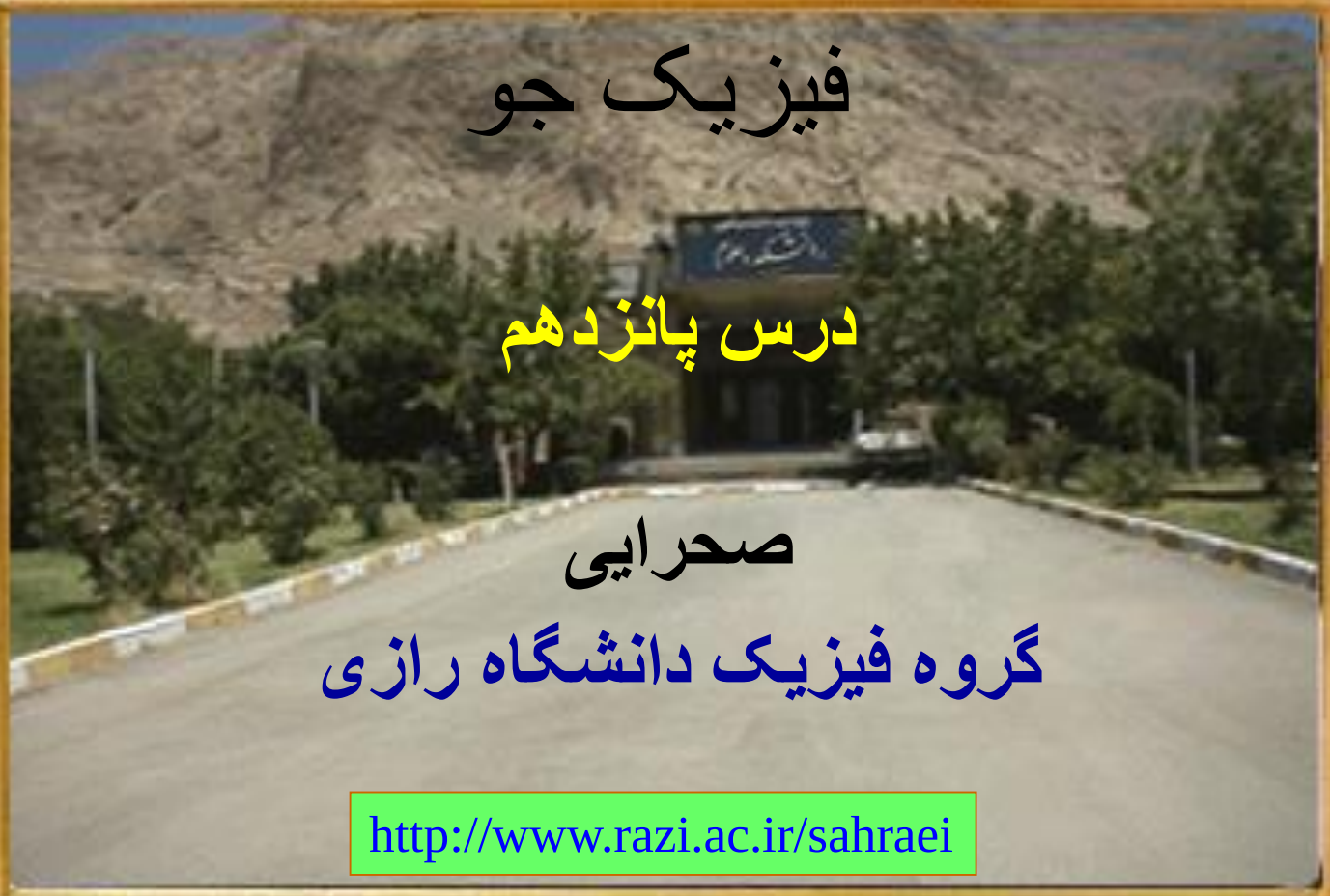

فیزیک جو

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یونیزاسیون

الف) تولید الکترون در اثر تابش خورشیدی
Photo-ionisation

$$A + h\nu \rightarrow A^*$$

$$A + h\nu \rightarrow A^+ + e^-$$

ب) جدا شدن الکترون Detachement

1)جدا شدن الکترون در اثر تابش خورشیدی photodetachement

$$O_2^- + h\nu \rightarrow O_2 + e^-$$

$$O^- + h\nu \rightarrow O + e^-$$

$$A^- + h\nu \rightarrow A + e^-$$

$$\frac{dne}{dt} = \gamma' . n(A^-)$$

2) جدا شدن الکترون در اثر برخورد

$$A^- + M \rightarrow A + M + e^-$$

$$\frac{dne}{dt} = \gamma . n(A^-) . n(M)$$

از بین رفتن الکترونها

Desionisation **عمل عکس یونیزاسیون**

1) ترکیب مجدد تابشی

$$O^+ + e \rightarrow O + h\nu(10ev)$$

$$A^+ + e^- \rightarrow A + h\nu$$

2) ترکیب مجدد در اثر برخورد

$$A^{+} + e^{-} + M \rightarrow A + M + h\nu$$

$$\frac{dne}{dt} = -\alpha.ne.n(A^{+})$$

$$\frac{dne}{dt} = -\alpha.ne^{2}$$

Attachment (3 اتصال

$$O_2 + e^- \rightarrow O_2^- + h\nu$$

$$O + e^- \rightarrow O^- + h\nu$$

$$A + e^- \rightarrow A^- + h\nu$$

$$\frac{dne}{dt} = -b.ne.n(A) = -\beta.ne$$

4) ترکیب مجدد تجزیه ای
Recombination dissociation

$$xy^{+} + e^{-} \rightarrow x + y$$

$$xy + A^{+} \rightarrow xy^{+} + A$$

At night, recombination can result in the loss of the D region.

$$O_2^{+} + e^{-} \rightarrow O + O$$

$$NO^{+} + e^{-} \rightarrow N + O$$

$$N_2^{+} + e^{-} \rightarrow N + N$$

$$\left[\frac{dne}{dt}\right]_L = -k_2 .ne.n(xy^+)$$

$$\left[\frac{dn(A^+)}{dt}\right]_L = -k_1 .n(A^+).n(xy)$$

according : $A + h\nu \rightarrow A^+ + e^-$

$$\left[\frac{dn(A^+)}{dt}\right] = \left[\frac{dne}{dt}\right] = q$$

$$q = k_1 .n(A^+).n(xy)$$

$$q = k_2 .n(xy^+).ne$$

we know $n(A^+) + n(xy^+) = ne$

$$\frac{q}{k_1 .n(xy)} + \frac{q}{k_2 .ne} = ne$$

$$q = \frac{k_1 k_2 .n(xy).ne^2}{k_1 .n(xy) + k_2 .ne}$$

دو حالت ممکن است وجود داشته باشد:

1) $k_1 n(xy) >> k_2 .ne \Rightarrow q = k_2 .ne^2$

$$comparing \;\; with \;\; q = -\alpha ne^2$$

2) $k_1 n(xy) << k_2 .ne \Rightarrow$

$q = k_1 .n(xy).ne = \beta ne$

comparing with $q = -\beta ne$

if $xy = o_2$, $A = o$

$$\begin{cases} O_2 + O^+ \rightarrow O_2^+ + O + 1.53\,ev \\ O_2^+ + e^- \rightarrow O + O + 6.96\,ev \end{cases}$$

$$\begin{cases} O^+ + N_2 \rightarrow NO^+ + N + 1.09\,ev \\ N_2^+ + O \rightarrow NO^+ + N + 3.09\,ev \end{cases}$$

$$\begin{cases} NO^+ + e^- \rightarrow N + O + 2.76\,ev \\ N_2^+ + e^- \rightarrow N + N + 5.02\,ev \end{cases}$$

فرمول کلی از بین رفتن و بوجود آمدن یونهای منفی و الکترونها

1) فرمول کلی تغییرات یونهای منفی

$$\frac{dn(A^-)}{dt} = -\alpha_i.n(A^-).n(A^+) + b.n(A).ne -$$

$$- \gamma.n(M).n(A^-) - \gamma'.n(A^-)$$

$$\frac{dn(A^-)}{dt} = 0$$

$$b.n(A).n_e = \gamma.n(M).n(A^-) + \gamma'.n(A^-)$$

$$b.n(A) = \gamma.n(M).\frac{n(A^-)}{ne} + \gamma'\frac{n(A^-)}{ne}$$

$$\frac{n(A^-)}{ne} = \lambda \qquad \lambda = \frac{n(A^-)}{ne} = \frac{bn(A)}{n(M)\gamma + \gamma'}$$

2) فرمول کلی تغییرات الکترونها

$$\frac{d(ne)}{dt} = q - \alpha ne.n(A^+) - b.n(A).ne$$

$$+ \gamma n(A^-).n(M) + \gamma' n(A^-)$$

$$\frac{dn(A^-)}{dt} - \alpha_i n(A^-).n(A^+)$$

$$\frac{d(ne)}{dt} = q - \alpha.ne.n(A^+) - \frac{dn(A^-)}{dt} - \alpha_i n(A^-).n(A^+)$$

$$n(A^+) = n(A^-) + ne$$

$$n(A^+) = ne\left(\frac{n(A^-)}{ne} + 1\right) = (1+\lambda)ne \quad *$$

$$\lambda = \frac{n(A^-)}{ne} \rightarrow n(A^-) = \lambda ne \quad **$$

$$\frac{dn(A^-)}{dt} = \frac{d(\lambda.ne)}{dt} = \lambda\frac{dne}{dt} + ne\frac{d\lambda}{dt} \quad ***$$

$$\frac{d(ne)}{dt} = q - \alpha(1+\lambda).n_e^{\,2} - \lambda\frac{dne}{dt} -$$

$$- ne\frac{d\lambda}{dt} - \alpha_i\lambda(1+\lambda).n_e^{\,2}$$

$$(1+\lambda)\frac{d(ne)}{dt} = (1+\lambda)\left[\frac{q}{1+\lambda} - (\alpha+\lambda\alpha_i)n_e^{\,2} - \frac{ne}{1+\lambda}.\frac{d\lambda}{dt}\right]$$

$$\frac{d(ne)}{dt} = q_e - \alpha_e.n_e^{\,2}$$

$$n_e = \left(\frac{q_e}{a_e}\right)^{1/2} \qquad n_e = \frac{q_e}{\beta}$$

$$\frac{dne}{dt} = q - L + T$$

$$\frac{dne}{dt} = q - \alpha n_e^{\,2} - \beta ne$$

Transport انتقال

$$\frac{dne}{dt} = q - L + T$$

$$\frac{dn_e}{dt} = q - L - div(N\vec{V})$$

$$T = -\frac{d}{dz}(n_e . V_z)$$

$$\frac{dn_e}{dt} = q - L - \frac{d}{dz}(n_e . V_z)$$

Diffusion

$$F_z = -\frac{1}{N}\frac{dp}{dz} - mg$$

$$p = NkT \rightarrow \frac{dp}{dz} = kT\,\frac{dN}{dz}$$

$$F_z = -\frac{kT}{N}\frac{dN}{dz} - mg$$

$$F_z = ma = m\frac{dv_z}{dt} = \frac{dmv_z}{dt}$$

$$\Delta mv_z = F_z \Delta t$$

$$F_z = \frac{\Delta mv_z}{\Delta t} = \frac{mv_z}{t} = \frac{mv_z}{1/\nu}$$

$$\nu mv_z = -\frac{kT}{N}\frac{dN}{dz} - mg$$

$$v_z = -\frac{kT}{\nu m}\left(\frac{1}{N}\frac{dN}{dz} + \frac{mg}{kT}\right)$$

$$v_z = -\frac{kT}{\nu m}\left(\frac{1}{N}\frac{dN}{dz} + \frac{1}{H}\right) \qquad H = \frac{kT}{mg}$$

$$N = N_0 e^{-Z/H}$$

$$D = \frac{kT}{\nu m} \qquad v_z = -D\left(\frac{1}{N}\frac{dN}{dz} + \frac{1}{H}\right)$$

$$v_z = -\frac{D}{kT}\left(\frac{kT}{N}\frac{dN}{dz} + mg\right)$$

$$v_z = \frac{D}{kT}F_z$$

$$\frac{1}{H_i} = \frac{m_i g}{kT_i} \quad , \quad \frac{1}{H_e} = \frac{m_e g}{kT_e}$$

$$D_e = \frac{kT_e}{m_e \nu_e} \quad , \quad D_i = \frac{kT_i}{m_i \nu_i}$$

$$\nu_i \approx \nu_e \quad , \quad m_e \prec\prec m_i$$

$$m_e \nu_e \prec\prec m_i \nu_i \Rightarrow D_e \succ\succ D_i \Rightarrow \nu_{ze} \succ\succ \nu_{zi}$$

$$F_z = -\frac{kT}{N}\frac{dN}{dz} - mg - eE$$

$$F_z = -\frac{kT}{N}\frac{dN}{dz} - mg + eE$$

$$v_{ze} = -D_e\left(\frac{1}{N_e}\frac{dN_e}{dz} + \frac{1}{H_e} - \frac{eE_z}{kT_e}\right)$$

$$v_{zi} = -D_i\left(\frac{1}{N_i}\frac{dN_i}{dz} + \frac{1}{H_i} + \frac{eE_z}{kT_i}\right)$$

$$\left(v_z\right)_{e,i} = -D\left(\frac{1}{ne}\frac{dne}{dz} + \frac{1}{H_e} - \frac{eE_z}{kT}\right)$$

One-Fluid Theory

$$m_e \;;\; q_e = -e \qquad m_i \;,\; q_i = ze$$

$$n = n_e = n_i \qquad J = 0 \qquad n_e v_e = n_i v_i$$

$$T_e = T_i = T$$

$$\frac{eE_z}{kT} = -\frac{v_z}{D_e} - \frac{1}{H_e} - \frac{1}{N_e}\frac{dN_e}{dz} = \frac{v_z}{D_i} + \frac{1}{H_i} + \frac{1}{N_i}\frac{dN_i}{dz}$$

$$-v_z\left(\frac{1}{D_e}+\frac{1}{D_i}\right)-\left(\frac{1}{H_e}+\frac{1}{H_i}\right)-\frac{1}{N_e}\frac{dN_e}{dz}-\frac{1}{N_i}\frac{dN_i}{dz}=0$$

$$-v_z\frac{2}{D}-\frac{2}{H}-\frac{2}{n}\frac{dn}{dz}=0$$

$$(v_z)=-D\left(\frac{1}{n}\frac{dn}{dz}+\frac{1}{H}\right)$$

b) Formation of the F2 region

* key reactions

Photoionization:

$$O + h\nu \rightarrow O^+ + e^- \qquad (\lambda<911\text{Å}) \qquad (1)\ *$$

$$N_2 + h\nu \rightarrow N_2^+ + e^- \qquad (\lambda< 796\text{Å}) \qquad (2a)$$

$$N_2^+ + O \xrightarrow{(fast)} NO^+ + N \qquad (2b)$$

$$O_2 + h\nu \rightarrow O_2^+ + e^- \qquad (\lambda< 1026\text{Å}) \qquad (3)$$

Dissociative recombination (rapid) **:**

$$O_2^+ + e^- \rightarrow O + O + h\nu \qquad (\lambda= 6300\text{Å})\ \text{“Airglow”} \qquad (4)\ * \qquad k_{O_2^+} \approx 3\times10^{-7} cm^{-3} s^{-1}$$

$$NO^+ + e^- \rightarrow N + O \qquad (5)\ * \qquad k_{NO^+} \approx 3\times10^{-7} cm^{-3} s^{-1}$$

$$N_2^+ + e^- \rightarrow N + N \qquad (6)$$

$$O_2^+ + N(^4S) \rightarrow NO + O \qquad (7)$$

Radiative recombination (slow) **:**

$$O^+ + e^- \rightarrow O^* \rightarrow O + h\nu \quad (7774\ \text{Å}) \qquad (8)$$

Charge transfer:

$$O^+ + O_2 \rightarrow O_2^+ + O \qquad (9) \qquad * \quad k_{O_2} \approx 2\times10^{-11} cm^{-3} s^{-1}$$

$$N^+ + O \rightarrow O^+ + N \qquad (10)$$

$$O_2^+ + NO \rightarrow NO^+ + O_2 \qquad (11)$$

Ion-atom interchange:

$$O^+ + N_2 \rightarrow NO^+ + N \qquad (12) \qquad * \quad k_{N_2} \approx 1\times10^{-12} cm^{-3} s^{-1}$$

$$N^+ + O_2 \rightarrow NO^+ + O \qquad (13)$$

$$N^+ + O_2 \rightarrow O_2^+ + N(^4S) \qquad (14)$$