Exercice 3: Nucleation and growth

1) What are the 4 nucleation and growth models?
2) What property and parameters determine:
   - The nucleation and growth mode?
   - The number density of available nucleation sites?
   - There exists a special case named « underpotential deposition ». Define it!
3) The induction time is the formation of critical nuclei and their growth as discrete islands on the substrate.

   3.1. Show that the current that crosses a single hemispherical nucleus and a single cylindrical nucleus varies with t^2 and t, respectively.

   3.2. Considering that nucleation follows a linear kinetics model $\mathrm{N(t)} = N_0(1 - e^{-k_n t})$, express the total current as a function of the time for the 4 scenarios. (no overlapping)

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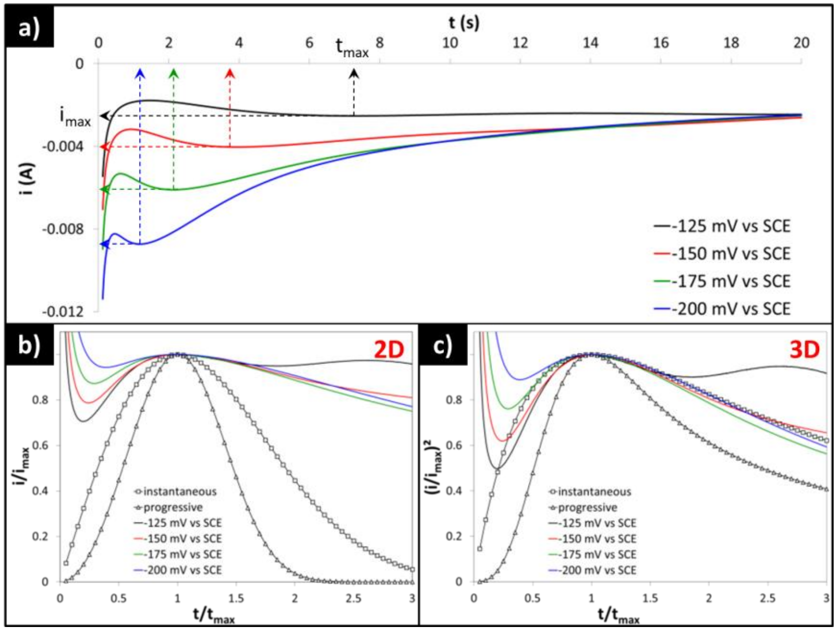
4) Accounting for overlapping, Scharifker and coworkers established the following equations:

	Instantaneous	Progressive
3D	$\left(\frac{i}{i_{max}}\right)^2 = 1.9542\left(\frac{t_{max}}{t}\right)\left[1 - exp^{-1.2564\left(\frac{t}{t_{max}}\right)}\right]^2$	$\left(\frac{i}{i_{max}}\right)^2 = 1.2254\left(\frac{t_{max}}{t}\right)\left[1 - exp^{-2.3367\left(\frac{t}{t_{max}}\right)^2}\right]^2$
2D	$\left(\frac{i}{i_{max}}\right) = \left(\frac{t}{t_{max}}\right)e^{\left[\frac{1}{2}-\frac{1}{2}\left(\frac{t}{t_{max}}\right)^2\right]}$	$\left(\frac{i}{i_{max}}\right) = \left(\frac{t}{t_{max}}\right)^2 e^{\left[\frac{2}{3}-\frac{2}{3}\left(\frac{t}{t_{max}}\right)^3\right]}$

Copper depositions below -150 mV vs SCE demonstrated 3D instantaneous nucleations. Integrating the quantity of charge at t_{max} gives:

$$Q_{max} = \int_0^{t_{max}} i(t).dt = \mathbf{0.83545}\, \boldsymbol{i_{max}}\, \boldsymbol{t_{max}}$$

SEM observations showed that the contact angle was 90°, making perfect hemispherical nuclei.



1) Express the maximum radius of nuclei and their density under the assumption that Nuclei are ideally packed on the surface (compact hexagonal arrangement)

2) For a 1 cm^2 substrate, you integrated Q_{max} and found 12.7 mC, 10.5 mC, and 8.3 mC at -150 mV, -175 mV, and -200 mV, respectively. What can you conclude? (z=2 and V_m=7.09 $cm^3.mol^{-1}$)