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QUESTION PAPER

(June – 2019)

(Solved)

INORGANIC CHEMISTRY

Time: 2 Hours] *[Maximum Marks: 50*

Note: *Answer all the **five** questions. All questions carry **equal** marks.*

Q. 1. Answer all parts of the following:

***(a)* Give the systematic name and symbol of the element having atomic number 110.**

Ans. Ununnilium Uun.

***(b)* Out of C, N and O, which one has the highest first ionisation energy?**

Ans. Nitrogen (N) has the highest first ionisation energy.

***(c)* What is the largest use of hydrogen?**

Ans. The largest use of hydrogen is in the synthesis of ammonia which is used in the manufacture of mitalic acid and nitrogenenous fertilisers.

***(d)* On burning in excess of air, which one of Li, Na and K forms superoxide as the final product?**

Ans. Reactivity of metals Li, Na, K towards air increases from Li to Cs. K reacts with air producing and flame and forms superoxides as the final product K_2O.

***(e)* Which one of $BeCO^3$, $MgCO^3$and $CaCO^3$ is thermally the least stable?**

Ans. The stability of carbonates increases on moving down the group. $BeCO_3$ is thermally the least-stable.

***(f)* Write the chemical formulae of the carbides of boron and aluminium.**

Ans. Carbides of Boron-Boron Carbide B_4C carbides of Aluminium – Aluminium Carbide Al_4C_3.

***(g)* Which one of the silicon compounds is used as a thermal insulator?**

Ans. Mica and Asbestos are the silicon compounds used as a thermal insulator.

(h) Which one of the elements of Group 15 forms the largest number of oxides?

Ans. Nitrogen (N) forms the largest number of Oxides e.g., Nitrogen Oxides (N_2O), Nitric Oxide (No), Dinitrogen trioxide N_2O_3, Nitrogen NO_2, Dinitrogen tetroxide N_2O_4, Dinitrogen pentoxide N_2O_5, etc.

***(i)* Which one of the elements of Group 16 has the highest first ionisation energy?**

Ans. Oxygen (O) has the highest – first ionisation energy.

***(j)* Which one of the halogen elements is solid at room temperature?**

Ans. Iodine is solid at room temperature.

***(k)* Which one of the noble gases is the most abundant in nature?**

Ans. Argon (Ar) is the most abundant noble gas in nature.

***(l)* What is the highest oxidation state exhibited by manganese?**

Ans. The highest oxidation state of manganese is +2.

***(m)* Name any one ore of lanthanides.**

Ans. Ore of lanthaxides – Monazite.

***(n)* What is the oxidation state of cobalt in $[Co(NH_3)5NO_2]CI_2$?**

Ans. The oxidation state of cobalt in $[Co(NH_3)_5NO_2] Cl_2$ is + 3.

Q. 2. Answer the following questions:

***(a)* Describe the important features of the Long Form of the Periodic Table.**

Ans. Important features of the long form of the Periodic Table:

(i) It shows arrangement of elements based on modern periodic law.

(ii) Elements are arranged in eighteen vertical columns by keeping the elements belonging to A and B sub-groups in separate column.

(b) **Amongst the ions Na^+, Mg^{2+}, F^- and 0^{2-}, which one has the largest ionic radius and which one has the smallest ionic radius? Explain.**

Ans. O^{2-} has the largest ionic radius and Mg^{2+} has the smallest ionic radius as the more +ve the charge, the smaller the ionic radius. The number of electrons decreases by 2 in Mg^{2+} compared to neutral Mg atom, but the number of protons inside the nuclear remains the same. The effective nuclear charge hence increases causing the electrons to be pulled towards the nuclear, thus smaller ionic radius and *vice-versa*.

(c) **Explain the effect of hydrogen bonding on the boiling points of hydrides of Group 16 elements.**

Ans. Bonds between hydrogen and Group-16 atoms are covalent so the hydrides of Group 16 element are covalent molecules. Group 16 the boiling point of water (H_2O) molecule is unexpectedly high due to the stranger hydrogen bondo acting between water molecular.

(d) **How does the conductivity of aqueous solutions of alkali metal salts vary down the group? Explain.**

Ans. Ref.: See Chapter-4, Page No. 43, Q. No. 4.

(e) **How does the solubility of sulphates of alkaline earth metals in water vary down the group? Explain.**

Ans. The sulphates of alkaline earth metals are all white solides. The solubility of the sulphates in water decreases down the group i.e. Be > Mg > Ca > Sc > Ba. Thus, $BeSO_4$ and $MgSO_4$, are highly soluble, $CaSO_4$ is sparingly Soluble but the sulphates of Sr. Ba and Ra are virtually insoluble.

(f) **How do boron and aluminium react with sodium hydroxide? Write the chemical equations of the reactions.**

Ans. Boron can dissolve in NaOH to form sodium borate and hydrogen.

$$2B + 6NaOH \rightarrow 2\ Na_2\ BO_3 + 3H_2$$

Aluminium is amphoteric in nature, so it can react with both acid and base. When aluminium is reacted with NaOH, aluminium gives sodium aluminate and hydrogen gas and sodium oxide.

$$Al + 3NaOH \rightarrow NaAlO_2 + H_2 + Na_2O$$

(g) **Why is carbon dioxide a gas and silicon dioxide a solid at room temperature? Explain.**

Ans. Ref.: See Chapter-7, Page No. 70, Q. No. 5 *(iii)*.

Q. 3. Answer the following questions:

(a) **What is hydrazine? How is it prepared?**

Ans. Hydrozine is an inorganic compound with the chemical formula N_2H_4. It is a simple prictogen hydride and is a colourless and flammable liquid with an ammonia like adour Hydrozine is highly toxic and dangerously unstable unless handled in solution as e.g. hydrozine hydrate.

Preparation: It is obtained early by the action of sodium hypochloride, NaoCl, on concentrated ammonia in presence of glue.

$$NH_3 + NaoCl \rightarrow NH_2\ Cl + NaOH$$
$$NH_3 + NH_2CI \rightarrow NH_2\ NH_2 + HCI$$

or

$$2NH_3 + NaOH \rightarrow NH_2\ NH_2 + NaCI + H_2O.$$

(b) **What is the chemical formula of sodium thiosulphate and how does it react with iodine solution?**

Ans. Sodium thiosulphate – $Na_2S_2O_3.\ 5H_2O$

Sodium thiosulphate reach with iodine to produce tetrathionate sodium and sodium iodide.

$$2Na_2S_2O_3 + I_2 \rightarrow 2Na_2S_4O_6 + 2NaI$$

Sodium thiosulphate reduce iodine to iodide.

(c) **Why do noble gases form compounds only with oxygen and fluorine?**

Ans. Ref.: See Chapter-11, Page No. 116, Q. No. 4 *(ii)*.

(d) **The aqueous solutions of salts of hypohalous acids are alkaline in nature. Explain.**

Ans. Ref.: See Chapter-10, Page No. 108, Q. No. 5.

(e) **The observed magnetic moment of $[Co(H_20)_6]^2+$ ion is higher than the spin-only value. Explain.**

Ans. Ref.: See Chapter-12, Page No. 125, Q. No. 6.

(f) **What are rare-earth elements and why are they so named?**

Ans. Ref.: See Chapter-13, Page No. 133, Q. No. 2.

(g) **What is electronic isomerism? Explain with an example.**

Ans. Electronic isomerism or electromerism is a type of isomerism between a pair of molecular

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The Chapter

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INORGANIC CHEMISTRY

The Periodic Table

1

1.1 INTRODUCTION

Scientists born very beginning have attempted to systematise the knowledge they gain through their observation and experiments. Development of the periodic law and the periodic table of the elements is one such attempt. This has brought order in the study of the vast chemistry of more than a hundred elements know now. Therefore, it is quite natural to begin your study of inorganic chemistry with the study of the periodic table in this unit.

1.2 EARLIER ATTEMPTS AT CLASSIFICATION

In 1829, I.W. Dobereiner observed that there existed certain groups of three elements which he called triads. He also observed that eleon in a triad not only had similar properties but also the atomic weight of the middle element was approximately an average of the atomic weights of the other two elements of the triad. A few examples cited by him were: Li, Na, K, Ca, Sr, Te and Cl, Br, I. Although Dobereiner relationship seemed to work only for a few elements, he was the first to point out a systematic relationship among the elements.

In 1864, the English chemist John Newlands reported his 'Law of Octaves'. He suggested that if the elements be arranged in the order of increasing atomic weight, every eight element had properties similar to the first element just like every eight note resembles the first in octaves of music.

For example, he arranged the elements in the following manner:

Element	Li	Be	B	C	N	O	F
At. wt.	7	9	11	12	14	16	19
Element	Na	Mg	Al	Si	P	S	Cl
At. wt.	23	24	27	29	31	32	35.5
Element	K	Ca	Ti	Cr			
At. wt.	39	40	48	52			

Thus we see, K resembles Na and Li; Ca resembles Mg and Be; Al resembles B: Si resembles C, etc. Newland's law of octaves was rejected due to two reasons. Firstly, it did not hold good for elements heavier than Ca. Secondly, he believed that there existed some mystical connection between music and chemistry.

Mendeleev's Periodic Law

As soon as sufficiently large number of elements had been isolated and described, it was felt that there must be some order or regularity which controlled their properties. The periodic law stated by Mendeleev in 1869 was the first successful attempt in the classification of elements and their comparative study. According to this law:

The physical and chemical properties of elements are a periodic function of their atomic weights.

He arranged the elements in the order of their increasing atomic weights in the form of a Table known as Mendeleev's periodic table dividing the elements into groups and periods.

Elements in the same group had the same valency while elements in one period showed a successive decrease in the electro-negative valency and increase in electro-positive valency. The table had no zero group and there were a number of vacant places or *gaps* for the elements not known at that time. Mendeleev predicted their properties and when these elements were later on discovered, their properties remarkably agreed with the predicted ones.

The post-Mendeleev developments, however, brought out a number of defects and anomalies in the Table. The chief anomaly was the position of three pairs of elements *tellurium and iodine, argon and potassium and nickel and cobalt* which was not in accordance with their chemical behaviour. The accommodation of *rare earth* and *isotopes* on the basis of their rising atomic weights also posed a problem.

Although Newlands and Lother Meyor also contributed in developing the periodic law, the main credit goes to mendeleev because of the following reasons:

- He included, along with his table, a detailed analysis of the properties of all the known elements and correlated a broad range of physical and chemical properties with atomic weights.
- He kept his primary goal of arranging similar elements in the same group quite clearly. Therefore, he was bold enough in reversing the order of certain elements. For example, iodine with lower atomic weight than that of tellurium (Group VI was placed in Group VII along with fluorine, chlorine and bromine because of similarities in properties.
- He also correlated the atomic weights of certain elements to include them in proper groups. For example, he corrected the atomic weights of beryllium (from 13.5 to 9) and indium (from 76 to 114) without doing any actual measurements, his conjecture was proved correct as Be and In with equivalent weights of 4.5 and 3.8, respectively are actually bivalent and trivalent.

1.3 MODERN PERIODIC LAW

Most of the anomalies and defects of the Mendeleev's table disappear if the basis of classification is changed from atomic weights to atomic numbers. In the modern plan of the Mendeleev Table shown in below, the elements are arranged in the order of their increasing atomic numbers.

A study of the Table shows that leaving out the *Trans-uranium elements* described later, there are places for 92 elements, hydrogen being the lightest and uranium the last and the heaviest. There are nine vertical rows which constitute *(a) seven regular groups (Group I to Group VII) (b) one transitional group (group VIII)* and *(c) one zero group* containing the inert gases. There are seven horizontal rows which constitute the *seven periods*. The first period is of two elements. All periods start with an alkali element and end with an inert gas. The second and third are of 8 elements each (**short periods**), the fourth and fifth of 18 elements each (**long periods**), the sixth of 32 elements and the seventh of 6 elements. *Each long period* consists of two series, *first series* and *second series* and because of these two series, we get **Sub-Group A** and **Sub Group B**. The elements of Sub-Group A resemble one another but differ from the elements of Sub-Group B of the same groups, all elements of the group showing the same valency. Members of one sub-group have similar physical and chemical properties which vary gradually with increase of atomic number.

The classification based on atomic numbers has not only solved the problem of *isotopy* but that of a anomalous pairs as well for the atomic numbers of argon (18), potassium (19), cobalt (27), nickel (28) tellurium (52), and iodine (53) justify their position in the Table.

After *lanthanum* (57) are placed fourteen rare earth elements (58-71) known as *lanthanides*, very similar in properties amongst themselves. All of them are metals which are either trivalent or tetravalent in their salts. Their compounds are so closely related to one another that their separation involved tremendous difficulties. With respect to this behaviour, all of them are entitled to be placed in one and the same group. The position assigned to these in the Table does not appear to be anomalous when the matter is examined from the point of view of their electronic configuration for it is quite natural that after the element lanthanum, one should have fourteen elements to complete the $4f$-shell (which has the maximum capacity for holding 14 electrons). Since all of these members of the rare earths are characterised by +3 oxidation state (*i.e.*, positively trivalent), their structure is either $4f^n : 5s^2, 5p^6, 5d^1 ; 6s^2$ as suggested by Hund, with the valency electrons $5d^1 . 6s^2$, or more rigidly the structure $4f^m . 5s^2 . 5p^6 . 6s^2$ (the valency electrons being one from $4f$ and two from $6s^2$).

Periodic Table

Group	I A	I B	II A	II B	III A	III B	IV A	IV B	V A	V B	VI A	VI B	VII A	VII B	VIII	0
Period 1	H1 1.008												H1 1.008			He 4.003
Period 2	Li 3 6.940		Be 4 9.09		B 5 10.82		C 6 12.01		N 7 14.0		O 8 16.00		F 9 19.00			Ne 10 20.183
Period 3	Na 11 23.00		Mg 12 24.32		Al 13 26.07		Si 14 28.08		P 15 31		S 16 32.06		Cl 17 35.46			A 18 39.944
Period 4 First Series	K 19 39.10		Ca 20 40.08			Sc 21 45.10		Ti 22 47.90		V 23 50.95		Cr 24 52.01		Mn 25 54.93	Fe 26 55.84, Co 27 58.94, Ni 28 38.69	
Period 4 Second Series		Cu 29 63.57		Zn 30 66.38	Ga 31 69.72		Ge 32 72.69		As 33 74.91		Se 34 78.96		Br 35 79.92			Kr 36 83.7
Period 5 First Series	Rb 3.7 85.48		Sr 38 87.63			Y 39 88.92		Zr 40 91.22		Nb 41 92.91		Mo 42 95.95		Tc 43 97.8	Ru 44 101.7, Rh 45 102.91, Pd 46 108.7	
Period 5 Second Series		Ag 47 107.88		Cd 48 112.41	In 49 114.76		Sn 50 118.78		Sb 51 121.76		Te 52 127.61		I. 53 126.92			Xe 54 131.3
Period 6 First Series	Ca 55 132.91		Ba 56 137.36			La 57 138.92		Hf 72 178.6		Ta 73 180.88		W 74 103.92		Re 75 186.31	Os 76 190.2, Ir 77 193.1, Pt 78 195.23	
Period 6 Second Series		Au 79 197.2		Hg 80 200.62	T1 61 204.39		Pb 82 207.21		Bi 83 200.00		Po 84 210		At 85 (210)			Rn 86 222
Period 7	Fr 87		Ra 83 226.05			Ac 89 229		Th 90 232.12		Pa 91 231		U 92 8.07				

Rare Earths (Lanthanides) 58–71	Ce 58 140.13	Pr 59 140.9	Nd 63 144.7	Pm 61	Sm 62 150.4	Eu 63 152	Gd 64 156.9							
	Tb 65 159.2	Dy 66 162.45	Ho 67 163.5	Er 68 167.2	Tm 69 168.93	Yb 70 173.04	Lu 71 174.89							
**ACTINIDES	Th 90 232.13	Pa 93 231	U 92 238.05	Np 93 237	Pu 94 242	Am 95 243	Cm 96 245	Bk 97 247	Cf 96 249	Es 99 254	Fm 100 252	Md 101 256	No 102 254	Lw 103 257

Similarly after *actinium* (89), there is another group of fourteen elements very similar in their properties known as **actinides** (At. no: 90–103) in which the sub-shell 5*f* is being completed (Th $5f^0$ to *Cf* $5f^{10}$ and onwards to *Lw* $5f^{14}$).

Long Form of the Periodic Table

You have now learnt that in the modern form of Mendeleev's periodic table, elements are arranged in seven horizontal rows and eight vertical columns. Normal and transition element belonging to A and B subgroups of a group were placed in one and the same column of the table. In the long form of the periodic table given below, elements are arranged in eighteen vertical columns by keeping the elements belonging to A and B sub groups in separate column.

Originally Mendeleev gave A and B designations to the groups containing normal and transition elements respectively. However, in his periodic table, this division into A and B groups is often done arbitrarily. In different books, for the elements of III to VIII groups, this designation of A and B groups is often reserved. To avoid this controversy, International Union of Pure and Applied Chemistry (IUPAC) has adopted Arabic Numbers 1, 2, 3, ... 18 on the newest group designation in the long form of periodic table.

1.4 NOMENCLATURE OF ELEMENTS HAVING Z > 100

The IUPAC has made an official recommendation that until a new element's discovery has been proved, a systematic nomenclature be applied according to the following IUPAC nomenclature rules:

(1) The name be derived directly from the atomic member of element using the following numerical roots:

0	1	2	3	4	5	6	7	8	9
nil	un	bi	tri	quad	pent	hex	sept	oct	enn

(2) The roots be put together in the order of the digits when make the atomic number and be terminated by 'ium', and ending occuring in the names of all the metallic elements, as these are. The final 'n' of emn be dropped when it occurs before 'nil' and the final 'i' of 'bi' and 'tri' be dropped when it occurs before 'ium'.

(3) The symbol of the element be composed of the initial letters of the numerical roots which make up the name.

In given table systematic names and symbols of elements having *z* = 101 to 106 derived by IUPAC names are listed.

Atomic number	*Systematic Name*	*Symbol*	*Trivial Name*
101	unnilunium	unu	Mond elevium
102	unnilbium	unb	Nobelium
103	unniltrium	unt	Low rencium
104	unnilauadium	unq	—
105	unnilpentium	unp	—
106	unnilhexium	unh	—

1.5 ELECTRONIC CONFIGURATION OF ATOMS

In this section you will study the electronic configurations of atoms to understand the cause of periodicity in the properties of the elements. The electronic configurations of isolated atoms of elements are verified experimentally by a detailed analysis of atomic spectra which are two complex for discussion here. However, the electronic configurations of the atoms can be predicted with the help of aufbau or the building up process.

Aufbau is a German term meaning 'building up'. The principle is utilised to deduce the electronic structure of poly - electron atoms by building them up, that is by adding protons and electrons, one by one, to the hydrogen atom. It may be stated in a simple form as follows :

Electrons of a poly-electron atom occupy the energy orbitals in the order of increasing energy or decreasing stability.

In other words, we should place the electrons of a poly-electron atom in a set of orbitals formally the same as those for hydrogen in the order of decreasing stability and taking account of the exclusion principle.

Hydrogen atom in its ground state is specified as 1*s* which merely states that there is only one electron occupying 1*s* orbital. It is not necessary to specify the spin since there is one electron. In *helium*, there are two electrons and they can be specified as having quantum numbers $n = 1$, $l = 0$, $m = 0$ and spin $+\frac{1}{2}$ and $-\frac{1}{2}$. We can build up helium atom on Aufbau principle, starting from He^{2+} nucleus. On adding one electron to it, we shall have He^+ which would be similar to hydrogen atom. The electron would occupy 1*s* orbital and would have the quantum number $n = 1$, $l = 0$, $m = 0$ and $s = +\frac{1}{2}$. On adding the second electron, we have $He^+ + e = He$ and this second electron would also come to 1*s* orbital since it is the most stable orbital and while coming to it, there is no violation of the exclusion principle. It would have the quantum number $n = 1$,