Measurement of the Oxygen Potential of Non-Ferrous Slags with an Ex-Situ Electrochemical Device

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Contents

Introduction : importance of p_{O_2}

- Affects reactivity with
  - Metal
  - Matte
  - Lining of reactor

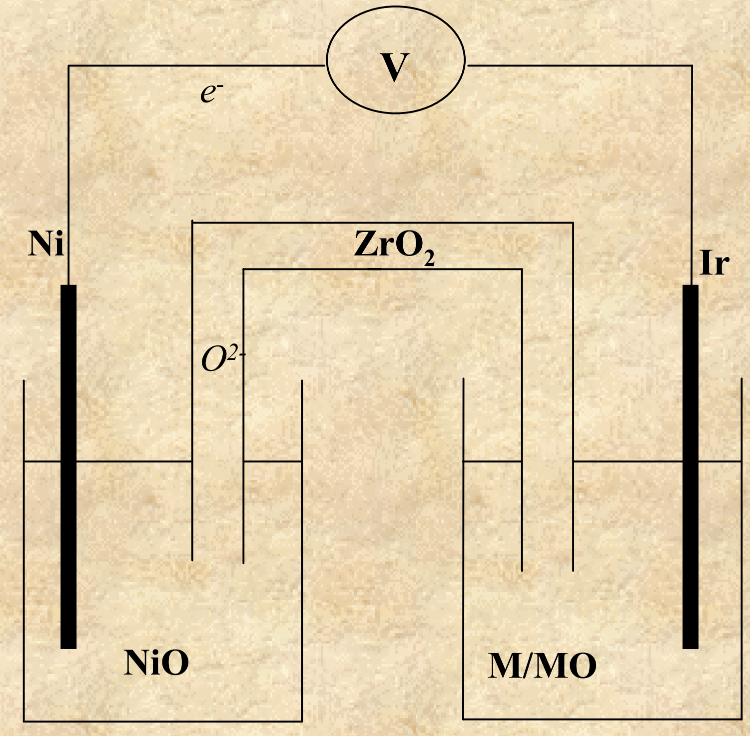
- Available devices
  - In-situ: Celox™, Celox-SLAC™
  - Ex-situ: Ferro-Actis™, RAPIDOX™

Experimental procedure: measurement

- **Electrochemical cell**

Ni / NiO // ZrO_2(MgO) // slag / Ir

- *Reference electrode* :
  - Ni/NiO (1050 ^{0}C-1400 ^{0}C)
  - Mo/MoO (1400 ^{0}C -1650 ^{0}C)
- *Bath electrode :*
  - Iridium conductor partially covered by silica
- *Solid electrolyte :*
  - MgO stabilized ZrO_2



Experimental procedure: measurement

- Formulas
  - Nernst's law :

$$EMF = \frac{RT}{nF} \ln \frac{p_{O_2}(slag)}{p_{O_2}(ref)}$$

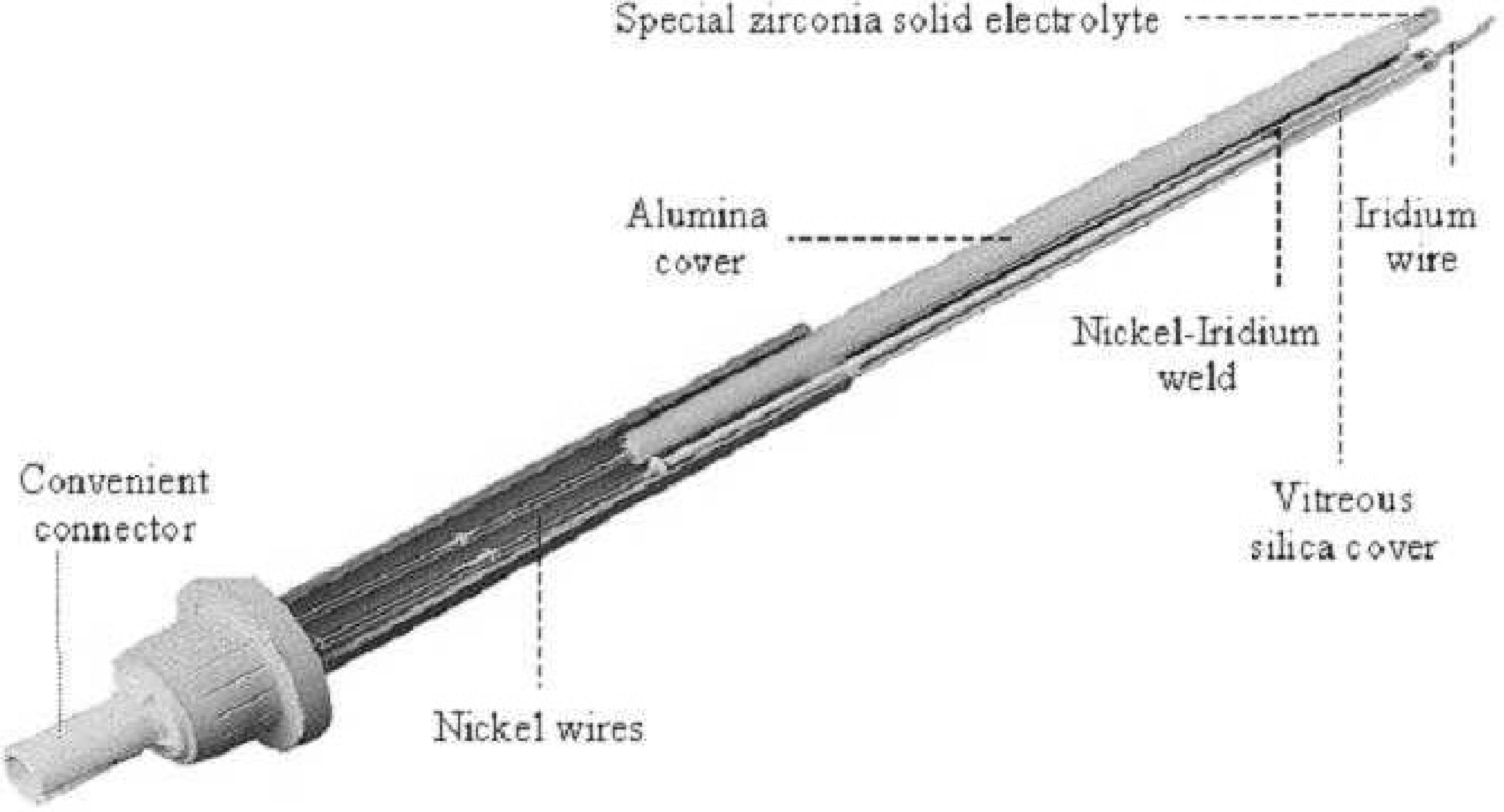
  - For a Ni/NiO reference :

$$\log\left(p_{O_2}\right) = \frac{20.171 * EMF - 24,420}{T} + 8.88$$

p_{O_2}(bar), EMF (mV), T (K)

Experimental procedure: measurement

- **RAPIDOX Sensor**

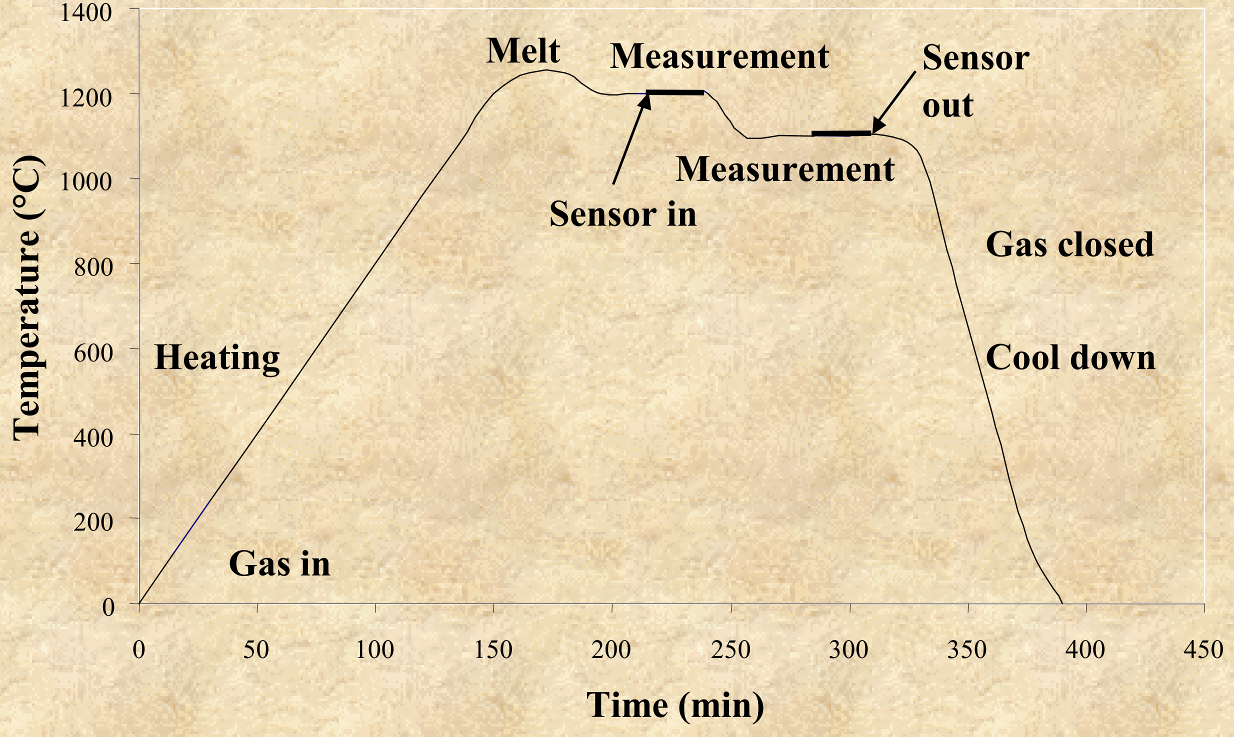


Experimental procedure: measurement

- **Atmosphere**
  - Nitrogen (99.8 %) (N_2)
  - Nitrogen + 5% hydrogen (N_2+5%H_2)
  - Nitrogen + thin layer (30-40 g) carbon black fine cokes (N_2+C)

- **Rotating crucible + eccentrically placed sensor**
  - Limitation of polarisation
  - Homogenisation of melt

Experimental procedure: measurement



Experimental procedure: materials

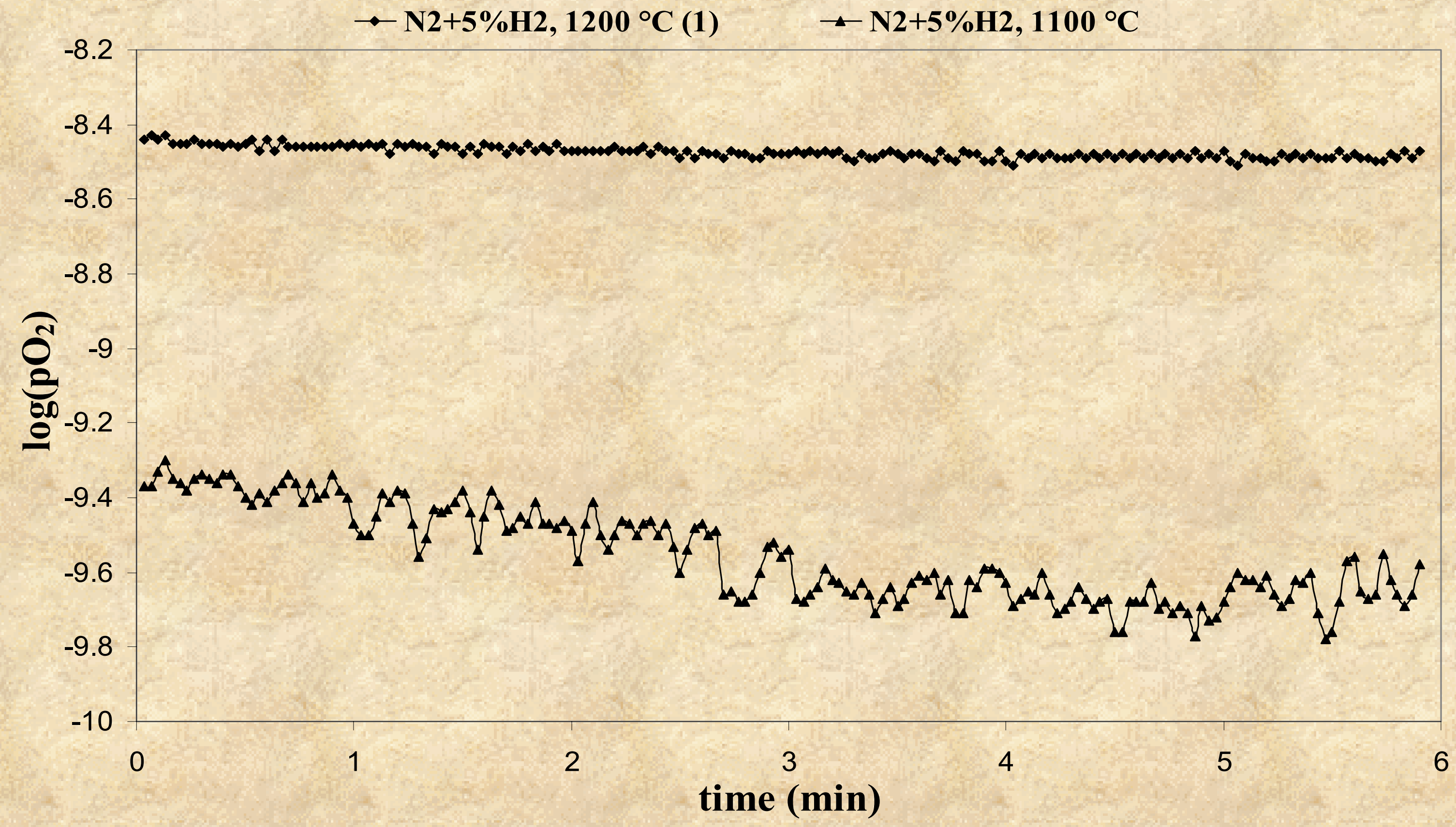
	Pb	Cu	Ni	Zn	Fe	
Slag 1	2.5	0.2	<0.1	5.9	25.0	Lead blast furnace slag
Slag 2	0,74	0.30	<0.02	5.1	21.5	Cleaned lead blast furnace slag
Slag 3	<0.1	0.10	<0.1	0.7	0.3	Reduced lead blast furnace slag
Slag 4	29.9	2.7	1.7	3.6	10.1	Lead-copper smelter slag
Slag 5	36.0	24.0	5.6	1.3	3.0	Copper convertor slag

Experimental procedure: calculations

- **Calculations using FactSage** (thermodynamic software)
- **Equilibrium with metal** (100 g slag/ 1 g metal)
  - Slags 1, 2 and 3: Pb rich metallic phase
  - Slags 4 and 5: Cu rich metallic phase
- **Slag components** = oxides
- **p_{O_2} of the system** = result

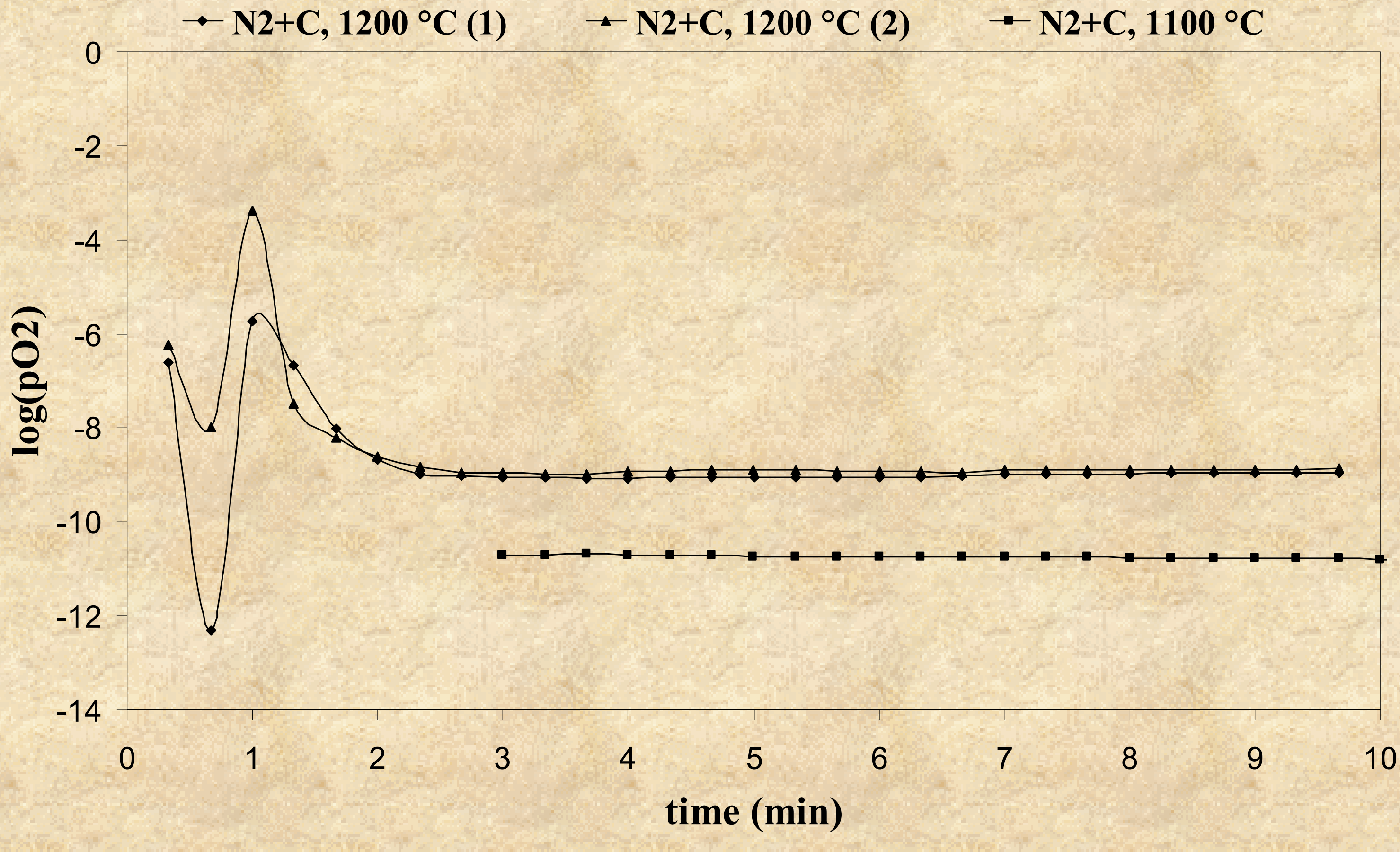
Results

- **Slag 1**



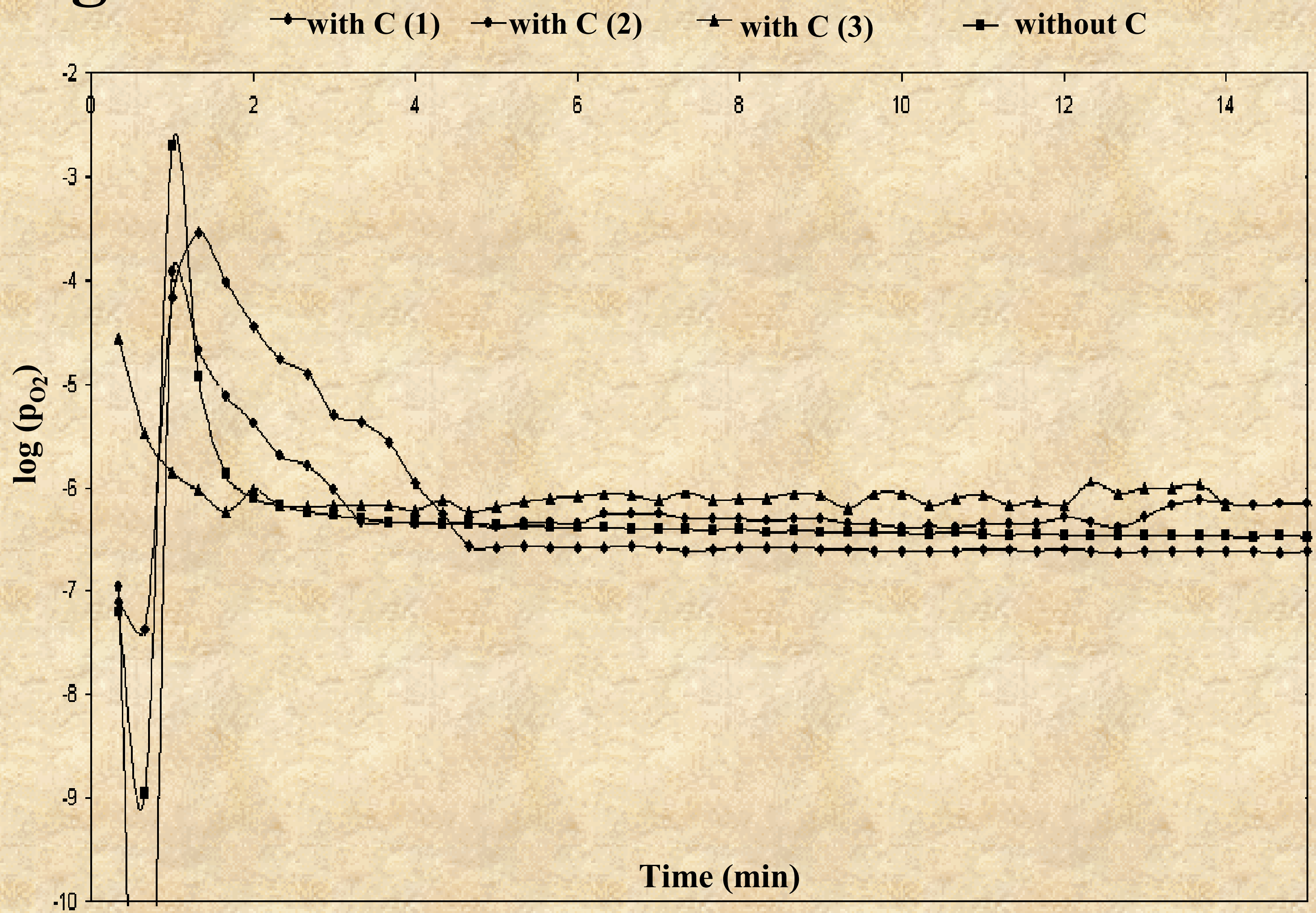
Results

- **Slag 1**



Results

- **Slag 4**



Results

Slag	Measured $\log(p_{O_2})$					Calculated $\log(p_{O_2})$	
	N_2 (+ 5% H_2)			N_2 + C			
	1100 °C	1200 °C	1300 °C	1100 °C	1200 °C	1100 °C	1200 °C
1	-9.5	-8.4		-10.8	-9.0	-10.5	-9.6
2		-7.7	-6.6			-10.7	-10.3
3					-10.6	-11.3	-10.4
4		-6.5			-6.4	-8.1	-7.1
5		-3.7					-6.8

Conclusions

- Range : 10^{-3}-10^{-12} bar
- $p_{O_2} < 10^{-6}$: carbon layer
- Ideal measurement temperature :
  - Depends on slag system
  - Corresponds to tapping temperature
- Problems
  - Dissolution of silica protection and corrosion of sensor
  - Polarisation
  - Homogenisation of the melt