INORGANIC CHEMISTRY

NEET

CRASH COURSE

COORDINATION COMPOUND

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SUMMARY

The chemistry of coordination compounds is an important and challenging area of modern inorganic chemistry. During the last fifty years, advances in this area, have provided development of new concepts and models of bonding and molecular structure, novel breakthroughs in **chemical industry** and vital insights into the functioning of critical components of **biological systems.**

The first systematic attempt at explaining the formation, reactions, structure and bonding of a coordination compound was made by **A. Werner.** His theory postulated the use of two types of **linkages (primary and secondary)** by a metal atom/ion in a coordination compound. In the modern language of chemistry these linkages are recognised as the ionisable (ionic) and non-ionisable (covalent) bonds, respectively. Using the property of isomerism, Werner predicted the geometrical shapes of a large number of coordination entities.

The Valence Bond Theory (VBT) explains with reasonable success, the formation, magnetic behaviour and geometrical shapes of coordination compounds. It, however, fails to provide a quantitative interpretation of magnetic behaviour and has nothing to say about the optical properties of these compounds.

The Crystal Field Theory (CFT) to coordination compounds is based on the effect of different crystal fields (provided by the ligands taken as point charges), on the degeneracy of *d* orbital energies of the central metal atom/ion. The splitting of the *d* orbitals provides different electronic arrangements in strong and weak crystal fields. The treatment provides for quantitative estimations of orbital separation energies, magnetic moments and spectral and stability parameters. However, the assumption that ligands consititute point charges creates many theoretical difficulties.

The metal–carbon bond in metal carbonyls possesses both σ and π character. The ligand to metal is σ bond and metal to ligand is π bond. This unique synergic bonding provides stability to metal carbonyls.

The stability of coordination compounds is measured in terms of **stepwise stability (or formation) constant (K) or overall stability constant (β)**. The stabilisation of coordination compound due to chelation is called the chelate effect. The stability of coordination compounds is related to Gibbs energy, enthalpy and entropy terms.

Coordination compounds are of great importance. These compounds provide critical insights into the functioning and structures of vital components of biological systems. Coordination compounds also find extensive applications in **metallurgical processes, analytical and medicinal chemistry.**

COORDINATION COMPOUND

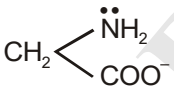
Q.1 Which of the following is not a double salt but is a complex salt :
(1) $KCl.MgCl_2.6H_2O$ (2) $FeSO_4.(NH_4)_2SO_4.6H_2O$
(3) $K_2SO_4.Al_2(SO_4)_3.2H_2O$ (4) $4KCN.Fe(CN)_2$

Q.2 The donor atoms in EDTA are –
(1) Two N and Two O (2) Two N and four O
(3) Four N and Two O (4) Three N and three O

Q.3 An ambidentate ligand is one which –
(1) is linked to the metal atom at two points
(2) has two donor atoms but only one of them has the capacity to form a coordinate bond
(3) Has two donor atoms but either of the two can form a co-ordinate bond
(4) forms chelate rings

Q.4 The co-ordination number and oxidation number of ' x ' in the following compound $[x(SO_4)(NH_3)_5]Cl$ will be:
(1) 10 & 3 (2) 2 & 6 (3) 6 & 3 (4) 6 & 4

Q.5 In SCN ligand if N is attached to central atom, the name of ligand is –
(1) Thiocyanato-N (2) Cyanato-N (3) Thiocyanato-S (4) Cyanato-S

Q.6 Glycinato ligand is –
(1)  (2) Bidentate ligand
(3) Two donor sites N and O^- (4) All of these

Q.7 For the complex $[Cr(C_2O_4)_2(H_2O)_2]^-$, the oxidation number of Cr is .....and the coordination number of Cr is .....
(1) +3, 6 (2) +3, 4 (3) +2, 6 (4) +2, 4

Q.8 How many EDTA molecules are required to make an octahedral complex with a Ca^{2+} ion ?
(1) Six (2) Three (3) One (4) Two

Q.9 A complex cation is formed by Pt (in some oxidation state) with ligands (in proper number so that coordination number of Pt becomes six). Which of the following can be its correct IUPAC name :
(1) Diammineethylenediaminedithiocyanato-S-platinum (II) ion
(2) Diammineethylenediaminedithiocyanato-S-platinate (IV) ion
(3) Diammineethylenediaminedithiocyanato-S-platinum (IV) ion
(4) Diamminebis (ethylenediamine) dithiocyanate-S- platinum (IV) ion

Q.10 Formula of ferrocene is:
(1) $[Fe(CN)_6]^{4-}$ (2) $[Fe(CN)_6]^{3+}$ (3) $[Fe(CO)_5]$ (4) $[Fe(C_5H_5)_2]$

Q.11 The correct IUPAC name of $KAl(SO_4)_2 . 12 H_2O$ is :
(1) aluminium potassium sulphate –12 water
(2) potassium aluminium (III) sulphate –12 water
(3) potassium aluminium (III) sulphate hydrate
(4) aluminium (III) potassium sulphate hydrate 12.

Q.12 When $AgNO_3$ is added to a solution of $Co(NH_3)_5Cl_3$, the precipitate of AgCl shows two ionisable chloride ions. This means –
(1) Two chlorine atom satisfy primary valency and one chlorine atom satisfies primary valency as well as secondary valency.
(2) One chlorine atom satisfies primary valency.
(3) Two chlorine atoms satisfy secondary valency.
(4) Three chlorine atoms satisfy secondary valency.

Q.13 Which of the following is non–conducting of electricity?
(1) $CoCl_3.6NH_3$ (2) $CoCl_3.5NH_3$ (3) $CoCl_3.4NH_3$ (4) $CoCl_3.3NH_3$

Q.14 Which isomer of $CrCl_3.6H_2O$ is dark green in colour and forms one mole of AgCl with excess of $AgNO_3$ solution –
(1) $[Cr(H_2O)_6]Cl_3$ (2) $[Cr(H_2O)_5Cl]Cl_2.H_2O$
(3) $[Cr(H_2O)_4Cl_2]Cl.2H_2O$ (4) $[Cr(H_2O)_3Cl_3].3H_2O$

Q.15 A complex of platinum, ammonia and chloride produces four ions per molecule in the solution. The structure consistent with the observation is:
(1) $[Pt(NH_3)_4]Cl_4$ (2) $[Pt(NH_3)_2Cl_4]$
(3) $[Pt(NH_3)_5Cl]Cl_3$ (4) $[Pt(NH_3)_4Cl_2]Cl_2$

Q.16 EAN of the central metal in the complexes – $K_2[Ni(CN_4)]$, $[Cu(NH_3)_4]SO_4$ and $K_2[PtCl_6]$ are respectively:
(1) 36, 35, 86 (2) 34, 35, 84 (3) 34, 35, 86 (4) 34, 36, 86

Q.17 Give the correct increasing order of electrical conductivity of aqueous solutions of following complex entities –
I. $[Pt(NH_3)_6]Cl_4$ II. $[Cr(NH_3)_6]Cl_3$ III. $[Co(NH_3)_4Cl_2]Cl$ IV. $K_2[PtCl_6]$
(1) III < IV < II < I (2) IV < II < III < I (3) II < I < IV < III (4) I < II < IV < III

Q.18 The number of ions given by $[Co(NH_3)_6]Cl_3$ in aqueous solution is –
(1) 2 (2) 3 (3) 1 (4) 4

Q.19 Among the following, which one has higher CFSE?
(1) $[Zn(NH_3)_4]^{2+}$ (2) $[Zn(OH)_4]^{2-}$ (3) $[Zn(CN)_4]^{2-}$ (4) $[Zn(H_2O)_4]^{2+}$

Q.20 Which one is the most likely structure of $CrCl_3 \cdot 6H_2O$ if 1/3 of total chlorine of the compound is precipitated by adding $AgNO_3$ to its aqueous solution:
(1) $CrCl_3 \cdot 6H_2O$ (2) $[CrCl_3(H_2O)_3] \cdot (H_2O)_3$
(3) $[CrCl_2(H_2O)_4] \cdot Cl \cdot 2H_2O$ (4) $[CrCl(H_2O)_5]Cl_2 \cdot H_2O$

Q.21 All the following complex ions are found to be paramagnetic :
P : $[FeF_6]^{3-}$; Q : $[CoF_6]^{3-}$
R : $[V(H_2O)_6]^{3+}$; S : $[Ti(H_2O)_6]^{3+}$
The correct order of their paramagnetic moment (spin only) is :
(1) P > Q > R > S (2) P < Q < R < S (3) P = Q = R = S (4) P > R > Q > S

Q.22 The fraction of chlorine precipitated by $AgNO_3$ solution from $[Co(NH_3)_5Cl]Cl_2$ is –
(1) 1/2 (2) 2/3 (3) 1/3 (4) 1/4

Q.23 Among TiF_6^{2-}, CoF_6^{3-}, Cu_2Cl_2 and $NiCl_4^{2-}$ the colourless species are:
(1) CoF_6^{3-} and $NiCl_4^{2-}$ (2) TiF_6^{2-} and CoF_6^{3-} (3) $NiCl_4^{2-}$ and Cu_2Cl_2 (4) TiF_6^{2-} and Cu_2Cl_2

Q.24 The IUPAC name for $[Co(NCS)(NH_3)_5]Cl_2$ is –
(1) Pentaammine (thiocyanato-N) cobalt (III) chloride
(2) Pentaammine (thiocyanato-S) cobalt (III) chloride
(3) Pentaamine (isothiocyanato-N,S) cobalt (III) chloride
(4) Pentaammine (mercapto-N) cobalt (III) chloride

Q.25 The purple colour of $[Ti(H_2O)_6]^{3+}$ in aqueous solution is due to :
(1) d-d transition of unpaired d-electron (2) charge transfer spectrum
(3) intermolecular vibration (4) polarisation of cation.

Q.26 The IUPAC name for $K_2[OsCl_5N]$ is –
(1) Potassium pentachloroazidoosmate (VIII) (2) Potassium pentachloroazidoosmate (VI)
(3) Potassium pentachloronitridoosmate (VI) (4) Potassium nitroosmate (III)

Q.27 The IUPAC name of $K_2[Cr(CN)_2O_2(O)_2(NH_3)]$ is –
(1) Potassiumamminedicyanodioxoperoxo chromate (VI)
(2) Potassiumamminecyanoperoxodioxo chromium (VI)
(3) Potassiumamminecyanoperoxodioxo chromium (III)
(4) Potassiumamminecyanoperoxodioxo chromate (IV)

Q.28 Which of the following statements is correct with respect to the crystal field theory ?
(1) It considers only the metal ion d–orbitals and gives no consideration at all to other metal orbitals.
(2) It cannot account for the π bonding in complexes.
(3) The ligands are point charges which are either ions or neutral molecules.
(4) All of these

Q.29 $[Co(en)_3]^{3+}$ ion is expected to show
(1) two optically active isomers: d and *l* forms
(2) three optically active isomers: d, *l* and meso forms
(3) four optically active isomers: cis, d and *l* isomers and trans d and *l* isomers
(4) No optical isomerism but can show cis-trans isomerism

Q.30 Which of the following complex will show optical activity ?
(1) trans -$[Co(NH_3)_4Cl_2]^+$ (2) $[Cr(H_2O)_6]^{3+}$
(3) cis -$[Co(NH_3)_2(en)_2]^{3+}$ (4) trans -$[Co(NH_3)_2(en)_2]^{3+}$

Q.31 Which of the following statements are wrong ?
(a) Al_4C_3 is an organometallic compounds
(b) Metal carbonyls are organometallic compounds
(c) TEL is π bonded organometallic compound
(d) Frankland reagent is π – bonded organometallic compound
(1) c and d (2) a and c (3) b and c (4) All are correct

Q.32 Out of the following which will not show geometrical isomerism –
(1) $[Pt(NH_3)_2(H_2O)_2]^{+2}$ (2) $[Cr(NH_3)_5Cl]Cl_2$
(3) $[Co(en)_2Cl_2]Cl$ (4) $[Co(NH_3)_4Cl_2]Cl$

Q.33 Solution of $TiCl_4$ and trialkylaluminium used as a catalyst in polymerisation of olefins is called :
(1) Wilkinson's catalyst (2) Zeigler Natta catalyst
(3) Homogeneous catalyst (4) Grignard reagent

Q.34 Which of the following is π–complex?
(1) Trimethyl aluminium (2) Ferrocene
(3) Diethyl zinc (4) Nickel carbonyl

Q.35 Which of the following is pair of ionization isomers ?
(1) $[Co(NH_3)_5Br]SO_4$ and $[Co(NH_3)_5SO_4]Br$
(2) $[Cr(H_2O)_5Cl]Cl_2.H_2O$ and $[Cr(H_2O)_4.Cl_2]Cl.2H_2O$
(3) $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$
(4) cis-$[Pt(NH_3)_2Cl_2]$ and trans-$[Pt(NH_3)_2Cl_2]$

Q.36 Which of the following is not correctly matched ?
(1) Sodium (ethylenediaminetetraacetato)chromate(II) – $Na_2[Cr(CH_3COO)_4(en)]$
(2) Dichlorobis (ethane–1, 2–diamine)cobalt(III) ion – $[Co(en)_2Cl_2]^+$
(3) Tris(bipyridine) iron(II)ion – $[Fe(NH_4C_5 – C_5H_4N)_3]^{2+}$
(4) Ammineaquadibromidocopper(II) – $[Cu(H_2O)(NH_3)Br_2]$

Q.37 Which one of the following octahedral complexes will not show geometrical isomerism (A and B are monodentate ligands) ?
(1) $[Ma_5b]$ (2) $[Ma_2b_4]$ (3) $[Ma_3b_3]$ (4) $[Ma_4b_2]$

Q.38 Which one of the following pairs of isomers and types of isomerism are correctly matched –
(a) $[Co(NH_3)_5(NO_2)]Cl_2$ and $[Co(NH_3)_5(ONO)]Cl_2$.... Linkage
(b) $[Cu(NH_3)_4](PtCl_4)]$ and $[Pt(NH_3)_4][CuCl_4]$.....co-ordination
(c) $[Pt(NH_3)_4Cl_2)]Br_2$ and $[Pt(NH_3)_4Br_2)]Cl_2$.....Ionization
Select the correct answer using the codes given below –
(1) b and c (2) a, b and c (3) a and c (4) a and b

Q.39 In metal carbonyls, there is –
(1) No π bond between CO and metal atom
(2) Only σ bond between metal atom and CO molecules
(3) One σ and one π bond (back-donation) between metal atom and CO molecules
(4) The metal-carbon bonds does not exist at all

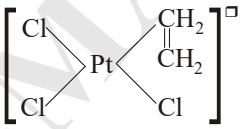
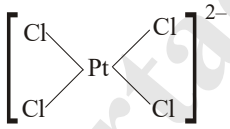
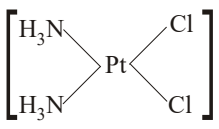
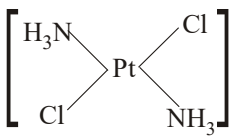
Q.40 Haemoglobin and chlorophyll are coordination compounds in which the central metal atoms are respectively:
(1) manganese and cobalt (2) potassium and platinum
(3) iron and magnesium (4) iron and palladium

Q.41 The valency of copper ion in cuprammonium ion is –
(1) + 4 (2) + 2 (3) – 2 (4) – 4

Q.42 In nitroprusside ion the iron and NO exist as Fe^{II} and NO^{+} rather than Fe^{III} and NO. These forms can be differentiated by –
(1) Estimating the concentration of iron
(2) Measuring the concentration of CN^{-}
(3) Measuring the solid state magnetic moment
(4) Thermally decomposing the compound

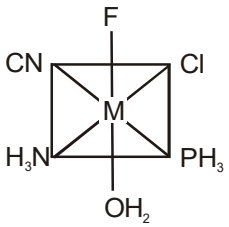
Q.43 Which of the following statements is not correct?
(1) $Ti(NO_3)_4$ is a colourless compound
(2) $[Cr(NH_3)_6)]Cl_3$ is a coloured compound
(3) $K_3[VF_6]$ is a colourless compound
(4) $[Cu(NCCH_3)_4][BF_4]$ is a colourless compound

Q.44 Which of the following is considered to be an anticancer species ?

(1) 
(2) 
(3) 
(4) 

Q.45 The total number of possible coordination isomers of the compound $[Cu^{II}(NH_3)_4]\,[Pt^{II}Cl_4]$ are:
(1) 3 (2) 5 (3) 4 (4) 6

Q.46 A complex shown below –



(1) Optical isomerism only (2) Geometrical isomerism only
(3) Both optical and geometrical isomerism (4) Linkage isomerism only

Q.47 In which of the following coordination entities, the magnitude of Δ_0 [CFSE in octahedral field] will be maximum? :
(1) $[Co(CN)_6]^{3-}$ (2) $[Co(C_2O_4)_3]^{3-}$
(3) $[Co(H_2O)_6]^{3+}$ (4) $[Co(NH_3)_6]^{3+}$

Q.48 In $Fe(CO)_5$, the Fe–C bond possesses –
(1) ionic character (2) σ-character only
(3) π-character (4) both σ and π character

Q.49 Coordination compounds have great importance in biological systems. In this contect which of the following statements is incorrect ?
(1) Cyanocobalamin is vitamin B_{12} and contains cobalt
(2) Haemoglobin is the red pigment of blood and contains iron
(3) Chlorophylls are green pigments in plants and contain calcium
(4) Carboxypeptidase-A is an enzyme and contains zinc

Q.50 It is given that a complex formed by one Ni^{2+} ion and some Cl^- ions and some PPh_3 molecules does not show geometrical isomerism and its solution does not show electrical conductance. Then which is correct about the complex :
(1) It is square planar (2) It is tetrahedral
(3) It is diamagnetic (4) none of the above is correct

Q.51 Which order is correct in spectrochemical series of ligands –
(1) $Cl^- < F^- < C_2O_4^{2-} < NO_2^- < CN^-$
(2) $CN^- < C_2O_4^{2-} < Cl^- > NO_2^- < F^-$
(3) $C_2O_4^{2-} < F^- < Cl^- > NO_2^- < CN^-$
(4) $F^- < Cl^- < NO_2^- < CN^- < C_2O_4^{2-}$

Q.52 The number of geometrical isomers for octahedral $[Co(NH_3)_2Cl_4]^-$, square planar $AuCl_2Br_2^-$ are :
(1) 2, 2 (2) 2, 2 (3) 3, 2 (4) 2, 3

Q.53 Point out the correct statements amongst the following
(1) $[Cu(CN)_4]^{3-}$ has tetrahedral geometry and dsp^2 hybridization
(2) $[Ni(CN)_6]^{4-}$ is octahedral and Ni has d^2sp^3 hybridization
(3) $[ZnBr_4]^{2-}$ is tetrahedral and diamagnetic
(4) $[Cr(NH_3)_6]^{3+}$ has octahedral geometry and sp^3d^2 hybridization

Q.54 Which of the following complex ions does not show optical activity :
(1) $[PtBrClI(NO_2)(H_2O)NH_3]$ (2) $cis[Co(en)_2Cl_2]^+$
(3) $cis[Co(en)(NH_3)_2Cl_2]^+$ (4) $[Co(NH_3)_4Cl_2]^+$

ASSERTION AND REASON

Directions : Each of these questions contains an Assertion followed by reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.

(1) If both assertion and reason are true and reason is the correct explanation of assertion.
(2) If both assertion and reason are true but reason is not the correct explanation of assertion.
(3) If Assertion is true but reason is false.
(4) If both assertion and reason are false.

Q.55 **Assertion :** Co-ordination isomerism is shown by the compounds in which both cation and anions are complexes.
Reason : Complexes containing ambidentate ligands exhibit co-ordination isomerism.

Q.56 **Assertion :** The species $[CuCl_4]^{2-}$ exists but $[CuI_4]^{2-}$ does not.
Reason : $[NiCl_2(PPh_3)_2]$ have tetrahedral geometry.

Q.57 **Assertion :** Mercury(II) tetrathiocynatocobaltate(II), a crystalline blue complex is paramagnetic in nature.
Reason : It contains three unpaired electrons.

Q.58 **Assertion :** In complex, $[Co(NH_3)_5(CO_3)]Cl$, the oxidation state of cobalt is +3.
Reason : Carbonate ligand is a monodentate bivalent anion.

PREVIOUS YEARS QUESTION

Q.1 Which one of the following complexes will have four isomers ? **[AIPMT 2000]**
(en = ethylenediamine)
(1) $[Co(en)(NH_3)_2Cl_2]Cl$ (2) $[Co(PPh_3)_2(NH_3)_2Cl_2]Cl$
(3) $[Co(en)_3]Cl_3$ (4) $[Co(en)_2Cl_2]Br$

Q.2 The correct structure of $Fe(CO)_5$ is : **[AIPMT 2000]**
(1) octahedral (2) tetrahedral (3) square pyramidal (4) trigonal bipyramidal

Q.3 Which of the following has magnesium ? **[AIPMT 2000]**
(1) Chlorophyll (2) Haemocyanin (3) Carbonic anhydrase (4) Vitamin B_{12}

Q.4 Which of the following will exhibit maximum ionic conductivity? **[AIPMT 2001]**
(1) $K_4[Fe(CN)_6]$ (2) $[Co(NH_3)_6]Cl_3$ (3) $[Cu(NH_3)_4]Cl_2$ (4) $[Ni(CO)_4]$

Q.5 Which statement is incorrect? **[AIPMT 2001]**
(1) $Ni(CO)_4$ -tetrahedral, paramagnetic (2) $[Ni(CN)_4]^{2-}$ -square planar, diamagnetic
(3) $Ni(CO)_4$- tetrahedral, diamagnetic (4) $[Ni(Cl)_4]^{2-}$ tetrahedral, paramagnetic

Q.6 Coordination number of Ni in $[Ni(C_2O_4)_3]^{4-}$ is : **[AIPMT 2001]**
(1) 3 (2) 6 (3) 4 (4) 2

Q.72 **Assertion :** $Co[Hg(SCN)_6]$ and $Hg[Co(SCN)_6]$ are isomers. **[AIIMS- 2016]**
Reason : SCN^- is a stronger ligand as compared to NCS^-
(1) If both assertion and reason are true and reason is the correct explanation of assertion
(2) If both assertion and reason are true but reason is not the correct explanation of assertion
(3) If assertion is true but reason is false
(4) If both assertion and reason are false

Q.73 An example of a sigma bonded organometallic compound is **[NEET - 2017]**
(1) Ruthenocene (2) Grignard's reagent (3) Ferrocene (4) Cobaltocene

Q.74 Correct increasing order for the wavelength of absorption in the visible region for the complexes of Co^{3+} is : **[NEET - 2017]**
(1) $[Co(en)_3]^{3+}$, $[Co(NH_3)_6]^{3+}$, $[Co(H_2O)_6]^{3+}$
(2) $[Co(H_2O)_6]^{3+}$, $[Co(en)_3]^{3+}$, $[Co(NH_3)_6]^{3+}$
(3) $[Co(H_2O)_6]^{3+}$, $[Co(NH_3)_6]^{3+}$, $[Co(en)_3]^{3+}$
(4) $[Co(NH_3)_6]^{3+}$, $[Co(en)_3]^{3+}$, $[Co(H_2O)_6]^{3+}$

Q.75 Pick out the correct statement with respect to $[Mn(CN)_6]^{3-}$: **[NEET - 2017]**
(1) It is sp^3d^2 hybridised and octahedral (2) It is sp^3d^2 hybridised an tetrahedral
(3) It is d^2sp^3 hybridised and octahedral (4) It is dsp^2 hybridised and square planar

ANSWER KEY

Q.1	4	Q.2	2	Q.3	3	Q.4	3	Q.5	1	Q.6	4	Q.7	1
Q.8	3	Q.9	3	Q.10	4	Q.11	2	Q.12	1	Q.13	4	Q.14	3
Q.15	3	Q.16	3	Q.17	1	Q.18	4	Q.19	3	Q.20	3	Q.21	1
Q.22	2	Q.23	4	Q.24	1	Q.25	1	Q.26	3	Q.27	1	Q.28	4
Q.29	1	Q.30	3	Q.31	2	Q.32	2	Q.33	2	Q.34	2	Q.35	1
Q.36	1	Q.37	1	Q.38	2	Q.39	3	Q.40	3	Q.41	2	Q.42	3
Q.43	3	Q.44	3	Q.45	3	Q.46	3	Q.47	1	Q.48	4	Q.49	3
Q.50	2	Q.51	1	Q.52	2	Q.53	3	Q.54	4	Q.55	3	Q.56	2
Q.57	1	Q.58	1										