MPH-016

ASSIGNMENT BOOKLET

M.Sc. (Physics) Programme
(MSCPH)

ATOMIC AND MOLECULAR PHYSICS

Valid from 1st January, 2026 to 31st December, 2026

School of Sciences
Indira Gandhi National Open University
Maidan Garhi, New Delhi-110068
(2026)

Dear Student,

Please read the section on assignments in the Programme Guide for M.Sc. (Physics). A weightage of 30 per cent, as you are aware, has been earmarked for continuous evaluation, **which would consist of one tutor-marked assignment** for this course. The assignment is in this booklet. The total marks for this assignment is 100, of which 40 marks are needed to pass it.

Instructions for Formatting Your Assignments

Before attempting the assignment please read the following instructions carefully:

1) On top of the first page of your answer sheet, please write the details exactly in the following format:

ENROLMENT NO.: ……

NAME: ……

ADDRESS: ……

COURSE CODE:……..

COURSE TITLE: ……

ASSIGNMENT CODE: ……..

STUDY CENTRE: …….. **DATE:** ……

PLEASE FOLLOW THE ABOVE FORMAT STRICTLY TO FACILITATE EVALUATION AND TO AVOID DELAY.

2) Use only foolscap size writing paper (but not of very thin variety) for writing your answers.

3) Leave 4 cm margin on the left, top and bottom of your answer sheet.

4) Your answers should be precise.

5) **Submit the assignment answer sheets within the due date.**

6) The assignment answer sheets are to be submitted to your Study Centre as per the schedule. **Answer sheets received after the due date shall not be accepted. We strongly suggest that you retain a copy of your answer sheets.**

7) This assignment is **valid from 1st January, 2026 to 31st December, 2026**. If you have failed in this assignment or fail to submit it by December 31, 2026, then you need to get the assignment for the year 2027, and submit it as per the instructions given in the Programme Guide.

8) **You cannot fill the examination form for this course** until you have submitted the assignment for the course. For any queries, please contact: srjha@ignou.ac.in; mbnewmai@ignou.ac.in

We wish you good luck.

Tutor Marked Assignment
ATOMIC AND MOLECULAR PHYSICS

Course Code: MPH-016
Assignment Code: MPH-016/TMA/2026
Max. Marks: 100

Note: Attempt all questions. The marks for each question are indicated against it.

PART A

1. a) Determine the shift in energy caused by relativistic correction to kinetic energy for $n = 2$ and $n = 1$ levels of hydrogen atom. Using appropriate selection rules, show which transitions are allowed. (10)

   b) The anti-symmetric spin function for a two electron system is given as:

   $$\chi_{-}(1, 2) = \frac{1}{\sqrt{2}}[\alpha(1)\beta(2) - \beta(1)\alpha(2)]$$

   Prove that $\chi_{-}(1, 2)$ is an eigenfunction of $(\hat{S})^2$. (10)

   c) Using Thomas-Fermi method, derive an expression for the total kinetic energy of *N* electrons in a cubic box of side *L*, and hence obtain the expression for pressure. (10)

   d) Using molecular orbital method, construct all pssible trial wavefunctions (including spin) for a diatomic molecule. Of these functions, which trial function is expected to have the minimum energy? Give justification for your answer. (15)

   e) Write the Hamiltonian of a multi-electron atom. Obtain an expression for the effective potential experienced by an electron of this atom under the central field approximation. (5)

PART B

2. a) The HCl molecule shows its first and second overtone transitions at $566.0\,\text{cm}^{-1}$ and $8339.0\,\text{cm}^{-1}$, respectively. Assuming anharmonic oscillator model, determine the anharmoniticity constant, the equilibrium vibrational frequency, zero point energy, and the force constant of this molecule. (10)

   b) The rotational constant for the excited electronic state of a particular molecule is 20% smaller as compared to the rotational constant of its ground electronic state. Determine the values for the first 15 lines of the *R*-branch. Discuss the variation of the separation between successive transition lines of this branch. (10)

c) i) The fundamental vibrational frequency of a molecule occurs at $1730\,cm^{-1}$. Determine the position of Raman line if the molecule is excited with a laser of wavelength 514.5 nm. (5)

ii) The spacing between *S*-branch of N_2 molecule in Raman spectrum is $8\,cm^{-1}$. Calculate the bond length of the molecule. (5)

d) Determine the collisional width for He-Ne laser operating at a gas pressure of 1 torr and gas temperature of 450 K. Obtain the ratio of spontaneous and stimulated emission if the wavelength is 632.8 nm. (5+5)

e) Write the laser rate equation for a two level system and hence prove that the steady state population inversion cannot be achieved in a two level system. (10)

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