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EXTENSIONS TO THE TWO ATOM BLOCKING MODEL

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MASTER

EXTENSIONS TO THE TWO ATOM BLOCKING MODEL

Blocking Model

Widely used to interpret blocking and surface scattering experiments.

Shadow cones

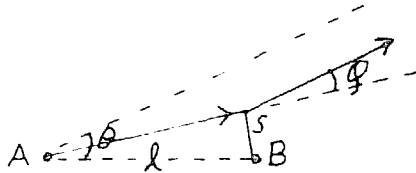
Surface structure

Aono experiments

Nuclear lifetimes

Backward glory effect — 180° enhanced backscattering

Ingredients of Model

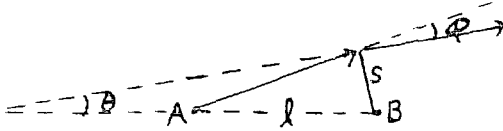


Projectile of energy E starts at atom A and is scattered by atom B

1. Classical scattering theory
2. Impulse approximation
3. Thermal displacements included

ATTRACTIVE POTENTIAL

BLOCKING \rightarrow FOCUSsing



$$\theta = \frac{s}{l} - \phi(s)$$

Normalized differential scattering cross section per unit solid angle is

$$F_A(\theta) = \frac{1}{l^2} \left| \frac{s}{\theta} \right| \frac{ds}{d\theta}$$

for Coulomb potential

$$\phi(s) = b/s, \quad b = \frac{Z_1 Z_2 e^2}{E}$$

$$\theta^* = 0.5 \left(s^* - \frac{1}{s^*} \right) \quad \text{where}$$

$$\theta^* = \frac{\theta}{\theta_c}, \quad \theta_c = 2\sqrt{b/l}, \quad s^* = \frac{s}{s_c}, \quad s_c = \sqrt{bl}$$

$$F_A = \frac{1}{2} \left\{ \frac{\sqrt{\theta^{*2} + 1}}{\theta^*} + \frac{\theta^*}{\sqrt{\theta^{*2} + 1}} \right\} \quad |\theta^*| > 0$$

$$F_R = \frac{1}{2} \left\{ \frac{\sqrt{\theta^{*2} - 1}}{\theta^*} + \frac{\theta^*}{\sqrt{\theta^{*2} - 1}} \right\} \quad |\theta^*| > \theta_c$$

SOME OBSERVATIONS

1. For attractive potential, the singularity in the scattering pattern occurs when $\theta^* = 0$.
2. For attractive case, some $+\theta^*$ come from negative s^* , for Coulomb scattering the separation occurs when $s^* = 1$ or $s = \sqrt{bl}$.
3. The equation giving the attractive Coulomb scattering pattern is the same as for repulsive Coulomb except for the sign within the radical.

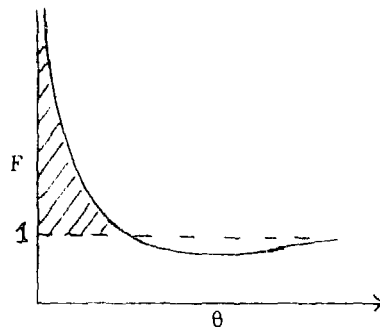
Compensation ?

$$G = 2\pi \int_0^{\theta_m} [F(\theta) - 1] \theta d\theta$$

$$= \pi \left[\frac{s^2 u}{\ell^2} - \frac{s^2 \ell}{\ell^2} - \theta_m^2 \right]$$

$$= \pi \left[\frac{s^2 u}{\ell^2} - \frac{s^2 \ell}{\ell^2} - \frac{s^2 u}{\ell^2} + \frac{2s_u \phi_u}{\ell} - \phi_u^2 \right] \} + 0 \quad \text{Provided } \phi \rightarrow 0 \text{ faster than Coulomb}$$

$$= \frac{\pi 2b}{\ell} = \frac{\pi \theta_c^2}{2} \quad \text{for Coulomb}$$



for arbitrary potential

Two particle emission for attractive (repulsive) potential

$$F(\theta) = \int_0^{\infty} \frac{2s ds}{\langle \rho^2 \rangle} \exp\left[-\frac{(\ell\theta)^2 + (s \pm \ell\phi)^2}{\langle \rho^2 \rangle}\right] I_0\left[\frac{2\ell\theta(s \pm \ell\phi)}{\langle \rho^2 \rangle}\right]$$

- attractive

+ repulsive

ρ is relative thermal displacement

I_0 is modified Bessel function of 1st kind

$$F(0) = 2 \int_0^{\infty} \frac{s ds}{\langle \rho^2 \rangle} \exp\left[-\frac{(s \pm \ell\phi)^2}{\langle \rho^2 \rangle}\right]$$

Specializing to Coulomb potential

$$F(\theta) = \eta \exp(-\alpha \pm \eta) \sum_{k=0}^{\infty} f_k \quad \begin{array}{l} - F_R \\ + F_A \end{array}$$

$$\text{where } \alpha = \frac{(\ell\theta)^2}{\langle p^2 \rangle}, \quad \eta = \frac{\theta^2 \ell^2}{2\langle p^2 \rangle}$$

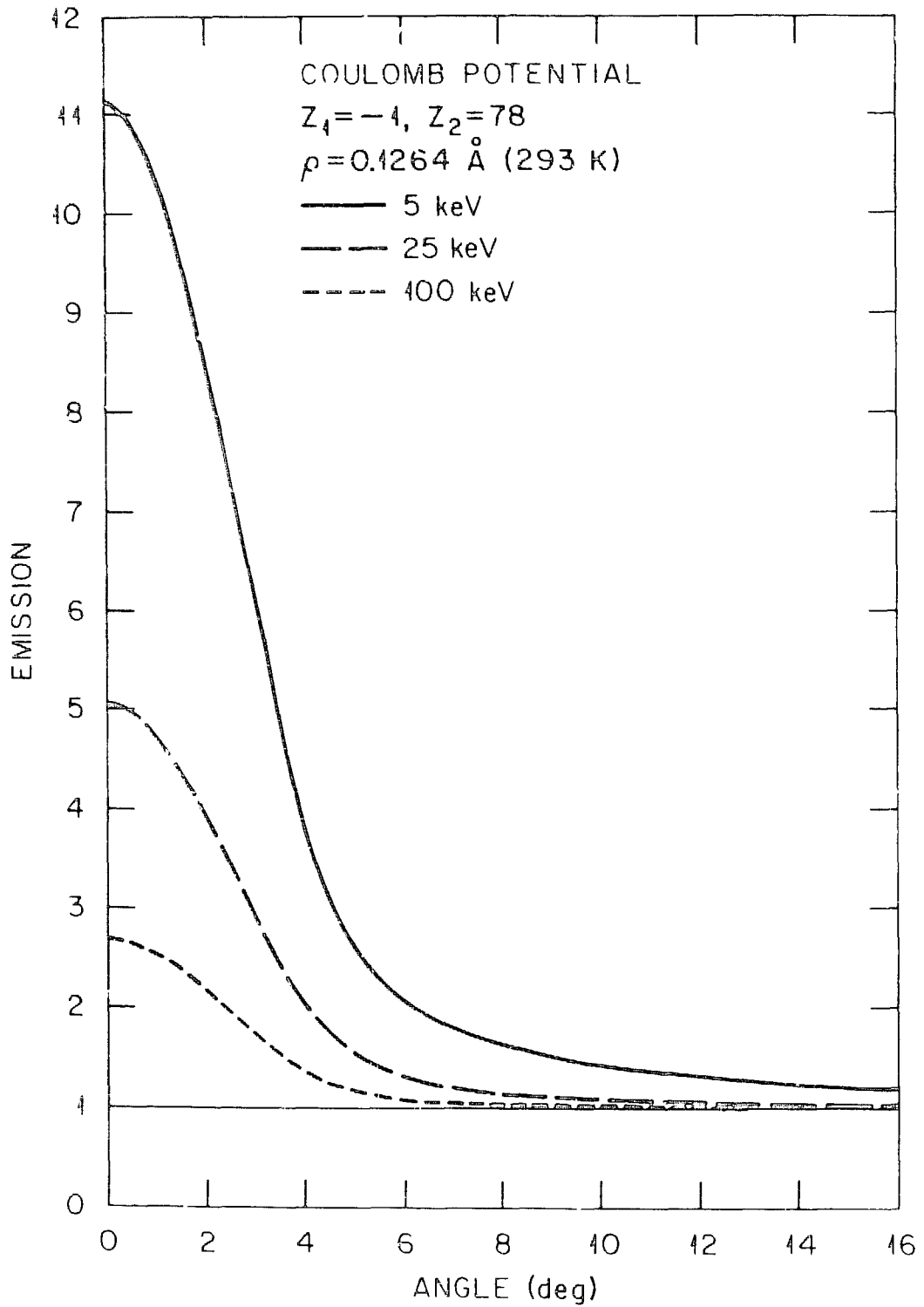
$$f_k = \left(\frac{\alpha\eta}{2}\right)^k \frac{g_k}{(k!)^2}$$

$$g_k = \sum_{r=0}^{2k} \frac{(\mp 1)^r (2k)!}{(2k-r)! r!} K_{r+1-k}(\eta)$$

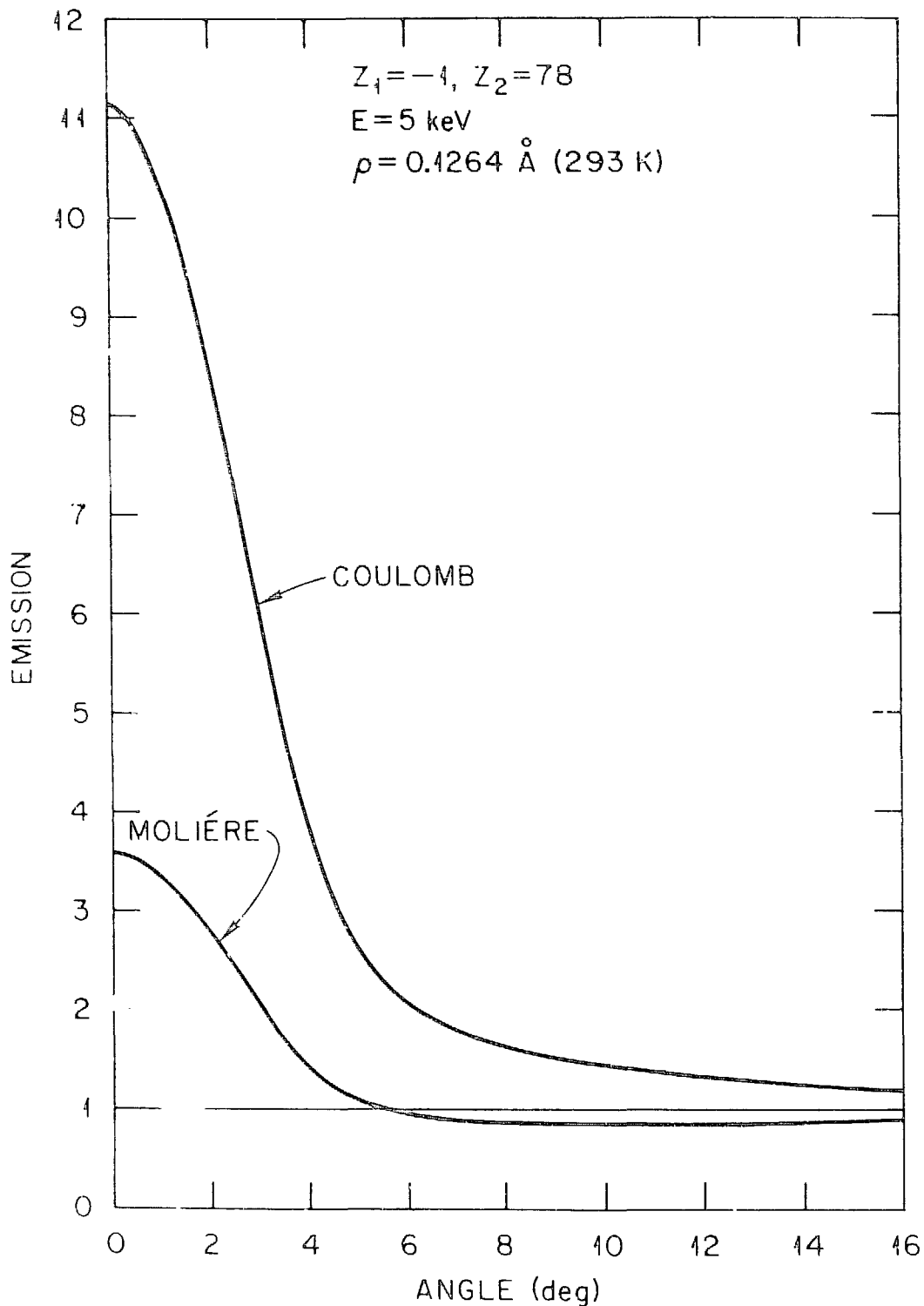
K_r is modified Bessel fcn. of 3rd kind

$$F(0) = \eta \exp(-\alpha \pm \eta) K_1(\eta)$$

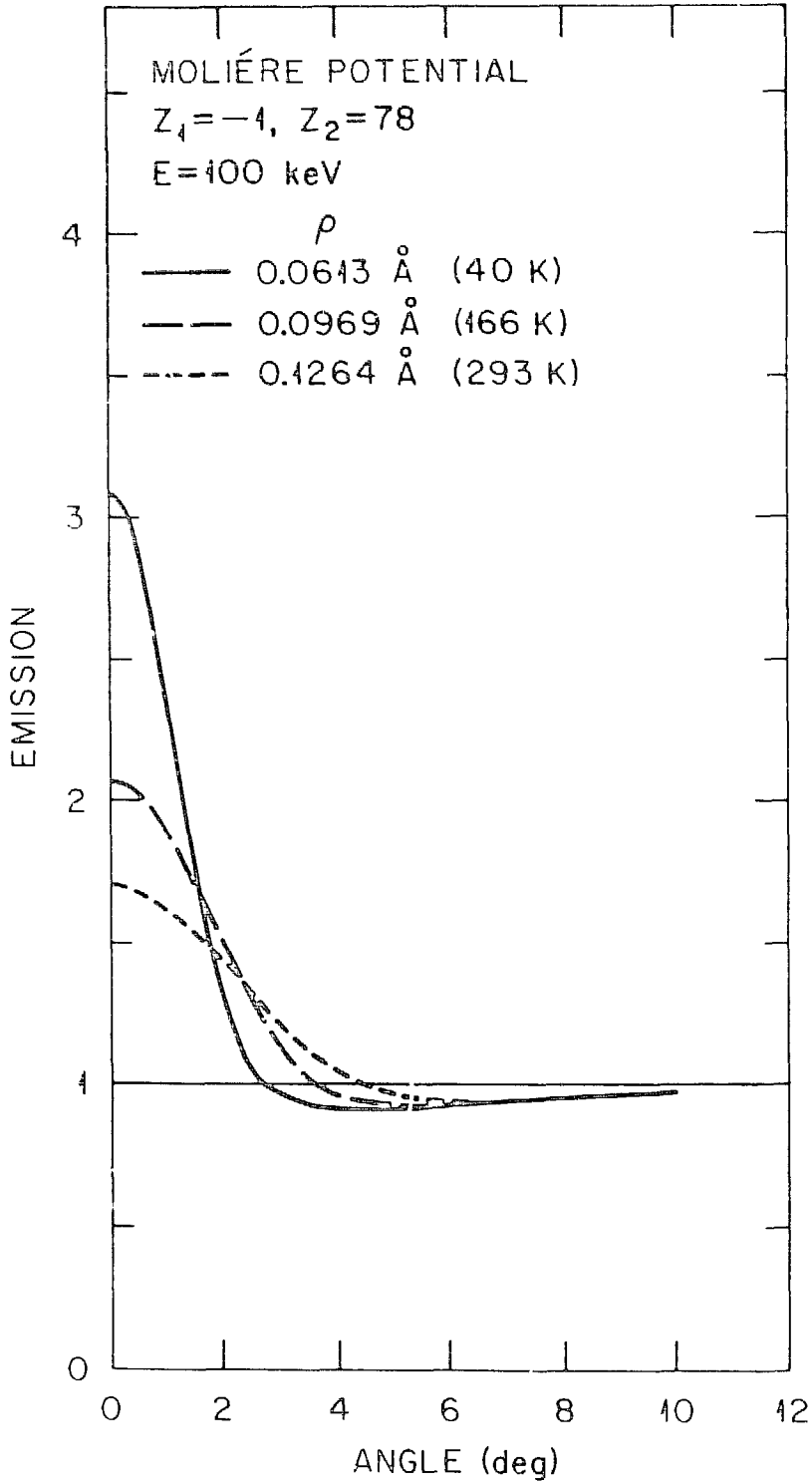
EMISSION vs ANGLE FOR
DIFFERENT ENERGIES

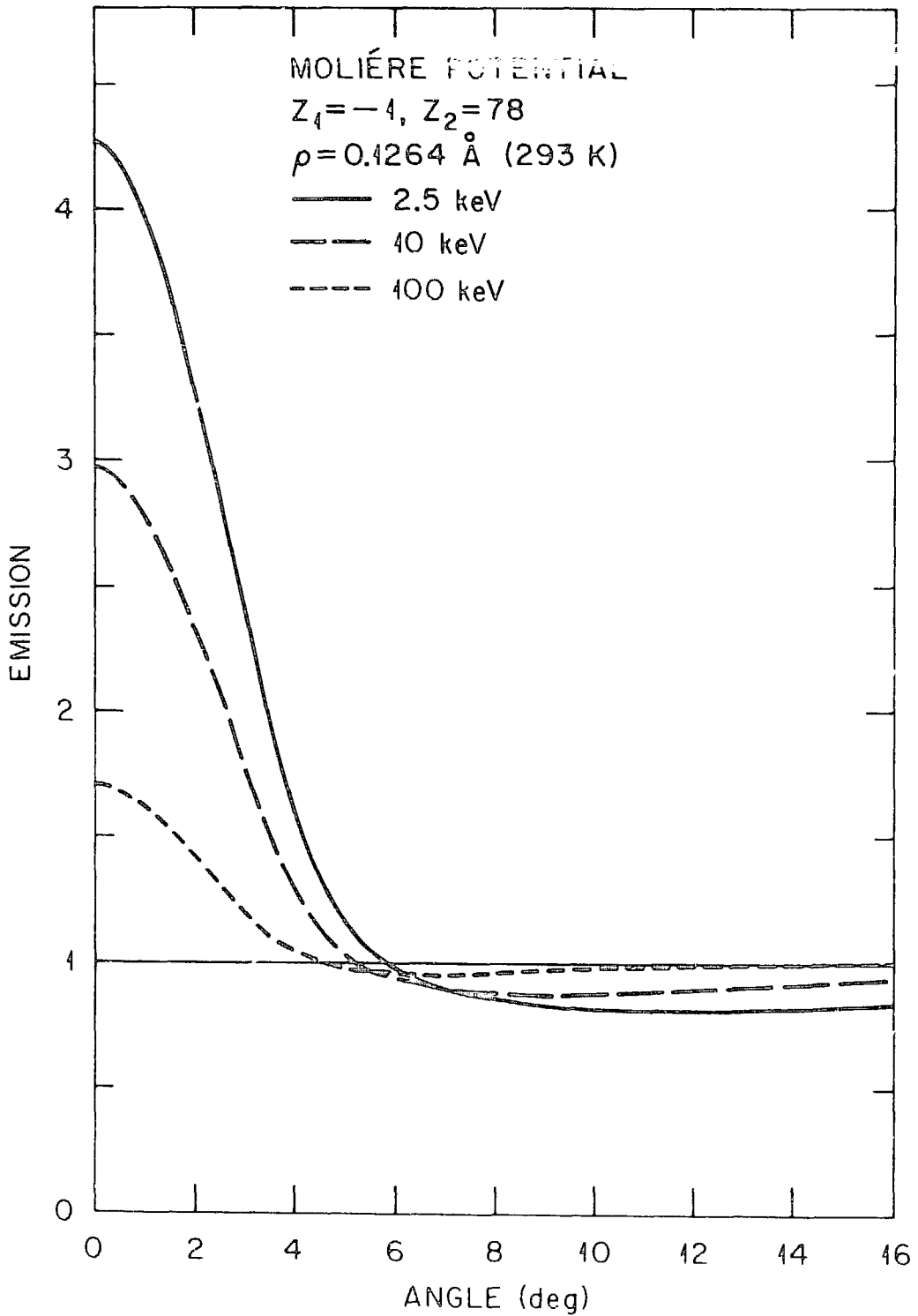


EMISSION vs ANGLE FOR MOLIÉRE AND COULOMB SCATTERING

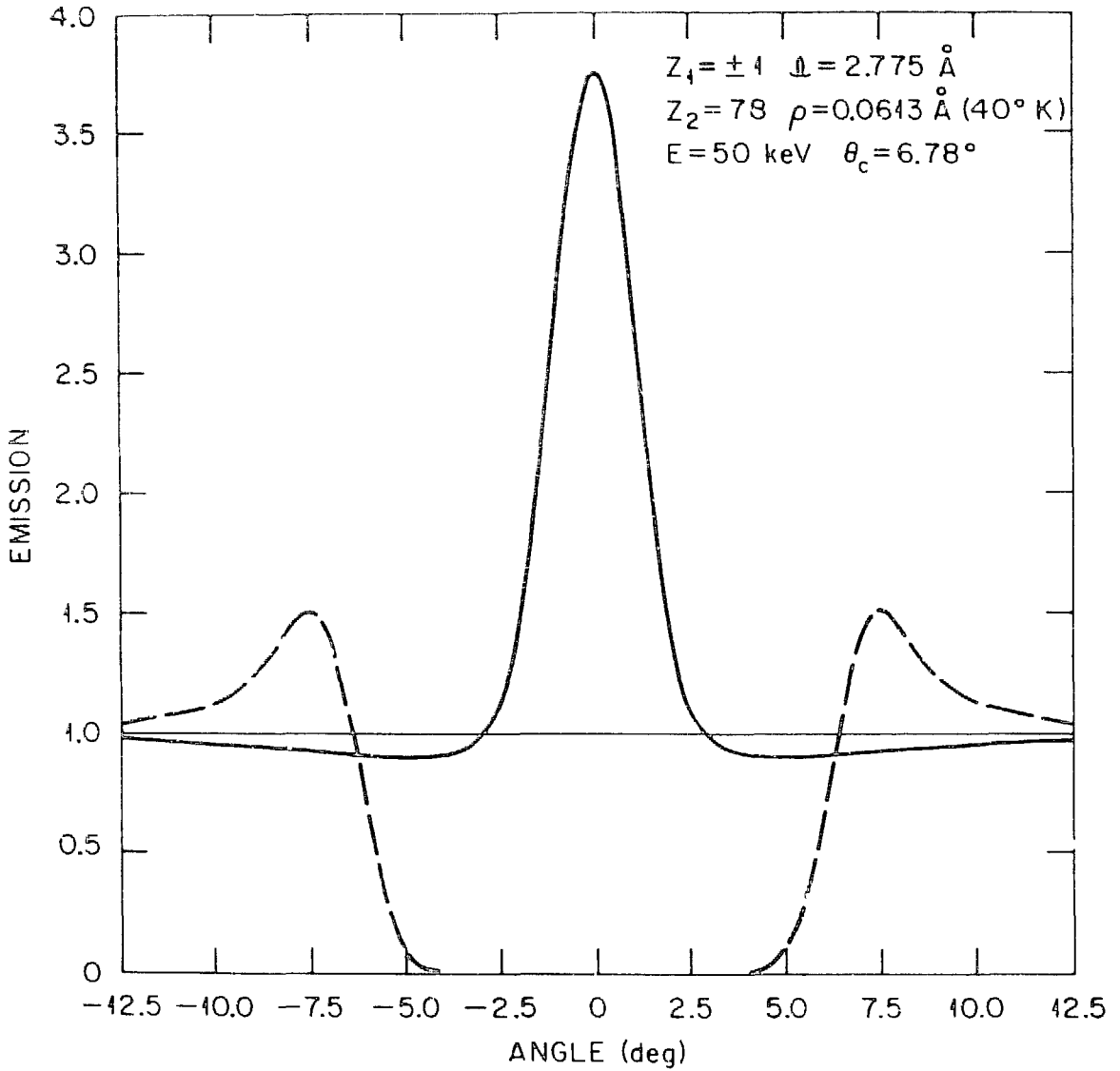


EMISSION vs ANGLE FOR
DIFFERENT TEMPERATURES

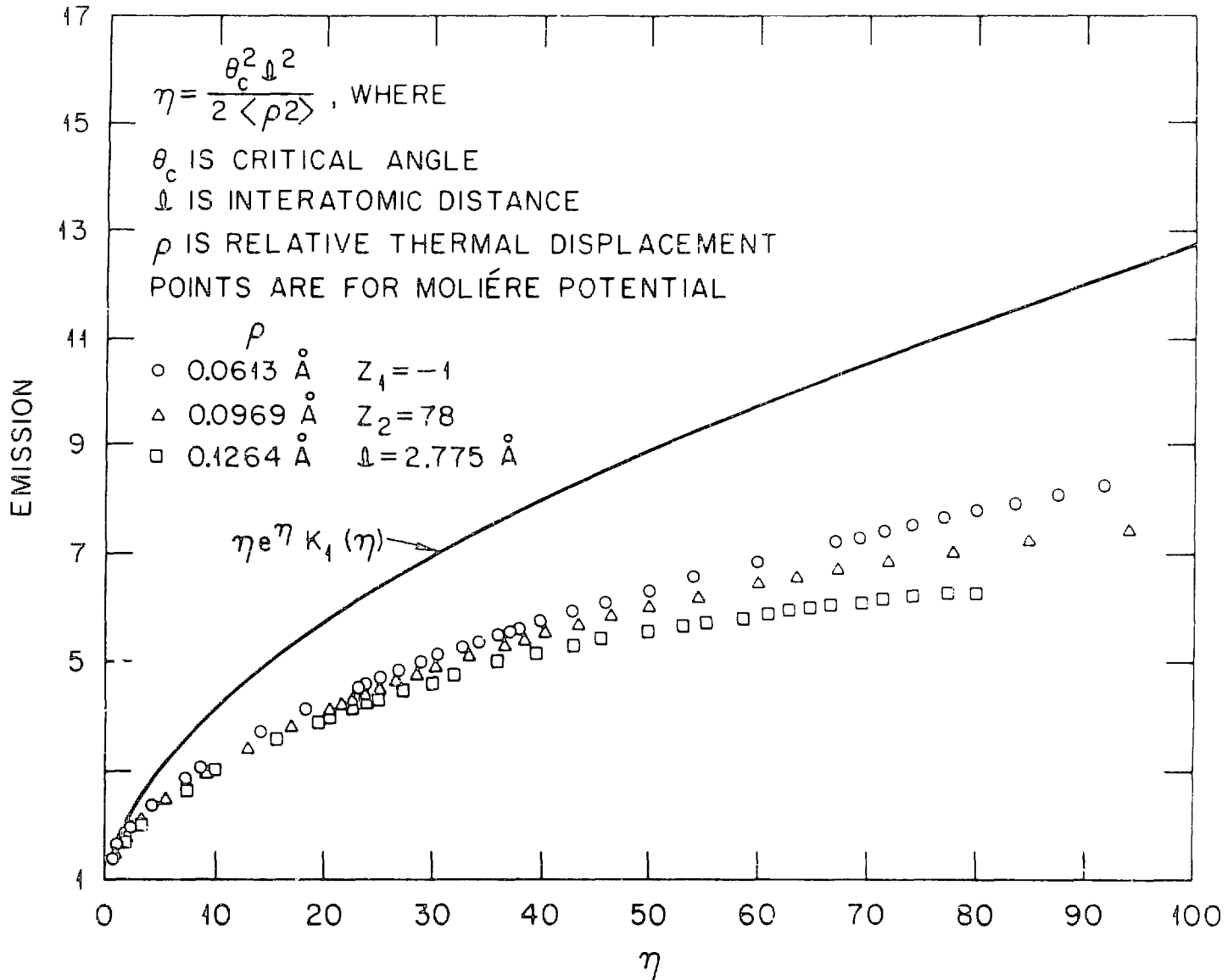


EMISSION vs ANGLE FOR
DIFFERENT ENERGIES

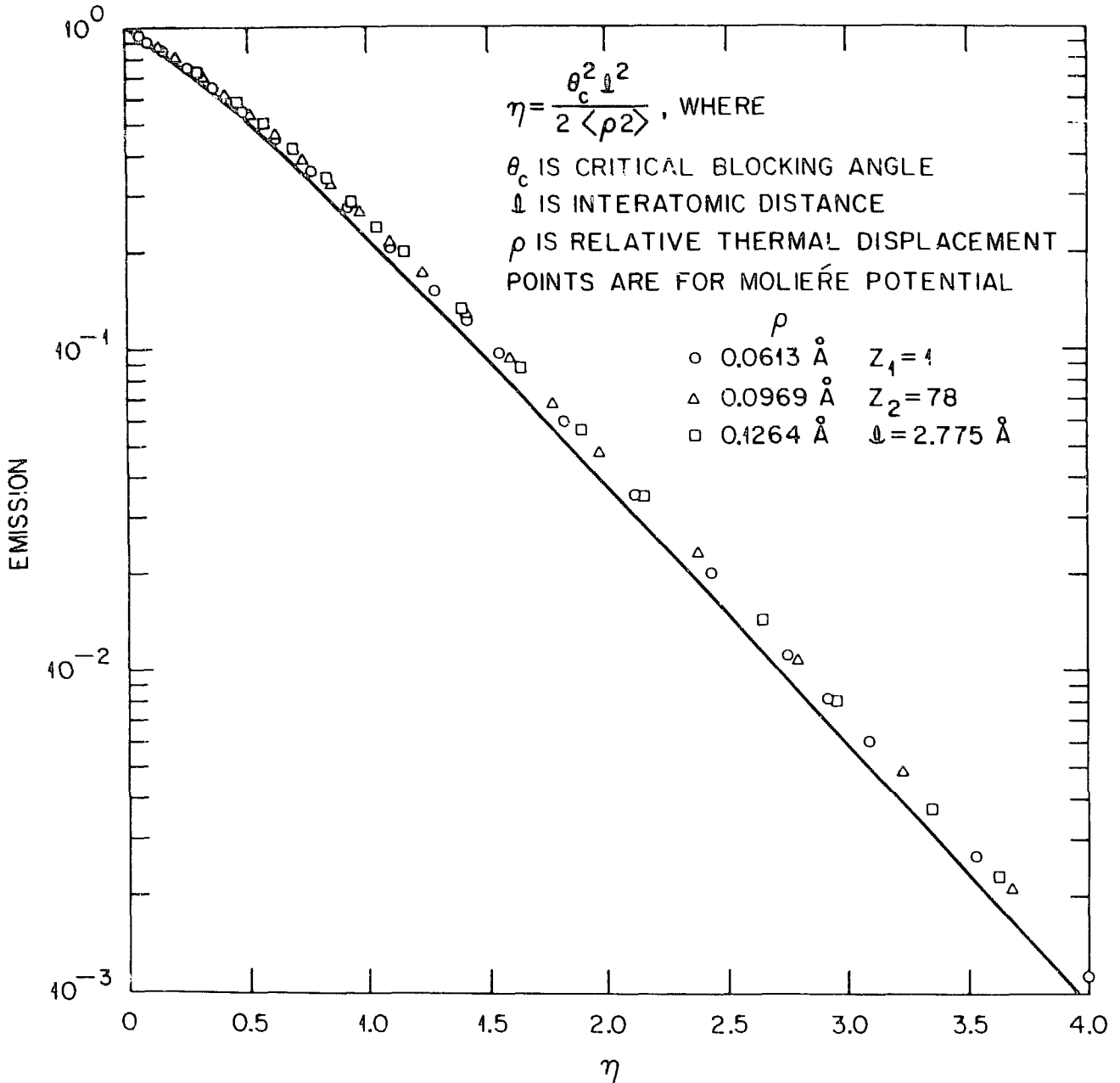
EMISSION vs ANGLE FOR ATTRACTIVE AND
 REPULSIVE MOLIÉRE POTENTIALS



EMISSION AT 0° vs REDUCED VARIABLE η FOR ATTRACTIVE POTENTIAL



EMISSION AT 0° vs REDUCED VARIABLE η FOR
REPULSIVE POTENTIAL



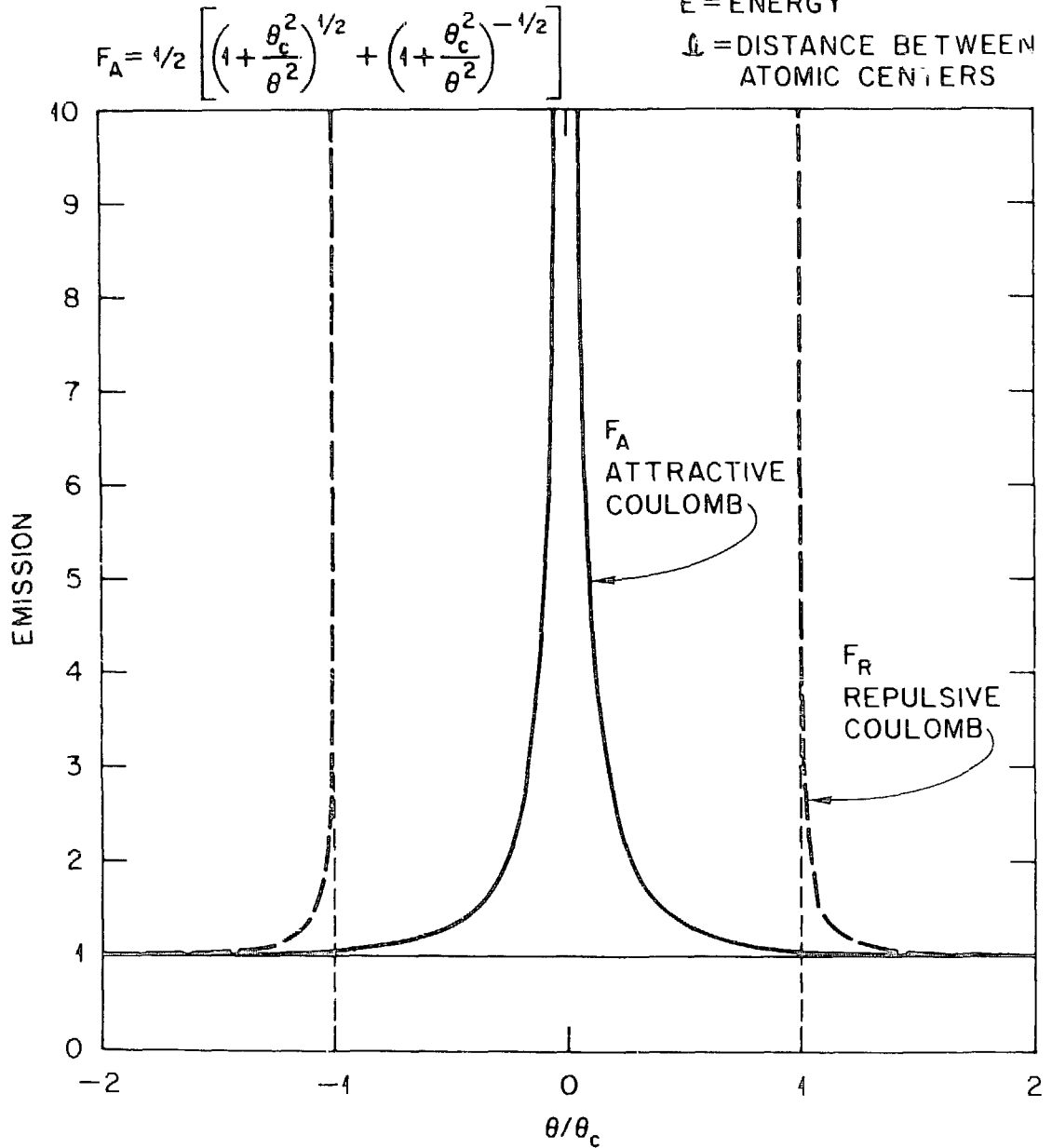
EMISSION vs REDUCED ANGLE

$$F_R = \frac{1}{2} \left[\left(1 - \frac{\theta_c^2}{\theta^2}\right)^{1/2} + \left(1 - \frac{\theta_c^2}{\theta^2}\right)^{-1/2} \right]$$

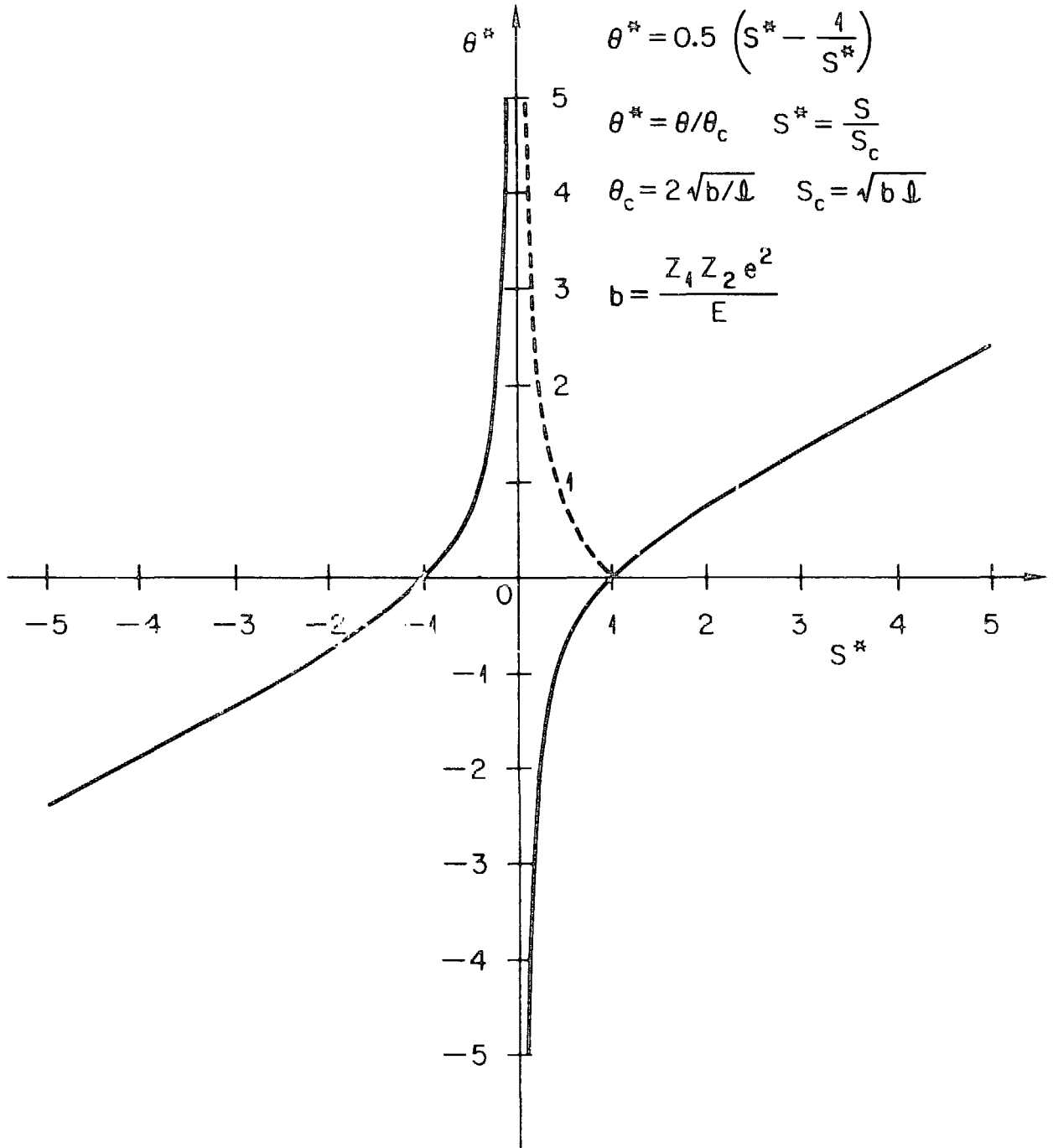
$$\theta_c = 2 \sqrt{\frac{Z_1 Z_2 e^2}{\Delta E}}$$

E = ENERGY

Δ = DISTANCE BETWEEN ATOMIC CENTERS



REDUCED DEVIATION ANGLE θ^{**} vs REDUCED IMPACT
 PARAMETER S^{**} (ATTRACTIVE COULOMB POTENTIAL)



REDUCED DEVIATION ANGLE θ^* vs REDUCED IMPACT
PARAMETER S^* (REPULSIVE COULOMB POTENTIAL)

$$\theta^* = 0.5 \left(S^* + \frac{1}{S^*} \right)$$

$$\theta^* = \theta / \theta_c \quad S^* = \frac{S}{S_c}$$

$$\theta_c = 2 \sqrt{b/l} \quad S_c = \sqrt{b/l}$$

$$b = \frac{Z_1 Z_2 e^2}{E}$$

