B.Sc. part III, paper VII Group A

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Page 1

"Saha's equation in case of double ionization"

If both single and double ionisation occur, Saha's equation is modified. If x_1 and x_2 represent the degree of ionisation for single and double ionisation respectively then it can be shown that

$$\frac{x_2(x_1+2x_2)}{x_1(1+x_1+2x_2)} P = \left(\frac{2\pi m}{h^2}\right)^{3/2} (KT)^{5/2} \cdot \frac{g_e g_a^{+}}{g_a} e^{-U/KT}$$

Applications:-

(1) Calculation of percentage of ionisation of elements: For calculating the percentage of ionisation of an element by the above formula under varying conditions of temperature and pressure we need a knowledge of the heat of ionisation. For an atom,

$$A \rightleftharpoons A^{+} + e - U$$

Where U is the energy released due to ionisation. ~~For an atom.~~ and is given by

$U = V_i \times 1.62 \times 10^{-12}$ ergs

where V_i is the ionisation potential of atom.

$\because$ 1 calorie $= 4.18 \times 10^{7}$ ergs

$\therefore U = V_i \times 1.62 \times 10^{-12} / 4.18 \times 10^{7}$ calories

$\therefore$ U for one gram atom =

$$\frac{V_i \times 1.62 \times 10^{-12}}{4.18 \times 10^{7} \times 1.62 \times 10^{-24}}$$

$= V_i \times 23050$ calories.

for Na $V_i = 5.12$ volts.

$\therefore U = 117$ K calories

Hence from the ionisation formula, It is possible to calculate the percentage ionisation x for different values of temperature and pressure.

For Ca, $g_e = 2$ $g_a^+ = 2$ and $g_e = 1$

Therefore, the ionisation formula for Ca is

$$\log \frac{x^2}{1 - x^2} P = \frac{5}{2} \log T + \log 2 + \log 4 - \frac{U}{4.57 T}$$

Where $I = \{(2\pi m)^{3/2} k^{5/2}\} / h^3$

Thus the percentage of ionisation of an atom depends to a large extent upon the factor U and temperature and hence upon the ionisation potential.

(2) Explanation of stellar spectra:

Fowler and Milne observed that there is a remarkable difference between the variation of principal lines of neutral elements and that of the subordinate lines in the steller spectra. The principal lines are most intense at the lowest temperature and gradually die out with the increase of temperature but the subordinate lines appear at a stage depending upon the excitation potential of the element. They are very faint at the lowest temperature, gradually attains a maximum intensity and again fall off to zero intensity. This sequence is explained on the assumption that at the lowest temperature all the atoms are in the ground state and there is none in the higher states. with the rise of temperature the highest states begin to come out where the temperature further rises the atoms begin to get ionised and the proportion of atoms in the excited state begins to drop and lines due to ionised atoms i.e subordinate lines begin to appear.

Franhoffer lines due to the Sun have been photographed and as may as 20027 lines covering the wavelength region 2725 Å and from 7833 Å to 10195 Å have been identified. Since the earth is a minute fraction of the ~~Sun~~ Sun, all the 92 elements found in the earth have been identified in the solar spectra by application of ionisation theory.