D 121307 **(Pages : 2)** **Name.....................................**

Reg. No.................................

FOURTH SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2025

(CBCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

Section A

(8 *Short questions, each answerable within* 7.5 *minutes*)

(Answer **all** *questions, each question carries weightage* 1)

1. Draw the schematic diagram of a microwave spectrometer

2. What are the parts of Raman spectrometer ?

3. Define mono chromator ?

4. Define depolarization ratio of Raman scattered light

5. What are the two directions of rotations of a symmetric top ?

6. List out some industrial applications of Raman spectroscopy.

7. Explain the importance of Raman effect for phase transition studies.

8. What is isomer shift ?

(8 × 1 = 8 weightage)

Section B

(4 *Essay questions, each answerable within* 30 *minutes*)

(*Answer any* **two** *questions. Each question carries weightage* 5)

9. Define Raman effect. Derive and explain rotational Raman spectra with figure

10. Explain diatomic vibrating rotator.

Turn over

11. Explain rotational fine structure of electronic vibration spectra. Explain P, Q and R branches.

12. Explain with figure the instrumentation of IR spectrometer. Explain the techniques used for recording the spectra ?

(2 × 5 = 10 weightage)

Section C

(7 *problem questions, each answerable within* 15 *minutes*)

(*Answer any* **four** *questions. Each question carries weightage* 3)

13. Draw and explain Fortrat parabola.

14. Explain nuclear magnetic resonance condition.

15. Rotational and centrifugal distortion constants of HCl molecule are 10.593 cm^{-1} and 5.3×10^{-4} cm^{-1} respectively. Estimate the vibrational frequency and force constant of the molecule

16. Derive the expression for the frequencies of stark components of J = 1 to J = 2 states.

17. Irradiation of carbon tetrachloride by 4.358Å radiation gives Raman lines at 4400, 4419, 4447 Å

    Calculate the Raman shift for each of these lines in cm^{-1}.

18. With figure write a note on Raman microscopy.

19. With necessary details explain Paschen back effect ?

(4 × 3 = 12 weightage)

D 101292 **(Pages : 2)** **Name....................................**

Reg. No................................

FOURTH SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2024

(CBCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

Section A

8 *short questions, each answerable within* 7.5 *minutes.*
Answer **all** *questions.*
Each question carries weightage 1.

1. Define Shark effect.
2. Figure the normal modes of water molecule.
3. Draw the schematic diagram of IR spectrometer.
4. What are the selection rules for the parallel vibrations ?
5. What is the principle of ESR ?
6. Define nuclear magneton.
7. What is the principle of FTIR ?
8. What is chemical shift ?

(8 × 1 = 8 weightage)

Section B

4 *Essay questions, each answerable within* 30 *minutes.*
Answer any **two** *questions.*
Each question carries weightage 5.

9. Explain rotational fine structure of electronic vibration spectra. Explain P,Q and R branches Explanation, figure.
10. Explain vector atom model. With necessary figure briefly explain :
    (a) L-S coupling.
    (b) J-J coupling ?

Turn over

11. Explain diatomic vibrating rotator.

12. Explain with figure Vibrational Raman spectra.

(2 × 5 = 10 weightage)

Section C

7 problem questions, each answerable within 15 minutes.

Answer any **four** *questions.*

Each question carries weightage 3.

13. Rotational and centrifugal distortion constants of HCl molecule are 10.593 cm^{-1} and 5.3×10^{-4} cm^{-1} respectively. Estimate the vibrational frequency and force constant of the molecule.

14. Explain dissociation.

15. Explain with figure vibrational coarse structure.

16. The band origin of a transition in C2 is observed at 19,378 cm^{-1} while rotational fine structure indicates that the rotational constants in excited and ground states are respectively B' = 1.7527 cm^{-1} and B' = 1.6326 cm^{-1} Estimate the position of the band'head

17. Derive the classical theory of Raman scattering.

18. Draw and explain Fortrat parabola.

19. Explain nuclear magnetic resonance condition.

(4 × 3 = 12 weightage)

C 42047 **(Pages : 2)** **Name.......................................**

Reg. No...................................

FOURTH SEMESTER M.Sc. DEGREE (REGULAR/SUPPLEMENTARY) EXAMINATION, APRIL 2023

(CBCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

Section A

8 *Short questions answerable within* 7.5 *minutes*
Answer **all** *questions, each carry weightage* 1.

1. Give the features of Paschen-Back effect.
2. IR and Raman measurement complement each other and the complete picture of the vibrational problem can only be obtained by using both the techniques. Substantiate.
3. The observed rotational spectrum of HF shows decrease in the line separation on the high frequency side. Why ?
4. State and explain Franck Condon Principle.
5. Obtain the resonance condition in NMR spectroscopy ?
6. Why microwave source and techniques have to be applied for the observation of ESR ?
7. What is the significance of spin-spin coupling ?
8. Explain how Mossbauer spectrum is useful in understanding electronic structure of molecules.

(8 × 1 = 8 weightage)

Section B

4 *essay questions answerable within* 30 *minutes*
Answer any **two** *questions, each carry weightage* 5.

9. Explain the concepts underlaying vector atom model and discuss in details LS and JJ coupling schemes in many electron atoms. Give examples
10. Describe normal modes and vibration of H_2O and CO_2 molecules and explain the principle of Fourier transformation Infrared Spectroscopy.

Turn over

11. Explain the basic principle of stimulated Raman and Inverse Raman scattering.

12. Explain Recoilless emission and absorption of γ-rays and briefly explain the use of chemical shift in understanding molecular structure.

(2 × 5 = 10 weightage)

Section C

7 problems answerable within 15 minutes
Answer any **four** *questions, each carry Weightage 3.*

13. The red line of cadmium splits into three components separated by 120 MHz when the source is placed in a magnetic field of flux density 8.6 mT, the light being examined in direction perpendicular to the magnetic field. Calculate the ratio of charge to mass (e/m) of the electron.

14. The first line in the rotational spectrum of carbon monoxide has a frequency of 3.8424 cm^{-1}. Calculate the rotational constant and hence the C-O bond length in carbon monoxide. Avogadro number is 6.022×10^{23}/mol.

15. The first three rotational Raman lines of a linear triatomic molecular are at 4.86, 8.14 and 11.36 cm^{-1} from the exciting Raman lines. Estimate the rotational constant B and the moment of inertia of the molecule.

16. The spectroscopic bond dissociation energy of Cl^{35} O^{16} radical is 1.9 eV. Calculate the equilibrium bond dissociation energy of ClO , if the fundamental vibrational frequency is 780 cm^{-1}.

17. In the NMR spectrum of N^{14} with I = 1, how many spectral lines will be observed ? Calculate the frequency required for the NMR line at an external field of 1.4T (g = 0.403).

18. Calculate the recoil velocity and energy of the free Mossbauer nucleus S_n^{119} when emitting a γ-ray of frequency 5.76×10^{18} Hz. What is the Doppler shift of the γ-ray frequency to n outside observer ? Avogadro number is 6.02×10^{23} mol^{-1}.

19. Electron spin resonance is observed in atomic hydrogen at a magnetic field B = 0.34T. Calculate g value for the electron in the hydrogen atom. If the operating frequency is 9.5 GHz.

(4 × 3 = 12 weightage)

C 22578 **(Pages : 2)** **Name.......................................**

Reg. No...................................

FOURTH SEMESTER M.Sc. DEGREE [REGULAR/SUPPLEMENTARY] EXAMINATION, APRIL 2022

(CBCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2019 Admission onwards)

Time : Three Hours Maximum : 30 Weightage

General Instructions

1. *In cases where choices are provided, students can attend* **all** *questions in each section.*
2. *The minimum number of questions to be attended from the Section / Part shall remain the same.*
3. *The instruction if any, to attend a minimum number of questions from each sub section / sub part / sub division may be ignored.*
4. *There will be an overall ceiling for each Section / Part that is equivalent to the maximum weightage of the Section / Part.*

Section A

8 *Short questions answerable within* 7.5 *minutes.*
Answer **all** *questions, each question carries weightage* 1.

1. Explain clearly the phenomenon of normal and anomalous Zeeman effect.
2. Mention the concepts underlaying vector atom model of the atom and the different quantum numbers associated with it.
3. Explain the principle of Fourier transformation I R Spectroscopy.
4. With the help of a diagram, explain fortrat parabola.
5. Obtain a simple relation for the relative intensity of Stokes lines and anti-Stokes lines. How does the intensity vary with temperature ?
6. Briefly explain recoilless emission and absorption of γ-rays.
7. Distinguish between spin lattice and spin-spin relaxation.
8. Explain the basic principle of Stimulated Raman Scattering.

(8 × 1 = 8 weightage)

Turn over

Section B

4 essay questions answerable within 30 minutes.
Answer any **two** *questions, each question carries weightage 5.*

9. Discuss the theory of the rotational spectrum of symmetric top molecule, what is the information derived from Rotational Spectrum ?

10. Describe the rotational Raman spectrum of symmetric top molecules. Bring out the salient features.

11. Discuss the rotational fine structure of the electronic vibrational transitions. Explain band head formation.

12. Explain the Bloch equations and the steady state solutions in the case of NMR.

(2 × 5 = 10 weightage)

Section C

7 problems answerable within 15 minutes.
Answer any **four** *questions, each question carries weightage 3.*

13. Consider a hydrogen atom in the $D_{3/2}$ state, (i) Find the possible values of I_Z. (ii) What are the different orientations of the J-vector in space.

14. Rotational and centrifugal distortion constants of HCl molecule are 10.593 cm^{-1} and $5.3 \times 10^{-4} \text{ cm}^{-1}$ respectively. Estimate the vibrational frequency and force constant of the molecule.

15. If the bond length of H_2 is 0.07417nm, what would be the positions of the first three rotational Raman lines in the spectrum ?

16. The vibrational structure of the absorption spectrum of O_2 becomes a continuum at 56876 cm^{-1}. If the upper electronic state dissociates into one ground state atom and one excited atom with excitation energy 15875 cm^{-1}, estimate the dissociation energy of the ground state of O_2 in cm^{-1} and in kJmol^{-1}.

17. What is the nuclear g_N factor for F^{19} nucleus which has a magnetic moment of $2.6273 \ \mu_N$. Nuclear spin quantum number $I = 1/2$.

18. Calculate the recoil velocity of a free Mossbauer nucleus of mass 1.67×10^{-25} kg (equivalent at wt. 100) when emitting a γ-ray of wavelength 0.1 nm. What is the Doppler shift of the γ-ray frequency to an outside observer ?

19. A free electron is placed in a magnetic field of strength 1.3T. Calculate the resonance frequency if $g = 2.0023$.

(4 × 3 = 12 weightage)

C 2058

(Pages : 2)

Name...

Reg. No....................................

FOURTH SEMESTER M.Sc. DEGREE (REGULAR) EXAMINATION MARCH 2021

(CBCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2019 Syllabus Year)

Time : Three Hours

Maximum : 30 Weightage

General Instructions

1. *In cases where choices are provided, students can attend* **all** *questions in each section.*
2. *The minimum number of questions to be attended from the Section / Part shall remain the same.*
3. *There will be an overall ceiling for each Section / Part that is equivalent to the maximum weightage of the Section / Part.*

Section A

(8 *Short questions answerable within* 7½ *minutes*)
Answer **all** *questions, each carry weightage* 1.

1. **Explain spin-orbit coupling.**
2. **Iron could not be heated with a Microwave oven. But microwave oven can be used to heat food materials. Why ?**
3. **Explain Born -Oppenheimer approximation.**
4. **What is Inverse Raman effect ?**
5. **Explain briefly the information one can get from vibrational analysis of electronic spectra.**
6. **Explain the factors responsible for the hyperfine structure in ESR spectra.**
7. **What is isomer shift ? Explain with an example.**
8. **Explain Larmour precession. What is Larmour frequency ?**

(8 × 1 = 8 weightage)

Section B

(4 *essay questions answerable within* 30 *minutes*)
Answer any **two** *questions, each carry weightage* 5.

9. Discuss the theory of Zeeman effect and Explain Stark effect on one electron system.
10. Explain the basic principle of Non-linear Raman effect and Hyper Raman effect.

Turn over

11. (a) Discuss Franck Condon Principle.

    (b) Explain fortrat parabola, dissociation and pre dissociation energy.

12. Explain in detail :

    (a) Relaxation process in NMR.

    (b) Theory of Chemical shift with an example.

(2 × 5 = 10 weightage)

Section C

(*7 problems answerable within* 15 *minutes*)
Answer any **four** *questions, each carry weightage* 3.

13. Electron spin resonance is observed for atomic hydrogen with an instrument operating at 9.5GHz. If the *g* value for the electron in the hydrogen atom is 2.0026, what is the magnetic field ? Bohr magnetron $\mu_B = 9.274 \times 10^{-24}$ J/K.

14. A Mossbauer nucleus Fe^{57} makes the transition from the excited state of energy 14.4 keV to the ground state. What is its recoil velocity ?

15. The band origin of a transition in C_2 is observed at 19378 cm^{-1} while the rotational fine structure indicates that the rotational constants in excited and ground states are respectively $B' = 1.7527\ cm^{-1}$ and $B'' = 1.6326\ cm^{-1}$. Estimate the position of the band head.

16. The first Stokes line in the rotational Raman Spectrum of $N^{14}N^{15}$ is observed at 11.5416 cm^{-1}. What is its B value ? Calculate its bond length.

17. Given that the spacing between the vibrational levels of a CO molecule is 8.45×10^{-2} electron volt and the reduced mass is 1.14×10^{-24} kg. Calculate the value of the force constant *k* of the bond in a CO molecule.

18. Calculate the wavelength separation between the two component lines which observed in the normal Zeeman effect. The magnetic field used is 0.4 weber/m^2 specific charge $= 1.76 \times 10^{11}$ Ckg^{-1} and $\lambda = 6000$Å.

19. What is the average period of rotation of HCl molecule if it is the in the $j = 1$ state? The internuclear distance of HCl is 0.1274 nm. Given the mass of hydrogen and Chlorine atom are 1.673×10^{-27}kg and 58.06×10^{-27}kg respectively.

(4 × 3 = 12 weightage)

C 80729 **(Pages : 2)** **Name..................................**

Reg. No...............................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, MARCH 2020

(CUCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2012 Admissions)

Time : Three Hours | Maximum : 36 Weightage

Section A

Answer **all** *questions from section A.*
Each question carries a weightage of 1.

1. What is L-S coupling scheme ?
2. What is Zeeman effect ?
3. Why NMR spectroscopy is used in biological applications ?
4. What are merits of FTIR spectrum ?
5. With neat diagram give the normal modes of H_2O ? What are its frequencies ?
6. Describe the vibrational coarse structure of electronic absorption from the ground state.
7. What is meant by inverse Raman effect ?
8. What is υ'' progression ?
9. Explain Larmour precision ?
10. What are the important applications of ESR Spectroscopy ?
11. What are the merits of LASER as an excitation source for recoding Raman spectra of a samples ?
12. What is the basic principle of Mössbauer spectroscopy ?

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions from section B.*
Each question carries a weightage of 6.

13. Draw the block diagram of Raman spectrometer and explain its working.
14. Describe with necessary theory account for the splitting of spectral lines in the presence of strong magnetic field.

Turn over

15. Describe with neat diagram the dissociation and predissociation of molecules

16. Derive the Bloch equations by considering nucleus posses magnetic moment and angular momentum.

(2 × 6 = 12 weightage)

Section C

Answer any **four** *questions from section* C.
Each question carries a weightage of 3.

17. The reduced mass of a molecule is 13 × 10^{-27} kg. and its equilibrium vibration frequency is 1900 cm^{-1}, determine the force constant. $c = 3 \times 10^8$ m/s.

18. Bands in the absorption spectrum of a diatomic molecule ceases its continous bands at 1761 Å. The ground state zero point energy is 793 cm^{-1} and the difference in potential energy minima for the two electronic states corresponds to 49,800 cm^{-1}. Find out the D'_e of the diatomic molecule.

19. Determine the frequency of an unpaired electron when it is subjected to a magnetic field of strength of 0.45 Tesla. $\beta = 9.274 \times 10^{-24}$ JT^1. $h = 6.62 \times 10^{-34}$J.

20. Raman line at 4570 Å is observed from a material when the exciting line is at 4358 Å. Determine the positions of Stokes and anti-stokes lines if the wavelength of the exciting line is changed to 488 nm.

21. Determine the Zeeman components in Å unit, when a spectral line of wavelength 4500 Å, is subjected to a magnetic field of strength 0.3 Tesla. Mass of the electron is 9.1 × 10^{-31} Kg ; $c = 3 \times 10^8$ m/s.; charge of the electron is 1.6 × 10^{-19} C.

22. A system of protons at a temperature of 25 °C is placed in magnetic field of strength 3T. Determine the ratio of number of proton spins in the lower to the upper state.

$k = 1.381 \times 10^{-23} JK^{-1}$ $g_N = 5.585$, $\mu_N = 5.052 \times 10^{-27}$T.

(4 × 3 = 12 weightage)

C 80720 (Pages : 2) Name..................................

Reg. No...............................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, MARCH 2020

(CUCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2017 Admission onwards)

Time : Three Hours Maximum : 36 Weightage

Section A

Answer **all** *questions, each carries weightage* 1.

1. Explain Stark effect.
2. State and explain Hund's rule. Give an example.
3. Give the selection rules for Zeeman pattern.
4. What are hot bands ? How are they formed ?
5. How do you find out the bond length and angles from the rotational spectra for a symmetric top molecule ? Give the relevant equations.
6. Explain Mutual exclusion principle. In which type of molecule it is observed and why ?
7. Distinguish between Anti-Stokes Raman scattering and inverse Anti-Stokes Raman Scattering. Give the conditions for them to occur.
8. Explain the intensity variation of vibrational electronic spectra on the basis of Franck -Condon principle.
9. What are progressions and sequences in the vibrational analysis of a spectrum ?
10. Briefly explain recoilless emission and absorption of gamma rays.
11. What is chemical shift ? Describe its relevance.
12. Derive the resonance condition in ESR spectroscopy.

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions, each carries weightage* 6.

13. Compare Paschen Back Effect and Zeeman effect. Illustrate with the example of a principal series doublet.
14. Discuss in detail the spectra of a diatomic vibrating rotator. Explain the break down of the Born Oppenheimer approximation.

Turn over

15. Describe with the diagrams the Raman Spectrometer and the sample handling techniques for the same.

16. Derive Bloch equations in NMR spectroscopy. Describe how they can be used to define the susceptibilities.

(2 × 6 = 12 weightage)

Section C

Answer any **four** *questions, each carries weightage* 3.

17. Compute the interaction energies for pd electrons in LS coupling.

18. Rotational and centrifugal distortion constants of HCl molecule are 10.593 $\mathrm{cm^{-1}}$ and 5.3×10^{-4} $\mathrm{cm^{-1}}$ respectively Estimate the vibrational frequency and the force constant of the molecule. Given the mass of hydrogen and chlorine are 1.673×10^{-27} kg. and 58.06×10^{-27} kg. respectively.

19. Describe the method for the structure determination of triatomic molecules using Raman Spectroscopy. Illustrate with the example of CO_2.

20. The band origin of a transition in C_2 is observed at 19,378 $\mathrm{cm^{-1}}$ while the rotational fine structure indicates that the rotational constants in excited and ground states are respectively $B' = 1.7527$ $\mathrm{cm^{-1}}$ and $B'' = 1.6326$ $\mathrm{cm^{-1}}$. Estimate the position of the band head. Which state has the larger inter nuclear distance ?

21. The spectroscopic bond dissociation energy of $^{35}Cl^{16}O$ radical is 1.9 eV. Calculate the equilibrium bond dissociation energy of ClO, if the fundamental frequency is 780 $\mathrm{cm^{-1}}$. Given Avagadro number = 6.022×10^{23} $\mathrm{mol^{-1}}$, Planck's constant = 6.626×10^{-34} Js.

22. Illustrate the decay scheme of ^{57}Co in ^{57}Fe with respect to Mössbauer transition.

(4 × 3 = 12 weightage)

C 61929 (Pages : 2) Name..................................

Reg. No...............................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2019

(CUCSS—PG)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2017 Admissions)

Time : Three Hours Maximum : 36 Weightage

Section A

Answer **all** *questions.*
Each question carries weightage 1.

1. Find Lande's g factor of $^3P_{3/2}$.
2. Give the graphical representation of the Lande interval for a ^3D term.
3. Give the intensity rule for the Zeeman effect.
4. With the help of schematic diagram describe the normal modes of water molecule.
5. What is Born Oppenheimer approximation ?
6. Describe Hyper Raman effect.
7. CO_2 molecule obeys the mutual exclusion principle. Illustrate. Why water molecule is active in both IR and Raman ?
8. What is dissociation energy of a diatomic molecule ? How does it differ from equilibrium dissociation energy ?
9. Illustrate progressions and sequences in the vibrational analysis of a spectrum.
10. How does Mössbauer spectrum split into due to quadrupole interaction ?
11. What is isomer shift ?
12. What is ESR ? Explain.

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions.*
Each question carries weightage 6.

13. With necessary theory, explain Stark effect in weak and strong fields for hydrogen atom.
14. Describe the instrumentation for Microwave and IR Spectroscopy.

Turn over

15. Describe with theory : (a) Rotational Raman spectrum of a symmetric top molecule ; and (b) vibrational Raman spectra.

16. Discuss the rotational structure of electronic-vibration spectra. What are the information derived from vibrational analysis ?

(2 × 6 = 12 weightage)

Section C

Answer any **four** *questions.*
Each question carries weightage 3.

17. Find the interaction energies between two sp (valence) electrons in LS coupling. Give the schematic representation.

18. Discuss the rotational spectra of CH_3 Cl molecule.

19. A molecule AB_2 has the following IR and Raman spectra. Discuss the molecular structure and assign the observed lines to molecular vibrations.

Frequency 3750 cm^{-1} is very strong in IR but absent in Raman.

Frequency 3650 is strong in IR and strong and polarized in Raman.

Frequency 1595 is very strong in IR but absent in Raman.

20. Explain Fortrart parabolae and find band head and band origin.

21. In the NMR spectrum of ^{14}N with $I = 1$, how many spectral lines will be observed ? Calculate the frequency required for the NMR line at an external field of 1.4 T. Given $g_N = 0.403$, $\mu_N = 5.051 \times 10^{-27} JT^{-1}$, planck's constant = 6.626×10^{-34} Js.

22. Describe the energy level diagram and the allowed transitions for an electron coupled to a nucleus of spin $I = 1$. Neglect I.B interaction.

(4 × 3 = 12 weightage)

C 61944 **(Pages : 2)**

Name..

Reg. No..

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2019

(CUCSS—PG)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2012 Admissions)

Time : Three Hours

Maximum : 36 Weightage

Section A

Answer **all** *questions.*
Each question carries a weightage of 1.

1. What is Paschen Back effect ?
2. What are singlet and triplet state ?
3. Find the bond length of nitrogen molecule, If the spacing between two adjacent Raman line is 8 cm^{-1}.
4. What are different types of relaxation processes associated with ESR ?
5. Explain an asymmetric top molecule with an example ?
6. State the conditions for a molecule to be Raman active.
7. Give the fundamental modes of CO_2 molecule.
8. What are progressions ?
9. What is inverse Raman effect ?
10. Explain chemical shift.
11. Explain pre dissociation of a molecule.
12. Molecules such as CO and HF show rotational spectrum, why ?

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions.*
Each question carries a weightage of 6.

13. Explain LS and jj coupling schemes. Taking ps configuration as an example show that the number of spectral terms arising from these schemes are the same.
14. Discuss the energy's and spectra of a diatomic vibrating rotator as an unharmonic oscillator. Explain how different branches occur in the spectra.

Turn over

15. Explain band origin and band effect formation for the rotational fine structure of electronic vibration spectra.

16. Discuss in detail the principle of ESR. What is the effect of hyperfine interactions. What is its effect on the spectrum.

(2 × 6 = 12 weightage)

Section C

Answer any **four** *questions.*
Each carries a weightage of 3.

17. The D_1 and D_2 lines of sodium atoms are 589 nm and 589.6 nm respectively, evaluate the spin orbit coupling constant for the upper state in cm^{-1}.

18. The mean intemuclear distance for HCl^{35} in the v = 0 and v = 1 levels is 1.293 Å, calculate the difference in cm^{-1} between the R (0) and P (1) lines of the fundamental bond of HCl^{35}.

19. The first rotational Raman line of H_2 appears at 346 cm^{-1} from the exciting line. Calculate the bond length of H_2 molecule ($^1H = 1.673 \times 10^{-27} Kg$).

20. Calculate the magnetic field strength required for a transition frequency of 60MHz for fluorine, given $g_N = 5.255$.

21. The fundamental and first overtone transitions of CO are centred at 2143.3 cm^{-1} and 4260 cm^{-1}, calculate the equilibrium oscillation frequency and the unharmonicity constant.

22. The frequency separation between protons in C_6H_6 and TMS is approximately 510 Hz when the field is 1.65 T, evaluate the chemical shift (given $g_N = 5.585$)

(4 × 3 = 12 weightage)

D 42564 **(Pages : 2)** **Name..............................**

Reg. No..............................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2018

(CUCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

Section A

Answer **all** *questions.*
Each question carries a weightage of 1.

1. What are the possible values of *n*, *l* and m_s if a hydrogen atom has $m_1 = -2$?
2. Explain the role of spin orbit interaction in fine structure splitting.
3. Is the state $5^2D_{3/2}$ correct or erroneous ?
4. What is centrifugal distortion ?
5. Outline the effect of isotopic substation on the rotational spectra of molecules.
6. What are hot bands ? Why are they called so ?
7. Why anti-stocks lines are less intense than stocks line ?
8. Explain mutual exclusion principle with example.
9. What is predissociation ?
10. What is Larmour precession ?
11. Explain spin-lattice relaxation.
12. Explain the term chemical shift.

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions.*
Each question carries a weightage of 6.

13. Describe normal Zeeman effect and explain normal Zeeman effect using quantum theory.
14. Explain Born-Oppenhemier approximation. Discuss on the normal modes and vibrations of H_2O and CO_2 molecules.
15. Discuss Raman spectra of diatomic molecules. Point out the similarity and differences in infrared and Raman spectra.
16. Discuss the various relaxation processes for nuclei and derive Blosh equations.

(2 × 6 =12 weightage)

Turn over

Section C

Answer any **four** *questions.*
Each question carries a weightage of 3.

17. Obtain the terms for the sp electronic configuration in LS coupling scheme.

18. The IR spectrum of H^1Br^{79} consists of a series of lines spaced 17 cm^{-1} apart, find the inter nuclear distance of H^1Br^{79}.

19. Value of ω_e and $\omega_e x_e$ are 1580.36 and 12.073 cm^{-1} respectively for the ground state of O_2 calculate the zero point energy (1 ev = 8068 cm^{-1}).

20. The fundamental and first overtone of CO occur at 2143.3 cm^{-1} and 4260 cm^{-1} calculate the dissociation energy.

21. A free electron gives resonance at the frequency of 9.5 GHz when the magnetic field strength is 0.34 T, at what frequency the resonance occurs if the magnetic field is 1.3 T ?

22. A mossbeaur nucleus ^{57}Fe makes the transition from the excited state of energy 14.4 KeV to the ground state. Evaluate its recoil velocity.

(4 × 3 = 12 weightage)

C 22106 (Pages : 2) Name..................................

Reg. No..................................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2017

(CUCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

Section-A

Answer **all** *questions.*
Each question carries a weightage of 1.

1. Illustrate the fine structure transitions of sodium atom.
2. Distinguish between Zeeman effect and Paschen back effect.
3. Why nitrogen molecules do not show IR absorption or emission ?
4. A homo nuclear diatomic molecule does not respond to microwave radiation, why ?
5. Why a micro wave source and techniques are applied to observe ESR.
6. Explain Fronde-Condon principle.
7. What is isomer shift ? What information it gives ?
8. Explain hyper Raman effect.
9. Deduce the condition for NMR.
10. Give the decay schemes of ^{57}Co and ^{119}Sn.
11. Explain Morse curve.
12. What are P,Q and R branches ?

(12 × 1 = 12 weightage)

Section - B

Answer any **two** *questions.*
Each question carries a weightage of 6.

13. What are equivalent and nonequivalent electrons ? Using jj coupling scheme obtain the term symbols of a ps configuration.
14. (A) With necessary theory obtained the energy levels of a rigid rotator.

    (B) Explain the effect of nonrigidity and isotope substitutions on these levels.
15. Discuss the rotational fine structure of electronic vibrational transitions, what is Fortrat parabola.
16. Give an account of Mossbauer effect. Discuss isomer shift with example.

(2 × 6 = 12 weightage)

Section - C

Answer any **four** *questions.*
Each carries a weightage of 3.

17. Evaluate the Lande 'g' factors and the splitting factors 'mg' for the doublet terms $^2P_{1/2}$ and $^2P_{3/2}$.

18. The micro wave spectra of CN radical shows a series of lines spaced by a constant amount of 3.8 cm^{-1}. What is the bond length of CN ?

19. A Raman line is observed at 4768.5 Å, when acetylene was irradiated by 4358.3 Å radiation, Calculate the equilibrium vibrational frequency that causes the shift.

20. The fundamental band for HCl centred at a 2886 cm^{-1} assume that the inter nuclear distance is 1.276 Å. Calculate the wave number of the first two lines of each of the P and R branches of HCl.

21. Given that the bond dissociation energy of oxygen is 6eV and its vibrational frequency is 1580cm^{-1} estimate the maximum vibrational quantum number possible for Oxygen.

22. Obtain the resonance frequency and the number of hyperfine components of the ESR spectrum for the free radical CH_3 in a magnetic field of 0.34 T (given g=2.0023).

(4 × 3 = 12 weightage)

C 3534 (Pages : 2)

Name.....................................

Reg. No.....................................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2016

(CUCSS)

Physics

PHY 4C 12 – ATOMIC AND MOLECULAR SPECTROSCOPY

(2012 Admission onwards)

Time : Three Hours

Maximum : 36 Weightage

Section A

Answer **all** *questions.*

Each question carries 1 *weightage.*

1. Write a note on space quantisation.
2. Explain Hund's rule with examples.
3. What are the salient features of rotational spectra?
4. Outline the effect of isotopic substitution on the rotational spectra of a molecule.
5. Diatomic molecule do not show vibrational spectra. Justify the statement.
6. State the conditions to be satisfied for a vibration to be Raman active considering the normal vibrations of CO_2 molecules as example.
7. Explain inverse Raman scattering.
8. Write a note on Franck-Condon principle.
9. Explain Fortrat diagram.
10. What is chemical shift? Explain it with an example.
11. Deduce the condition for NMR.
12. With the help of a block diagram, explain Mossbauer spectrometer.

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions.*

Each question carries 6 *weightage.*

13. (a) Derive an expression for Lande's splitting factor and explain the anamalous Zeeman effect of sodium doublet lines D_1 and D_2 with its help.

    (b) State rules of Zeeman components.

14. Discuss in detail the construction and working of a Microwave spectrometer.

Turn over

15. Describe with necessary theory how structure of diatomic and triatomic molecules can be determined by combining Raman and Infrared spectroscopy.

16. Explain the different relaxation processes from nuclei and derive Block equations.

(2 × 6 = 12 weightage)

Section C

Answer any **four** *questions.*

Each question carries 3 *weightage.*

17. In an atom obeying 2-S coupling the components of a normal triplet state have separations 20 cm^{-1} and 40cm^{-1} between adjacent components. There is a higher state for which the separations are 22 cm^{-1} and 33 cm^{-1} respectively. Determine the terms for the two states and show the allowed transitions on an energy level diagram.

18. In the intra-red spectrum of HCl molecule the first line falls at 20.8 cm^{-1}. Calculate the moment of inertia reduced mass and the bond length of molecule.

19. A Raman line is observed at 4768.5 Å when acetylene was irradiated by 4358.3 Å radiations. Calculate the equilibrium vibrational frequency that causes their shift.

20. The rotational lines of a band system of electronic vibration spectra is given by $\bar{\upsilon} = (24{,}762 + 25\,m - 2.1\,m^2)\ cm^{-1}$ $m = \pm 1, \pm 2, \ldots\ldots\ldots$ Deduce the values of B, B" and the position of the band head. Comment on the inter nuclear distance of the two states and on the degradation of the band system.

21. The band origin of a transition in C_2 is observed at 19378 cm^{-1}, while the rotational fine structure indicates that the rotational constants in excited and ground states are, respectively, $B^1 = 1.7527\ cm^{-1}$ and $B^{11} = 1.6326\ cm^{-1}$. Estimate the position of the band head. Which state has the larger internuclear distance?

22. Consider the ESR spectrum of the free radicle CH_3 observed in a magnetic field of 0.34 T (i) If $g = 2.0023$ for free electron, find the frequency at which resonance is obtained ; (ii) How many hyperfine components are observes? (iii) Represent the transitions in an energy level diagram. Given $\mu_B = 9.274 \times 10^{-24}\ JT^{-1}$.

(4 × 3 = 12 weightage)

C 82501 **(Pages : 2)** **Name.......................................**

Reg. No...................................

FOURTH SEMESTER M.Sc. DEGREE EXAMINATION, JUNE 2015

(CUCSS)

Physics

PHY 4C 12—ATOMIC AND MOLECULAR SPECTROSCOPY

(2012 Admissions)

Time : Three Hours Maximum : 36 Weightage

Section A

Answer **all** *questions, each has weightage* 1.

1. Explain singlet and triplet states with examples.
2. Distinguish between Paschen-Back, normal and anamalous Zeeman effect.
3. How will you classify the notation of a three dimensional molecule based on the relative values of principal moment of inertia ?
4. What are the salient features of vibrational-rotational spectra ?
5. Briefly outline the advantages of FTIR spectroscopy over the conversional procedure.
6. Illustrate mutual exclusion principle with example.
7. What is hyper-Raman effect ?
8. What is Fortrat parabola ?
9. Distinguish between v' and v'' progression. Explain why the wave number separation of bands in v'' progression decreases towards longer wave length whereas that in v' progression decreases towards shorter wavelengths.
10. Deduce the condition for NMR.
11. What is chemical shift ? Explain it with an example.
12. Outline the principle of ESR.

(12 × 1 = 12 weightage)

Section B

Answer any **two** *questions, each has weightage* 6.

13. (a) Discuss in detail rotational spectra of a diatomic molecule, considering it as a non-rigid rotator.

    (b) How will you account the isotope effect in the above spectrum ?

14. With the help of a schematic diagram, describe the construction and working of a Raman spectrometer.

Turn over

15. (a) Discuss in detail the rotational fine structure of electronic vibrational transitions.

    (b) Explain conditions under which the band heads are degraded towards violet and red in the electronic spectra.

16. Explain the different relaxation processes for nuclei and derive Bloch equations.

(2 × 6 = 12 weightage)

Section C

Answer any **four** *questions, each has weightage* 3.

17. Suppose that the separation between two components of normal Zeeman pattern is 4×10^{10} cycles/sec. What should be the value of magnetic field B so that their lines may be resolved by a spectrometer capable of resolving lines separated by 0.05 Å.

18. The spin-orbit effect splits the $3P \rightarrow 3S$ transitions into two lines, 5885 Å corresponding to $^2P_{3/2} \rightarrow {}^2S_{1/2}$ and 5890 Å corresponding to $2p_{1/2} \rightarrow 2s_{1/2}$. Calculate, by using then wavelengths, the effective magnetic induction experienced by an outer electron in the sodium atom as a result of its orbital motion.

19. The force constant of the bond in CO molecule is 1870 N/m and its reduced mass is 1.4×10^{-26} kg. Calculate the frequency of vibration of the molecule and the spacing between its vibrational energy levels in eV.

20. The first rotational Raman line of H_2 appears at 346 cm^{-1} from the exciting line. Calculate the bond length of H_2 molecule. $^1H = 1.673 \times 10^{-27}$ kg.

21. The frequency separation between protons in C_6H_6 and TMS is 510.5 Hz when the field is 1.65 T. What is the chemical shift ? (Given $g_N = 5.585$).

22. For ^{39}K nucleus $I = \frac{3}{2}$ and $g_I = 0.2606$:

    (a) Draw all possible energy levels in a magnetic field.

    (b) Calculate the transition frequency from one of these orientations to an adjacent one in a magnetic field of 0.1T (0.2 MHz).

(4 × 3 = 12 weightage)