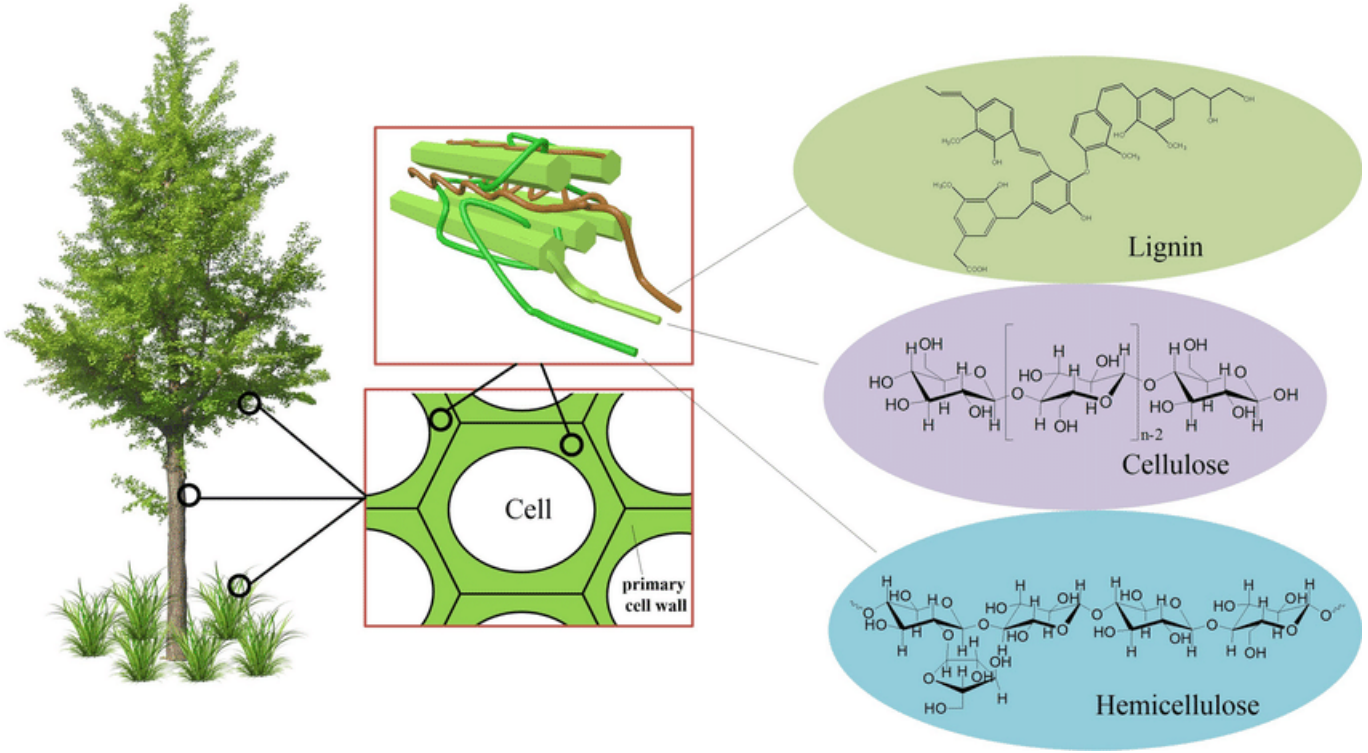
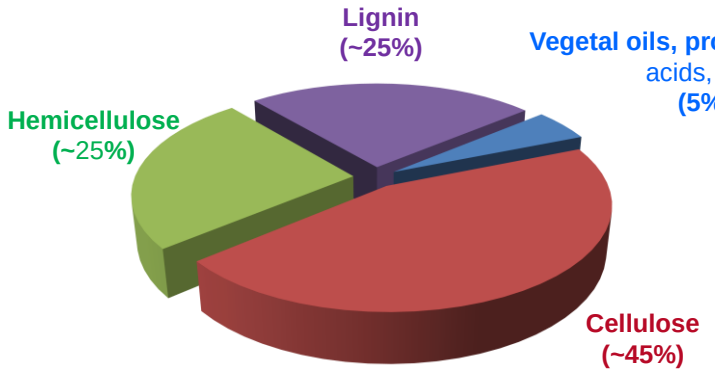
L’hydrogène comme coproduit de la conversion électrocatalytique du glucose en composés à haute valeur ajoutée

T. Faverge, N. Neha, T. Rafaïdeen, B. Gilles, A. Bonnefont, F. Maillard, M. Chatenet, C. Coutanceau

christophe.coutanceau@univ-poitiers.fr

Non-edible ligno-cellulosic biomass





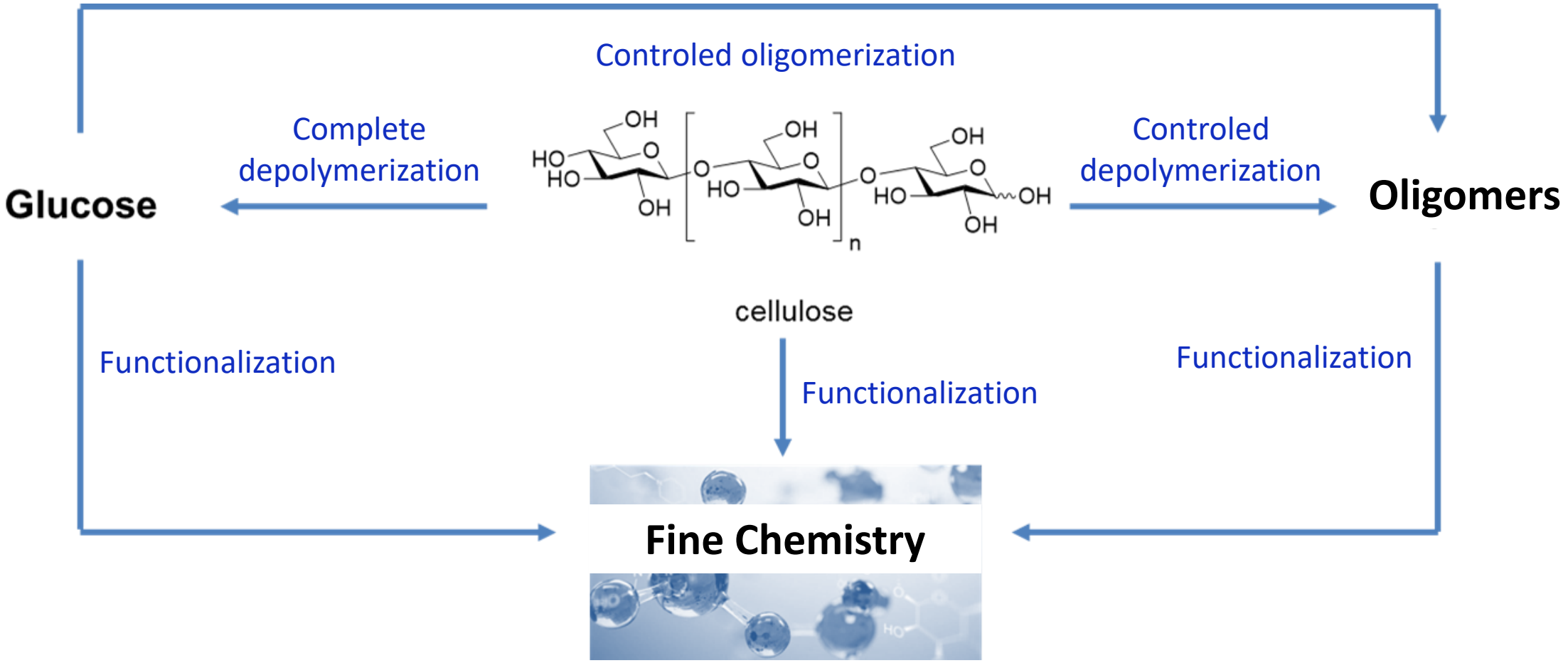
Biomass production > ***200 billion tons / y***

Fuels
ethanol, hydrocarbons, hydrogen, etc.

Fine chemistry
Platerform molecules : glucose, xylose, Furanic derivatives, bioethanol, glycerol, etc.

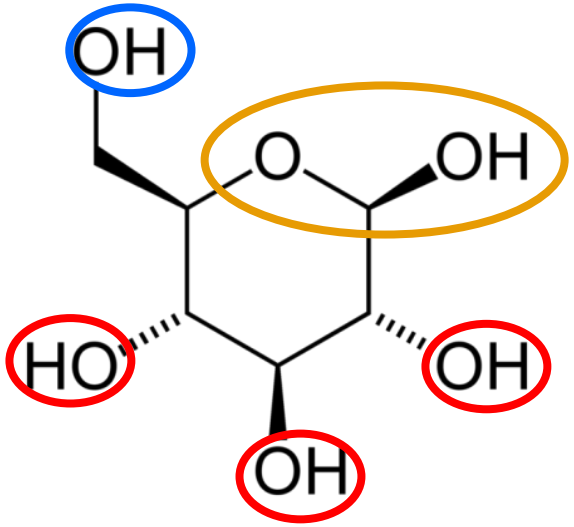
Z. Yuan, W. Dai, S. Zhang, F. Wang, J. Jian, J. Zeng, H. Zhou. Heterogeneous strategies for selective conversion of lignocellulosic polysaccharides. Cellulose 29 (2022)1-19.

Depolymerization of cellulose



Glucose as biomass model molecule

C6 : Primary alcohol
Themodynamically hard to oxidize



C1 : anomeric function
Can be oxidized or reduced

Secondary alcohols
Reactivity ?

Paired electrolysis

Biomass molecules from biorefinery:

=> either reduced or oxidized into valuable compounds,

Paired-electrochemical processes allow decreasing the electrical energy cost

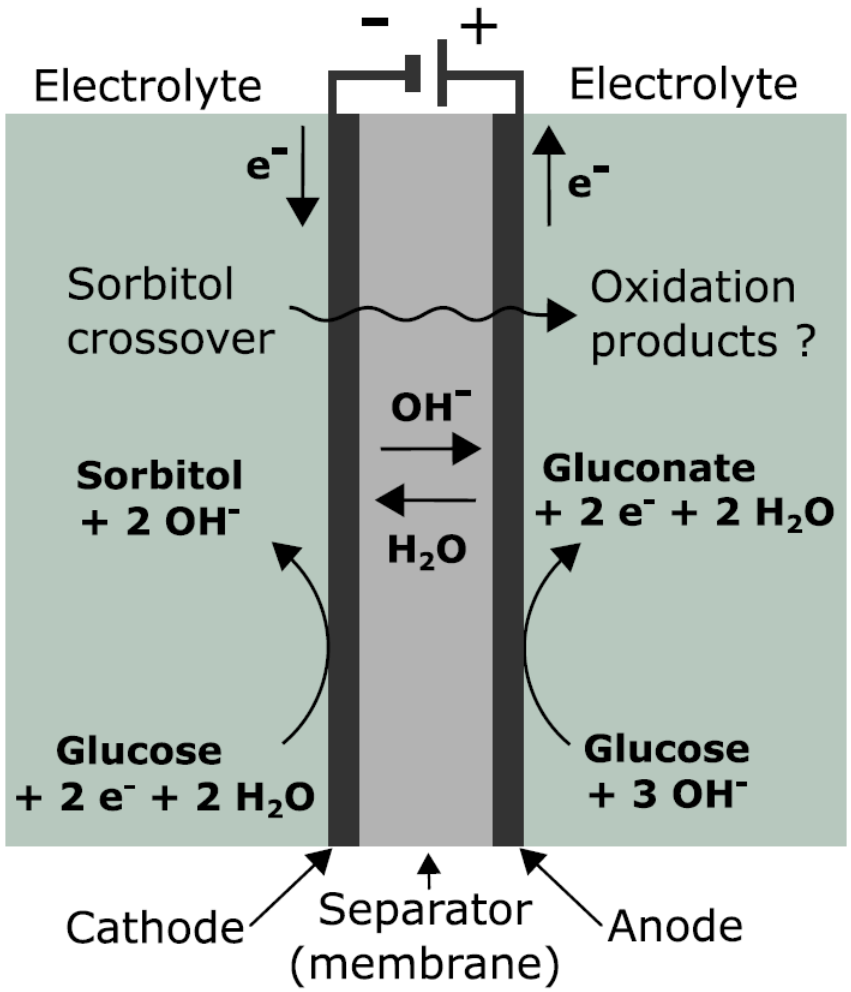
=> value-added compounds formed at both electrodes.

Process intensification can be achieved by the development of microreactors.

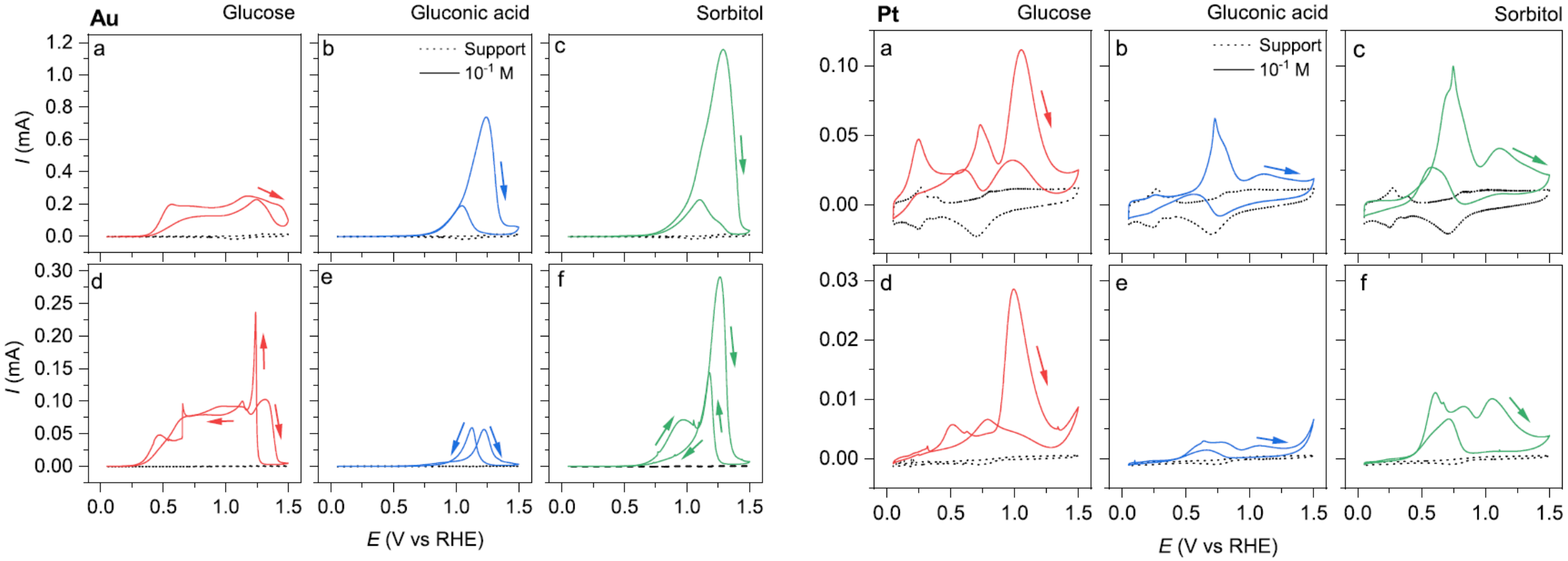
High activity of the electrocatalyst

High selectivity towards a given compounds (here gluconate)

Specificity towards a given reactant



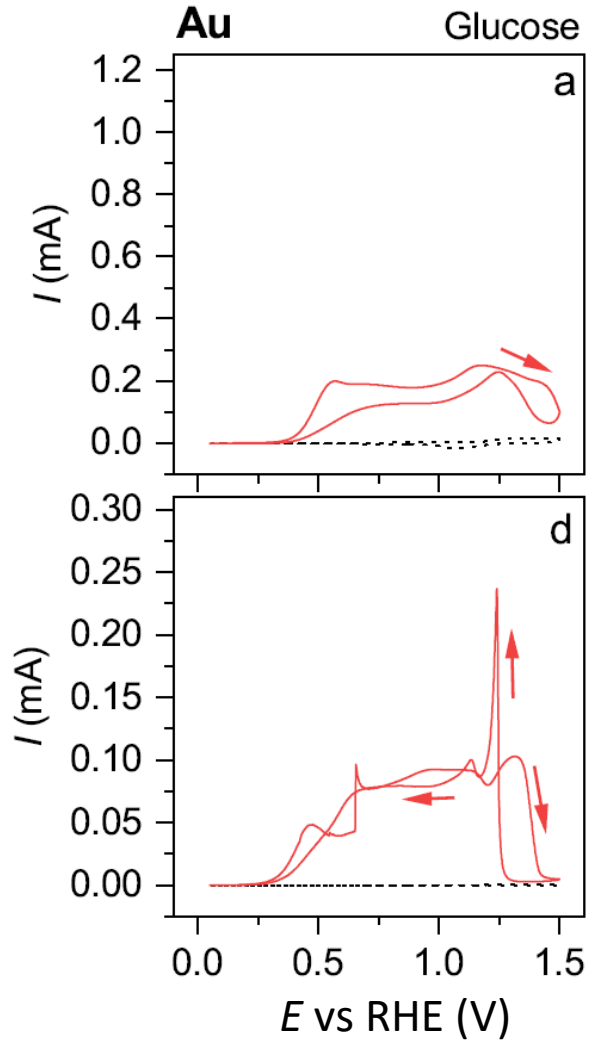
Au and Pt surfaces as illustrations

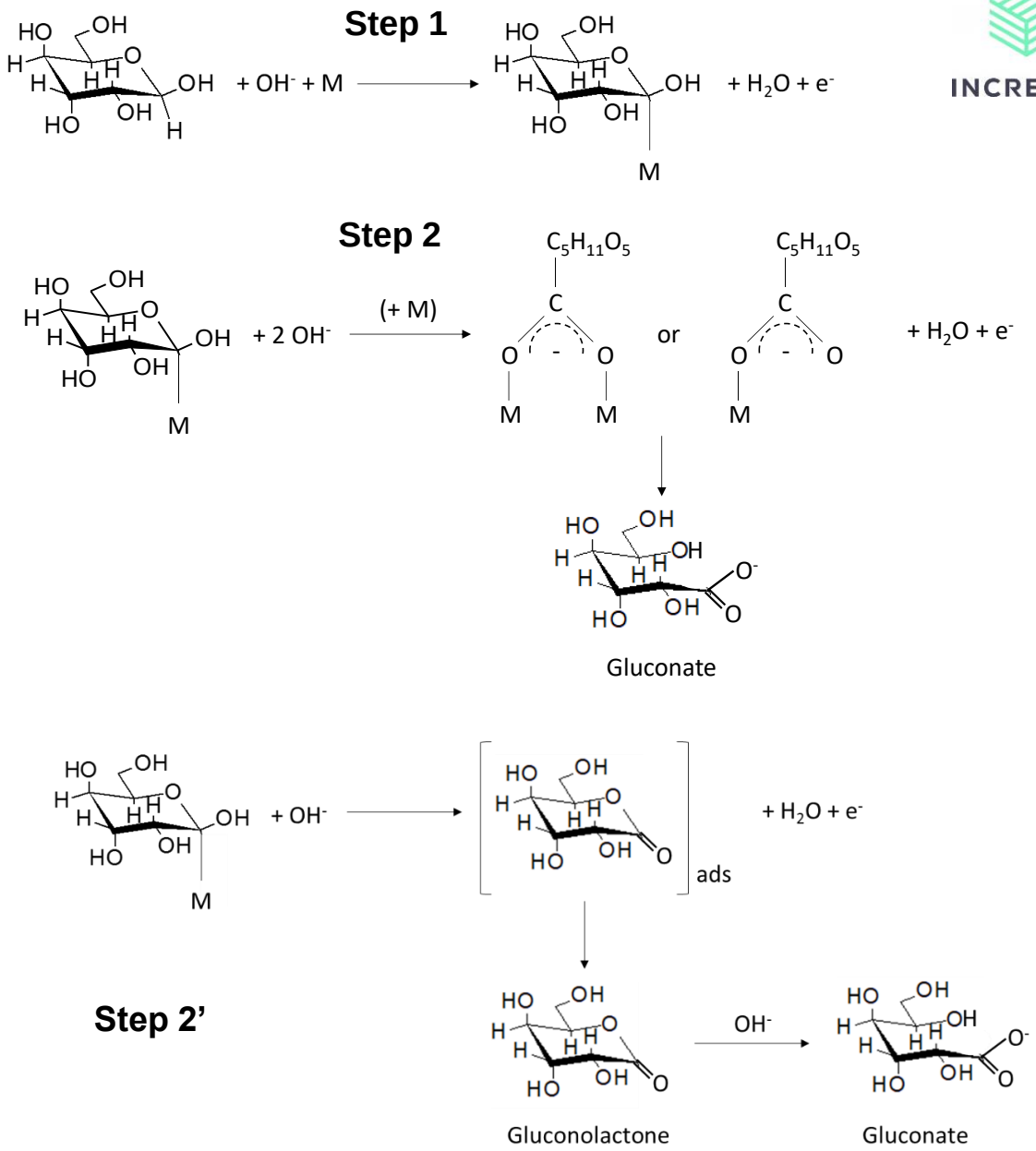


Cyclic voltammograms of bulk Pt and Au at 100 (upper panels) and 0.001 V.s^{-1} (lower panels). Blank cyclic voltammograms measured in supporting electrolyte (10^{-1} M NaOH) are reported in dotted (black) line, while cyclic voltammograms with 10^{-1} M glucose in supporting electrolyte are reported in solid line. T = 293 K

T. Faverge, B. Gilles, A. Bonnefont, F. Maillard, C. Coutanceau, M. Chatenet, In situ investigation of D-glucose oxidation into value-added products on Au, Pt and Pd under alkaline conditions: a comparative study. ACS Catal. 13 (2023) 2657–2669.

Generally proposed mechanism on Au

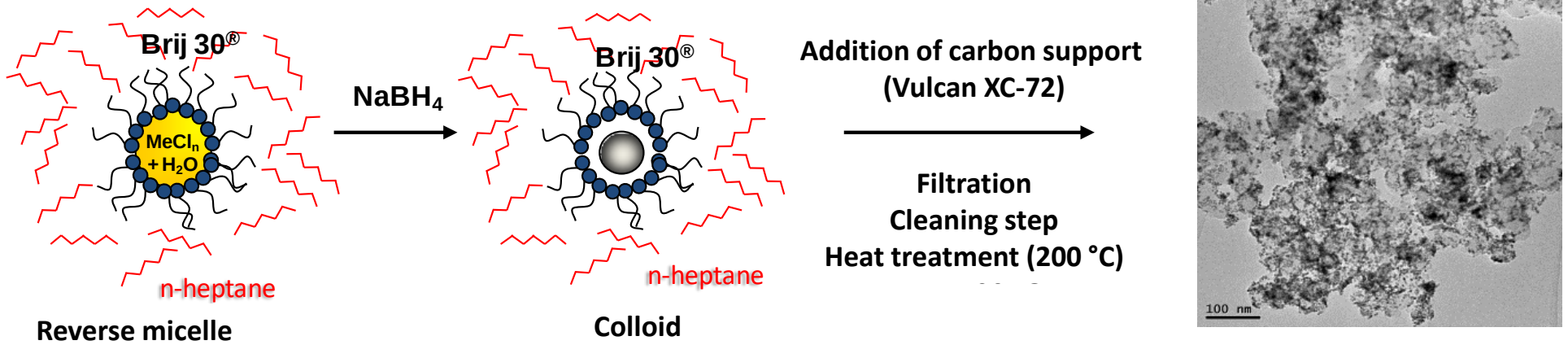




B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

M. Pasta, F. La Mantia, Y. Cui, Mechanism of glucose electrochemical oxidation on gold surface, Electrochim. Acta 55 (2010) 5561–5568.

Synthesis and characterization of Pt/C and Au/C



Synthesis parameters:

- ❑ $HAuCl_4 \bullet 3H_2O$
- ❑ Metal salt concentration: 0.1 mol L^{-1}
- ❑ Brij®30: 16.1 g
- ❑ Heptane: 37 g
- ❑ $NaBH_4$: 100 mg (large excess)
- ❑ Nominal metal loading: 40 wt%

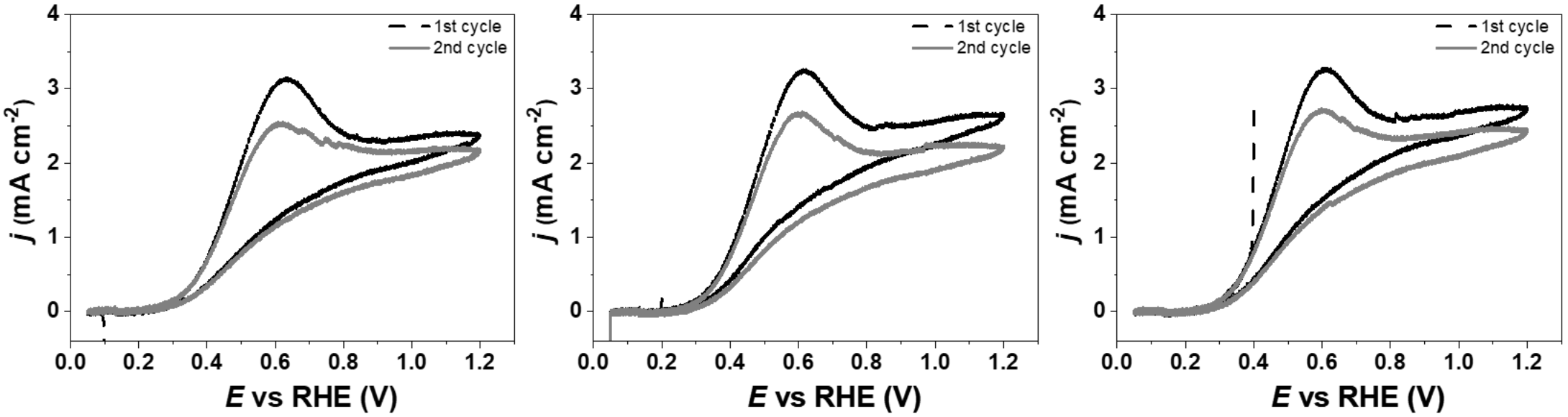
	W / wt% (TGA)	*a* / Å (XRD)	L_v / nm (XRD)	d_{TEM} (TEM)	ECSA / $m^2\ g^{-1}$ (CV*)
Au-NPs/C	35.4	4.047	4.4	6.8	14

* Reduction of AuO monolayer

T. Rafaïdeen, S. Baranton, C. Coutanceau, Highly efficient and selective electrooxidation of glucose and xylose in alkaline medium at carbon supported alloyed PdAu nanocatalysts, Appl. Catal. B: Env. 243 (2019) 641-656.

N. Neha, S. R. B. Kouamé, T. Rafaïdeen, S. Baranton, C. Coutanceau, Remarkably efficient carbon-supported nanostructured platinum-bismuth catalysts for the selective electrooxidation of glucose and methyl-glucoside, Electrocatalysis 12 (2021) 1-14.

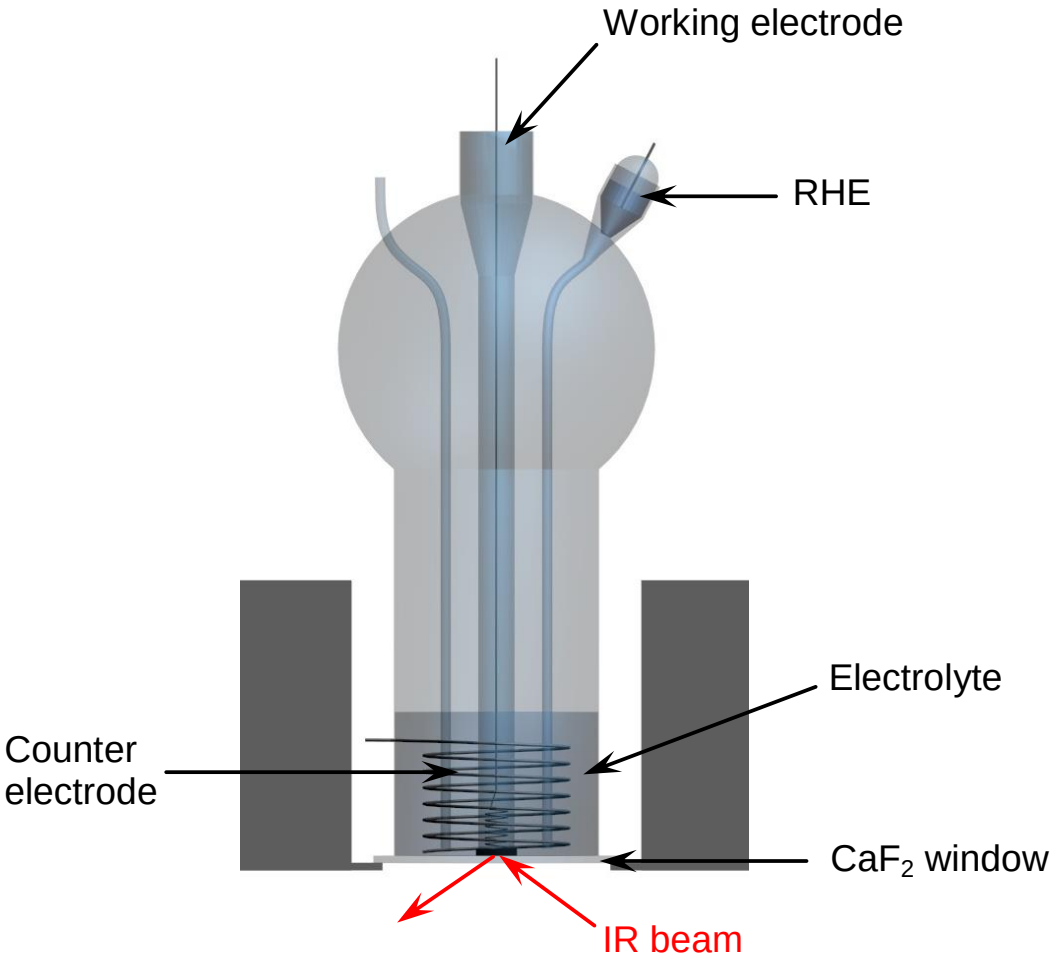
CVs recorded after CAs on Pt/C

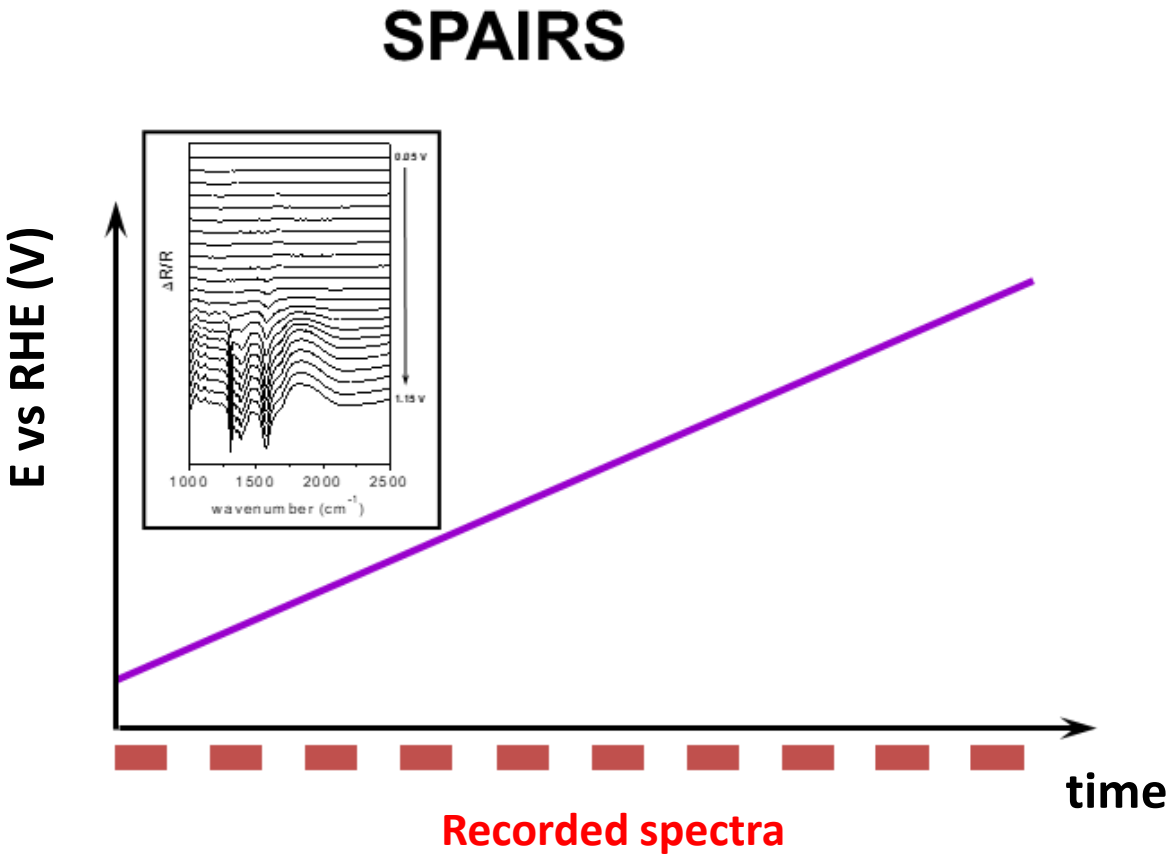


Cyclic voltammograms recorded in N_2-purged 0.10 mol L^{-1} NaOH electrolyte at a (a) Pt-NPs/C electrode and (b) Au/C electrode in the absence (black plain line), and in the presence (dotted black line for the first cycle and plain grey line for the second one) of 0.10 mol L^{-1} glucose after chronoamperometry.
Scan rate = 0.005 V s^{-1}, T = 293 K

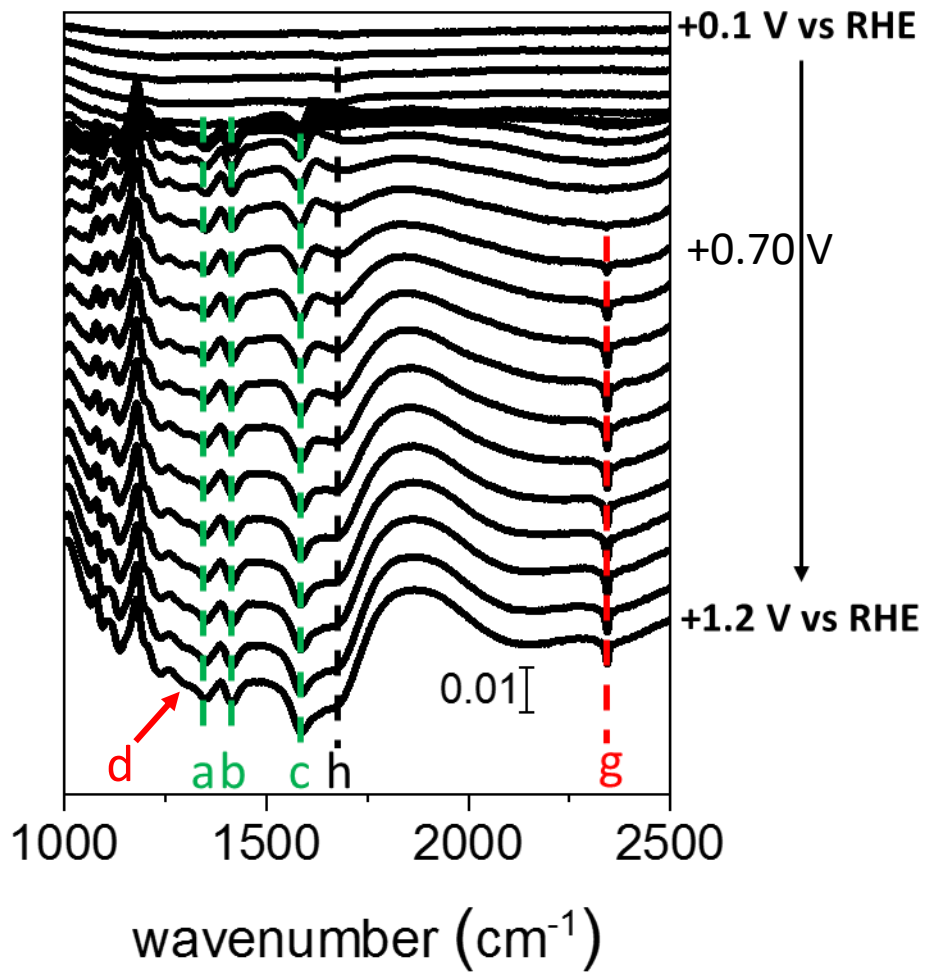
N. Neha, T. Rafaïdeen, T. Faverge, F. maillard, M. Chatenet, C. Coutanceau. Revisited mechanism for glucose electrooxidation at plartiunum and gold nanoparticles. Electrocatalysis 14 (2023) 121–130.

In-situ FTRIRS study





In-situ FTRIRS study on Au/C



IR spectra recorded every 0.050 V during 0.10 mol L^{-1} glucose electrooxidation in 0.10 mol L^{-1} NaOH electrolyte from +0.100 V to +1.200 V vs RHE on Au-NPs/C catalysts. Scan rate: 0.001 V s^{-1}, resolution 4 cm^{-1}, T = 293 K. Vertical scale: $\Delta R/R$

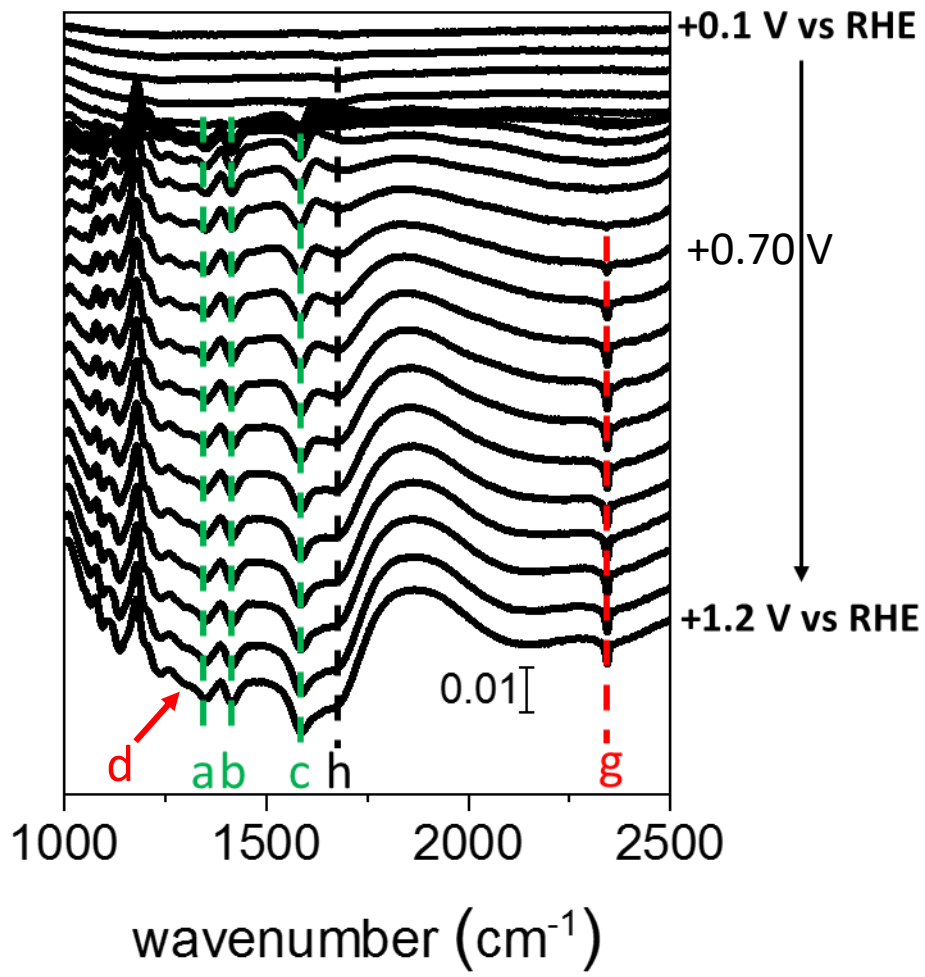
a: 1346 cm^{-1} => $\delta(CH_2)$ mode of gluconate or gluconolactone

b: 1415 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

c: 1581 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

In-situ FTRIRS study on Au/C



IR spectra recorded every 0.050 V during 0.10 mol L^{-1} glucose electrooxidation in 0.10 mol L^{-1} NaOH electrolyte from +0.100 V to +1.200 V vs RHE on Au-NPs/C catalysts. Scan rate: 0.001 V s^{-1}, resolution 4 cm^{-1}, T = 293 K. Vertical scale: $\Delta R/R$

a: 1346 cm^{-1} => $\delta(CH_2)$ mode of gluconate or gluconolactone

b: 1415 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

c: 1581 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

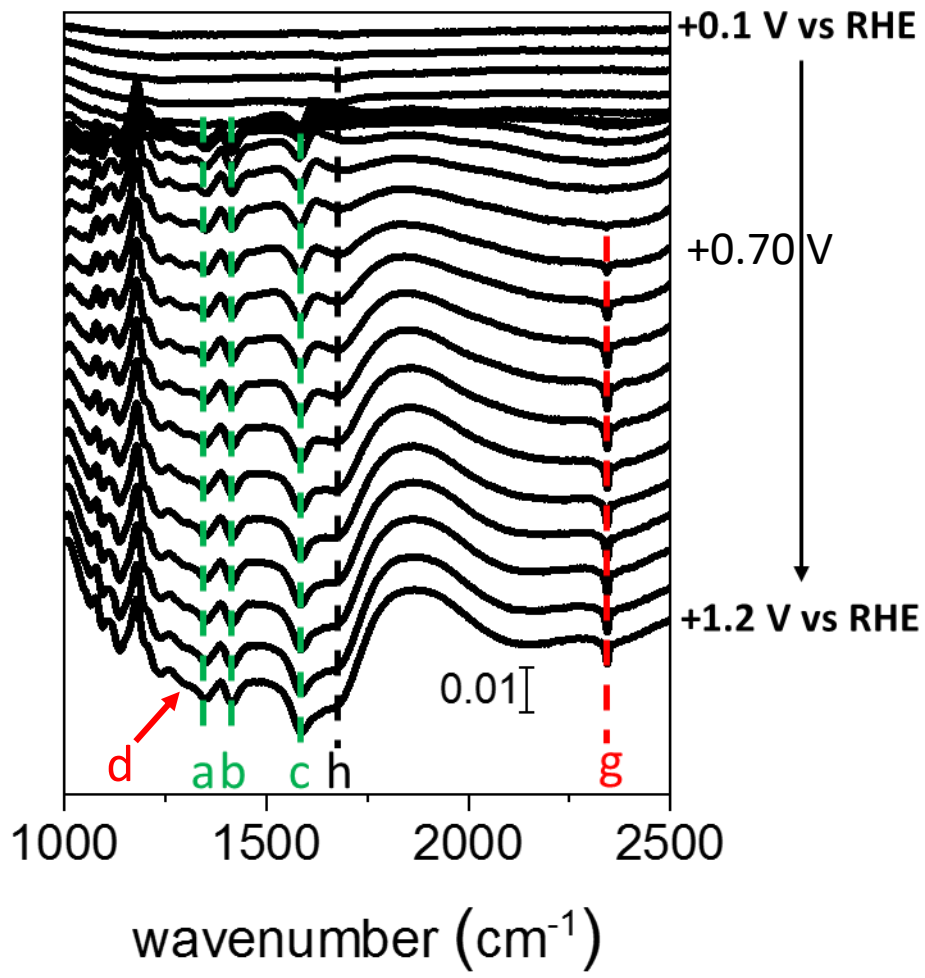
d: 1304 cm^{-1} => HCO_3^-

g: 2343 cm^{-1} => interfacial CO_2

C. Lafforgue, F. Maillard, V. Martin, L. Dubau, M. Chatenet, Degradation of carbon-supported platinum-group-metal electrocatalysts in alkaline media studied by in situ Fourier transform infrared spectroscopy and identical-location transmission electron microscopy, ACS Catal. 9 (2019) 5613−5622.

L. Dubau, F. Hahn, C. Coutanceau, J.-M. Léger, C. Lamy, On the structure effects of bimetallic PtRu electrocatalysts towards methanol oxidation, J. Electroanal. Chem. 554/555 (2003) 407-415.

In-situ FTRIRS study on Au/C



IR spectra recorded every 0.050 V during 0.10 mol L^{-1} glucose electrooxidation in 0.10 mol L^{-1} NaOH electrolyte from +0.100 V to +1.200 V vs RHE on Au-NPs/C catalysts. Scan rate: 0.001 V s^{-1}, resolution 4 cm^{-1}, T = 293 K. Vertical scale: $\Delta R/R$

a: 1346 cm^{-1} => $\delta(CH_2)$ mode of gluconate or gluconolactone

b: 1415 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

c: 1581 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

d: 1304 cm^{-1} => HCO_3^-

g: 2343 cm^{-1} => interfacial CO_2

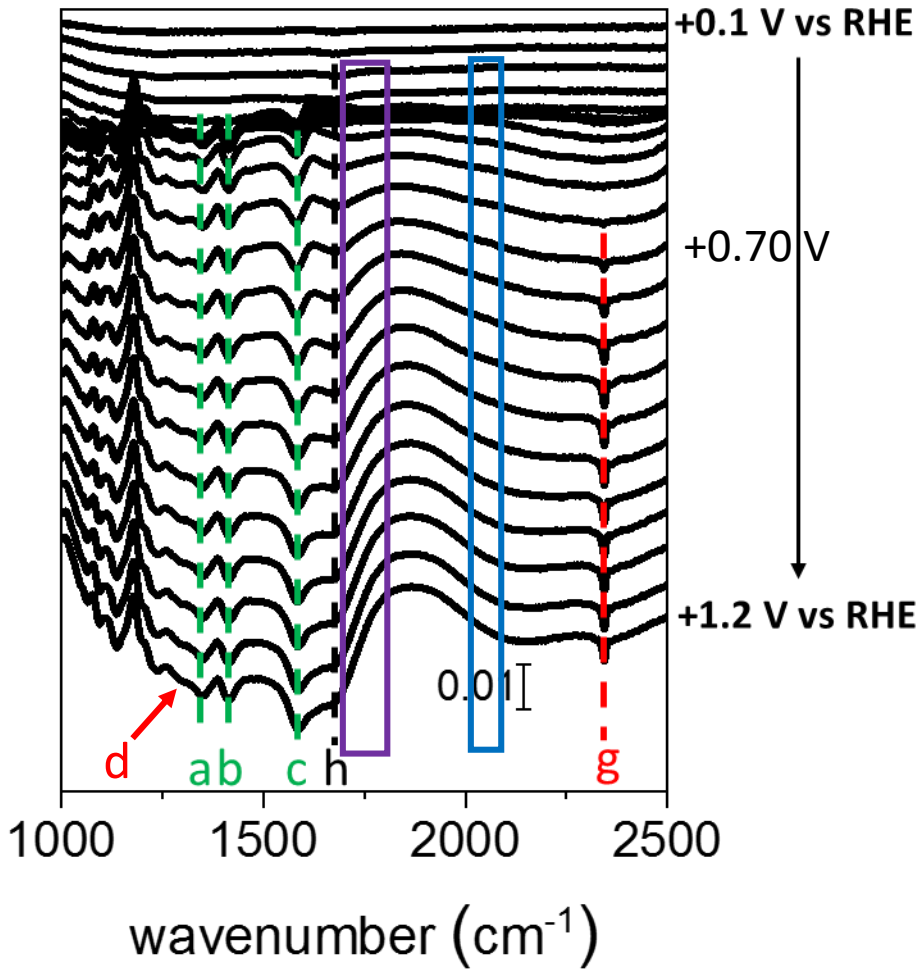
C. Lafforgue, F. Maillard, V. Martin, L. Dubau, M. Chatenet, Degradation of carbon-supported platinum-group-metal electrocatalysts in alkaline media studied by in situ Fourier transform infrared spectroscopy and identical-location transmission electron microscopy, ACS Catal. 9 (2019) 5613−5622.

L. Dubau, F. Hahn, C. Coutanceau, J.-M. Léger, C. Lamy, On the structure effects of bimetallic PtRu electrocatalysts towards methanol oxidation, J. Electroanal. Chem. 554/555 (2003) 407-415.

h: 1680 cm^{-1}=> any possible assignation to carbonyl species, pseudo-band related to the interfacial water band at 1640 cm^{-1}

A. Rodes, E. Pastor, T. Iwasita, An FTIR study on the adsorption of acetate at the basal planes of platinum single-crystal electrodes, J. Electroanal. Chem. 376 (1994) 109-118.

In-situ FTRIRS study on Au/C



IR spectra recorded every 0.050 V during 0.10 mol L^{-1} glucose electrooxidation in 0.10 mol L^{-1} NaOH electrolyte from +0.100 V to +1.200 V vs RHE on Au-NPs/C catalysts. Scan rate: 0.001 V s^{-1}, resolution 4 cm^{-1}, *T* = 293 K. Vertical scale: Δ*R*/*R*

a: 1346 cm^{-1} => $\delta(CH_2)$ mode of gluconate or gluconolactone

b: 1415 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

c: 1581 cm^{-1} => $\nu_{sym.}$ (O-C-O) of carboxylate

B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

d: 1304 cm^{-1} => HCO_3^-

g: 2343 cm^{-1} => interfacial CO_2

C. Lafforgue, F. Maillard, V. Martin, L. Dubau, M. Chatenet, Degradation of carbon-supported platinum-group-metal electrocatalysts in alkaline media studied by in situ Fourier transform infrared spectroscopy and identical-location transmission electron microscopy, ACS Catal. 9 (2019) 5613−5622.

L. Dubau, F. Hahn, C. Coutanceau, J.-M. Léger, C. Lamy, On the structure effects of bimetallic PtRu electrocatalysts towards methanol oxidation, J. Electroanal. Chem. 554/555 (2003) 407-415.

h: 1680 cm^{-1}=> any possible assignation to carbonyl species, pseudo-band related to the interfacial water band at 1640 cm^{-1}

A. Rodes, E. Pastor, T. Iwasita, An FTIR study on the adsorption of acetate at the basal planes of platinum single-crystal electrodes, J. Electroanal. Chem. 376 (1994) 109-118.

Missing bands:

1720 cm^{-1} => ν(C=O) of δ-gluconolactone

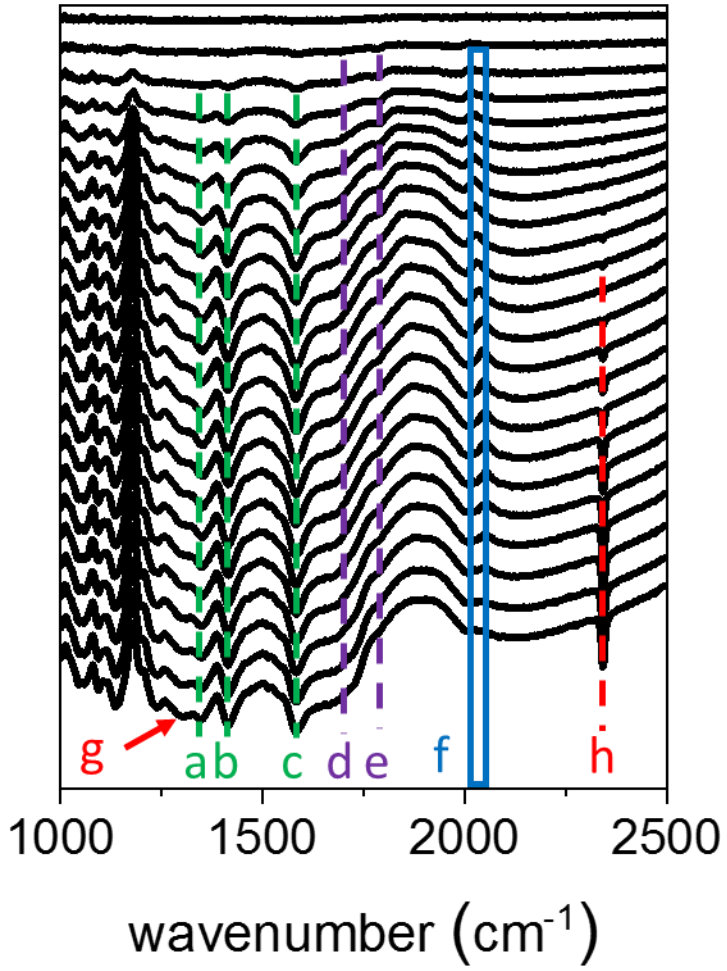
1785 cm^{-1} => ν(C=O) of γ-gluconolactone

B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

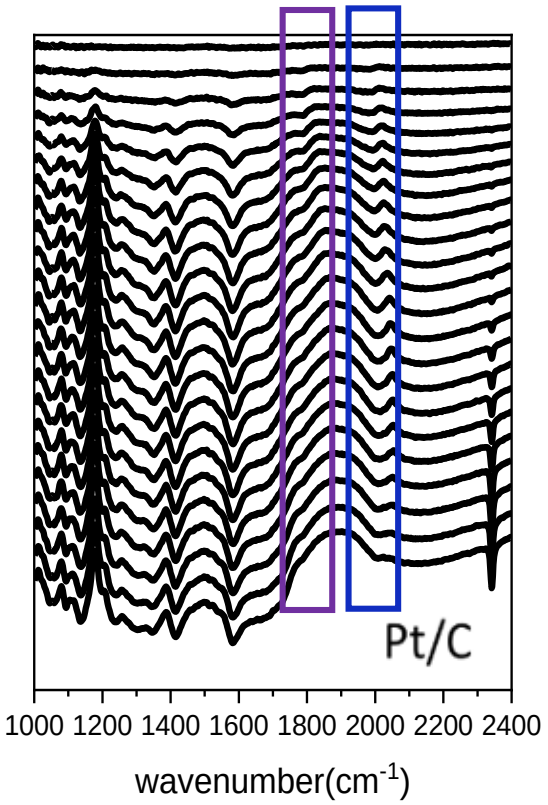
2050 cm^{-1} => linearly adsorbed CO species

A. Couto, A. Rincon, M. C. Perez, C. Gutierrez, Adsorption and electrooxidation of carbon monoxide on polycrystalline platinum at pH 0.3–13, Electrochim. Acta 46 (2001) 1285–1296.

In-situ FTRIRS study on Pt/C



IR spectra recorded every 0.050 V during 0.10 mol L^{-1} glucose electrooxidation in 0.10 mol L^{-1} NaOH electrolyte from +0.100 V to +1.200 V vs RHE on Pt-NPs/C catalysts. Scan rate: 0.001 V s^{-1}, resolution 4 cm^{-1}, T = 293 K. Vertical scale: $\Delta R/R$



Missing bands:

1720 cm^{-1} => ν(C=O) of δ-gluconolactone

1785 cm^{-1} => ν(C=O) of γ-gluconolactone

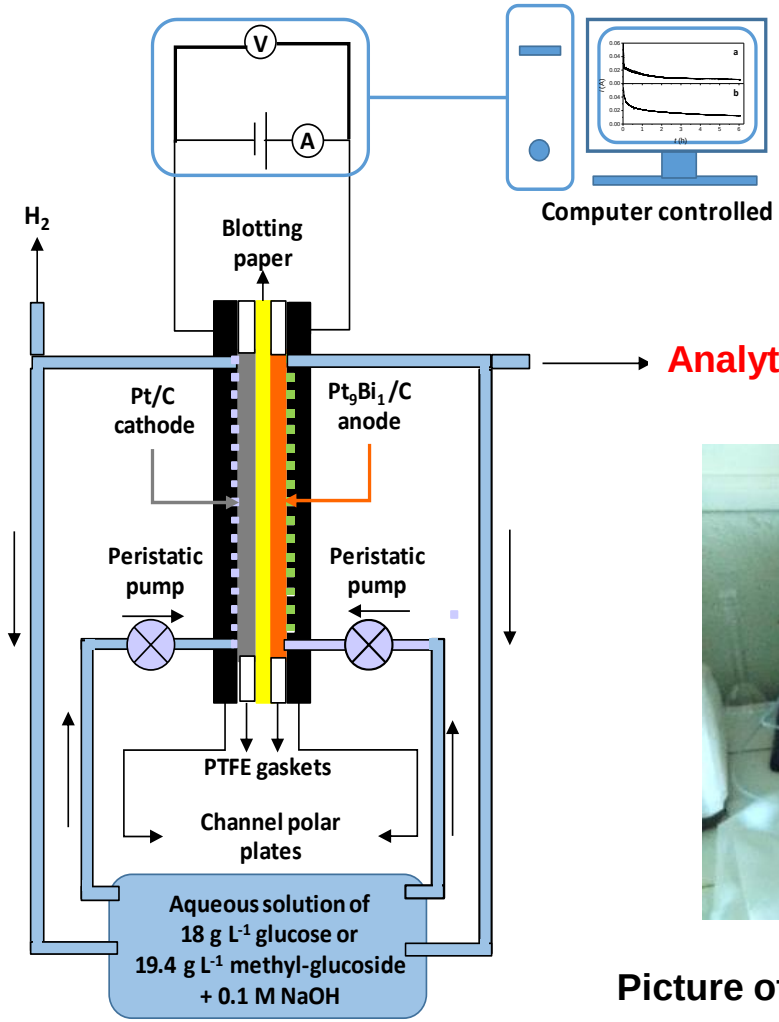
B. Beden, F. Largeaud, K. B. Kokoh, C. Lamy, Fourier transform infrared reflectance spectroscopic investigation of the electrocatalytic oxidation of D-glucose: identification of reactive intermediates and reaction products, Electrochim. Acta. 41, (1996) 701-709.

2050 cm^{-1} => linearly adsorbed CO species

A. Couto, A. Rincon, M. C. Perez, C. Gutierrez, Adsorption and electrooxidation of carbon monoxide on polycrystalline platinum at pH 0.3–13, Electrochim. Acta 46 (2001) 1285–1296.

Electrooxidation of glucose at Au/C

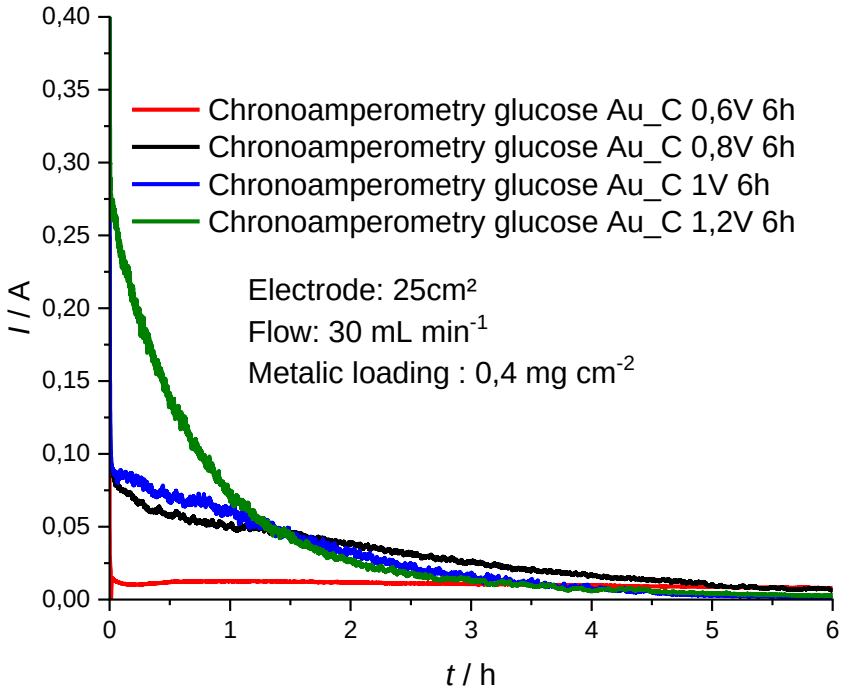
Scheme of principle for CA measurements



Analytical methods

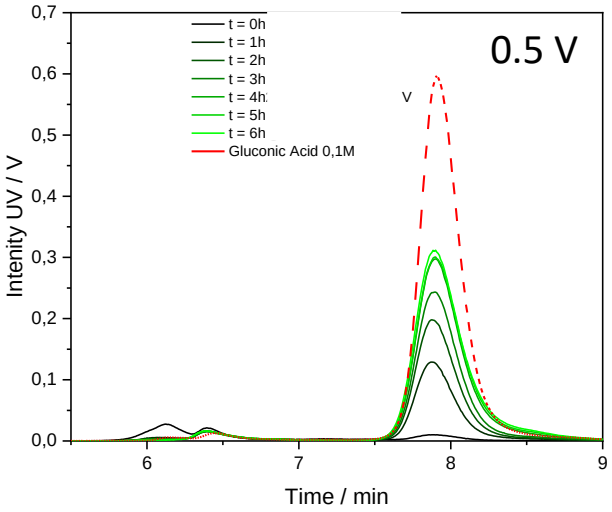
Picture of the experimental set-up

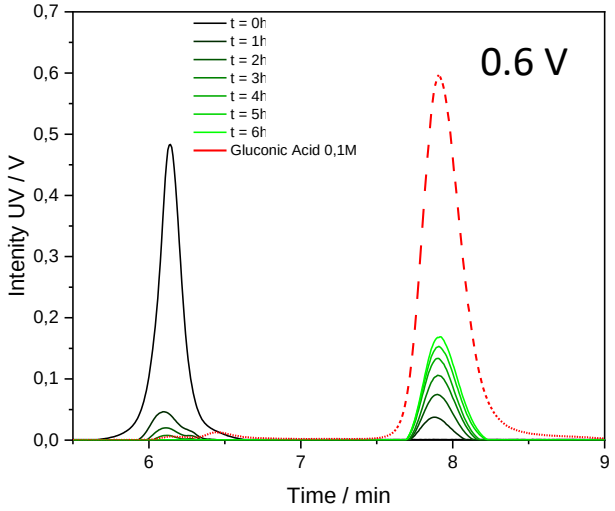
Chronoamperometry curves

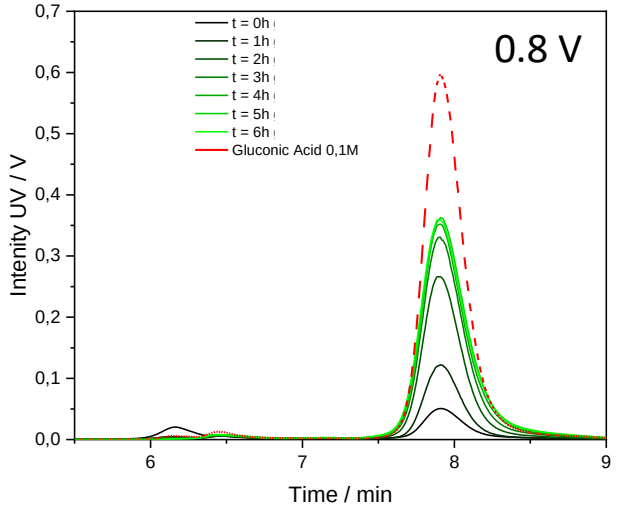


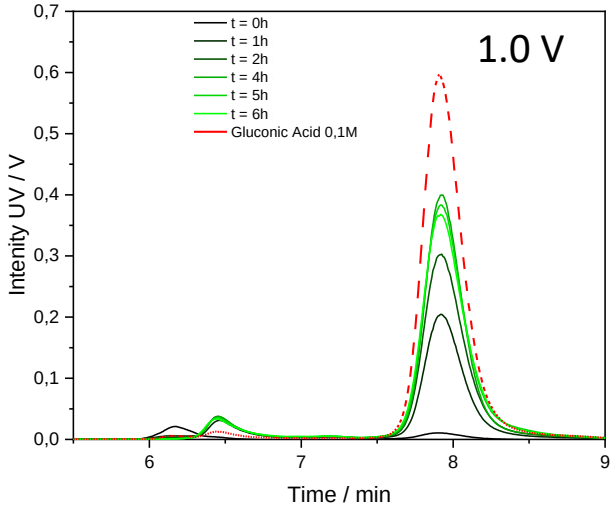
Anode: Au/C at 0.5 mg_{Aul} cm^{-2}
Cathode: Pt/C cathode at 0.5 mg_{Pt} cm^{-2}
Solution: 30 mL of 0.10 mol L^{-1} NaOH with 18.0 g L^{-1} glucose (0.1 mmol L^{-1})
T = 20 °C

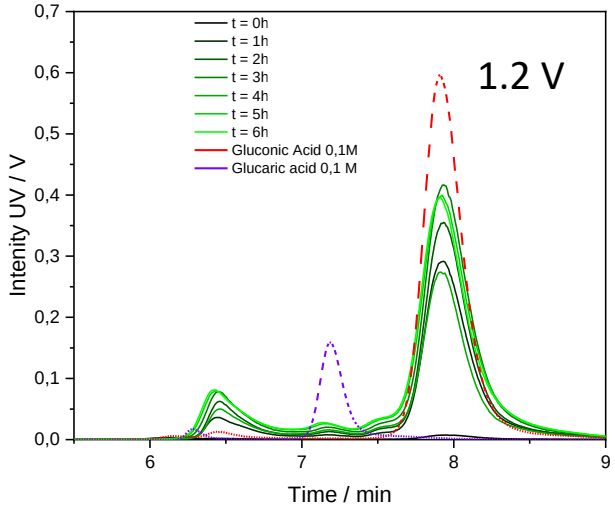
Electrooxidation of glucose at Au/C











Intermediary summary

From CA followed by CVs experiments: the first step of glucose adsorption is evidenced

From in-situ infrared spectroscopy: no CO_{ads} and no lactone detected by IR

=> adsorbed gluconate species from very low potentials
=> CO_2 only detected from ca. 0.700 V vs RHE

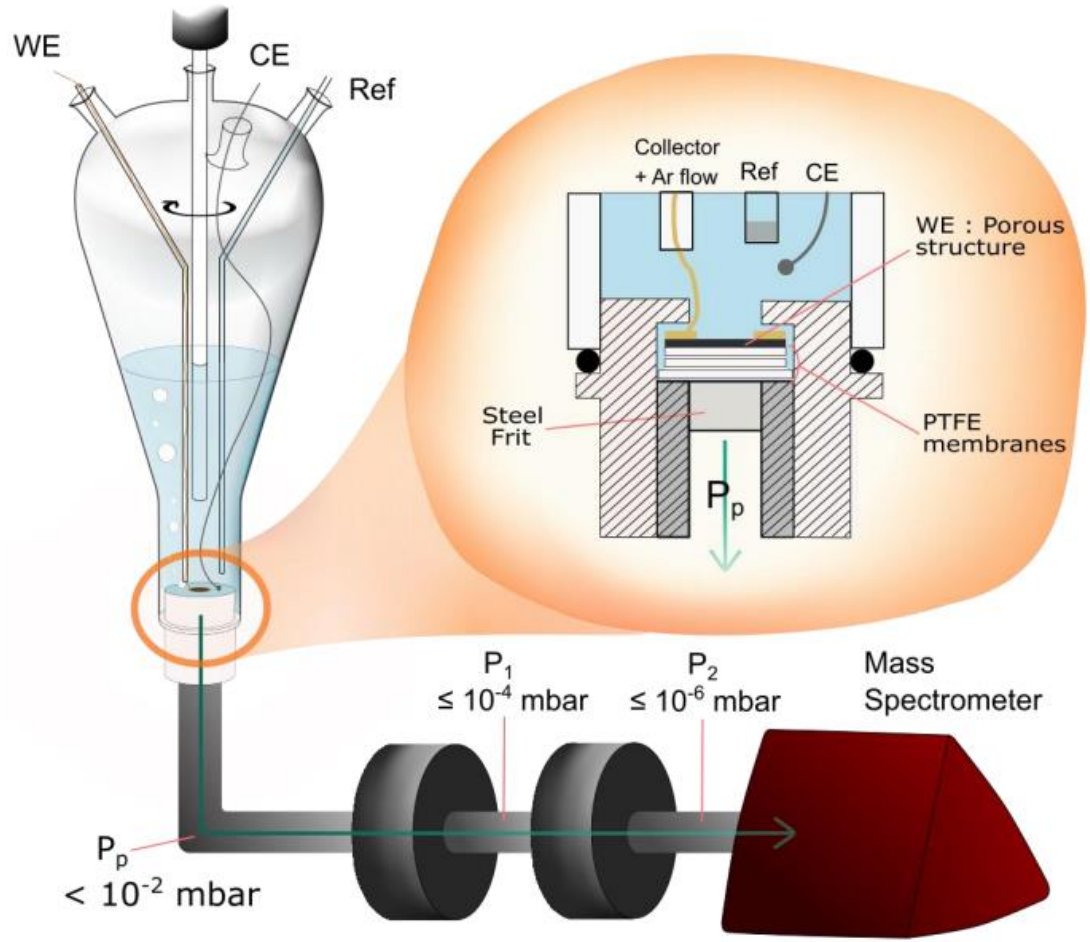
=> gluconate as main reaction product at low potentials
=> gluconate + overoxidized compounds + degaradation products + CO_2 at high potentials

Confirmed by CA and HPLC measuremenst of reaction products

Detection of gases and volatile species by the mass spectrometer during cyclinc volatmmetry

Detection of hydrogen (H_2, m/z = 2)

Detection of carbon dioxyde (CO_2, m/z = 44)



Guillaume Braesch : « Electrocatalyseurs pour la Réaction d'Oxydation des Borohydrures : des surfaces modèles aux électrodes non-nobles de piles à combustible » , Grenoble, 2020

DEMS study

To avoid any possible signal perturbation due to carbon support oxidation into CO_2 (potentials > 0.207 V vs RHE)

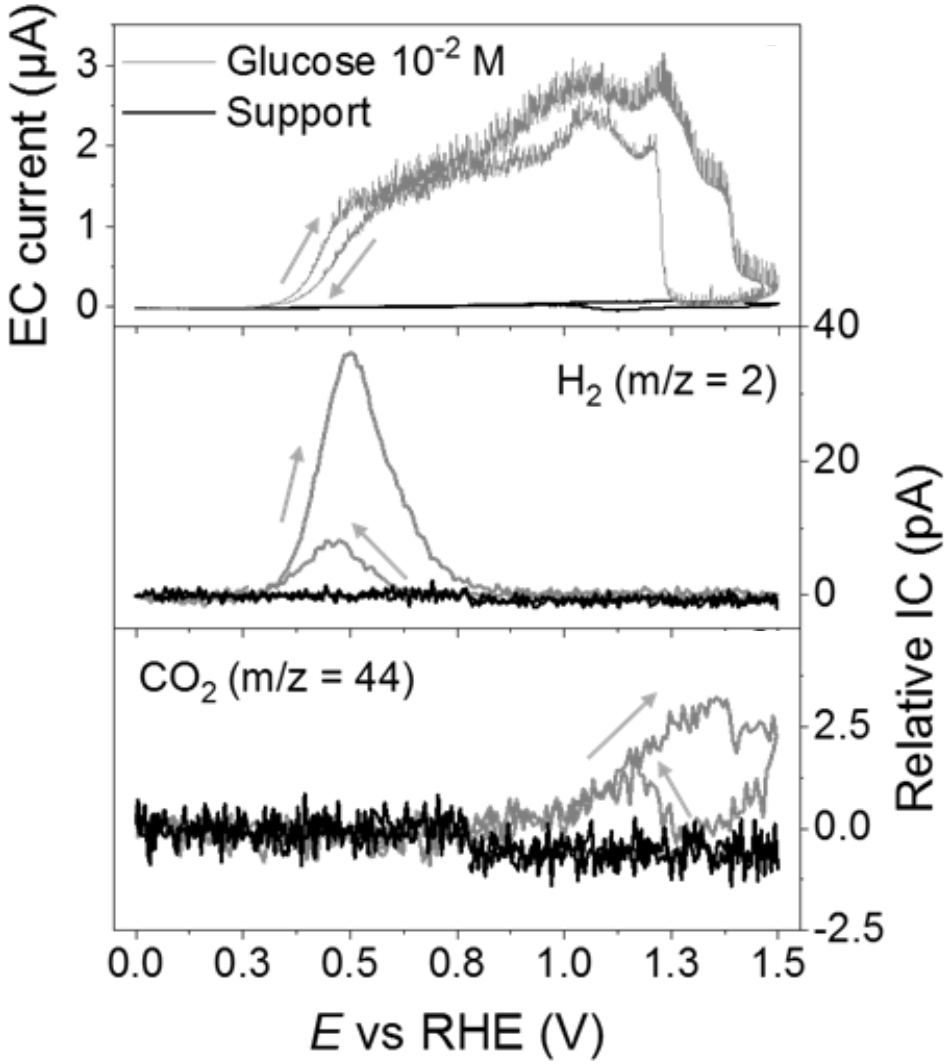
=> DEMS experiments carried out on unsupported sputtered Pt-NPs and Au-NPs

Working electrodes: Pt or Au nanoporous layer by sputtering onto the porous PTFE membrane (pore size 0.02 µm, thickness 20 µm, Cobetter filtration®), which serves as interface between the electrochemical cell and the high vacuum chamber of the mass spectrometer.

=> 0.28 cm^2 area, 50 nm +/- 10 nm average thickness

=> AFM: small grains of 5-10 nm with 1-2 nm root means square of profile height deviation from the mean line

DEMS study on Pt/C and Au/C



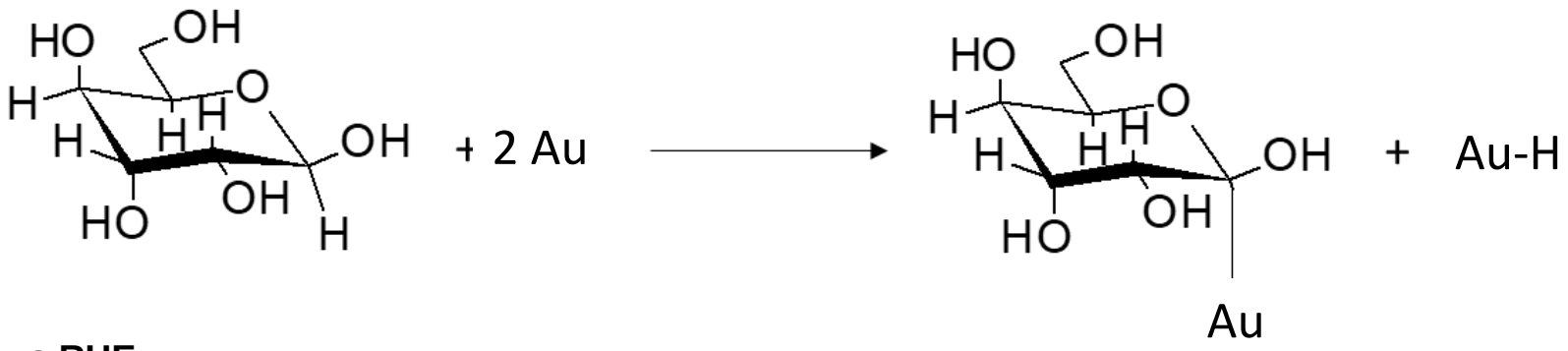
CVs of 10^{-2} M glucose oxidation in 10^{-1} NaOH electrolyte on sputtered Au-NPs. Scan rate: 0.010 V s^{-1}, *T* = 293 K.

DEMS measurement performed at m/z = 2 for the electrooxidation of 0.010 mol L^{-1} glucose oxidation in 0.10 mol L^{-1} NaOH electrolyte on sputtered Au-NPs;

DEMS measurement performed at m/z = 44 for the electrooxidation of 0.010 mol L^{-1} glucose oxidation in 0.10 mol L^{-1} NaOH electrolyte on sputtered Au-NPs.

Proposed mechanism on Au-NPs

Step 1 (Au)



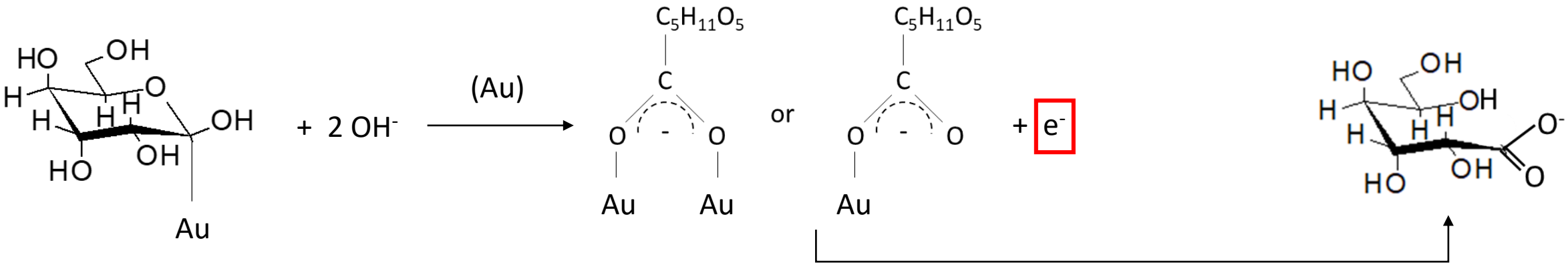
For 0.300 V < *E* < 0.450 V vs RHE

$$2\ \text{Au-H} \longrightarrow 2\ \text{Au} + H_2$$

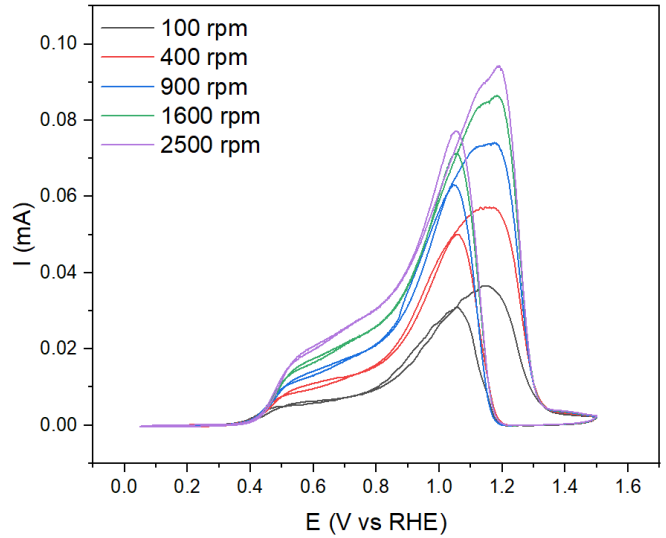
N. Arjona, G. Trejo, J. Ledesma-García, L. G. Arriaga, M. Guerra-Balcázar, An electrokinetic-combined electrochemical study of the glucose electrooxidation reaction: effect of gold surface energy, RSC Adv. 6 (2016) 15630–15638.

S. A. C. Carabineiro, B. E. Nieuwenhuys, Adsorption of small molecules on gold single crystal surfaces, Gold Bull. 42 (2009) 288-301.

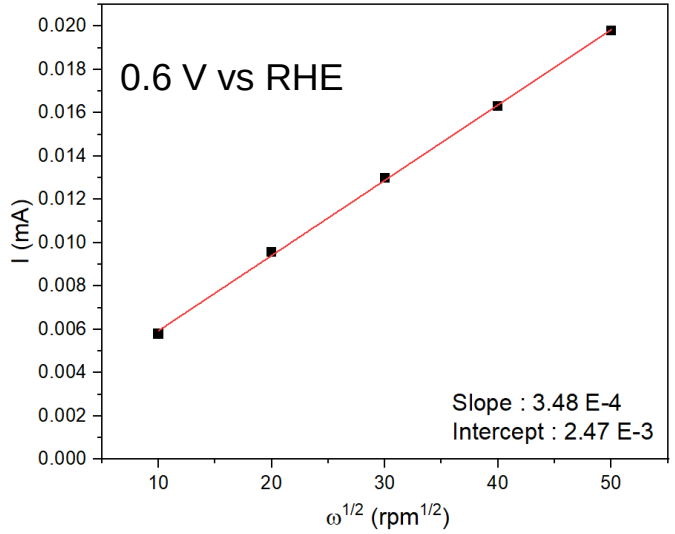
W. Watkins, Y. Borensztein, Mechanism of hydrogen adsorption on gold nanoparticles and charge transfer probed by anisotropic surface plasmon resonance, Phys. Chem. Chem. Phy.19 (2017) 27397 - 27405.



Number of exchanged electrons by Levich study

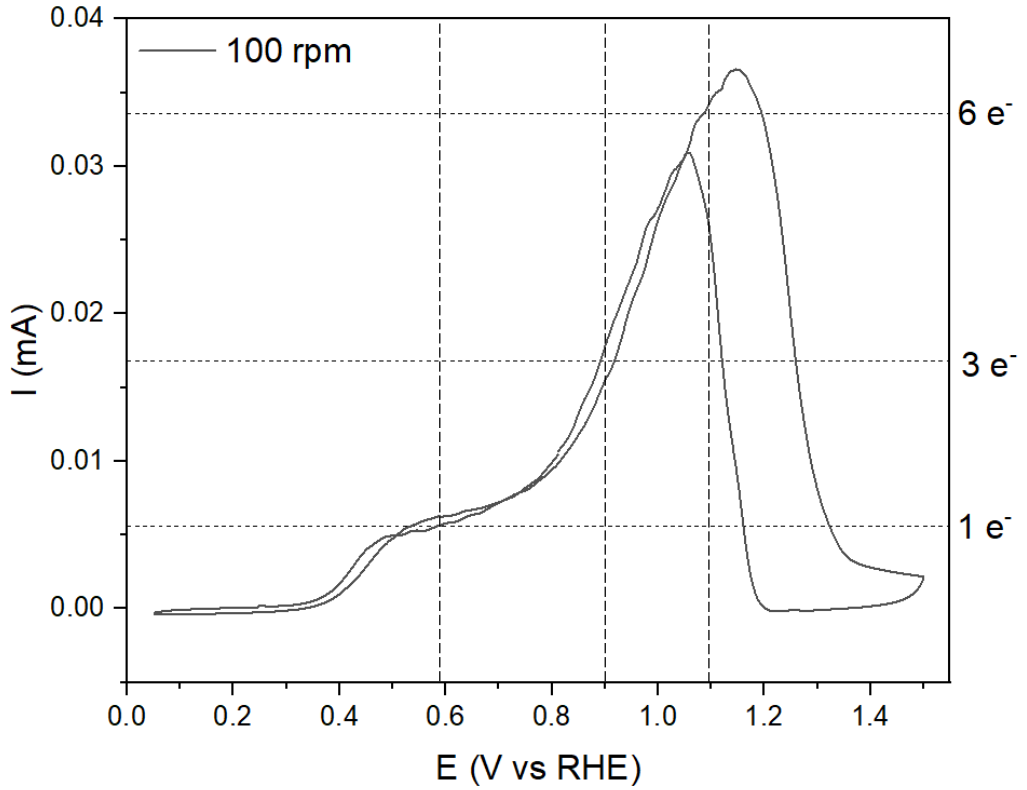


Glucose 10^{-3} M in NaOH 0,1 M, 10 mV/s, T_{amb}



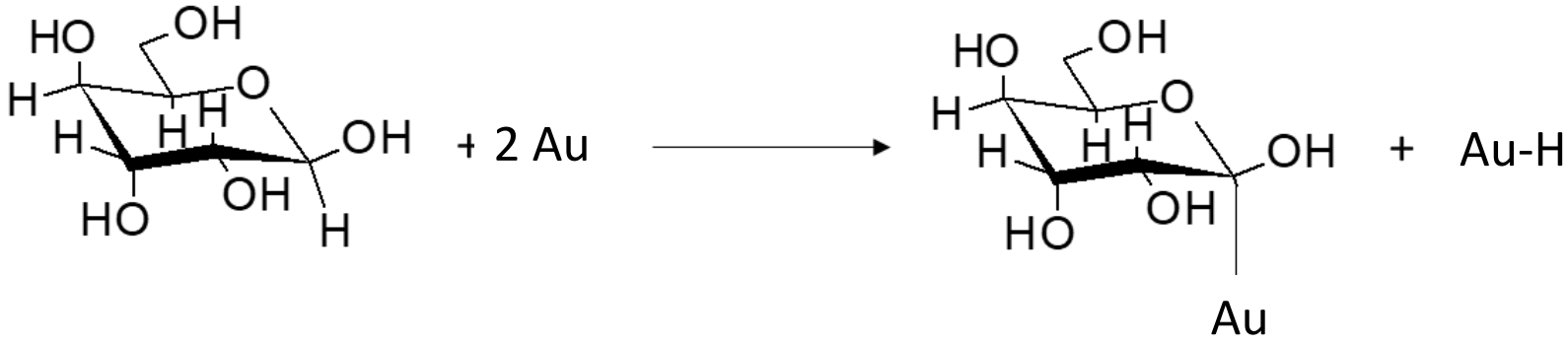
➔ Caution : not purely mass transport limited conditions

Levich equation: $I_L = 0.620\, n\, F\, A\, D^{\frac{2}{3}}\, \upsilon^{\frac{-1}{6}}\, C\, \omega^{\frac{1}{2}}$



Proposed mechanism on Au-NPs

Step 1 (Au)

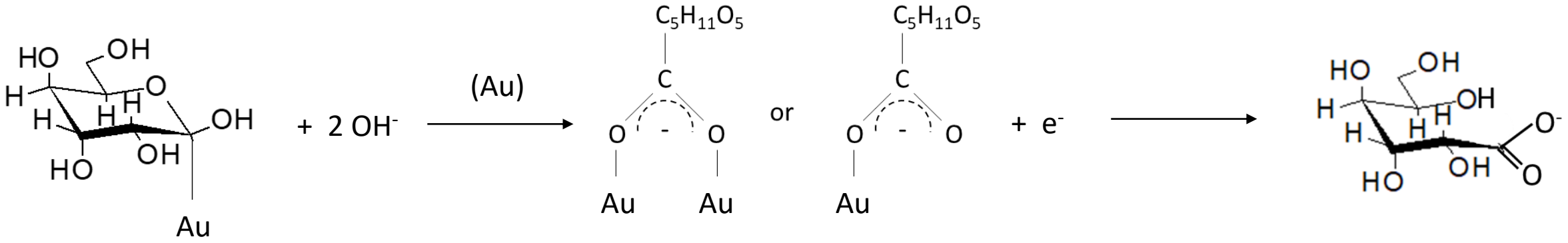


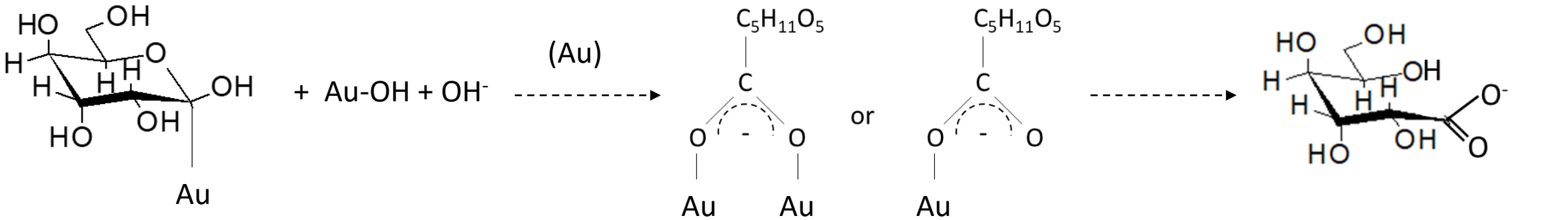
From 0.450 V < *E* < 0.500 V vs RHE

$2\ Au\text{-}H \longrightarrow 2\ Au + H_2$

$Au + OH^- \dashrightarrow Au\text{-}OH + e^-$

$Au\text{-}H + Au\text{-}OH \dashrightarrow 2\ Au + H_2O$

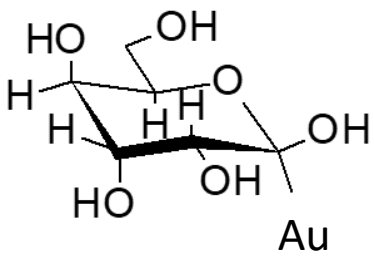




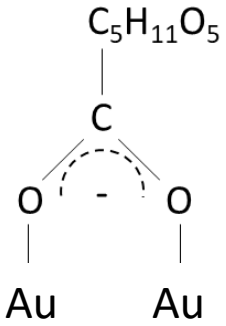
Proposed mechanism on Au-NPs

For 0.500 V < *E* < 0.850 V vs RHE

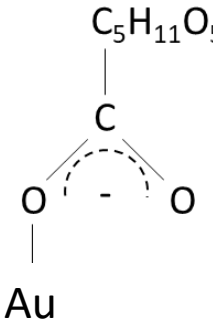
$2\ Au\text{-}H \dashrightarrow 2\ Au + H_2$ $\qquad Au + OH^- \longrightarrow Au\text{-}OH + e^-$ $\qquad Au\text{-}H + Au\text{-}OH \longrightarrow 2\ Au + H_2O$



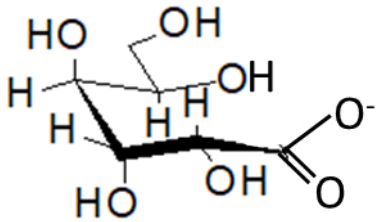
$+ Au\text{-}OH + OH^-$ ⟶



or



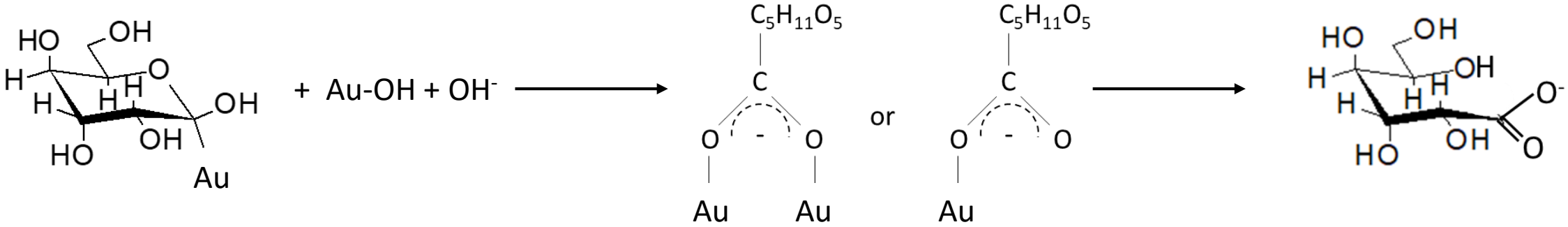
⟶



Proposed mechanism on Au-NPs

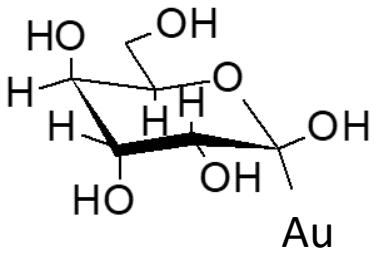
For 0.500 V < *E* < 0.850 V vs RHE

$2\ Au\text{-}H \dashrightarrow 2\ Au + H_2$ $\qquad Au + OH^- \longrightarrow Au\text{-}OH + e^-$ $\qquad Au\text{-}H + Au\text{-}OH \longrightarrow 2\ Au + H_2O$



For 0.850 V < *E* < 1.500 V vs RHE

$Au + OH^- \longrightarrow Au\text{-}OH + e^-$ $\qquad Au\text{-}H + Au\text{-}OH \longrightarrow 2\ Au + H_2O$



+ Au-OH $\xrightarrow{OH^-}$ Gluconate, overoxidized compounds, CO_2, degradation products (C1 to C5)

Conclusion and perspectives

→Au-NPs: high specificity, activity and selectivity towards gluconate for 0.300 V < *E* < 0.800 V vs RHE

- Gold appears as a good catalysts for the selective glucose electrooxidation

→H_2 evolution on gold over the same electrode potential range: bad or good news?

- Alloying gold with another metal (Pt or Pd) allowing H oxidation

→ Higher activity for U_{cell} = 0.5 V than for U_{cell} = 0.6 V

- Gold surface poisoning? Competitive reactions? Etc.?

→U_{cell} higner than 0.8 V leads to overoxidized products in agreement with in-situ FTIRS and DEMS measurements

Thank you for your attention

Special thanks to

Neha Neha (Post-doc IC2MP)

Thibault Rafaïdeen (Post-doc IC2MP)

Théo Faverge (PhD student IC2MP/LEPMI)

Marian Chatenet (Professor LEPMI)

Frédéric Maillard (CNRS Research Director LEPMI)

Nouvelle Aquitaine
County Council

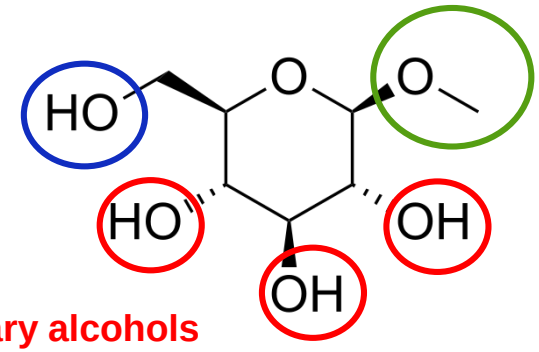
European commission
(ERDF)

GLUCONIC Project (ANR-20-CE43-0005)

In-situ FTRIRS study on Pt/C

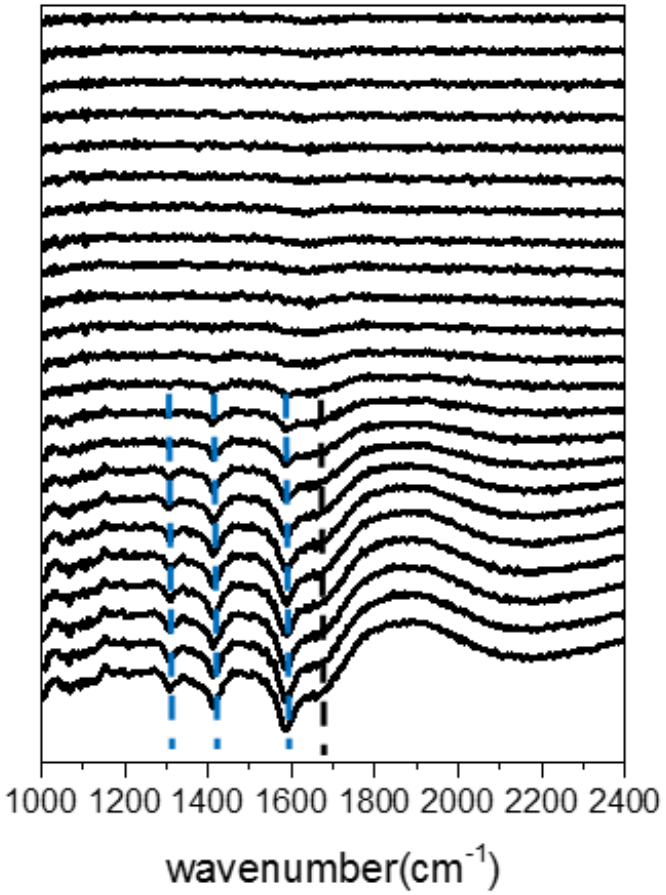
C6 : Primary alcohol
Themodynamically hard to oxidize

C1 : Protected anomeric function
Not oxidizable



Secondary alcohols
Reactivity ?

β-D-Methylglucoside



+0.1 V vs RHE

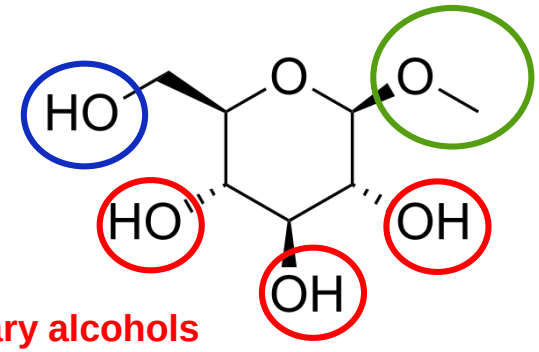
+1.2 V vs RHE

N. Neha, S. R. B. Kouamé, T. Rafaïdeen, S. Baranton, C. Coutanceau, Remarkably efficient carbon-supported nanostructured platinum-bismuth catalysts for the selective electrooxidation of glucose and methyl-glucoside, Electrocatalysis 12 (2021) 1-14.

In-situ FTRIRS study on Pt/C

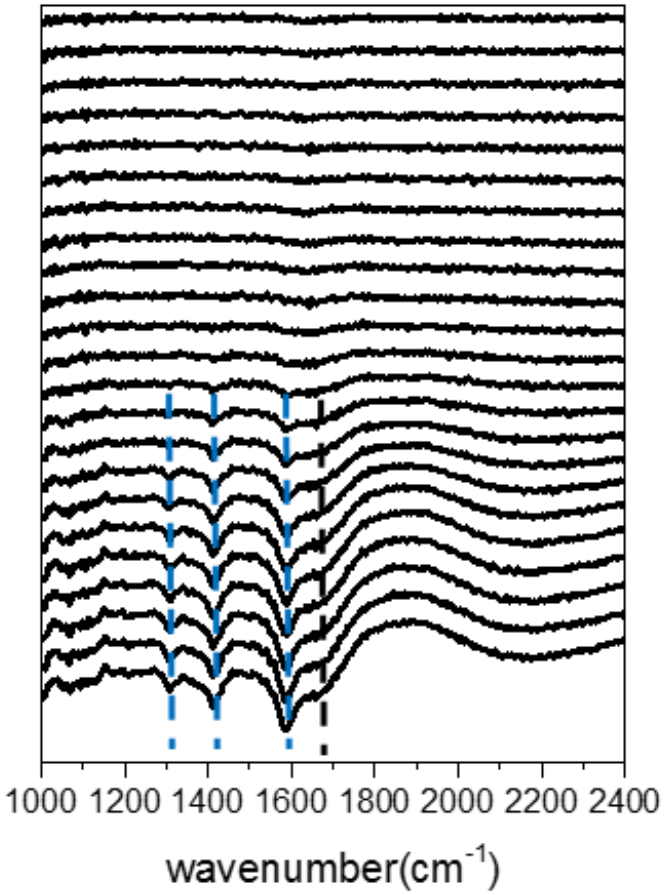
C6 : Primary alcohol
Themodynamically hard to oxidize

C1 : Protected anomeric function
Not oxidizable



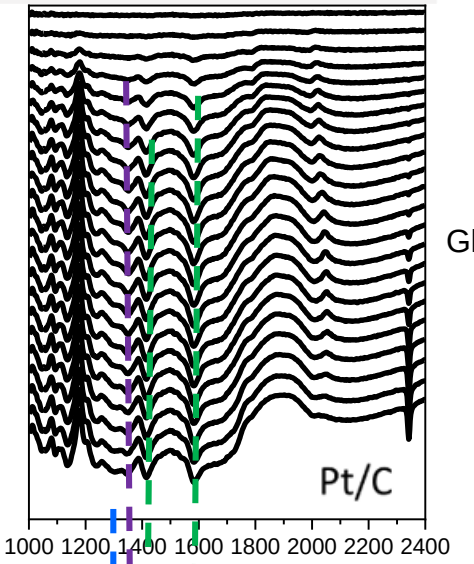
Secondary alcohols
Reactivity ?

β-D-Methylglucoside

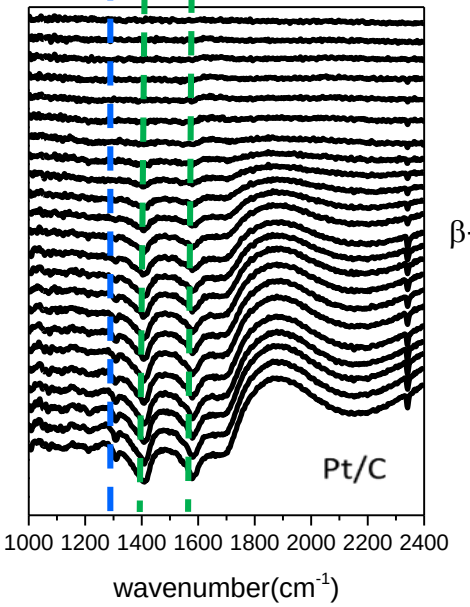


+0.1 V vs RHE

+1.2 V vs RHE

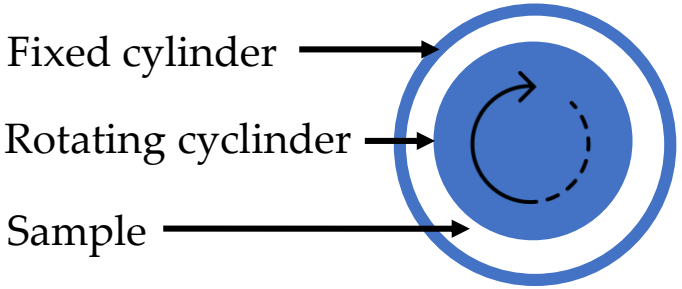


Glucose



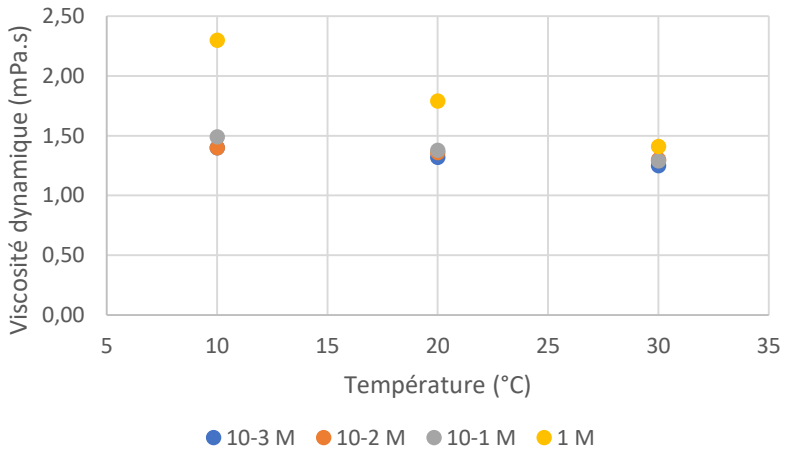
β-D-Methylglucoside

Dynamic viscosity (η) measurement – glucose in NaOH 0,1 M



The torque depends upon the sample viscosity

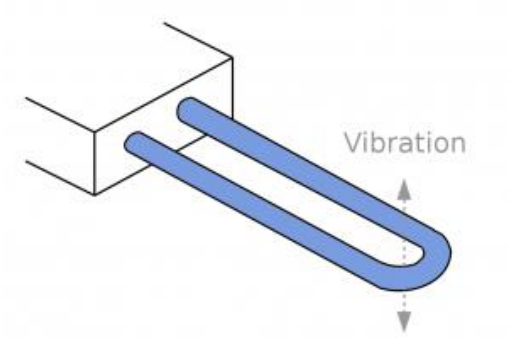
Dynamic viscosity, η (mPa.s)		Temperature		
		10°C	20°C	30°C
Glucose concentration	10^{-3} M	1,40	1,32	1,25
	10^{-2} M	1,40	1,36	1,30
	10^{-1} M	1,49	1,38	1,29
	1 M	2,30	1,79	1,41



➔ Density measurement missing to calculate kinematic viscosity (υ)

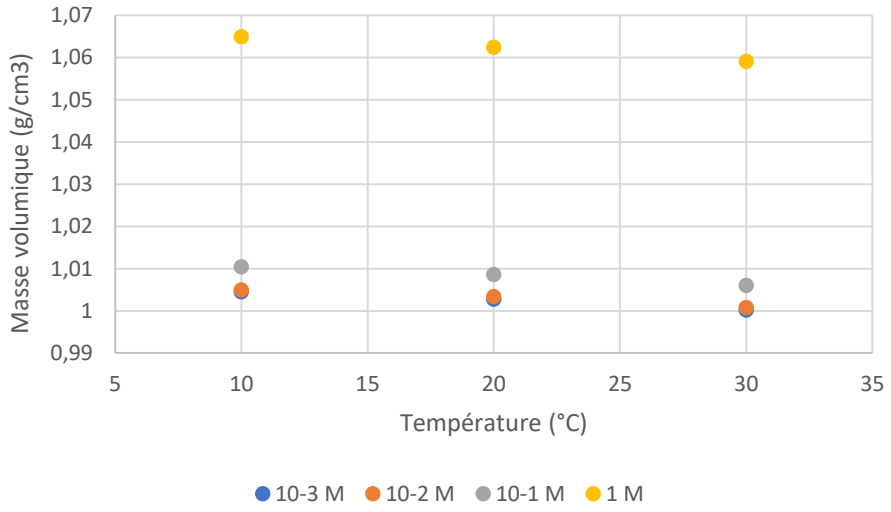
Density measurement – glucose in NaOH 0,1 M

Vibrating U tube filled with the sample



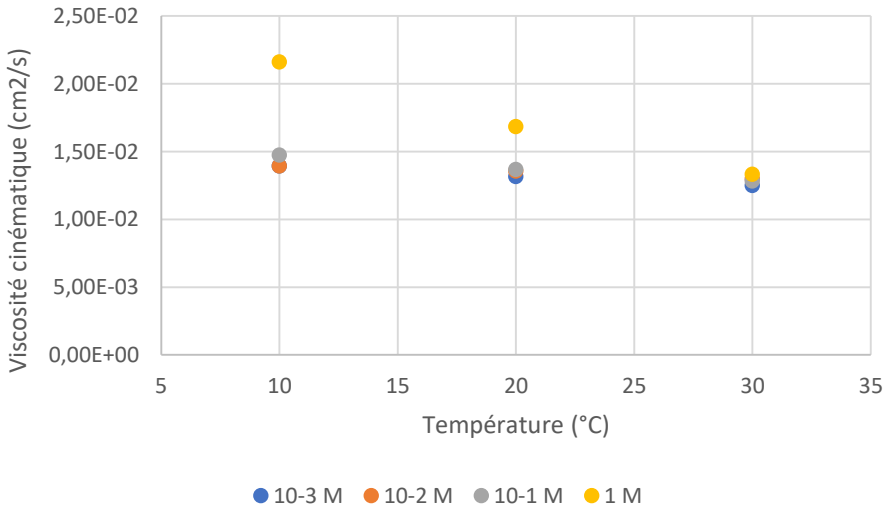
The vibration frequency depends upon the sample mass (and so its density)

Volumetric mass, ρ (g/cm³)		Temperature		
		10°C	20°C	30°C
Glucose concentration	10^{-3} M	1,0045	1,0028	1,0002
	10^{-2} M	1,005	1,0034	1,0008
	10^{-1} M	1,0104	1,0086	1,006
	1 M	1,0649	1,0624	1,0591

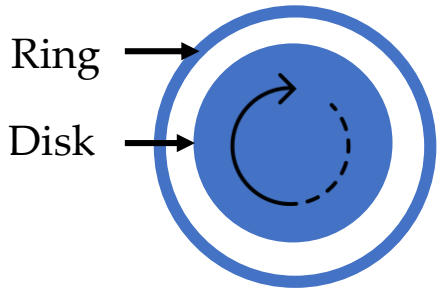


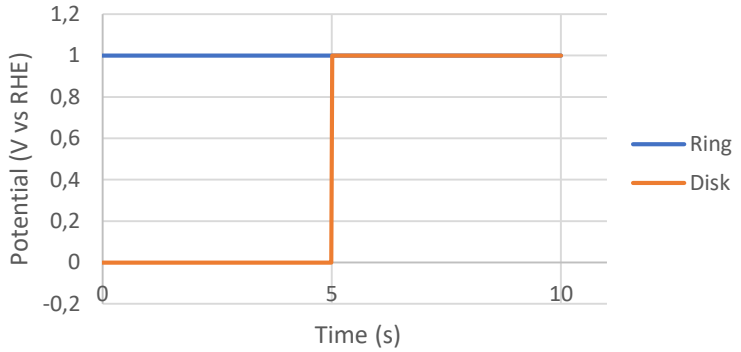
Kinematic viscosity (υ) calculation : $\upsilon = \eta / \rho$

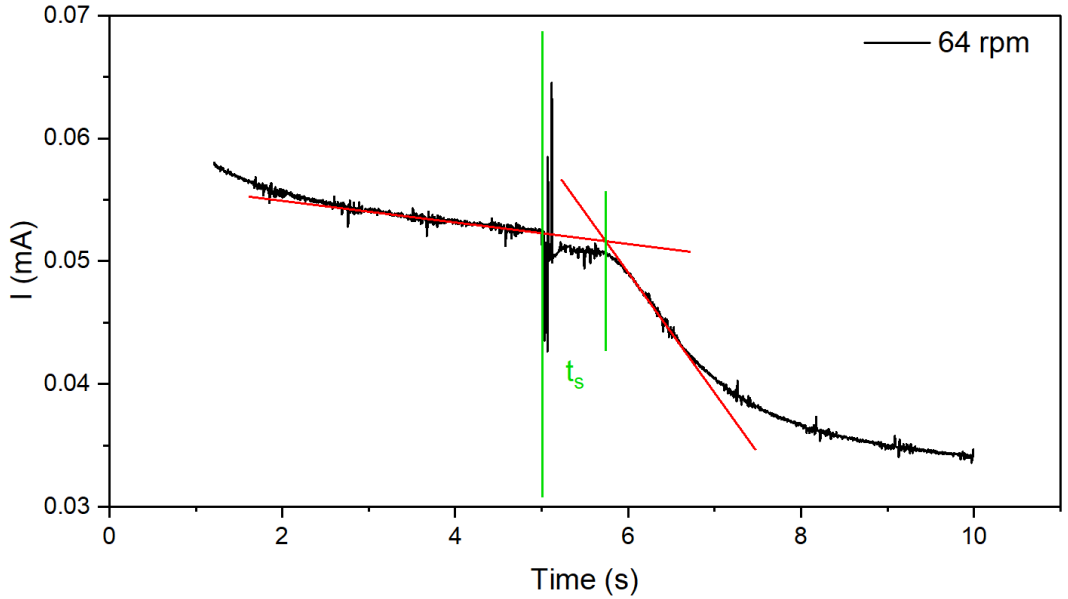
Kinematic viscosity, ν (10^{-2} cm^2/s)		Temperature		
		10°C	20°C	30°C
Glucose concentration	10^{-3} M	1,39	1,32	1,25
	10^{-2} M	1,39	1,36	1,30
	10^{-1} M	1,47	1,37	1,28
	1 M	2,16	1,68	1,33



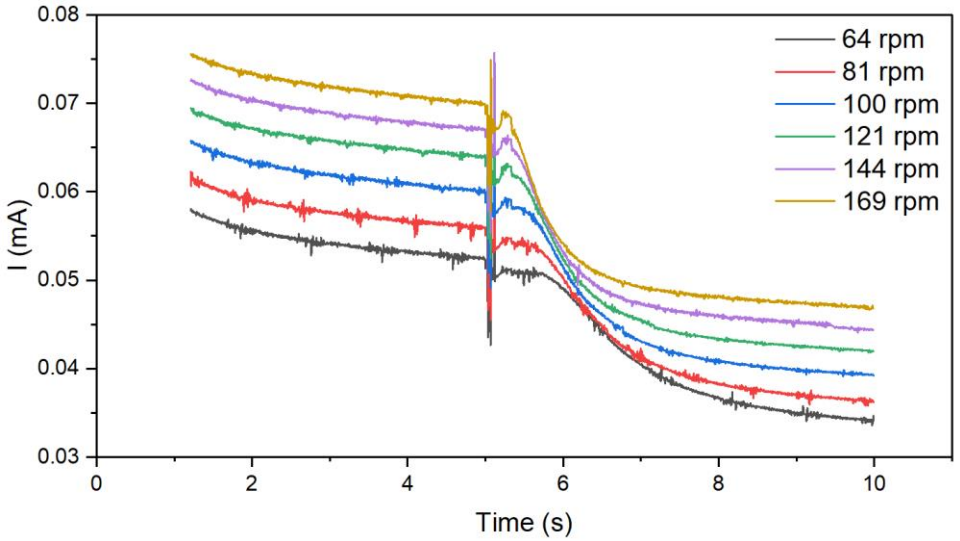
Diffusion coefficient measurement – RRDE transit time method







Diffusion coefficient measurement – RRDE transit time method

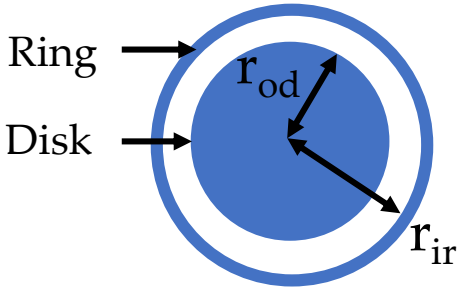


$$t_s = K\,(\frac{\nu}{D})^{\frac{1}{3}}\,\omega^{-1}$$

where

$$K = 43{,}1\,(\log\frac{r_{ir}}{r_{od}})^{\frac{2}{3}}$$

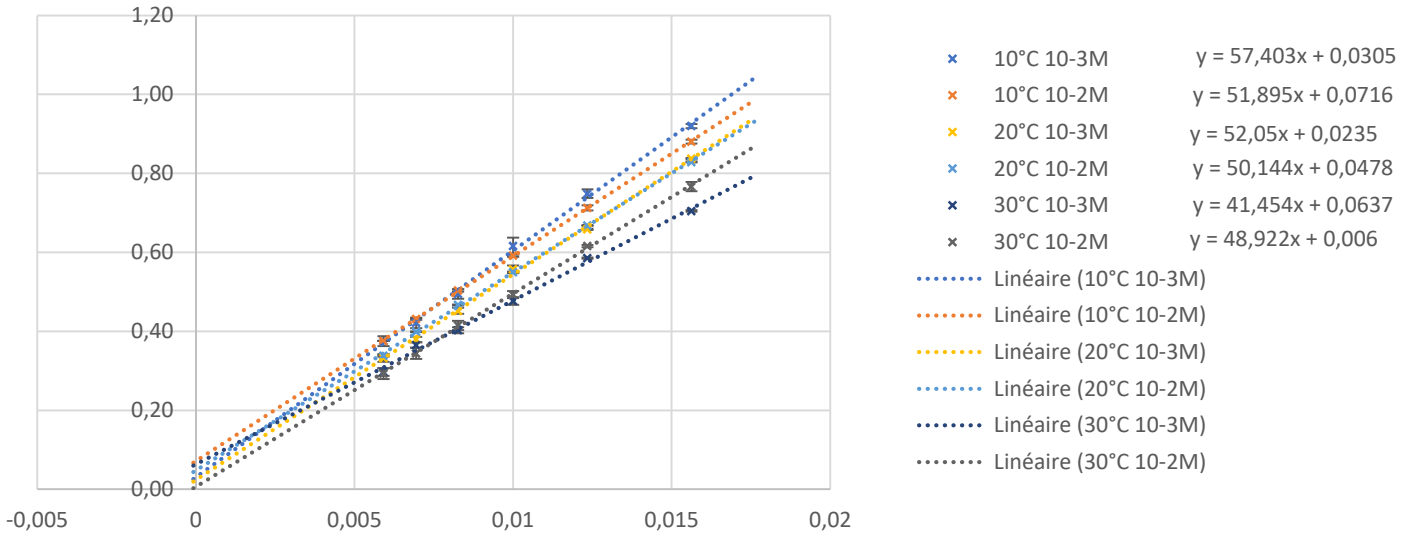
and



r_{ir} = ring inner radius

r_{od} = disk outer radius

Chatenet, M., Molina-Concha, M. B., El-Kissi, N., Parrour, G. & Diard, J. P. Direct rotating ring-disk measurement of the sodium borohydride diffusion coefficient in sodium hydroxide solutions. *Electrochim. Acta* **54**, 4426–4435 (2009)

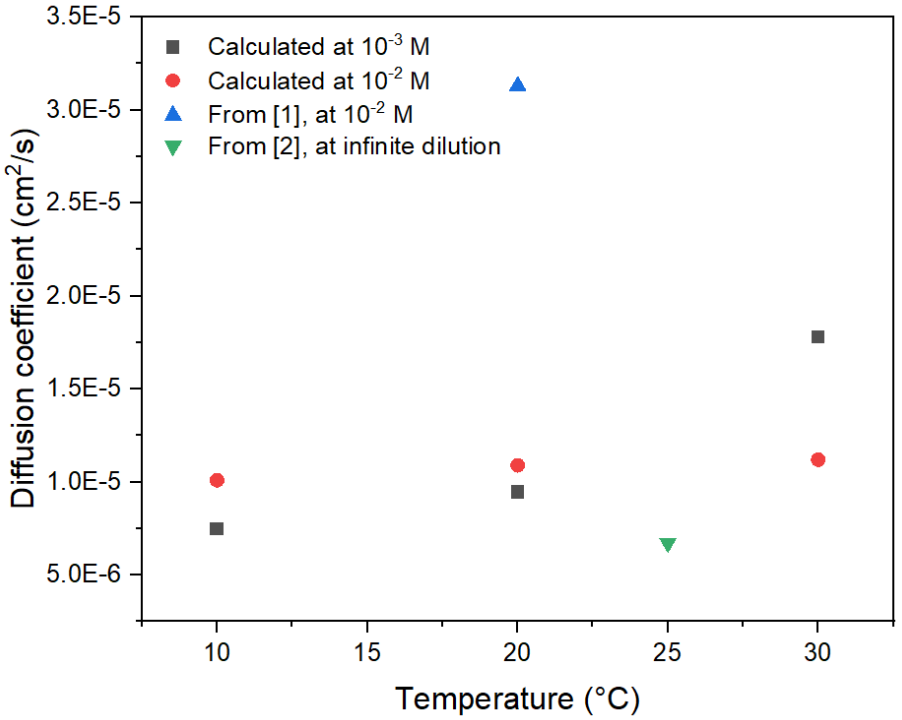


3 replicates per concentration, temperature and rotation rate

Diffusion coefficient measurement – RRDE transit time method

Here, r_{ir} = 4,96 mm & r_{od} = 4,57 mm ➔ K = 4,661

Diffusion coefficient, D (cm^2/s)		Temperature		
		10°C	20°C	30°C
Glucose concentration	10^{-3} M	7,46E-06	9,45E-06	1,78E-05
	10^{-2} M	1,01E-05	1,09E-05	1,12E-05
	10^{-1} M	Inoperable data		
	1 M	No data		



[1] Karim Hassaninejad-Darzi, S. & Yousefi, F. Electrocatalytic oxidation of glucose on the modified carbon paste electrode with sodalite nanozeolite for fuel cell. *Iran. J. Hydrog. Fuel Cell* **1**, 47–58 (2015).

[2] David R. Lide, ed., CRC Handbook of Chemistry and Physics, Internet Version 2005, <http://www.hbcpnetbase.com>, CRC Press, Boca Raton, FL, 2005