# QOS - Vacuum Considerations

Peter Mioduszewski
ORNL

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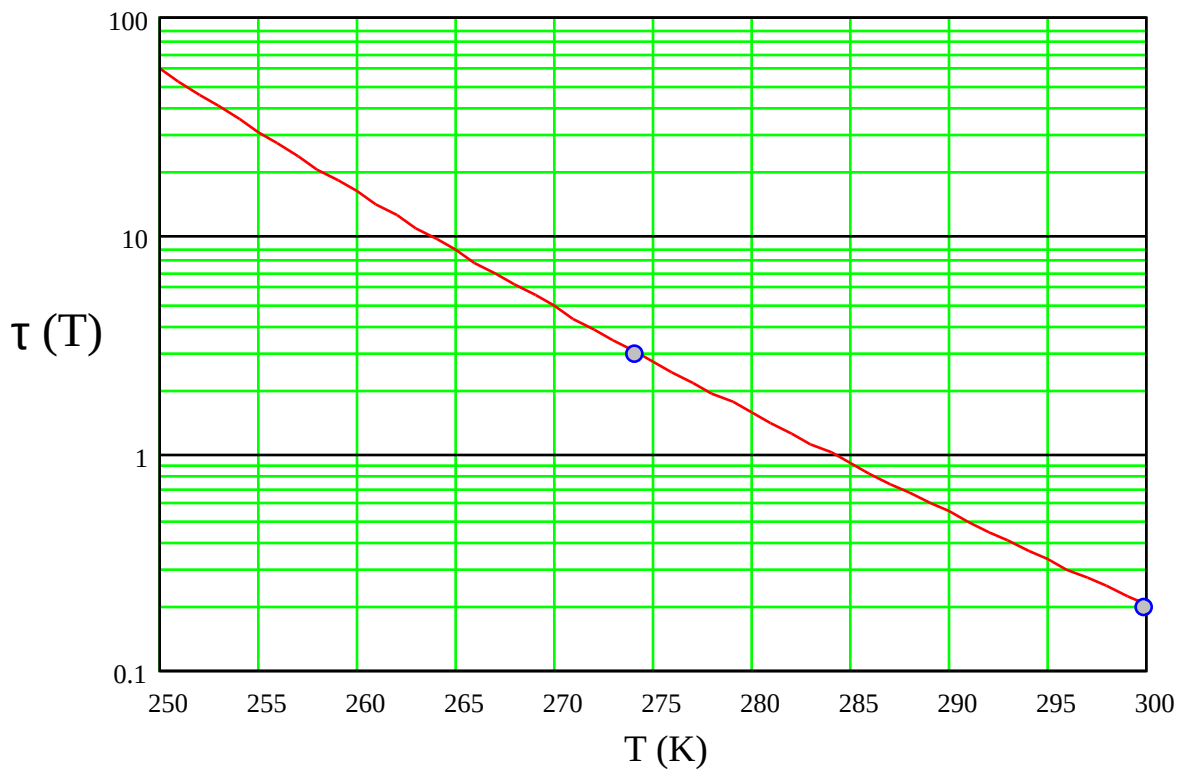
# In-Vessel Temperature Differences ?

- The question is whether or not we can have the coil casings at a lower temperature than the ambient temperature (of the vacuum vessel).
- The concern is, of course, that between shots impurities will accumulate on the colder surfaces and subsequently be released during the plasma discharge.
- Can we get a quantitative estimate for the impurity accumulation ?
- Here is the difficulty: surface physics is usually done under “clean” conditions, i.e. on super-clean single crystal surfaces with well defined conditions such as adsorption energies, etc.
- Technical surfaces have various degrees of surface roughness, oxide layers, contaminants, etc. and ill-defined adsorption energies, sticking coefficients, etc.; hence, quantitative estimates have to be taken with a (big) GRAIN of salt.

# Time of Sojourn As a Function Surface Temperature

The “time of sojourn” of a particle on the surface is given by the Frenkel equation:

$$\text{"Time of sojourn":} \quad \tau(T) = \tau_0 \, e^{\frac{E_D}{R \cdot T}} \quad \text{with} \quad \tau_0 = 10^{-13} s$$




$E_D$ = 17 kcal/mole
(water on s.s.)

T=273 K:
τ = 3s

T=300 K
τ = 0.2s

# Adsorption / Desorption Equilibrium

**Rate of adsorption:**

$$R_A = \alpha \cdot \frac{n \cdot v}{4} = \alpha \cdot 3.5 \cdot 10^{23} \frac{p}{\sqrt{M \cdot T_0}}$$

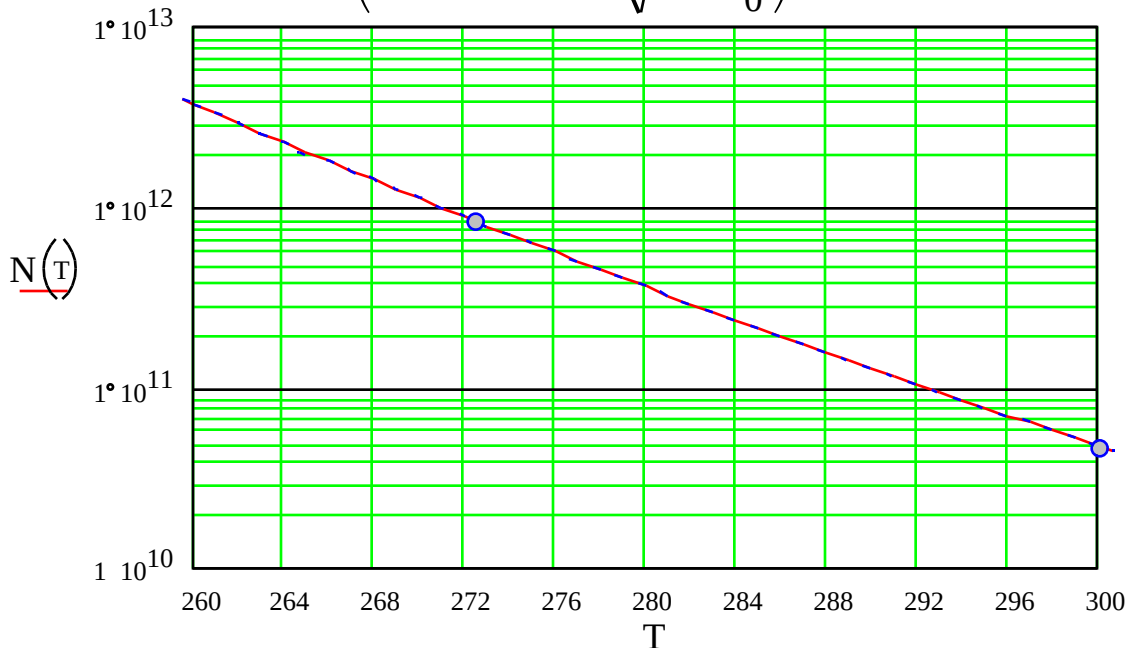
n=particle density in gas
N= on surface

**Rate of Desorption:**

$$R_D = \frac{N}{\tau(T)} = \frac{N}{\tau_0} e^{\frac{E_D}{R \cdot T}}$$

**Equilibrium surface coverage:**

$$N(T) = \left( \alpha \; 3.5 \cdot 10^{22} \frac{p}{\sqrt{M \cdot T_0}} \right) \tau_0 \; e^{\frac{E_D}{R \cdot T}}$$




$\alpha = 0.1$
$E_D = 17$ kcal/mole
$p = 5 \times 10^{-9}$ Torr

**T = 273 K**
**N = $8 \times 10^{11}$ cm$^2$**

**T = 300 K**
**N = $5 \times 10^{10}$ cm$^2$**

(in equilibrium!)

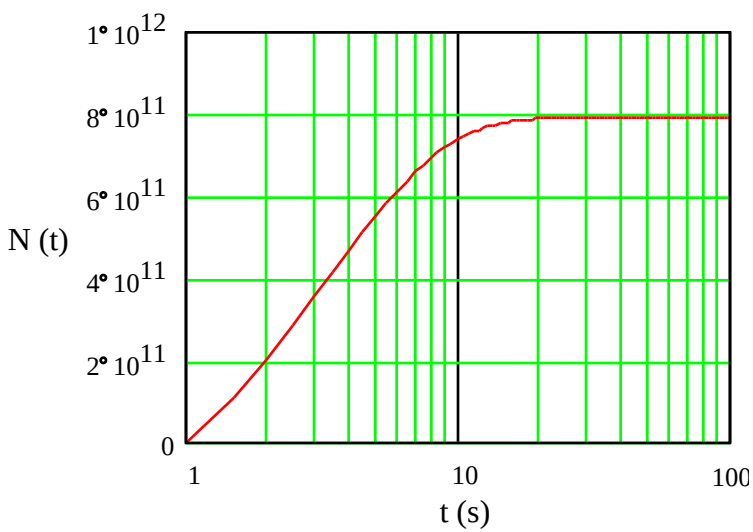
# How Fast Is Equilibrium Coverage Reached ?

We can assume that the equilibrium coverage is reached between discharges!

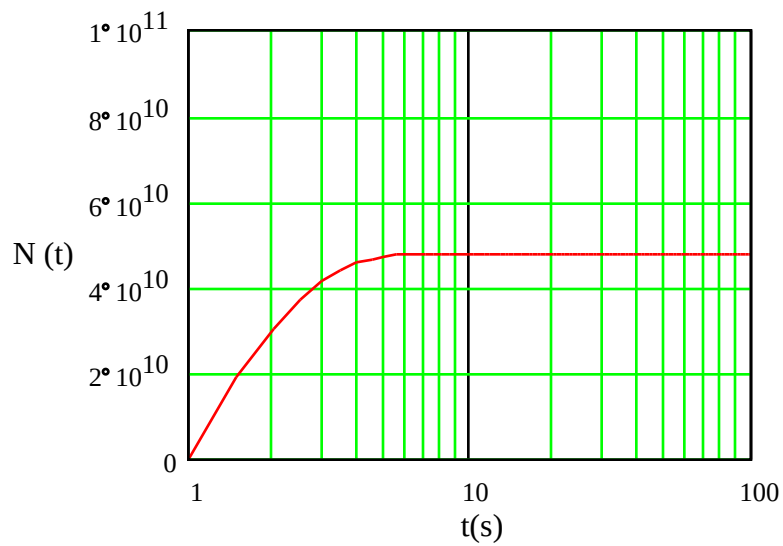
**Surface coverage evolution:**

$$\frac{dN}{dt} = \alpha \cdot 3.5 \cdot 10^{23} \cdot \frac{p}{\sqrt{M \cdot T_0}} - \frac{N}{\tau_0} \cdot e^{\frac{E_D}{R \cdot T}}$$

T = 273 K




T = 300 K



# Conclusions

- If the total cold surface area is as large as the vacuum vessel and roughly 1/4 of it is exposed to the plasma, then the total number of impurities available for the plasma is:

$$N_i = 8 \cdot 10^{11}\,\mathrm{cm}^{-2} \cdot 10^{4}\,\mathrm{cm}^{2} \cdot 15\mathrm{m}^{2} = 12 \cdot 10^{17}$$

- This would be less than one percent of the plasma inventory !
- Although this is not desirable, it doesn't look like a show stopper.
- Major uncertainties in the estimates are in the sticking coefficients and in the adsorption energies, which can depend strongly on the surface conditions.
- Need to do sensitivity analysis with reasonable (possible) ranges of surface parameters.

# Other Vacuum Considerations: O-Rings

- A concern arose about the outgassing of the viton o-rings:
- The total surface area of the o-rings exposed to the vacuum can be as high as 4 $m^2$ and the usually quoted outgassing rates would result in residual gas pressures of about an order of magnitude higher than desired (at the given pumping speeds).
- Good news: we found that outgassing rates can be reduced by 2 orders of magnitude by baking the viton at atmospheric pressures at 150$^o$C (P. Goranson).
- We conclude that with baked viton o-rings and double seals, vacuum conditions should be adequate.
- However, the bell-jar needs to be vacuum-tested before a final decision is made concerning it's usefulness .