2019 Y6 Prelims
H2 Chemistry 9729 Paper 1
Suggested Solutions

Answer Key

1	2	3	4	5	6	7	8	9	10
C	**C**	**B**	**C**	**C**	**D**	**C**	**D**	**A**	**D**

11	12	13	14	15	16	17	18	19	20
C	**C**	**B**	**A**	**D**	**C**	**A**	**B**	**A**	**D**

21	22	23	24	25	26	27	28	29	30
D	**C**	**C**	**C**	**B**	**D**	**B**	**A**	**A**	**B**

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1 **C**

From Reaction (1)
$2NaN_3 \equiv 2Na \equiv 3N_2$

From Reaction (2)
$10Na(s) + 2KNO_3(s) \rightarrow K_2O(s) + 5Na_2O(s) + N_2(g)$
$10Na \equiv 1\ N_2$

Combining reactions (1) and (2),
$2NaN_3$ gives $3N_2$ directly, while 2Na gives 1/5 N_2
Hence, $2NaN_3$ gives a total of 16/5 N_2
$1.25NaN_3 \equiv 2N_2$

2 **C**

Moles of sodium percarbonate = 10/1000 x 0.1
= 0.001 mol
Moles of CO_2 = (48/1000) / 24
= 0.002 mol
Since $(Na_2CO_3)_x \bullet y(H_2O_2) \equiv xCO_2$
x = 2
Moles of $KMnO_4$ = 24/1000 x 0.05
= 0.0012 mol
$2KMnO_4 \equiv 5\ H_2O_2$,
Moles of H_2O_2 = 5/2 x 0.00120
= 0.003 mol
Since $(Na_2CO_3)_x \bullet y(H_2O_2) \equiv y\ H_2O_2$
y = 3

y/x = 3/2

3 **B**

Note that elements in the same group (e.g. O and S) will have the same number of unpaired electrons in their ground state. Group 17 elements have only 1 unpaired electron. Hence, option 1 is incorrect.

×	**1**	Electronic configuration of Ti: [Ar]$3d^2 4s^2$ (2 unpaired electrons) *Cl*: [Ne] $3s^2 3p^5$ (1 unpaired electron)
✓	**2**	Electronic configuration of Si: [Ne] $3s^2 3p^2$ (2 unpaired electrons) O: $1s^2 2s^2 2p^4$ (2 unpaired electron)
✓	**3**	Electronic configuration of Ni: [Ar]$3d^8 4s^2$ (2 unpaired electrons) S: [Ne] $3s^2 3p^4$ (2 unpaired electron)

4 **C**

pV = nRT

For Graphs **A** and **B**,

For a fixed mass of gas at constant T,
pV = constant. Since we are plotting a p against pV graph, the graph should be a vertical line instead (i.e. x = constant graph)

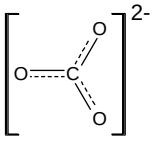
For Graphs **C** and **D**,
For a fixed mass of gas at constant p, V = (nR/p)T

The graph should be y=mx graph (upward sloping straight line that passes through origin), with gradient = (nR/p)

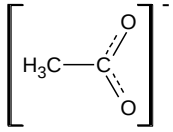
Since **I** has a higher M_r than **J**, number of moles of **I** will be smaller than **J** and hence graph of **I** should have a smaller gradient.

5 **C**

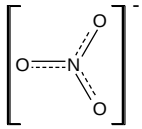
Carbonate



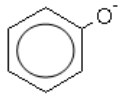
Ethanoate



Nitrate



Phenoxide



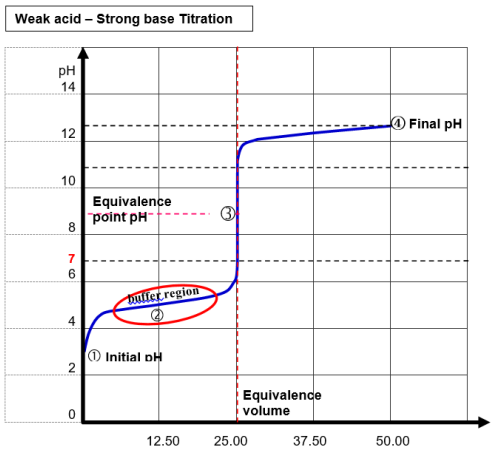
In ethanoate ion, the shape with respect to the methyl carbon is tetrahedral.

The common feature is the *delocalization of electrons.*

6 **D**

✓	**1**	At constant temperature, K_c remains unchanged. Hence $\Delta G^{\ominus}$ remains unchanged.
×	**2**	Reaction is spontaneous when $\Delta G^{\ominus} < 0$. For $0 < K_c < 1$, ln K_c is negative and hence $\Delta G^{\ominus} > 0$ (non-spontaneous)
×	**3**	Adding a catalyst increases rate of both forward and backward reaction to the same extent, hence the position of the equilibrium remains unchanged. K_c remains unchanged and hence $\Delta G^{\ominus}$ remains unchanged.

7	**C**
	$N_2H_5^+ + NH_3 \rightleftharpoons NH_4^+ + N_2H_4$ $Acid_1$ $Acid_2$ $NH_3 + HBr \rightleftharpoons NH_4^+ + Br^-$ $Acid_1$ $Acid_2$ $N_2H_4 + HBr \rightleftharpoons N_2H_5^+ + Br^-$ $Acid_1$ $Acid_2$ For all cases, since $K_c > 1$, strength of $acid_1 > acid_2$. From all 3 equations, we can deduce that Strength of acid: $HBr > N_2H_5^+ > NH_4^+$ Hence order in decreasing pH: $NH_4^+ > N_2H_5^+ > HBr$ Note: HBr is a strong acid. So the options can be narrowed down to options B and C.

8	**D**	
×	**A**	KOH (strong base) is in excess and resultant solution will have pH >7
×	**B**	This happens at equivalence point where KOH exactly neutralises benzoic acid. Salt hydrolysis occurs and basic salt will be formed. Resultant solution will have pH > 7.
×	**C**	Benzoic acid is in excess and acidic buffer will be formed. Since volume of KOH added is half the equivalence volume, this is at maximum buffer capacity. Resultant solution will have pH =pK_a.
✓	**D**	Benzoic acid is in excess and acidic buffer will be formed. Resultant solution will have pH < 7.  Since volume of KOH added is less than half the equivalence volume, pH will be less than that at maximum buffer capacity. Hence pH < pKa and option **D** will have the lowest pH.

9	**A**	
✓	**1**	Precipitate will start to occur when mass of solute dissolved exceed its solubility. For 10 g of KC*l*, first trace of ppt will start to appear at 30 °C. For 50 g of KC*l*O_3, first trace of ppt will start to appear at about 76 °C.
✓	**2**	At 10 °C, both solutes have exceeded its solubility and hence a saturated solution of KC*l* and KC*l*O_3 is formed.
✓	**3**	At temperatures between 30 °C and 76 °C, KC*l*O_3 ppt will be formed but not KC*l*. Mass of KC*l*O_3 ppt = 50 – 37 = 13g

10	**D**
	$2NH_3(g) + H_2O_2(l) \rightarrow N_2H_4(l) + 2H_2O(l)$ $\Delta H_{reaction}^{\ominus} = -241$ kJ mol^{-1} $\Delta H_{reaction}^{\ominus} = [\Delta H_f^{\ominus}(N_2H_4(l)) + 2\Delta H_f^{\ominus}(H_2O(l))] - [2\Delta H_f^{\ominus}(NH_3(g)) + \Delta H_f^{\ominus}(H_2O_2(l))]$ $-241 = [\Delta H_f^{\ominus}(N_2H_4(l)) + 2(-286)] - [2(-46) + (-188)]$ $\Delta H_f^{\ominus}(N_2H_4(l)) = +51$ kJ mol^{-1} Decomposition of $N_2H_4(l)$ is $N_2H_4(l) \rightarrow N_2(g) + 2H_2(g)$ The reverse of formation of hydrazine, therefore, $\Delta H^{\ominus}$ for decomposition of hydrazine is **–51 kJ mol^{-1}**

11	**C**
	$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ For the forward reaction, ΔS is negative as there is a decrease in the number of moles of gaseous molecules (resulting in a less disordered system). ΔH is negative as "higher yield of methanol can be achieved at a lower temperature." That is, at lower temperature, position of equilibrium is shifted to the right, favouring an exothermic reaction. $\Delta G = \Delta H - T\Delta S$ *At* T=0 K, $\Delta G = \Delta H$ ΔG is negative. Gradient is $-\Delta S$. Since ΔS is negative, gradient is positive.

12 **C**

From the first table, comparing expt 2&3, [P] x2, rate also x2, order of reaction with respect to [P] is 1.

Comparing expt 1&2, [P] x2, [Q] x2, rate x2. Since rate α [P], two times increase in [Q] has no effect on rate. Order of reaction with respect to [Q] is 0.

Therefore, rate equation is

rate =k[P]

From the second table, if we disregard the temperatures,

$rate_4 = k(0.10)$
$rate_5 = k(0.20)$
$rate_6 = k(0.30)$

Taking temperatures into consideration, relative rates are as follows. (Using 20 °C of expt 6 as the reference)

$rate_4 = k(0.10) \times 2 \times 2 = 0.40k$
$rate_5 = k(0.20) \times 2 = 0.40k$
$rate_6 = k(0.30) \times 1$ (reference expt) $= 0.30k$

Hence, only statements 1 and 3 are correct.

13 **B**

Element	**X** (=A*l*)	**Y** (=Na)	**Z** (=P)
Oxide of the element	Al_2O_3	Na_2O	P_4O_{10}
Chloride of the element	$AlCl_3$	NaC*l*	PCl_5

Oxides with HC*l*(aq)
$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$
$Na_2O + 2\ HCl \rightarrow 2NaCl + H_2O$

PCl_5 merely hydrolyses in aqueous solution of hydrochloric acid to give $H_3PO_4 + 5HCl$

SiO_2 is acidic and does not react with HC*l*.

Oxides with water:
Al_2O_3 has very exothermic lattice energy. Does not dissolve in water.

Na_2O forms NaOH in water.
$Na_2O + H_2O \rightarrow 2NaOH$

$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

Chlorides with water:
$AlCl_3(s) + 6H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3Cl^-(aq)$

$Al^{3+}(aq)$ has high charge density, it undergoes partial hydrolysis in water.

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

NaC*l* simply dissolves in water.

PCl_5 undergoes complete hydrolysis in water.
$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

14 **A**

	K$^-$ (aq)	**L**$^-$ (aq)	**M**$^-$ (aq)
K_2	no reaction	L_2 formed	no reaction
L_2	no reaction	no reaction	no reaction
M_2	K_2 formed	L_2 formed	no reaction

From the table, since M_2 displaces K_2 and L_2, M_2 is the strongest oxidising agent. If we consider the more common halogens (for convenience) – Cl_2, Br_2 and I_2, then M_2 is Cl_2.

× **1** Since L_2 cannot displace other halogens, L_2 is the weakest oxidising agent. L_2 is I_2.

So, when L_2 (ie. I_2) , the weakest oxidizing agent reacts with thiosulfate ions, $S_2O_3^{2-}$, oxidation state of sulfur changes from +2 in $S_2O_3^{2-}$ to +2.5 in $S_4O_6^{2-}$
On the other hand, when M_2 (ie. Cl_2 reacts with $S_2O_3^{2-}$, oxidation state of sulfur changes from +2 in $S_2O_3^{2-}$ to +6 in SO_4^{2-}. Statement 1 is not correct.

✓ **2** **L**$^-$ is I^- which forms AgI with silver nitrate. AgI is insoluble in excess aq. ammonia.

× **3** **K**$^-$ is Br^- while **M**$^-$ is Cl^-. They are halides, not halogens. Hexane can be used to distinguish between bromine and iodine but not bromide and iodide.

15 **D**

Note that all hydrogens atoms on the carbons of the C=C are unlikely to undergo free radical substitution.

In order to form a chiral carbon, the substitution must happen on a $–CH_2–$, not on a $–CH_3$.

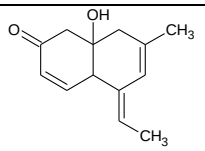
× **A** $CH_3CH=CH_2$
(a) (b) (c)
There are three types of hydrogen atoms. Only (a) tends to undergo FRS, but it will not generate a chiral centre. The monochlorinated product will not show cis–trans isomerism or enantiomerism.

× **B** $(CH_3)_2C=CH_2$
(a) (b)
There are two types of hydrogen atoms. Only (a) tends to undergo FRS, but it will not generate a chiral centre. The monochlorinated product will not show cis–trans isomerism or enantiomerism.

× **C** $CH_3CH=C(CH_3)_2$
(a) (b) (c)
There are three types of hydrogen atoms. Only (a) and (c) tend to undergo FRS, but no substitution will generate a chiral centre. The monochlorinated product will not show enantiomerism. Cis–trans isomerism is possible if (c) is substituted.

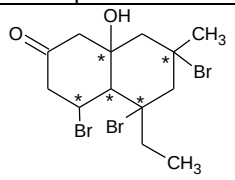
✓ **D** $CH_3CH=CHCH_2CH_3$
(a) (b) (c) (d) (e)
There are five types of hydrogen atoms. Only (a), (d) and (e) tend to undergo FRS. A chiral centre is formed when (d) is substituted. All products will show cis-trans isomerism.

16 **C**



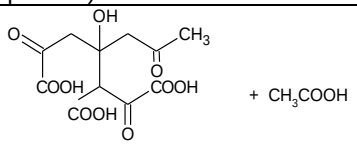
Compound **K**

× **A**



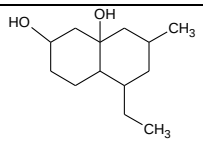
The product has five chiral centres.
(Need to apply Markovnikov's rule to obtain the major product)

× **B**



A tribasic carboxylic acid is formed upon strong oxidation of **K**.

✓ **C**

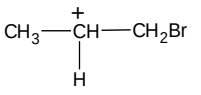


Alkene and ketone groups are reduced by H_2 to give the product above. 4 mol of H_2 for the three carbon-carbon double bonds and one ketone group.

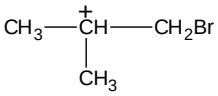
× **D**

The –OH group in **K** reacts with Na according to: ROH + Na → RO^-Na^+ + ½ H_2
1 mol of **K** produces ½ mol of H_2. (= ½ (24.0) dm^3)

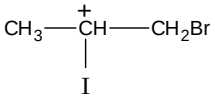
17 **A**



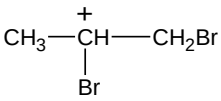
carbocation **S**



carbocation **T**



carbocation **U**



carbocation **V**

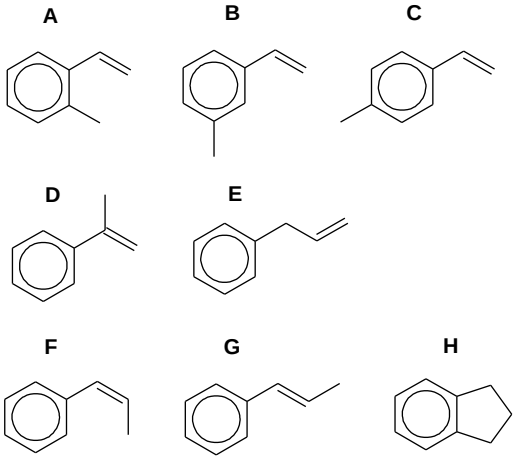
The above corresponding carbocations are formed when electrophilic end of bromine molecule is attached to the C atom of the double bond with more H atoms (follow Markovnikov's rule).

Carbocation **T** is most stable as there is an electron-donating $-CH_3$ substituent attached to the carbocation, dispersing the positive charge, stabilising the carbocation to the largest extent. Rate of bromination is the fastest.

I and Br atoms are both electronegative. Br is more electronegative than I. Br atom therefore, destabilises the carbocation **V** to the largest extent. Rate of addition of Br_2 /CCl_4 to **V** will be the slowest as carbocation intermediate **V** is the least stable.

18 **B**

There are 8 possible benzene-containing isomers.



Only **A** and **H** will produce benzene-1,2-dicarboxylic acid on heating with acidified manganate(VII) ions.

19	**A**	
✓	**1**	RCO_2^- nucleophile attacks the electrophilic δ+ bromine atom to form RCO_2Br.
✓	**2**	Homolytic fission of O–Br bond occurs to form RCOO• and Br• radicals.
✓	**3**	Correct movement of electrons showing the formation of C-O pi bond and the cleavage of R-C sigma bond.
×	**4**	Formation of R-Br bond releases energy.

20 **D**

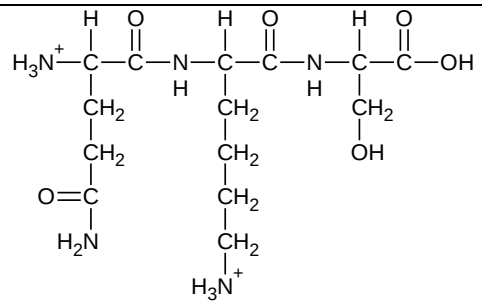
ROH + $SOCl_2$ → RC*l* + HC*l*(g) + SO_2(g)
Since 1 mol of ROH produces 2 mol of gas (HC*l* and SO_2), 1 mol of sorbitol has 6 mol of alcohol which will produce a total of 12 mol of gas.

21	**D**	
×	**A**	Benzaldehyde does not give a positive iodoform test with alkaline aqueous iodine.
×	**B**	The ester functional group does not give orange ppt with 2,4-DNPH.
×	**C**	$CH_3CH_2COCH_2CH_3$ does not give a positive iodoform test with alkaline aqueous iodine.
✓	**D**	The ketone functional groups can give orange ppt with 2,4-DNPH and do not react with Fehling's solution. The presence of $-COCH_3$ groups give a positive iodoform test with alkaline aqueous iodine.

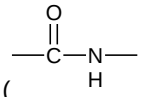
22 **C**

The amide functional group is hydrolysed when heated with NaOH(aq). Ammonia gas is also liberated when NH_4^+ is heated in the presence of hydroxide ions.

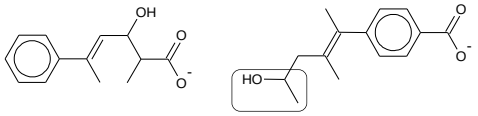
23	**C**

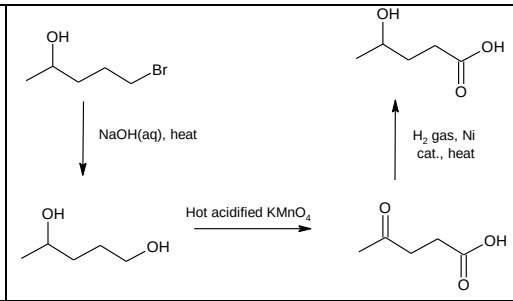
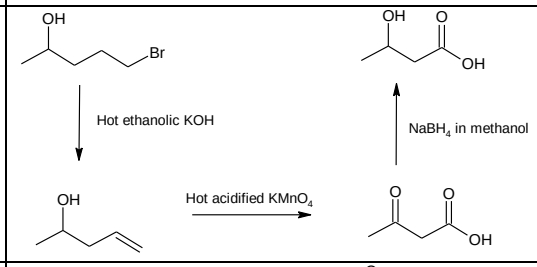
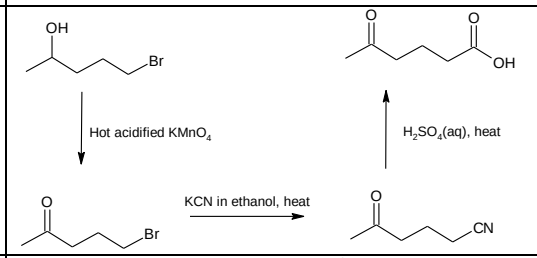
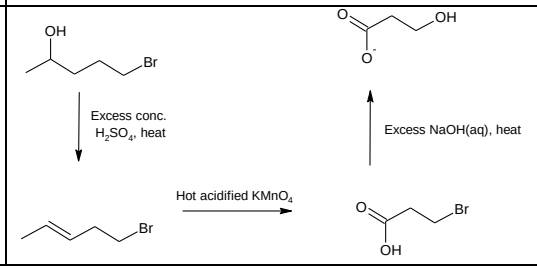


The correct structure must have



1. Peptide bonds ( ) between each amino acid
2. Basic groups will be protonated (i.e. all amines will be protonated)
3. Amide and alcohol groups are neutral and hence do not get protonated.
4. Carboxylic acid group is acidic and hence remains protonated.

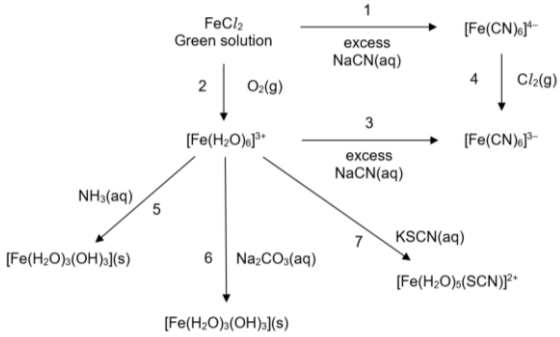
24	**C**	
×	**A**	Ester group undergoes alkaline hydrolysis to give the following products. One of them contains the –CH(OH)CH_3 group which will give the yellow ppt of CHI_3. 
×	**B**	PCl_5 reacts with alcohol and carboxylic acid groups to give white fumes of HCl.
✓	**C**	Ester and carboxylic acid groups are reduced to alcohols but there is no observable change.
×	**D**	Mild oxidation of alkene to diol occurs. Purple $KMnO_4$ decolourises and brown ppt of MnO_2 is formed.

25	**B**	
	Please note that there is a reduction of one carbon.	
×	**A**	
✓	**B**	
×	**C**	
×	**D**	

26	**D**
	Anode NO_3^- cannot be oxidised at the anode as nitrogen is in its highest oxidation state. Hence, water must have been oxidised at the anode. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ The gas produced at the anode is O_2. **Cathode** $2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$ $E^\ominus = -0.83$ V For the metal to be discharged at the cathode, the $E^\ominus$ must be more positive than –0.83 V. $Zn^{2+} + 2e^- \rightleftharpoons Zn$ $E^\ominus = -0.76$ V Hence, Zn^{2+} is reduced at the cathode to Zn metal.

27	**B**
	Amt of Zn = 0.4 ÷ 65.4 = 0.0061162 mol $Zn^{2+} + 2e^- \longrightarrow Zn$ No. of moles of e^- = 2 × 0.0061162 = 0.012232 mol Charge required = 0.012232 × 96500 = 1180.4 C Time required = 1180.4 ÷ 0.5 = 2360.9 s = **<u>39.3 min</u>** (3 s.f.)

28	**A**	
✓	**A**	$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O \quad E^\ominus = +1.77$ V $E^\ominus_{cell}$ = +1.77 – (+0.70) = +1.07 V Since $E^\ominus_{cell} > 0$, reaction is spontaneous.
×	**B**	$Br_2 + 2e^- \rightleftharpoons 2Br^- \quad E^\ominus = +1.07$ V $E^\ominus_{cell}$ = +1.07 – (+0.70) = +0.37 V Since $E^\ominus_{cell} > 0$, reaction is spontaneous. However, aq Br_2 will undergo an electrophilic substitution with quinol (due to the presence of the phenol grp). Hence, quinone will not be produced in good yield.
×	**C**	$Cu^{2+} + 2e^- \rightleftharpoons Cu \quad E^\ominus = +0.34$ V $E^\ominus_{cell}$ = +0.34 – (+0.70) = –0.36 V Since $E^\ominus_{cell} < 0$, reaction is not spontaneous.
×	**D**	Cl^- is a reducing agent and hence will not be able to oxidise quniol to quinone.

29	**A**
	

✓	**A**	**False** Step 5 involves the two equilibria below: $NH_3(aq) + H_2O \rightleftharpoons NH_4^+ + OH^-$ $Fe^{3+} + 3OH^- \rightleftharpoons Fe(OH)_3(s)$ Step 6 involves an acid-base reaction (because Fe^{3+} is an acidic cation) $2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \longrightarrow 2[Fe(H_2O)_3(OH)_3](s) + 3CO_2 + 6H_2O$
×	**B**	**True** $[Fe(H_2O)_6]^{3+} + SCN^- \rightleftharpoons [Fe(H_2O)_5(SCN)]^{2+} + H_2O$
×	**C**	**True** Fe^{2+} is oxidised to Fe^{3+} in step 2.
×	**D**	**True** $[Fe(CN)_6]^{3-} + e^- \rightleftharpoons [Fe(CN)_6]^{4-} \quad E^\ominus = +0.36$ V $Cl_2 + 2e^- \rightleftharpoons 2Cl^- \quad E^\ominus = +1.36$ V $E^\ominus_{cell}$ = +1.36 – (+0.36) = <u>+1.00 V</u>

30	**B**
	Since 2 mol of AgCl is formed from 1 mol of the ionic compound, there are 2 mol of free Cl^- ions that are not ligands. Hence, the charge of the complex cation must be 2+ for the ionic compound to be uncharged. Note that the other chloride anion is a ligand. It has already formed a dative bond with the central metal cation and hence, this chloride does not form a precipitate when $AgNO_3$ is added to the ionic compound.