UPDATED PYQ SOLUTION BOOK

NTA CSIR UGC NET/JRF

(JRF & LECTURESHIP)

CHEMICAL SCIENCE

14 YEARS(2011 - JULY 2024)

TOPIC AND SUBTOPIC WISE SORTED WITH DETAILED EXPLANATION

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P R E F A C E

The idea for a book containing detailed solutions for "**NTA UGC CSIR NET - CHEMICAL SCIENCE EXAMINATION"** arose from the students' need to plan strategy for post-graduate level Chemical Science competitive examinations, specifically the NTA CSIR - UGC NET Exam. This book may also be useful for GATE, SET, TIFR, BARC, PSC and other Ph. D. entrance exams.

This book covers over 2500 sorted and solved questions of CSIR UGC NET JRF Exam from the last 13 years (June 2011- July 2024). The question are sorted as per updated syllabus of CSIR NET Chemical Science and placed under 3 sections, namely, **1. Inorganic Chemistry, 2. Physical Chemistry, 3. Organic Chemistry**. Each Section starts with an analysis of questions asked in the exam. Each chapter has topic-wise sorted basic and applied conceptual questions, which will prove crucial for targeting NTA-CSIR-UGC Chemical Science in a systematic manner.

The answers to each question were provided using standard Chemical Science reference books and the author's best knowledge. The ultimate goal of this book is to provide the reader with a step-by-step approach to solving the challenging questions on these exams. It will also help students brainstorm, and grasp concepts for Chemical Science for acing the applied aspect of these exams. Every effort has been made to ensure that the book is error-free, but we are under no illusion. We welcome the reader's feedback, criticism, and suggestions for improving the content of this book.

A C K N O W L E D G E M E N T

First and foremost, we would like to thank the entire student population of our Institute for Advanced Studies (IFAS) for inspiring me to write this book. We would like to express our gratitude to Er. Radheshyam Choudhary and Mr. Dadasaheb Sondge for their invaluable assistance and critical suggestions in completing the work.

Our special thanks to Mr. Sohan Thakur, Ms. Harshita Soni and Mr. Hitesh Maurya, for reviewing and assisting in preparing the systematic layout; their comments were invaluable in improving the content of this book.

We also want to thank Ms Rani Mohite and Mr. Avdhoot Pasalkar for their assistance in sorting and compiling questions by chapter and section, for proofreading and verifying answers. We cannot forget to thank the entire IfAS team where we were able to further continue our teaching and especially learning the many facets of the process of building this book.

This book is the result of a collaborative effort, and it would not have been possible without the outstanding members of the IFAS publication team. During the production of this book, it was a pleasure to collaborate with many other dedicated and creative IFAS publications.

Special thanks to Mr. Vikendra Metha for turning our ideas into a beautiful cover page design and text diagram. Mr. Kuldeep Singh and his team should also be thanked for formatting and typesetting.

And finally, our humble gratitude to all who put their significant efforts and are unmentioned.

CSIR-UGC NET Cutoff for Junior Research Fellowship (JRF))

YEAR	UR (%)	EWS(%)	OBC(%)	SC(%)	ST(%)	PwD(%)
JULY 2024	55.500	47.500	47.750	36.000	30.750	25.000
DEC 2023	59.00	51.50	51.00	39.25	30.50	25.00
JUNE 2023	53.75	48.25	47.25	37.25	30.75	25.00
SEP 2022	50.75	44.25	43.50	33.50	27.50	25.00
FEB 2022	52.75	46.25	45.50	36.25	27.25	25.00
NOV 2020	50.50	44.50	43.25	33.25	25.50	25.50
DEC 2019	55.25	50.50	47.50	39.75	29.50	25.00
JUNE 2019	47.75	36.25	41.75	34.25	28.00	25.00
DEC 2018	57.75	-	49.75	40.25	30.25	26.00
JUNE 2018	48.00	-	41.00	33.50	25.25	25.00

CSIR-UGC NET Cutoff for Lectureship (LS)

YEAR	UR (%)	EWS(%)	OBC(%)	SC(%)	ST(%)	PwD(%)
JULY 2024	49.950	42.750	42.975	32.400	27.675	25.000
DEC 2023	53.10	46.35	45.90	35.325	27.45	25.00
JUNE 2023	48.375	43.425	42.525	33.525	27.675	25.00
SEP 2022	45.675	39.825	39.150	30.150	25.00	25.00
FEB 2022	47.48	41.63	40.95	32.63	25.00	25.00
NOV 2020	45.45	40.05	38.92	29.92	25.00	25.00
DEC 2019	49.73	49.73	42.75	35.78	26.55	25.00
JUNE 2019	42.98	33.00	37.58	30.83	25.20	25.00
DEC 2018	51.98	-	44.78	36.23	27.23	25.00
JUNE 2018	43.20	-	36.90	30.15	25.00	25.00

CSIR-UGC National Eligibility Test (NET) for Junior Research Fellowship and Lecturer-ship

CHEMICAL SCIENCES

Inorganic Chemistry

1. Chemical periodicity
2. Structure and bonding in homo- and hetero nuclear molecules, including shapes of molecules (VSEPR Theory).
3. Concepts of acids and bases, Hard-Soft acid base concept, Non-aqueous solvents.
4. Main group elements and their compounds: Allotropy, synthesis, structure and bonding, industrial importance of the compounds.
5. Transition elements and coordination compounds: structure, bonding theories, spectral and magnetic properties, reaction mechanisms.
6. Inner transition elements: spectral and magnetic properties, redox chemistry, analytical applications.
7. Organometallic compounds: synthesis, bonding and structure, and reactivity. Organometallics in homogeneous catalysis.
8. Cages and metal clusters.
9. Analytical chemistry- separation, spectroscopic, electro- and thermoanalytical methods.
10. Bioinorganic chemistry: photosystems, porphyrins, metalloenzymes, oxygen transport, electron-transfer reactions; nitrogen fixation, metal complexes in medicine.
11. Characterisation of inorganic compounds by IR, Raman, NMR, EPR, Mössbauer, UV-vis, NQR, MS, electron spectroscopy and microscopic techniques.
12. Nuclear chemistry: nuclear reactions, fission and fusion, radio-analytical techniques and activation analysis.

Physical Chemistry

1. Basic principles of quantum mechanics: Postulates; operator algebra; exactly- solvable systems: particle-in-a-box, harmonic oscillator and the hydrogen atom, including shapes of atomic orbitals; orbital and spin angular momenta; tunneling.
2. Approximate methods of quantum mechanics: Variational principle; perturbation theory up to second order in energy; applications.
3. Atomic structure and spectroscopy; term symbols; many-electron systems and antisymmetry principle.
4. Chemical bonding in diatomics; elementary concepts of MO and VB theories; Huckel theory for conjugated π-electron systems.
5. Chemical applications of group theory; symmetry elements; point groups; character tables; selection rules.

6. Molecular spectroscopy: Rotational and vibrational spectra of diatomic molecules; electronic spectra; IR and Raman activities – selection rules; basic principles of magnetic resonance.
7. Chemical thermodynamics: Laws, state and path functions and their applications; thermodynamic description of various types of processes; Maxwell's relations; spontaneity and equilibria; temperature and pressure dependence of thermodynamic quantities; Le Chatelier principle; elementary description of phase transitions; phase equilibria and phase rule; thermodynamics of ideal and non-ideal gases, and solutions.
8. Statistical thermodynamics: Boltzmann distribution; kinetic theory of gases; partition functions and their relation to thermodynamic quantities – calculations for model systems.
9. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Debye- Huckel theory; electrolytic conductance – Kohlrausch's law and its applications; ionic equilibria; conductometric and potentiometric titrations.
10. Chemical kinetics: Empirical rate laws and temperature dependence; complex reactions; steady state approximation; determination of reaction mechanisms; collision and transition state theories of rate constants; unimolecular reactions; enzyme kinetics; salt effects; homogeneous catalysis; photochemical reactions.
11. Colloids and surfaces: Stability and properties of colloids; isotherms and surface area; heterogeneous catalysis.
12. Solid state: Crystal structures; Bragg's law and applications; band structure of solids.
13. Polymer chemistry: Molar masses; kinetics of polymerization.
14. Data analysis: Mean and standard deviation; absolute and relative errors; linear regression; covariance and correlation coefficient.

Organic Chemistry

1. IUPAC nomenclature of organic molecules including regio- and stereoisomers.
2. Principles of stereochemistry: Configurational and conformational isomerism in acyclic and cyclic compounds; stereogenicity, stereoselectivity, enantioselectivity, diastereoselectivity and asymmetric induction.
3. Aromaticity: Benzenoid and non-benzenoid compounds – generation and reactions.
4. Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes.
5. Organic reaction mechanisms involving addition, elimination and substitution reactions with electrophilic, nucleophilic or radical species. Determination of reaction pathways.
6. Common named reactions and rearrangements – applications in organic synthesis.
7. Organic transformations and reagents: Functional group interconversion including oxidations and reductions; common catalysts and reagents (organic, inorganic, organometallic and enzymatic). Chemo, regio and stereoselective transformations.

8. Concepts in organic synthesis: Retrosynthesis, disconnection, synthons, linear and convergent synthesis, umpolung of reactivity and protecting groups.
9. Asymmetric synthesis: Chiral auxiliaries, methods of asymmetric induction – substrate, reagent and catalyst controlled reactions; determination of enantiomeric and diastereomeric excess; enantio-discrimination. Resolution – optical and kinetic.
10. Pericyclic reactions – electrocyclisation, cycloaddition, sigmatropic rearrangements and other related concerted reactions. Principles and applications of photochemical reactions in organic chemistry.
11. Synthesis and reactivity of common heterocyclic compounds containing one or two heteroatoms (O, N, S).
12. Chemistry of natural products: Carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids. Biogenesis of terpenoids and alkaloids.
13. Structure determination of organic compounds by IR, UV-Vis, 1H& 13C NMR and Mass spectroscopic techniques.

Interdisciplinary Topics

1. Chemistry in nanoscience and technology.
2. Catalysis and green chemistry.
3. Medicinal chemistry.
4. Supramolecular chemistry.
5. Environmental chemistry.

I N D E X

CSIR NET PYQs – INORGANIC CHEMISTRY		
CHAPTER NO.	**CHAPTER NAME**	**PAGE NO.**
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CSIR NET PYQs – ORGANIC CHEMISTRY		
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10	Structure Determination of Organic Compounds	**693**

SECTION - I

"INORGANIC CHEMISTRY"

NUMBER OF QUESTIONS ASKED IN CSIR UGC NET JRF (JUNE 2011- JULY 2024)

	Jul-24	Dec. 2023		Jun. 2023		Sep. 2022		Feb. 2022		Nov. 2020		Dec. 2019		June 2019		Dec. 2018		June 2018		Dec. 2017		June 2017		Dec. 2016		June 2016	
INORGANIC CHEMISTRY		B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks
Atomic Structure and Periodicity	0	4	0	2	4	0	4	2	0	4	4	0	0	0	0	0	0	6	8	2	4	0	0	0	0	0	0
Chemical Bonding	5	2	0	4	4	2	4	6	0	2	12	4	4	2	8	10	4	6	4	8	4	2	0	2	8	4	12
Acids and Bases	1	0	0	0	0	0	4	2	4	0	0	2	4	0	0	2	0	0	4	0	4	2	4	2	4	0	4
Main Group Elements	6	2	12	4	12	6	20	4	12	0	8	2	12	6	16	0	16	0	8	0	8	2	4	0	8	2	4
Coordination Compounds	7	8	4	2	16	2	20	8	16	8	16	4	24	4	20	6	12	6	12	4	12	8	16	8	20	2	16
Inner Transition Metal	1	6	8	4	8	2	0	2	0	2	4	2	0	2	0	0	4	2	4	2	8	2	0	2	0	2	0
Organometallic Compounds	10	2	20	2	16	6	12	4	20	2	28	2	16	6	16	2	28	4	32	0	20	4	16	4	32	8	24
Bioinorganic Chemistry	3	2	4	2	8	2	4	0	12	4	4	2	4	2	8	2	4	2	4	2	8	4	8	4	12	4	8
Nuclear Chemistry	1	0	4	2	4	2	0	2	0	2	0	2	0	0	8	0	4	0	4	2	0	2	8	2	0	2	4
Analytical Chemistry	1	2	0	2	4	0	4	0	4	2	4	2	8	4	4	2	4	0	4	2	8	2	4	4	8	6	4
Inorganic Spectra	6	2	8	2	4	0	4	0	8	0	0	0	4	0	0	0	4	0	4			0	8	4	8	2	24

	Dec. 2015		June 2015		Dec. 2014		June 2014		Dec. 2013		June 2013		Dec. 2012		June 2012		Dec. 2011		June 2011	
	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks	B 2 Marks	C 4 Marks
Atomic Structure and Periodicity	2	0	2	0	4	0	0	8	0	0	2	0	2	0	2	0	0	0	0	0
Chemical Bonding	2	4	0	4	0	4	4	0	12	4	0	4	4	0	4	4	4	8	6	12
Acids and Bases	0	0	0	4	4	0	0	0	2	0	0	4	2	4	2	4	0	0	0	0
Main Group Elements	10	12	6	16	0	20	0	8	2	32	6	4	0	12	2	16	8	8	0	12
Coordination Compounds	8	20	4	16	8	24	8	24	4	20	6	28	8	16	10	12	6	20	10	20
Inner Transition Metal	2	4	0	4	0	0	0	4	0	4	0	8	0	4	0	8	0	8	0	4
Organometallic Compounds	4	32	8	24	10	16	6	12	6	20	8	16	8	24	4	8	4	16	6	16
Bioinorganic Chemistry	4	4	4	4	6	8	4	12	4	4	4	4	2	12	2	8	2	12	2	4
Nuclear Chemistry	0	4	2	0	0	0	2	8	2	0	2	0	0	0	2	4	0	4	2	4
Analytical Chemistry	4	8	2	8	4	16	6	8	2	12	0	0	2	8	2	12	6	0	2	8
Inorganic Spectra	0	8	4	8	0	4	4	0	0	4	2	0	4	12	0	16	2	8	2	16

CHEMICAL PERIODICITY

Previous Year Exam Question & Solutions

MULTIPLE CHOICE QUESTIONS

[CSIR NET 2011]

1. In the molecules H_2O, NH_3 and CH_4.
   (1) The bond angles are same
   (2) The bond distances are same.
   (3) The hybridizations are same
   (4) The shapes are same.

[CSIR NET 2011]

2. The highest occupied MO in N_2 and O_2^+ respectively are (take x-axis as internuclear axis)
   (1) $\sigma 2p_x, \pi^* 2p_y$ (2) $\pi 2p_y, \pi 2p_z$
   (3) $\sigma^* 2p_x, \sigma 2p_x$ (4) $\pi^* 2p_y, \pi^* 2p_z$

[CSIR NET 2011]

3. The number of antibonding electrons in NO and CO according to MO theory are respectively.
   (1) 1, 0 (2) 2, 2
   (3) 3, 2 (4) 2, 3

CSIR NET 2012]

4. The decreasing order of dipole moment of molecules is
   (1) $NF_3 > NH_3 > H_2O$ (2) $NH_3 > NF_2 > H_2O$
   (3) $H_2O > NH_3 > NF_3$ (4) $H_2O > NF_3 > NH_3$

[CSIR NET 2013]

5. The reason for the chemical inertness of gaseous nitrogen at room temperature is best given by its
   (1) high bonding energy only
   (2) electronic configuration
   (3) HOMO-LUMO gap only
   (4) high bond energy and HOMO-LUMO gap

[CSIR NET 2013]

6. The orbital with two radial and two angular nodes is
   (1) 3p (2) 5d
   (3) 5f (4) 8d

[CSIR NET 2013]

7. If a homonuclear diatomic molecule is oriented along the Z-axis, the molecular orbital formed by linear combination of p, orbitals of the two atoms is
   (1) σ (2) σ^*
   (3) π (4) δ

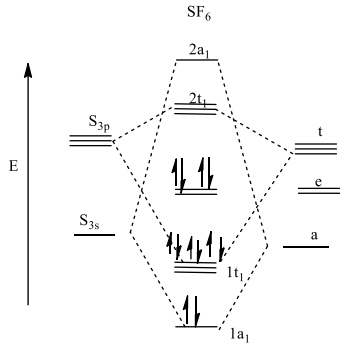
[CSIR NET 2013]

8. The molecule in which the bond order increases upon addition of an electron is
   (1) O_2 (2) B_2
   (3) P_2 (4) N_2

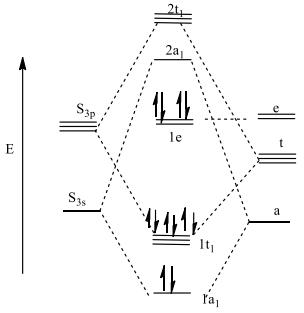
[CSIR NET 2014]

9. The correct schematic molecular energy diagram for SF_6 molecule is

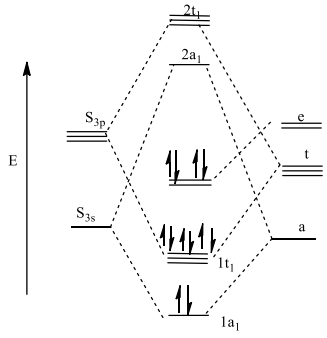
(1)



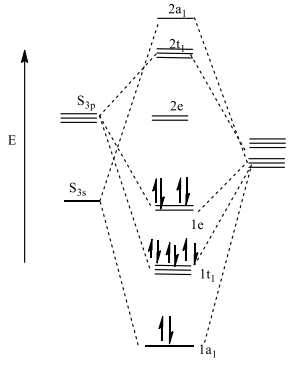
(2)



(3)



(4)



[CSIR NET 2016]

10. Correct combination for π and π^* orbitals in B_2 molecule is

π	π^*
(1) Gerade	Ungerade
(2) Ungerade	Gerade
(3) Gerade	Gerade
(4) Ungerade	Ungerade

[CSIR NET 2016]

11. The HOMO (highest occupied molecular orbital) to LUMO (lowest unoccupied molecular orbital) electronic transition responsible for the observed colours of halogen molecules (gas) is:
(1) π* -> σ* (2) π -> π*
(3) σ -> σ* (4) π -> σ*

[CSIR NET 2016]

12. The expected number of 19F NMR spectral lines, including satellites, for [XeF5]- is [Abundance of 129Xe(I = 1/2) = 26%]
(1) two (2) twenty one
(3) three (4) one

[CSIR NET 2016]

13. The expected H-H-H bond angle in [H3]+ is :
(1) 180^0 (2) 120^0
(3) 60^0 (4) 90^0

[CSIR NET DEC. 2017]

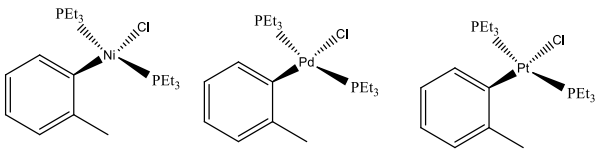
14. The first ionization energy is the lowest for
(1) Br (2) Se
(3) P (4) As

[CSIR NET NOV. 2020]

15. Correct statement/s among the following with respect to ionization energy (IE) is/are
(i) (IE_1 + IE_2 + IE_3) for indium is more than that of aluminium
(ii) IE_1 of scandium is higher than that of cobalt
(iii) IE_1 of gallium is lower than that of selenium
(iv) IE_1 of nitrogen is greater than that of oxygen
(1) (ii) and (iv) (2) (iii) and (iv)
(3) (i) and (iv) (4) (ii) and (iii)

[CSIR NET NOV. 2020]

16. The order of rate of substitution of chloride by pyridine (in ethanol) in the following complexes



is
(1) I > II > III (2) I = II = III
(3) I > II = III (4) I < II = III

[CSIR NET JUNE 2021]

17. The correct order of the electron affinity for one-electron gain of the elements is
(1) F > Cl > Br (2) P > N > As
(3) S > Se > O (4) K > Li > Na

[CSIR NET JUNE 2021]

18. The ionization Energies (IE_1 *to* IE_5) of 's' and 'p' block element are given below.

	IE_1 $(KJ\ mol^{-1})$	IE_2 $(KJ\ mol^{-1})$	IE_3 $(KJ\ mol^{-1})$
X	1086	2353	4620
Y	800	2427	3060
Z	496	4562	6910
	IE_4 $(KJ\ mol^{-1})$	IE_5 $(KJ\ mol^{-1})$	
X	6223	37830	
Y	25030	32830	
Z	9543	13350	

The Number of valence electrons in X, Y, Z are –
(1) $x = 2, y = 3, z = 4$ (2) $x = 4, y = 1, z = 1$
(3) $x = 4, y = 3, z = 1$ (4) $x = 1, y = 3, z = 4$

[CSIR NET JUNE 2023]

19. The correct order of second ionization enthalpies, is
(1) B > C > N > Be (2) N > C > Be > B
(3) B > N > C > Be (4) N > B > C > Be

[CSIR NET JUNE 2023]

20. For the Eu^{3+} ion (At No: 63),
A. the calculated and the observed magnetic moments are in agreement with each other.
B. the higher energy states $^7F_1$ and $^7F_2$ are populated and increase the observed magnetic moment.
C. the $4f$ orbital is more than half-filled.
D. the ground state term symbol is $^7F_0$
Of the above, the correct statements are
(1) A and D only (2) A and B only
(3) C and D only (4) B and D only

[CSIR NET DEC 2023]

21. The number of unpaired electrons in B_2 is
(1) 0 (2) 1
(3) 2 (4) 3

[CSIR NET DEC 2023]

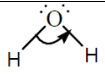
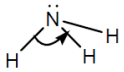
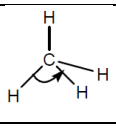
22. The difference in the second ionization energies of Li/Na, Be/Mg, B/AI and N/P are X_1, X_2, X_3 and X_4, respectively. The correct order of the difference in the second ionization energies is
(1) $X_1 > X_4 > X_3 > X_2$ (2) $X_1 > X_2 > X_3 > X_4$
(3) $X_4 > X_3 > X_1 > X_2$ (4) $X_1 > X_3 > X_4 > X_2$

ANSWER KEY									
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
3	1	1	3	4	2	3	2	1	2
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	3	3	2	2	1	3	4	4	4
21	**22**								
3	1								

:: SOLUTIONS ::

MULTIPLE CHOICE QUESTIONS

1. **Solution:** According to VSEPR theory, the three molecules can be studied as follows:

Property / Molecule	**H_2O**	**NH_3**	**CH_4**
Hybridization	sp^3	sp^3	sp^3
Geometry	Tetrahedral	Tetrahedral	Tetrahedral
Shape	Bent or Angular	Trigonal Pyramidal	Tetrahedral
Bond angle	104.5^0	107^0	109.5^0
Structure			
Bond length order	O–H < N–H < C–H		

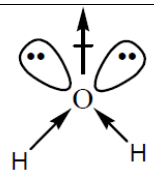
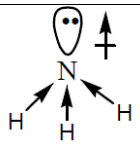
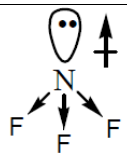
2. **Solution:** Correct Answer is 1.
Considering X axis as a internuclear axis:

For N_2 molecule	$\sigma_{1s}^2\ \sigma^*_{1s}{}^2\ \sigma_{2s}^2\ \sigma^*_{2s}{}^2\ \pi_{2px}^2\ \pi_{2py}^2\ \sigma_{2pz}^2$
For O_2 molecule	$\sigma_{1s}^2\ \sigma^*_{1s}{}^2\ \sigma_{2s}^2\ \sigma^*_{2s}{}^2\ \pi_{2px}^2\ \pi_{2py}^2\ \sigma_{2pz}^2\ \pi^*_{2py}{}^1\ \pi^*_{2py}{}^1$

3. **Solution:** Correct Answer is 1.
Consider the electronic configurations of the following molecules:

For NO molecule	$\sigma_{1s}^2\sigma_{1s}^{*2}\sigma_{2s}^2\sigma_{2s}^{*2}\pi_{2px}^2$ $\pi_{2py}^2\sigma_{2pz}^2\sigma_{2px}^{*1}$	Electrons in the MO =1
For CO molecule	$\sigma_{1nb}^2\sigma_2^2\pi_1^2 = \pi_2^2\sigma_{3nb}^2$	Electrons in the MO =0

4. **Solution:** Correct Answer is 4.
The order of dipole moment is H2O > NH3 > NF3.
Comparison of the dipole moments can be shown as follows:

		
More electronegativity difference between O and H	Less electronegativity difference between N and H	E.N. of F is greater than that of N

5. **Solution:** Correct Answer is 4.
Gasses nitrogen is chemically inert at room temperature because of its high bond energy resulting from a strong triple bond between nitrogen atoms and a large HOMO-LUMO gap, which creates an energy barrier hindering chemical reactions. This combination of factor makes nitrogen unreactive under standard conditions.

6. **Solution:** Correct Answer is 2.
5d (Principal quantum number n=5, azimuthal quantum number l=2).
Radial nodes: 5−2−1=2
Angular nodes: l=2

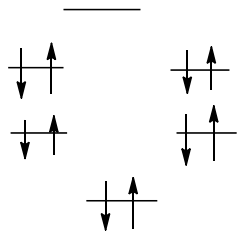
7. **Solution:** Correct Answer is 3.
If a homonuclear diatomic molecule is oriented along the Z-axis, the molecular orbital formed by the linear combination of px and py orbitals of the two atoms will result in a π (pi) bond, since these orbitals overlap laterally (sideways) rather than along the internuclear axis.
Therefore, the correct answer is (3) π.

8. **Solution:** Correct Answer is 2.
When electron added in bonding then bond order is increases and when added in antibonding then bond order decreases.

9. **Solution:** Correct Answer is 1.
SF6 is molecule with six fluorine atoms surrounded one sulfur atom. The molecular energy levels of the electrons in the molecule.
In the ground state all the electrons are at their lowest energy levels. The sulfur atom has 3d orbitals that are empty followed by 4s and 4p orbitals. The fluorine atoms have 2p orbitals that are half- filled with one electron each and three 2p orbitals are empty.

10. **Solution:** Correct Answer is 2.
In molecular orbital theory, π orbital are formed by the overlap of atomic orbitals are formed by the overlap of atomic p orbitals in a side to side manner while π^* orbital are antibonding orbitals resulting from the destructive interference of these p orbitals. In the case of B2 the combination of π orbitals result in an ungerade symmetry and the combination π^* orbitals results on a gerade symmetry.

11. **Solution:** Correct Answer is 1.
The origin of the colour of the halogens stems from the excitation between the highest occupied Π^* MO and the lowest unoccupied σ^* MO. The energy gap between the HOMO and LUMO decreases according to $F_2 > Cl_2 > Br_2 > I_2$.



12. **Solution:** Correct Answer is 3.
Molecule:- $[XeF_5]^-$
$Xe_{\times}$
SP^3d^2 (5 Bond + 2 Lone pair) pentagonal planar structure

X-F

X-F

X-F

X-F

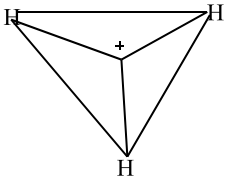
X-F

X ⎤ lone pair
X ⎦

X ⎤ lone pair
X ⎦

All fluorine are in same environment so one peak
And 75% Xe are NMR inactive hence a singlet of five fluorine and due to 26% nuclei a doublet of satellite
Hence total number of signal is = 3

13. **Solutions:** Correct Answer is 3.

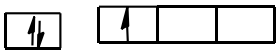


H_3^+ is expected to be triangular.
Function of H−H−H angle and the most stable is when this angle is 60^0

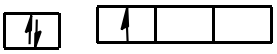
14. **Solution:** Correct Answer is 2.
→ general periodic trends.
→ Left to Right first ionisation Enthalpy increases.
→ Top to bottom decreases.
SO lowest first ionization energy is se.

15. **Solution:** Correct Answer is 2.
Ionization Energy
Energy required to removal of electron in outermost sell.
→ Increased Shielding Effect by inner electron and increased distance between the Nucleolus and the outer elements.
Much larger decreases in ionization energy occurs at the start of the next major quantum number requires that the new's' Electron have a much higher Energy
→ The maxima at the noble gases decrease with increasing Z because the outer electrons are Farther from Nucleus in the heavier elements.
→ Overall trends are toward higher ionization energy from left to right in periodic table and lower ionization energy from top to bottom.
→ In

In
[Kr] $4d^{10}\ 5s^2\ 5p^1$



Al
[Ne] $3s^2\ 3p^1$



→ after 1st ionisation Al aquire stable configuration and very close to Nucleus than In so second or third ionisation Energy Aluminium is greater than indium.
→ Higher Energy left to right in periodic table
$So \rightarrow CO > SC.$

16. **Solution:** Correct Answer is 1.
If principal quantum number increases. Metal ligand interaction also increases. So required high energy to substitution.
Hence order of rate of substitution $Ni > pd > pt$.
So option 1 is correct.

17. **Solution:** Correct Answer is 3.
Electron Affinity:-
Electron affinity can be defined as the energy required to remove an electron from a negative ion
$A_{(g)}^- \longrightarrow A_{(g)} + e^{\ominus}$
This reaction is endothermic (positive AU)
→ Elect gain Affinity (Negative ΔU)
→ in N, O, X Family 3d > 2nd period.

18. **Solution:** Correct Answer is 4.

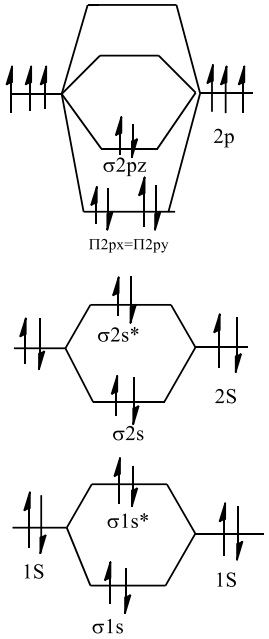
1) bond order.

→ bond order count by using MOT.

→ Bond order $= \frac{Number\ of\ bonding\ Ele^{-} - Number\ of\ anti\ .e^{\ominus}}{2}$

N_2

$N = 15^2 25^2 2p^3$



Bond order $= \frac{Bording\ e^{\ominus} - Antibonding\ e^{\ominus}}{2}$

$= \frac{10-4}{2} = 3$

Bond order of $N_2 = 3$

Similarly

$C_2 = 2$

$B_2 = 1$

$Li_2 = 0.5$

So correct order $= N_2 > C_2 > B_2 > Li_2$

2. Melting point: -

The melting point is usually defined as the point at which materials changes from solid to liquid.

$NH_3 > PH_3 > ASH_3 > SbH_3$

3. Electronegativity: -

Electronegativity provides a guide to the chemical behaviour of the main group elements. The extremely high electronegativity of fluorine and the Noble gases helium and Neon are evident with a steady decline in Electronegativity toward the left and the bottom of periodic table.

So correct order: - $S > P > Si > Al.$

4. First ionization Energy: -

Ionization Energy or Ionization potential is the energy required to remove an electron from a gaseous or ion.

Z- effect increases →

Li	Be	B	C
$2s^1$	$2s^2$	$2s^2 2p^1$	$2s^2 2p^2$

→ Z-Effect increases required more ionization Energy.

→ The general trand across the period is an increase in ionization Energy as the Nuclear charge Increases. Brick the trained in second period at Boron and again oxygen.

→ Because boron is the first atom to have an Electron in a higher Energy 2p orbital that is shielded.

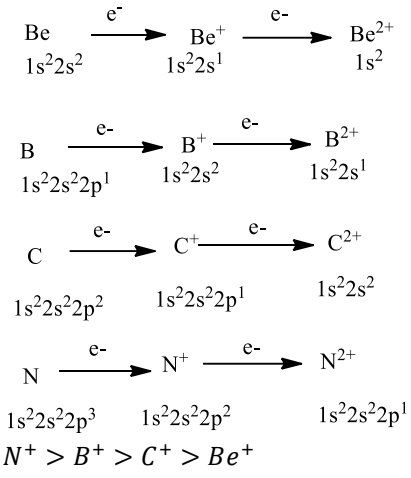
Somewhat by the 2s Electrons.

→ Boron is 2p electrons of beryllium Boron has the lowest Ionization Energy than Beryllium.

Order: - $C > Be > B > Li$

Hence option 4 is correct.

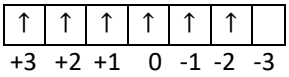
19. **Solution:** Correct Answer is 4.



$N^+ > B^+ > C^+ > Be^+$

20. **Solution:** Correct Answer is 4.

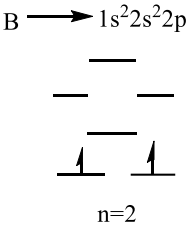
$Eu^{+3}\ electron\ configuration\ 4f^6$



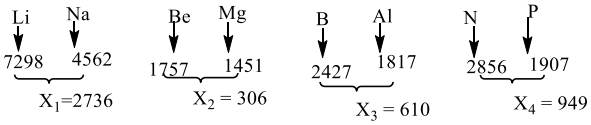
The electronic configuration is less the half filled

The ground state term symbol is $^7F_0$ the higher energy states $^7F_1$ and $^7F_2$ are populated and increase the observed magnetic moment.

21. **Solution:** Correct Answer is 3.



22. **Solution:** Correct answer is 1



Z_{effect} increase, I.E increases.

$X_1 > X_4 > X_3 > X_2$

STRUCTURE AND BONDING

Previous Year Exam Question & Solutions

MULTIPLE CHOICE QUESTIONS

[CSIR NET JUNE 2011]

1. Among SF_4, BF_4^- XeF_4 and ICI_4^- the number of species having two lone pair of electrons on the central atom according to VSEPR theory is:
   (1) 2 (2) 3
   (3) 4 (4) 0

[CSIR NET JUNE 2011]

2. The term symbol of a molecule with electronic configuration $(1\sigma_g)^2$, $(1\sigma_u)^2$, $(2\sigma_g)^2$, $(2\sigma_u)^2$, $(1\pi_u)^1$, $(1\pi_u)^1$
   (1) $^1\sum_g^+$ (2) $^3\sum_g^-$
   (3) $^1\sum_g^-$ (4) $^3\sum_g^+$

[CSIR NET JUNE 2011]

3. According to VSEPR theory, the molecule/ion having ideal tetrahedral shape is:
   (1) SF_4 (2) so_4^{2-}
   (3) S_2Cl_2 (4) so_2Cl_2

[CSIR NET JUNE 2011]

4. The molecule with highest number of lone-pairs and has a linear shape based on VSEPR theory is:
   (1) CO_2 (2) I_3^-
   (3) NO_2 (4) NO_2^+

[CSIR NET JUNE 2011]

5. Among the following pairs, those in which both species have similar structures are:
   A. N_3^-, XeF_2; B. $[ICl_4]^-, [PtCl_4]^{2-}$; C. $[ClF_2]^+, [ICl_2]^-$; D. XeO_3, SO_3
   (1) A and B only (2) A and C only
   (3) A, B and C only (4) B, C and D only

[CSIR NET JUNE 2011]

6. Match list I (compounds) with list II (structures), and select the correct answer using the codes given below.

List-I	List-II
(A) XeO_4	(i) square planar
(B) BrF_4^-	(ii) tetrahedral
(C) $SeCl_4$	(iii) distorted tetrahedral

   (1) (A-ii) (B-iii) (C-i) (2) (A-iii) (B-i) (C-ii)
   (3) (A-ii) (B-i) (C-iii) (4) (A-i) (B-ii) (C-iii)

[CSIR NET JUNE 2012]

7. The total number of lone pairs of electrons in I_3^-, is:
   (1) Zero (2) Three
   (3) Six (4) Nine

[CSIR NET JUNE 2012]

8. Which ones among CO_3^{2-}, SO_3, XeO_3, and NO_3^- have planar structure?
   (1) CO_3^{2-}, SO_3, and XeO_3 (2) SO_3, XeO_3, and NO_3^-
   (3) CO_3^{2-}, XeO_3, and NO_3^- (4) CO_3^{2-}, SO_3, and NO_3^-

[CSIR NET JUNE 2013]

9. According to VSEPR theory, the geometry (with lone pair) around the central iodine in I_3^+ and I_3^- ions respectively are
   (1) tetrahedral and tetrahedral
   (2) trigonal bipyramidal and trigonal bipyramidal
   (3) tetrahedral and trigonal bipyramidal
   (4) tetrahedral and octahedral

[CSIR NET JUNE 2013]

10. The number of lone-pairs are identical in the pairs:
    (1) XeF_4, ClF_3 (2) XeO_4, ICl_4^-
    (3) XeO_2F_2, ICl_4^- (4) XeO_4, ClF_3

[CSIR NET JUNE 2014]

11. The correct non-linear and iso-structural pair is
    (1) SCl_2 and I_3^- (2) SCl_2 and I_3^+
    (3) SCl_2 and ClF_2^- (4) I_3^+ and ClF_2^-

[CSIR NET JUNE 2014]

12. Structures of $SbPh_5$ and PPh_5 respectively are
    (1) Trigonal bipyramidal, square pyramidal
    (2) Trigonal bipyramidal, trigonal bipyramidal
    (3) Square pyramidal, trigonal bipyramidal
    (4) Square pyramidal, square pyramidal

[CSIR NET JUNE 2014]

13. The low temperature $(-98°C)$ ^{19}F NMR spectrum of SF_4 shows doublet of triplets. It is consistent with the point group symmetry.
    (1) C_{3v} (2) C_{4v}
    (3) T_d (4) C_{2v}

[CSIR NET JUNE 2015]

14. The geometries of $[Br_3]^+$ and $[I_5]^+$, respectively, are
    (1) trigonal and tetrahedral
    (2) tetrahedral and trigonal bipyramidal
    (3) tetrahedral and tetrahedral
    (4) linear and trigonal pyramidal

[CSIR NET DEC. 2015]

15. The structures of XeF_2 and XeO_2F_2 respectively are
(1) bent, tetrahedral (2) linear, square planar
(3) linear, see-saw (4) bent, see-saw

[CSIR NET DEC. 2015]

16. The number of lone pair(s) of electrons on the central atom in $[BrF_4]^-$, XeF_6 and $[SbCl_6]^{3-}$ are, respectively,
(1) 2, 0 and 1 (2) 1, 0 and 0
(3) 2, 1 and 1 (4) 2, 1 and 0

[CSIR NET JUNE 2016]

17. The correct shape of $[TeF_5]^-$ ion on the basis of VSEPR theory is
(1) Trigonal bipyramidal (2) Square pyramidal
(3) Pentagonal planar (4) See-saw

[CSIR NET JUNE 2017]

18. Based on VSEPR theory, the predicted shapes of $[XeF_5]^-$ and BrF_5, respectively, are
(1) pentagonal planar and square pyramidal
(2) square pyramidal and trigonal bipyramidal
(3) trigonal bipyramidal and square pyramidal
(4) square pyramidal and pentagonal planar

[CSIR NET JUNE 2017]

19. Among ClO_3^- XeO_3 and SO_3, species with pyramidal shape is/are?
(1) ClO_3^- and XeO_3 (2) XeO_3 and SO_3
(3) ClO_3^- and SO_3 (4) SO_3

[CSIR NET JUNE 2017]

20. Geometries of SNF_3 and XeF_2O_2, respectively, are
(1) square planar and square planar
(2) tetrahedral and tetrahedral
(3) square planar and trigonal bipyramidal
(4) tetrahedral and trigonal bipyramidal

[CSIR NET JUNE 2017]

21. According to Bent's rule, for *p*-block elements, the correct combination of geometry around the central atom and position of more electro- negative substituentis
(1) Trigonal bipyramidal and axial
(2) Trigonal bipyramidal and equatorial
(3) Square pyramidal and axial
(4) Square pyramidal and basal

[CSIR NET DEC. 2018]

22. The characters of LUMO of CN^- and O_2 respectively, are:
(1) σ_g and π_u (2) π_u and σ_u
(3) π_g and σ_u (4) σ_u and π_g

[CSIR NET DEC. 2018]

23. In compound $N_3P_3F_6$, the geometry around nitrogen and phosphorus, respectively, are:
(1) pyramidal and tetrahedral
(2) planar and tetrahedral
(3) pyramidal and planar
(4) planar and trigonal bipyramidal

[CSIR NET JUNE 2019]

24. O_2^- is
(1) having a shorter $O-O$ bond length than that in O_2
(2) a stronger oxidizing agent than O_2
(3) IR active
(4) unable to abstract proton from weak acids

[CSIR NET JUNE 2019]

25. Match the appropriate geometry on the right with each of the species on the left:

(A) $FXeO(OSO_2F)$	(i) linear
(B) $FXeN(SO_2F)_2$	(ii) pyramidal
(C) XeO_3	(iii) T-shaped
(D) $XeOF_2$	(iv) bent

(1) (A)-(i), (B)-(i), (C)-(ii), (D)-(iii)
(2) (A)-(i), (B)-(i), (C)-(ii), (D)-(iv)
(3) (A)-(iv), (B)-(i), (C)-(ii), (D)-(iii)
(4) (A)-(i), (B)-(iv), (C)-(ii), (D)-(iii)

[CSIR NET JUNE 2019]

26. Among the following, the correct statement about π-molecular orbitals $(\pi - MOs)$ of benzene is
(1) Only the lowest energy Mo is doubly degenerate
(2) Only LUMO is doubly degenerate
(3) Only HOMO is doubly degenerate
(4) Both the HOMO and LUMO are doubly degenerate

[CSIR NET DEC. 2019]

27. The magnitude of bond angles in gaseous NF_3, SbF_3 and $SbCl_3$ follow the order
(1) $NF_3 > SbF_3 > SbCl_2$ (2) $SbCl_3 > SbF_3 > NF_3$
(3) $SbF_3 > SbCl_3 > NF_3$ (4) $NF_3 > SbCl_3 > SbF_3$

[CSIR NET DEC. 2019]

28. The ion having the highest bond order is
(1) NO^+ (2) O_2^+
(3) N_2^+ (4) C_2^+

[CSIR NET DEC. 2019]

29. The species for which the shapes (geometry) can be predicted by VSEPR theory is/are
(A) $[PtCl_4]^{2-}$
(B) $[TeCl_6]^{2-}$
(C) PF_3 and SF_6
(1) A and C (2) B and C
(3) C only (4) A and B

[CSIR NET DEC. 2019]

30. Based on the MO diagram of HS (sulfanyl radical), choose the correct statement(s) from the following (the energies of the relevant atomic orbitals are: 1s(H)= -13.6 eV; 3s(S) = -20.7 eV; 3p(S)= -11.7 eV):

(a) σ-bond formed will have more 3p(S) character
(b) σ -bond will be formed between 1s(H) and 3p(S)
(c) σ -bond will be formed between 1s(H) and 3s(S)
(d) The unpaired electron will reside in the non-bonded p orbital

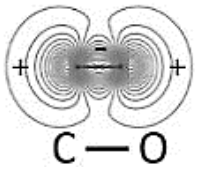
(1) (b) and (d) (2) (a), (b) and (d)
(3) (c) and (d) (4) (a) only

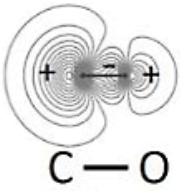
[CSIR NET NOV. 2020]

31. As per the VSEPR theory, shapes of SO_3^{2-}, CO_3^{2-} and BrF_4^- are, respectively
(1) trigonal pyramidal, trigonal planar and tetrahedral
(2) trigonal planar, trigonal pyramidal and square planar
(3) trigonal pyramidal, trigonal planar and square planar
(4) trigonal planar, trigonal pyramidal and tetrahedral

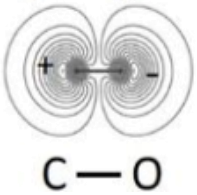
[CSIR NET NOV. 2020]

32. For CO, the contour plot of the molecular orbital which best represents the HOMO is

(1) 

(2) 

(3)

(4) 

[CSIR NET JUNE 2021]

33. Among the following which set of molecular/ionic species all have a planar structure?
(1) $BrF_3, FClO_2$ and $[XeF_5]^-$
(2) $XeO_3, [ClF_4]^-$ and $FClO_2$
(3) $[ClF_4]^-, BrF_3$ and $[XeF_5]$
(4) $FClO_2, [XeF_5]^-$ and XeO_3

[CSIR NET JUNE 2021]

34. The total number of lone pairs of electrons on all the atoms in cyanogen aside and thiocyanogen respectively, are
(1) 4 and 6 (2) 6 and 6
(3) 3 and 4 (4) 4 and 4

[CSIR NET JUNE 2021]

35. For $[Hg2]^{2+}$, the bond order and the orbitals involved in bonding are, respectively
(1) one; s and s (2) two; s and p
(3) one; p and p (4) three; s and d

[CSIR NET JUNE 2022]

36. Choose the correct order of energy of $2\sigma_g$ and $1TT_u$ molecular orbitals for B_2, C_2 and O_2:
(1) $2\sigma_g > 1\pi_u$ for all the three
(2) $2\sigma_g > 1\pi_u$ for B_2 and C_2 only
(3) $1\pi_u > 2\sigma_g$ for C_2 and O_2 only
(4) $2\sigma_g > 1\pi_u$ for B_2 and O_2 only

[CSIR NET JUNE 2022]

37. The geometry around Te in the symmetrical spacies of $[TeO_2F]^-$ is.
(1) Square planar (2) Tetrahedral
(3) Trigonal bipyramidal (4) octahedral.

[CSIR NET JUNE 2022]

38. The statement that corrects describe the molecular orbital (MO) diagram of $HO^{\cdot}$ (hydroxyl radical) is/are (consider the O-H bond to be along the X-axis)
A) The highest Occupied Molecular orbital (Homo) is a non-bonded Mo that is predominantly formed with $2p_z$ and $2p_y$ atomic orbitals (AO_5) of O-atom.
B) The Homo is a $\sigma -$ bonded MO that is predominantly formed by the overlap of $H(15)\ and\ O(25)\ Ao_5$
C) The $\sigma -$ bonding MD is formed by the overlapping of $H(15)\ and\ O(2p_z)\ AO_5$
D) The $\sigma -$ bonding MO is formed by the overlap of $H(Is)\ and\ O(2Px)\ AO_s$.
Option:
(1) A and C only (2) A and D only
(3) B only (4) D only

[CSIR NET JUNE 2022]

39. Hydrolysis of the purple isomer of the complex $[Co(tren)(NH_3)Cl]^{2+}[tren = tris\ (2 - amino\ - ethyl)\ amino]$ under basic condition results in two product. The geometry of the intermediate involved in this reaction is.
(1) Trigonal bipyramidal (2) square pyramidal
(3) pentagonal planar (4) Tetrahedral

[CSIR NET JUNE 2022]

40. The Ionization energies $(|E_1\ to|E_5)$ of 'S' and/or 'p' block elements $(X_1, Y\ and\ Z)$ are given below.

	$\|E_1$ ($kJ\ mol^{-1}$)	$\|E_2$ ($kJ\ mol^{-1}$	$\|E_3$ ($kJ\ mol^{-1}$	$\|E_4$ ($kJ\ mol^{-1}$	$\|E_5$ ($kJ\ mol^{-1}$
X	1086	2353	4620	6223	37830
Y	800	2427	3060	25030	32830
Z	496	4562	6910	9543	13350

The number of valence electrons in X, Y and Z are
(1) X = 2; Y = 3; Z = 4 (2) X = 4; Y = 1; Z = 1
(3) X = 4; Y = 3; Z = 1 (4) X = 1; Y = 3; Z = 4

[CSIR NET JUNE 2022]

41. Among the following which set of molecular/ionic species all have a planar structure?
(1) $BrF_3, FClO_2$ and $[XeF_5]^-$
(2) $XeO_3, [ClF_4]^-$ and $FClO_2$
(3) $[ClF_4]^-, BrF_3$ and $[XeF_5]^-$
(4) $FClO_2, [XeF_5]^-$ and XeO_3