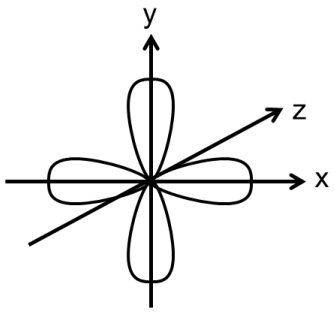
H2 Chemistry TYS 2020 suggested answers

Paper 1 Answer Key

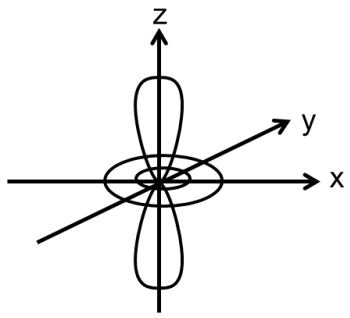
1	C		**11**	C		**21**	C
2	D		**12**	C		**22**	B
3	B		**13**	D		**23**	A
4	D		**14**	C		**24**	D
5	A		**15**	B		**25**	C
6	B		**16**	B		**26**	D
7	B		**17**	C		**27**	A
8	A		**18**	D		**28**	C
9	D		**19**	D		**29**	A
10	B		**20**	B		**30**	D

2020 A level Paper 1 suggested answers

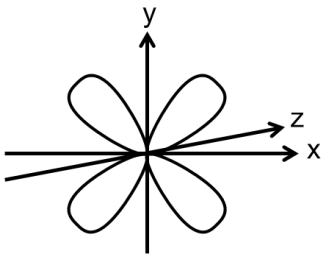
1)



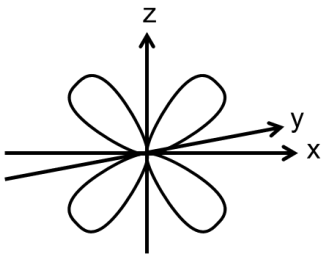
$d_{x^2-y^2}$ orbital



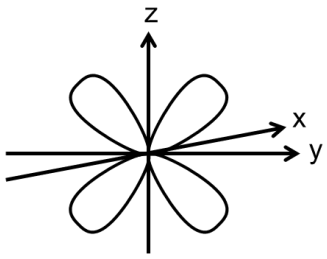
d_{z^2} orbital



d_{xy} orbital



d_{xz} orbital



d_{yz} orbital

Out of the d orbitals, 4 of them have four lobes. $d_{x^2-y^2}$, d_{xy}, d_{xz}, d_{yz}.

Ans: **C**

2) The largest increase in successive I.E. is from the 8th to 9th I.E. This shows that the 9th electron is removed from an inner principle quantum shell which experiences a stronger nuclear attraction. Hence the valence shell contains 8 valence electron and is most likely to be from Group 18.

Ans: **D**

3)

	Nucleon no.	Atomic no.	No. of neutrons	No. of electrons
Po^{2+}	217	84	133	82
At^{3+}	217	85	132	82
Rn^{4+}	217	86	131	82
Fr^{5+}	217	87	130	82

Ans: **B**

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4) The three alkanes are constituent isomers with the same molecular formula of C_5H_{12}. Alkanes are non-polar molecules with instantaneous dipole-induced dipole (id−id) attraction between molecules. During melting and boiling, energy is required to overcome the id−id attraction between the molecules. The strength of id−id is stronger for straight chain isomer due to larger surface area for interaction. For the branched-chain isomers, the id−id is weaker and hence lower boiling point.

Ans: **D**

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5) Question stated that upon mixing, stronger intermolecular forces are formed between CH_3Cl and CH_3COCH_3 molecules. The mixing process is exothermic and hence the temperature of the mixture increases to above 20 °C.

More energy would be required to overcome the intermolecular forces during boiling, hence the boiling point of the mixture will be higher than the boiling point of individual compound. (Qn states that mixture has stronger IMF than their original IMF)

Ans: **A**

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6) Amount of gas = $\frac{\text{mass}}{\text{molar mass}}$

Molar mass of the gases : CH_4 (16.0) < Ne (20.2) < N_2 (28.0) < Cl_2 (71.0)

For ideal gas, pV = nRT,
pV vs V graph gives a constant y-axis value (Y = nRT).
For equal masses of the four gases, amount of Ne is the second highest. Hence is correspond to line **B**.

Ans: **B**

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7)

	H_2 (g)	+	I_2 (g)	⇌	2 HI (g)
Initial / mol	0		0		0.04
Change / mol	+x		+x		−2x
Equilibrium / mol	x		x		0.04−2x

Total amount of gas at eqm = 0.04 – 2x + x + x = 0.04 mol

According to Dalton's law of partial pressure, $P_A = \frac{n_A}{n_{\text{total mol of gas}}} \times P_{\text{total}}$

$$K_p = \frac{(P_{HI})^2}{P_{H_2} \times P_{I_2}} = \frac{(\frac{0.04 - 2x}{0.04} \times 1.0)^2}{(\frac{x}{0.04} \times 1.0)^2}$$

$$54 = \frac{(0.04 - 2x)^2}{x^2}$$

$$7.348 = \frac{0.04 - 2x}{x}$$

$$9.348x = 0.04$$

$$x = 0.004279$$

$$P_{HI} = \frac{0.04 - 2(0.004279)}{0.04} \times 1.0 = 0.786 \text{ atm}$$

Ans: **B**

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8) Down the group, cations of Group 2 metals have the same charge but their size increases (make reference to their ionic radii). The $\frac{\text{charge}}{\text{size}}$ ratio of the cation decreases. This leads to a **decrease in polarising power**.

The **electron clouds in the carbonate anion** is being **distorted to a smaller extent** down the group and the **extent of weakening of C–O bond decreases** down the group.

More energy is required to break the C–O bonds in the carbonate anion.

Therefore, the **decomposition temperature increases** down the group

Ans: **A**

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9) Amount of $B_2O_3 = \frac{2.50}{10.8 \times 2 + 16.0 \times 3} = 0.03592$ mol

Amount of B = $2 \times 0.03592 = 0.07184$ mol

Amount of $CO_2 = \frac{0.80}{12.0 + 16.0 \times 2} = 0.01818$ mol = Amount of C

Mol ratio of B : C = 0.07184 : 0.01818 = 4 : 1

Ans: **D**

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10) For zero order reaction, as reaction proceeds, $[I_2]$ decreases, rate of reaction (gradient of conc vs time graph) remains constant.

Ans: **B**

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11) $\Delta G = \Delta H - T\Delta S$

Statement 1 is incorrect. ΔH = +ve and ΔS = −ve, reaction is NOT spontaneous at all temperature.

Statement 2 is correct. ΔH = −ve and ΔS = +ve, reaction is spontaneous at all temperature.

Statement 3 is incorrect. ΔH = −ve and ΔS = −ve, reaction is spontaneous at low temperature.

Ans: **C**

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12) Amount of MnO_4^- = $\frac{25.0}{1000} \times 0.01 = 0.00025$ mol

Amount of $C_2O_4^{2-}$ = $\frac{25.0}{1000} \times 0.01 = 0.00025$ mol

$C_2O_4^{2-}$ is the limiting reagent.
Amount of CO_2 produced = $2 \times 0.00025 = 0.00050$ mol

Maximum volume of $CO_2 = 0.00050 \times 22.7 = 0.01135\ dm^3 = 11.4\ cm^3$

Rate = $\frac{dV_{CO2}}{dt}$ = gradient of vol vs time graph.
Rate at t_2 is faster than rate at t_1.

Ans: **C**

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13) For first order reaction, half-life is constant

Time	[Reactant]	[Product]
0	100%	0%
1st $t_{1/2}$	50%	50%
2nd $t_{1/2}$	25%	75%
3rd $t_{1/2}$	12.5%	87.5%

After 3 half−lifes (40 mins × 3), 6.00 dm^3 of O_2 = 87.5% of O_2 produced.

Maximum volume of O_2 = $6.00 \times \frac{100}{87.5}$ = 6.857 dm^3

Maximum amount of O_2 at r.t.p. = $\frac{6.857}{24.0}$ = 0.2857 mol

Initial amount of H_2O_2 = 0.2857 × 2 = 0.5714 mol

Initial conc of H_2O_2 = $\frac{0.5714}{200/1000}$ = 2.857 mol dm^{-3}

Ans: **D**

14) $K_c = \frac{[R]^{\prime}[S]^2}{[P]^{\prime}[Q]}$

	Experiment 1	Experiment 2	Experiment 3
Value of K_c	0.0375	0.0510	0.0375

Comparing experiments 1 and 2, when temperature of the system increases, the value of K_c increases. This shows that the position of equilibrium shifter to the forward reaction at higher temperature.
By Le Chatelier's Principle, endothermic reaction is favoured at higher temperature to absorb the excess heat. Hence, we can conclude that the forward reaction is endothermic.

Ans: **C**

15) A suitable indicator for acid base titration should have a working range pH that coincide with the region of sharp change of pH at the equivalence point.

For first equivalence point : sharp change in pH is 2.5-7, the best indicator is naphthyl red
For second equivalence point : sharp change in pH is 8-11, the best indicator is thymol blue

Ans: **B**

16) Option A is wrong. Point X is the reaction intermediate (product of step 1)

Option B is correct. The reaction pathway diagram shows that step 1 has a higher activation energy than step 2.

Option C is wrong. Step 1 is endothermic but that involves the breaking of C=O π bond and formation of C−C bond.

Option D is inconclusive. Based on the reaction pathway diagram alone, we cannot deduce whether the reaction is reversible or not.

Ans: **B**

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17) Option A is wrong. C_4H_{10} has two constitutional isomers: $CH_3CH_2CH_2CH_3$ and $CH_3CH(CH_3)CH_3$.

Option B is wrong. But-1-ene and pent-1-ene are not isomers, they have different molecular formula.

Option C is correct. Constitutional isomers that are functional group isomers have different chemical properties. E.g. CH_3CH_2COOH (carboxylic acid) and CH_3COOCH_3 (ester)

Option D is wrong. Isomers have the same molecular formula.

Ans: **C**

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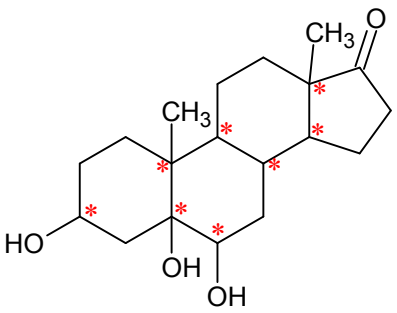
18) Androstenolone undergoes mild oxidation with cold $KMnO_4$, addition of two −OH groups across C=C.



Ans: **D**

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19) Statement 1 is wrong. The C−C*l* bond is weaker than C−F bond, the major free radical formed during initiation should be C*l*• and •CC*l*F_2.

Statement 2 is correct. The halogen radical takes part in the reaction and is regenerated at the end of the reaction.

Statement 3 is wrong. Halogen radical is formed during the initiation and propagation step. Termination step produces molecules, not radical.

Ans: **D**

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20) Statement 1 is wrong. CO_2 is produced in the reactions in the catalytic converter.

Statement 2 is correct. $NO + CO \longrightarrow CO_2 + ½\ N_2$.

Statement 3 is correct. Unburnt hydrocarbon undergoes oxidation to give $CO_2 + H_2O$.

Ans: **B**

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21) Chlorobenzene is least reactive towards nucleophile due to the two reasons.
1) C atom of C–C*l* is electron rich due to delocalized π electrons of benzene. This repels nucleophile.
2) Partial double bond character of C–C*l* bond due to the overlapping of the p orbital of C*l* with the π electron cloud of the benzene ring.

Ans: **C**

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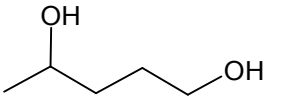
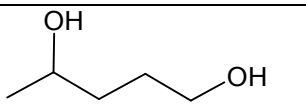
22) V contains an aldehyde group, W contains a methyl carbinol group −CH(OH)CH_3.

	V	W
Option 1 is correct	Contains Aldehyde	 Contains methyl carbinol
Option 2 is correct	Contains Aldehyde	 Contains methyl carbinol

Option 3 is wrong. No aldehyde group in the proposed structure of V.

Ans: **B**

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23) Reaction with $NaBH_4$, T contains one carbonyl group.

T undergoes oxidation reaction to gain 1 O atom without losing H atom.

Reaction with 2,4-DNPH, T contains carbonyl group.

No reaction with Na(s). T does not contain −OH or −COOH group

Ans: **A**

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24) A Lewis base is an electron pair acceptor. The strength of a base depends on the availability of the lone pair electron for donation. Diethylamine has two electron donating alkyl groups attached to the N atom which increases the electron density on the N atom. Hence, diethylamine is a stronger base than ethylamine.

Ans: **D**

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25) Statement A is wrong. Its name is butanamide.

Statement B is wrong. When heated with NaOH(aq), it will form sodium butanoate.

Statement D is wrong. Butanoic acid and NH_3 undergoes acid-base reaction to give $C_3H_7COO^-NH_4^+$. The produce amide, we will need acyl chloride C_3H_7COCl and NH_3.

Ans: **C**

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26) With cold NaOH(aq), only the acidic phenol −OH group undergoes acid-base reaction.
Alcohol group is neutral.
Hydrolysis of amide only occurs with NaOH(aq), heat

Ans: **D**

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27) In this alkaline H_2/O_2 fuel cell, electrode X is the anode for oxidation of H_2, electrode Y is the cathode for the reduction of O_2. Hence electron flow from X to Y in the external circuit.

In alkaline medium, the following reduction half equation is chosen.
$O_2 + 2H_2O + 4e^- \longrightarrow 4OH^-$ $E^e = +0.40V$

Ans: **A**

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28) At anode, oxidation of H_2O occurs.
[O] $2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$

$Q = I \times t = n_e \times F$
$20.0 \times 3 \times 60 = n_e \times 96500$
$n_e = 0.03731$ mol

Amount of O_2 produced = $¼ \times 0.03731 = 0.009328 \approx 0.00933$ mol

Ans: **C**

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29) In an octahedral geometry, four of the bonds lies in a square plane, with two other bonds on top and below the plane. Option A is the best representation of the octahedral geometry.

Ans: **A**

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30) Vanadium is a transition element. It should have high density and high melting point.

Ans: **D**

2020 A level Paper 2 suggested answers

1 (a) (i) $HCN + H_2O \rightleftharpoons CN^- + H_3O^+$

Note: HCN is a weak acid, it dissociates partially in H_2O.
Qn states the reaction with H_2O, hence H_2O must be a reactant.

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1 (a) (ii) $NaCN + H_2O \rightleftharpoons HCN + NaOH$

Note: CN^- is the conjugate base (with K_b value) of a weak acid (with K_a value), it ionises partially in H_2O.
Qn states the reaction with H_2O, hence H_2O must be a reactant.

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1 (a) (iii) Acid : H_2O (H^+ donor) Conjugate base : OH^-

Base : CN^- (H^+ acceptor) Conjugate acid : HCN

Note: The two species of conjugate acid-base pair differ by 1 H^+

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1 (a) (iv) $pK_a = 4.79$
$-\lg K_a = 4.79$
$K_a = 10^{-4.79} =$ **1.62×10^{-5} mol dm^{-3}**

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1 (a) (v) At 25 °C, pK_a of HCN + pK_b of CN^- = 14.0

pK_b of CN^- = 14.0 – 4.79 = **9.21** (3.s.f.)

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1 (b) (i) Nucleophilic Addition

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1 (b) (ii) In slightly acidic conditions, a mixture of CN^- and HCN is obtained.

$HCN \rightleftharpoons H^+ + CN^-$

There would still be high concentration of CN^- to react with the carbonyl compound in the rate determining step of nucleophilic addition mechanism. [if solution is very acidic, $[CN^-]$ will be very low]

HCN would take part in step 2 of the reaction mechanism to produce the hydroxynitrile. [if solution is not acidic, there will be no HCN for step 2]

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1 (b) (iii)

The additional electron can also be assigned to C.
Final structure should have a lone pair on C and N each and a triple bond between C and N.

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1 (b) (iv) C atom is less electronegative than N atom. Hence **C of CN^- is more likely to donate its lone pair of electron** to react with the electron deficient (δ+) C atom in carbonyl C=O.

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1 (c) (i) The C atom of CN^- donates its lone pair electron via coordinate bond to the energetically accessible 5d orbitals of the Au^+ cation.

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1 (c) (ii) $[Au(CN)_2]^-$

Note: Coordination number of Au^+ = 2, similar to that of Ag^+ and Cu^+ (same Group)

2020 A level Paper 2 suggested answers

2 (a) Al_2O_3 is an ionic compound. The **energy released when Al^{3+} and O^{2-} form ion-dipole interaction with H_2O** is **insufficient** to compensate for the **energy required to break the strong ionic bond between Al^{3+} and O^{2-}** and to **overcome the hydrogen bonding between H_2O molecules.**

Hence, Al_2O_3 is insoluble in water.

2 (b) (i) Al_2O_3 (s) + 2NaOH (aq) + $3H_2O$ (l) $\longrightarrow$ 2 Na[$Al(OH)_4$] (aq)

Note: state symbols are required.

2 (b) (ii) After the oxide layer has reacted, the Al metal can undergo a redox reaction with H_2O to produce H_2 gas.

[R] $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

[O] $Al \longrightarrow Al^{3+} + 3e^-$

Overall equation : $2\,Al + 6\,H_2O \longrightarrow 3\,H_2 + 2Al(OH)_3$

$E^{\ominus}_{cell} = -0.83 - (-1.66) = +0.83V$ (Redox reaction is spontaneous)

OR

[R] $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

[O] $Al + 4OH^- \longrightarrow [Al(OH)_4]^- + 3e^-$ formation of complex ion in alkaline medium

Overall equation : $2\,Al + 2OH^- + 6\,H_2O \longrightarrow 3\,H_2 + 2[Al(OH)_4]^-$

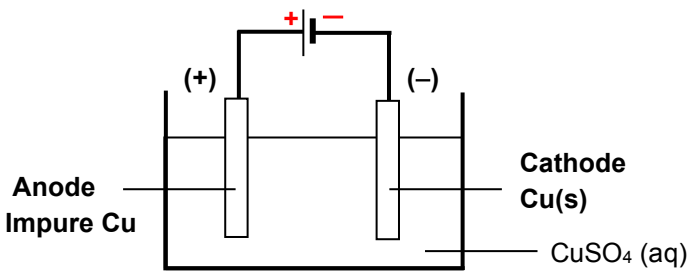
2 (c) (i) Aluminium is a reactive metal and can be oxidised easily. When aluminium objects are anodised, the outer surface is oxidized to Al_2O_3. This Al_2O_3 oxide layer is resistant to corrosion and it acts as a protective layer which seals off the aluminium beneath it from further reaction.

Anodising is a surface treatment to increase the thickness of the corrosion resistant Al_2O_3 layer on the surface of aluminium metal by electrolysis where aluminium metal is placed at the anode.

2 (c) (ii)

	type of reaction occuring	half-equation(s)
anode	oxidation	$2Al + 3H_2O \longrightarrow Al_2O_3 + 6H^+ + 6e^-$ **(Oxidation of Al to Al_2O_3 in acidic medium, balance the half equation)**
cathode	reduction	$2H^+ + 2e^- \longrightarrow H_2$

2 (d)



2 (e) (i) Al^{3+}: $1s^2\,2s^2\,2p^6$

Cr^{3+}: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^3$

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2 (e) (ii) Despite Cr^{3+} having an additional occupied principal quantum shell of electrons as compared to Al^{3+}, Cr^{3+} contains 11 more protons than Al^{3+} and this lead to an increase in nuclear charge for Cr^{3+}.

The overall nuclear attraction experienced by the valence shell electrons in Cr^{3+} and Al^{3+} are comparable and hence they have similar ionic radius.

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3 (a) Condensation

Note: amino acids undergoes condensation to form polypeptides

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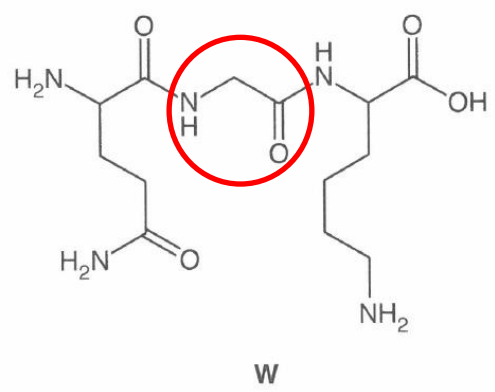
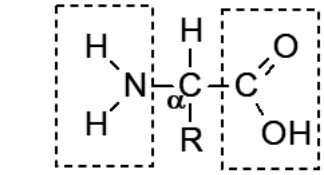
3 (b) Amino acid **X** does not contain a chiral carbon as it does not rotate plane-polarised light.



W

Note: Amino acid has the following general sructure.



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3 (c) Zwitterion has **both positive and negative charges and net charge is zero**.

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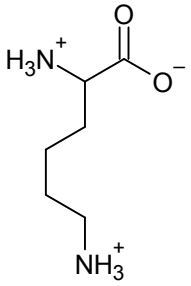
3 (d) (i)



Note: pK_a values of amino acids are meant for the protonated form of the amino acids where the amino groups exist as its conjugate acid $-NH_3^+$.

pH 7 > pK_{a1}, $-COOH$ group will lose H^+.
pH 7 < pK_{a2} and pK_{a3}, both $-NH_3^+$ groups retain the H^+.

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3 (d) (ii) pH = 10.0 (Any value between 9.16 and 10.67)

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3 (e) (i) Side-chain of Y : amine

Side-chain of Z : amide

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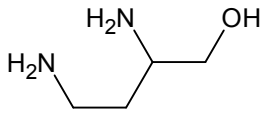
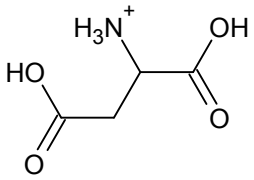
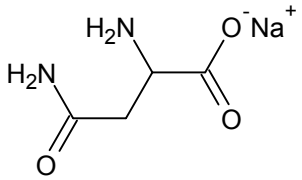
3 (e) (ii) In the **amine group** in the side-chain of Y, there is a lone pair of electrons on the nitrogen atom, which is available for donation to a H^+. **The conjugate acid $-NH_3^+$ group is acidic and thus the side-chain of lysine has a pK_a value**.

In the **amide group** in the side-chain of Z, the lone pair of electrons on the nitrogen atom is delocalized into the π electron cloud of the adjacent carbonyl group, making the lone pair of electrons **unable to accept a proton, thus the side-chain of Glutamine does not have a conjugate acid and hence no pK_a value.**

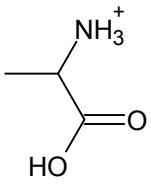
3 (f)

 **Note: Reduction of amide to amine and carboxylic acid to 1° alcohol.** compound **T**	 **Note: Hydrolysis of amide to −COOH and NH_4^+ and acid-base reaction of amine to give $-NH_3^+$** compound **U**	 **Note: Acid-carbonate reaction of carboxylic acid to give $-COO^-$ and CO_2** compound **V**

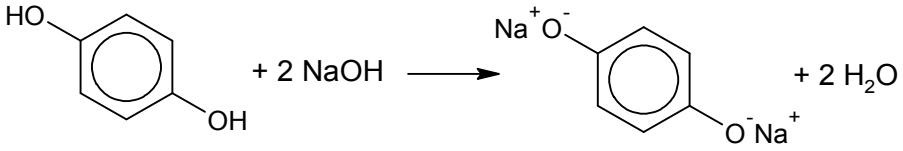
3 (g) Step a : $K_2Cr_2O_7$, H_2SO_4(aq), heat with immediate distillation
Note: controlled oxidation of 1° alcohol to aldehyde

Step b : H_2SO_4 (aq), heat
Note: hydrolysis of −CN to −COOH

Note : for step b, it will actually produce the following compound under acidic hydrolysis, but acidic hydrolysis the best answer for this conversion.



4 (a)



4 (b) Amount of sodium = $\frac{0.30}{23.0}$ = 0.0130 mol

0.010 mol of ethanol and phenol reacts with 0.010 mol of Na(s)
0.010 mol of hydroquinone requires 0.020 mol of Na(s)

For hydroquinone, Na(s) is the limiting reagent and will be used up completely, effervescence of H_2(g) is also observed.

For both ethanol and phenol, Na(s) is in excess, there will be some Na(s) left after the reaction is completed. As phenol is more acidic than ethanol, the reaction of phenol with Na(s) will be more vigorous, and we can observe that the effervescence of H_2(g) will stop at an earlier timing as compared to ethanol.

2020 A level Paper 2 suggested answers

4 (c) (i) AgBr is an ionic compound with ionic lattice structure. A large amount of energy is required to overcome the strong ionic bond between Ag^+ and Br^- ions. Hence, AgBr has a relatively high melting point.

4 (c) (ii) $AgBr \longrightarrow Ag + Br$

[Information from point 1-3 suggest that Ag^+ is reduced to Ag and Br^- oxidised to Br]

4 (c) (iii) Light of a lower frequency contains a smaller amount of energy.

$X^- \longrightarrow X + e^-$

The most loosely held electron in Br^- is located in the 4p orbital while that of Cl^- is located in the 3p orbital. Valence electrons for Br^- are found **further away** from the nucleus. Br^- also experiences **greater shielding effect** due to greater number of inner core electrons. These factors **outweigh the increase in nuclear charge.**

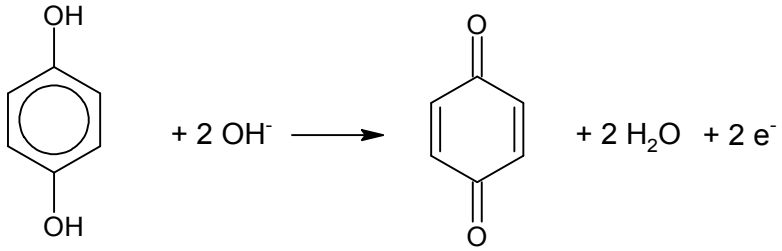
Hence, valence electrons of Br^- experiences lesser nuclear attraction and less energy is required to remove the most loosely held electron from Br^- as compared to Cl^-. Hence Br^- are more affected by light of a lower frequency.

4 (c) (iv) **[Data-based question]**

During the photographic film development process, if the film is exposed to light again, it will cause more AgX to decompose into Ag atom, thus producing unintended images.

It is essential to develop the film in dark to preserve the original image captured during photo taking.

4 (d) **Note: Alkaline condition is used in this context.**

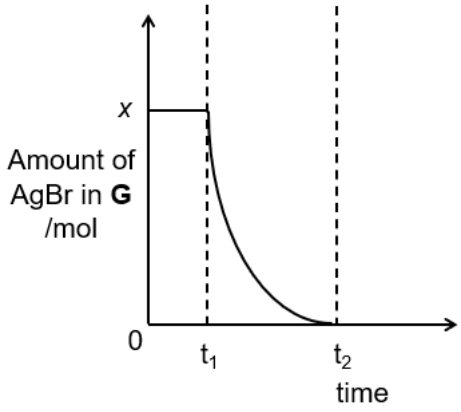


4 (e) (i) **[Data-based question]**

Silver atoms function as a catalyst in step 4 as a silver halide crystal containing silver atoms turns black approximately 10^{10} times faster than a silver halide crystal without silver atom.

4 (e) (ii) **Thinking process:**

After exposure to light, a hidden image (Ag atom catalyst) is produced.
No changes in AgBr from t = 0 to t_1, no reaction with hydroquinone.
At t_1, reaction with hydroquinone leads to rapid decrease in AgBr from t_1 to t_2 due to the presence of catalyst.
Reaction stops at t_2, hence amount of AgBr = 0.



2020 A level Paper 2 suggested answers

5 (a) (i) Assuming 100 g of reaction mixture,

Mass of hydroquinone = 10 g Mass of H_2O_2 = 25 g

Amount of hydroquinone = $\frac{10}{110.0}$ = 0.09091 mol

Amount of H_2O_2 = $\frac{25}{34.0}$ = 0.7353 mol

Hence, H_2O_2 is present in exess.

5 (a) (ii) When H_2O_2 undergoes decomposition catalysed by catalase, there is a rapid production of large amount of O_2(g). This caused the pressure inside the reaction chamber to increase rapidly.

5 (b)

$$C_6H_6O_2(aq) + H_2O_2(aq) \xrightarrow{y} C_6H_4O_2(aq) + 2H_2O(l)$$

$$\downarrow +177.2 \qquad \uparrow -285.5$$

$$C_6H_4O_2(aq) + H_2(g) + H_2O_2(aq) \xrightarrow[-189.0 \times ½]{} C_6H_4O_2(aq) + H_2(g) + H_2O(l) + ½\ O_2(g)$$

By Hess's Law,

y = 177.2 + ½ × (−189.0) −285.5

= −202.8 ≈ **−203 kJ mol^{-1}**

5 (c) Total energy released = energy released from equation 1 + energy released from equation 2

In 1.0×10^{-3} g of reaction mixture,

Mass of hydroquinone (10%) = $\frac{10}{100} \times 1.0 \times 10^{-3} = 0.0001$ g

Amount of hydroquinone = $\frac{0.0001}{110.0} = 9.091 \times 10^{-7}$ mol

Energy released from equation 1 = $202.8 \times 9.091 \times 10^{-7}$

= 1.844×10^{-4} kJ

Using answer from (a)(i)

Mass of H_2O_2 (25%) = $\frac{25}{100} \times 1.0 \times 10^{-3} = 0.00025$ g

Initial amount of H_2O_2 = $\frac{0.00025}{34.0} = 7.353 \times 10^{-6}$ mol

Amount of unreacted H_2O_2 = $7.353 \times 10^{-6} - 9.091 \times 10^{-7} = 6.444 \times 10^{-6}$ mol

H_2O_2 (aq) ⟶ H_2O(l) + ½ O_2(g) $\Delta H = -189.0 \times ½ = -94.5$ kJ mol^{-1}

Energy released from equation 2 = $94.5 \times 6.444 \times 10^{-6} = 6.089 \times 10^{-4}$ kJ

Total energy released = $1.844 \times 10^{-4} + 6.089 \times 10^{-4}$

= $7.933 \times 10^{-4} \approx$ **7.93×10^{-4} kJ**

5 (d) (i) ΔG_{eqn1} is a negative value, indicating the reaction is spontaneous.

5 (d) (ii) The reaction have a high activation energy, hence it does not occur in the reservoir where the enzymes are absent.

When the reaction mixture enters the reaction chamber, the enzymes function as a biological catalyst that provides an alternative reaction pathway with lower activation energy, causing the reaction to occur quickly.

---

5 (e) At high $[H_2O_2]$, all the active sites of the enzyme catalase are saturated.
Any increase in the concentration of H_2O_2 cannot increase the rate of reaction. The rate of reaction no longer depends on $[H_2O_2]$ and is zero-order with respect to H_2O_2.

---

5 (f) $\Delta G^{\ominus} = -nFE^{\ominus}_{cell}$

$[O]\ C_6H_6O_2 \longrightarrow C_6H_4O_2 + 2H^+ + 2e^-$

$n = 2$

$-206.5 \times 10^3 = -2 \times 96500 \times E^{\ominus}_{cell}$ **ΔG needs to be in J mol^{-1} for this formula!**

$E^{\ominus}_{cell} = +1.07V$

$E^{\ominus}_{cell} = E^{\ominus}(H_2O_2/H_2O) - E^{\ominus}(C_6H_4O_2/C_6H_6O_2)$

$+1.07 = +1.77 - E^{\ominus}(C_6H_4O_2/C_6H_6O_2)$

$E^{\ominus}(C_6H_4O_2/C_6H_6O_2) = +$**0.70V**

2020 A level Paper 3 suggested answers

1 (a) (i) A transition element is a **d-block element** which forms **one or more stable ions** with ***partially filled d subshell.***

1 (a) (ii) Let % of ^{63}Cu be x and % of ^{65}Cu be (100−x)

$$\frac{62.930x + 64.928(100-x)}{100} = 63.546$$

$62.930x + 6492.8 – 64.928x = 6354.6$
$138.2 = 1.998x$
$x = 69.2$

% of ^{63}Cu = **69.2%**

% of ^{65}Cu = 100 – 69.2 = **30.8%**

1 (b) (i) In the **presence of ligands, electronic repulsion** between lone pair electrons of ligands and the d orbitals electrons causes the **degenerate d-orbitals** of the transition element ion **to split into two different energy levels with a small energy gap, ΔE. (d splitting)**

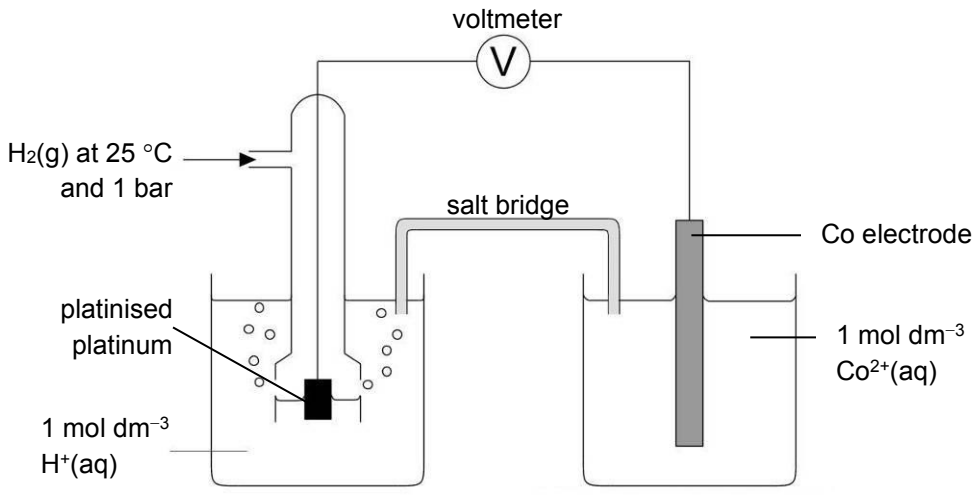
As the **3d subshell is partially filled**, electrons in the **lower energy d-orbitals** can absorb **light of a certain wavelength in the visible light spectrum** with energy corresponding to the energy gap, ΔE, and be **promoted to the higher energy d-orbitals (d-d transition).**

The **colour observed** is the **complement of the colour absorbed**.

1 (b) (ii) Electronic configuration for Cu^{2+} is [Ar] **$3d^9$**. In presence of ligands, d splitting occurs, **d-d transition is possible** as there **is vacancy at the higher energy d orbitals**, thus **certain wavelength of visible light spectrum is absorbed**, and the solutions **appear coloured**.

Electronic configuration for Cu^{+} is [Ar] **$3d^{10}$**. In presence of ligands, d splitting occurs, **no d-d transition occur** as the **higher energy d orbitals are fully occupied**, thus **light from visible light spectrum is not absorbed**, and the solutions **appear colourless**.

1 (c) (i)



Note: Standard Hydrogen Electrode is used as a reference electrode to measure the standard electrode potential of Co^{2+}/Co half−cell.
Temp = 25 °C (298 K), Pressure = 1 bar
Concentration of all aqueous ions = 1 mol dm^{-3}
Each half-cell need an electrical conductor as the electrode

2020 A level Paper 3 suggested answers

1 (c) (ii) $Co^{2+} + 2e^- \rightleftharpoons Co$ $E^\ominus = -0.28V$

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ $E^\ominus = +0.77V$

Redox reaction between Fe^{3+} and Co.

Overall redox reaction : $2Fe^{3+} + Co \longrightarrow 2Fe^{2+} + Co^{2+}$

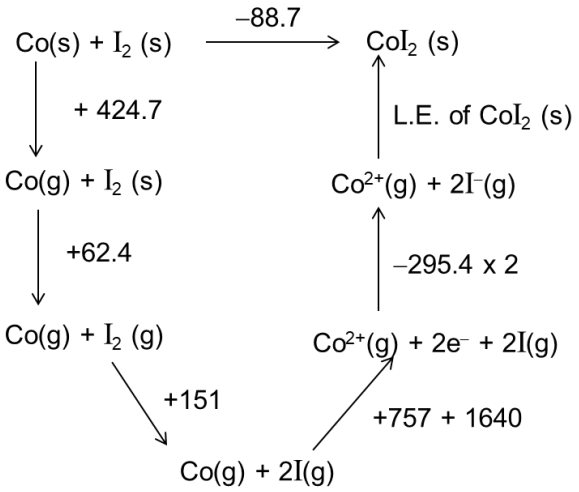
$E^\ominus_{cell} = +0.77 - (-0.28) =$ **+1.05V** (The redox reaction is spontaneous)

---

1 (d) (i) Lattice energy is the amount of energy released when 1 mol of ionic solid is formed from its constituent gaseous ions.

---

1 (d) (ii)



By Hess's Law,

$-88.7 = 424.7 + 62.4 + 151 + 757 + 1640 - 2(295.4) +$ L.E. of $CoI_2(s)$

L.E. of $CoI_2(s) = -2533 \approx$ **-2530 kJ mol^{-1}**

---

1 (d) (iii) Magnitude of lattice energy in decreasing order CoO > CoF_2 > CoI_2.

$|L.E| \propto \left| \frac{q_+ \times q_-}{r_+ + r_-} \right|$, the cation is the same Co^{2+} for the 3 compounds.

For the anions, O^{2-} has the greatest charge of −2 and a small ionic radius of 0.140 nm, giving rise to the largest magnitude for lattice energy. The ionic radius of I^- (0.216 nm) is larger than that of F^- (0.136 nm), CoI_2 has the smallest magnitude of lattice energy due to greater interionic distance.

Note: Variation in ionic charge has a greater effect on the lattice energy due to the multiplication factor ($q_+ \times q_-$), whereas the variation in ionic radius is an addition factor ($r_+ + r_-$).

---

1 (e) The formula for A is $Co(NH_3)_3(NO_2)_3$. (M_r = 247.9)

The oxidation number of Co is +3.

B has a molecular formula of $Co_2(NH_3)_6(NO_2)_6$.

The ions in B are

$[Co(NH_3)_6]^{3+}$ and $[Co(NO_2)_6]^{3-}$

OR

$[Co(NH_3)_5(NO_2)]^{2+}$ and $[Co(NH_3)(NO_2)_5]^{2-}$

OR

$[Co(NH_3)_4(NO_2)_2]^{+}$ and $[Co(NH_3)_2(NO_2)_4]^{-}$

Note: Since B contains 2 Co^{3+} cations with 6 NH_3 and 6 NO_2^- ligands, it is likely to exist as 2 complex ions, a complex cation and a complex anion.

2020 A level Paper 3 suggested answers

1 (f) (i) $2MnO_4^- + 6H^+ + 5NO_2^- \longrightarrow 2Mn^{2+} + 3H_2O + 5NO_3^-$

1 (f) (ii) Reaction 1 : $2MnO_4^- + 6H^+ + 5NO_2^- \longrightarrow 2Mn^{2+} + 3H_2O + 5NO_3^-$

Reaction 2 : $2MnO_4^- + 16H^+ + 10I^- \longrightarrow 2Mn^{2+} + 8H_2O + 5I_2$

Reaction 3 : $2S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2I^-$

Amount of $S_2O_3^{2-}$ used for reaction 3 = $\frac{22.4}{1000} \times 0.0150 = 0.000336$ mol

Amount of I_2 in reaction 3 = amount of I_2 produced in reaction 2
= ½ × 0.000336 = 0.000168 mol

Amount of MnO_4^- reacted in reaction 2 = $\frac{2}{5} \times 0.000168 = 0.0000672$ mol

Total amount of MnO_4^- used = $\frac{50}{1000} \times 0.00500 = 0.000250$ mol
Amount of MnO_4^- used in reaction 1 = 0.000250 – 0.0000672 = 0.0001828 mol

Amount of NO_2^- in sample = $\frac{5}{2} \times 0.0001828 = 0.000457$ mol
Mass of $NaNO_2$ in 1.00g sample = 0.000457 × (23.0 + 14.0 + 16.0 × 2) = 0.03153g

% by mass of $NaNO_2$ in 1.00g sample = $\frac{0.03153}{1.00} \times 100 =$ **3.15%**

2020 A level Paper 3 suggested answers

2 (a) **Note: In aqueous medium, we uses Bronsted-Lowry base definition, bases are protons (H^+) acceptor.**

Basicity decreases from ethylamine to phenylamine to ethanamide.

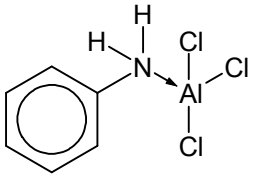
Ethanamide is neutral. Due to **significant delocalization to adjacent C=O (highly electronegative O atom)**, the lone pair of electrons on N is **not available** to accept H^+ from H_2O.

Ethylamine is a stronger base than phenylamine. The **electron-donating alkyl group (CH_3CH_2-) increases the electron density** on N atom and it is more available to accept H^+ from H_2O as compared to phenylamine.

For phenylamine, due to **delocalization of lone pair of electrons on N into the benzene ring**, this **decreases the electron density** on N atom and it is less available to accept H^+ from H_2O as compared to ethylamine.

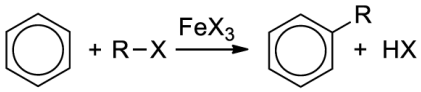
2 (b) **Note: Qn mentioned that amine reacts with $AlCl_3$ to form a neutral compound C, meaning the lone pair electron on N is not available to accept H^+ in compound C.**

Dative bonding using lone pair electrons from N atom of phenylamine to empty 3p orbital of Al atom of $AlCl_3$ (Al in $AlCl_3$ only have 6 electrons in valence shell after bonding, it is an electron pair acceptor)

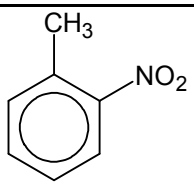
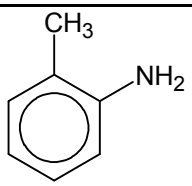


FYI

- **Friedel-Crafts ALKYLATION (formation of alkylbenzene)**



2 (c) (i)

 Compound D	 Compound E

2 (c) (ii) Step 1 : Conc HNO_3, conc H_2SO_4

Note: As $-CH_3$ is a weakly activating group, electrophilic substitution takes place more readily and heating is not required **(FYI)**.

Step 2 : Sn, conc HCl, heat, followed by excess NaOH(aq)

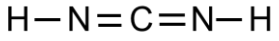
Note: Reduction of $-NO_2$ to $-NH_2$.

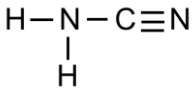
Step 3: limited CH_3CH_2Cl, heat (**N atom of compound E function as the nucleuphile**)

Note: nucleophilic substitution of halogenoethane (2 carbon).

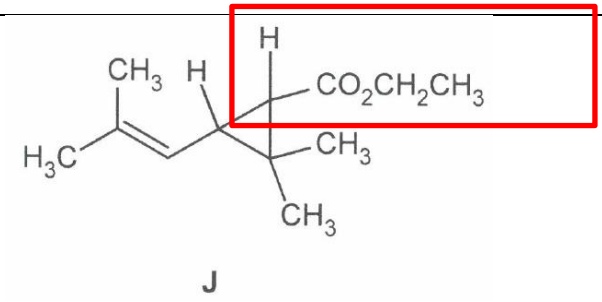
2020 A level Paper 3 suggested answers

2 (d)





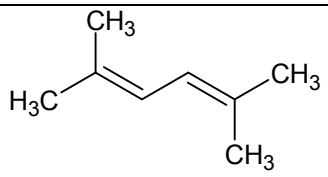
2 (e) (i)



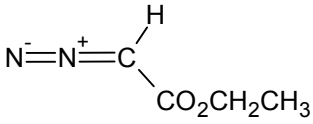
J

Boxed up portion is from **H**

(**G** is hydrocarbon, thus **G** cannot contain the $-CO_2CH_2CH_3$ group)

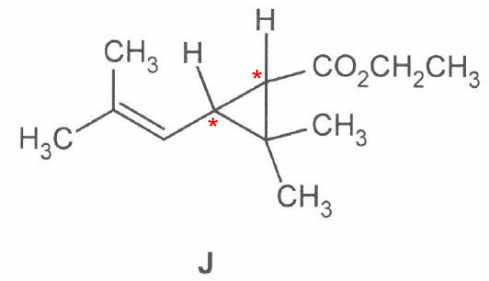


Compound **G** (Hydrocarbon)



Compound **H**

2 (e) (ii)



J

J contains 2 chiral C to display enantiomerism (optical isomerism) and no C=C with cis-trans isomerism (requires 2 different groups on each C of C=C).

Total number of stereoisomer for J
$= 2^2 =$ **4**

2 (f) (i)

Note: Concept of ring strain / angle strain for 3-membered or 4-membered ring is also tested in TYS 2014 Paper 3

The C−C bond energy in cyclopropane is lower due to the angle strain in a 3 membered ring.

Based on VSEPR theory, the four bond pairs around the C atom are supposed to be 109.5° apart to minimise repulsion. However in cyclopropane, two of the C−C bonds in the 3 membered ring are forced to be only 60° apart, and these bonds experiences stronger repulsion between the bond pair electrons, causing the C−C bond to be weaker than that in propane.

2 (f) (ii)

Assuming cyclopropane and propene are both in gaseous state,

$\Delta H_{rxn} = \sum$(BE of reactants) $- \sum$(BE of products)

$-31 = [289\times3 + 6(\text{BE of C–H in cyclopropane})] - [350 + 610 + 6\times410]$

6(BE of C−H in cyclopropane) = 2522

Average BE of C−H in cyclopropane = 420.3 ≈ **420 kJ mol^{-1}**

2020 A level Paper 3 suggested answers

2 (f) (iii) We can plot a graph of [cyclopropane] against time using the data from the different experiments. For each experiment, the initial rate can be calculated by drawing a tangent at t = 0 and calculate the gradient of the tangent.

To confirm that it is first order w.r.t cyclopropane, comparing the experiments, when [cyclopropane] is varied, the initial rate should change by the same extent. For example, when [cyclopropane] × 3, initial rate also ×3.

---

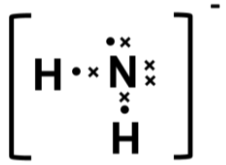
2 (f) (iv) The presence of catalyst speed up the reaction, causing the rate constant, k, to be larger. The activation energy, E_a, of the reaction is lowered by the presence of catalyst.

---

3 (a) (i) VSEPR theory suggests that electron regions (bond pairs + lone pairs) around the central atoms arrange themselves as far as possible to minimise mutual repulsion.

For $[Na(NH_3)_6]^+$, there are 6 ligands (bond pairs) around the Na^+ cation. It is octahedral around Na^+ with bond angle of 90°.

For NH_2^-, there are 2 bond pairs and 2 lone pairs electrons around the N atom. It is bent shape around N with bond angle of 104.5° (109.5° – 2 × 2.5°) between the N−H bonds.



FYI

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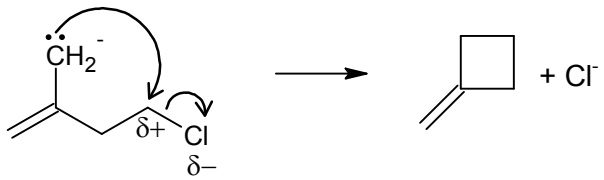
3 (a) (ii)



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3 (a) (iii) $2NaNH_2 + \frac{5}{2} O_2 \longrightarrow Na_2O + 2NO + 2H_2O$

---

3 (b) Increasing acidity : butanoic acid < 2−iodobutanoic acid < 2−chlorobutanoic acid

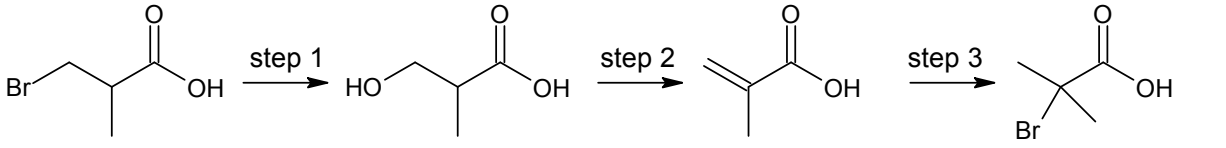
Eqm 1 : $CH_3CH_2CH_2COOH \rightleftharpoons CH_3CH_2CH_2COO^- + H^+$
Eqm 2 :$CH_3CH_2CHClCOOH \rightleftharpoons CH_3CH_2CHClCOO^- + H^+$
Eqm 3 :$CH_3CH_2CHICOOH \rightleftharpoons CH_3CH_2CHICOO^- + H^+$

The presence of electron-withdrawing −C*l* and −I groups decrease the intensity of the negative charge on the conjugate base, thus the dissociation into H^+ and conjugate base is more favourable. Hence 2-chlorobutanoic acid and 2-iodobutanoic acid are more acidic than butanoic acid.

The more electronegative the electron-withdrawing groups, the greater the extent of dispersing the intensity of the negative charge on the conjugate base, thus the dissociation into H^+ and conjugate base is more favourable. C*l* is more electronegative than I, thus position of eqm 2 lies more to the right hand side than eqm 3, 2−chlorobutanoic acid is a stronger acid than 2−iodobutanoic acid.

2020 A level Paper 3 suggested answers

3 (c)



$(C_4H_7O_2Br)$ **N**

$(C_4H_8O_3)$ **P**

Q

2-bromo-2-methyl propanoic acid

Step 1 : NaOH(aq), heat, **followed by H^+(aq)**
[Nucleophilic Substitution of −Br with −OH, however basic condition will produce $-COO^-$
H^+(aq) is required to acidify the solution to convert $-COO^-$ to −COOH]

Step 2 : excess conc H_2SO_4, heat [Elimination of H & OH from adjacent C atoms]

Step 3 : HBr(g) [Electrophilic addition of H & Br on adjacent C atoms]

3 (d)

Method 1

Amount of HA = $\frac{1.76}{M_r}$ mol

Initial concentration of HA = $\frac{1.76}{M_r}$ mol dm^{-3}

$HA \rightleftharpoons H^+ + A^-$

$[H^+]_{eqm} = 10^{-3.28} = 0.0005248$ mol dm^{-3} = $[A^-]_{eqm}$

$[HA]_{eqm} = \frac{1.76}{M_r} - 0.0005248$

$K_a = \frac{[H^+]_{eqm} \times [A^-]_{eqm}}{[HA]_{eqm}}$

$1.38 \times 10^{-5} = \frac{(0.0005248) \times (0.0005248)}{(1.76/M_r - 0.0005248)}$

$\frac{1.76}{M_r} - 0.0005248 = 0.01996$

$\frac{1.76}{M_r} = 0.02048$

M_r = **85.9**

The carboxylic acid is C_3H_5COOH (M_r = 86.0)

Since HA is a **branched chain** carboxylic acid, its structure is $CH_2=C(CH_3)COOH$

Method 2

Amount of HA = $\frac{1.76}{M_r}$ mol

Initial concentration of HA = $\frac{1.76}{M_r}$ mol dm^{-3}

$HA \rightleftharpoons H^+ + A^-$

For weak acid,
$[H^+] = \sqrt{K_a \times [HA]}$

$[HA] = \frac{(10^{-3.28})^2}{1.38 \times 10^{-5}} = 0.01996$

$\frac{1.76}{M_r} = 0.01996$

M_r = **88.2**

The carboxylic acid is C_3H_7COOH (M_r = 88.0)

Since HA is a **branched chain** carboxylic acid, its structure is $CH_3CH(CH_3)COOH$

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4 (a) (i) 1) 1−bromobutane will react via S_N2 mechanism as it is a primary halogenoalkane with little steric hindrance and the nucleophile can approach the δ+ C easily in the slow step of the mechanism.

2) 2-bromo-2methylpropane will react via S_N1 mechanism as it is a tertiary halogenoalkane with significant steric hindrance and presence of 3 $-CH_3$ groups around the δ+ C prevent the nucleophile from approaching the δ+ C in the slow step of the mechanism.

Tertiary halogenalkane also favour S_N1 mechanism as the 3° carbocation (C+) produced in step 1 of the mechanism is stabilised by 3 electron donating alkyl groups.

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4 (a) (ii) For S_N2 mechanism, the nucleophile approach the δ+ C from the opposite side of the leaving group, producing a single enantiomer.

For S_N1 mechanism, a trigonal planar carbocation is formed in step 1 of the mechanism. In step 2 of the mechanism, the nucleophile can approach the trigonal planar carbocation (C+) from either side of the plane with equal probability, producing a racemic mixture containing equal amount of the two enantiomers.

---

4 (b) $\Delta H^{\ominus}_{sol} = \sum \Delta H^{\ominus}_f$ products $- \sum \Delta H^{\ominus}_f$ reactants

$= 64.8 + 2(-230.0) - (-449.8)$

$=$ **$+54.6$ kJ mol^{-1}**

$\Delta G^{\ominus}_{sol} = \Delta H^{\ominus}_{sol} - T\Delta S^{\ominus}_{sol}$

$= 54.6 - 298 \times (\frac{-196.2}{1000})$ [Note: ΔG, ΔH and ΔS should be in same units of J or kJ]

$= +113.1 \approx$ **$+113$ kJ mol^{-1}**

Since $\Delta G^{\ominus}_{sol}$ is a positive value, it shows the dissolution of $Cu(OH)_2(s)$ is not spontaneous and hence it is only sparingly soluble in water.

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4 (c) (i) A **buffer solution** contains a mixture of weak acid and its conjugate base (or weak base and its conjugate acid) and it can **resist a change in pH when a small amount of H^+or OH^- is added to it.**

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4 (c) (ii) **Note: In this buffer, HSO_3^- is the weak acid, SO_3^{2-} is the conjugate base**
Use full arrow for acid-base reaction.

When a small amount of H^+ is added,
$SO_3^{2-} + H^+ \longrightarrow HSO_3^-$

When a small amount of OH^- is added,
$HSO_3^- + OH^- \longrightarrow SO_3^{2-} + H_2O$

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4 (c) (iii) $NaHSO_3$ reacts with NaOH (neutralization), use ICF table (in mol) to determine limiting reagent.

$$\text{Amount of } OH^- = \frac{25.0}{1000} \times 0.600 = 0.015 \text{ mol}$$

$$\text{Amount of } HSO_3^- = \frac{50.0}{1000} \times 0.500 = 0.025 \text{ mol}$$

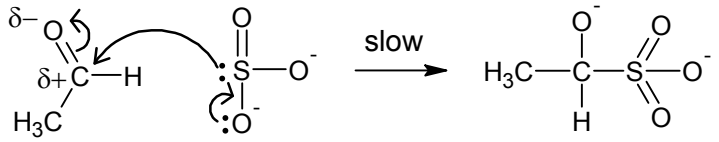
	OH^-	$+ HSO_3^-$	$\rightarrow$	SO_3^{2-}	$+ H_2O$
I / mol	0.015 (L.R.)	0.025		0	–
C / mol	–0.015	–0.015		+0.015	–
F / mol	0	0.010		0.015	–

The final mixture contains a buffer solution of HSO_3^- and SO_3^{2-}.

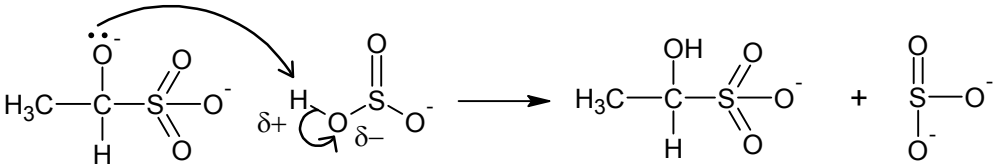
$$pH = pK_a + \lg \frac{[SO_3^{2-}]}{[HSO_3^-]} = -\lg (6.73 \times 10^{-8}) + \lg \frac{0.015/V}{0.010/V} = \underline{\mathbf{7.35}}$$

4 (c) (iv)

step 1 :



step 2 :

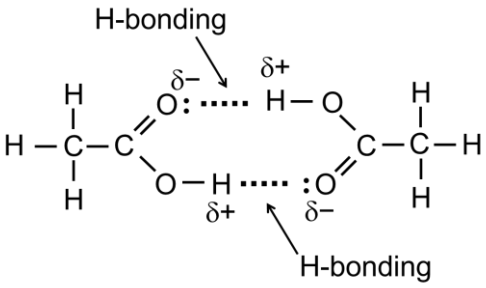


Note: similar to nucleophilic addition of HCN to carbonyl group.
SO_3^{2-} is similar to CN^-, take part in step 1 of the mechanism and regenerate at end of step 2.

HSO_3^- is similar to HCN, take part in step 2 of the mechanism to donate the H^+ and regenerate SO_3^{2-}.

4 (d) (i) At dynamic equilibrium, the **rate of forward and backward (or reverse) reactions equal**, and **concentrations of reactants and products do not change.**

4 (d) (ii)



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4 (d) (iii)

$$2\ CH_3COOH \rightleftharpoons (CH_3COOH)_2$$

I / mol dm^{-3}	0.100		0
C / mol dm^{-3}	-0.0417×2		+0.0417
E / mol dm^{-3}	0.0166		0.0417

$$\frac{[(CH_3COOH)_2]}{[CH_3COOH]} = \frac{0.0417}{0.0166}$$

$$= 2.512 \approx \underline{\mathbf{2.51}}$$

4 (d) (iv) In aqueous solution, CH_3COOH is more likely to form hydrogen bonding with the surrounding H_2O molecules (which is present in large excess) than forming a dimer with another molecule of CH_3COOH. Hence the **ΔG** for this equilibrium in an aqueous solution is **less negative** (reaction is less spontaneous as CH_3COOH is more likely to exist in the monomer form).

5 (a) General trend, first ionisation energy of elements increases across Period 3. **Nuclear charge increases** due to increasing number of protons in the nucleus, **shielding effect remains relatively constant** due to the same number of inner shell electrons. This results in **stronger nuclear attraction for the valence electrons**, hence **more energy is required to remove the most loosely held electron**.

Variation 1: Small dip between Mg and Al
The most loosely held electron from Al is in the **higher energy 3p subshell** while that of Mg is in the 3s subshell.
Hence **less energy is required to remove the most loosely held 3p electron from Al, resulting in lower first I.E. of Al.**

Variation 2: Small dip between P and S
All the 3p electrons in P are unpaired; while in S, two of the 3p electrons are paired. There is **inter-electron repulsion between the paired electrons in the 3p subshell in S**. Thus, **less energy is required to remove the most loosely held electron from S**, **resulting in lower first I.E. of S.**

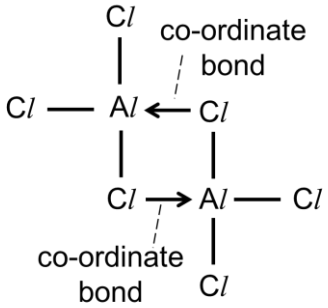
5 (b) (i) Al_2O_3 has no reaction with water, the resulting mixture has **pH = 7**.

$$AlCl_3(s) + 6\ H_2O(l) \longrightarrow [Al(H_2O)_6]^{3+}(aq) + 3\ Cl^-(aq)$$

$$[Al(H_2O)_6]^{3+}(aq) \rightleftharpoons [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$$ Note: Reversible arrow

Due to high $\frac{\text{charge}}{\text{size}}$ ratio of Al^{3+} cation, significant hydrolysis occurs and produces some $H^+(aq)$, giving an acidic solution of **pH = 3**

5 (b) (ii)



Note : Al of $AlCl_3$ has an empty 3p orbital (total 6 valence electron after bonding) to accept a lone pair electrons from Cl of another $AlCl_3$ molecule.

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5 (c) (i) $K_{sp} = [Zn^{2+}][OH^-]^2$ units: $mol^3\ dm^{-9}$

5 (c) (ii) Let the solubility of $Zn(OH)_2 = s$ mol dm^{-3}

	$Zn(OH)_2(s)$	$\rightleftharpoons$	$Zn^{2+}(aq)$	+	$2\ OH^-(aq)$
Initial /mol dm^{-3}			0		0
Change /mol dm^{-3}	$-s$		$+s$		$+2s$
Eqm /mol dm^{-3}			s		$2s$

K_{sp} of $Zn(OH)_2 = [Zn^{2+}][OH^-]^2 = (s)(2s)^2$
$2.0 \times 10^{-17} = 4s^3$
$s = 1.710 \times 10^{-6}$

$[OH^-]_{eqm} = 2 \times 1.710 \times 10^{-6} = 3.42 \times 10^{-6}$ mol dm^{-3}
pOH = $-\lg[OH^-] = 5.466$
pH = 14 – pOH = **8.53**

5 (c) (iii) Eqm 1 : $Zn(OH)_2(s) \rightleftharpoons Zn^{2+}(aq) + 2\ OH^-(aq)$

Addition of HC*l*(aq) will lead to a **decrease in $[OH^-]$**, the position of eqm 1 shifts to the RHS, **increasing the solubility of $Zn(OH)_2(s)$**.

Addition of $ZnCl_2$(aq) will lead to an **increase in $[Zn^{2+}]$**, the position of eqm 1 shifts to the LHS, **decreasing the solubility of $Zn(OH)_2(s)$**.

5 (d) (i) Since $E^\ominus$ for reduction of MnO_2 is more positive, this half cell undergoes reduction.

$2MnO_2(s) + Zn(s) \longrightarrow Mn_2O_3(s) + ZnO(s)$

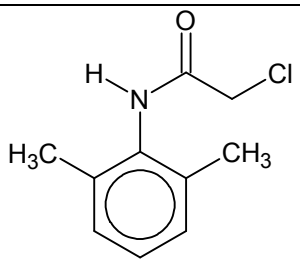
$E^\ominus_{cell} = +0.15 - (-1.28) =$ **+ 1.43 V**

5 (d) (ii) $\Delta G^\ominus = -nFE^\ominus_{cell}$, where n = 2 for this reaction.
$\Delta G^\ominus = -2 \times 96500 \times 1.43$
$= -275990\ J\ mol^{-1}$
$\approx$ **− 276 kJ mol^{-1}**

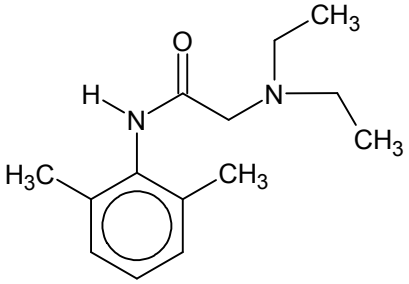
5 (e) (i) 2,6-dimethylphenylamine

5 (e) (ii) **Thinking process:**
Molecular formula of S is $C_8H_{11}N$, the phenylamine group of S undergoes condensation reaction with a 2 carbon acyl chloride to give amide in compound T. The new carbon chain contains a C*l* group.

Compound U undergoes acid-base reaction with H_2SO_4 to give the lidocaine salt. Hence compound U have a tertiary amine group that can accept H^+.

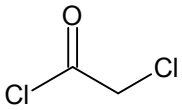


Compound **T** ($C_{10}H_{12}NOCl$)

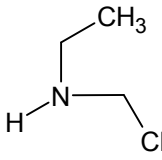


Compound **U**

5 (e) (iii) Step 1 :



Step 2 :



, heat (This function as a nucleophile to react with C−C*l* of compound T)

5 (e) (iv) Acid-base reaction