Diffusion in Zeolites

Project 2:

Transient and Equilibrium Measurements of Sorption on Zeolites

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1. Experimental
2. Kinetic of Adsorption Processes
3. Macroscopic Diffusion Coefficient
4. Gas-Adsorption Equilibria

Gas Adsorption Equilibria

Measurement Methods

		M	G	O	SP	CHR	D	C
Manometry	(M)		++	+	0	++	++	0
Gravimetry	(G)	2		+	0	+	+	0
Oscillometry	(O)	1, V	1, V		0	0	0	0
Spectroscopy	(SP)	(2)	(2)	1, V		–	–	AMA
Chromatography	(CHR)	≥2	≥2	≥2*	–		–	–
Densimetry	(D)	2	2	1, V	–	–		–
Calorimetry	(C)	(1)	(1)	(1)	1	–	–	

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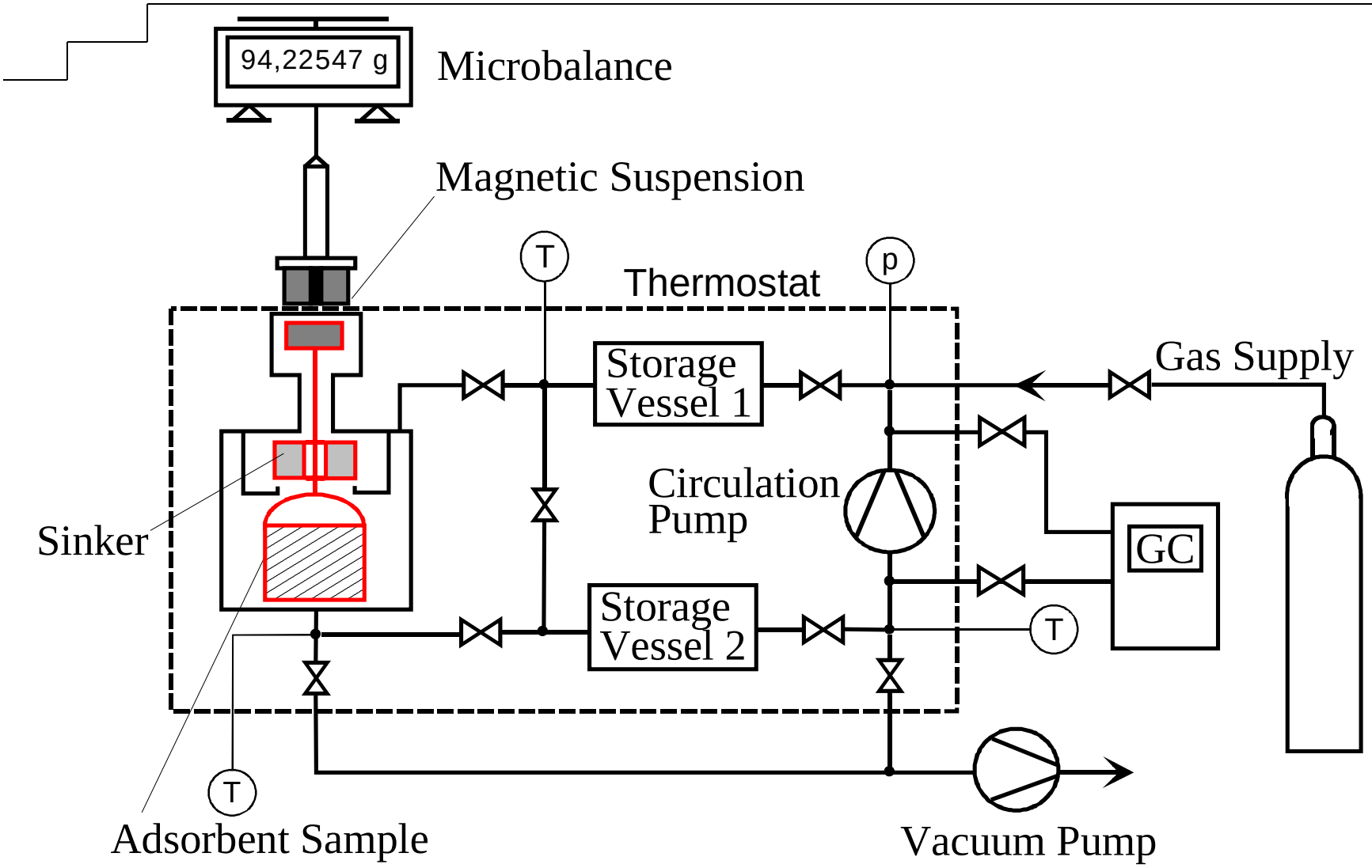
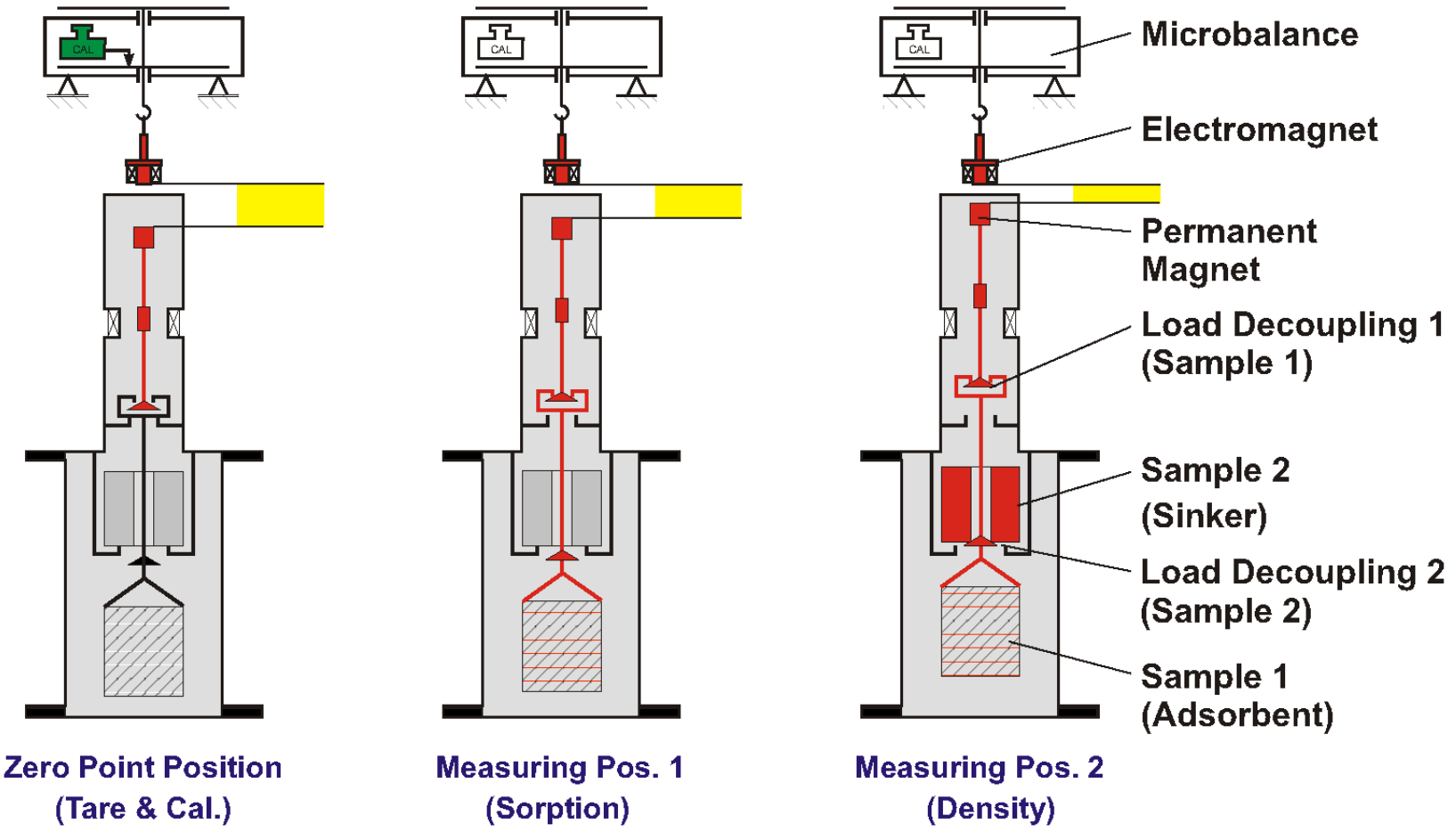
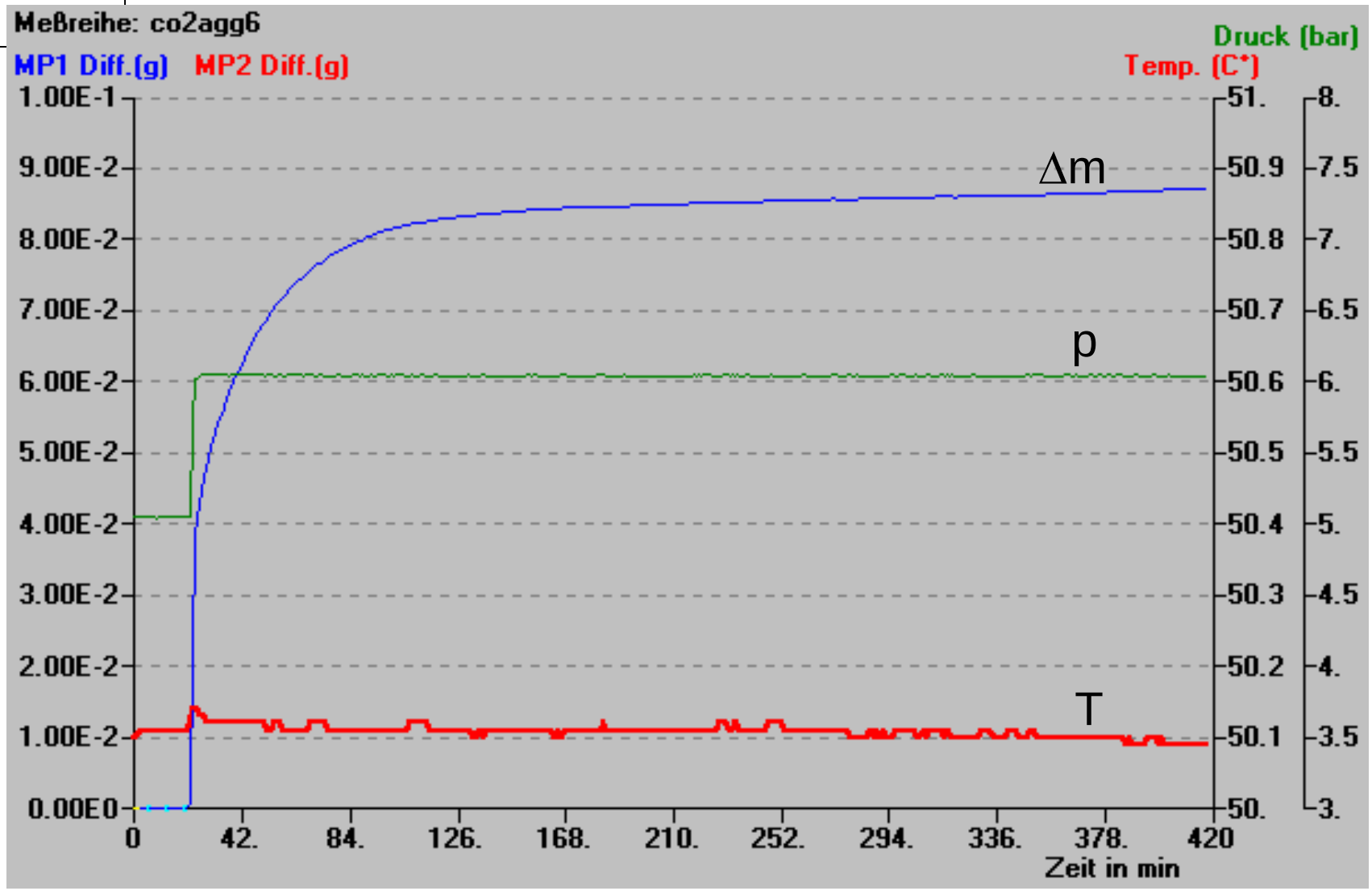


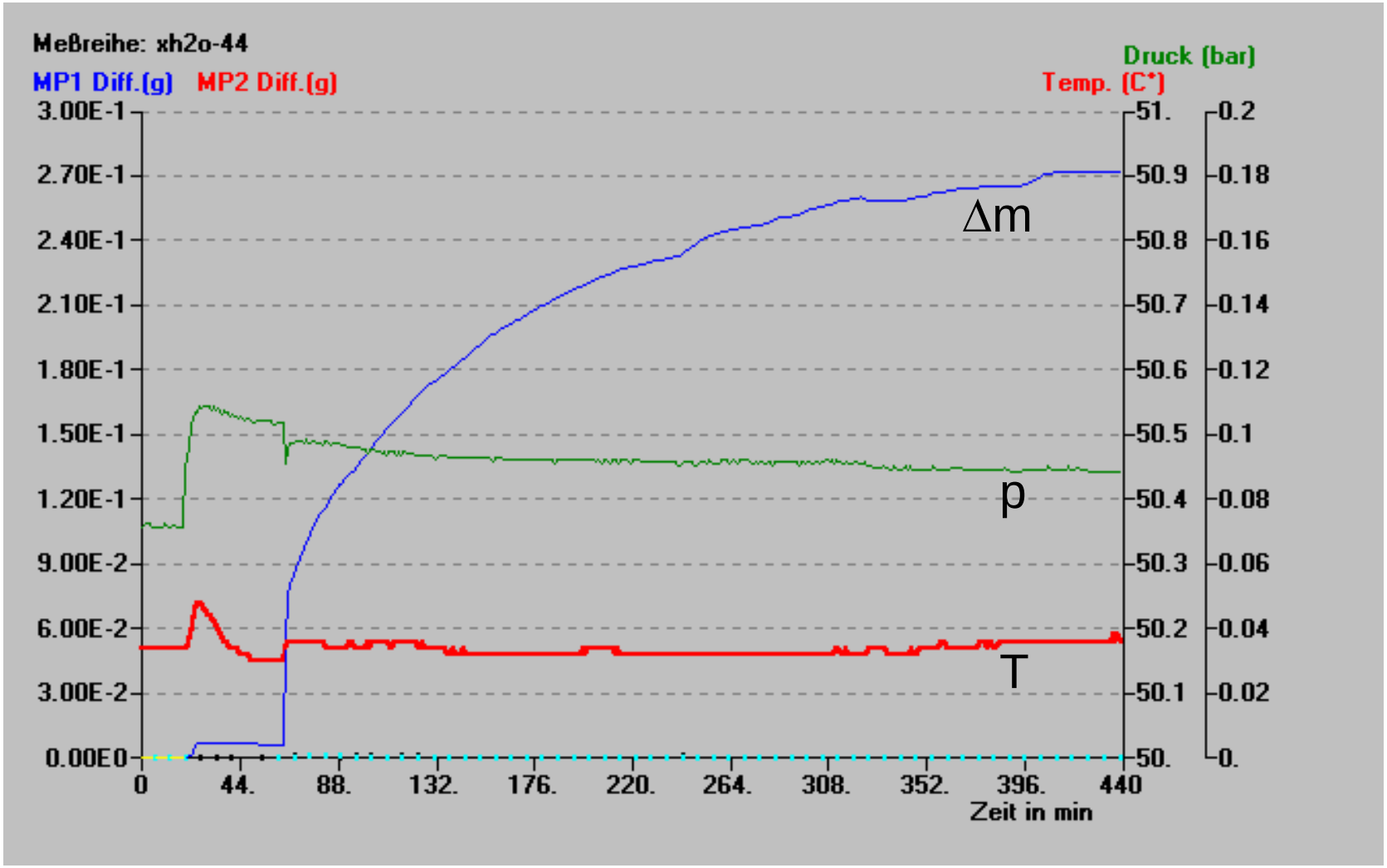
Instrument for gravimetric measurements of transient adsorption and adsorption equilibria



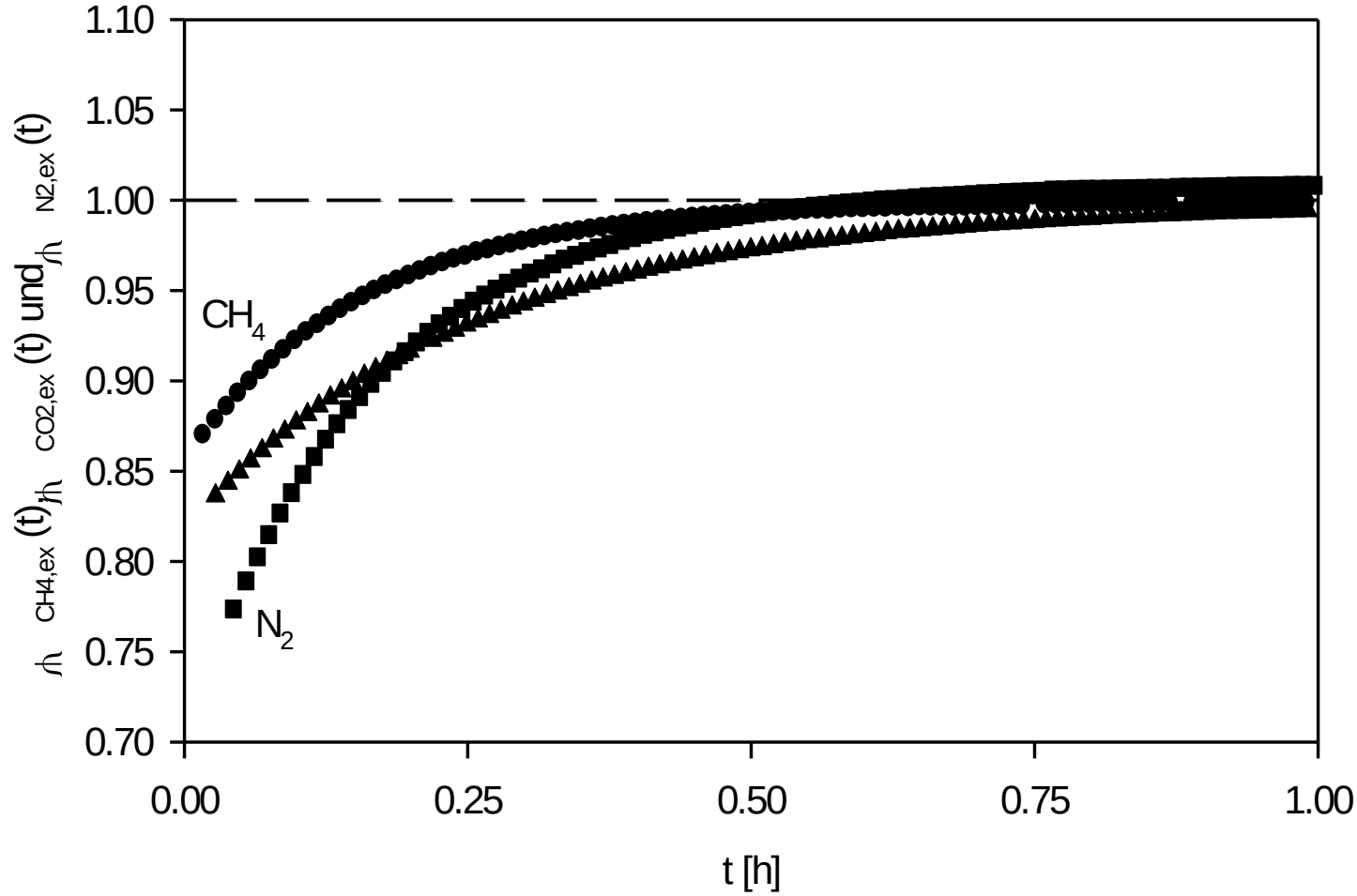
Dual mode suspension balance. Schematics of working positions.



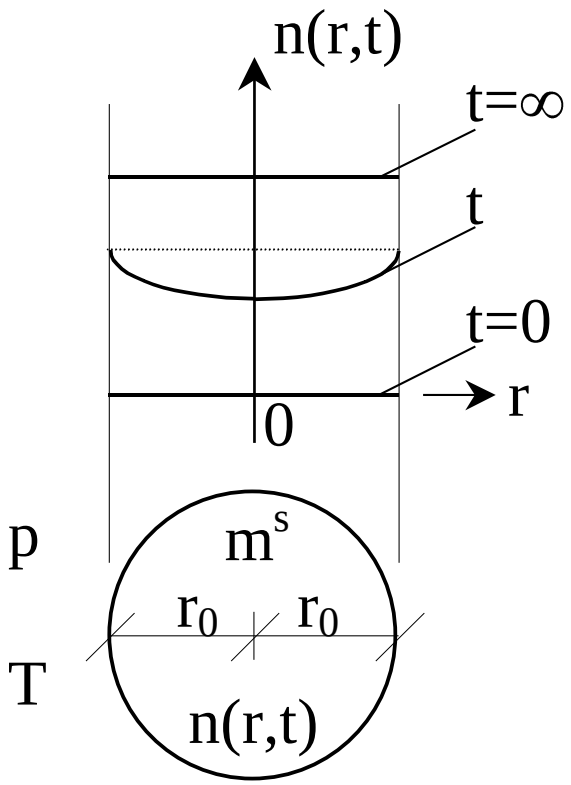
Measuring record: Sorption of gaseous carbon dioxide on water preloaded molecular sieve Na 13X (56 mg H_2O/g Na 13X).



Measuring record: Sorption of H_2O on Na 13X at T = 50.18 C.



Relative excess amount adsorbed ($\Psi_i=n_0(t)/n_i(\infty)$) of gases i=$CH_4$, CO_2, N_2 on activated carbon Norit R1 at T=298K. Equilibrium gas pressure: p(CH_4)=0.64bar, p(CO_2)=0.14bar, p(N_2)=6.3 bar. Ref.: F. Dreisbach, VDI, Ser. 3, Nr. 547, p. 130, 1998.



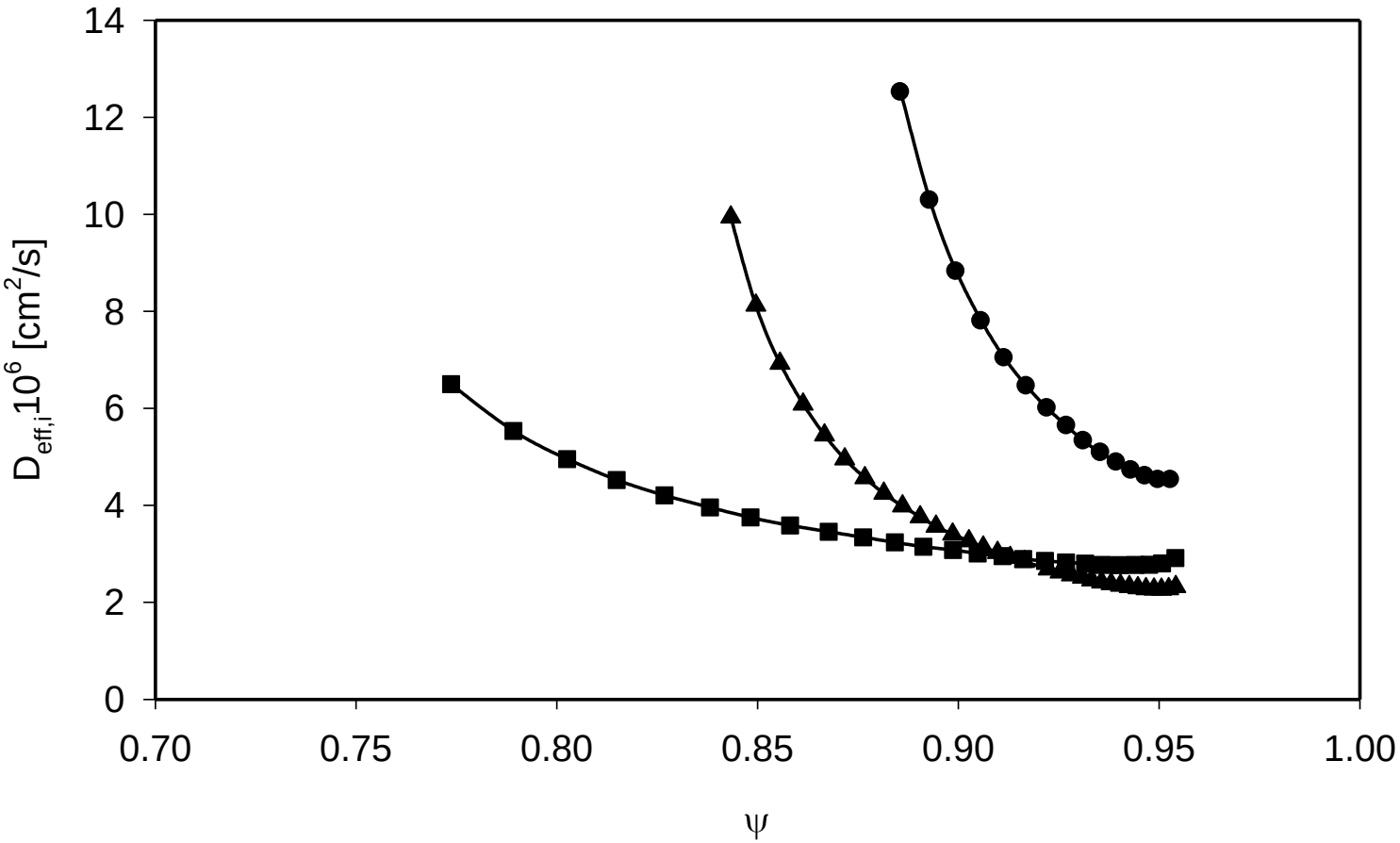
$$n\ t = \int_0^{r_0} n\ r,t\ dr$$

$$\Psi\ t = \frac{n\ t}{n\ \infty}$$

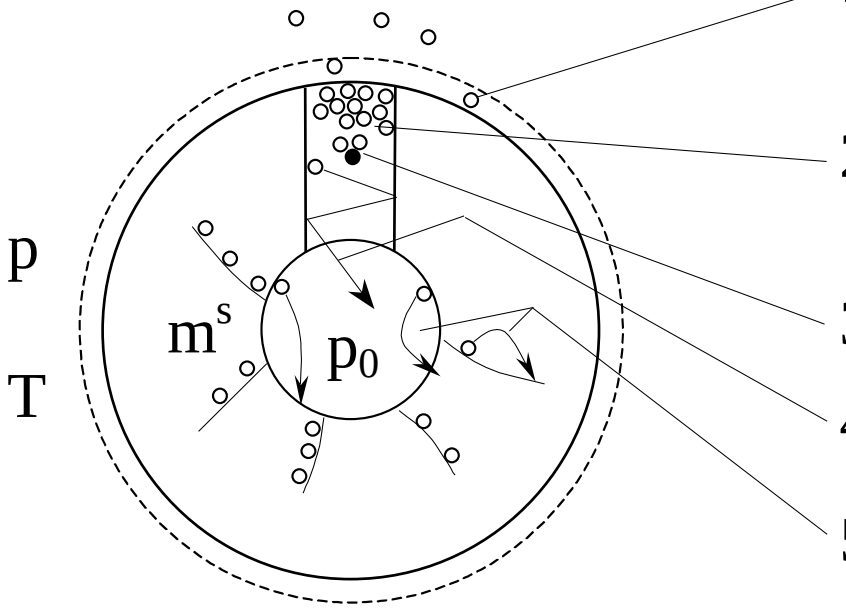
$$\partial_t n\ r,t = D_{eff}\ \Psi\ \Delta n\ r,t$$

$$D_{eff}\ \Psi = \frac{r_0^2}{\pi\, t\ \Psi}\left(1-\sqrt{1-\frac{\pi}{3}\Psi}\right)^2$$

Isothermal mass transfer process from gas (p, T) to sorbent (m^s). Effective or equivalent Diffusivity (D_{eff}).

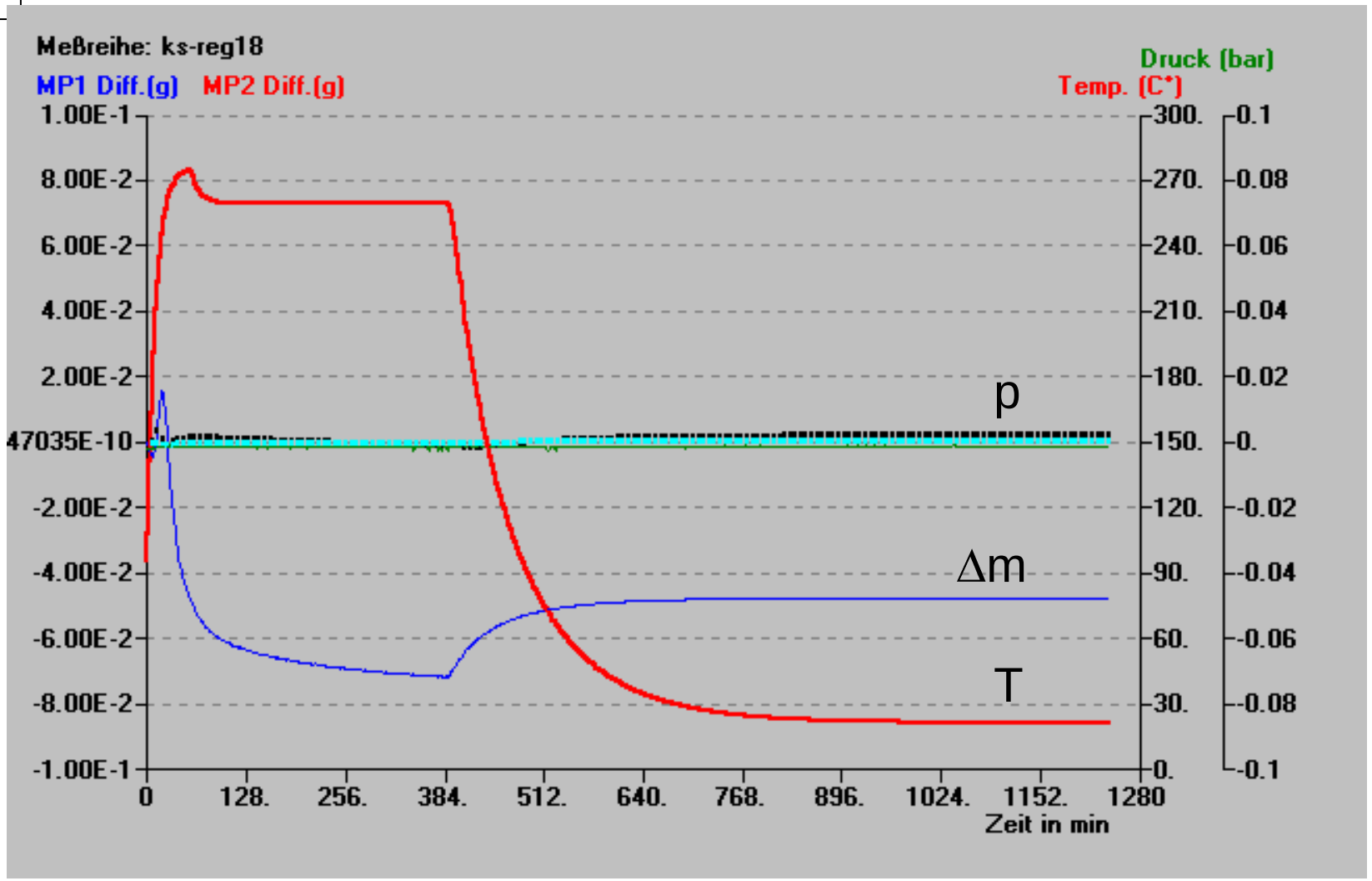


Effective or equivalent diffusion coefficient (D_{eff}) of gases CH_4 (•), CO_2 ( ), N_2 ( ) during isothermal adsorption on activated carbon Norit R1 at T=298K and gas pressures p(CH_4)=0.64bar, p(CO_2)=0.14bar, p(N_2)=6.3bar. Ref.: F. Dreisbach, VDI, Ser. 3, Nr. 547, p. 132, 1998.

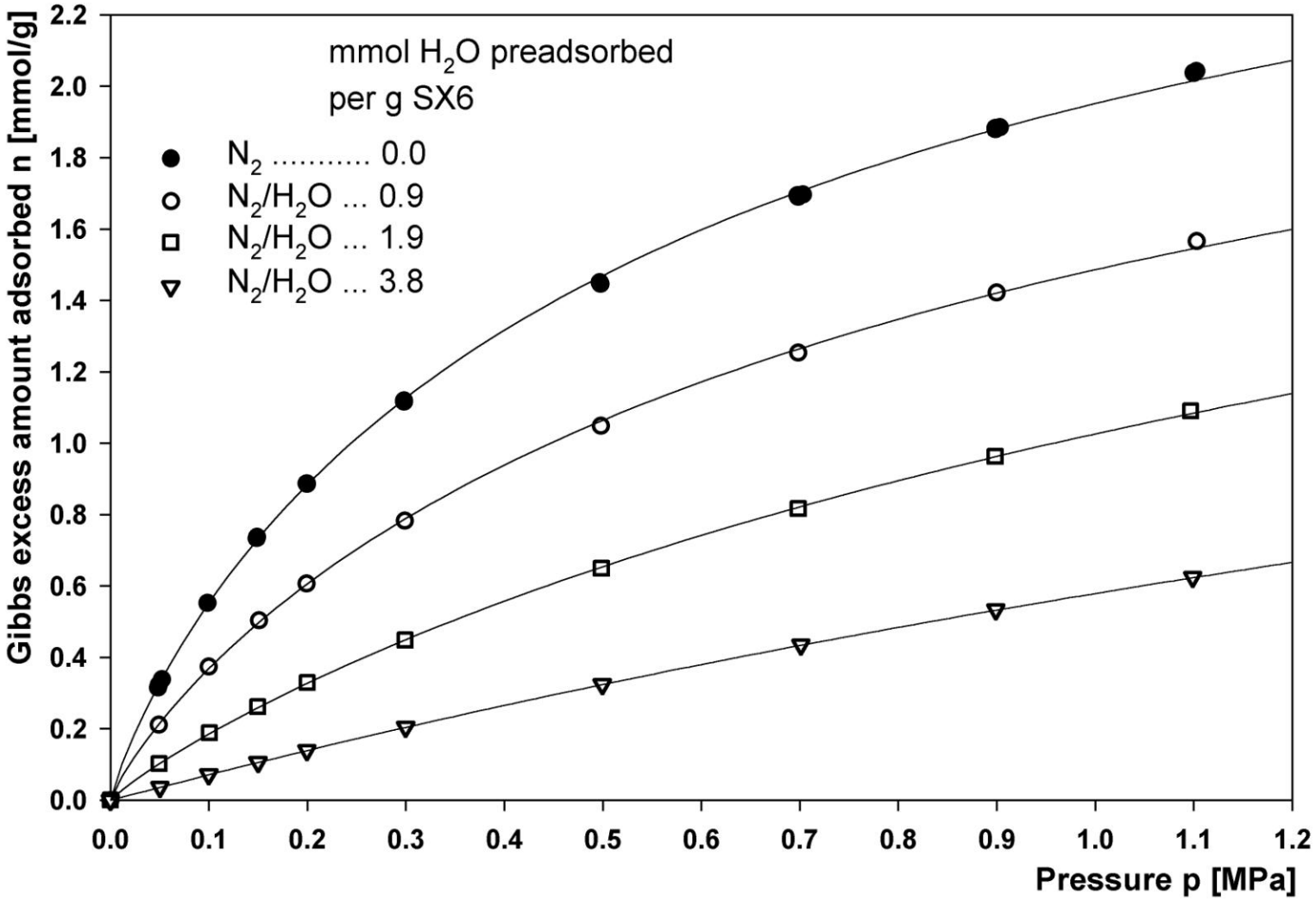


1. Film diffusion in boundary layer ($\lambda \sim d$)
2. Hagen-Poiseuille-Flow ($\lambda \sim d$), ($p-p_0$), (a)
3. Carrier Gas Diffusion (Δc), (a)
4. Knudson Flow ($\lambda \gg d$), (a, e, i)
5. Surface Diffusion ($\Delta \pi$), (a, e, i)

Mass transport mechanisms during pure gas adsorption processes on porous sorbents.



Regeneration process of zeolite Köstrolith SX6 in Vacuum during 5h at T = 523K.



Adsorption isotherms of nitrogen (N_2) on zeolite Köstrolith SX6 without and with presorbed water of (0.91, 1.88, 3.81) mmol H_2O / g SX6 at 313 K.

Gravimetry: $\Omega = m^a - \rho^f V^a$ (1)

Buoyancy correction:

A: Gibbs excess mass

$$V^{as} = 0 + V^s_{He} \quad (2A)$$

$$\Omega_{He} = -\rho^f V^s_{He} \quad (3)$$

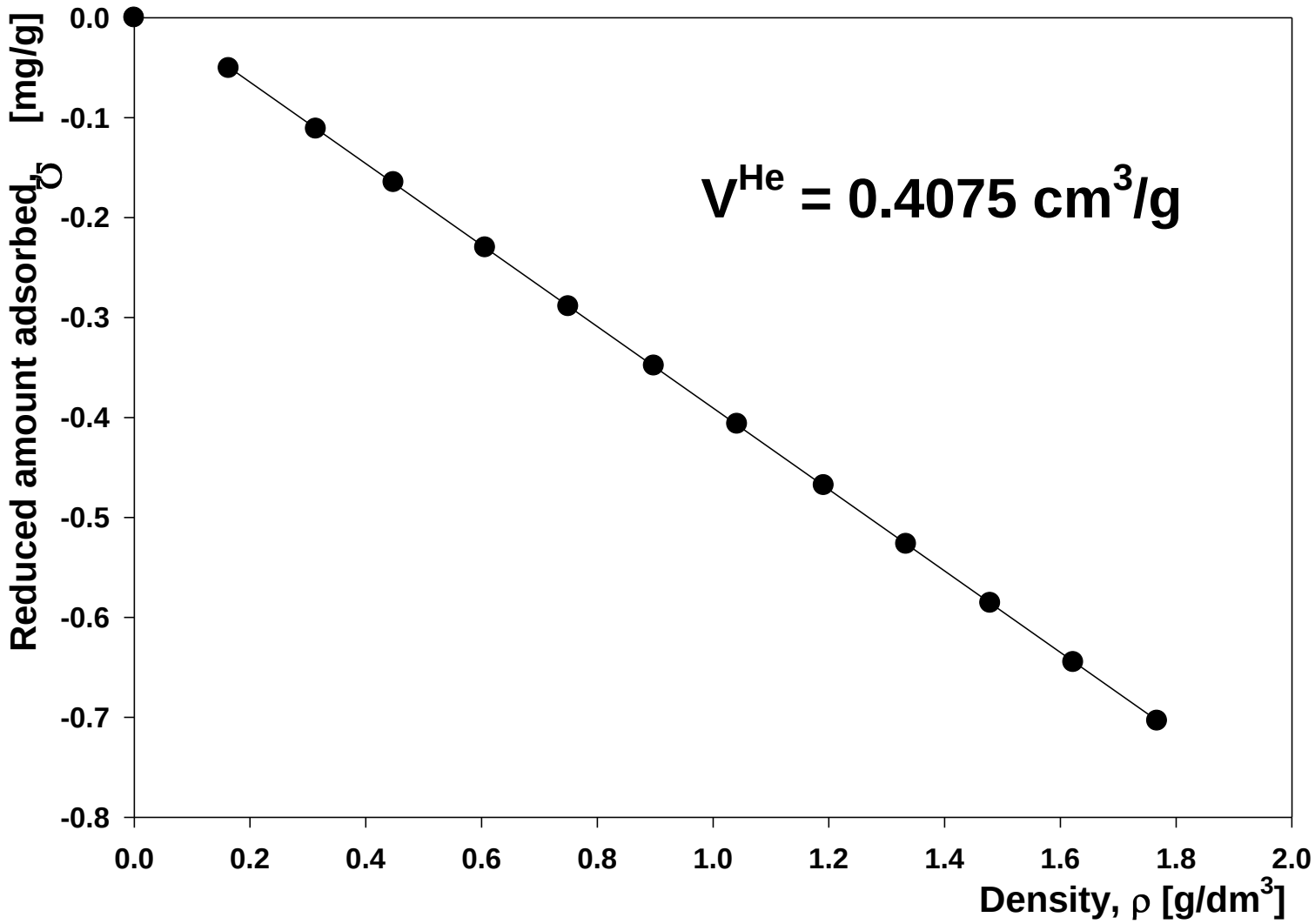
(1, 2A) $m^a_{GE} = \Omega + \rho^f V^s_{He}$ (4)

B: Absolute mass adsorbed

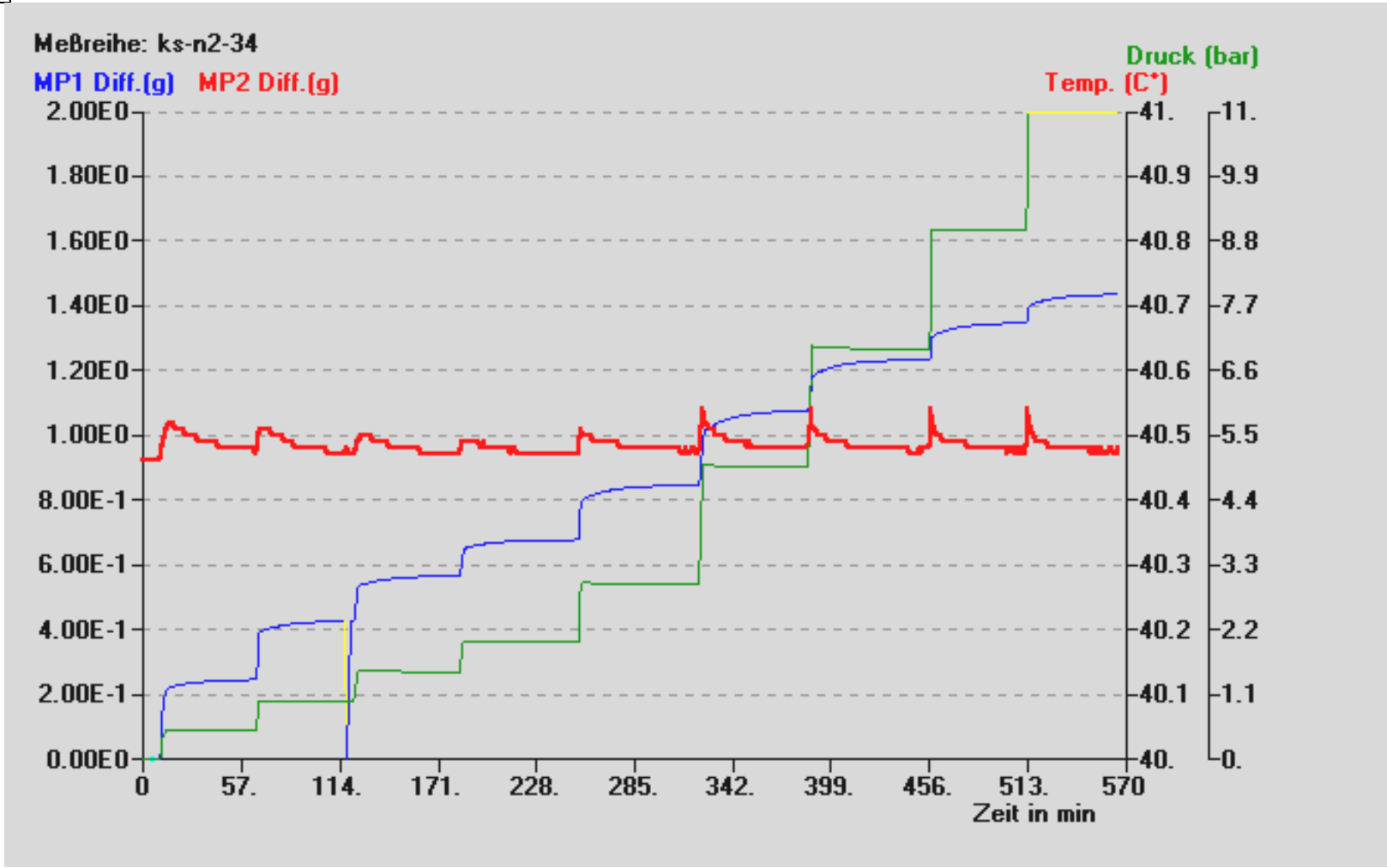
$$V^{as} = \frac{m^a}{\rho^L_0} + V^s_{He} \quad (2B)$$

$$m^a = \frac{\Omega + \rho^f V^s_{He}}{1 - \rho^f / \rho^L_0}$$

(1, 2B) $m^a = \dfrac{m^a_{GE}}{1 - \rho^f / \rho^L_0} \cong m^a_{GE} \quad \rho^f \to 0$

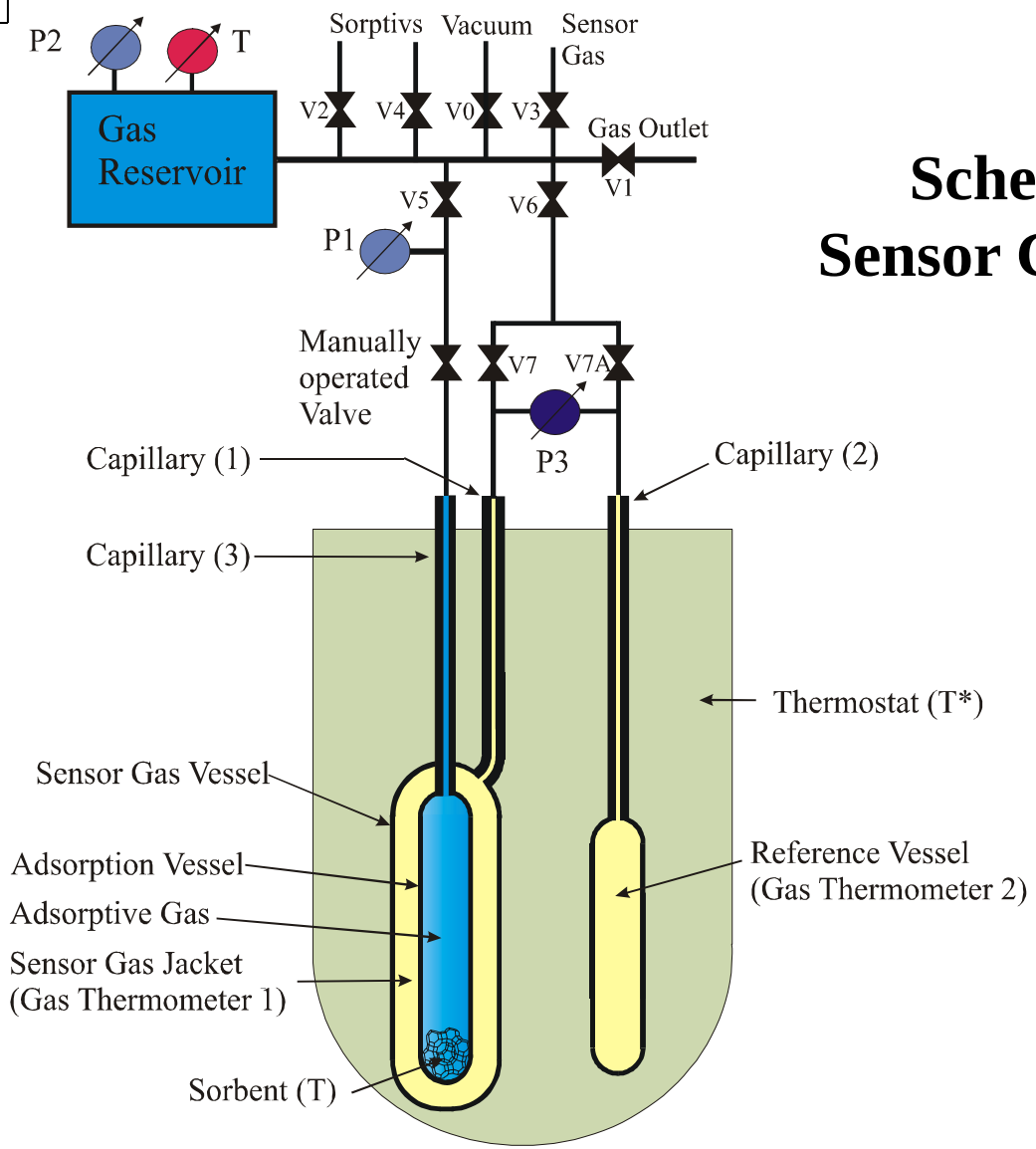


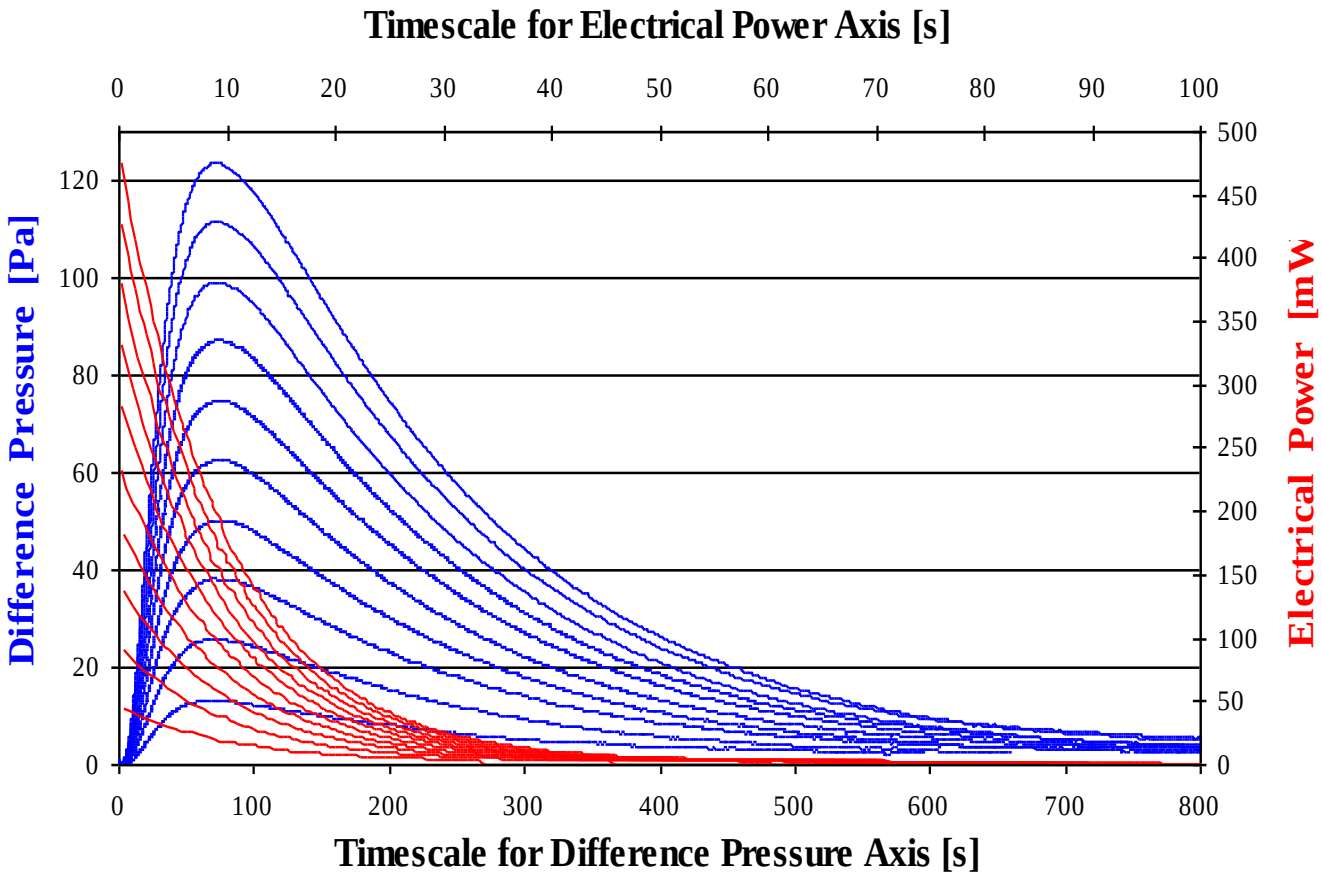
Measured adsorption equilibria of pure Helium on molecular sieve (Na 13X, Linde AG) at T = 323 K.



Adsorption of N_2 in molecular sieve Köstrolith SX6 at T=313.6K

Schematic diagram of a Sensor Gas Calorimeter (SGC)

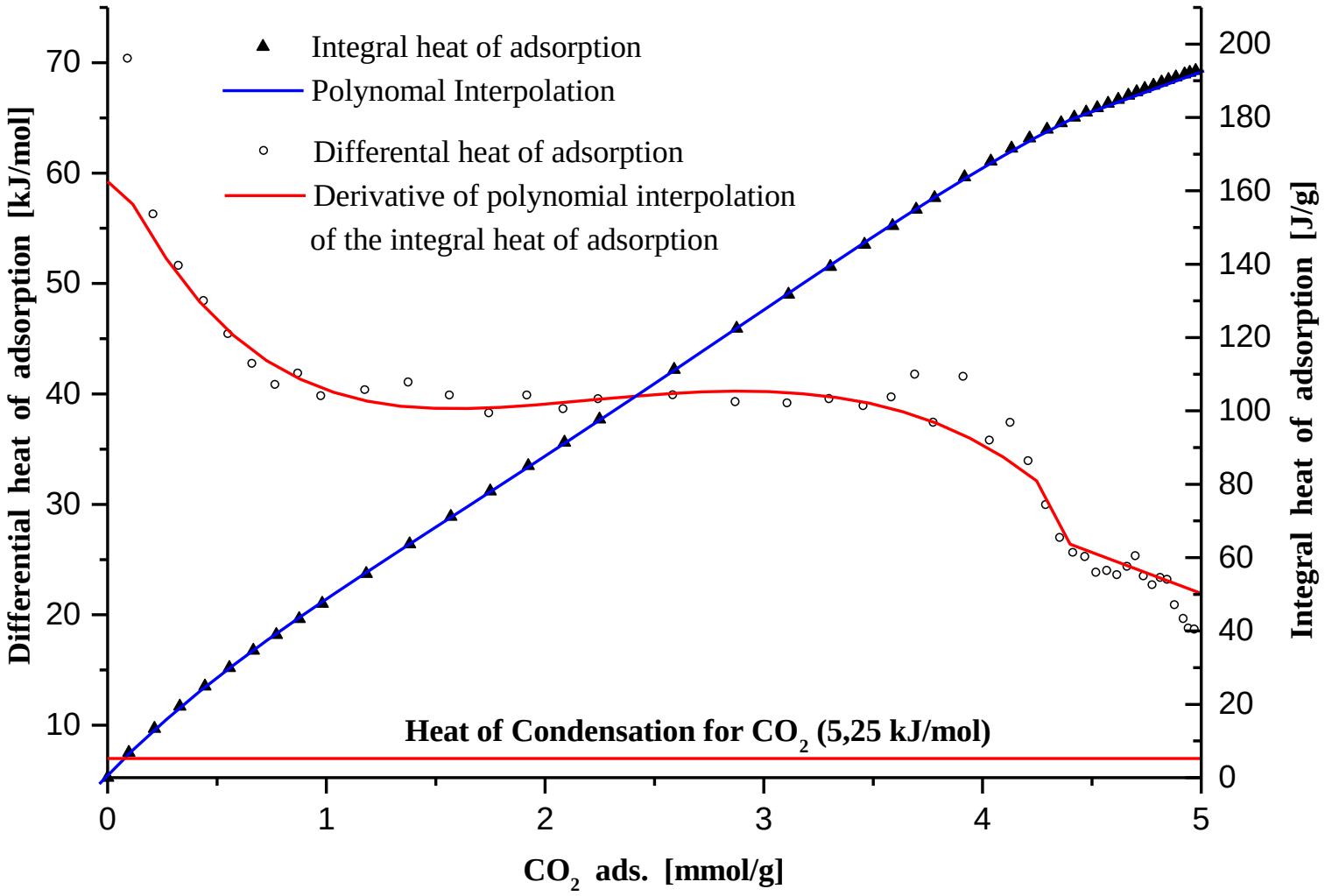




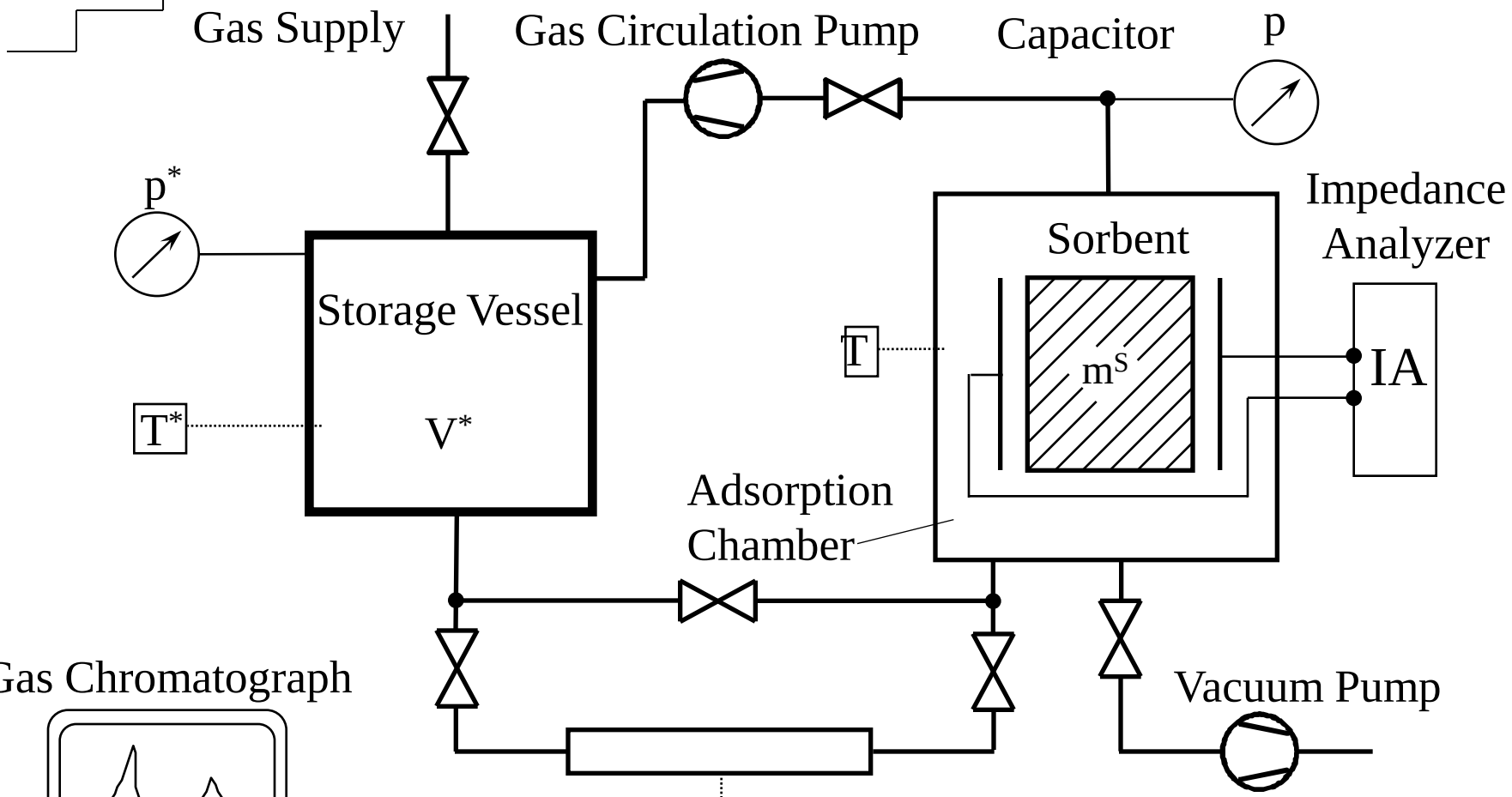
Calibration experiments in the SGC 0.5J to 5J

Sensor gas N_2 (1.6bar), T=298K, τ=10s

Ohmian heat release (red lines) → Pressure signal (blue lines)



Heat of adsorption for CO_2 / Na13X, T=298K



$$\text{V, M} \quad m_{MG} = m^* - \left(V^* - V^{as}\right)\rho^f(p,T), \quad V^{as} \cong V_{He}$$

$$\text{DE} \quad \Omega_{DE} = \alpha(p,T)\, m_{MG}$$

Experimental setup for volumetric-dielectric measurements

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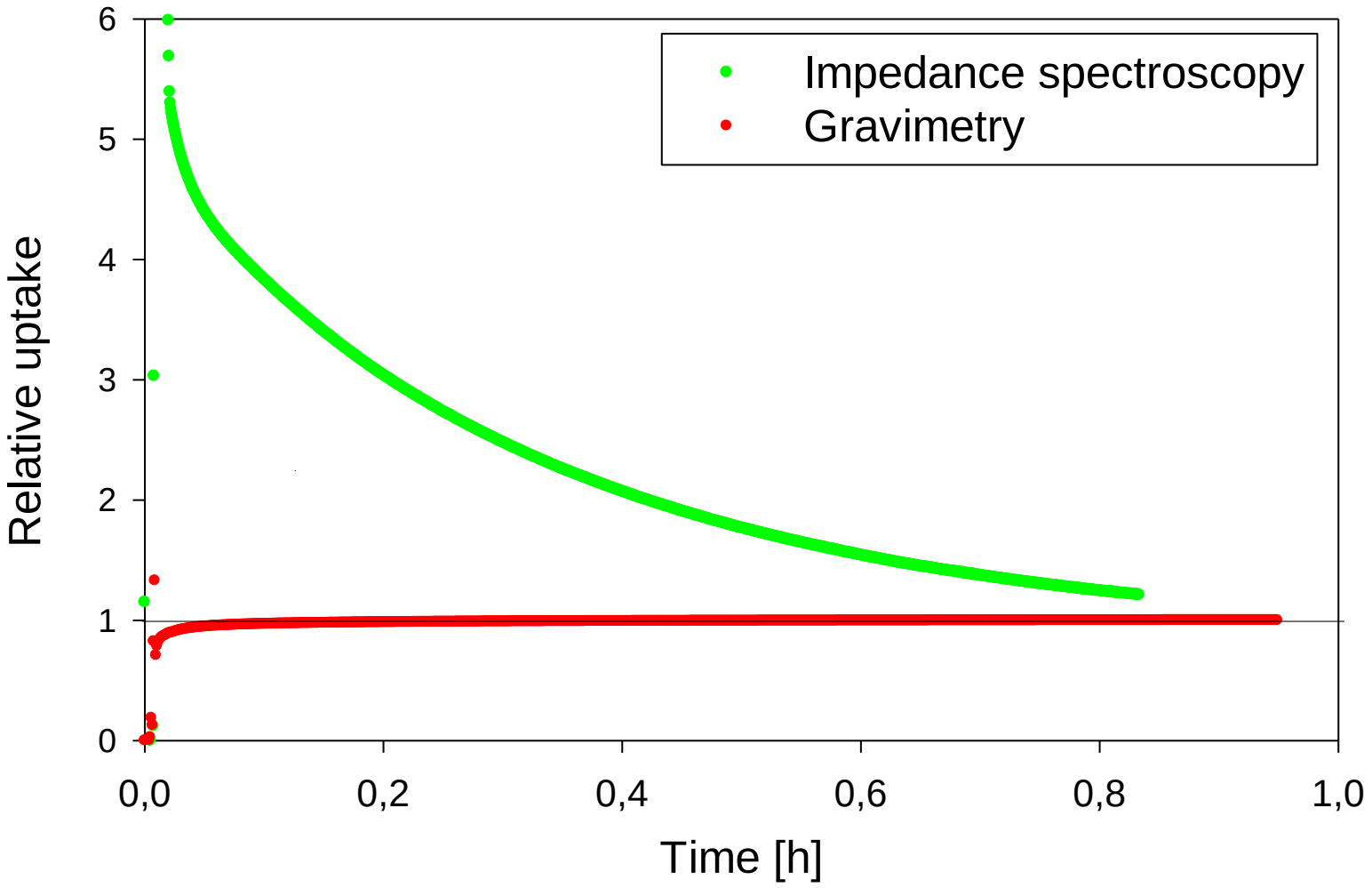

Uptake curves of H_2S on MS 13X, T=298K