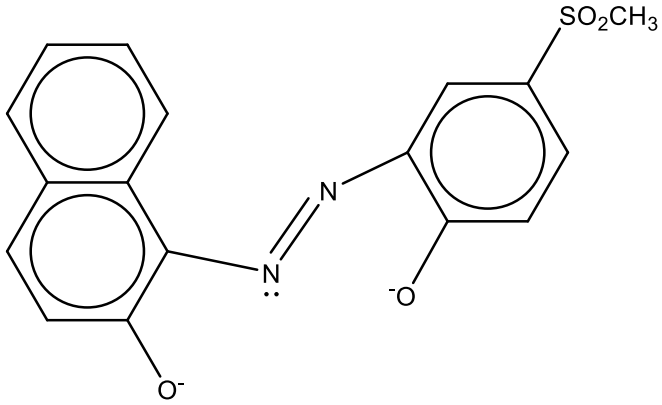
Option	Explanation
A	Changing the size of the metal electrode has no effect on the standard electrode potential, hence the reading on the voltmeter does not change.
B	Adding water dilutes the concentration of the Fe^{2+} ions, the equilibrium $Fe^{2+} + 2e^- \rightleftharpoons Fe$ favours the reverse reaction, and the electrode potential of Fe^{2+}/Fe becomes more negative, so the voltmeter would register a more positive reading.
C	Adding aqueous $AgNO_3$ decreases the concentration of Cl^- ions due to precipitation of $AgCl$. The equilibrium $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ favours the forward reaction, making the electrode potential of Cl_2/Cl^- more positive, causing the voltmeter reading to become more positive.
D	Decreasing the pressure of the chlorine gas would cause the equilibrium $Cl_2 + 2e^- \rightleftharpoons 2Cl^-$ to favour the reverse reaction, causing the electrode potential of Cl_2/Cl^- to become less positive, resulting in a less positive voltmeter reading.

28 D At the cathode, reduction occurs. The species with the more positive reduction potential will be the one undergoing the reduction.

At the anode, oxidation occurs. The species with the less positive reduction potential will be the one undergoing the oxidation.

Option	Explanation
A	At the cathode, $E^{\ominus}(Na^+/Na) = -2.71V$; $E^{\ominus}(H_2O/H_2) = -0.83V$. Hence the reaction that occurs will be $2H_2O + 2e^- \rightarrow H_2 + OH^-$. A gas is produced. At the anode, $E^{\ominus}(Cl_2/Cl^-) = +1.36V$; $E^{\ominus}(O_2/H_2O) = +1.23V$. Hence the reaction that occurs will be $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$. A gas is produced.
B	For the cathode, it will be similar to that in Option A. At the anode however, due to the high concentration of Cl^-, $E(Cl_2/Cl^-)$ is likely to be less positive than $E^{\ominus}(O_2/H_2O)$. Hence, $2Cl^- \rightarrow Cl_2 + 2e^-$. A gas is also produced.
C	At the cathode, $E^{\ominus}(Cu^{2+}/Cu) = +0.34V$; $E^{\ominus}(H_2O/H_2) = -0.83V$. Hence the reaction that occurs will be $Cu^{2+} + 2e^- \rightarrow Cu$. No gas will be produced. At the anode, Cu is used. Hence the reaction that occurs will be $Cu \rightarrow Cu^{2+} + 2e$. No gas will be produced too.
D	The cathode reaction will be similar to that in Option C. An inert electrode is used as the anode in this case. The reaction that occurs will be $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$. A gas is produced.

29 C This is the ligand used which has a charge of 2−.



Since the complex has an overall charge of 0 and two such ligands are used, Cr must have an oxidation number of +4.

30 D $E^{\ominus}(VO_3^-/VO^{2+}) = +1.00V$
$E^{\ominus}(VO^{2+}/V^{3+}) = +0.34V$
$E^{\ominus}(V^{3+}/V^{2+}) = -0.26V$

$E^{\ominus}(Zn^{2+}/Zn) = -0.76V$
$E^{\ominus}(SO_4^{2-}/SO_2) = +0.17V$
$E^{\ominus}(NO_3^-/NO_2) = +0.81V$

For the solution to be green at the end of the reaction, the final oxidation state of vanadium-containing ion should be +3. For the species to be able to reduce the vanadium-containing ions, the reduction potential of the vanadium-containing ion should be more positive than that of the added reagent.

For zinc, $E^{\ominus}(VO_3^-/VO^{2+})$, $E^{\ominus}(VO^{2+}/V^{3+})$ and $E^{\ominus}(V^{3+}/V^{2+})$ are more positive than $E^{\ominus}(Zn^{2+}/Zn)$. Hence zinc is able to reduce the vanadium-containing ions to an oxidation state of +2, giving a violet solution at the end.

For sulfur dioxide, $E^{\ominus}(VO_3^-/VO^{2+})$ and $E^{\ominus}(VO^{2+}/V^{3+})$ are more positive than $E^{\ominus}(SO_4^{2-}/SO_2)$. Hence sulfur dioxide is able to reduce the vanadium-containing ions to an oxidation state of +3.

For nitrogen dioxide, only $E^{\ominus}(VO_3^-/VO^{2+})$ is more positive than $E^{\ominus}(NO_3^-/NO_2)$. Hence nitrogen dioxide is only able to reduce the vanadium-containing ions to an oxidation state of +4, giving a blue solution at the end.