Coulomb gap. Efros-Shklovskii law.

In principle, in a strongly disordered system the potential felt by a newly added electron depends on the other electrons in the system.

Let's assume there are localisation centres, labelled by their indices. The energy needed to add an electron on impurity i

$$\varepsilon_i = U_i - \sum_{k\neq i}^{acc} \frac{e^2}{|r_i - r_k|} + \sum_{k\neq i}^{don} \frac{e^2}{|r_i - r_k|} + \sum_{k\neq j} \frac{n_j}{|r_i - r_j|}$$

Potential on i-th impurity

(acceptor = impurity with charge $-e$, may trap an electron)

(donor = impurity with charge e, may lose an electron = accept a hole)

At $T=0$ there is some ground-state configuration of charges, and we may introduce energies ε_i^+ and ε_i^- of particle and hole excitations.

The energy needed to create a „dipole" = particle-hole excitation

e^2

= particle - hole excitation

$$\varepsilon_{ij}^{+-} = \varepsilon_i^{+} + \varepsilon_j^{-} - \frac{e^2}{r_{ij}}$$

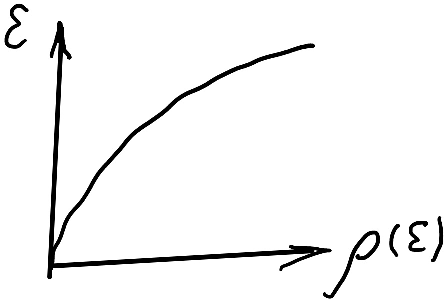
Sites of energy $\sim \varepsilon$ cannot be too close to each other. $\varepsilon \gtrsim \frac{e^2}{r(\varepsilon)}$

The concentration of sites with energies $\lesssim \varepsilon$

$$N(\varepsilon) \lesssim \left(\frac{\varepsilon}{e^2}\right)^d$$

From considering higher-order excitations, stricter constraints do not arise, so we may assume that the inequality is saturated

$$N(\varepsilon) \sim \left(\frac{\varepsilon}{e^2}\right)^d \longrightarrow \boxed{\rho(\varepsilon) \sim \frac{\varepsilon^{d-1}}{e^{2d}}}$$



Also, the only combination allowed by dimensions!!!

Hopping transport

$$\frac{r(\varepsilon)}{\xi} + \frac{\varepsilon}{T} \to \min$$

$$\frac{e^2}{\cdots} + \frac{\varepsilon}{T} \to \min \implies \varepsilon \sim \left(\frac{e^2}{T\xi}\right)^{\frac{1}{2}}$$

$$\frac{e^2}{\varepsilon \xi} + \frac{\varepsilon}{T} \rightarrow \min \Rightarrow \varepsilon \sim (T\xi)$$

$$\boxed{R(T) \sim e^{\left(\frac{T_0}{T}\right)^{\frac{1}{2}}} \quad \text{with } T_0 \sim \frac{e^2}{\xi}}$$