Q1 Option 1: Amount of $H_2SO_4$ = 0.5 x 1 = 0.5 mol

$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

Amount of $H^+$ = 0.5 x 2 = 1 mol

Option 2: Amount of $SO_3$ molecules = 6 / 24 = 0.25 mol

1 $SO_3$ molecule has 4 atoms (1 S and 3 O atoms)

Amount of atoms = 0.25 x 4 = 1 mol

Option 3: Amount of $SO_2$ molecule = 64.1 / (32.1 + 16.0 x 2) = 1 mol

1 $SO_2$ molecule has 16 + 8 x 2 = 32 electrons

Amount of electrons = 1 x 32 = 32 mol

Option 4: Amount of $S_8$ molecule = 1.6 /(32.1 x 8) = 0.00623 mol

1 $S_8$ molecule has 16 x 8 = 128 neutrons

Amount of neutrons = 0.798 mol

**Ans: 1 and 2 are correct => A**

Q2 $CH_3CH_2CH_2OH + 4O_2 \rightarrow 2CO_2 + CO + 4H_2O$

Since mole ratio = volume ratio of gases,

Vol of $O_2$ consumed = 4y

**Ans: B**

Q3 [R] $MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2\ H_2O$

[O] $Mn^{2+} + 2H_2O \rightarrow MnO_2 + 4H^+ + 2e^-$

$2MnO_4^- + 3Mn^{2+} + 2H_2O \rightarrow 2MnO_2 + 3MnO_2 + 4H^+$

2 mol of $MnO_4^-$ reacts with 3 mol of $Mn^{2+}$

1 mol of $MnO_4^-$ reacts with 1.5 mol of $Mn^{2+}$

**Ans: C**

Q4 $Z^{2+}$ has 12 electrons and 15 neutrons

Z has 14 electrons, 14 protons and 15 neutrons=> $A_r$ = 14 + 25 = 39

**Option A: angle of deflection** $\propto \frac{\text{charge}}{\text{mass}}$

$\frac{\text{charge}}{\text{mass}}$ **for** $Z^{2+} = \frac{+2}{14+15} = \frac{+2}{29}$

$\frac{\text{charge}}{\text{mass}}$ **for** $Mg^{2+} = \frac{+2}{24.3}$

$\frac{\text{charge}}{\text{mass}}$ **for** $Mg^{2+} > \frac{\text{charge}}{\text{mass}}$ **for** $Z^{2+}$

Angle of deflection for $Mg^{2+}$ > Angle of deflection for $Z^{2+}$

**Option A is correct**

Option B: Based on the proton number, **Z** is referring to Silicon.

Si has a higher IE than Al (Group 13 element in the same period as Z) => You can check from Data Booklet or recall from the trend across the period.

Option C: $SiCl_4$ has a lower melting point than $MgCl_2$ as $SiCl_4$ has a simple molecular structure while $MgCl_2$ has a giant ionic structure. Larger amount of energy is needed to overcome the stronger electrostatic forces of attraction between $Mg^{2+}$ and $Cl^-$ than the weaker instantaneous dipole-induced dipole forces of attraction between $SiCl_4$ molecules.

Option D: Element **Z** has 14 electrons while neon has 10 electrons. Hence, they are not isoelectronic.

Q5

All options have simple molecular structures.

Option 1 and 4 have instantaneous dipole-induced dipole forces of attraction between molecules

Option 2 has hydrogen bonding between molecule

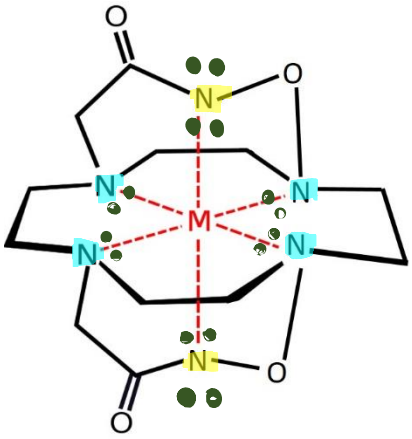
Option 3 has permanent dipole-permanent dipole forces of attraction between molecules.

Hence option 2 will be the highest followed by option 3

For option 1 and 4, the two molecules are isomers of each other. Thus, the surface area determines the boiling point. Since option 1 is a straight-chained molecule, it has a larger surface area between molecules which results in stronger instantaneous dipole-induced dipole forces of attraction than that of option 4 since option 4 is a branched-chain molecule. Hence option 4 as the lowest boiling point.

**Boiling point: 4 < 1 < 3 < 2 => Option D is correct**

Q6




The N highlighted in yellow has 6 electrons from N hence this N has a charge of -1.

The N highlighted in turquoise has 5 electrons from N hence thus N has no charge.

Since the complex has no overall charge, M has a charge of +2.

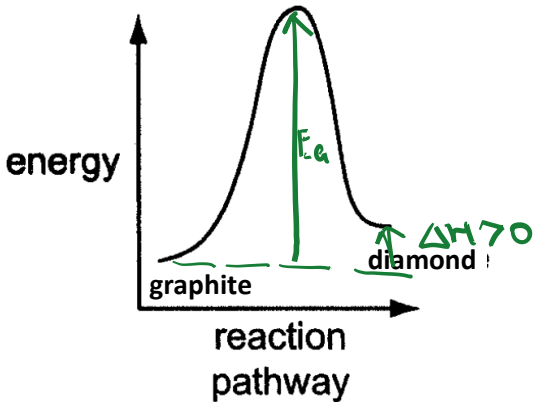
Bond between $M^{2+}$ and N (in turquoise) is due to dative bond.

Bond between $M^{2+}$ and N (in yellow) is due to ionic bond.

**Ans: 1 and 2 => B is correct**

Q7 Converting from graphite to diamond has ΔH > 0 and k is small refers to large $E_a$.

Thus C is the answer.




Q8 Reaction 1: Evaporation of ethanol: $C_2H_5OH(l) \rightarrow C_2H_5OH(g)$

ΔH > 0 => energy is taken in to overcome the hydrogen bonding between the molecules to convert liquid to gas.
Recall: Liquid is more closely packed than gas

ΔS > 0 => increase in number of gas molecules from zero to one.
More ways of arranging the particels. Entropy increases.

ΔG = 0 as it is an equilibrium reaction

Reaction 2: Atomisation of magnesium: $Mg(s) \rightarrow Mg(g)$
ΔH > 0 => energy is taken in to overcome the forces of attraction to convert solid to gas.
Recall: solid is more closely packed than gas

ΔS > 0 => increase in number of gas molecules from zero to one.
More ways of arranging the particels. Entropy increases.

Reaction 3: Initiation step for the free radical substitution between chlorine and ethane

$$Cl_2(g) \xrightarrow[uv]{} 2Cl\bullet_{(g)}$$

ΔH > 0 => energy is taken in to break the covalent bond between the Cl atoms

ΔS > 0 => increase in number of gas molecules from zero to one.
More ways of arranging the particels. Entropy increases.

ΔG > 0 as it is not a spontaneous reaction since uv light is supplied for the reaction to occur.
**Option 1 and 2 are correct=> C**

Q9 $pV = nRT$

Since nR and V are constant, $p=kT$

$\frac{p}{T} = k$

$\frac{p_1}{T_1} = \frac{p_2}{T_2}$

$\frac{p_1}{T_1} = \frac{1.2p_1}{T_1+273}$

$\frac{T_1+273}{T_1} = 1.2$

$0.2T_1 = 273$

$T_1 = 1365$ K

**Ans: D**

Q10 $H_2O + ClO^- \rightleftharpoons HOCl + OH^-$

Acid and its conjugate base is a difference of $H^+$

Hence $H_2O$ is the acid and $OH^-$ is its conjugate base

$ClO^-$ is the base and HOCl is the conjugate acid.

**Hence, option A is the correct answer**

Q11 rate equation depends on the slow step and it **cannot include intermediate**.

To determine if the species is an intermediate, write the overall equation by summing up the steps in the mechanism. If the species appear on either side of the overall equation, it is not an intermediate.

Overall equation: $A + 2B \rightarrow AB_2$

Based on slow step, rate= k[AB][B]

Since AB is an intermediate, it has to be re-expressed by using $K_C$.

$K_c = \frac{[AB]}{[A][B]}$ => $[AB] = K_c[A][B]$

rate= $k[AB][B] = k\{K_c[A][B]\}[B] = k'[A][B]^2$

**Ans: D**

Q 12 [Rxt] 100% → 50% → 25% …

[Pdt] 0% → 50% → 25% …

| | 2A(g) | → | B(g) | + | C(s) |
|---|---|---|---|---|---|
| I | x | | 0 | | 0 |
| C | -x | | +½x | | - |
| F | 0 | | ½x | | - |

This is based on completion of reaction, hence A will be completely used up.

Hence ½x = 200 Pa  x = 400 Pa

Note: pressure only applies to gas, hence carbon solid is ignored.

At the 1st half-life, 50% of A will be used up.

| | 2A(g) | → | B(g) | + | C(s) |
|---|---|---|---|---|---|
| I | x | | 0 | | 0 |
| C | -½x | | +¼x | | - |
| F | ½x | | ¼x | | - |
| | =200 | | =100 | | |

At the 1st half-life, the total pressure = 200 + 100 = 300Pa

**$t_{1/2}$ = 10 min => B is correct**

13 $\Delta H_{rxn}$ = [-685.3 + 2(-92.3)] – [2(-485.3)] = +127.5 kJ $mol^{-1}$

As temperature increases, the system is disturbed. By LCP, the system will oppose the change by decreasing the temperature and favours the endothermic reaction to absorb the heat. Position of equilibrium shifts right and produces more products. Hence, [$CHClF_2$] decreases with increasing temperature.

**Ans: C**

14 Consider if there is a reaction from the mixtures and determine the resultant species left in the solution to decide if it is a buffer.

**Recall that a buffer must contain either:**

**a weak acid and its conjugate base OR a weak base and its conjugate acid.**

Option A is made up of a salt and acid which does not react.

resultant species: NaC*l* and HC*l* => not a buffer as it contains a strong acid

Option B: a reaction will take place

$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

| | | | | |
|---|---|---|---|---|
| I | 0.75 | 0.25 | 0 | 0 |
| C | -0.25 | -0.25 | +0.25 | +0.25 |
| F | 0.50 | 0 | 0.25 | 0.25 |

**resultant species: $CH_3COOH$ and $CH_3COONa$ => a buffer since it contains a weak acid ($CH_3COOH$) and its conjugate base ($CH_3COO^-$)**

**Option B is correct**

Option C: a reaction will take place

$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$

| | | | |
|---|---|---|---|
| I | 0.6 | 0.4 | 0 |
| C | -0.6 | -0.3 | +0.3 |
| F | 0 | 0.1 | 0.3 |

resultant species: $H_2SO_4$ and $(NH_4)_2SO_4$ => not a buffer as it contains a strong acid

Option D: a reaction will take place.

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

| | | | | |
|---|---|---|---|---|
| I | 0.4 | 0.6 | 0 | 0 |
| C | - 0.4 | -0.2 | +0.2 | +0.4 |
| F | 0 | 0.4 | 0.2 | 0.4 |

resultant species: $H_2SO_4$ and $Na_2SO_4$ => not a buffer as it contains a strong acid

Q15 $[H^+]$ from pH 2 = $10^{-2}$

$[H^+]$ from pH 3 = $10^{-3}$

When equal volumes are mixed, each concentration is halved.

$[H^+]_{total\ after\ mixing}$= ½ $[10^{-2} + 10^{-3}]$ = 0.00550 mol $dm^{-3}$

pH = -log 0.00550 = 2.26

**Ans: B**

Q16 MgO has the highest melting point across Period 3 oxides. => **R** is Mg

Al has the highest electrical conductivity => **Q** is Al

Ar has the lowest melting point => **S** is Ar

**Ans: Na is not represented. Option A is the answer.**

Q17 HF is a weak acid

Fluorine is a pale yellow gas => not intensely coloured.

Melting point of fluorine is low as it has simple molecular structure.

F – F bond is unusually weak as observed from the trend. General trend of X –X bond decreases down the group due to increasing bond length. However, F –F bond is the weakest as seen from the values in Data Booklet. This is due to the repulsion as a result of the small atomic radius of F.

| Bond | Bond energy |
|---|---|
| F-F | +158 |
| Cl-Cl | +244 |
| Br-Br | +193 |
| I-I | +151 |

**Ans: D**

18 $Zn^{2+} + 2e^- \rightleftharpoons Zn$ $E^{\theta} = -0.76$ V

$Cu^{2+} + 2e^- \rightleftharpoons Cu$ $E^{\theta} = +0.34$V

Based on the standard electrode potential, Zn is the anode while Cu is the cathode.

[O] $Zn \rightarrow Zn^{2+} + 2e^-$ –(1)

[R] $Cu^{2+} + 2e^- \rightarrow Cu$ –(2)

$E_2$ is the reaction that happens at standard condition since the ions are 1 mol $dm^{-3}$

$E_2 = +0.34 – (-0.76) = + 1.10$ V

For $E_1$ and $E_3$, the reactions are not at standard conditions.

For the reaction that is represented by $E_1$, $[Cu^{2+}]$ is lower than that of the standard condition. By LCP, the system will oppose the change by shifting the position of equilibrium (2) to the left to replenish the $Cu^{2+}$. This results in oxidation to be preferred and makes $E_{Cu2+/Cu}$ less positive.

$E_1 = E_{cathode} – E_{anode} = E_{Cu2+/Cu} – E_{Zn2+/Zn}$ => $E_1$ will be less positive than $E_2$

For the reaction that is represented by $E_3$, $[Zn^{2+}]$ is lower than that of the standard condition. By LCP, the system will oppose the change by shifting the position of equilibrium to the right (1) to replenish the $Zn^{2+}$. This results in oxidation to be preferred and makes $E_{Zn2+/Zn}$ less positive.

$E_1 = E_{cathode} – E_{anode} = E_{Cu2+/Cu} – E_{Zn2+/Zn}$ => $E_3$ will be more positive than $E_2$

**Hence $E_3 > E_2 > E_1$ => Ans: B**

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

$n_e = 0.01 \times 2 = 0.02$

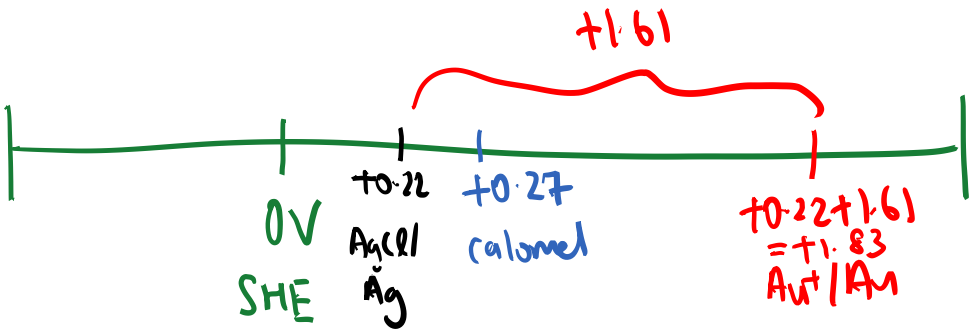
$Q = n_eF = It$

$0.02 \times 96500 = 0.1t$

$t = 19300$ s

**Ans: B**

20




**Option A is correct as observed from the number line. Hence E($Au^+$/Au) is +1.83 V wrt SHE**

Option B: E($Au^+$/Au) wrt calomel = +1.83 – (+0.27) = +1.56V

Option C: $E_{AgCl/Ag}$ is more positive than $E_{H+/H2}$ => Hence $H_2$ is more likely to be oxidised than Ag. Thus, $H_2$ is a stronger reducing agent.

Option D: $E_{HgCl2/Hg}$ is more positive than $E_{AgCl/Ag}$ => Hence $HgCl_2$ is more likely to be reduced than AgCl. Thus, $HgCl_2$ is a stronger oxidising agent.

21 Option A is correct:

When $Fe^{2+}$ is the catalyst,

$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$

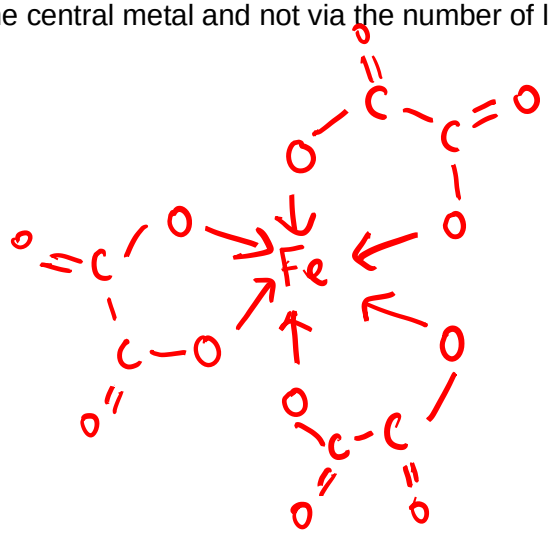
$2Fe^{3+} + 2I^- \rightarrow I_2 + 2Fe^{2+}$

When $Fe^{3+}$ is the catalyst,

$2Fe^{3+} + 2I^- \rightarrow I_2 + 2Fe^{2+}$

$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$

Option B: coordination number is denoted by the number of dative bonds formed around the central metal and not via the number of ligands. Coordination no = 6




Option C: $[Fe(H_2O)_6]^{3+}$ forms a more acidic solution than $[Fe(H_2O)_6]^{2+}$ due to the higher charge density of $Fe^{3+}$ which has a stronger polarizing power and thus distorts the O-H bond to a larger extent, releasing $H^+$. Thus, $[Fe(H_2O)_6]^{3+}$ has a lower $pK_a$.

**Option D: The appearance of the colour of solution is complementary to the colour absorbed. Thus the green solution observed is due to the absorption of red light. This statement is not correct.**

22 $Co^{3+}$: $[Ar]3d^6$

$Cu^{+}$: $[Ar]3d^{10}$

$Mn^{3+}$: $[Ar]3d^4$

$Ti^{2+}$: $[Ar]3d^2$

**Ans: B since there is no d-d transition which can take place as the d-orbitals are fully filled. The other options have partially filled d-orbitals which result in d-d transition.**

23 The number of moles of AgCl represents the no of free $Cl^-$ found outside of the complex.

Complex **I**: Since there are 3 moles of AgCl, there are 3 free $Cl^-$ outside of the complex. Complex formula: $[Co(NH_3)_6]^{3+}$

Complex **II**: Since there are 2 moles of AgCl, there are 2 free $Cl^-$ outside of the complex. Complex formula: $[Co(NH_3)_5Cl]^{2+}\ 2Cl^- \bullet NH_3$

Complex **III**: Since there is 1 mole of AgCl, there is 1 free $Cl^-$ outside of the complex. Complex formula: $[Co(NH_3)_4Cl_2]^+\ Cl^- \bullet 2NH_3$

Complex **IV**: Since there is 1 mole of AgCl, there is 1 free $Cl^-$ outside of the complex. Complex formula: $[Co(NH_3)_4Cl_2]^+\ Cl^- \bullet 2NH_3$

Option 1 is correct as complex **I** only contains $NH_3$ ligand.

Option 2 is incorrect as the charge are different for the complexes.

Option 3 is correct as complexes **III** and **IV** can form cis-trans isomers.

Option 4 is correct.

**Ans: D**

24 $CH_3CH_2CO_2Na$: forms ion-dipole interaction with water

$CH_3CH_2CH_2OH$: forms hydrogen bonding with water

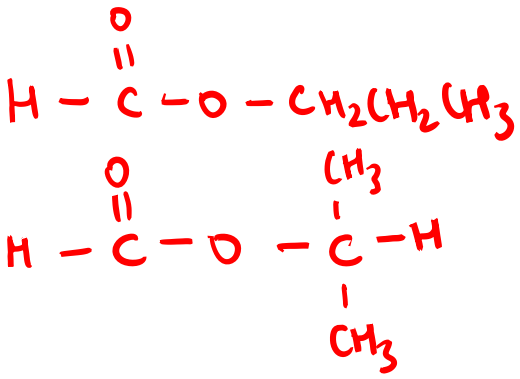
$CH_3CH_2CH_2Cl$*:* forms permanent dipole- permanent dipole with water

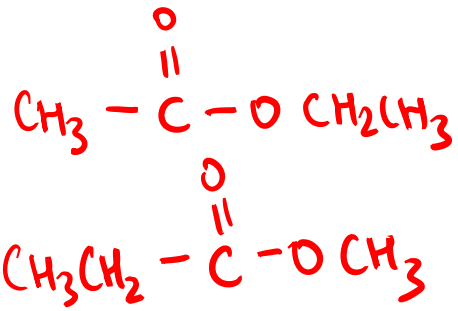
Strength: ion-dipole interaction> hydrogen bonding > permanent dipole- permanent dipole

**Increasing order: $CH_3CH_2CH_2Cl$*,* $CH_3CH_2CH_2OH$, $CH_3CH_2CO_2Na$,**

Ans: B

25





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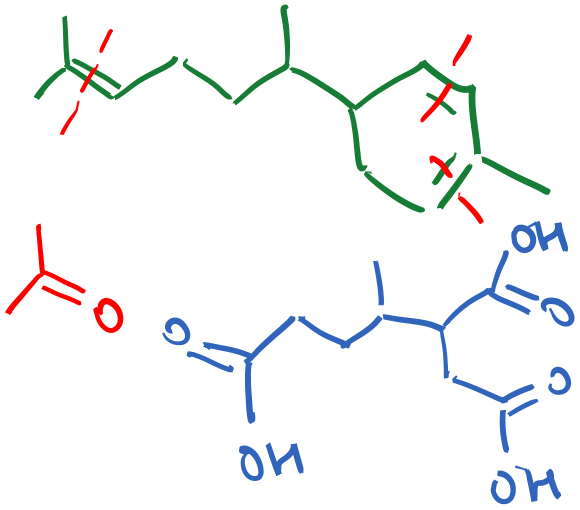
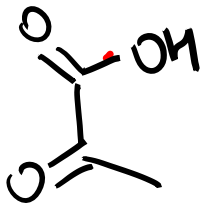


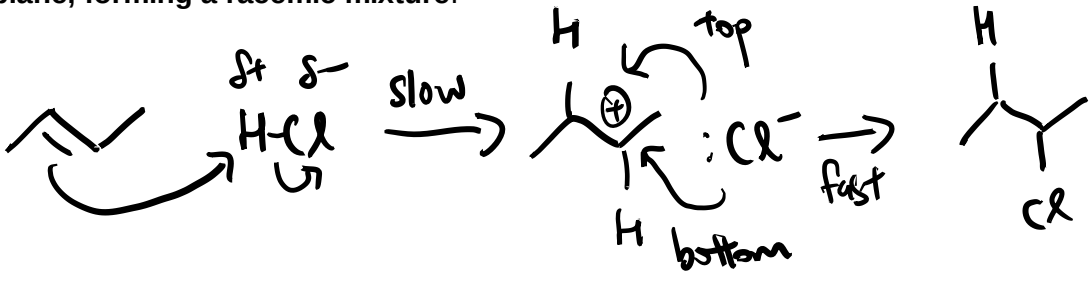


**Ans: 1,2 and 4=> Option C**

27 Option 1: 1-chloropropane undergoes $S_N2$ nucleophilic substitution to form propan-1-ol which will result in the inversion of configuration.

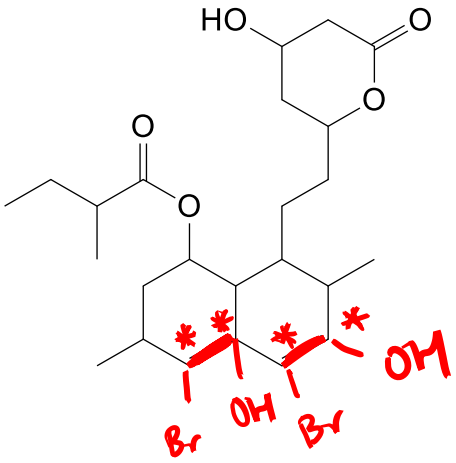
**Option 2: A racemic mixture is formed as the reactive C in ethanal is trigonal planar in shape, hence the $CN^-$ nucleophile can attack from the top or bottom of the plane, forming a racemic mixture.**

**Option 3: A racemic mixture is formed as the intermediate is trigonal planar in shape, hence the nucleophile can attack from the top or bottom of the plane, forming a racemic mixture**.



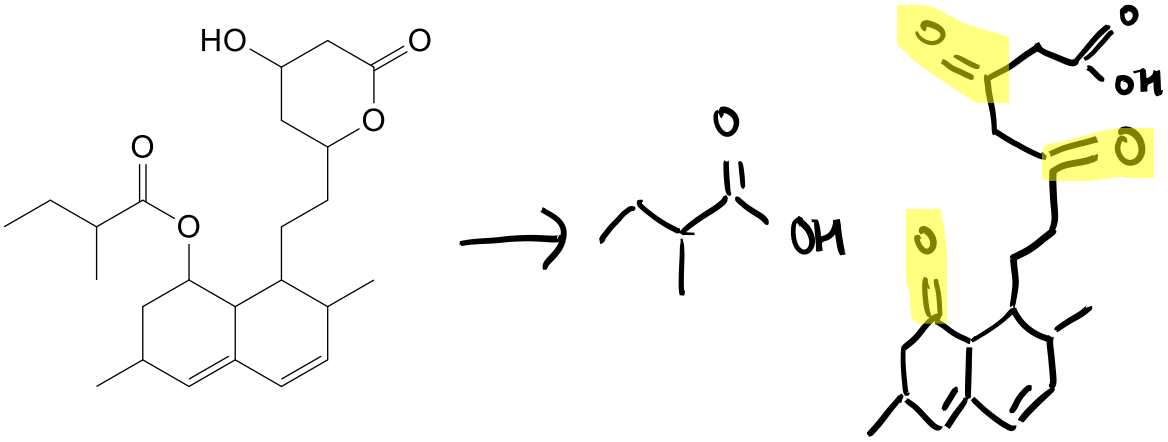

**Ans: C**

28 Option A is correct:



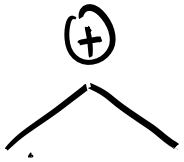

Option B is correct as the secondary alcohol will react with ethanoic acid to form ester in the presence of conc $H_2SO_4$.

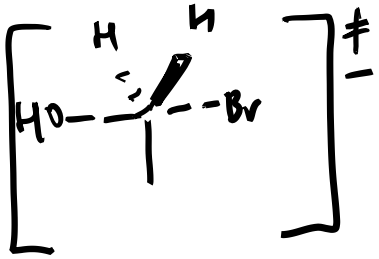
Option C is correct as secondary alcohol undergoes oxidation and acidic hydrolysis takes place for ester.

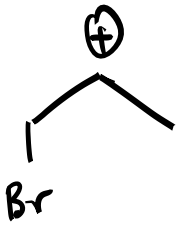


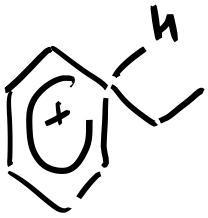

**Option D: There is no carbonyl group present, thus no orange precipitate will be observed.**

29

A 

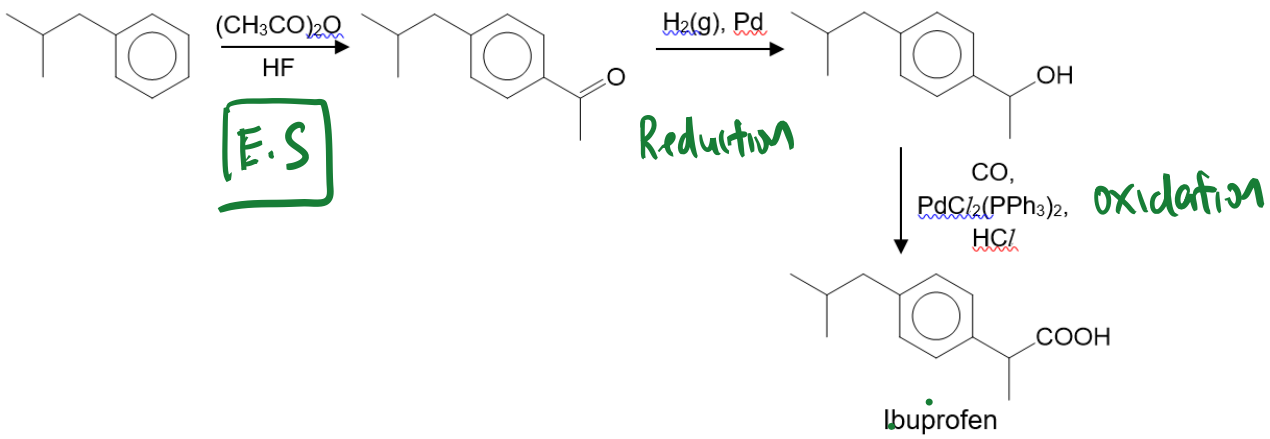
B  (no intermediate)

C 

D 

Ans: B

30


(CH3CO)2O
HF
E.S
O
H2(g), Pd
Reduction
OH
CO,
PdCl2(PPh3)2,
HCl
oxidation
COOH
Ibuprofen

Ans: B