

2016 SAJC H2 CHEM PRELIM PAPER 1 (Worked solutions)

1	2	3	4	5	6	7	8	9	10
C	B	A	D	B	D	C	C	C	C
11	12	13	14	15	16	17	18	19	20
A	D	B	A	A	B	A	B	D	B
21	22	23	24	25	26	27	28	29	30
B	B	B	B	B	C	B	A	A	C
31	32	33	34	35	36	37	38	39	40
D	D	D	C	D	D	B	B	A	D

1. Ratio of methane: ethene = 40 : 60 = 2 : 3

Let the total volume of mixture be $y \text{ cm}^3$

i.e. fraction of methane in mixture = $\frac{2}{5}$; fraction of ethene in mixture = $\frac{3}{5}$

	$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$		$\text{C}_2\text{H}_4 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O}$	
Volume/ cm^3	$\frac{2}{5}y$	$\frac{2}{5}y$	$\frac{3}{5}y$	$2 \times (\frac{3}{5}y)$

$$\text{Hence, total volume of CO}_2 = \frac{2}{5}y + 2\left(\frac{3}{5}y\right) = \frac{8y}{5} \text{ cm}^3$$

2. From $2\text{MnO}_4^- (\text{aq}) + 5\text{C}_2\text{O}_4^{2-} (\text{aq}) + 16\text{H}^+ (\text{aq}) \rightarrow 2\text{Mn}^{2+} (\text{aq}) + 10\text{CO}_2 (\text{g}) + 8\text{H}_2\text{O} (\text{l})$,

Reacting mole ratio of $\text{MnO}_4^- : \text{C}_2\text{O}_4^{2-} = 2 : 5$ --- (*)

1 mol of $\text{NaHC}_2\text{O}_4 \cdot \text{H}_2\text{C}_2\text{O}_4$ gives 2 mol of $\text{C}_2\text{O}_4^{2-}$.

1.0×10^{-3} mol of $\text{NaHC}_2\text{O}_4 \cdot \text{H}_2\text{C}_2\text{O}_4$ gives 2.0×10^{-3} mol of $\text{C}_2\text{O}_4^{2-}$.

From (*),

$$\text{no. of moles of MnO}_4^- \text{ reacted with } 2.0 \times 10^{-3} \text{ moles of C}_2\text{O}_4^{2-} = \frac{2}{5} \times 2.0 \times 10^{-3} = 0.008 \text{ mol}$$

$$\text{Hence, volume of KMnO}_4 \text{ solution required} = \frac{0.008}{0.2} = 0.040 \text{ dm}^3 = 40 \text{ cm}^3$$

3. $pV = nRT$

$$pV = \frac{m}{M_r} RT$$

Option A: Shape of graph is correct. $\frac{m}{M_r} R$ is the gradient. Since **X** has a higher M_r , its gradient is less steep. (Correct)

Option B: Shape of graph is correct. From above, since **X** has a higher M_r , its gradient should be less steep. Hence graph is wrong.

Option C: Shape of graph is wrong. The graphs should be a horizontal line. Since T is constant, pV is constant for each compound.

Option D: Shape of graph is wrong. The graphs should be a vertical line. Since T is constant, pV is constant for each compound.

4. Element **A** belongs to Group V. This is because the first big jump in ionisation energy occurs between the 5th and 6th I.E., indicating that the 6th electron is removed from the inner quantum shell. Valence configuration: ns^2np^3

Element **B** belongs to Group IV. This is because the first big jump in ionisation energy occurs between the 4th and 5th I.E., indicating that the 5th electron is removed from the inner quantum shell. Valence configuration: ns^2np^2

Element **C** **may** belongs to Group VIII. This is because there is no noticeable big jump between the ionisation energies.

Element **D** belongs to Group II. This is because the first big jump in ionisation energy occurs between the 2nd and 3rd I.E., indicating that the 3th electron is removed from the inner quantum shell. **Hence its valence electronic configuration is ns^2 and has no p electrons in the valence shell.**

5. Option A is correct as the 2 hydrogen bonds and 2 O-H covalent bonds would form a bond angle of 109.5°.

Option B is wrong as two lone pairs from each oxygen atom are involved in hydrogen bonding.

Option C is correct as intermolecular forces of attraction are weaker than strong covalent bonds.

Option D is correct and this is the explanation why ice floats on water.

6. Option A is wrong as 1st ionisation energy is endothermic.

Option B is wrong as lattice dissociation energy (or opposite of lattice energy) is endothermic.

Option C is wrong as bond breaking (breaking the $\text{N} \equiv \text{N}$ bond) is endothermic.

Option D is correct as 1st electron affinity releases heat due to electrostatic forces of attraction between the nucleus of F and electron.

7. NH_3 deviate the most from ideal gas because it has stronger hydrogen bonding between the molecules than induced dipole-induced dipole interactions which exist in C_2H_6 and Ne.

Large and heavy gas particles with significant electron cloud size deviate more than smaller gas particles (Ne vs C_2H_6 ; C_2H_6 has a larger electron cloud size). The greater the electron cloud size, the stronger the van der Waals' forces of attraction between the gas particles. Thus Ne has the least deviation.

Hence, gas 1 is Ne, gas 2 is C_2H_6 , gas 3 is NH_3 .

8. Option A has the wrong shape for a first order reaction.

Option B is wrong as the constant half-life is not stated. Hence, it does not confirm whether it is a first order or second order reaction.

Option C is correct. Rate is directly proportional to concentration of NH_4Cl .

Option D is wrong as rate should increase when concentration of NH_4Cl is high.

9. Enzyme-substrate complex is an intermediate. Hence it cannot appear in the rate equation. The rate equation should be: $\text{rate} = k [\text{enzyme}] [\text{substrate}]$.

10. Option A is wrong as a catalyst will lower the activation energy of both forward and backward reactions by the same magnitude.

Option B is wrong as equilibrium constant is only affected by a change in temperature.

Option C is correct as when the temperature decreases, the rate constants of both forward and backward reactions will decrease. The position of equilibrium will shift to the right to release heat. Since forward reaction is favoured, the rate constant of the backward reaction will decrease more than that for the forward reaction.

Option D is wrong as the rate constants of both forward and backward reactions should increase when temperature increases.

11. Option A is correct as this is a weak acid-strong base titration, which will result in the formation of carboxylate salt that undergoes basic hydrolysis to give a pH > 7 at equivalence point.

12. $S = [\text{Mg}^{2+}]^3 [\text{AsO}_4^{3-}]^2$

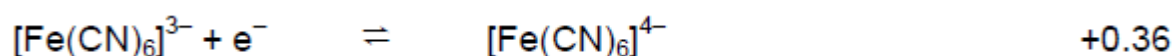
Let the solubility of $\text{Mg}_3(\text{AsO}_4)_2$ be $x \text{ mol dm}^{-3}$

$$S = (3x)^3 (2x)^2 \rightarrow 108 x^5 = S$$

$$x = (1/108 S)^{1/5}$$

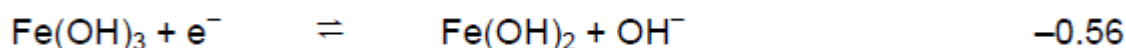
$$[\text{AsO}_4^{3-}] = 2x = (32/108 S)^{1/5} = (8/27 S)^{1/5}$$

13. Option A is wrong as when NaCN is added to the $\text{Fe}^{3+}/\text{Fe}^{2+}$ half cell, the half equation to look at is as given below.



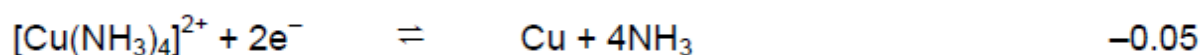
Therefore E^\ominus_{cell} is $+0.36 - (+0.34) = +0.02 \text{ V}$.

Option B is correct.



Since Cu^{2+}/Cu has a more positive E^\ominus value, it will be the cathode where reduction takes place. Therefore, Cu will be the positive electrode.

Option C is wrong.



E^\ominus_{cell} before adding excess aq $\text{NH}_3 = (+0.77) - (+0.34) = +0.43 \text{ V}$

E^\ominus_{cell} after adding excess aq $\text{NH}_3 = (+0.77) - (-0.05) = +0.82 \text{ V}$ (more spontaneous)

Option D is wrong. Since Cu^{2+}/Cu is the anode, this means that Cu^{2+} will be formed and to maintain electrical neutrality, anions in the salt bridge will move over instead.

14.	period 3 elements	Mg	Al	Si	P	S
	period 4 elements	Ca	Ga	Ge	As	Se

MgO dissolves in water to form alkaline solution.

Al_2O_3 and SiO_2 do not dissolve in water, hence the solution remains neutral.

P_4O_6 P_4O_{10}	Both oxides of phosphorous react vigorously with water to form <u>acidic</u> solutions.	$\text{P}_4\text{O}_6(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}_3\text{PO}_3^*(\text{aq})$ $\text{P}_4\text{O}_{10}(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}_3\text{PO}_4(\text{aq})$ * H_3PO_3 is a weak dibasic acid. Only 2 of the H atoms are acidic.
SO_2 SO_3	SO_2 dissolves readily in water to form an <u>acidic</u> solution of sulfurous acid. SO_3 reacts exothermically with water to form sulfuric acid, which is a strongly acidic solution.	$\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_3(\text{aq})$ $\text{SO}_3(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{SO}_4(\text{aq})$

- 15.
- **W** has the highest melting point among all the Period 3 elements. Hence **W** is Si.
 - The chloride of **X** is neutral. Hence **X** is Na.
 - The oxide of **Z** is amphoteric. Hence **Z** is Al.
 - The chloride of **Y** is acidic and the oxide of **Y** is basic. Hence **Y** is Mg.

Option A is correct: The atomic radius increases in the following order: $\text{Si} < \text{Al} < \text{Mg} < \text{Na}$ which is **W < Z < Y < X**.

Option B is wrong: The first ionisation energy should decrease in the following order: $\text{Si} > \text{Mg} > \text{Al} > \text{Na}$ which is **W > Y > Z > X** (From the data booklet).

Option C is wrong: The pH of the chlorides should decrease in the following order: $\text{Na} > \text{Mg} > \text{Al} > \text{Si}$ which is **X > Y > Z > W**.

Option D is wrong: The electrical conductivity should increase in the following order: $\text{Si} < \text{Na} < \text{Mg} < \text{Al}$ which is **W < X < Y < Z**; From Na to Al, number of delocalised valence electrons increases from 1 to 3, therefore there is an increase in electrical conductivity of these metals. Si is a metalloid (*semi-metal*), thus it is not a good conductor (it is a semi-conductor with low conductivity).

16. Reactions of Group II elements with water

	$E^{\circ}_{\text{red}} / V^*$ $M^{2+} (aq) + 2e^{-} \rightarrow M (s)$	Reaction with water
Mg	-2.38	<p>Reacts slowly with cold water but readily with steam to form hydrogen and hydroxides.</p> $Mg (s) + H_2O (g) \rightarrow MgO (s) + H_2 (g)$ <p>reacts vigorously with steam</p> $Mg (s) + 2H_2O (l) \rightarrow Mg(OH)_2 (s) + H_2 (g)$ <p>reacts slowly with cold water</p>

17. Chlorine is more reactive than bromine. Hence, the aq chlorine would displace the bromide ion to form bromine and chloride ion. Bromine is more soluble in organic solvent than water (since the energy released from the van der Waals' forces between bromine and tetrachloromethane is more than that released from the van der Waals' forces between bromine and water), bromine would dissolve in the organic solvent to form a reddish brown layer. The chloride ion will be in the aqueous layer. There will be two immiscible layers.

18. Since visible light in the 500 nm region is the least absorbed, this means that it is reflected and seen as the colour of the complex, which is green.

3 mol of $AgCl$ are formed which means that there are 3 mol of free Cl^{-} . This suggests that none of the Cl^{-} are dative bonded to Cr^{3+} .

19. Since Compound **X** can be oxidised, it must have primary alcohol or secondary alcohol or aldehyde. $NaBH_4$ only reduces carbonyl compound. Hence, **X** must contain aldehyde or ketone.

Option A is wrong: ester and primary alcohol (no carbonyl compound present).

Option B is wrong: secondary alcohol and carboxylic acid (no carbonyl compound present).

Option C is wrong: ester and primary alcohol (no carbonyl compound present).

Option D is correct: primary alcohol, secondary alcohol and aldehyde present.

- 20.** Option A is wrong as FeCl_3 must be anhydrous as it undergoes hydrolysis in the presence of water. Hence FeCl_3 is destroyed and cannot act as catalyst.

Option B is correct as HBr(g) is produced which reacts with $-\text{OH}$ (nucleophilic substitution) and $\text{C}=\text{C}$ (electrophilic addition).

Option C is wrong as LiAlH_4 does not reduce alkenes.

Option D is wrong as the conditions given are meant for nucleophilic addition of carbonyl compounds, not nucleophilic substitution of chloroalkanes.

- 21.** Option A is wrong: Only 3 moles of Na is required to react with 3-OH.

Option B is correct: 5 moles of HBr reacts with 2 moles of $\text{C}=\text{C}$ and 3 moles of $-\text{OH}$.

Option C is wrong: There is only one ester that can undergo basic hydrolysis.

Option D is wrong: There are only two carbonyl groups (ketones) present.

- 22.** Only $\text{CH}_3\text{CH}_2\text{COC}l$ can react with water to produce $\text{CH}_3\text{CH}_2\text{COOH}$ and HCl . Cl^- reacts with Ag^+ to form AgCl .

- 23.** Option A: Cl_2 is not a good distinguishing test for alkanes and alkenes.

Option B: Yellow precipitate is seen for $\text{CH}_3\text{COCH}_2\text{I}$ but not for $\text{CH}_3\text{CH}_2\text{CHO}$.

Option C: To distinguish halogenoalkanes, the unknowns must first be heated with NaOH(aq) , followed by cooling and acidification with $\text{HNO}_3\text{(aq)}$. Lastly, $\text{AgNO}_3\text{(aq)}$ must be added for the silver halide ppt to be formed.

Option D: Tollens' reagent will oxidise both compounds and be reduced to Ag and silver mirror is seen.

24.

Option A: Compound **P** is HO-C(=O)-CH2-CH2-CH2-CH2-NH2 and does not react with 2,4-DNPH.

Option B: Compound **Q** has a primary alcohol from reduction of -COOH and can react with PCl_5 .

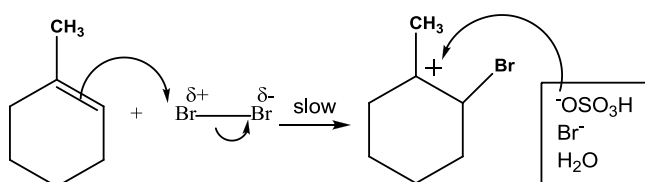
Option C: Step 3 is elimination. (Elimination of alcohol to form alkene)

Option D: An acid chloride is required to form an amide.

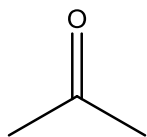
25.

Only polarised $\overset{\delta+}{\text{Br}}-\overset{\delta-}{\text{Br}}$ can provide the electrophile to attack $\text{C}=\text{C}$ in the first step to form the intermediate. Electrophile, Br^{6+} will be added to C with more H. Other negatively charged species and water will be attracted to carbocation in the next step.

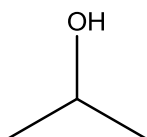
Electrophilic Addition



26. Oxidation of alcohol with KMnO_4 will yield either carboxylic acid (if it's primary alcohol) or ketone (if it's secondary alcohol). Since the compound only has 1 oxygen atom, it should be a ketone. The structural formula of the compound is:



Thus, structural formula of alcohol **W** is:



(Propan-2-ol) as secondary alcohol undergoes oxidation to give ketone.

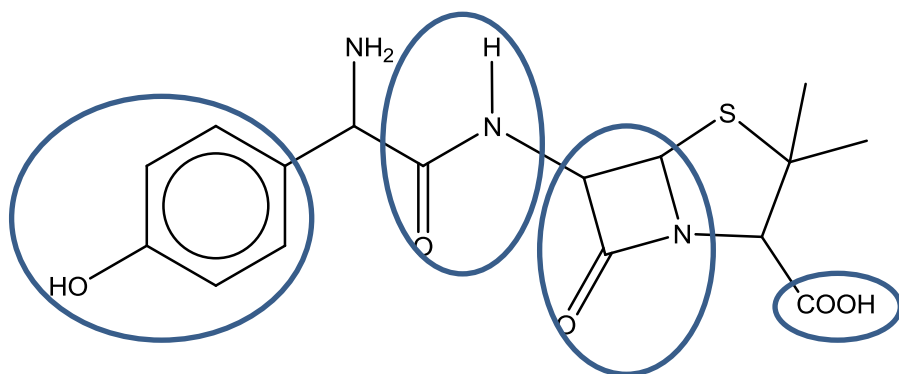
Option A: Elimination reaction to yield alkene. (Wrong)

Option B: Reduction of acid to yield primary alcohol. (Wrong)

Option C: Nucleophilic substitution to yield propan-2-ol, a secondary alcohol. (Correct)

Option D: Electrophilic addition would require conc H_2SO_4 at $0\text{ }^\circ\text{C}$ followed by boiling with H_2O . (Wrong)

27.

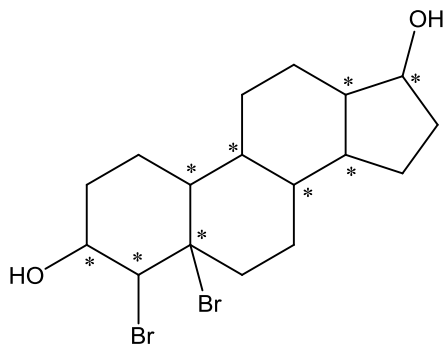


Phenol and carboxylic acid groups will undergo neutralisation.

2 amide groups will undergo alkaline hydrolysis.

Thus, 4 moles of NaOH are required.

28.



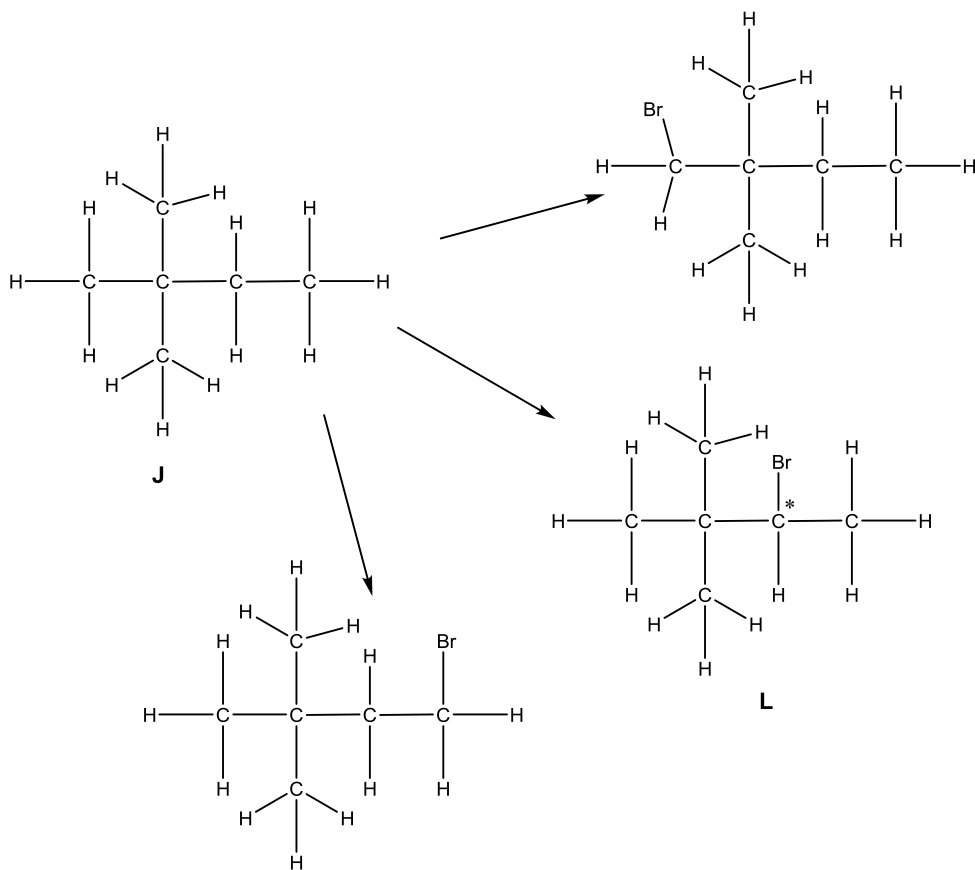
Option A: False. There are 2^9 stereoisomers.

Option B: Elimination of H_2O produces 2 more $\text{C}=\text{C}$. Total of 3 $\text{C}=\text{C}$.

Option C: Both 2° alcohol can be oxidised.

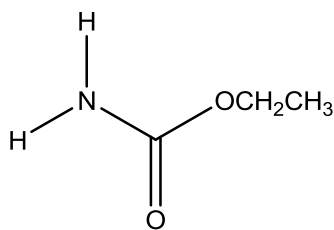
Option D: 2 -OH groups reacts with Na to form 1 mole of H_2 .

29. Option A is correct.



Although Option D gives 3 isomers, 2 of them have chiral carbons.

30. Structural formula of ethyl carbamate:

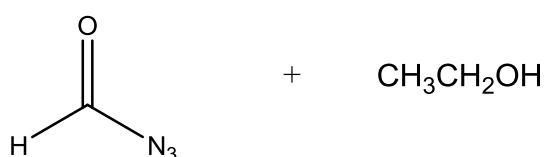


From the pattern,

$R = H$

$R' = CH_3CH_2$

Thus, the acyl azide and alcohol used are:



31. Option **i** is correct as there is a lone electron on N.

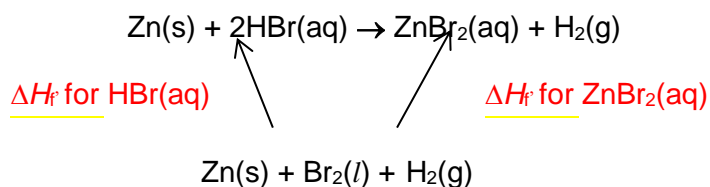
Option **ii** is wrong as NaH is a reducing agent, just like $NaBH_4$ and $LiAlH_4$.

Option **iii** is wrong as the oxidation number of Cr remains at +6. It is an acid-base reaction instead.

32. Option 2 is wrong as $AlBr_3$ and P_4O_{10} are both simple covalent structures. Si is giant covalent structure. There is no giant ionic structure.

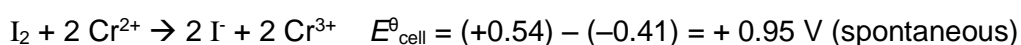
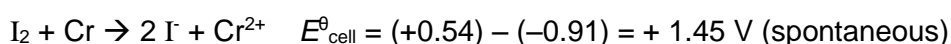
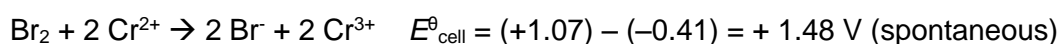
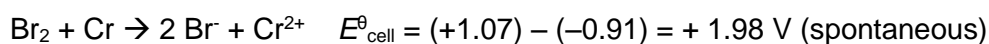
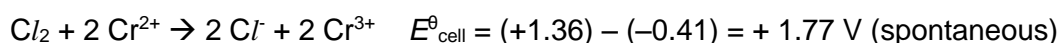
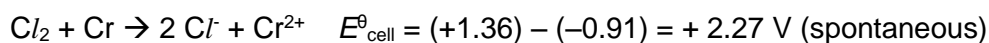
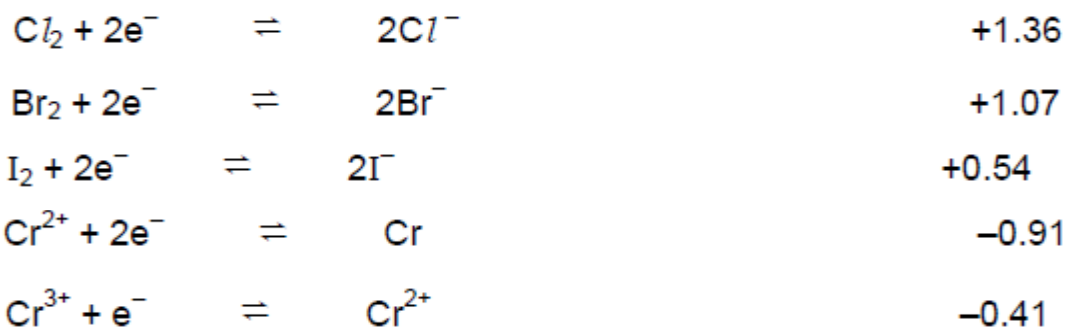
Option 3 is wrong as Al_2O_3 has giant ionic structure. BF_3 and $SiCl_4$ are both simple covalent molecules. There is no giant covalent structure.

33.



Note ΔH_f for elements in standard states (e.g. $Zn(s)$ & $H_2(g)$) is zero. Thus it is not needed.

34.



Therefore, CrCl_3 , CrBr_3 and CrI_3 will be the final products obtained.

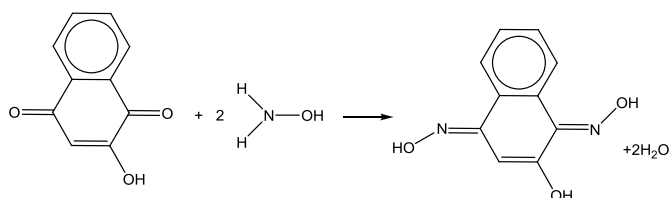
35. Option 1 is correct. Ligand exchange with the hexadentate edta ion results in an increase in number of species from 2 to 7, as shown below.



Option 2 is wrong as the d orbitals in species D, $[\text{CuCl}_4]^{2-}$ are non-degenerate since there are ligands bonded to Cu^{2+} which split the d-orbitals into 2 different energy levels.

Option 3 is wrong as steps V and VI involve redox reaction. Colour change is due to Cu^{2+} being reduced to Cu^+ .

36. Option 1: Condensation takes place between NH_2OH and $-\text{C}=\text{O}$ in Lawsone.



Options 2 & 3: Tollens' reagent and conc. HNO_3 do not react with Lawsone. There are no aldehyde groups to react with Tollens' reagent. Electrophilic substitution of benzene ring requires conc HNO_3 with conc H_2SO_4 catalyst at 55°C .

37. Option 1 is true. In presence of NaOH , $-\text{NH}_2$ is behaving as a Bronsted acid as it has donated a H^+ . Hence NaOH is acting as a base.

Option 2 is true as Br_2 can be polarised in to produce $\overset{\delta+}{\text{Br}}-\overset{\delta-}{\text{Br}}$.

Option 3 is wrong as oxidation state of Br^1 is +1. Reason: As N is more electronegative than Br, N will draw the electrons in the covalent bond between N and Br towards itself, hence Br has 6 electrons around it. Since Br is supposed to have 7 valence electrons but it now has only 6, the oxidation state of Br is +1.

38. Option 1: Hydrolysis took place in step 1 to cleave the ester bond.

Option 2: Nucleophilic substitution occurs in steps II to IV.

Option 3: No electrophilic substitution took place.

39. Option 1: True. Disulfide bonds are formed via oxidation. Adding a reducing agent will reverse the reaction, disrupting the disulfide bonds.

Option 2: True.

Option 3: True as glutamic acid can react with NaOH to form carboxylate ions. Hence, hydrogen bonding can be disrupted.

40. Option 1 is correct: Amine + Acid chloride = Amide

Option 2 is wrong: Tertiary amines cannot undergo condensation with acid chlorides to form amides as it does not have a H atom to be removed. Hence, no amide will be formed.

Option 3 is wrong: Amine + carboxylic acid = Salt. This is a neutralisation reaction so amide will not be produced.

END OF PAPER