University of Nottingham

FACULTY OF PURE SCIENCE

SCHOOL OF PHYSICS

PART II EXAMINATION, 1968

PHYSICS (v)

THURSDAY *June 7th* 2.30 - 5.30

Answer FOUR *questions*

1. An atom has two of its electrons outside closed shells and in one configuration they are both in the 3*p* shell. Derive and explain the resultant energy level diagram and the associated degeneracies, assuming Russell - Saunders coupling and a nuclear spin of zero.

Show also that if there were *j-j* instead of *R-S* coupling the possible values for *J* would be unaltered. Also derive and explain the energy levels and degeneracies when one electron is in the 3*p* shell and the other is in the 4*p*, assuming *R-S* coupling. What changes would occur if the nuclear spin were ½?

2. The atoms of a monatomic gas have non-degenerate energy levels E_1, E_2, E_3.... where $E_{n-1} < E_n$. . The gas is enclosed in a box having black body walls at temperature *T*. Considering onlv interaction with the radiation, describe what is meant by the statement that the gas is in thermal equilibrium with the walls and show that its Boltzmann population distribution is consistent with a black body radiation distribution.

Assuming that only the two lowest energy levels have non-negligible populations, discuss the physical processes which will occur if the walls of the box are suddenly changed to a temperature ½*T*. Would there be any differences in the behaviour if the walls of the box were only partial absorbers of electromagnetic radiation?

3. Give a full account of the spectrum of atomic hydrogen including its finer features.

4. Compare and contrast the information which can be obtained from pure rotation spectra. vibration-rotation spectra and Raman spectra. Gaseous NCC1 consists of linear molecules. How many normal modes of vibration does this molecule exhibit; what are they and in which spectra may they be observed?

5. Give an account of the basic principles of electron paramagnetic resonance and describe an apparatus for detecting it. In what types of material may the resonance be detected?

If in a free radical the unpaired electron is equally coupled to four protons in the molecule, what hyperfine structure can be expected in the electron paramagnetic resonance spectrum? How would the spectrum change if there was, in addition, a weaker coupling to one other proton?

6. Describe in outline experiments which may be performed to determine the following:

(*a*) the magnetic moment of the proton in absolute units,

(*b*) the magnetic moment of the proton in nuclear magnetons,

(*c*) the magnetic moment of the deuteron in any units,

(*d*) the sign of the magnetic moment of the deuteron,

(*e*) the spin of the deuteron.

[*Turn over*

7. Using Rayleigh's criterion show that the chromatic resolving power of a Fabry-Perot interferometer for a wavelength λ is

$$\frac{\pi}{1.21}\frac{b}{(1-b^2)}\frac{2\mu t}{\lambda}$$

where t is the separation of the reflecting surfaces, b is their reflection coefficient and μ is the refractive index of the medium separating them. You may assume that the intensity pattern of the fringes from such an interferometer is given by

$$\frac{I}{I_o} = \{1 + \frac{4b^2}{(1-b^2)^2}\sin^2\frac{1}{2}\delta\}^{-1}$$

where I_o is the maximum intensity of a fringe and δ is the phase difference between adjacent interfering beams.

The cadmium red line $3^1D_2 \rightarrow 2^1P_1$, forms a normal Zeeman pattern when the degeneracv is removed by a magnetic field. Illustrate the form of the resultant spectral pattern and calculate the minimum magnetic field necessary for the spectrum to be resolved as separate fringe systems with a Fabrv-Perot etalon of plate separation 2 cm. Assume that the refractive index of air is unity and the reflection coefficient of the plates is 94.8%.

[$h = 6.6 \times 10^{-27}$ erg sec, $c = 3.0 \times 10^{10}$ cm sec^1, Bohr magneton $\beta = 0.9 \times 10^{-20}$erg Oe^{-1}.]

8. Discuss briefly the instrumental techniques involved in experiments using (a) infra-red radiation and (*b*) ultra-violet radiation. Indicate the usefulness of experiments conducted with radiation from these regions of the electromagnetic spectrum other than information concerned with molecular motion.

A concave grating having a length of arc equal to 10 cm is mounted in an Eagle configuration with an angle of incidence of 5^o. Calculate the resolving power of this instrument in the region of the viewing slit if it is found that the second order diffraction from a spectral line of wavelength 2000 Å falls next to the slit.

9. Describe the propagation of a parallel beam of plane polarized light through a uniaxial crystal plate assuming normal incidence.

A Babinet compensator is formed from prisms cut from such a uniaxial crystal. Describhe the mode of action of this compensator and explain how you would use it to find the phase difference between the components of elliptically polarized light.

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