UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Sc. *M.Sci.*

Astronomy 3C38: Astronomical Spectroscopy

COURSE CODE	:	**ASTR3C38**
UNIT VALUE	:	**0.50**
DATE	:	**17-MAY-04**
TIME	:	**10.00**
TIME ALLOWED	:	**2 Hours 30 Minutes**

04-C0088-3-50

TURN OVER

Answer ALL SIX questions from Section A and TWO questions from Section B.

The numbers in square brackets in the right hand margin indicate the provisional allocation of maximum marks per sub-section of a question.

The following constant may be used:

Rydberg constant R_∞ = 109737.31 cm^{-1} = 13.6057 eV

SECTION A

1. The quantum numbers (n, l, m, s, s_z) are used to define the states of the hydrogen atom. Explain the significance of each quantum number and give its allowed range of values. **[8]**

2. Explain what is meant by the **hyperfine structure** of an atomic transition. To what transition does the H atomic line at a wavelength of 21 cm correspond? Explain why this transition is so important in astronomy. **[7]**

3. The Schrödinger equation of the helium atom can be written

$$\left[-\frac{\hbar^2}{2m_e}(\nabla_1^2 + \nabla_2^2) + \frac{e^2}{4\pi\epsilon_0}\left(-\frac{Z}{r_1} - \frac{Z}{r_2} + \frac{1}{r_{12}}\right) - E\right]\Psi = 0$$

where $e = 1, 4\pi\epsilon_0 = 1, \hbar = 1$ in atomic units. With the aid of a diagram, define the other symbols used and briefly explain the physical origin of the various terms. Which term makes this equation analytically insoluble? **[7]**

4. What atomic processes give rise to discrete X-ray spectra in astronomical objects? Give two examples of astronomical objects from which discrete X-ray spectra have been observed. Briefly discuss the role of temperature in determining the discrete X-ray spectra in such objects. **[6]**

5. Without going into numerical details, explain how molecular spectra can be used to determine the temperature of environments such as interstellar molecular clouds or the atmospheres of cool stars. **[6]**

6. A heteronuclear diatomic molecule such as CO can give rise to three types of spectra. Explain:

   (a) What types of motion give rise to each of these spectra;

   (b) At what wavelengths do each of these spectra typically occur. [6]

SECTION B

7. Configurations of lithium-like carbon, C^{3+}, can be written $1s^2 n\ell^1$. In terms of R_∞ and the quantum defect, give an expression for the energy levels of this system. Briefly explain the physical significance of the quantum defect and how it depends on n and ℓ. [9]

   A C^{3+} ion is formed in its $1s^2 3d$ configuration. With the aid of a diagram, explain between which configurations allowed transitions should subsequently be observed. [6]

   At high resolution each transition is found to consist of more than one line. Explain why this is and say how many lines you would expect in each case. Designate the lines in one of these transitions using full spectroscopic notation. [8]

   Explain why it is astronomically useful to study the relative intensity of the lines in a particular transition. [4]

   Why might the precise wavelength separation between the lines in a transition also be of astrophysical interest? [3]

8. In atomic structure, what are **configurations**, **terms** and **levels**? As an example, give the ground state configuration, term and level of the carbon atom. [9]

   An atom is in its ${}^4P^o_{\frac{1}{2}}$ level. Carefully explain what information is conveyed by this symbol. What other levels arise from the same term? [6]

   Explain what is the minimum number of electrons required to produce an atom in its ${}^4P^o_{\frac{1}{2}}$ level. Give a possible configuration, with this number of electrons, which could give rise to this level. Explain whether you would expect this configuration to correspond to a truly bound state or a resonance. [6]

   The ${}^4P^o_{\frac{1}{2}}$ level can emit to levels ${}^2P_{\frac{3}{2}}$, ${}^4D_{\frac{3}{2}}$, ${}^4D^o_{\frac{3}{2}}$ and ${}^4F_{\frac{3}{2}}$. Order these transitions by their probable strengths giving your reasons. [9]

9. Describe the processes **radiative recombination** and **dielectronic recombination**. Give an example of a species which undergoes only radiative recombination and an example of a species which undergoes both processes. [8]

The radio recombination lines 40α and 50β can be observed together in a single spectrum. To what transitions do these lines correspond? Obtain a value for the frequency of the 40α line assuming an atom of infinite mass. [6]

Hence, taking the mass of the hydrogen nucleus to be 1836 electron masses, obtain the frequency of the 40α transition of atomic hydrogen. [4]

Explain how the 40α transition can be observed for several atomic species and why this technique is limited. [6]

An attempt is made to observe the H40α transition from the following sources:

(a) The atmosphere of hot star;

(b) A planetary nebula;

(c) An H I region.

Explain which of these attempts is most likely to succeed. [6]

10. Explain what is meant by the **reduced mass** of a system. Give an expression for the reduced mass of a system of two particles of mass m_1 and m_2. [6]

The ^{6}LiH molecule has a rotational constant $B = 7.513$ cm^{-1} and a harmonic vibrational frequency of $\omega = 1405.7$ cm^{-1}. In the cold interstellar medium only the lowest two levels of the molecule are occupied. Estimate the frequencies at which the molecule will absorb radiation against suitable starlight. Comment briefly on the ease of observing these transitions. [12]

Assuming integer values for the atomic masses, estimate values for the rotational constant and fundamental vibrational frequency for the less abundant ^{7}LiH molecule. [8]

The early Universe consisted largely of hydrogen and helium, with only a trace of lithium. Why might the LiH molecule have still played an important role at this early epoch? [4]

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