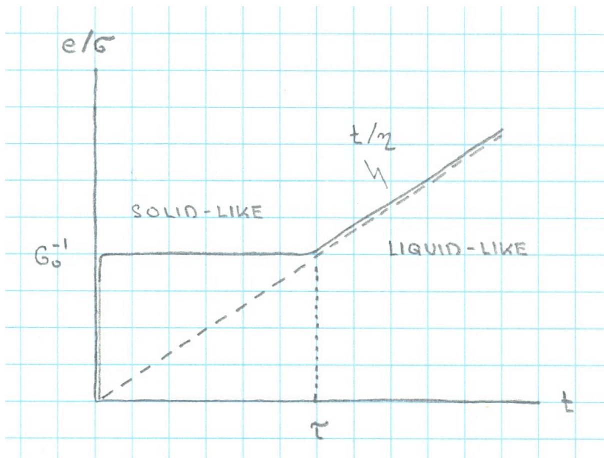
Simple model of viscoelasticity [pln23]

Characteristic stress relaxation time τ delimits regimes:

- $t \ll \tau$: solid-like (elastic) response, $\sigma = G_0 e \quad \Rightarrow \quad \dfrac{e}{\sigma} = G_0^{-1}$,
- $t \gg \tau$: liquid-like (viscous) response, $\sigma = \eta \dot{e} \quad \Rightarrow \quad \dfrac{e}{\sigma} = \eta^{-1} t$,
- $t \simeq \tau$: crossover behavior



Relation between shear modulus G_0 and viscosity η from graph e/σ vs t:

$$\frac{G_0^{-1}}{\tau} = \eta^{-1} \quad \Rightarrow \quad \eta = G_0 \tau.$$

Relaxation is due to thermally activated hopping: $\tau^{-1} = \nu \exp\left(-\dfrac{\epsilon}{k_B T}\right)$

- ▷ ϵ: energy barrier for hopping,[1]
- ▷ ν: optical phonon frequency.

Arrhenius law: $\eta = \dfrac{G_0}{\nu} \exp\left(\dfrac{\epsilon}{k_B T}\right) \quad \Rightarrow \quad \ln \eta \propto \dfrac{1}{k_B T}$.

Arrhenius law experimentally verified at not too low T.

In a more realistic scenario the viscoeleastic response is described by multiple relaxation times.

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[1] as derived, for example, from the latent heat of vaporization per molecule.