# University of Pretoria

Inaugural Lecture and Address

at University of Pretoria, 28 July 2005

# Virtual Thermodynamic Potential


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# Outline of the presentation

Introduction

A bit of history

- Dynamic physical chemistry (kinetics)
- Equilibrium physical chemistry (thermodynamic)

Solution chemistry - work done in South Africa

- Potentiometric (equilibrium) data by non-equilibrium equation
- Dynamic (non-equilibrium) data by potentiometric equation

Virtual thermodynamics in action - examples

Conclusions

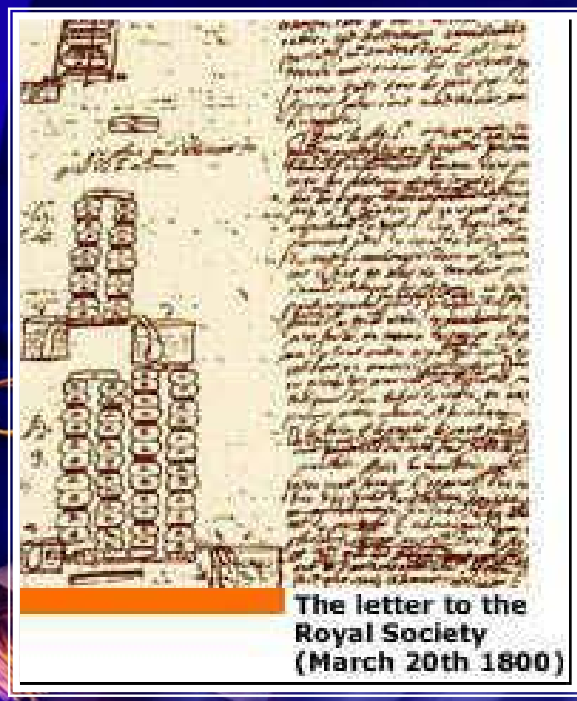
Department of Chemistry at UP – my vision

Acknowledgements

Alessandro Giuseppe Antonio Anastasio

VOLTA (1745 – 1827)

A voltaic Pile conserved in the "Tempio Voltiano"



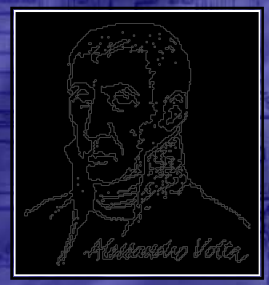
The letter to the Royal Society (March 20th 1800)

On 20 March 1800, Volta, Italian physicist, informs the President of the Royal Society, Sir Joseph Banks, of the invention of the pile.

Pile device was the first in history "electric battery", a source of continuous current

New source of energy

## Volta demonstrating the Voltaic Pile to Napoleon Bonaparte



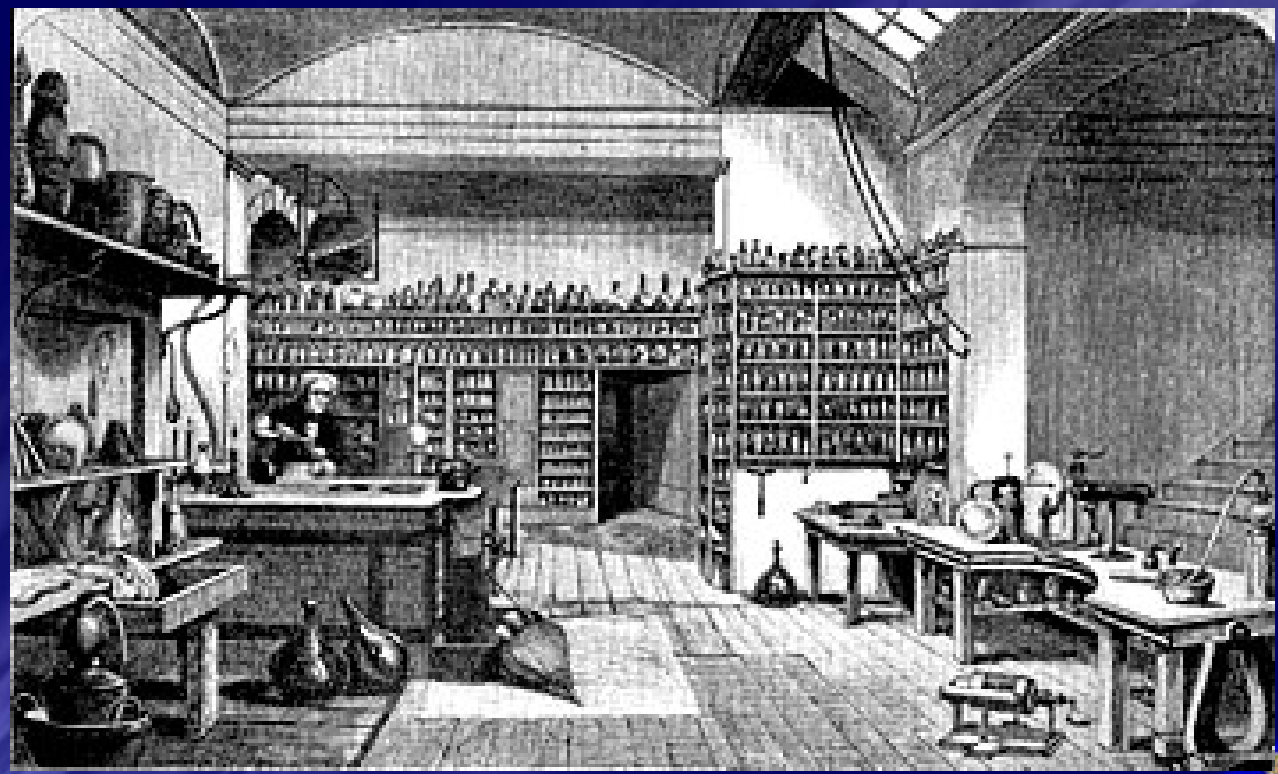

In June 1800, Napoleon reconfirms Volta as Professor of Experimental Physics

at the University of Pavia.

Till today presidents of some European countries confirm scientists as Full Professor at Universities

# Michael Faraday (1791-1867 )

English physicist and chemist



Faraday at work in his bottle-lined laboratory in the basement of the Royal Institution in London.

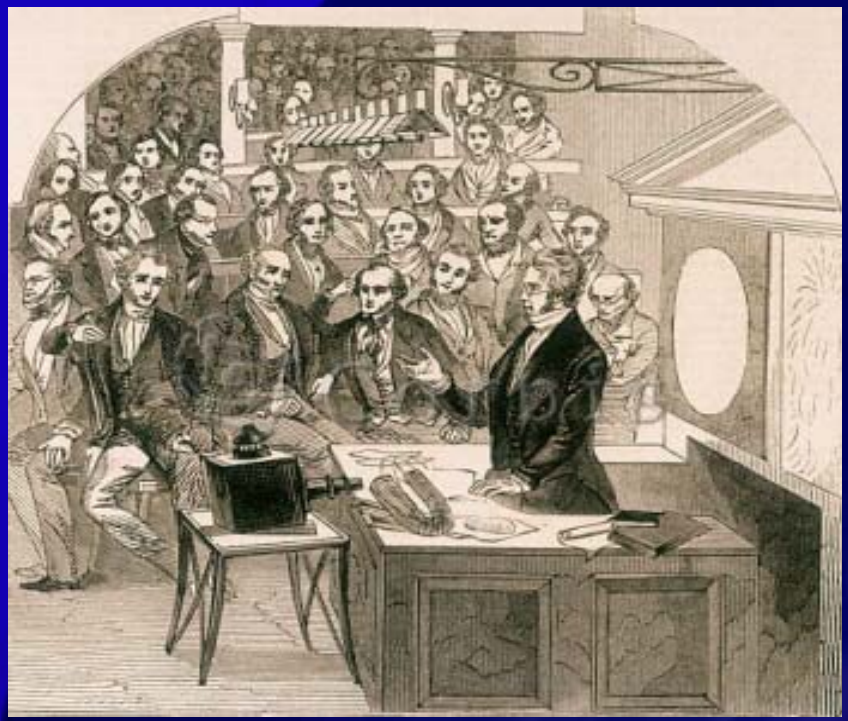
## Michael Faraday

## Theory of electrochemistry

## Faraday's two laws of electrochemistry:

(1) The amount of a substance deposited on each electrode of an electrolytic cell is directly proportional to the quantity of electricity passed through the cell.

(2) The quantities of different elements deposited by a given amount of electricity are in the ratio of their chemical equivalent weights



Here, members of the Royal Institution attend a lecture on

**Magnetism and Light**

by Professor Faraday

(London 1846)

Many years later, as **Maxwell** later freely admitted, the basic **ideas** for his mathematical theory of electrical and magnetic fields **came from Faraday.**

## Faraday introduced to science

## paramagnetics and diamagnetics

Tyndall said:

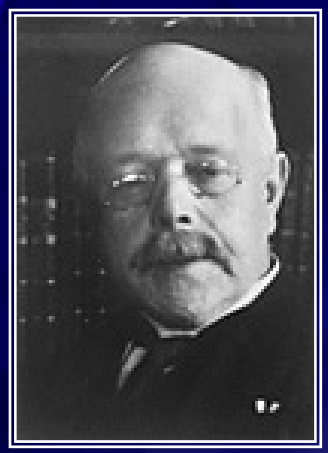
"Michael Faraday was the greatest experimental philosopher the world has ever seen; ... the mighty investigator"

Every year on Christmas Day, he presented at the Royal Institution his **Faraday Lectures for Children**

**Christmas lectures for children continue to this day.**

Two electrical units (for capacitance ar
Michael Faraday to honour his accomp

The discoveries by Galvani, Volta, Faraday and others indicated a promising future for dynamic electrochemistry.



## Walther Hermann Nernst (1864 - 1941)

German physicist and chemist

## The Nobel Prize in Chemistry 1920

Nobel Lecture, December 12, 1921

Studies in Chemical Thermodynamics

# The Nernst Equation and the Third Law of Thermodynamics

$$E = E^\circ - \frac{RT}{nF}\ln Q$$

$$\ln K = E^\circ \frac{nF}{RT}$$

$$\Delta_r G^\circ = -RT \ln K$$
$$\Delta_r G^\circ = -nFE^\circ$$

**Overthermodynamical approach prevents development of charge transfer at interfaces.**

**The direct conversion of chemical to electrical energy was stopped for some 50 years.**

# Dynamic Electrochemistry becomes recognised

## Max Volmer (1885 – 1965)

German professor of physical chemistry and electrochemistry

Max Volmer's work formed the basis of phenomenological kinetic electrochemistry

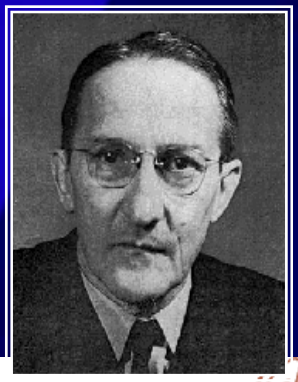
Butler-Volmer equation

$$E = E^{\circ} - \frac{RT}{nF}\ln Q$$

$$i = i_o\left[\exp\left(\frac{\alpha_A nF}{RT}\eta\right) - \exp-\left(\frac{\alpha_C nF}{RT}\eta\right)\right]$$

Max Volmer became a director of the Institute of Physical Chemistry and Electrochemistry.

# Dynamic Electrochemistry – highest Honours



J. Heyrovský

(1890 - 1967)

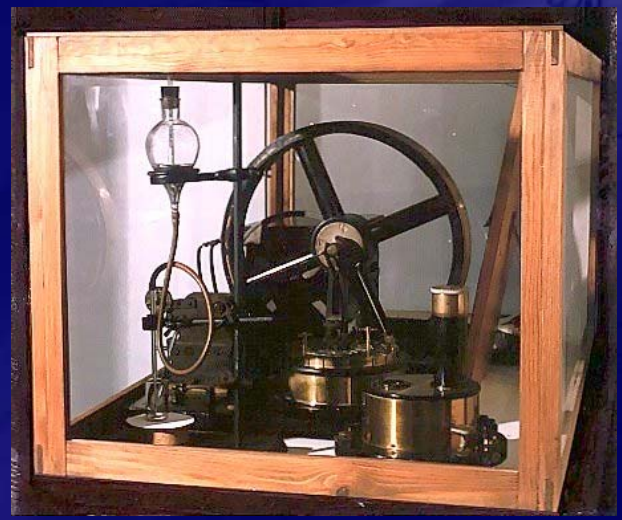
Charles University, Prague

Jaroslav Heyrovský, father of electroanalytical chemistry, recipient of the Nobel Prize.

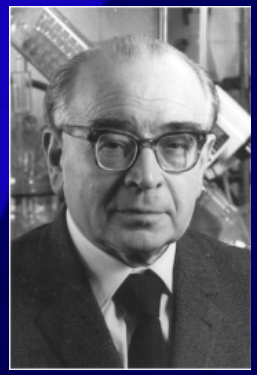
All voltammetric methods used now in electroanalytical chemistry originate from polarography developed by him.

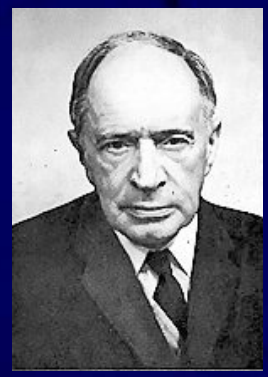
1959

*Jaroslav Heyrovský and his son Michael*



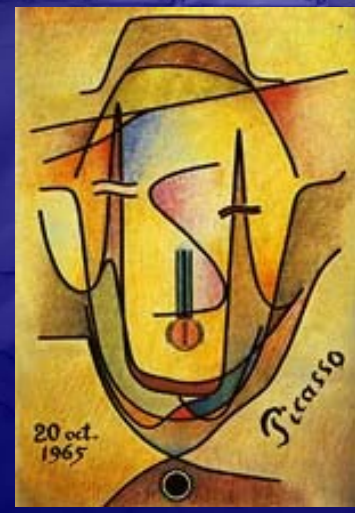
# Dynamic Electrochemistry - well established science





*Wiktor Kemula*

## Alexander Naumovich Frumkin "father" of Russian electrochemistry.




**The portrait of Frumkin painted in the Picasso's manner**

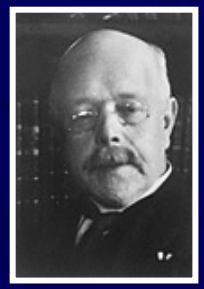
***A.N. Frumkin and J. O'M. Bockris (U.S.A. 1960)***

***According to Bockris:***

***"The Great Nernstian Hiatus"***

***was ended by Frumkin***

## EQUILIBRIUM E-CHEMISTRY



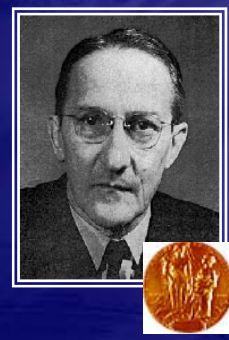
Walther Hermann Nernst

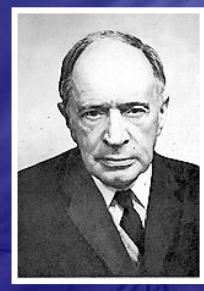
Physical Chemistry textbook by Atkins

Physical Chemistry textbook by Levine

Analytical Chemistry textbooks

## DYNAMIC E-CHEMISTRY (KINETICS)





M. Volmer J. Heyrovský A.N. Frumkin

Physical Chemistry textbook by Atkins

Analytical Chemistry textbooks

# Metal-Ligand interactions ( $M_pL_qH_r$)

## Model of a Metal-Ligand system & thermodynamic stability constants

### EQUILIBRIUM E-CHEMISTRY

**Glass electrode potentiometry**

**Nernst equation**

**Thermodynamic potential**

### DYNAMIC E-CHEMISTRY

**Voltammetric techniques**

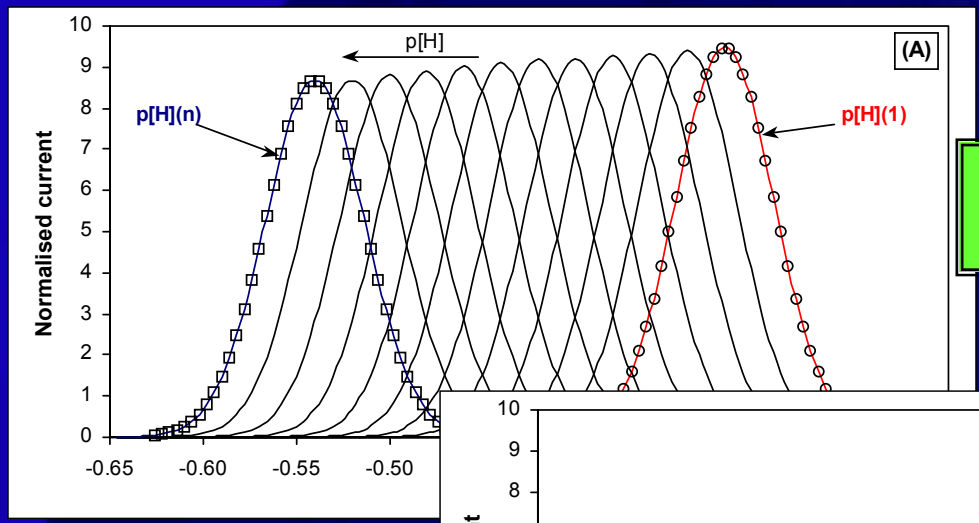
**Many simplified equation**

**Thermodynamics**

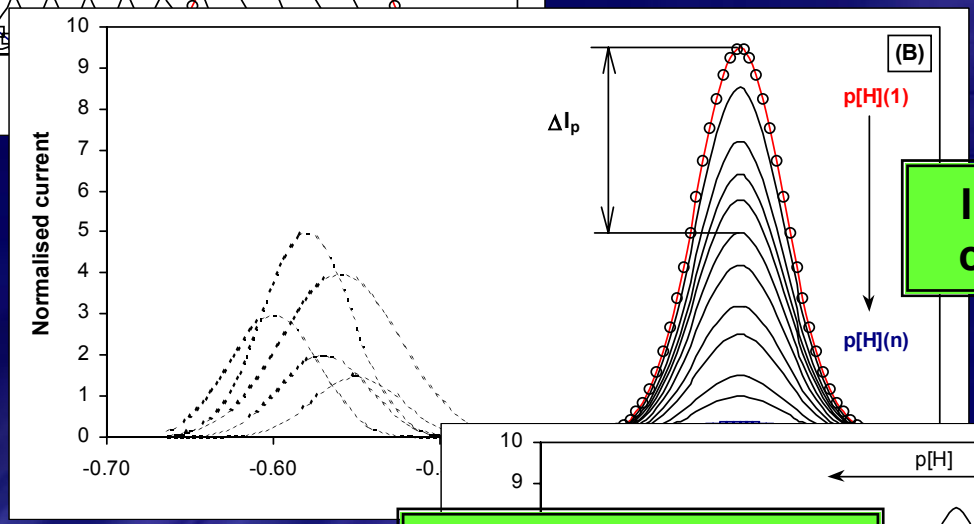
**Kinetics (electron transfer)**

**Transport (to & from interface)**

**Two different WORLDS that did not talk to each other at all.**




Dynamic and labile M-L system




Inert metal complexes

Homogeneous Equilibria

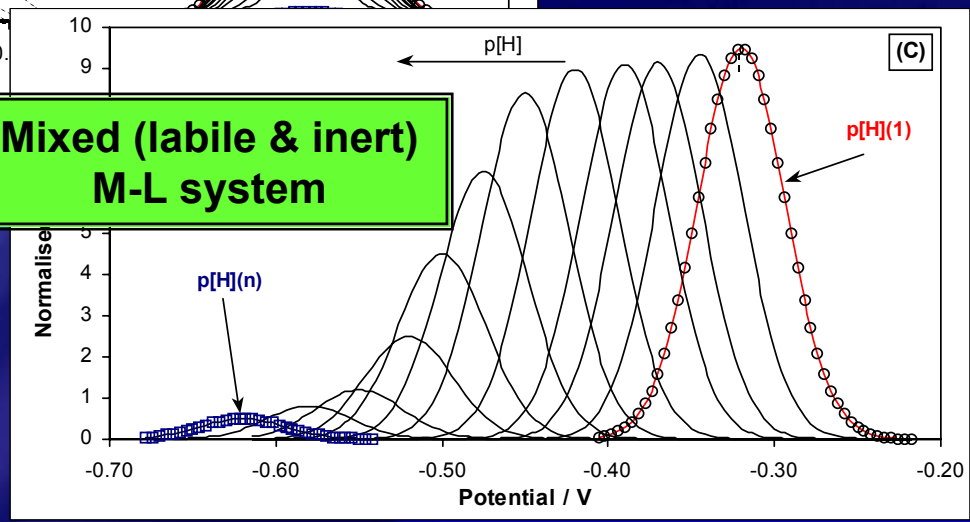
Interfacial kinetics?

Reversible

Quasi-Reversible

Irreversible

Mixed (labile & inert) M-L system



## 1) Main experimental variable – $\Delta E$

Skoog, …Fundamentals of Anal. Chem 6th ed. 1992

$$\Delta E_{1/2} - \frac{RT}{nF}\ln\frac{I(c)}{I(s)} = \frac{RT}{nF}\ln\beta_{ML_j}[L_T]^J$$

Lingane
1941

$$\Delta E_{1/2} - \frac{RT}{nF}\ln\frac{I(c)}{I(s)} = \frac{RT}{nF}\ln\sum_0^N \beta_{ML_j}[L_T]^j$$

DeFord-Hume
1951

Still regarded as the method in the field

$$F_0[X] = \sum_0^N \beta_{MX_j}[X_T]^j$$

Leden–DeFord–Hume
1951

$$F_{00}[X,Y] = \sum_0^N \beta_{MX_jY_i}[X_T]^j[Y_T]^i$$

Leden–Schaap–Mc Master
1961

Dynamic and labile M-L system

Mass-balance equations not involved

No rigorous refinement of stability constants

Limited applications with quite uncertain results

**2) Experimental variable – $\Delta I$**

$$\overline{D} = \frac{D_M + D_{ML} K_{ML}[L]}{1 + K_{ML}[L]}$$

Kačena and Matoušek
1953

**Inert comlex ML (at fixed pH)**

$$K_{ML} = K_{NL} \times \frac{(I_N - I_{N(M)})(c_M I_N - c_N I_{N(M)})}{(I_{N(M)})^2}$$

Schwarzenbach
1952

**No rigorous data evaluation**

**Is there any room for further development?**

A paradigm shift

(1996)

**Any kind of comlex $M_xL(1)_yL(2)_z$ (at any experimental conditions)**

**Corrected shift in potential ($\Delta E_p$ or $\Delta E_{1/2}$) or change in potential (ISE)**

$$\left(E(s)-E(c)\right)_{x(i)} - \frac{RT}{nF}\ln\left(\frac{I(c)}{I(s)}\right)_{x(i)} = \frac{RT}{nF}\ln\left(\frac{[M_T]}{[M]}\right)_{x(i)}$$

[M] from mass-balance equations; modelling–refinement: ECFC & CCFC

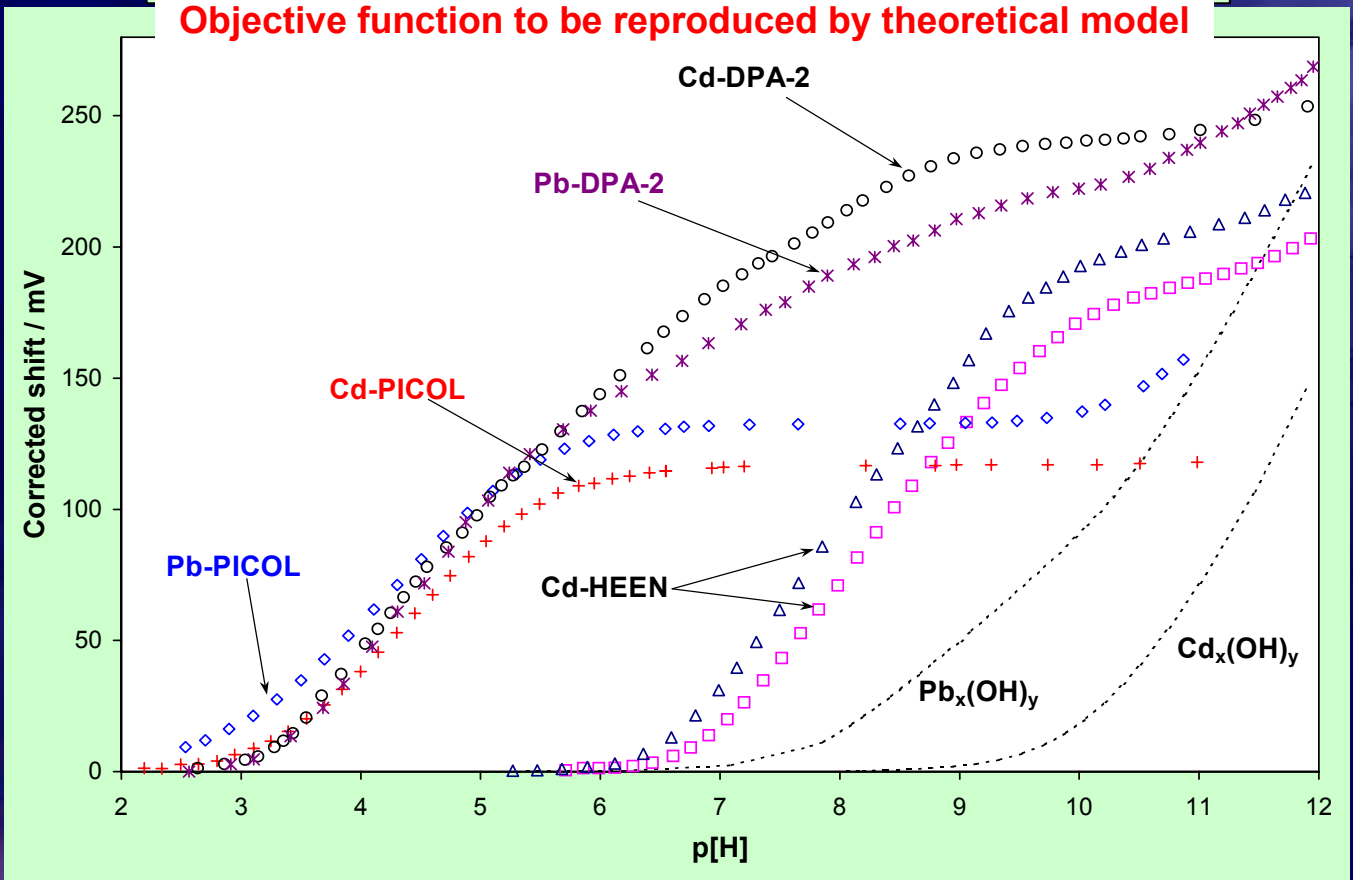
I. Cukrowski, *Anal. Chim. Acta* 336 (1996) 23-36

I. Cukrowski, M. Adsetts, *J. Electroanal. Chem.* 429 (1997) 129-137

## Corrected shift & Experimental Complex Formation Curves

$$CS_{x(i)} = \left(E(s) - E(c)\right)_{x(i)} - \frac{RT}{nF} \ln\left(\frac{I(c)}{I(s)}\right)_{x(i)}$$

**Objective function to be reproduced by theoretical model**




I. Cukrowski, M. Adsetts, *J. Electroanal. Chem.* 429 (1997) 129-137

| | |
|---|---|
| $M + 4H + L \leftrightarrow M(H_4L)$ | $\beta_{M(H_4L)} = [MH_4L] / [M][H]^4[L]$ |
| $M + 2H + L \leftrightarrow M(H_2L)$ | $\beta_{M(H_2L)} = [MH_2L] / [M][H]^2[L]$ |
| $2M + L \leftrightarrow M_2L$ | $\beta_{M_2L} = [M_2L] / [M]^2[L]$ |
| $M + L \leftrightarrow ML$ | $\beta_{ML} = [ML] / [M][L]$ |
| $M + 2L \leftrightarrow ML_2$ | $\beta_{ML_2} = [ML_2] / [M][L]^2$ |
| $M + L + OH \leftrightarrow ML(OH)$ | $\beta_{ML(OH)} = [ML(OH)] / [M][L][OH]$ |

**Complexes:**

**Protonated**

**Polynuclear**

**Labile**

**Inert**

**hydroxo**

| | |
|---|---|
| $M + OH \leftrightarrow M(OH)$ | $\beta_{M(OH)} = [M(OH)] / [M][OH]$ |
| $M + 2OH \leftrightarrow M(OH)_2$ | $\beta_{M(OH)_2} = [M(OH)_2] / [M][OH]^2$ |
| $M + 3OH \leftrightarrow M(OH)_3$ | $\beta_{M(OH)_3} = [M(OH)_3] / [M][OH]^3$ |
| $M + 4OH \leftrightarrow M(OH)_4$ | $\beta_{M(OH)_4} = [M(OH)_4] / [M][OH]^4$ |
| $2M + OH \leftrightarrow M_2(OH)$ | $\beta_{M_2(OH)} = [M_2(OH)] / [M]^2[OH]$ |
| $4M + 4OH \leftrightarrow M_4(OH)_4$ | $\beta_{M_4(OH)_4} = [M_4(OH)_4] / [M]^4[OH]^4$ |

| | |
|---|---|
| $H + L \leftrightarrow HL$ | $K_1^H = [HL] / [H][L]$ |
| $H + HL \leftrightarrow H_2L$ | $K_2^H = [H_2L] / [H][HL]$ |
| $H + H_2L \leftrightarrow H_3L$ | $K_3^H = [H_3L] / [H][H_2L]$ |
| $H + H_3L \leftrightarrow H_4L$ | $K_4^H = [H_4L] / [H][H_3L]$ |
| $H + H_4L \leftrightarrow H_5L$ | $K_5^H = [H_5L] / [H][H_4L]$ |
| $H + H_5L \leftrightarrow H_6L$ | $K_6^H = [H_6L] / [H][H_5L]$ |

I. Cukrowski et al, *Anal. Chim. Acta* 379 (1999) 217-226

$$[M_T] = [M] + \beta_{M(H_4L)}[M][H]^4[L] + \beta_{M(H_2L)}[M][H]^2[L] + 2\beta_{M_2L}[M]^2[L] + \beta_{ML}[M][L] + \beta_{ML_2}[M][L]^2 + \beta_{ML(OH)}[M][L][OH] + \beta_{M(OH)}[M][OH] + \beta_{M(OH)_2}[M][OH]^2 + \beta_{M(OH)_3}[M][OH]^3 + \beta_{M(OH)_4}[M][OH]^4 + 2\beta_{M_2(OH)}[M]^2[OH] + + 4\beta_{M_4(OH)_4}[M]^4[OH]^4$$

$$[L_T] = [L] + K_1^H[H][L] + K_1^H K_2^H[H]^2[L] + K_1^H K_2^H K_3^H[H]^3[L] + K_1^H K_2^H K_3^H K_4^H[H]^4[L] + K_1^H K_2^H K_3^H K_4^H K_5^H[H]^5[L] + K_1^H K_2^H K_3^H K_4^H K_5^H K_6^H[H]^6[L] + \beta_{M(H_4L)}[M][H]^4[L] + \beta_{M(H_2L)}[M][H]^2[L] + \beta_{M_2L}[M]^2[L] + \beta_{ML}[M][L] + 2\beta_{ML_2}[M][L]^2 + \beta_{ML(OH)}[M][L][OH]$$

$$\{q(RT/nF)\}/p$$

$$\frac{RT}{nF}\ln\left(\frac{[M_T]}{[M]}\right)_{x(i)}$$

**Computed Complex Formation Curve**

**Theoretical model**

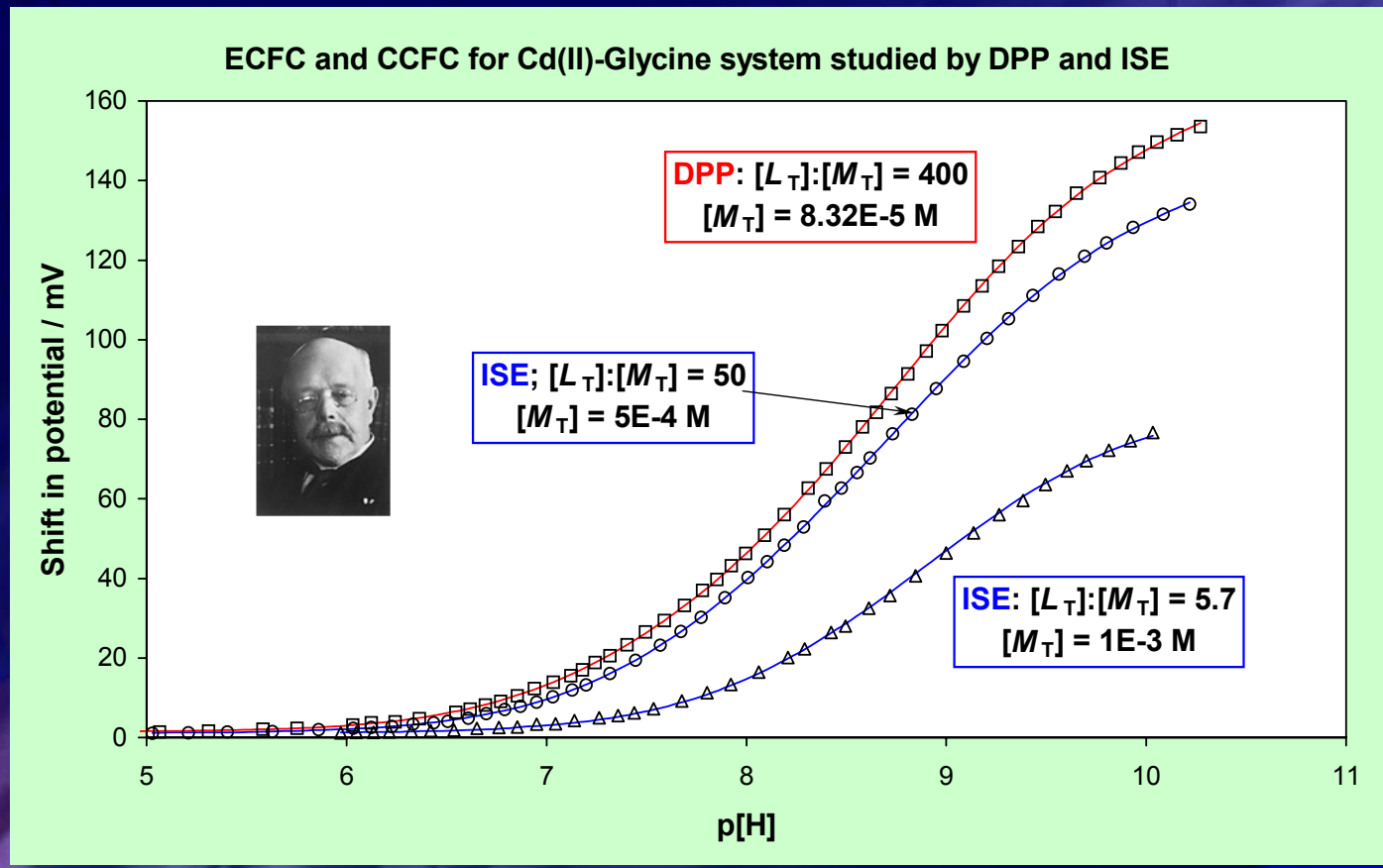
**New definition of Nernstian slope**

**(modelling of M-L systems)**

I. Cukrowski et al, *Anal. Chim. Acta* 379 (1999) 217-226

## Nernstian data by DYNAMIC ELECTROCHEMISTRY equation

$$\left(E(s)-E(c)\right)_{x(i)} = \frac{RT}{nF}\ln\left(\frac{[M_T]}{[M]}\right)_{x(i)}$$




I. Cukrowski, G. Ngigi, *Electroanalysis* 13 No. 15 (2001) 1242-1252

# Metal-Ligand interactions ( $M_pL_qH_r$)

## Model of a Metal-Ligand system & thermodynamic stability constants

**EQUILIBRIUM E-CHEMISTRY**

**DYNAMIC E-CHEMISTRY**

Potentiometric data changed to

Virtual dynamic data

$$\left(E(s)-E(c)\right)_{x(i)} \qquad = \frac{RT}{nF}\ln\left(\frac{[M_T]}{[M]}\right)_{x(i)}$$

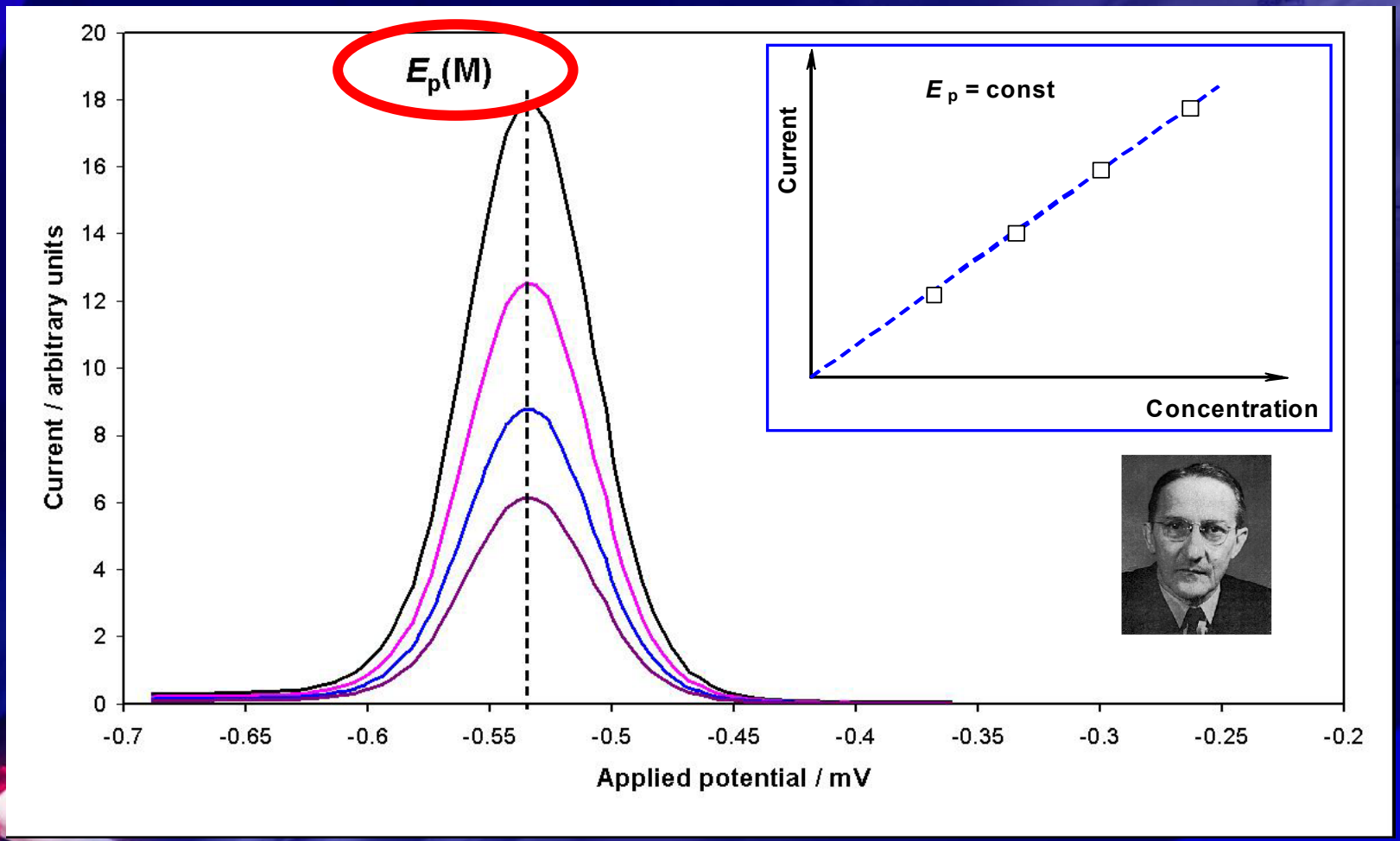
The same equation is valid for fully dynamic and reversible M-L system studied by voltammetry

**Nernst domain by equation for the dynamic data treatment at any experimental conditions**

I. Cukrowski, G. Ngigi, *Electroanalysis* 13 No. 15 (2001) 1242-1252

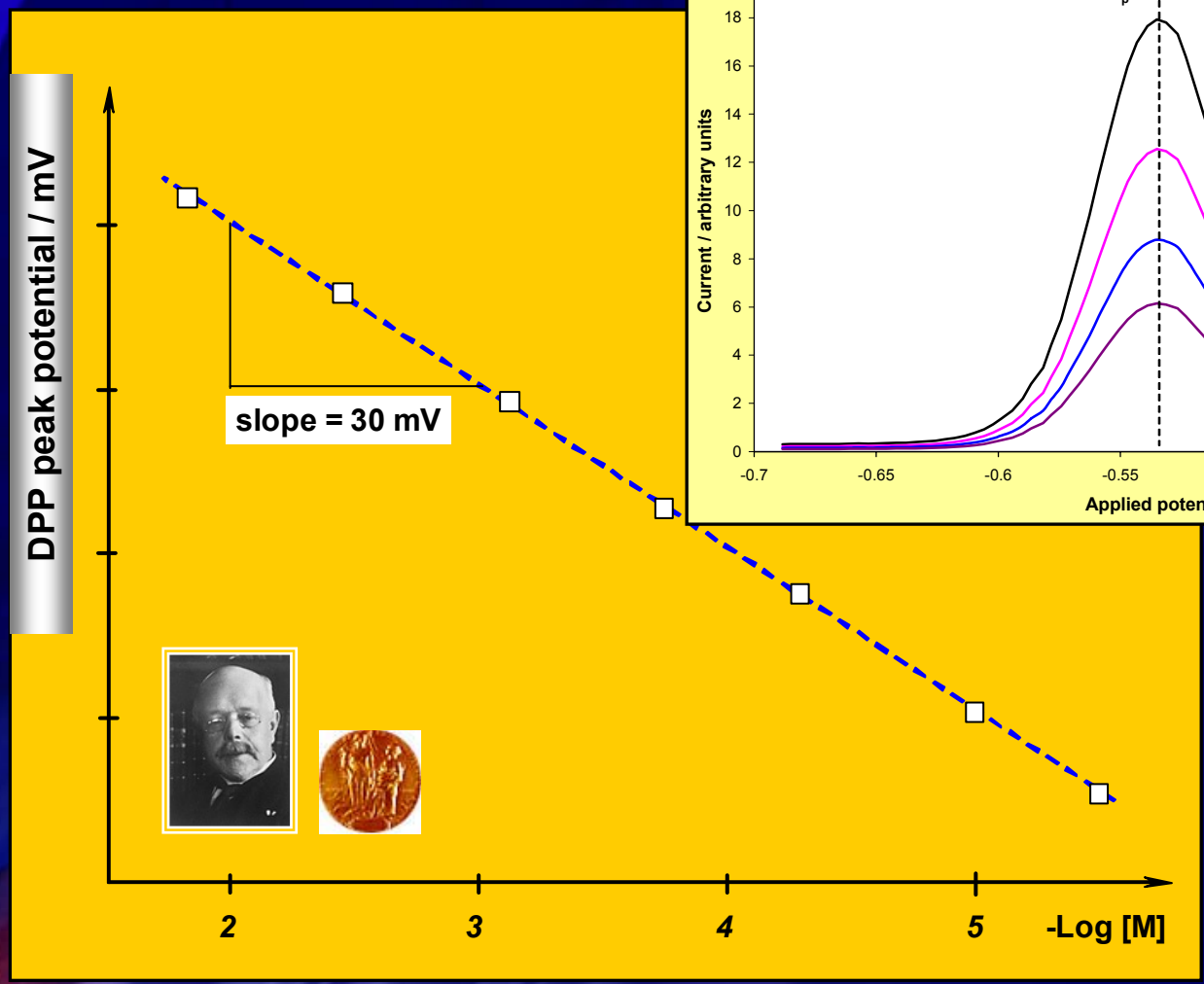
I. Cukrowski, N. Maseko, *Electroanalysis* 15 No. 17 (2003) 1377-1388

## Quantitative voltammetric analysis of a metal ion



# 'Virtual ISE' from polarographic results

## Virtual thermodynamic data



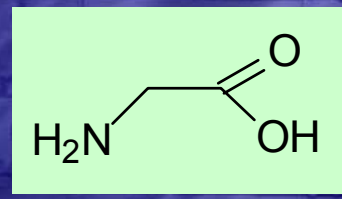
# DPP of a labile (or dynamic) M-L system

Peak representing all metal species

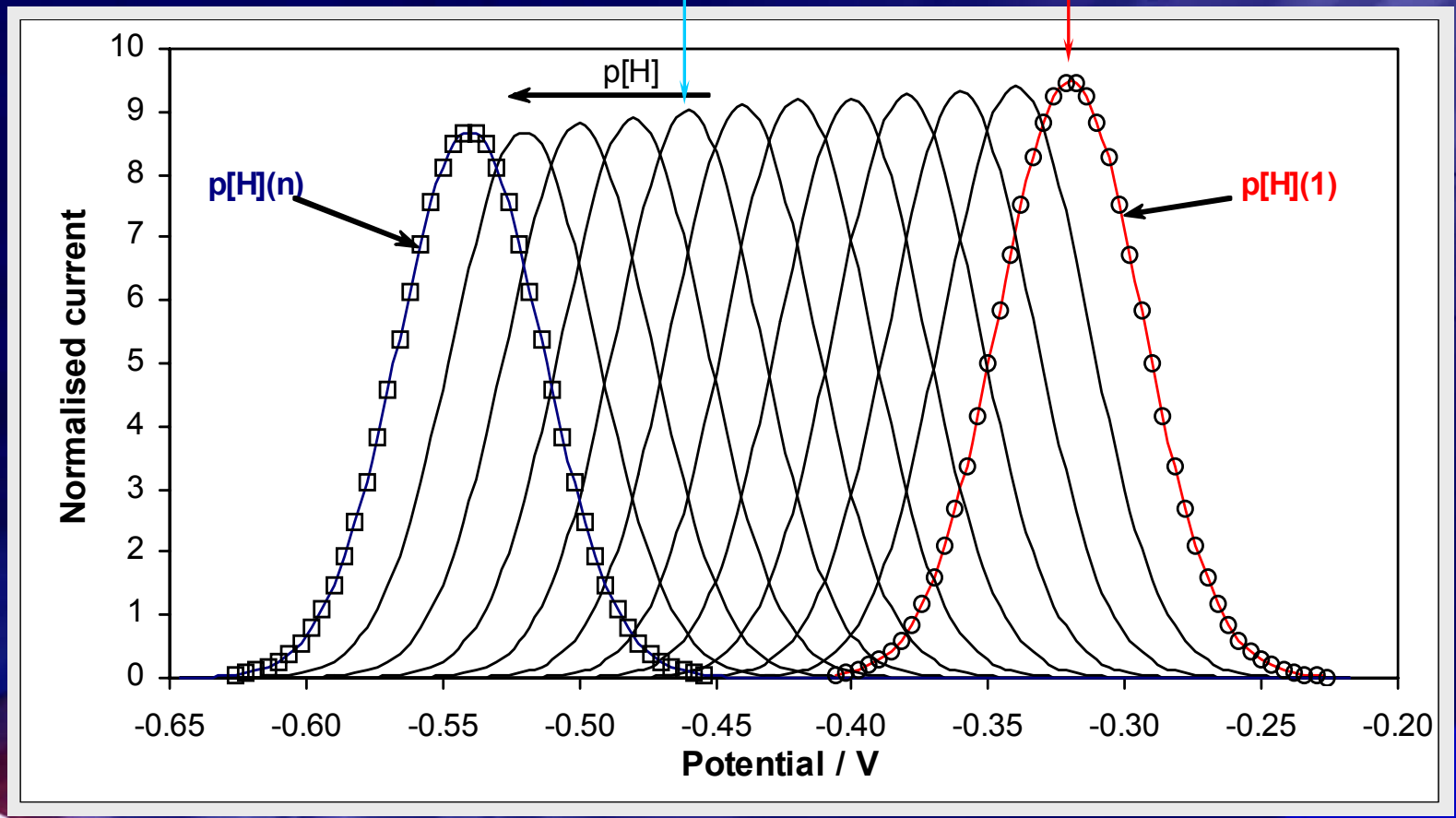
Peak of a free metal ion

Shift in $E_p$

$\{E_p(s) - E_p(c)\}$



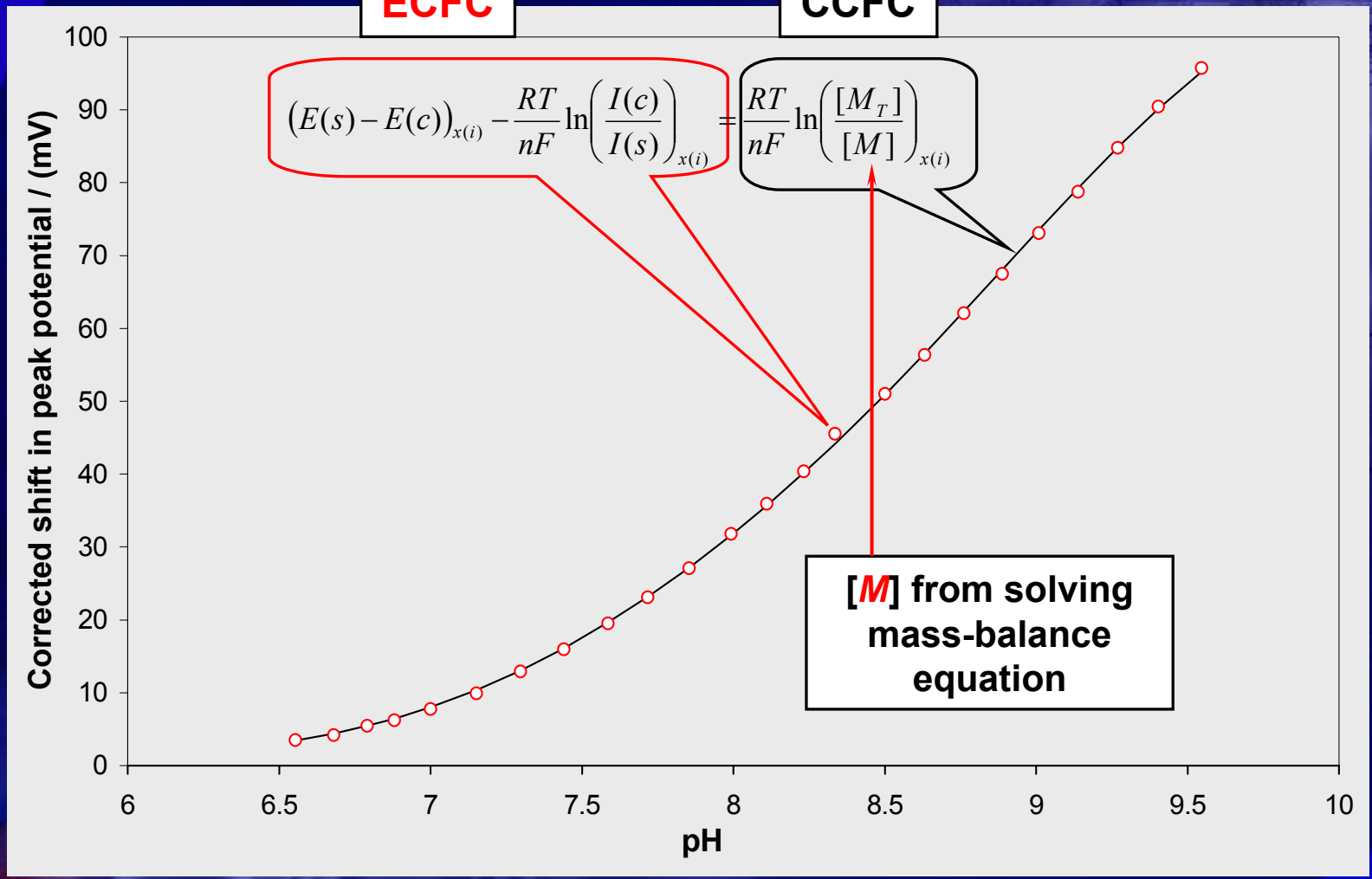

Glycine




Cd-Glycine-OH system

# Refinement of stability constants: complex formation curves

**ECFC** **CCFC**



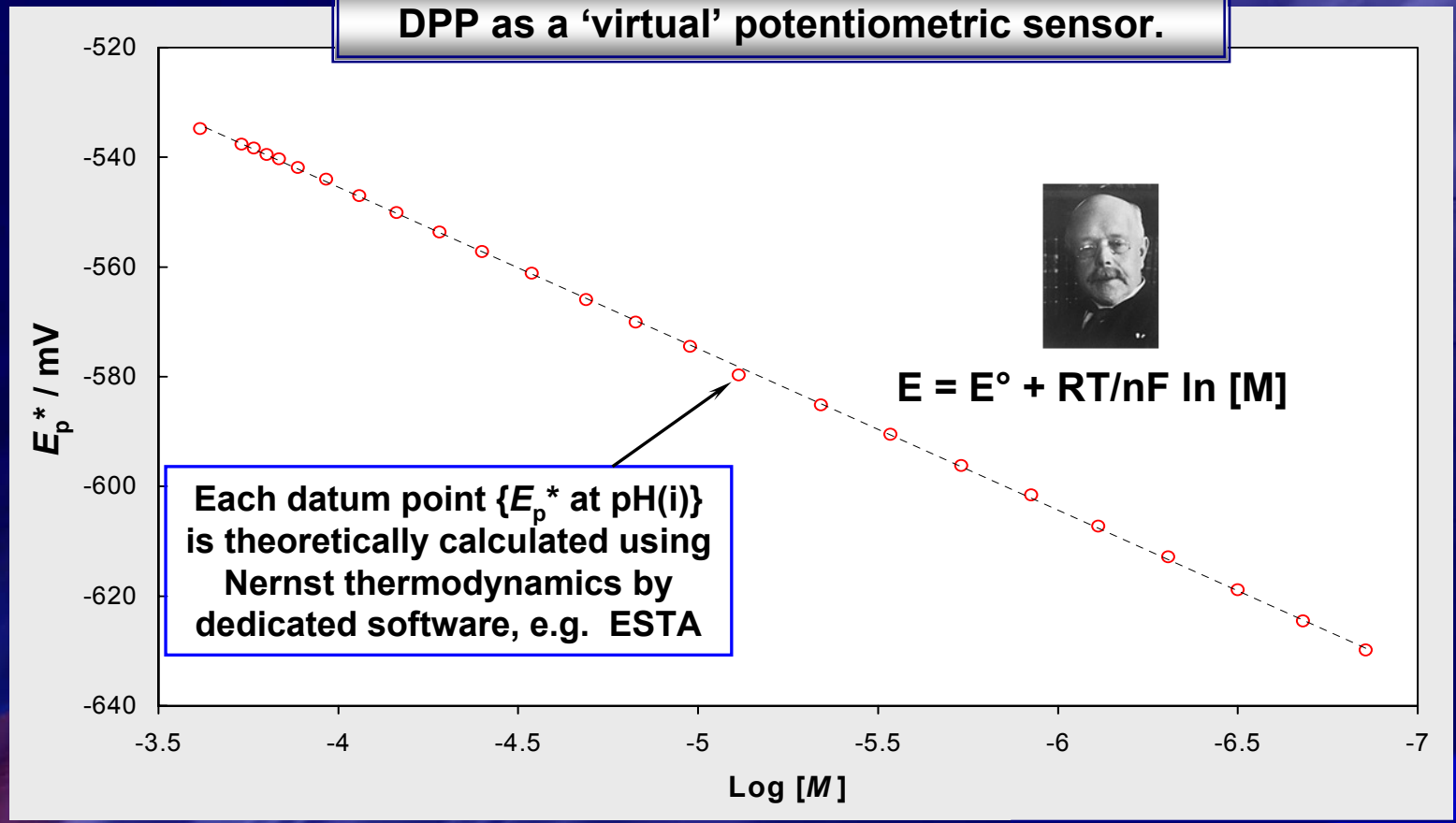

I. Cukrowski, *Anal. Chim. Acta* 319 (1996) 39 – 48.
I. Cukrowski, M. Adsetts, *J. Electroanal. Chem.* 429 (1997) 129 - 137

Cd-Glycine-OH system

$$E_p(c)_{x(i)} + \frac{RT}{nF}\ln\left(\frac{I(c)}{I(s)}\right)_{x(i)} = (E_p^*)_{x(i)}$$

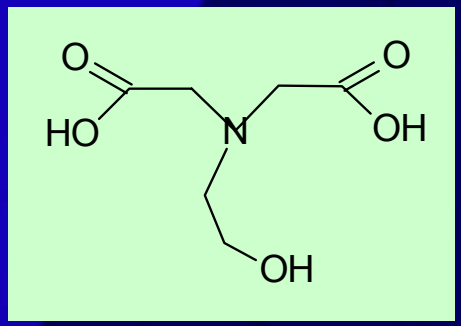
$$E_p^* < E_p(c) \quad if \quad I(c) < I(s)$$

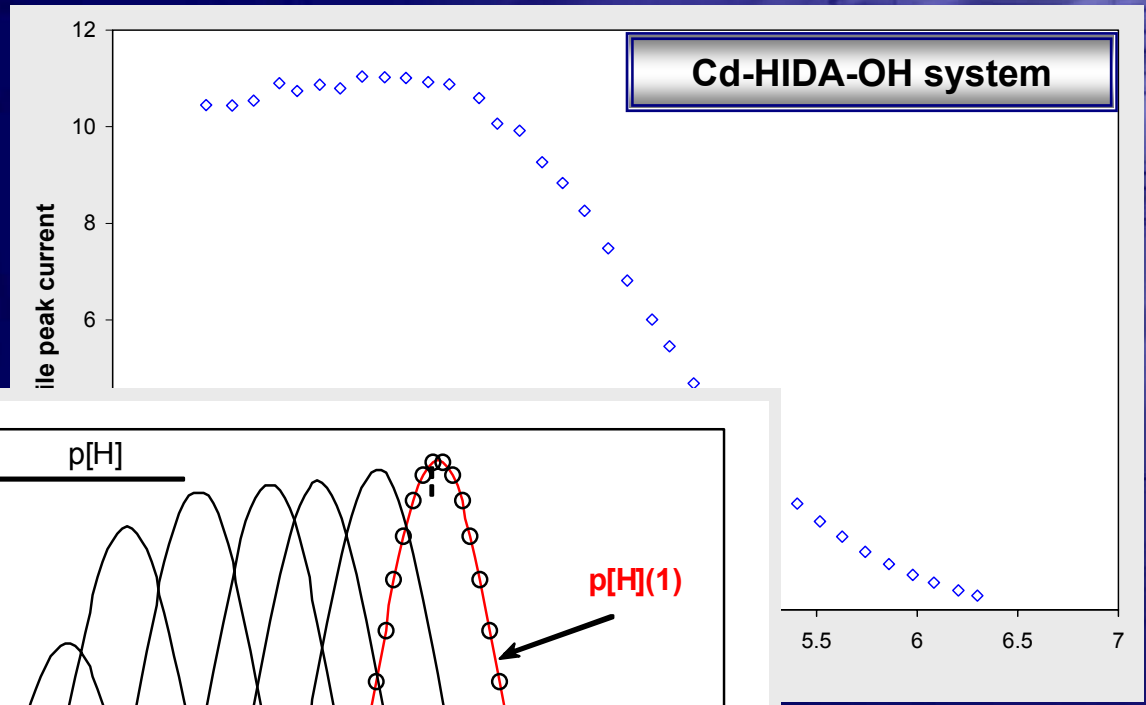
## DPP as a 'virtual' potentiometric sensor.

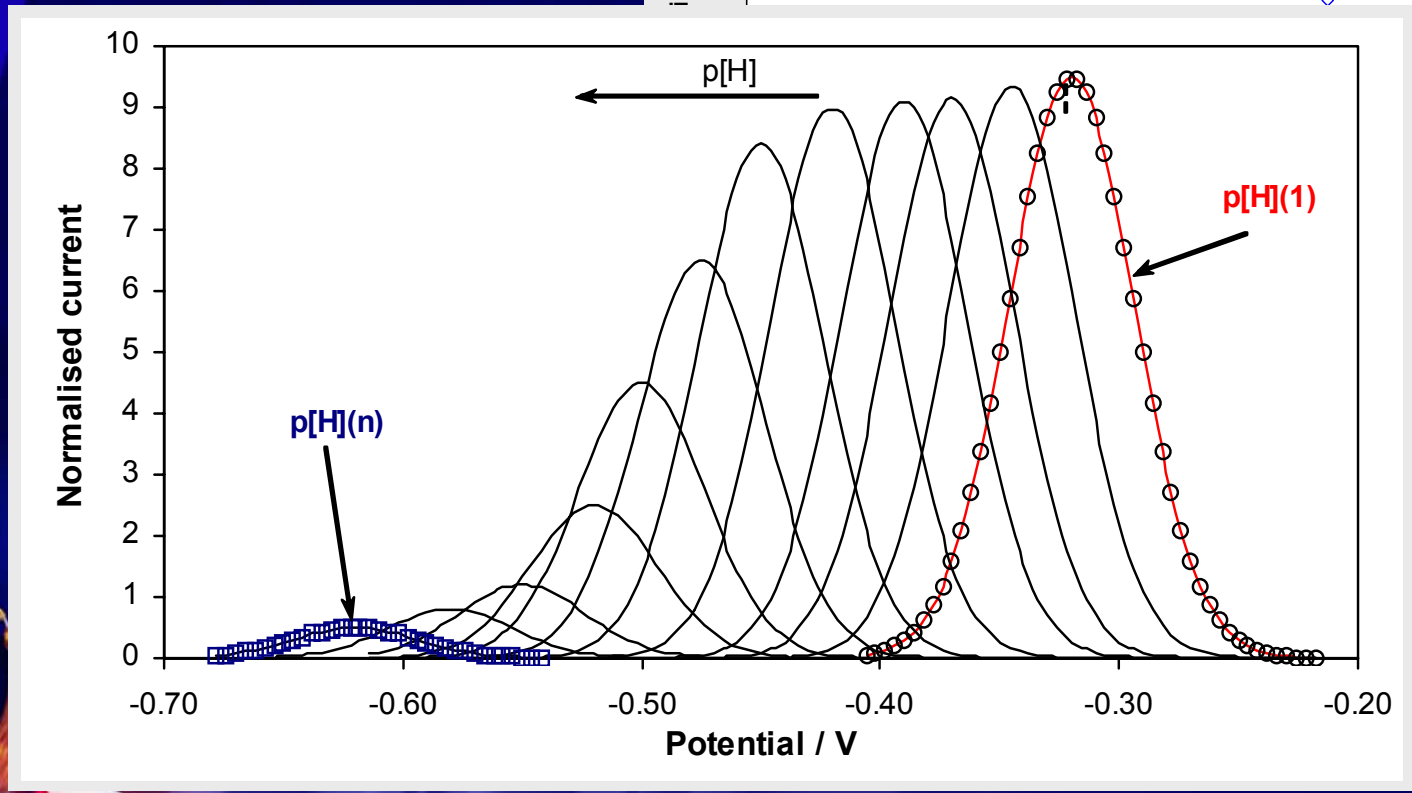



Cd-Glycine-OH system

I. Cukrowski, J. Zhang, *Electroanalysis* 16, No. 8 (2004) 612 - 626

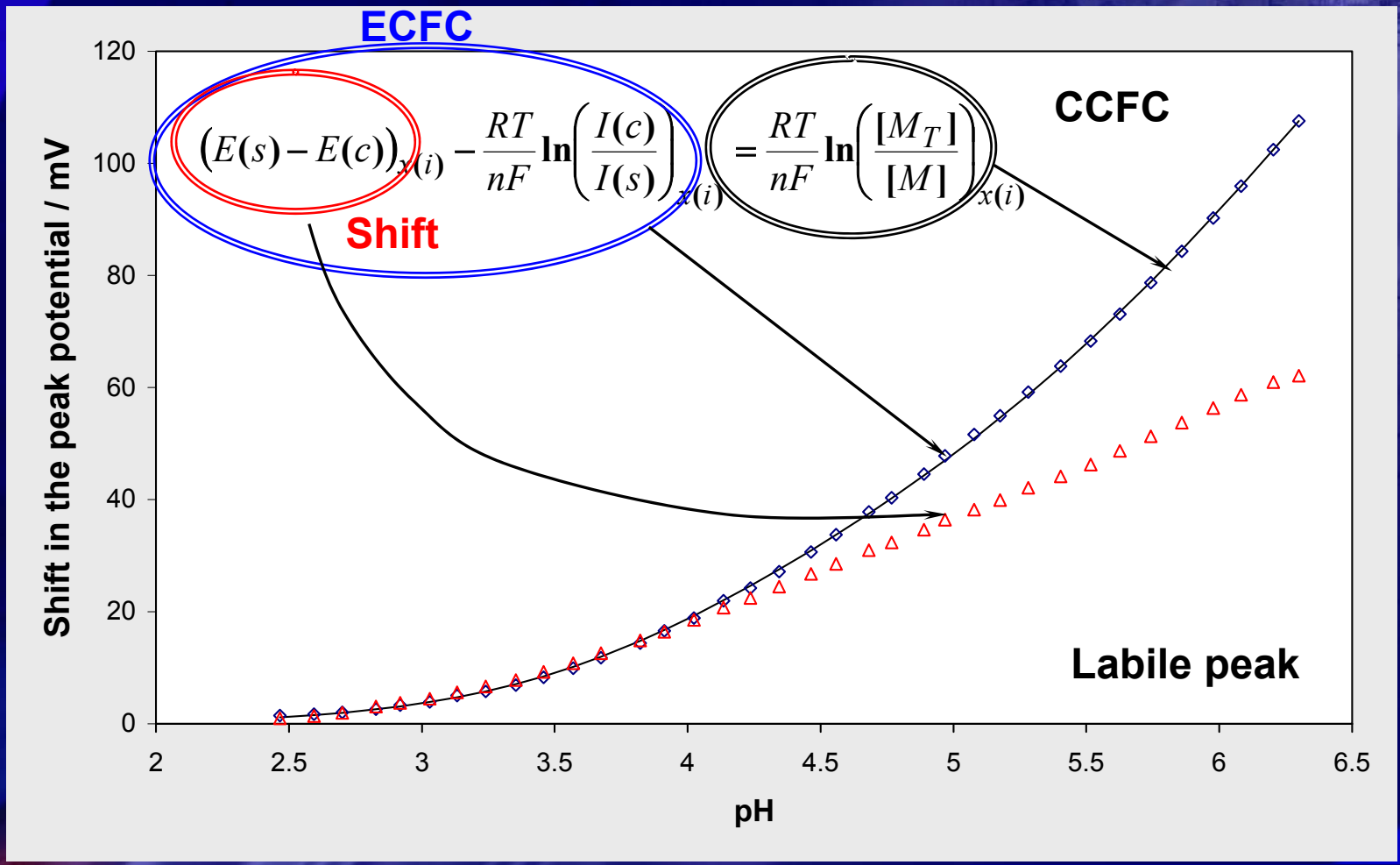



I. Cukrowski, N. Maseko, *Electroanalysis* 15 No. 17 (2003) 1377-1388

# Experimental and Computed Complex Formation Curves




Cd-HIDA-OH system

I. Cukrowski, N. Maseko, *Electroanalysis* 15 No. 17 (2003) 1377-1388

# Virtual thermodynamic data

$$E_p(c)_{x(i)} + \frac{RT}{nF}\ln\left(\frac{I(c)}{I(s)}\right)_{x(i)} = (E_p^*)_{x(i)}$$

E = E° + RT/nF ln [M]

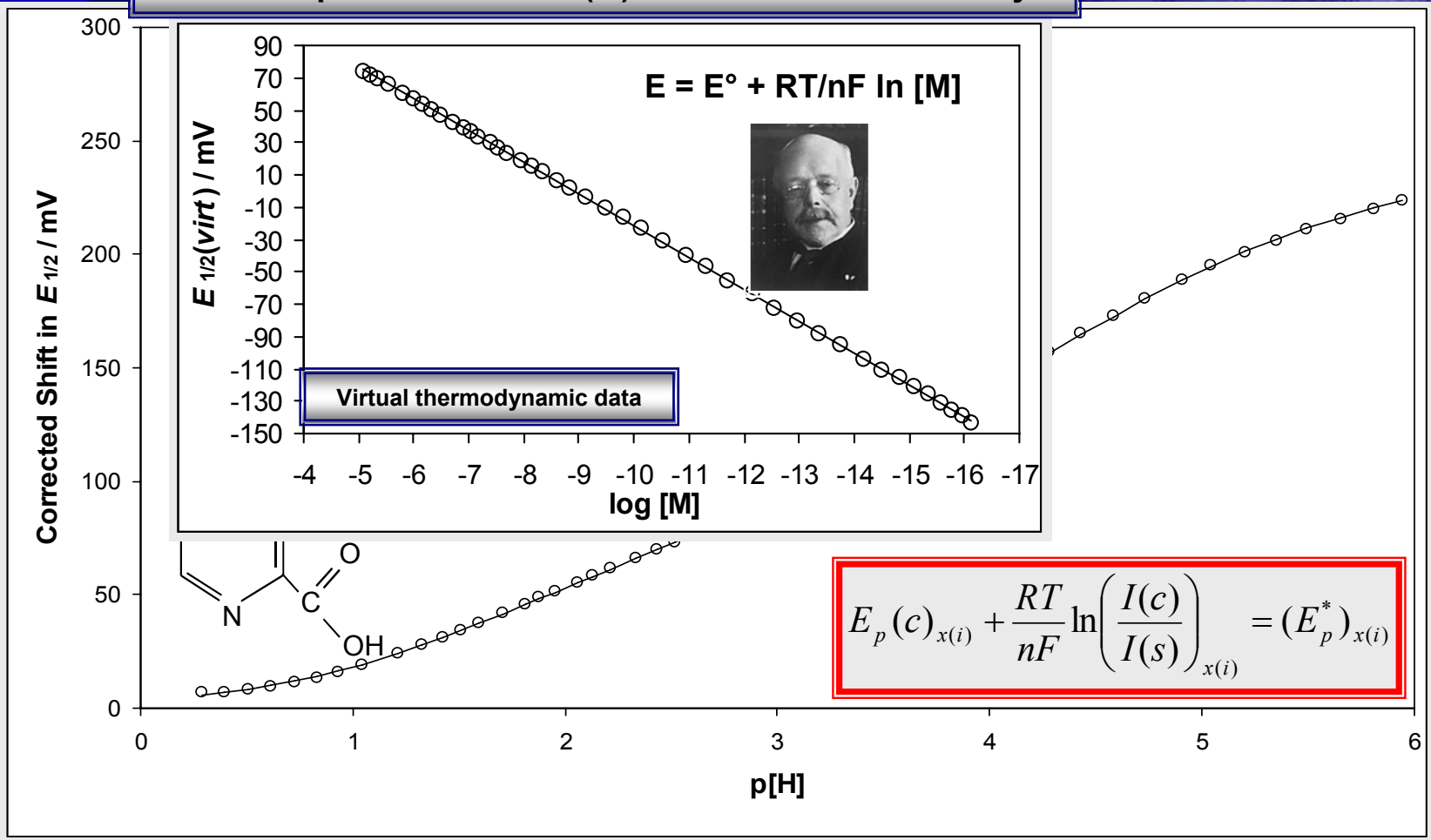



'Virtual' potentiometric [Cd] (ISE) sensor from voltammetry

I. Cukrowski, J.M. Zhang, unpublished results

Cd-HIDA-OH system

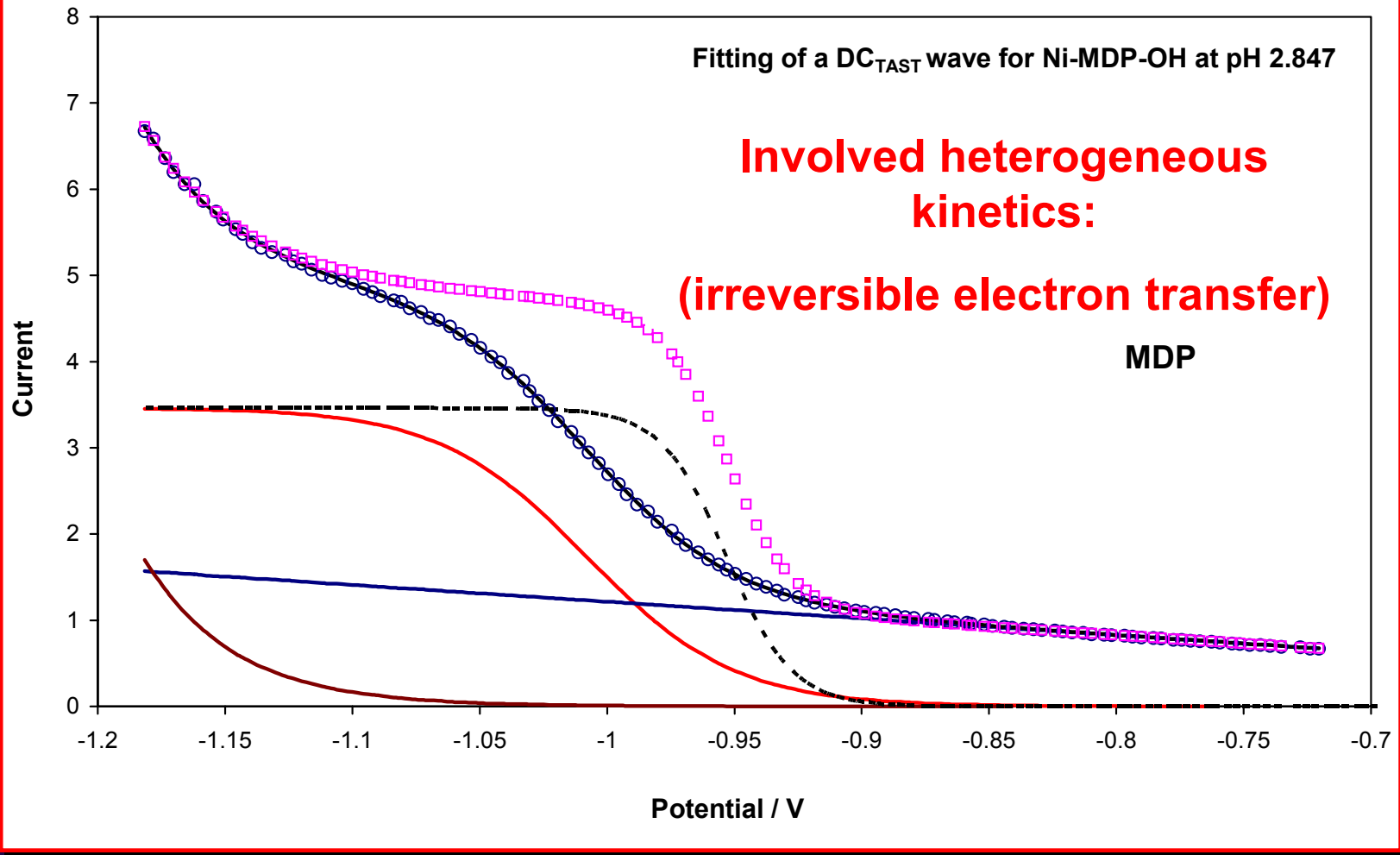
## 'Virtual' potentiometric Bi(III) sensor from voltammetry




Bi(III)-(Picolinic Acid)-OH system

I. Cukrowski, J.M. Zhang, A. v Aswegen, *Helv. Chim. Acta*, Vol. 87 (2004) 2135 – 2158

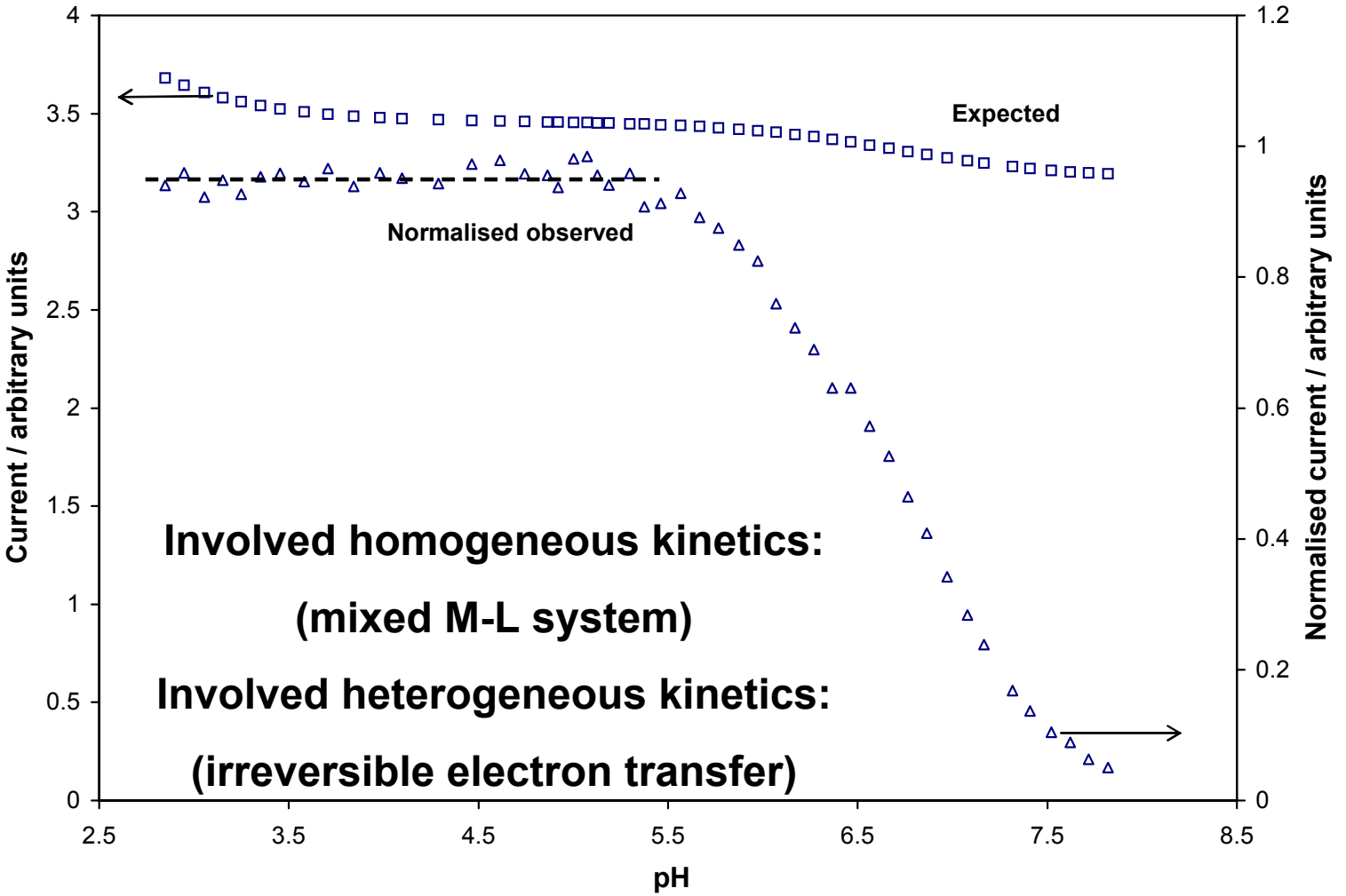
## Irreversible and mixed M-L-OH system




Ni-MDP-OH system

I. Cukrowski, D.M. Mogano and J.R. Zeevaart, sent to *J. Inorg. Biochem.*

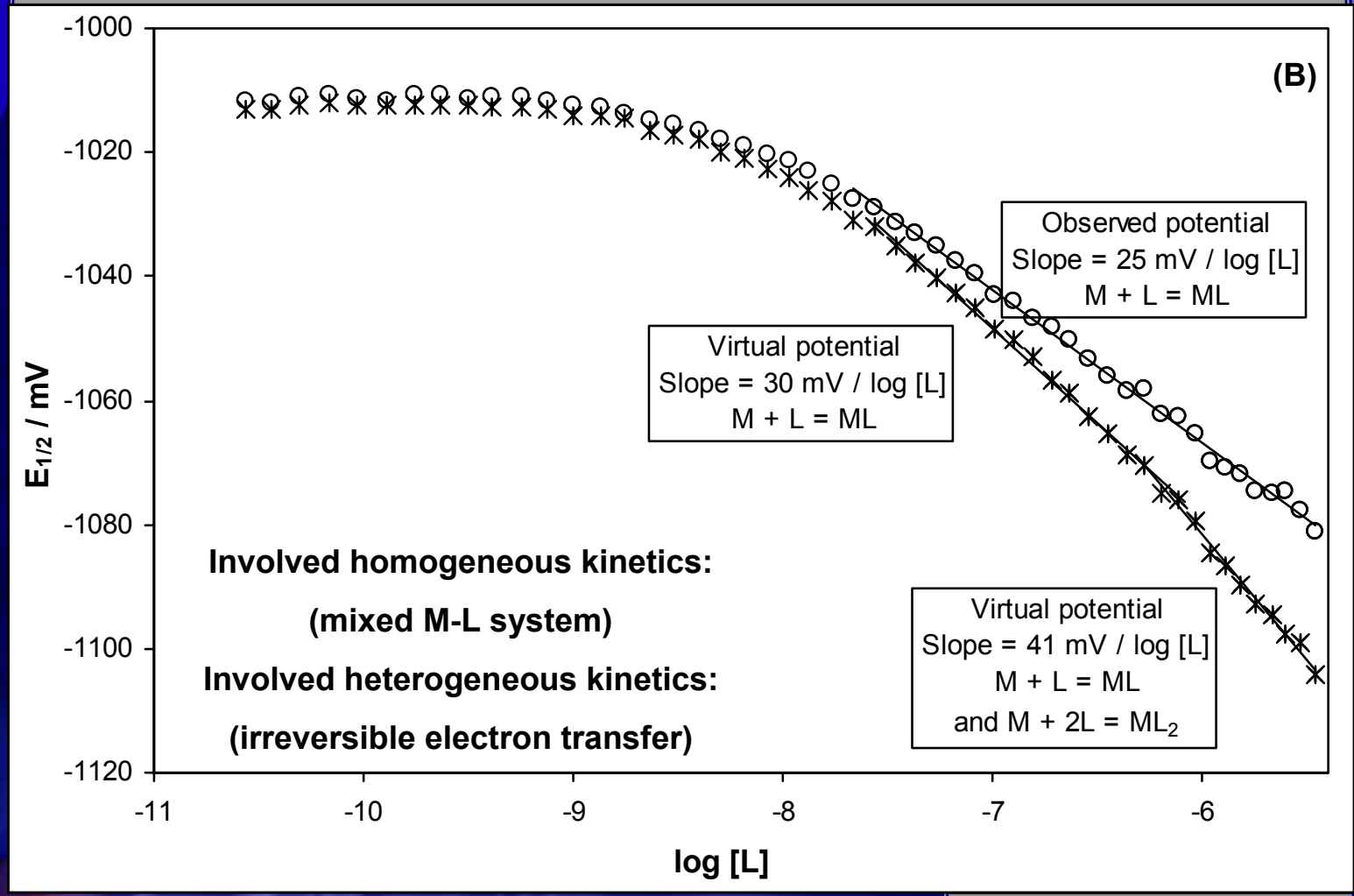
# Kinetics of the M-L-OH system




Ni-MDP-OH system

I. Cukrowski, D.M. Mogano and J.R. Zeevaart, sent to *J. Inorg. Biochem.*

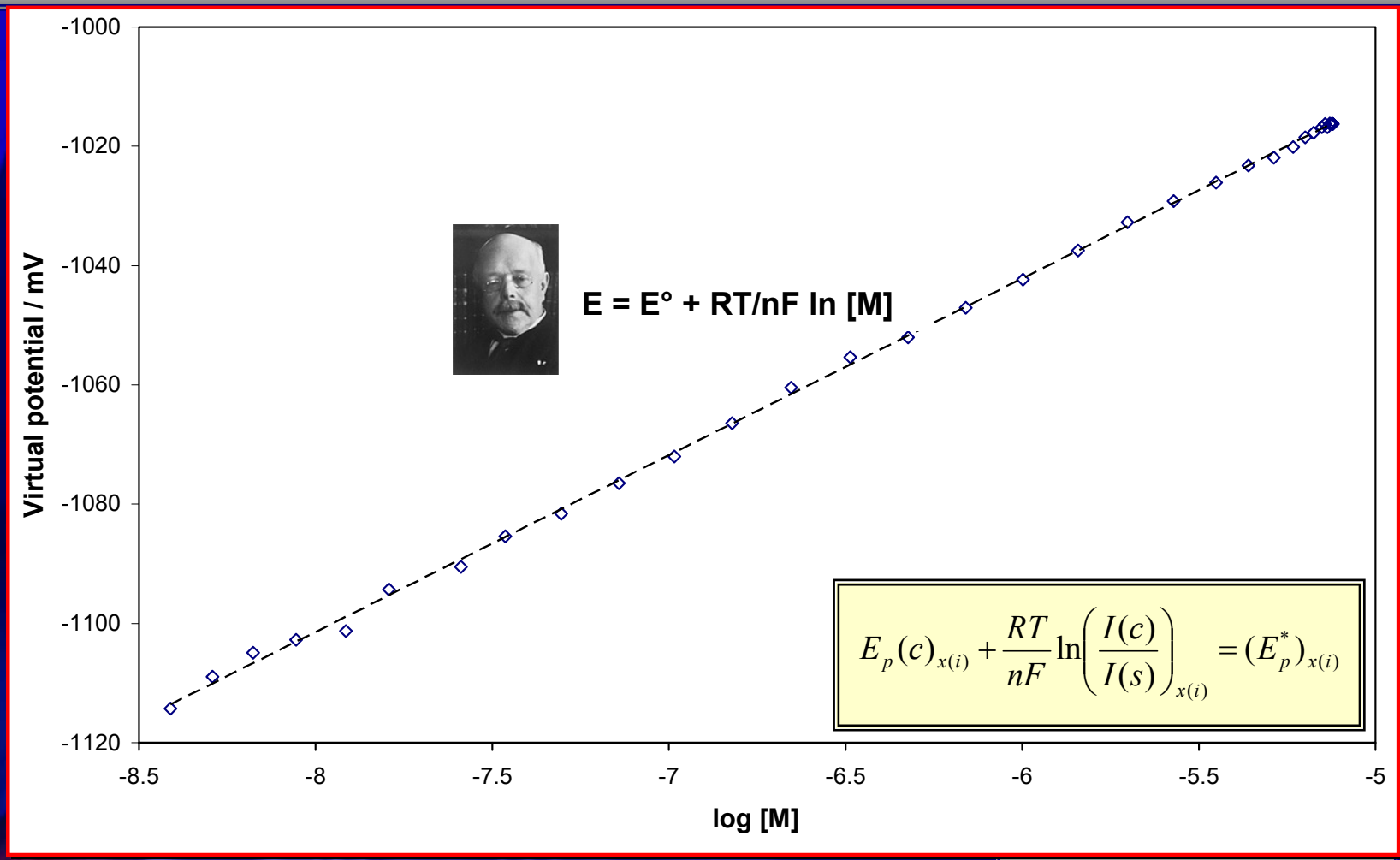
# Virtual potential in modelling of the M-L-OH system




Ni-MDP-OH system

I. Cukrowski, D.M. Mogano and J.R. Zeevaart, sent to *J. Inorg. Biochem.*

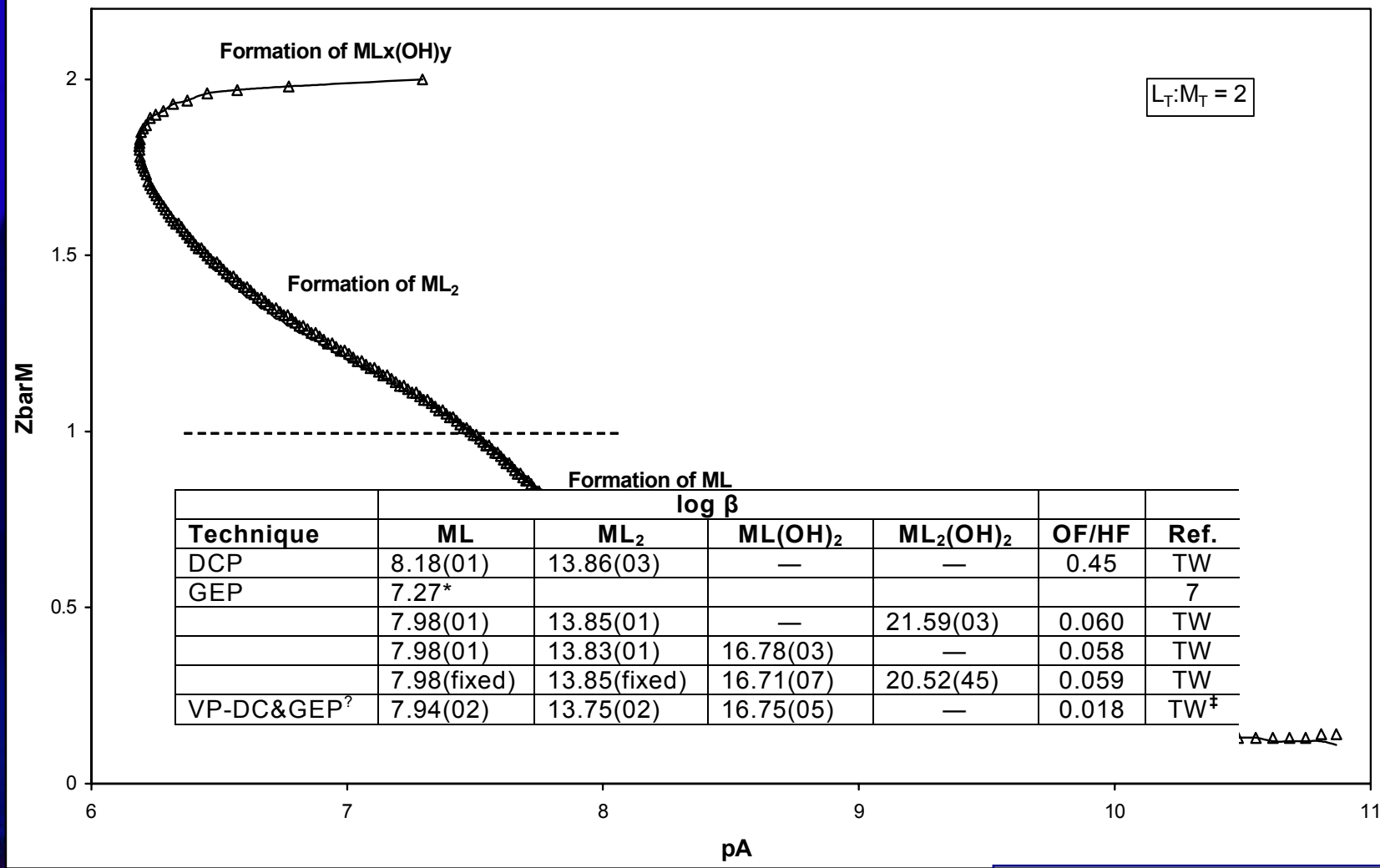
## Virtual potential ($E_{1/2}$*) vs. [Ni]. DCP as a 'virtual' potentiometric sensor.




Ni-MDP-OH system

I. Cukrowski, D.M. Mogano and J.R. Zeevaart, sent to *J. Inorg. Biochem.*

# Kinetic and equilibrium data working together in refinement operations

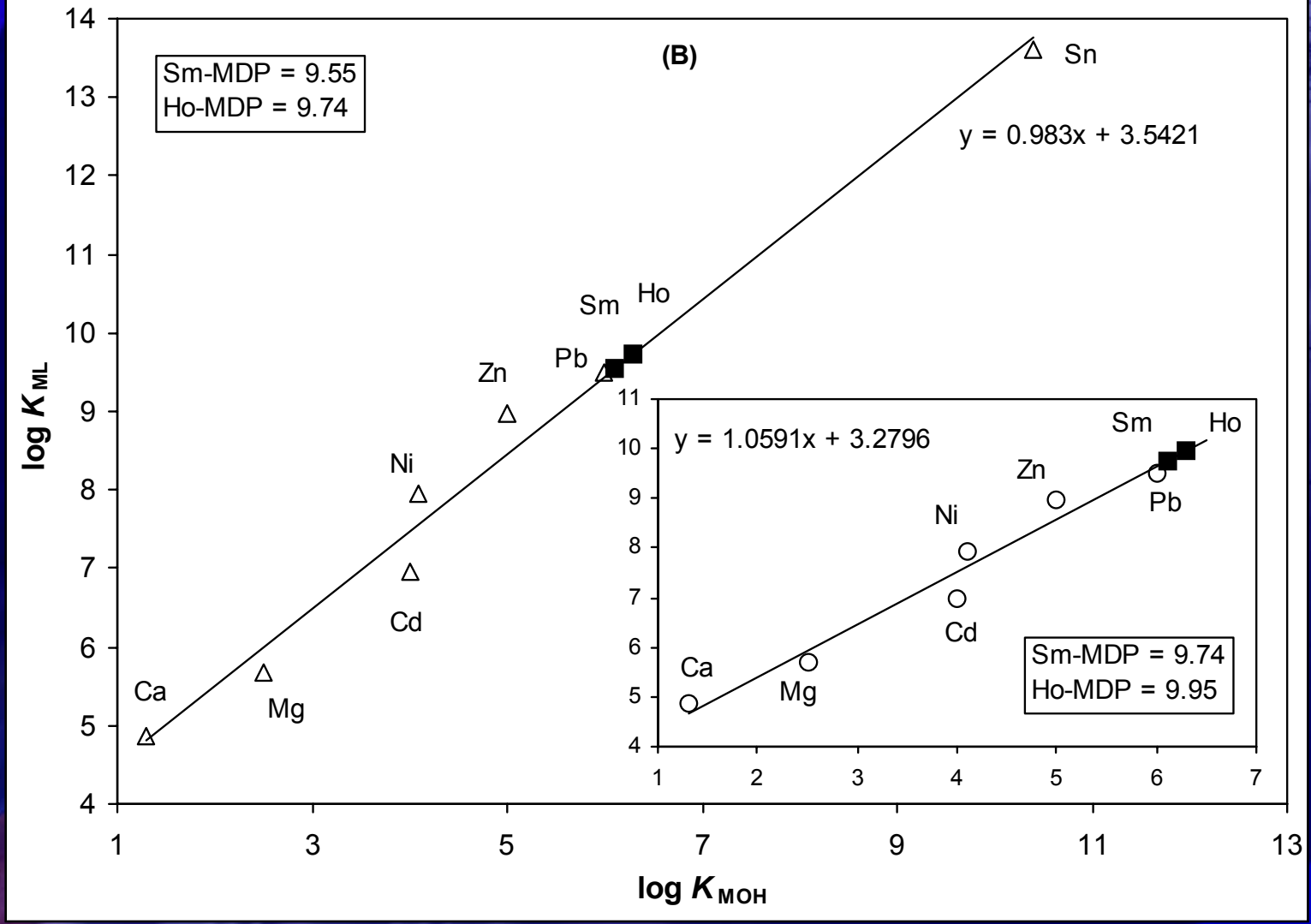



| | log β | | | | | |
|---|---|---|---|---|---|---|
| **Technique** | **ML** | **$ML_2$** | **$ML(OH)_2$** | **$ML_2(OH)_2$** | **OF/HF** | **Ref.** |
| DCP | 8.18(01) | 13.86(03) | — | — | 0.45 | TW |
| GEP | 7.27* | | | | | 7 |
| | 7.98(01) | 13.85(01) | — | 21.59(03) | 0.060 | TW |
| | 7.98(01) | 13.83(01) | 16.78(03) | — | 0.058 | TW |
| | 7.98(fixed) | 13.85(fixed) | 16.71(07) | 20.52(45) | 0.059 | TW |
| VP-DC&GEP[?] | 7.94(02) | 13.75(02) | 16.75(05) | — | 0.018 | TW‡ |

**Ni-MDP-OH system**

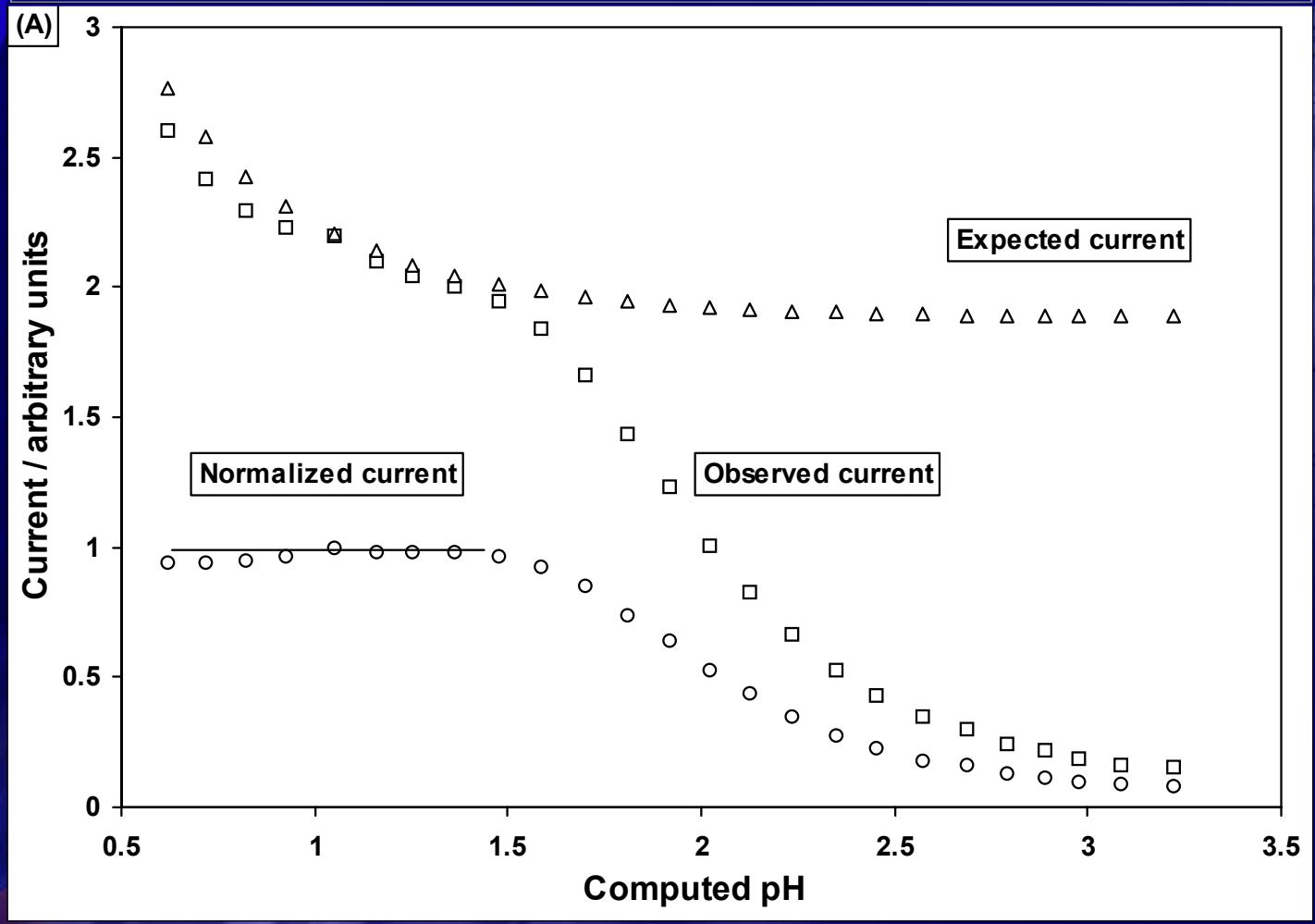
I. Cukrowski, D.M. Mogano and J.R. Zeevaart, sent to *J. Inorg. Biochem.*

# Linear Free Energy Relationships in prediction of Log $K_1$




I. Cukrowski, D.M. Mogano and J.R. Zeevaart, sent to *J. Inorg. Biochem.*

# A study of Bi(III) by 2 voltammetric techniques

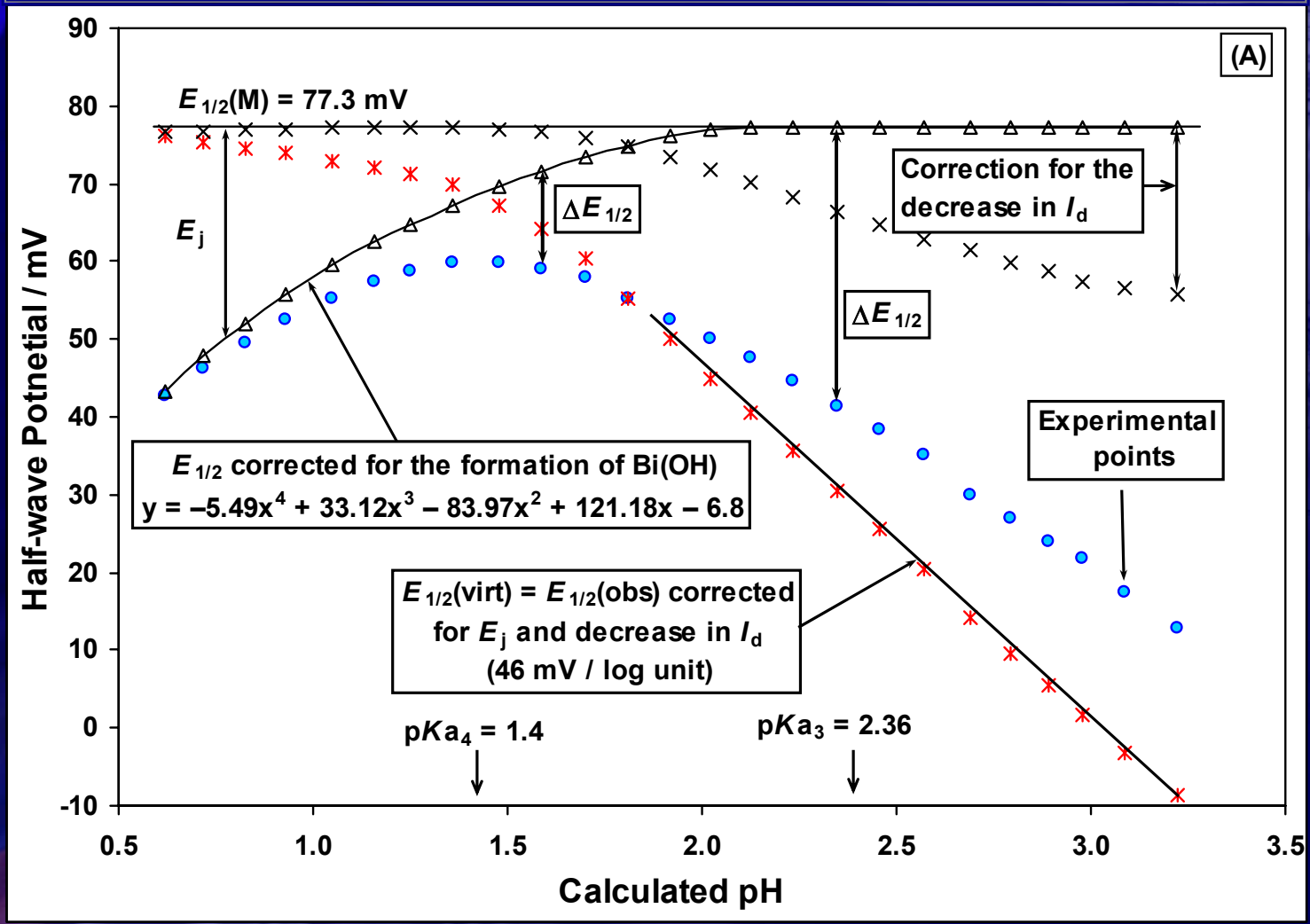



**Bi(III)-EDDA-OH system**

M(HL) – labile; ML & $ML_2$ - inert

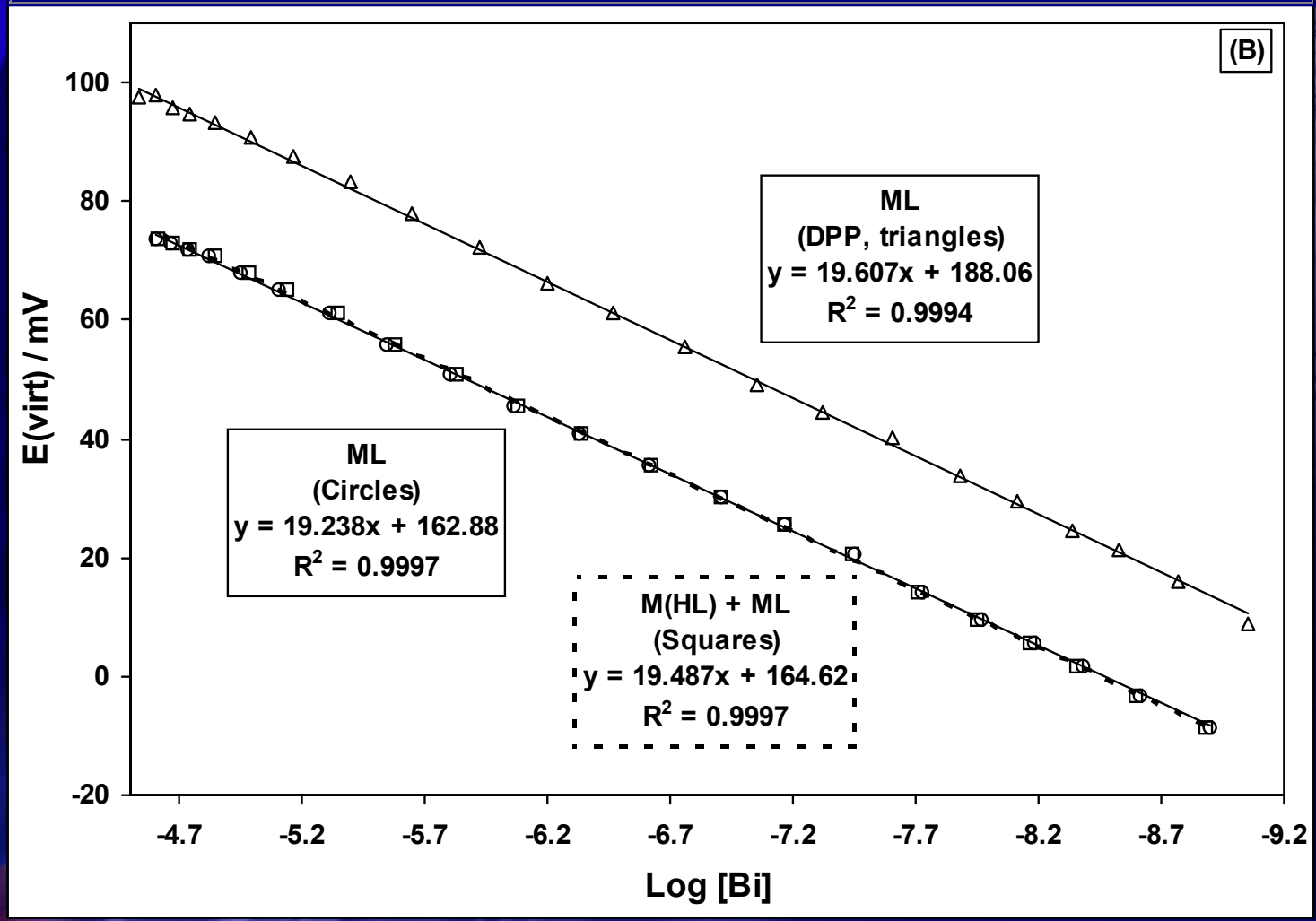
I. Cukrowski, J.M. Zhang, *Chem. Anal.*, Vol. 50 (2005) 3-36

# A study of Bi(III) by 2 voltammetric techniques




I. Cukrowski, J.M. Zhang, *Chem. Anal.*, Vol. 50 (2005) 3-36

# 2 voltammetric techniques as virtual ISE in the study of Bi




I. Cukrowski, J.M. Zhang, *Chem. Anal.*, Vol. 50 (2005) 3-36

## Double function of virtual potential (modelling & refinement)

| | | M(HL) labile | ML labile | $ML_2$ inert | |
|---|---|---|---|---|---|
| pH 1.7 and A-B | VP-DP & VP-DC | 18.85 ± 0.07 | 17.07 ± 0.08 | 31.70 ± 0.04 | 0.039 |

$E = E° + RT/nF \ln [M]$




**Acid-base and ligand titration voltammetric data from 2 virtual sensors refined simultaneously by ESTA**

I. Cukrowski, J.M. Zhang, *Chem. Anal.*, Vol. 50 (2005) 3-36

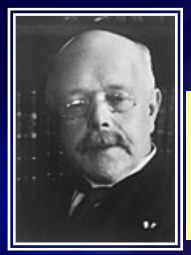
# Metal-Ligand interactions ( $M_pL_qH_r$)

## Model of a Metal-Ligand system & thermodynamic stability constants

### EQUILIBRIUM E-CHEMISTRY

Change in thermodynamic potential (ISE)

Virtual dynamic data



$$E = E^{\circ} - \frac{RT}{nF}\ln Q$$

### DYNAMIC E-CHEMISTRY

$$\left(E(s) - E(c)\right)_{x(i)} = \frac{RT}{nF}\ln\left(\frac{[M_T]}{[M]}\right)_{x(i)}$$

Dynamic data in the form of a virtual thermodynamic potential

$$E_p(c)_{x(i)} + \frac{RT}{nF}\ln\left(\frac{I(c)}{I(s)}\right)_{x(i)} = (E_p^*)_{x(i)}$$

Now two different WORLDS are talking to each other

Virtual THERMODYNAMICS is working

## Conclusions (Solution Chemistry)

1. Polarography-based virtual potentiometric sensor:

   a) does not have linearity range limits (its response is of the widest-known linearity, by far better than reigning for many years glass electrode)

   b) is ion non-specific (opposite to ISE)

   c) in principle, several metals might be monitored (opposite to ISE)

   d) should be possible to monitor pH (if the M-L system is)

2. Simultaneous refinement of data from several polarographic experiments (e.g. DPP and DCP).

3. Simultaneous refinement of glass potentiometric (low $[L_T]$:$[M_T]$) and polarographic (high $[L_T]$:$[M_T]$) from several titrations.

4. Simultaneous refinement of glass electrode, and ISE or metallic potentiometric and polarographic data from several titrations.

5. Prediction of species formed (modelling of solution composition) must be based on the analysis of virtual potential

6. Significantly improved reliability of models and refined stability constants.

What Future Reads?

New World in Physical Chemistry?

# *Quo Vadis?*

**Nobel Prize in Literature 1905**

**Henryk Sieńkiewicz**

**simply**

***The Best***

**For any University in the world the challenge is to:**

1. Accept public support and broaden its social contribution without compromising its traditional independence

2. Strike a satisfactory balance between teaching and research

3. Find an ideal blend of required and elected courses

4. Satisfy students continuous demands for better instruction and satisfy promotion criteria based mainly on faculty member's scholarly work

## Each university's basic traditional function is to:

1. Enable students to learn from their cultural heritage
2. Help students to realize their intellectual and creative abilities
3. Encourage students to become humane and responsible people
4. Expend knowledge across the entire spectrum of disciplines
5. Add to the understanding and enjoyment of life
6. Provide imaginative solutions to the problems of society

## University of Pretoria:

1. In many respects, is as any other University in the World
2. Has the same social functions to perform
3. Has the same aims and goals to achieve

4. Is, to some extend, a unique establishment, as any other University is

**We, as the University, are not that different**

**But as Department of Chemistry, we are very much different**

**simply**

***The Best***

# What is University known and internationally recognized for?

- ❑ Number of students, or number of faculty staff?
- ❑ Rector, Dean, HOD (administrative leaders)?
- ❑ Wonderful or excellent (or unbearable) administration?
- ❑ Best (or worst) teaching facilities (lecture theatres or laboratories)?

**No, not at all**

- ✓ Famous scientists (discoveries made)?
- ✓ Nobel prize winners – where they were educated?
- ✓ Nobel prize winners – where they have made their contributions?
- ✓ Published excellent research work

**Yes, very much so**


To become the best implies
TEAM WORK
Outstanding research
Exceptional teaching
National and international standing and recognition

**To become a strong Research Department requires**

**Existing Research**

**Build on existing strengths**

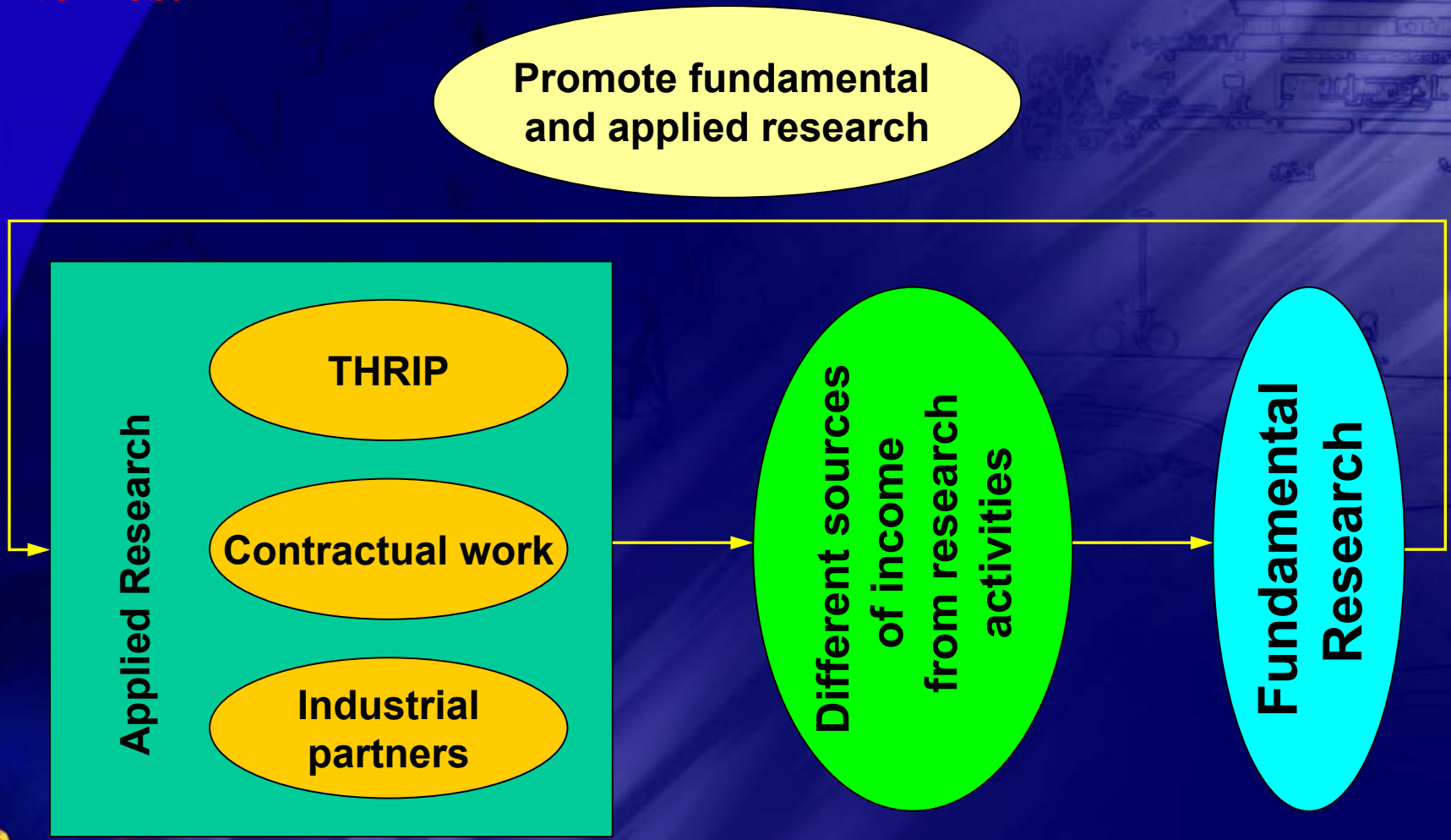
**Develop potential strengths**

**Outstanding Research**

**Unique Expertise in the Department**

**Centre of Excellence**

**Strong research activities**


Promote fundamental and applied research
Applied Research
THRIP
Contractual work
Industrial partners
Different sources of income from research activities
Fundamental Research

## Dedication to highest quality teaching

1. Excellence in teaching of 1st year chemistry

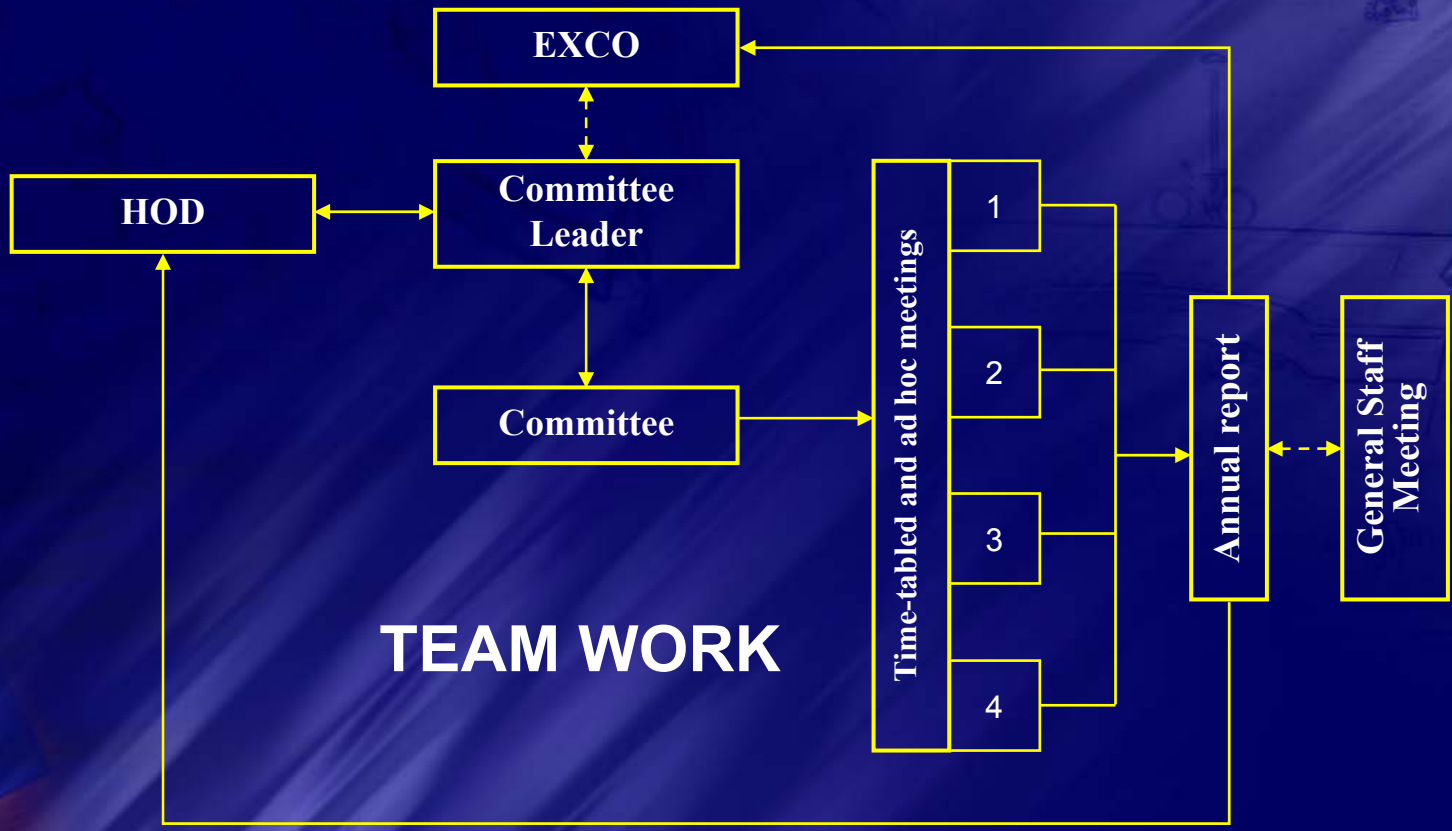
2. Establish and support a team of staff members dedicated to education

3. Research in education to be tested on our own chemistry students (continuous refinement of operation in improving educational goals)

4. Well-designed teaching program throughout the whole chemistry course, from 1st to 4th year level

5. Promote and support students with outstanding performance in chemistry

# Operational Structure of the Department



# Operational Structure of the Department

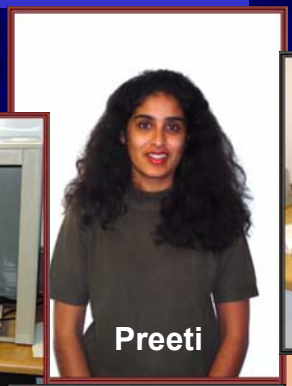
## Departmental Committees

1. Educational Research Activities (ERA) - Marietjie Potgieter
2. Departmental Teaching Coordination Committee - Wentzel Schoeman
3. Research Coordination Committee (RCC) - Simon Lotz
4. Maintenance and Safety Committee (MSC) - Robert Vleggaar
5. Communication (liaison, publicity) Committee (CC) – Wentzel Schoeman
6. Aesthetics Committee (AC) – Christien Strydom
7. Support and Technical Staff Committee (STSC) – Robin Muir
8. Fixed Facilities Committee (FFC) – Peet van Rooyen
9. Centre for Interfacial Chemistry Committee (CICC) – Ignacy Cukrowski
10. IT (PhD students and Staff Facilities) Committee (ITC) – Peet van Rooyen
11. Finance Committee (FC) – Robert Vleggaar

# Recent students involved in solution chemistry

**Inaugural Lecture at UP 28 July 2005**

## Acknowledgments

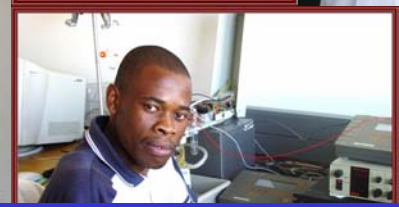





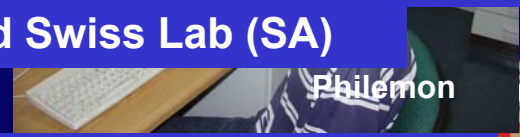











University of Pretoria

Wits University

Industry (SASOL, Anglo-Platinum, NECSA, CISA, PBMR)

Metrohm (Switzerland) and Swiss Lab (SA)

NRF

Co-workers (local and abroad)

# Thank you for attending my Inaugural Address at UP