H2 Chemistry TYS 2022 suggested answers

Paper 1 Answer Key

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

2022 A level Paper 1 suggested answers

1 Ans: C

NaF is an ionic compound with strong ionic bonds between Na^+ and F^- ions. Largest amount of energy is required to overcome strong ionic bond and it has the highest boiling point.

$CH_3CH_2CH_3$, $CH_3CH_2NH_2$ and CH_3CH_2OH are covalent compounds with simple molecular structure. $CH_3CH_2CH_3$ is non-polar with instantaneous dipole-induced dipole (id-id) interaction between its molecules while $CH_3CH_2NH_2$ and CH_3CH_2OH are polar with id-id and hydrogen bonding (H-bond) between molecules. Least amount of energy is required to overcome the id-id in $CH_3CH_2CH_3$ and it has the lowest boiling point.

As O is more electronegative than N, the dipole of O−H bond is greater than N−H bond. More energy is required to overcome the stronger H-bond between CH_3CH_2OH molecules as compared to $CH_3CH_2NH_2$. Hence boiling point of CH_3CH_2OH is greater than $CH_3CH_2NH_2$.

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2 Ans: C

Electronegativity decreases down the Group. C*l* is more electronegative than Br. Statement A is incorrect.

Statement B is correct but it does not help to explain the polarity of the bond.

Outer shell electrons in Br experience greater shielding effect due to greater number of INNER shell electrons than C*l*. Down the Group, the increase in shielding effect and increase in distance of outer shell electron from the nucleus outweighs the increase in nuclear charge. Nuclear attraction towards outer shell electrons decreases down the Group and hence Br is less electronegative than C*l*, leading to a polar covalent bond between Br and C*l*. Statement C is correct and explain the polarity.

Statement D is incorrect, the repulsion between electrons in outer shell is negligible. E.g. repulsion between 4s and 4p electrons.

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3 Ans: D

$pK_a = -\lg K_a$, hence $K_a = 10^{-pKa}$. Data suggests that thioacetic acid has a larger K_a value and dissociates into H^+ more readily than ethanoic acid. Statements 1&2 are incorrect.

If the solutions are of the same concentration, thioacetic acid (larger K_a) will give a higher $[H^+]$. We can use this information to deduce that the S−H bond is broken more readily than O−H bond. Bond energy values in Data Booklet also support this (O−H 460 kJ mol^{-1} vs S−H 347 kJ mol^{-1})
Statement 3 is correct.

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4 Ans: C

pV = nRT (Note: p in Pa, V in m^3, T in K)

total mol of gas, $n = \frac{pV}{RT} = \frac{3.55 \times 10^7 \times 5 \times 10^{-3}}{8.31 \times (20+273)} = 72.9$ mol

Since the gas contains equal amount of O_2 and N_2O, amount of N_2O = 36.45 mol

Mass of N_2O used = $36.45 \times (14.0 \times 2 + 16.0) = 1604$ g ≈ 1.60 kg

5 Ans: A

Solution of $AlCl_3$ is pH 3 due to significant cation hydrolysis, dissociated H^+ can react with Na_2CO_3 to give effervescence of CO_2(g).

Solution of $MgCl_2$ is pH 6.5 due to slight cation hydrolysis, it is weakly acidic. It might or might not react with a weak base Na_2CO_3.

Solution of $NaCl$ is pH 7, no reaction with Na_2CO_3.

The best available option is A, only $AlCl_3$

6 Ans: B

Electronegativity decreases down the Group. Since X is more electronegative than As, X must be P (Phosphorus).

Electronegativity increases across the Period. Since Y is more electronegative than P, Y must be S (Sulfur), proton number 16.

7 Ans: A

In 100 g of solder glass, mass of B_2O_3 = 16 g, mass of PbO = 84 g.

Amount of $B_2O_3 = \frac{16}{10.8 \times 2 + 16.0 \times 3} = 0.2299$ mol Amount of PbO $= \frac{84}{207.2 + 16.0} = 0.3763$ mol

Amount of B = $2 \times 0.2299 = 0.4598$ mol Amount of Pb = 0.3763 mol

Mol ratio of Pb : B $= \frac{0.3763}{0.4598} = 0.818$

8 Ans: B

Sixth I.E. involves the removal of the 6th most loosely held electron.

$X^{5+}(g) \longrightarrow X^{6+}(g) + e^-$

For Group 15 elements, the sixth I.E. would be significantly larger than that of Group 16 elements.

The sixth electron for a Group 15 element would come from an inner principal quantum shell and experiences stronger nuclear attraction, thus a large amount of energy is required to remove the 6th electron as compared to Group 16 elements.

We can conclude that J and M are from Group 15 while G and H are from Group 16.

I.E. decreases down the Group as the electrons experiences weaker nuclear attraction.

Hence G is from Period 4 and H is from Period 3.

9 Ans: B

Cs^+, I^- and Xe are isoelectronic species (same number of electrons).

The nuclear attraction towards the most loosely held electron is affected by the number of protons in the species.

Since proton number increases from I^- to Xe to Cs^+, most energy is required to remove the most loosely held electron in Cs^+. $\Delta H_1 > \Delta H_3 > \Delta H_2$

10 Ans: D

$|L.E.| \propto |\frac{q_+ \times q_-}{r_+ + r_-}|$

The product of charges ($q_+ \times q_-$) is the same for the 4 compounds.
Hence, we should compare the inter-ionic distance of the 4 ionic compounds, Zn^{2+} and Cl^- has the smallest inter-ionic distance, and this would mean that the lattice energy for $ZnCl_2$ is expected to be the most exothermic.

11 Ans: D

ΔS for the reaction is a positive value as the number of gas particles increases after the reaction.

$\Delta G = \Delta H - T\Delta S$
With ΔH = −ve and ΔS = +ve, the reaction is spontaneous at all temperature.

12 Ans: C

Information shows that PbO_2 function as a catalyst for the decomposition of H_2O_2.
- Rate of reaction (gradient of vol vs time graph) is faster in presence of PbO_2.
- PbO_2 remains chemically unchanged at the end of the reaction.

We can conclude that activation energy is lowered for experiment 2. And this caused the rate constant, k, to be higher for experiment 2.

FYI: $k = Ae^{-\frac{E_a}{RT}}$

13 Ans: B

	$2SO_2(g)$	$+ O_2(g)$	$\rightleftharpoons$	$2SO_3(g)$
Initial /mol	2.00	2.00		0
Change /mol	−1.80	−0.90		+1.80
Eqm /mol	0.20	1.10		1.80

$$K_c = \frac{[SO_3]^2}{[SO_2]^2 \times [O_2]} = \frac{[\frac{1.80}{0.5}]^2}{[\frac{0.20}{0.5}]^2 \times [\frac{1.10}{0.5}]} = 36.8 \text{ mol}^{-1} \text{ dm}^3$$

14 Ans: B

For a buffer solution,

$$pH = pK_a + \lg\frac{[HCO_3^-]}{[H_2CO_3]}$$

$$7.4 = -\lg(2.5 \times 10^{-4}) + \lg\frac{[HCO_3^-]}{[H_2CO_3]}$$

$$3.8 = \lg\frac{[HCO_3^-]}{[H_2CO_3]}$$

$$\frac{[HCO_3^-]}{[H_2CO_3]} = 6280$$

$$\frac{[H_2CO_3]}{[HCO_3^-]} = 1.59 \times 10^{-4}$$

15 Ans: C

$AgCl(s) + aq \rightleftharpoons Ag^+(aq) + Cl^-(aq)$ ---- **eqm 1**

When NH_3 is added, $Ag^+(aq)$ reacts with $NH_3(aq)$ to form the soluble complex ion $[Ag(NH_3)_2]^+$. This causes $[Ag^+(aq)]$ to decrease, by LCP, position of eqm 1 would shifts to the right to partially offset the decrease in $[Ag^+(aq)]$, and solubility of $AgCl(s)$ increases.

When $NaCl(aq)$ is added, this causes $[Cl^-(aq)]$ to increase, by LCP, position of eqm 1 would shifts to the left to partially offset the increase in $[Cl^-(aq)]$, and solubility of $AgCl(s)$ decreases.

16 Ans: C

When $Ag_2SO_4(s)$ is dissolved in water,
Let the solubility of $Ag_2SO_4(s)$ be s mol dm^{-3}

	$Ag_2SO_4(s)$	+ aq	$\rightleftharpoons$	$2Ag^+(aq)$	+ $SO_4^{2-}(aq)$
Initial /mol dm^{-3}		-		0	0
Change /mol dm^{-3}	−s	-		+2s	s
Eqm /mol dm^{-3}		-		2s	s

Given that $[Ag^+(aq)] = 0.032$ mol dm^{-3}, s = 0.016
K_{sp} of $Ag_2SO_4(s) = [Ag^+]^2 \times [SO_4^{2-}] = (0.032)^2 \times (0.016) = 1.638 \times 10^{-5}$ mol^3 dm^{-9}

In the second eqm when $[SO_4^{2-}(aq)] = 0.50$ mol dm^{-3}, the resulting solution is saturated with $Ag_2SO_4(aq)$.
Ionic Product = K_{sp}
$[Ag^+(aq)]^2 \times [SO_4^{2-}] = 1.638 \times 10^{-5}$
$[Ag^+(aq)]^2 \times 0.50 = 1.638 \times 10^{-5}$
$[Ag^+(aq)] = 5.72 \times 10^{-3}$ mol dm^{-3}

17 Ans: A

Option 1 would lead to formation of a C−C*l* sigma bond, the product is $(CH_3)_3C-Cl$.

Option 2 shows a heterolytic cleavage of polar C−C*l* bond, the product is $(CH_3)_3C^+$, a carbocation.

Option 3 shows a heterolytic cleavage of polar C−O bond, the product is $(CH_3)_3C^+$, a carbocation.

Option 4 shows a heterolytic cleavage of polar C−C*l* bond, AND formation of C=O pi bond. The product is $(CH_3)_2C=O$.

18 Ans: C

Option 1 is correct. Enantiomers are stereoisomers that are non-superimposable mirror images of each other. They have different interaction with plane of plane-polarised light and different interaction with stereo specific reactant (requires specific 3D arrangement). Biological receptors are similar to enzymes and only interact with molecules of a specific 3D arrangement to trigger a biological response.

Option 2 is incorrect. Enantiomers are stereoisomers that have similar chemical properties (e.g. undergo similar chemical reactions) due to same type of functional group present. Except in their interactions with another chiral molecule. This statement is incorrect as enantiomers are NOT structural isomers.

Option 3 is incorrect. Enantiomers have same physical properties (e.g. melting and boiling points) due to same type of intermolecular forces of attraction.

19 Ans: B

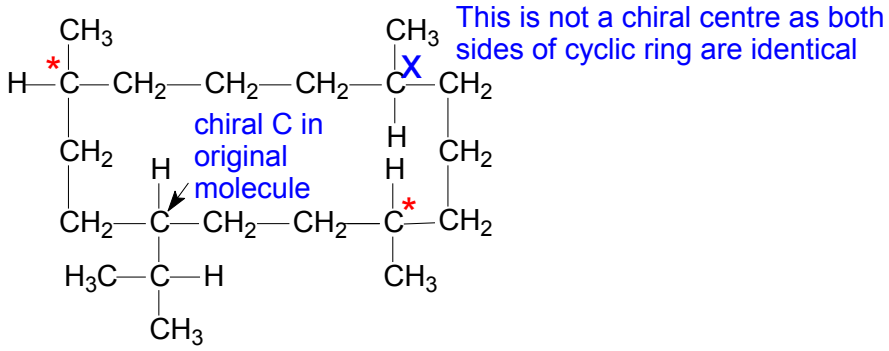
The alkene group is reduced (gain H atoms) to give alkane while the primary alcohol group is oxidised (lose H atoms) to give aldehyde.

Hence it is not appropriate to classify the overall reaction as hydrogenation/reduction/oxidation.

The molecular formula of the compound remains the same as C_3H_6O but the structural formula changes. Hence the most appropriate classification is isomerisation.

20 No Answer

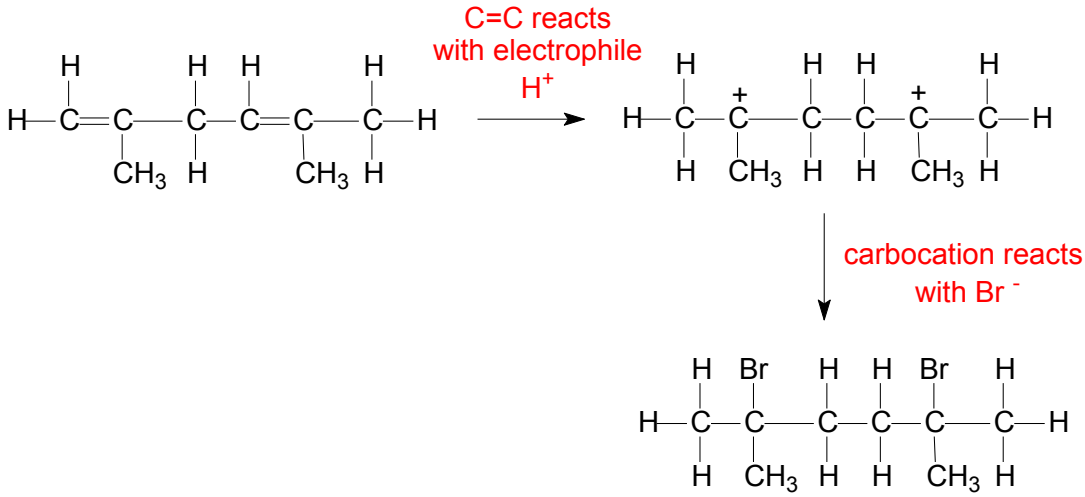
C=C bonds undergo reduction to alkane. The structure of the product is



Only 2 **NEW** chiral C are produced **in this reaction**.

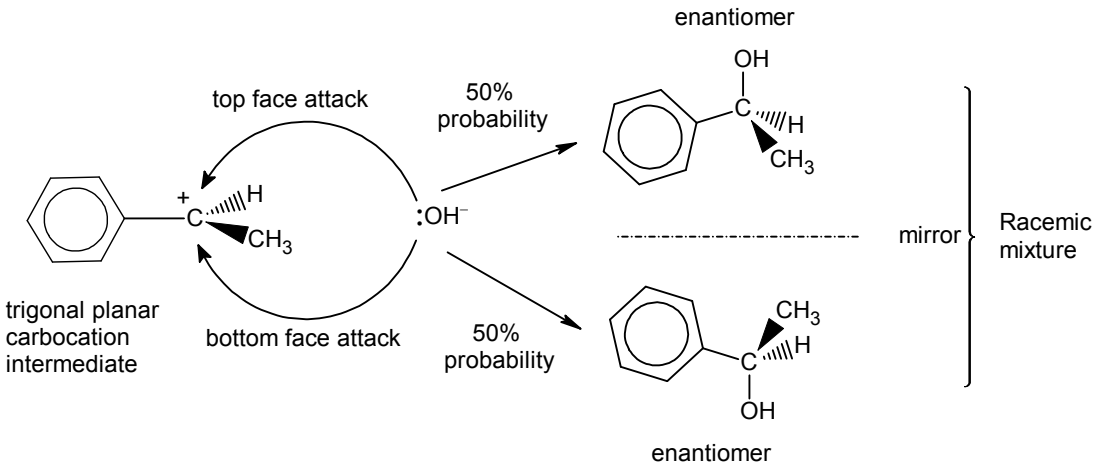
21 Ans: A

Recall: Markonikov's rule.
Electrophilic addition of C=C favours the production of a more stable carbocation that is bonded to greater number of electron donating alkyl groups.



22 Ans: B

The hydrolysis reaction undergoes a S_N1 mechanism via a trigonal carbocation to produce a racemic mixture containing equal amount of the two enantiomers.



Statement 2 is incorrect as only ONE carbocation intermediate is formed.

23 Ans: B

The proposed reactions are
Step 1: Heat with NaOH, nucleophilic substitution of C−X with OH^-, thus producing X^-(aq)
Step 2: Acidified with HNO_3, acid-base reaction to remove excess OH^- (prevent formation of AgOH ppt)
Step 3: $AgNO_3$(aq), precipitation of AgX ppt.
Step 4: NH_3(aq), check for solubility of AgX ppt in NH_3(aq).

Iodobenzene (3rd compound) would not undergo nucleophilic sub due to partial double bond in C−I due to delocalisation of lone pair electron of I into the benzene ring.

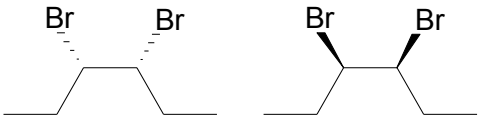
The other three compounds would produce Cl^-(aq) and I^-(aq) that eventually lead to formation of AgCl and AgI ppt.

Only AgCl is soluble in NH_3(aq), AgI ppt remains

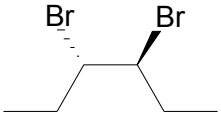
24 Ans: B

Note: The initial way of drawing DOES NOT allow us to see the internal plane of symmetry. We would need to rotate the C−C bond to visualise the followings.

Compounds 3 & 4 can also be drawn as follows, they contains 2 chiral carbons and are meso compound with an internal plane of symmetry, rotation of plane−polarised light by each chiral carbon gets cancelled out completely.

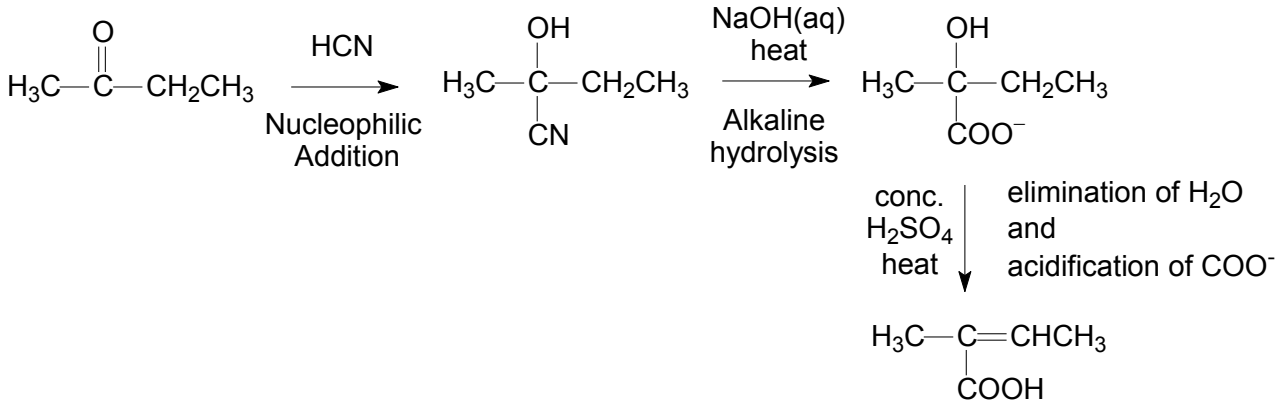


Compound 2 contains 2 chiral carbons and does not have an internal plane of symmetry, it can rotate plane polarised light.



Compound 1 has a chiral carbon and can rotate plane polarised light.

25 Ans: D



26 Ans: D

Statement A is incorrect.
$HCOOH \rightleftharpoons HCOO^- + H^+$
$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$
Electron-donating $-CH_3$ groups **increase the intensity of the negative charge** on the conjugate base,CH_3COO^-, thus the **dissociation** of CH_3COOH into H^+ and conjugate base is **less favourable** than HCOOH. Hence this **decreases the acidity** of the CH_3COOH.
HCOOH would have a K_a value that is greater than 1.75×10^{-5}.

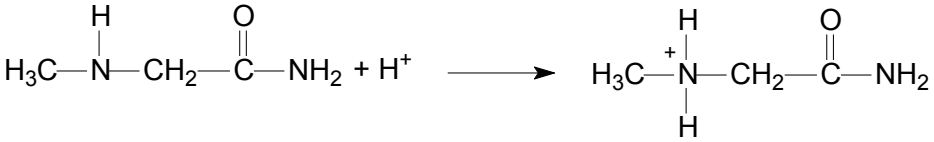
Statement B is incorrect.
Electron-withdrawing groups ($-Cl$, $-I$) **decrease the intensity of the negative charge** on the conjugate base, thus the **dissociation** into H^+ and conjugate base is **more favourable**. Hence this **increases the acidity** of the compound. Compound with stronger electron withdrawing group (more electronegative), would have a greater acidity.
K_a ($CH_2ClCOOH$) > K_a (CH_2ICOOH) > K_a (CH_3COOH)

Statement C is incorrect.
CH_3COOH and C_6H_5COOH acid dissociation are of different extent (different K_a values).
C_6H_5COOH dissociates more readily to give a slightly higher concentration of $C_6H_5COO^-$ as compared to CH_3COO^-.

Statement D is correct.
4−chlorobenzoic acid is more acidic than benzoic acid due to the presence of electron withdrawing $-Cl$. If the aqueous solutions have the same pH ($[H^+]_{eqm}$), we requires lower concentration of 4-chlorobenzoic acid to give the same $[H^+]_{eqm}$.
Hence there must be a greater concentration of benzoic acid than 4−chlorobenzoic acid.

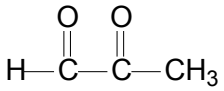
27 Ans: A

Amine group is basic while amide group is neutral.
Lone pair electron of N of amine is able to accept H^+ when reacted with cold HCl(aq).



28 Ans: A

Reaction	Y ($C_3H_4O_2$)	Conclusion
Hot acidified $K_2Cr_2O_7$	Orange to green	Y contains 1°/2° alcohol or aldehyde
Alkaline aqueous iodine	Positive reaction	Y contains methyl carbinol or methyl carbonyl group
Sodium metal	No reaction	Y does not contain −OH or −COOH group



compound Y

Compound Y has the structure and would react with both Fehling's solution (test for aldehyde) and 2,4-DNPH (test for carbonyl group).

29 Ans: D

$Zn^{2+} + 2e^- \rightleftharpoons Zn$ $\quad E^e = -0.76V$

$Sn^{2+} + 2e^- \rightleftharpoons Sn$ $\quad E^e = -0.14V$

Since metallic Zinc and tin can only be oxidised, the VO_2^+ must have been reduced.
Check if reduction of $VO_2^+ \longrightarrow VO^{2+}$ is feasible. E^e_{cell} must be positive
If feasible, as excess metal is present, check if further reduction of $VO^{2+} \longrightarrow V^{3+} \longrightarrow V^{2+}$ is feasible.

	Zn	Sn
Reaction with VO_2^+	E^e_{cell} = +1.76 V	E^e_{cell} = +1.14 V
Reaction with VO^{2+}	E^e_{cell} = +1.10 V	E^e_{cell} = +0.48 V
Reaction with V^{3+}	E^e_{cell} = +0.50 V	E^e_{cell} = −0.12 V
Final oxidation state of vanadium ion	V^{2+}	V^{3+}

30 Ans: D

Electronic configuration of the atoms
Fe: [Ar] $3d^6\ 4s^2$
Co: [Ar] $3d^8\ 4s^2$

Across the Period 4 transition elements,

- Nuclear charge increases
- Electrons are added to the inner principal quantum shell (3d subshell)
- Shielding effect for valence shell 4s electrons increases due to the increase in no. of inner shell (3d) electrons
- Nuclear attraction for the valence electrons is almost constant
- Hence atomic radii and first I.E. of Fe and Co are approximately constant.

2022 A level Paper 2 suggested answers

1 (a) Isotopes of same element : F and G
Recall : Isotopes are atoms of the same element with the same number of protons but different number of neutrons. F and G are ^{35}Cl and ^{37}Cl

Cation with the same electronic configuration as argon : D
Note: D is Ca^{2+}, 20 protons and $18e^-$

Atoms of different elements with the same nucleon number : A and C
Recall : Nucleon number is the sum of proton + neutron. Atoms does not carry charge.
Note: A is ^{40}Ar, C is ^{40}Ca.

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1 (b) (i) C has electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$
D has electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

C and D has the same nuclear charge (no. of protons). The valence electrons in C are further away from the nucleus due to having more filled principal quantum shell and experiences greater shielding effect due to greater number of inner shell electrons.

Valence electrons in C experiences weaker nuclear attraction hence C is larger than D.

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1 (b) (ii) D and E are isoelectronic with the same number of electrons.

D has a greater nuclear charge (no. of protons) attracting the same number of electrons.

Valence electrons in D experiences stronger nuclear attraction than E.

E is larger than D.

2022 A level Paper 2 suggested answers

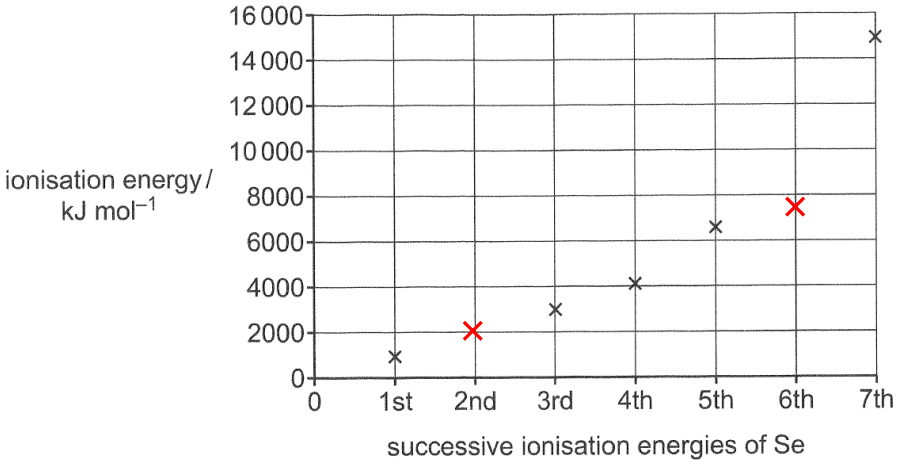
2 (a) The number of protons exerting nuclear attraction on the electrons remains the same while the number of remaining electrons decreases with the progressive removal of electron from the same element.
Attraction between the nucleus and the remaining electrons increases, more energy is required to remove each subsequent most loosely held electrons. Hence giving rise to general increase in successive ionisation energies.

2 (b) Electronic configuration of Se : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^4$

Note: in $4p^4$ configuration, only 2 electrons are paired in the 4p subshell.

Out of 34 electrons, only 32 electrons are paired up.
Total number of electron pairs = 16

2 (c)



General increase in successive ionisation energies and a large increase is expected between the 6th and 7th I.E. as the 7th electron is removed from the next inner principal quantum shell.

2 (d) Se is below O in Group 16. Down the group, the valence electron is **further away from the nucleus** due to having **more filled principal quantum shell** and experiences **increase in shielding effect** (due to greater no. of inner core electrons). These factors **outweigh** **the increase in nuclear charge** (due to greater no. of protons).

Se has a weaker nuclear attraction for the bonding pairs of electrons in a covalent bond and thus **electronegativity is lower than O**. Electronegativity value for Se could be 2.5 (any value between 0.7 to 3.5)

2 (e) Mass of Se in one Brazil nut = $\frac{0.57\ \text{mg}}{6}$ = 0.095 mg = 9.5×10^{-5} g

Amount of Se = $\frac{9.5 \times 10^{-5}}{79.0}$ = 1.203×10^{-6} mol

No. of Se atoms = $1.203 \times 10^{-6} \times 6.02 \times 10^{23}$ = $\underline{7.24 \times 10^{17}}$

2 (f) (i) $P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$ (pH < 7)

$SO_3 + H_2O \longrightarrow H_2SO_4$ (pH < 7)

2 (f) (ii) These oxides are acidic oxides. Another reagent is NaOH(aq).

2022 A level Paper 2 suggested answers

3 (a) Acid hydrolysis (M is an ester)

3 (b) (i) Ethanoic acid

3 (b) (ii) $2CH_3COOH + Na_2CO_3 \longrightarrow 2\ CH_3COONa + CO_2 + H_2O$

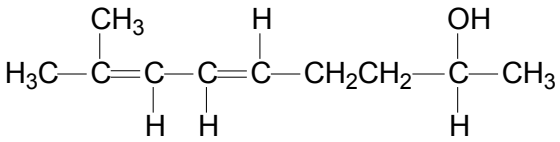
3 (b) (iii) Reduction

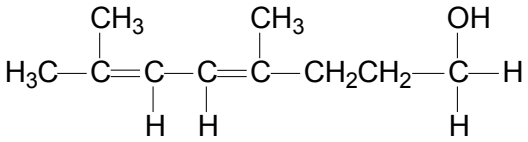
3 (c) K has no reaction with Na_2CO_3 but give misty acid fumes with PCl_5.
$\longrightarrow$ K contains −OH group, but not −COOH.

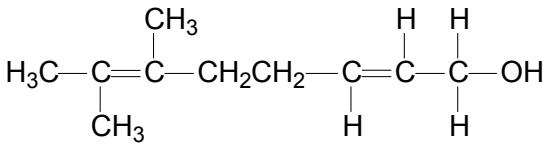
K reacts with hot $KMnO_4$ to give 3 products.
$\longrightarrow$ K contains two C=C. (note: if K contains 1°/2° alcohol, −OH would also be oxidized)

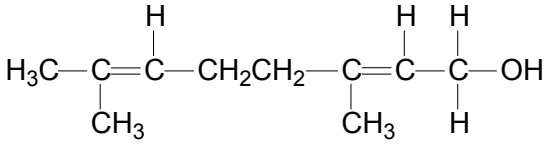
Through the balanced equation for hydrolysis of M, we can deduce that K is $C_{10}H_{18}O$.
$C_{12}H_{20}O_2 + H_2O \longrightarrow C_2H_4O_2 + C_{10}H_{18}O$

There are several possible structures of K that can give the vigorous oxidations products.



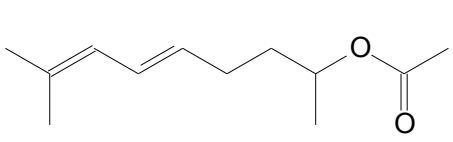


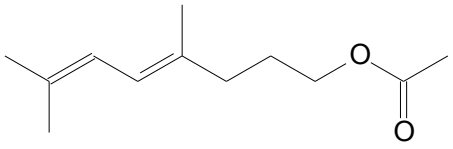


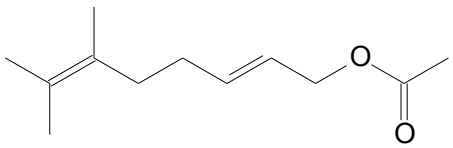


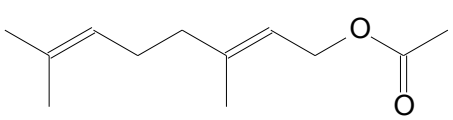
3 (d) $LiAlH_4$ uses H^- nucleophile for reduction. H^- is attracted to the δ+ C in −COOH and causes reduction reaction. However, H^- is repelled by the electron rich C=C in alkenes, hence reduction does not occur.

3 (e) M is an ester, there are multiple possible structures for M based on your structure of K in **3(c)**.









3 (f) CO_2 reacts with NaOH and we can conclude that 15 cm^3 of CO_2 is present in the mixture.

Volume of unreacted O_2 = 77.5 cm^3
Volume of O_2 involved in the reaction = 100 – 77.5 = 22.5 cm^3

	C_xH_yO	+ $(x + \frac{y}{4} - \frac{1}{2})$ O_2	⟶	x CO_2	+ $\frac{y}{2}$ H_2O
Reacting vol / cm^3		22.5		15	

Amount of CO_2 = $\frac{15}{24000}$ = 6.25×10^{-4} mol

Amount of O_2 reacted = $\frac{22.5}{24000}$ = 9.375×10^{-4} mol

Mol ratio of C_xH_yO : O_2 : CO_2 = 1 : 1.5 : 1

Hence we can conclude x = 1

$x + \frac{y}{4} - \frac{1}{2} = 1.5$
$\frac{y}{4} = 1$

y = 4

Compound N is CH_4O

2022 A level Paper 2 suggested answers

4 (a) (i) This is a redox reaction. Using half equations in Data Booklet.

[R] $NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$

[O] $Cu \longrightarrow Cu^{2+} + 2e^-$

Overall equation : $Cu + 2NO_3^- + 4H^+ \longrightarrow Cu^{2+} + 2NO_2 + 2H_2O$

4 (a) (ii) Any two reasons from below

Positive $E^{\ominus}_{cell}$ shows that the reaction is spontaneous and the formation of product is favoured. Equilibrium is usually for redox reactions with $E^{\ominus}_{cell} = 0$

This is not a closed system. $NO_2(g)$ produced is allowed to escape from the reaction system. Equilibrium state cannot be achieved.

$NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O$ $E^{\ominus} = +0.81V$ under standard conditions of 298 K and concentrations of all aqueous ions at 1 mol dm^{-3}. When concentrated HNO_3 is used, the concentration of NO_3^- and H^+ are greater than 1 mol dm^{-3}. This increase in concentration would shift the position of equilibrium to the right, favouring reduction, increasing the $E^{\ominus}$ value for this half cell and hence causing $E^{\ominus}_{cell}$ to become more positive. The overall redox reaction would favour the formation of products when concentrated HNO_3 is used, the reaction is unlikely to be an equilibrium mixture.

4 (a) (iii) The $E^{\ominus}$ value for $Cu^{2+} + e^- \rightleftharpoons Cu^+$ half-cell is under standard conditions of 298 K and concentrations of all aqueous ions at 1 mol dm^{-3}. In this reaction, Cu^+ is produced as CuI(s). Due to low solubility of CuI(s), $[Cu^+(aq)]$ will be much lower than 1 mol dm^{-3} and hence the position of equilibrium would shift to the right, favouring the reduction, increasing the $E^{\ominus}$ value for this half cell and hence causing $E^{\ominus}_{cell}$ to become more positive.

4 (a) (iv) $CuI(s) + aq \rightleftharpoons Cu^+(aq) + I^-(aq)$

$K_{sp} = [Cu^+(aq)] \times [I^-(aq)]$ units = $mol^2\ dm^{-6}$

4 (a) (v) [R] $Cu^{2+} + e^- + I^- \longrightarrow CuI$

$E^{\ominus}_{cell} = E^{\ominus}(Cu^{2+}/CuI) - E^{\ominus}(I_2/I^-)$
$+0.32 = E^{\ominus}(Cu^{2+}/CuI) - (+0.54)$
$E^{\ominus}(Cu^{2+}/CuI) = +0.86V$

4 (a) (vi) The K_c value for equation 1 (3×10^5) is much larger than 1. This suggest that the reaction mixture contains a large proportion of products (I_2) as compared to the reactant (Cu^{2+}).

Furthermore, when the reaction mixture is titrated with $S_2O_3^{2-}$, reaction of I_2 and $S_2O_3^{2-}$ will decrease $[I_2(aq)]$ and cause the position of equilibrium of equation 1 to shift to the right. As the titration continues, all Cu^{2+} would react with I^- to form CuI and I_2.
Amount of I_2 produced from equation can be related to Cu^{2+} present via stoichiometric ratio as the reaction eventually goes to completion.

4 (a) (vii) Oxidation state of Cu in CuI = +1
Cu^+ : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

Note: Cu has electronic configuration of $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$
The most loosely held electron is in the outermost PQS, 4s subshell.

4 (a) (viii) Solid CuI would be a white solid.
In Cu^+, the 3d orbitals are fully filled, <u>no d-d transition</u> is possible as the higher energy d orbitals are fully occupied, white light is not absorbed, and the solid appears white.

2022 A level Paper 2 suggested answers

4 (b) (i)

	Formula of complex ion	Number of ligands in complex ion	Shape of complex ion
Complex ion in **H**	$[Cu(H_2O)_6]^{2+}$	6	Octahedral
Complex ion in **J**	$[CuCl_4]^{2-}$	4	tetrahedral

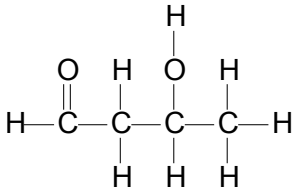
4 (b) (ii) We can observe that when the ligands changes from H_2O to Cl^-, the number of ligands surrounding the Cu^{2+} decreases.
Electron cloud of Cl^- is larger as compared to that of H_2O, less Cl^- can be placed around the central Cu^{2+} ion in the complex ion.

Note: The term “suggest” means we should provide reasonable explanation that account for the observed trend.

2022 A level Paper 2 suggested answers

5 (a) Aldehyde and 2° alcohol

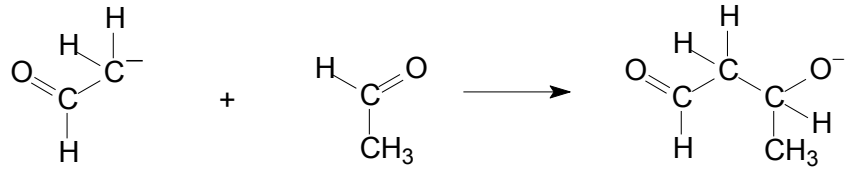
5 (b)



Total number of electrons in σ bond = $26e^-$ (13 σ bonds)

Total number of electrons in π bond = $2e^-$ (1 π bond in C=O)

5 (c) (i)



5 (c) (ii) Stage 1 : Ethanal behaves as a Bronsted acid, it is a H^+ donor.

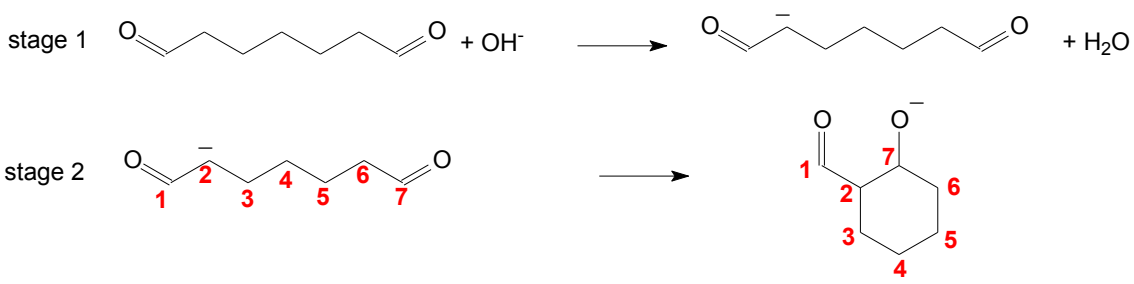
Stage 2 : Ethanal behaves as a Lewis acid, C of C=O is an electron pair acceptor.

5 (c) (iii) NaOH acts as a catalyst in the overall reaction. OH^- takes part in step 1 of the mechanism and is regenerated in step 3.

5 (c) (iv) M_r of **T** = 7 × 12.0 + 12 × 1.0 + 2 × 16.0 = 128.0

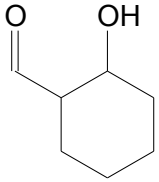
Since M_r of Q is also 128, compound **T** would have undergone intramolecular aldol reaction between its 2 aldehyde groups.

Following the pattern in the mechanism,



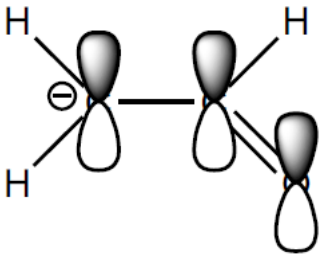
In stage 2, C^- in position 2 forms a covalent bond with C_7 of C=O, forming a cyclic structure.

Compound T is shown below, molecular formula is $C_7H_{12}O_2$, M_r = 128



2022 A level Paper 2 suggested answers

5 (d) (i) Continuous side way overlap of the p orbitals on the 3 connected atoms (C, C, O) allows the π electrons to delocalise across these 3 atoms.



5 (d) (ii) 4 delocalised electrons
(For **W**, 2 e^- from the C=O π bond + 2 e^- from the lone pair electron on C^-)
(For **V**, 2 e^- from the C=C π bond + 2 e^- from the lone pair electron on O^-)

5 (d) (iii) As a result of delocalisation of electrons, enolate would have a resonance structure with partial double bond character for carbon-carbon-oxygen.

Bond energy of carbon-carbon bond in enolate : 500 kJ mol^{-1}
(any value between 350 (C−C) and 610 (C=C))

Bond energy of carbon-oxygen bond in enolate : 600 kJ mol^{-1}
(any value between 360 (C−O) and 740 (C=O))

5 (d) (iv) As O is more electronegative than C, the delocalised electrons have a greater tendency to be found at oxygen as compared to carbon. Hence it is more likely for O to holds the negative charge, similar to that in **V**.

2022 A level Paper 2 suggested answers

6 (a) Increased concentrations of greenhouse gases has led to additional heat retained in the Earth's atmosphere and an increase in the global average surface temperatures. This disrupts the Earth's climate equilibrium.

6 (b) Nitrogen oxides act as a catalyst for the oxidation of SO_2 to SO_3. SO_3 dissolves in rainwater to form acid rains containing $H_2SO_4(aq)$.

6 (c) At 25 °C, $CH_4(g) + O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$

Note: $\Delta H_f\ (O_2(g)) = 0$

$\Delta H_c\ (CH_4(g)) = \sum n\,\Delta H_f^{\ominus}$ (products) $- \sum m$ (reactants)
$= [(-393.5) + 2 \times (-285.8)] - (-74.8)$
$= -890\ kJ\ mol^{-1}$

6 (d) Electrolysis of $Li_2CO_3(l)$ produces $O_2(g)$ which is channelled back into the chamber for the combustion of $CH_4(g)$. This increases the percentage of $O_2(g)$ in the air mixture (atmospheric air mixture only contains 21% of O_2), and hence would lead to an increase in percentage combustion efficiency as shown in Table 6.2.

6 (e) $$\% \text{ combustion efficiency} = \frac{525 + 134}{890} \times 100\% = 74.0\%$$

Percentage of O_2 in the air mixture $\approx$ 34% (between 21-38%, closer to 38%)

6 (f) Thermal decomposition of Li_2CO_3 (similar to Group 2 carbonates).

$Li_2CO_3 \longrightarrow Li_2O + CO_2$

6 (g) $Q = I \times t = n_e \times F$

$1.0 \times (1 \times 60 \times 60) = n_e \times 96500$

$n_e = 0.03731$ mol

During reduction, oxidation state of C decreases by 4 units from +4 (in CO_3^{2-}) to 0 (in C(s)).
4 mol of electrons is required to produce 1 mol of C(s)

Amount of C = $\frac{1}{4} \times 0.03731 = 0.009326$ mol

Expected mass of C formed = $0.009326 \times 12.0 = 0.112$ g

The experimental value is very close to the theoretical value. The process is highly efficient.

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6 (h) (i) Giant covalent lattice (similar to the structure of graphite)

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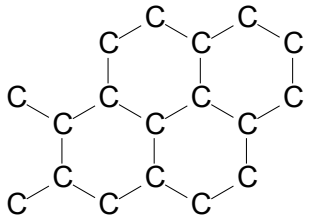
6 (h) (ii)



(similar to structure of graphite, note total of 18 C and at least 2 complete hexagonal ring)

C−C−C bond angle = 120 °

2022 A level Paper 3 suggested answers

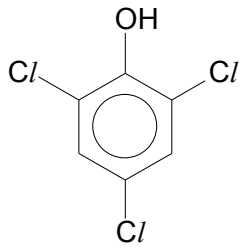
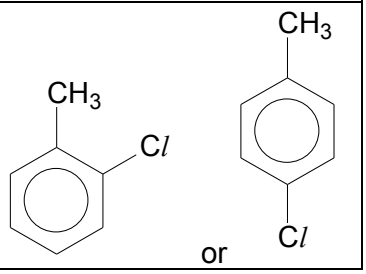
1 (a) Rate of hydrolysis : $C_6H_5COCl > C_6H_5CH_2Cl > C_6H_5Cl$

Compound **C** is an acyl chloride and undergoes hydrolysis most readily. The presence of highly electronegative O atom and C*l* atom attached to the carboxyl C atom makes the C atom highly electron-deficient (δ+), hence most susceptible to nucleophilic attack by H_2O.

Compound **A** is a halogenoalkane, it reacts less readily than acyl chloride. Energy is required to break the C−C*l* bond during hydrolysis.

Compound **B** is a chlorobenzene, it is resistant towards hydrolysis. C atom of C–C*l* is electron rich due to delocalized π electrons of benzene. This repels electron rich nucleophile H_2O.
Or
Presence of strong partial double bond character of C–C*l* bond of chlorobenzene due to the delocalisation of π electrons across the overlapping p orbitals of C*l* and C of the benzene ring.

1 (b) (i)

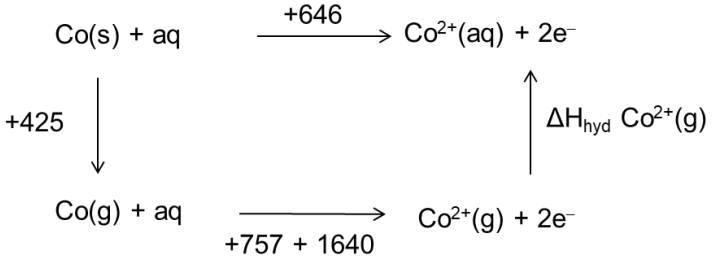
Compound	Reagents and conditions	Organic product
Phenol	Cl_2(aq)	
Methylbenzene	Cl_2 with anhydrous $AlCl_3$	 or

1 (b) (ii) In phenol, the delocalisation of the lone pair of electrons on oxygen into the benzene ring **increases** the electron density in the ring significantly. This makes phenol **more susceptible** than methylbenzene towards electrophilic attack.

Even though methyl group of methylbenzene is also electron donating, it is only weakly activating whereas −OH of phenol is strongly activating.

1 (c) (i) The enthalpy change of hydration is the <u>energy released</u> when <u>one mole</u> of <u>gaseous ions</u> is hydrated to form an infinitely dilute solution.

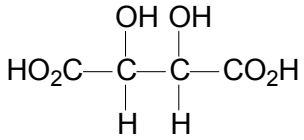
1 (c) (ii)



By Hess' Law,
$\Delta H_{hyd}\ Co^{2+}(g) = -757 - 1640 - 425 + 646 = -2176 \approx -2180\ kJ\ mol^{-1}$

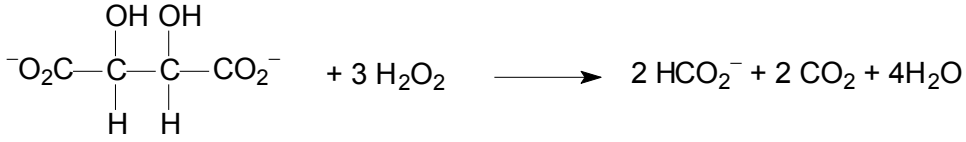
2022 A level Paper 3 suggested answers

1 (d) (i)



2,3-dihydroxybutanedioic acid

1 (d) (ii)



Note: It is hard to balance redox overall equation directly. We can work from the half equations.

[R] $H_2O_2 + 2H^+ + 2e^- \longrightarrow 2H_2O$
[O] $^-O_2CCH(OH)CH(OH)CO_2^- + 2H_2O \longrightarrow 2HCO_2^- + 2CO_2 + 6H^+ + 6e^-$

1 (e) (i) Transition elements have ions of variable oxidation state, this allows it to function as homogeneous catalyst.
or
Transition metal solid has partially filled d subshells and this would allow it to accept electron from reactants and act as heterogeneous catalyst.

1 (e) (ii) Homogeneous catalysis. The catalyst is in the same state as the reactants.

1 (e) (iii) Use high concentration for one of the reactants (H_2O_2, H^+ or Co^{2+}) of step 1.

As concentration of reactants increases, by Le Chatelier's Principle, the position of equilibrium for step 1 would shift to the right, favouring the forward reaction.

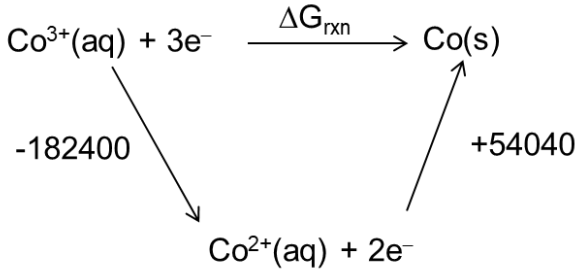
1 (e) (iv) **D** is a dianion containing two $-COO^-$ groups. If pH goes lower than 6.8, the basic $-COO^-$ would react with H^+ to give $-COOH$.

1 (e) (v) $\Delta G = -nFE^{\ominus}_{cell}$

To find $E^{\ominus}$ for Co^{3+}/Co, we would need to use an energy cycle to find $\Delta G^{\ominus}$ for the half equation.

$Co^{2+} + 2e^- \longrightarrow Co$ using n = 2, $\Delta G = -2 \times 96500 \times (-0.28) = +54040$ J mol^{-1}

$Co^{3+} + e^- \longrightarrow Co^{2+}$ using n = 1, $\Delta G = -1 \times 96500 \times (+1.89) = -182400$ J mol^{-1}



By Hess' Law,
$\Delta G_{rxn} = -182400 + 54040 = -128400$ J mol^{-1}

$Co^{3+} + 3e^- \longrightarrow Co$ using n = 3,
$-128400 = -3 \times 96500 \times E^{\ominus}(Co^{3+}/Co)$
$E^{\ominus}(Co^{3+}/Co) =$ **+ 0.444 V**

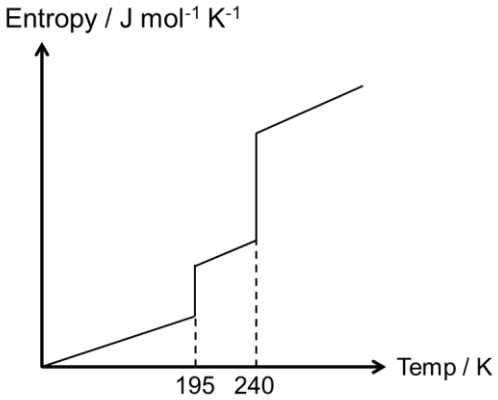
2022 A level Paper 3 suggested answers

2 (a) (i) $2\ NO_2(g) \longrightarrow N_2O_4(g)$

The entropy of the chemical system decreases as there are lesser gas particles after the reaction and there are less ways to arrange and distribute energy amongst the particles.

2 (a) (ii) When solid dissolves in a solvent, phenol molecules are able to move freely in the solvent, as compared to the fixed position in solid. There are more ways to arrange and distribute energy amongst the particles. Entropy of the chemical system increases.

2 (b)



As temperature increases, the NH_3 particles gain kinetic energy and entropy increases.
At 195K and 240K, there are sharp increases in entropy as there are changes in state from solid to liquid and liquid to gas respectively, leading to a significant increase in entropy. The increase in entropy from liquid to gas is more significant than that of solid to liquid.

2 (c) (i)

	$3H_2(g)$	$+ N_2(g)$	$\rightleftharpoons$	$2NH_3(g)$
Initial / mol	3	1		0
Change / mol	-0.4×3	-0.40		$+0.40 \times 2$
Eqm / mol	1.8	0.60		0.80

Eqm total mol = 1.8 + 0.6 + 0.8 = 3.2 mol

$P_{H2} = \frac{1.8}{3.2} \times 2.80 \times 10^4 = 1.575 \times 10^4$ kPa

$P_{N2} = \frac{0.60}{3.2} \times 2.80 \times 10^4 = 5.25 \times 10^3$ kPa

$P_{NH3} = \frac{0.8}{3.2} \times 2.80 \times 10^4 = 7.00 \times 10^3$ kPa

$K_p = \frac{(P_{NH3})^2}{(P_{H2})^3 \cdot P_{N2}} = \frac{(7000)^2}{(15750)^3 \cdot 5250} = \mathbf{2.39 \times 10^{-9}\ kPa^{-2}}$

2 (c) (ii) Ideally, a low temperature is required to favour the forward exothermic reaction, however rate of reaction would be too slow. A temperature of 450 °C is used to increase the rate of reaction.

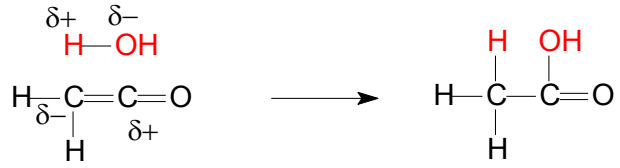
A high pressure is used to favour the forward reaction that have lesser number of gas particles.

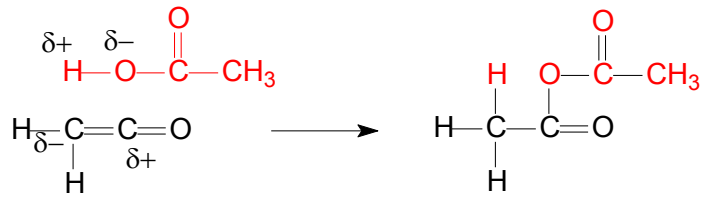
An iron catalyst is used to lower the activation energy and speed up the rate of reaction.

2022 A level Paper 3 suggested answers

2 (d) (i) $CH_2=C=O + 2O_2 \longrightarrow 2CO_2 + H_2O$

2 (d) (ii) Following the pattern of the reaction of ketene and H_2O,
$\delta+$ C of C=O attracts $\delta-$ OH while electron rich C of $=CH_2$ attracts $\delta+$ H.



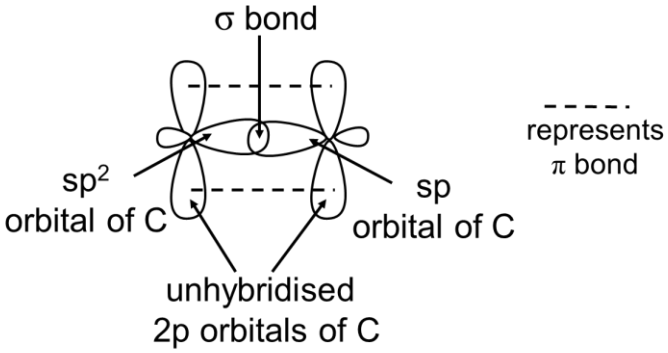


Organic product

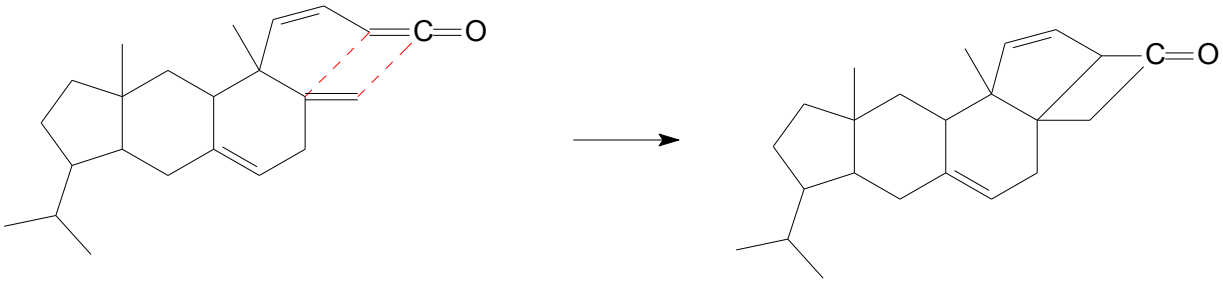
2 (e) The C=C bond is formed by

i) one sigma (σ) bond
head-on overlap between
sp^2 hybrid orbital of C_1 with
sp hybrid orbital of C_2.
Note C_2 with two double bonds is sp hybridised

ii) one pi (π) bond
sideway overlap between
unhybridised **2p** orbital of C_1 with
unhybridised **2p** orbital of C_2



2 (f)



2022 A level Paper 3 suggested answers

3 (a) $^1H^+$ and $^2H^+$ deflects towards the negatively charged plate in the electric field while e^- deflects towards the positively charged plate in the electric field.

Angle of deflection $\propto \frac{\text{charge}}{\text{mass}}$ angle of deflection of $e^- > {}^1H^+ > {}^2H^+$

3 (b) (i) Relative atomic mass $= \frac{83.91 \times 0.56 + 85.91 \times 9.86 + 86.91 \times 7.00 + 87.91 \times 82.58}{100}$

$=$ **87.62 (2 d.p.)**

3 (b) (ii)

	$E^\ominus$ (M^{2+}/M)/ V
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	−2.38
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	−2.87
$Ba^{2+}(aq) + 2e^- \rightleftharpoons Ba(s)$	−2.90

Down Group 2, $E^\ominus$ value becomes more negative, tendency for the backward reaction (i.e. oxidation) occurring increases. Group 2 metal undergoes oxidation more readily and hence reactivity of Group 2 metal increases down the Group.

3 (c) Down Group 2, cationic radius increases while charge remains the same. Hence, the $\frac{\text{charge}}{\text{size}}$ ratio of the cation decreases. This leads to a **decrease in polarising power of the cations**.

The **electron cloud of the O_2^{2-}** anion is being **distorted to a smaller extent** down the group, **decreasing the extent of weakening of O–O bond within the O_2^{2-}** anion.

More energy is required to break the O–O bond within the O_2^{2-} anion. Therefore, **thermal stability of the Group 2 peroxides increases** down the group.

3 (d) (i) **Order of reaction** with respect to a reactant is the ***power*** of the concentration of that reactant in the ***experimentally determined*** rate equation.

3 (d) (ii) As the reaction proceeds, concentration of benzoyl peroxide decreases. It is observed that the rate of reaction (gradient of conc vs time graph) decreases with a constant half-life of 30 mins. Hence it is first order w.r.t. benzoyl peroxide.

At 150 minutes, 5 sets of half-lives have passed (5 × 30mins).

[Benzoyl peroxide] at 150 minutes $= 2.0 \times 10^{-2} \times (\frac{1}{2})^5$ = **6.25×10^{-4} mol dm^{-3}**

3 (d) (iii) Draw a tangent at t = 0 and find the gradient of the tangent.

Initial rate $= \frac{0 - 0.02}{40 - 0}$ = **-0.0005 mol dm^{-3} min^{-1}**

3 (d) (iv) Rate = k[benzoyl peroxide]

Using initial rate and concentration, $0.0005 = k \times 0.02$

k = **0.0250 min^{-1}**

or

Using half-life = 30mins and $t_{1/2} = \frac{\ln 2}{k}$

k = **0.0231 min^{-1}**

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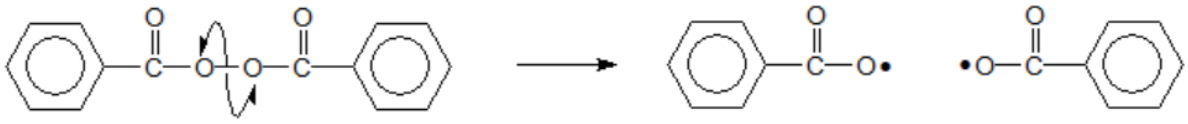
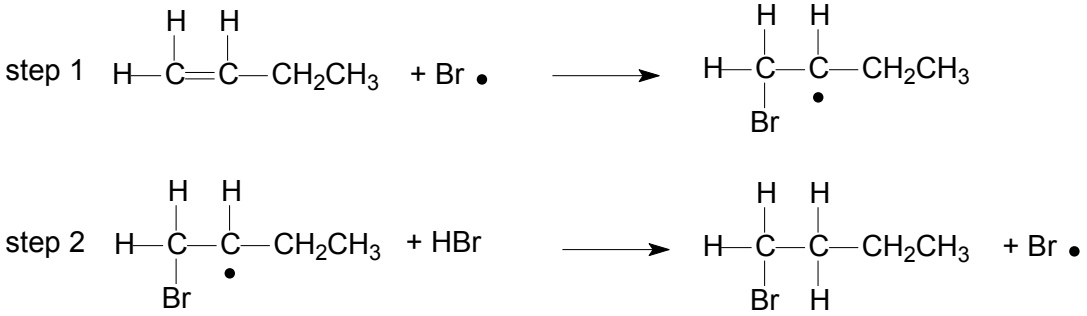
3 (e)



Note: use half arrows to show homolytic fission of O−O bond.

3 (f) (i)

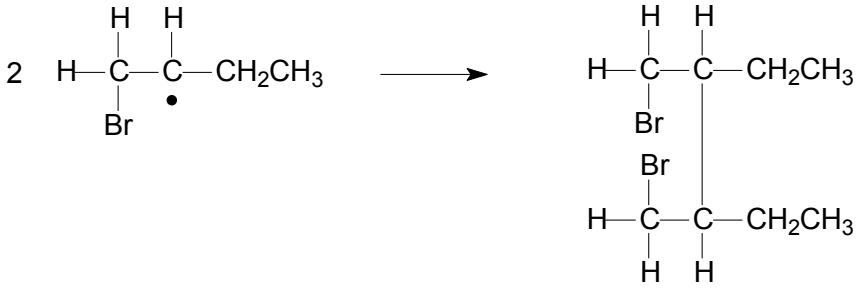


The secondary carbon radical formed is stabilized by two electron donating alkyl groups to reduce the electron deficiency on the C radical. This secondary carbon radical is formed preferentially as compared to the primary carbon radical.

secondard radical

primary radical

3 (f) (ii)



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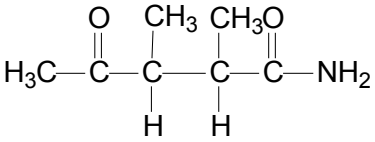
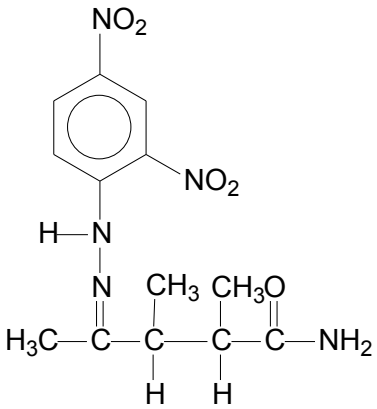
3	**(g)**	**F** ($C_7H_{13}NO_2$)	+ 2,4-DNPH ⟶	**G** ($C_{13}H_{17}N_5O_5$)		Condensation **F** contains carbonyl
		F ($C_7H_{13}NO_2$)	+ I_2, NaOH ⟶	**H** Yellow ppt	+ organic compound **J**	Redox reaction **F** contains methyl carbinol or methyl carbonyl
		F ($C_7H_{13}NO_2$)	+ Fehling's reagent	**No rxn**		Oxidation reaction **F** does not contain aldehyde
		F ($C_7H_{13}NO_2$)	+ HC*l*(aq), heat ⟶	**K** ($C_7H_{12}O_3$)		Hydrolysis **F** contains amide $-CONH_2$
		F ($C_7H_{13}NO_2$)	+ LiA*l*H_4 ⟶	**L** ($C_7H_{17}NO$)		Reduction

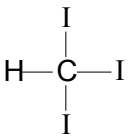
Combining all the deductions and information,
F contains a methyl ketone, an amide $-CONH_2$ and two chiral carbons.



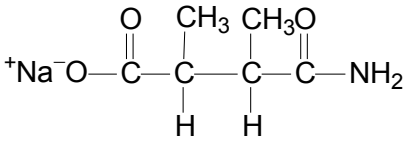
F
($C_7H_{13}NO_2$)



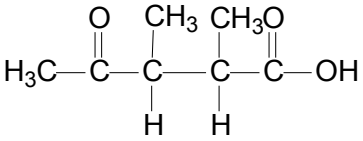
G
($C_{13}H_{17}N_5O_5$)



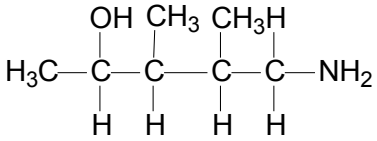
H



J



K
($C_7H_{12}O_3$)



L
($C_7H_{17}NO$)

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4 (a) Period 3 oxides changes from basic oxide (Na_2O and MgO) to amphoteric oxide (Al_2O_3) to acidic oxide (SiO_2, P_4O_{10} and SO_3).

Reactions with H_3PO_4:
$3Na_2O + 2H_3PO_4 \longrightarrow 2Na_3PO_4 + 3H_2O$

$Al_2O_3 + 2H_3PO_4 \longrightarrow 2AlPO_4 + 3H_2O$

Reactions with NaOH:
$Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2NaAl(OH)_4$

$SiO_2 + 2NaOH\ (conc) \longrightarrow Na_2SiO_3 + H_2O$
Note: SiO_2 only reacts with hot, concentrated NaOH.

---

4 (b) Recall: During anodising of aluminium, aluminium metal is made the anode with $H_2SO_4(aq)$ as the electrolyte.

Cathode : [R] $2H^+ + 2e^- \longrightarrow H_2$

Anode : [O] $2Al + 3H_2O \longrightarrow Al_2O_3 + 6H^+ + 6e^-$

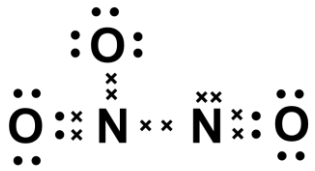
---

4 (c) $2NH_3 + NO + O_2 \longrightarrow \frac{3}{2} N_2 + 3H_2O$

$4NH_3 + 3NO_2 \longrightarrow \frac{7}{2} N_2 + 6H_2O$

---

4 (d) (i)



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4 (d) (ii) $K_a = 10^{-3.25} = 0.0005623$ mol dm^{-3}

For weak acid,
$[H^+]_{dissociated} = \sqrt{K_a \times [\text{weak acid}]}$
$= \sqrt{0.0005623 \times 0.25}$
$= 0.01186$ mol dm^{-3}

% of HNO_2 ionised $= \frac{0.01186}{0.25} \times 100\% =$ **4.74%**

---

4 (e) NO_2^+ and NO_3^-

(e) NO_2^+ and NO_3^-

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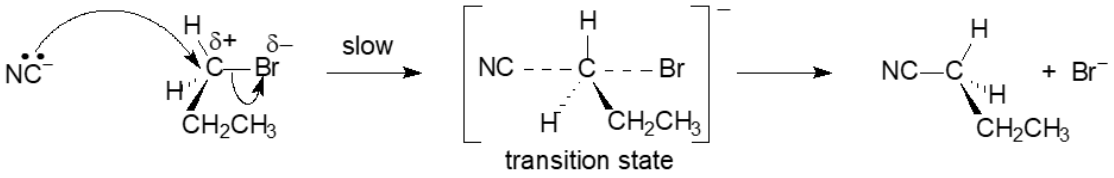
4 (f) (i) Nucleophilic Substitution, S_N2



4 (f) (ii) H_2O can act as a nucleophile, giving $CH_3CH_2CH_2OH$
or
Ethanol (CH_3CH_2OH) can act a nucleophile, giving $CH_3CH_2CH_2OCH_2CH_3$

4 (f) (iii) Rate of reaction **N** > **M** > **O**

C−X bond is broken during the rate determining step. C−I bond (BE = 240 kJ mol^{-1}) is weaker than C−Br bond (BE = 280 kJ mol^{-1}). Rate of reaction for **N** will be faster than **M** and **O**.

Rate of reaction for **O** will be slower than that of **M** due to the presence of the bulky group $C(CH_3)_3$ in **O**. This large, branched group would cause steric hindrance to the OH^- nucleophile, hence making the reaction slower than **M**.

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5 (a) Ethylamine, $CH_3CH_2NH_2$, is a polar covalent molecule with hydrogen bonding between its molecules while propane is a non-polar covalent molecule with instantaneous dipole-induced dipole (id-id) between its molecules.

More energy is required to overcome the stronger hydrogen bonding between ethylamine molecules than the id-id between propane molecules. Boiling point of ethylamine is higher than that of propane.

---

5 (b) In gaseous phase, relative basicities depends on the availability of lone pair electron on N to be donated during a reaction. (Lewis base definition)

Basicity of triethylamine > diethylamine > ethylamine

Ethyl groups are electron donating group. The greater number of electron donating ethyl group bonded to the N atom of triethylamine increases the electron density on N. Hence N atom of triethylamine would donate its lone pair electron most readily, followed by diethylamine and ethylamine.

Note: N only accept H^+ in **AQUEOUS** phase. (Bronsted base definition)

---

5 (c) (i) $CH_3CH_2NH_2$ and $CH_3CH_2NH_3^+$
This weak base and conjugate acid pair form a buffer solution.

When a small amount of H^+ is added, the large reservoir of $CH_3CH_2NH_2$ would react with the H^+, causing the pH to remain relatively constant.

$$CH_3CH_2NH_2 + H^+ \longrightarrow CH_3CH_2NH_3^+$$

---

5 (c) (ii) $CH_3CH_2NH_3^+$ is present at the equivalence point, it is a weak acid.

$$CH_3CH_2NH_3^+ \rightleftharpoons CH_3CH_2NH_2 + H^+$$

---

5 (d) Amount of $S_2O_3^{2-}$ used = $\frac{15.75}{1000} \times 0.150 = 0.002363$ mol

Amount of I_2 produced = ½ × 0.002363 = 0.001181 mol

Amount of ClO^- in 25.0 cm^3 = 0.001181 mol

Amount of ClO^- in 100 cm^3 diluted solution = $0.001181 \times \frac{100}{25}$ = 0.004724 mol

Amount of ClO^- in 5 cm^3 of bleach = 0.004724 mol

Concentration of ClO^- in 5 cm^3 of bleach = $\frac{0.004724}{5/1000}$ = **<u>0.945 mol dm^{-3}</u>**

---

5 (e) $NaClO + NH_3 \longrightarrow NaOH + NH_2Cl$

$NH_2Cl + (CH_3)_2NH \longrightarrow [(CH_3)_2N_2H_3]^+ Cl^-$

2022 A level Paper 3 suggested answers

5 (f) (i) Note: ΔH_f of $N_2(g) = 0$

$\Delta H_{rxn} = \sum n \Delta H_f^o$ (products) $- \sum m$ (reactants)
$= [2 \times (-393.5) + 4 \times (-241.8)] - [(+48.9) + 2 \times (-19.6)]$
$= -1764$ kJ mol^{-1}

$\Delta G = \Delta H - T\Delta S$
$= -1764 - 298 \times (1141.2/ 1000)$
$=$ **-2100 kJ mol^{-1}**

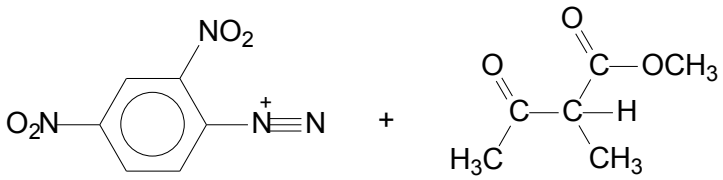
5 (f) (ii) Amount of $(CH_3)_2N_2H_2$ used $= \frac{1.5 \times 1000}{12.0 \times 2 + 1.0 \times 8 + 14.0 \times 2} =$ 25 mol

Acidic $CO_2(g)$ would react with KOH(aq).
Final gas contains only $N_2(g)$.

Amount of $N_2 = 3 \times 25 = 75$ mol

Volume of N_2 at r.t.p $= 75 \times 24 =$ **1800 dm^3**

5 (g) Note: from the structure of H, we can see that R_2 and R_3 are both CH_3
We can choose any alkyl group for R_1 of the β−keto ester



5 (h)