Ausrichtung des Physikunterrichts an Kompetenzen -
eine Neuorientierung für Schüler und Lehrer
Karlsruhe, 23. – 24. Mai 2008

Ein Kompetenzmodell zur Förderung eines interdisziplinären Zugangs zum systemdynamischen Denken

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1 – Why a *coordinated approach* to science teaching?

2 – The experimental background: description and interpretation

3 – The conceptual framework

4 – Skills concerning the reference model

5 – Conclusion and perspectives

1 - Why a *coordinated approach* to science teaching?

Students should have the possibility to appreciate science as a large, coherent and understandable description of natural phenomena.

Science teaching therefore must be planned in such a way that students can, in fact, recognize this unity.

Biology, chemistry and physics each have their own specificities: they must be acknowledged, maintained and highlighted!

But they all share a *conceptual transversal scaffolding*.

Step by step construction of a *coherent image* of natural phenomena.

A (new?) model for a *coordinated approach*?

Propaedeutical or hierarchical model ⟺ *Cognitive organizers*

- Energy model
- Corpuscular structure of matter
- Concept of system

Siehe Naturwissenschaften besser Verstehen – Lernhindenisse vermeiden, MNU April 2004

For each of these, we intend to elaborate a common frame of reference (knowledge and skills demanded of the pupils by the end of the *basic course).*

The time factor and restrictions resulting from the (supposed) hierarchical relationship of one subject with respect to another can be avoided.

The *consistency* with the agreed general model must be guaranteed by all subjects in *each*, *single* didactic action.

Edgar Morin

Die sieben Fundamente des Wissens für eine Erziehung der Zukunft

Die Prinzipien einer umfassenden Erkenntnis

- *Es ist wichtig eine Erkenntnis zu fördern, die fähig ist, die globalen und fundamentalen Probleme zu erfassen und die Partiellen und lokalen Erkenntnisse darin zu integrieren.*

Aus: Edgar Morin, *Die sieben Fundamente des Wissens für eine Erziehung der Zukunft*, Kämer Verlag Hamburg 2001, Seite 16

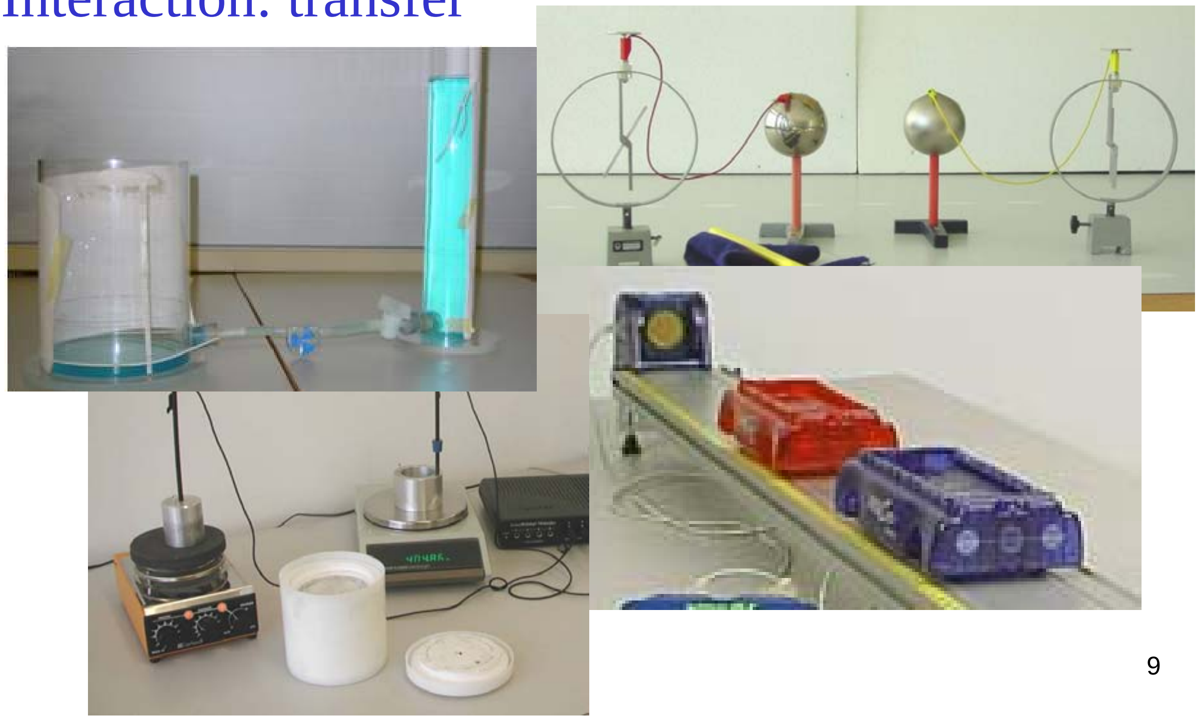
- *Eine fragmentierte Erkenntnis muss einer Erkenntnis Platz machen, die die Gegenstände in ihren Kontexten, ihren Komplexen und ihren Gesamtheiten erfasst.*

- *Es ist notwendig, alle Informationen in einen Kontext und in eine Gesamtheit zu stellen. Weiterhin ist es notwendig, Methoden zu vermitteln, die die gegenseitigen Beziehungen und Einflüsse zwischen Teilen und Ganzem in einer komplexem Welt erfassen.*

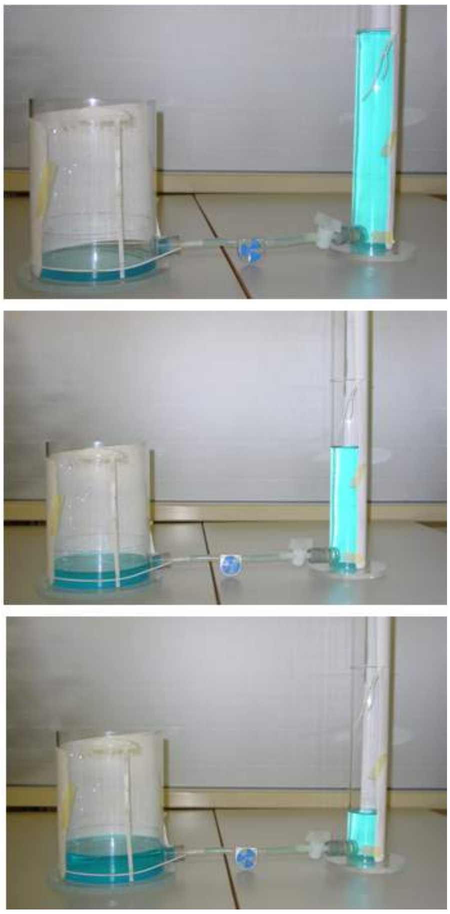
Aus: Edgar Morin, *Die sieben Fundamente des Wissens für eine Erziehung der Zukunft*, Kämer Verlag Hamburg, 2001, Seite 16

2 – The experimental background: description and interpretation

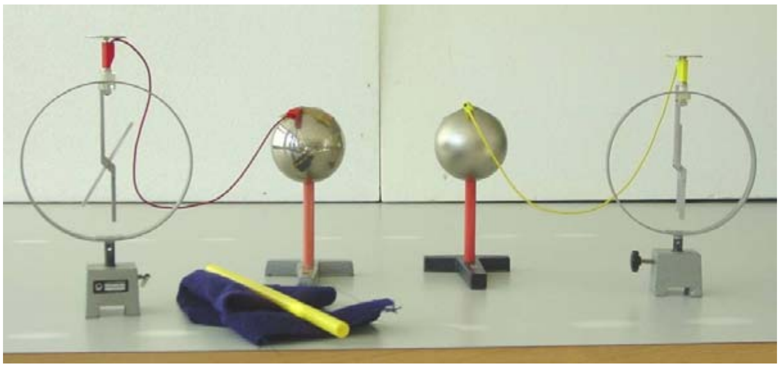
Interaction: transfer

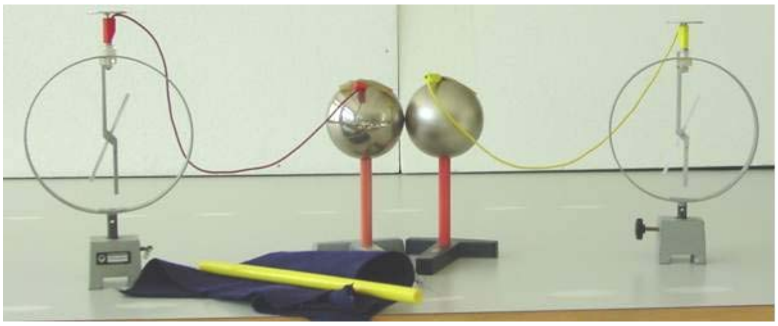


Interaction: transfer



Interaction: transfer





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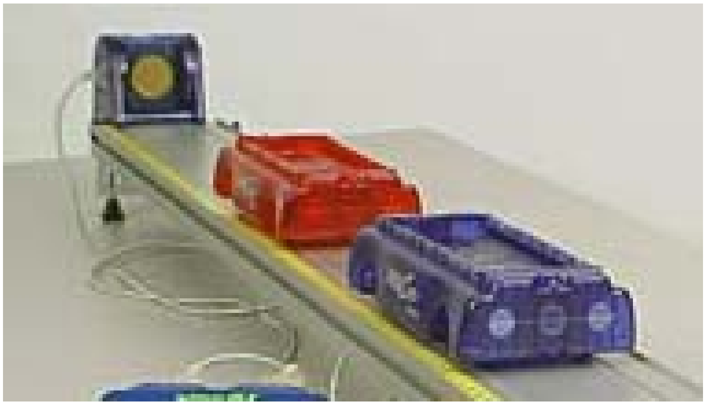

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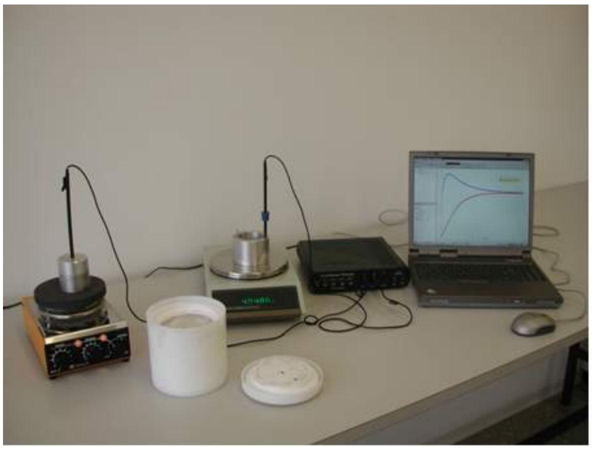
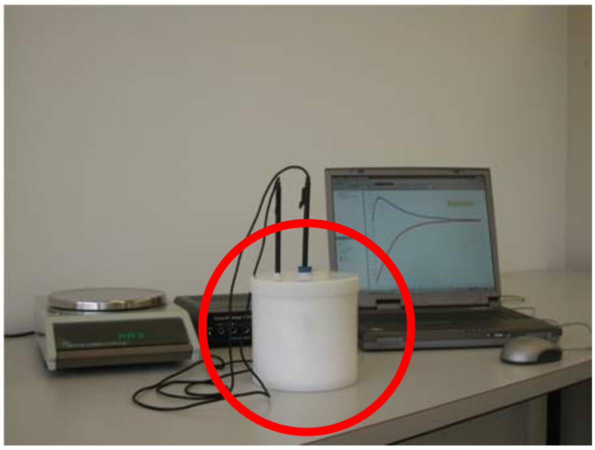
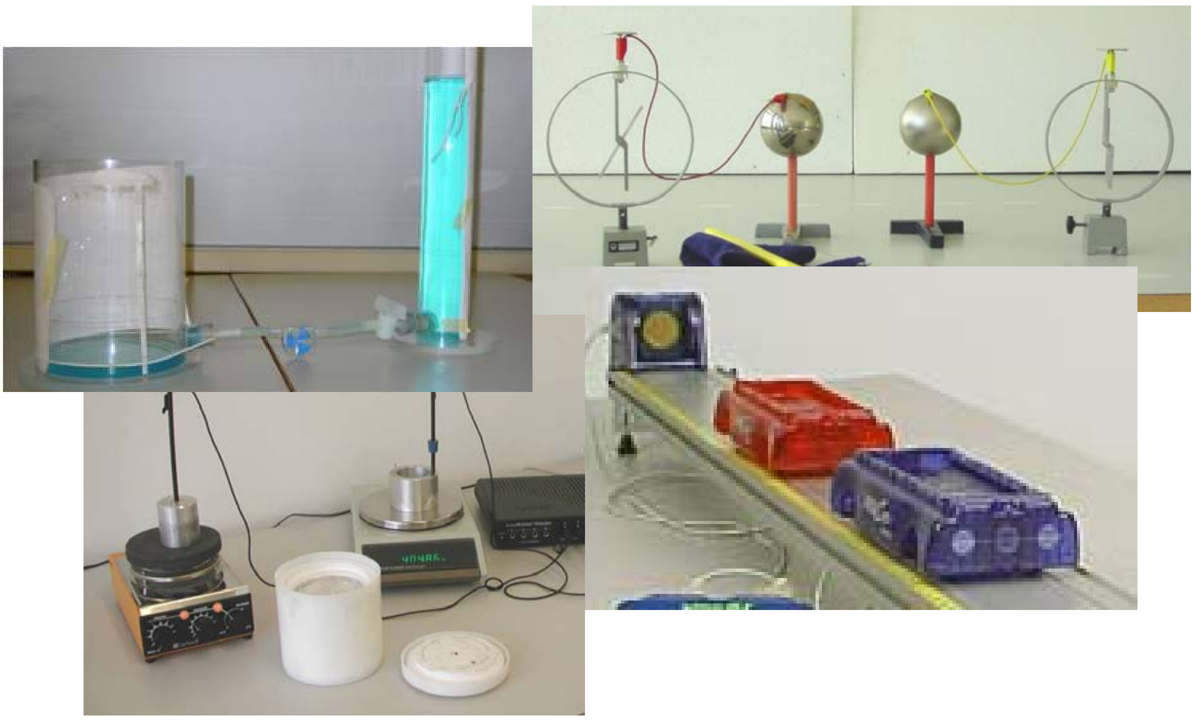


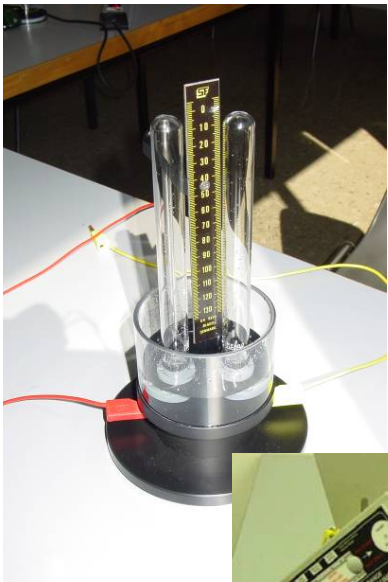


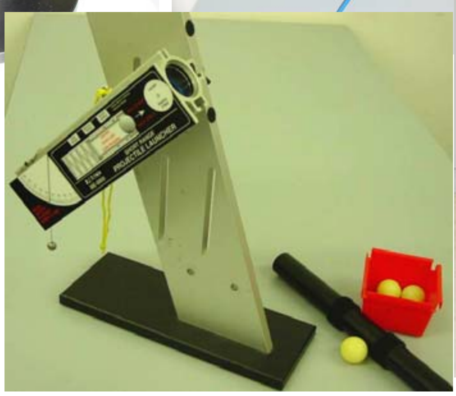
Interaction: transfer



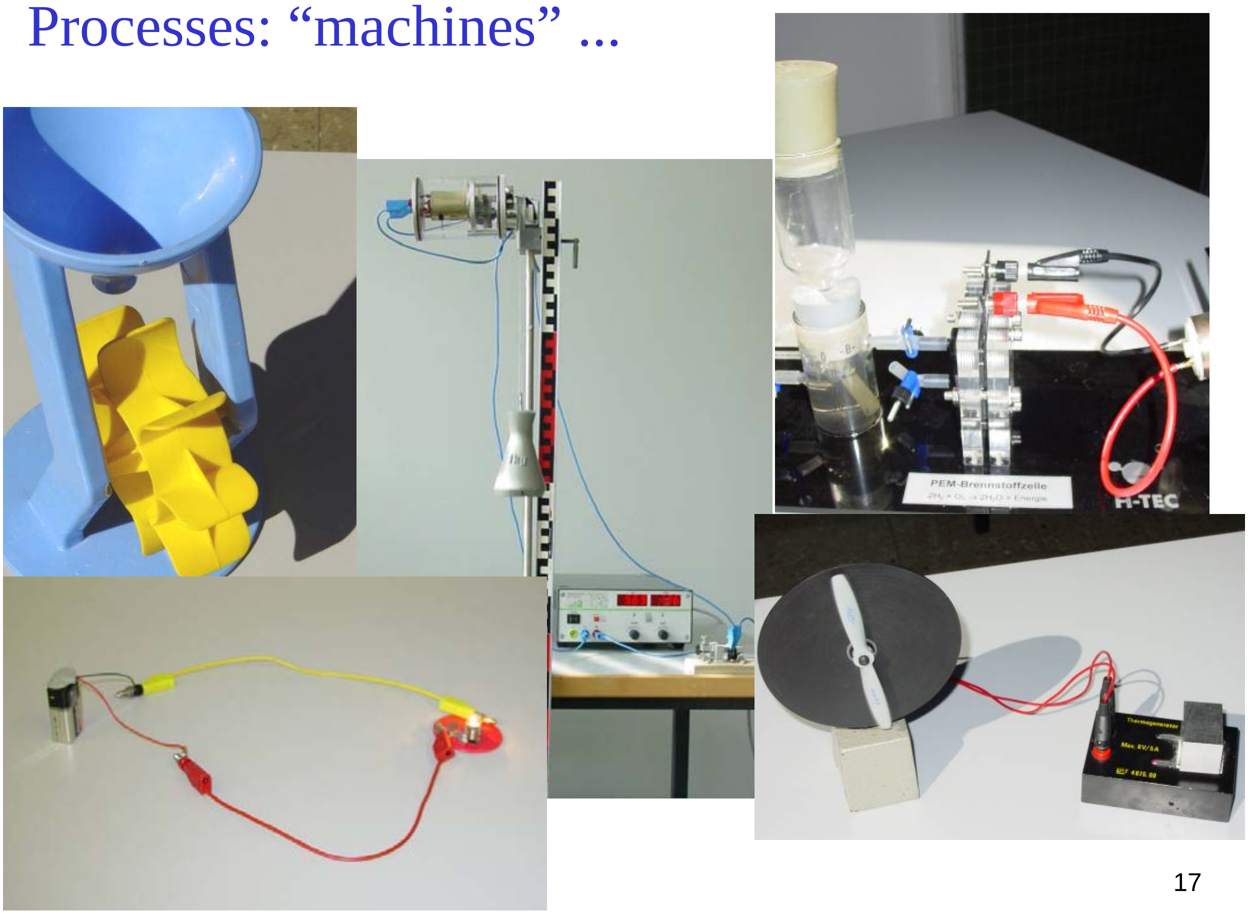
Processes: transfer and production / annihilation

Pumps create differences

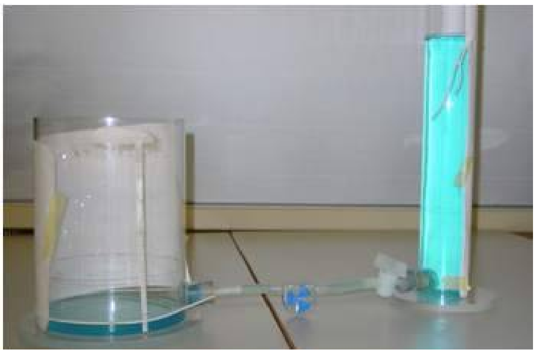


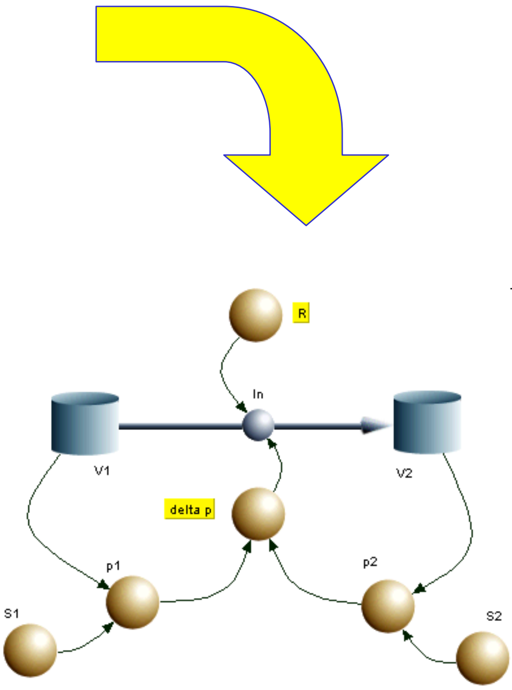


Processes: “machines” ...



Von der Beschreibung zur Interpretation (Modeling)





Interpretation der Phänomene:
Analogien als Werkzeug zur Modellbildung.

Postazione 2

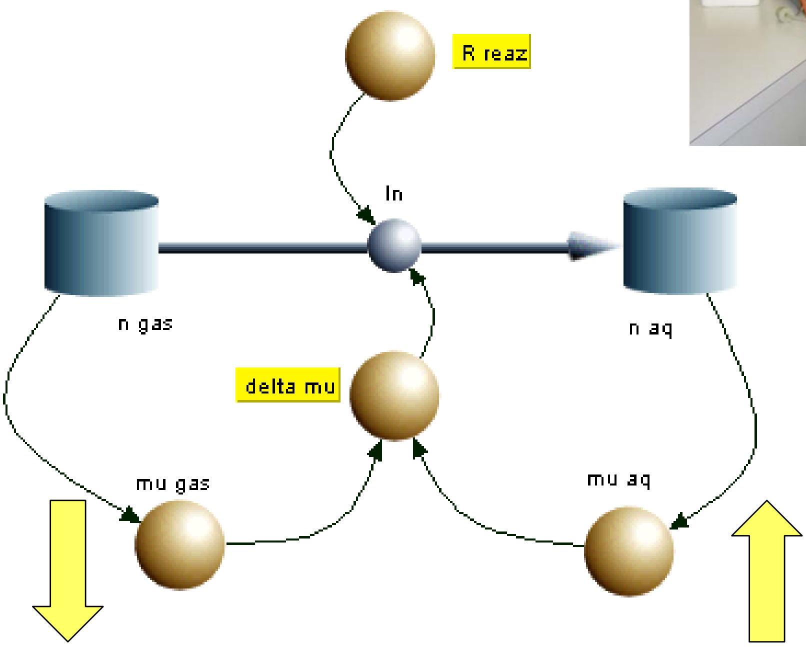
Solubilità di un gas nell’acqua

Introduci dell’anidride carbonica nel recipiente. È corretto aspettarsi la presenza di una spinta per il passaggio del gas in soluzione. Osserva il manometro: corrisponde alle tue previsioni? Agita vigorosamente l’ampolla: che cosa osservi?

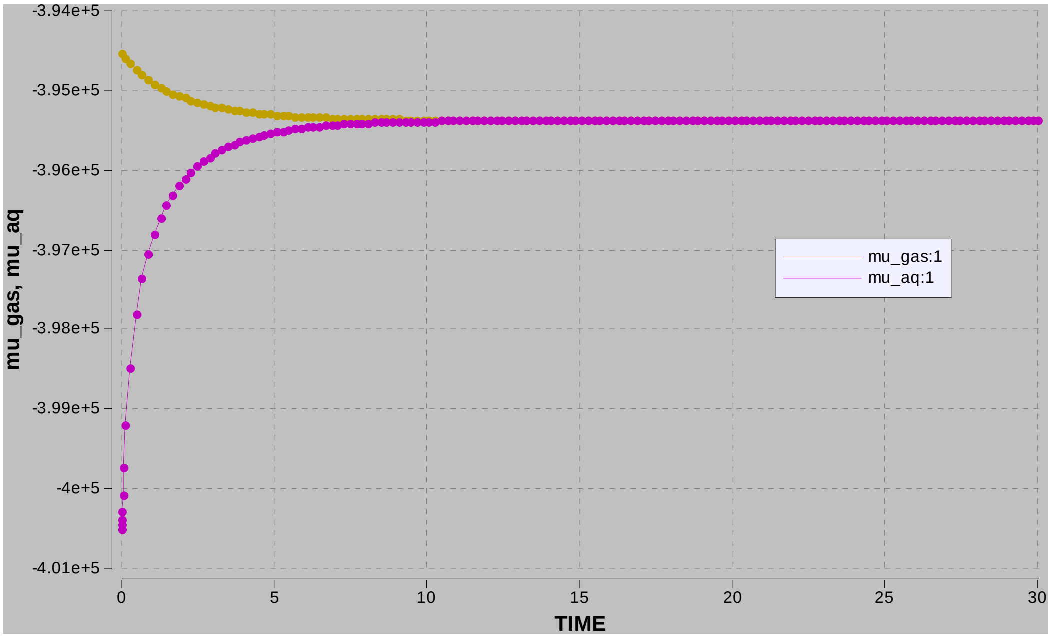
Versione alternativa: come sopra, ma impiegando una bottiglia di PET.

Considera il fenomeno da un punto di vista chimico. Quale potrebbe essere la descrizione in termini di quantità di sostanza, potenziale chimico e equazione di bilancio?
Rappresenta il potenziale chimico per la CO_2 nelle due fasi in funzione del tempo.

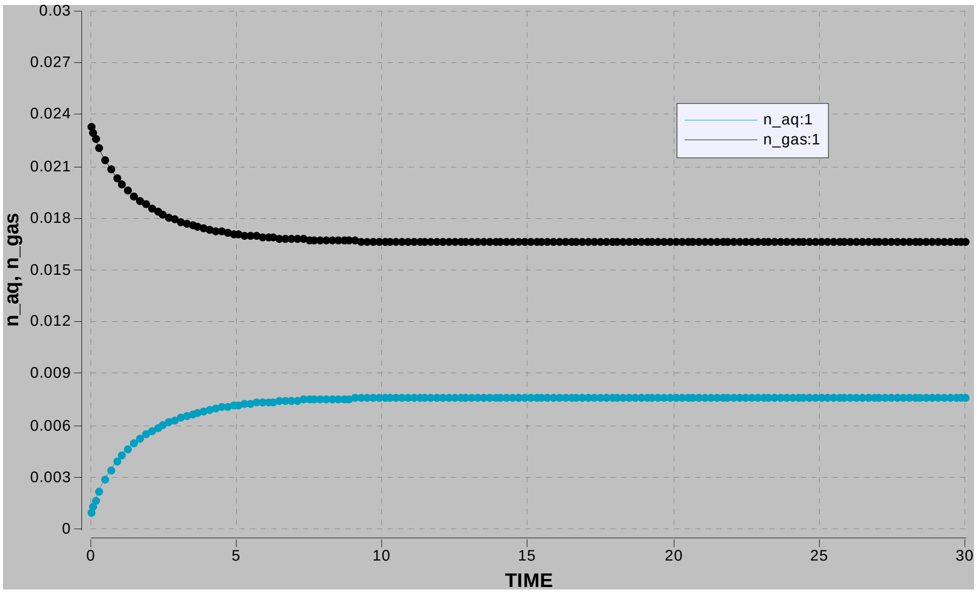
Systemdynamische Modellierung: Das Grundschema



Model results: chemical potential vs. time

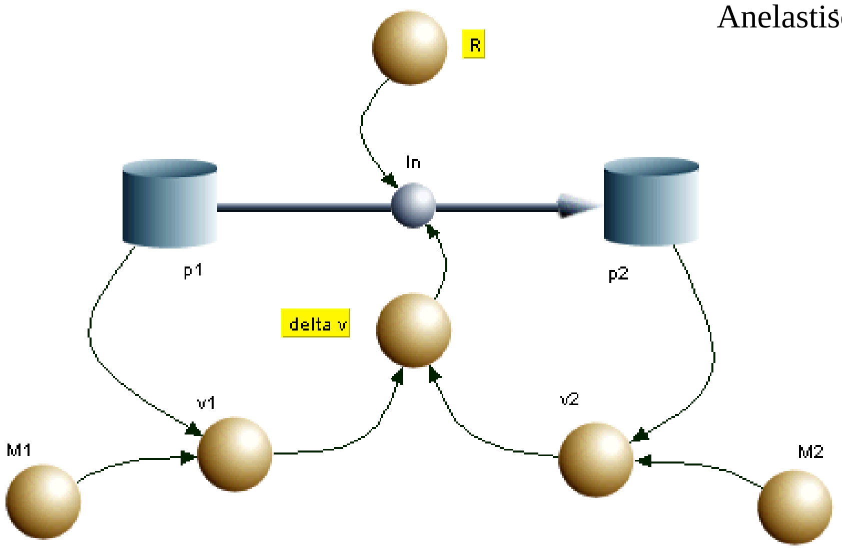


Model results: amount of substance vs. time

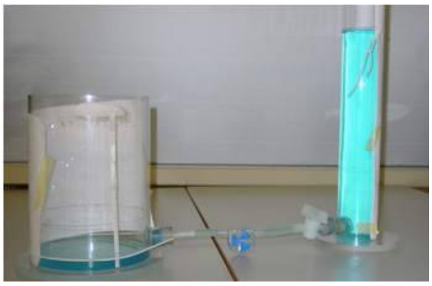


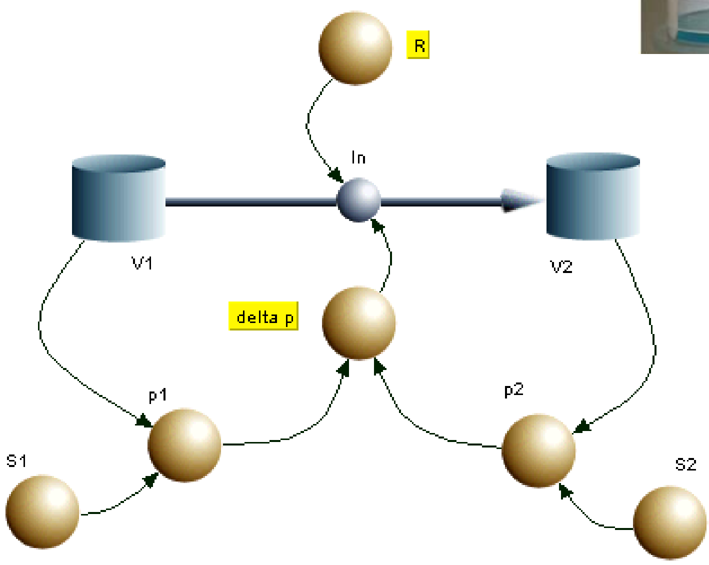
Systemdynamische Modellierung:
Das Grundschema

Anelastischer Stoss

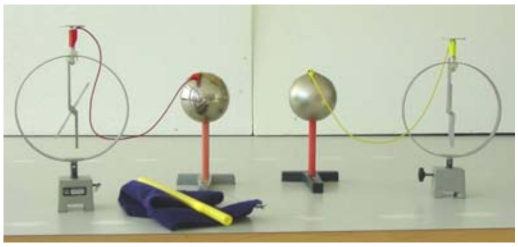


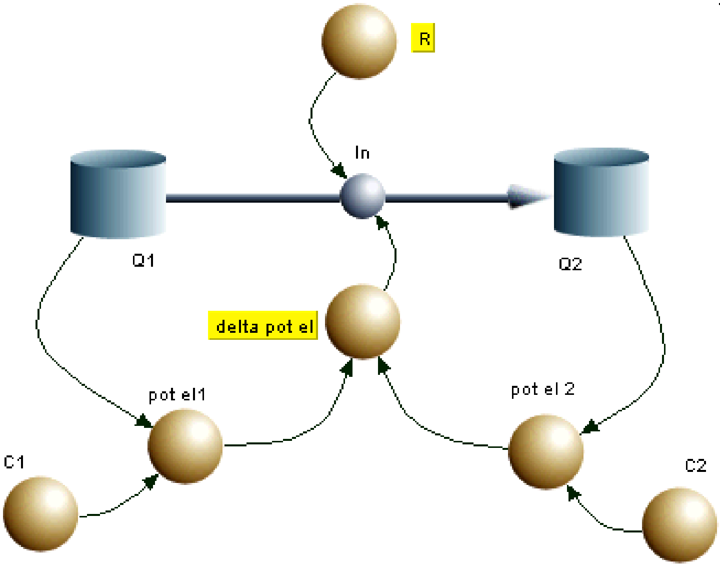
Systemdynamische Modellierung:
Das Grundschema



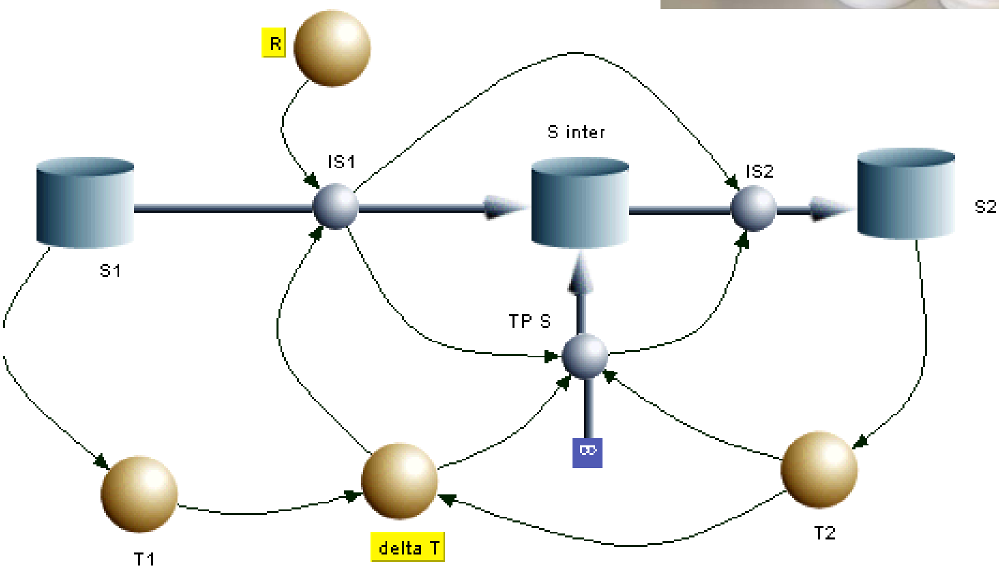


Systemdynamische Modellierung:
Das Grundschema





Systemdynamische Modellierung:
Das Grundschema



3 – The conceptual framework

Extensive physical quantity

- can be stored
- can be transferred from a system to another
- are submitted to a balance equation

Intensive quantities
whose differences represent the “driving forces” for physical processes

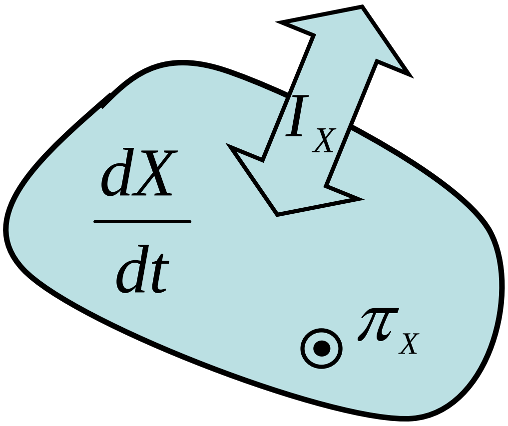
In addition, in order to obtain a suitable quantitative description of the observed phenomena it is necessary to introduce also the concepts of resistance and capacitance

	Mengenartige Grösse	Erhalten / NICHT erhalten	Intensität des zugeordneten Stromes	Potential	Antrieb
Hydraulik	**Volumen** V	erhalten	Wasser Strom I_V	**Druck** P	ΔP
Elektrizität	**Elektrische Ladung** Q	erhalten	Elektrischer Strom I_Q	**Elektrisches Potential** φ	$\Delta\varphi$
Mechanik Translationen	**Impuls** p_x	erhalten	Mechanischer Strom (Translationen) I_{px} (oder Kraft F)	**Geschwindig-keit** v_x	Δv_x
Mechanik Rotationen	**Drall** L_x	erhalten	Mechanischer Strom (Rotationen) I_{Lx} oder Moment M_{mecc}	**Winkelge-schwindigkeit** ω_x	$\Delta\omega_x$
Wärmelehre	**Entropie** S	NICHT erhalten	Entropiestrom I_S	**Absolute Temperatur** T	ΔT
Chemie	**Stoffmenge** n	NICHT erhalten	Chemischer Strom I_n	**Chemisches Potential** μ	$\Delta\mu$

Bilanzgesetz

Momentane Form des Bilanzgesetzes (Kontinuitätsgleichung)

$$\frac{dX}{dt} = I_X + \pi_X$$



X: Mass für die mengenartige Grösse **X**

I_X: Mass für die Intensität des Austausches

π_X: Mass für die Erzeugungs- / Vernichtungsrate

Bilanzgleichung

Hydraulik	$dV/dt = I_V$
Elektrizität	$dQ/dt = I_Q$
Mechanik	$d\mathbf{p}/dt = I_{\mathbf{p}} = \mathbf{F}$
Wärmelehre	$dS/dt = I_S + \pi_S$
Chemie	$dn/dt = I_n + \pi_n$

Ein Energiemodell

Energie

- kann gespeichert werden;
- kann von einem System zu einem anderen übertragen werden;
- beim Fliessen ist sie immer an einen Träger gebunden;
- kann von einem Träger zu einem anderen umgeladen werden;
- ist eine bilanzierbare Grösse;
- ist eine erhaltene Grösse.

Energie Transport

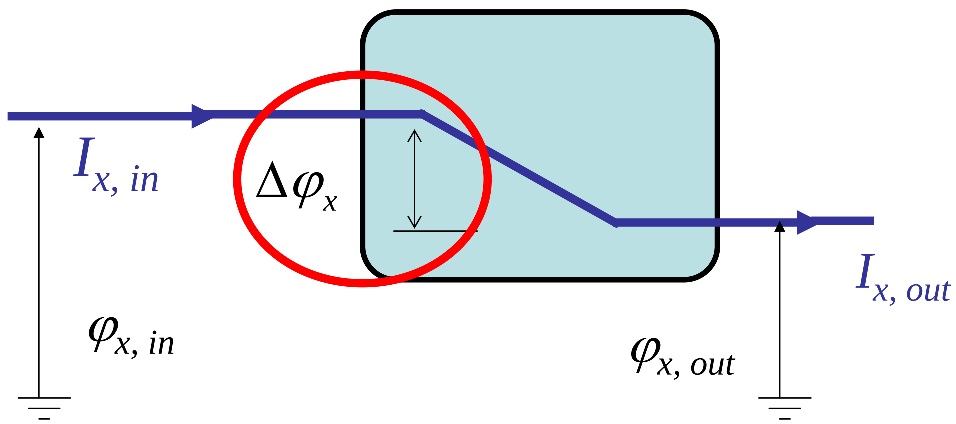
$$I_E = I_X \cdot \varphi_X$$

Energie Umladung

$$\mathcal{P} = I_X \cdot \Delta\varphi_X$$

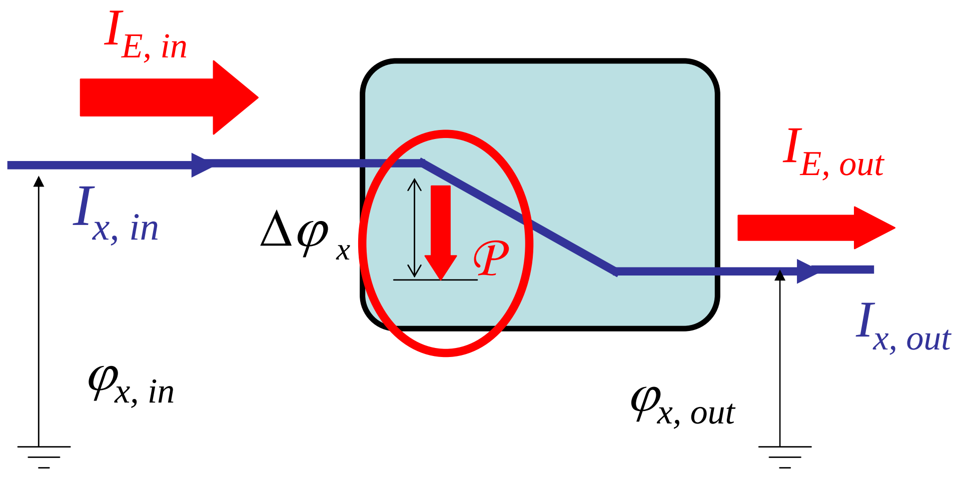
	Mengenartige Grösse	Potential	Intensität des zugeordneten Stromes	Energie Transport	Energie Umladung
Hydraulik	**Volumen** V	**Druck** p	Wasserstrom I_V	$I_E = I_V \cdot p$	$\mathcal{P} = I_V \cdot \Delta p$
Elektrizität	**Elektrische Ladung** Q	**Elektrisches Potential** φ	Elektrischer Strom I_Q	$I_E = I_Q \cdot \varphi$	$\mathcal{P} = I_Q \cdot \Delta\varphi$
Mechanik Translationen	**Impuls** p_x	**Geschwindig-keit** v_x	Mechanischer Strom (Translationen) I_{px} (oder Kraft F)	$I_E = I_{px} \cdot v_x$	$\mathcal{P} = I_{px} \cdot \Delta v_x$
Mechanik Rotationen	**Drall** L_x	**Winkelge-schwindigkeit** ω_x	Mechanischer Strom (Rotationen) I_{Lx} (oder Moment M_{mecc})	$I_E = I_{Lx} \cdot \omega_x$	$\mathcal{P} = I_{Lx} \cdot \Delta\omega_x$
Wärmelehre	**Entropie** S	**Absolute Temperatur** T	Entropiestrom I_S	$I_E = I_S \cdot T$	$\mathcal{P} = I_S \cdot \Delta T$
Chemie	**Stoffmenge** n	**Chemisches Potential** μ	Chemischer Strom I_n bzw. Produktionsrate $\pi_{n(R)}$	$I_E = I_n \cdot \mu$	$\mathcal{P} = I_n \cdot \Delta\mu$ $\mathcal{P} = \pi_{n(R)} \cdot \Delta\mu$

Graphical representation: process diagrams



$$I_{x,in} = |I_{x,\,out}|$$

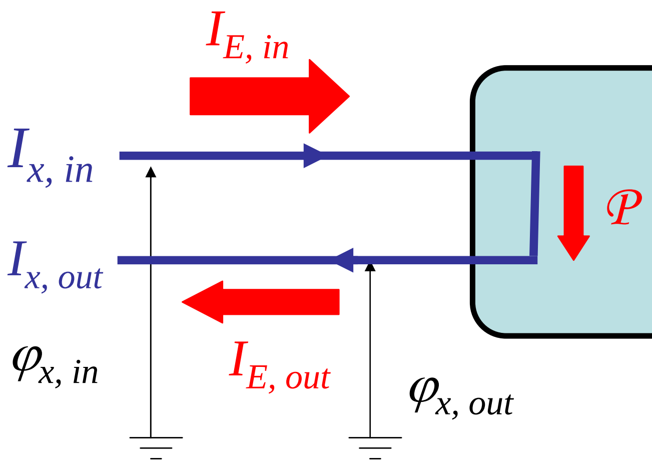
Graphical representation: process diagrams



Energy balance

$$\mathcal{P} = I_{E,in} - \left| I_{E,out} \right|$$

Graphical representation: process diagrams

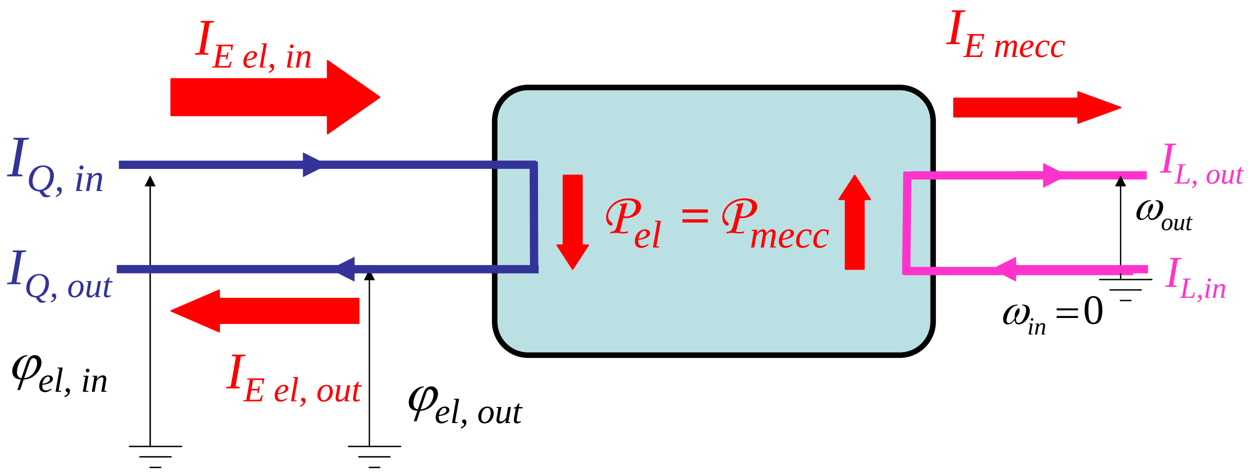


Energy balance

$$\mathcal{P} = I_{E,in} - \left| I_{E,out} \right|$$

Graphical representation: process diagrams

Example: electric motor (ideal)

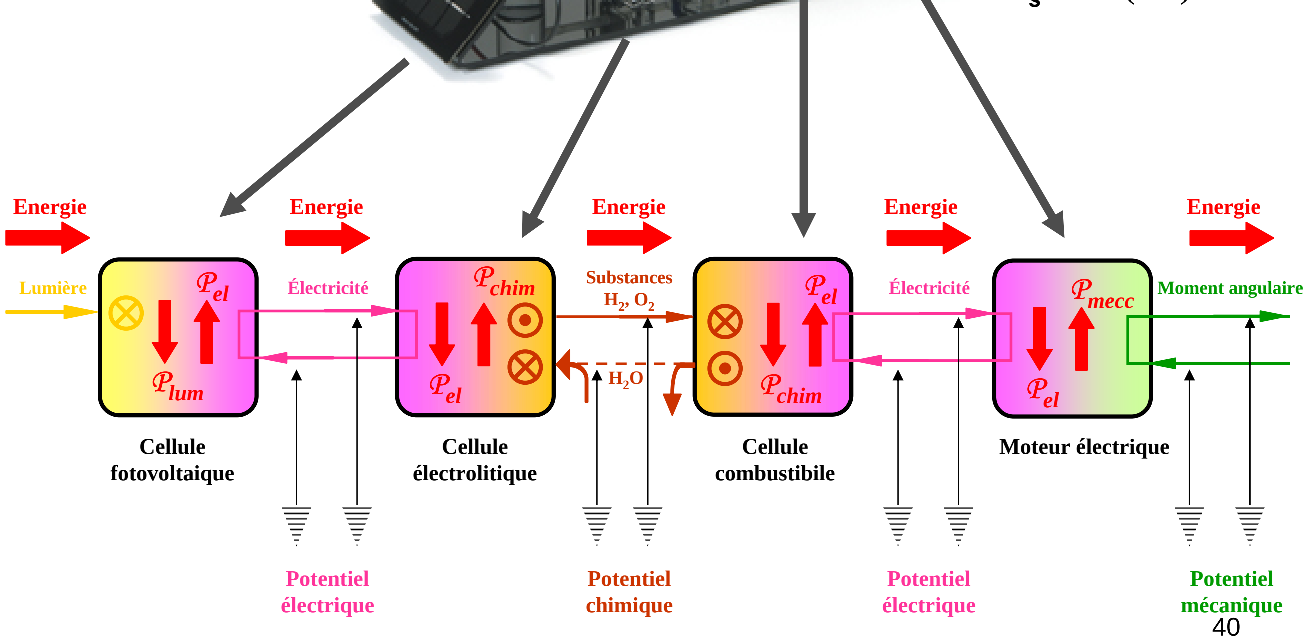


Energy balance:

$$\left| I_{E\ mecc} \right| = I_{E\ el,in} - \left| I_{E\ el,out} \right|$$

Exemple: modèle didactique

Hypothèse:
Efficience 100 %
Tous les processus sont réversibles:
$\boldsymbol{\pi_s}$ = 0 J/(K.s)

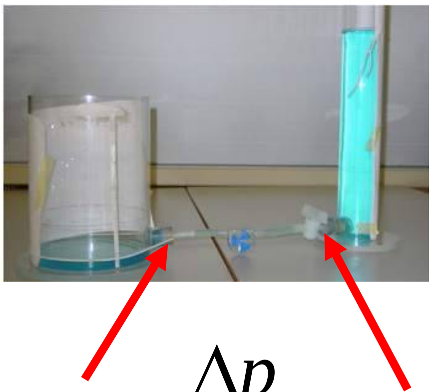


4 - Skills concerning the reference model

1 - When faced with a given experimental situation, the student must be able to:

1.1 - *sketch out* the description on a phenomenological level, singling out accurately the physical system to be examined, the fundamental quantities to be taken into consideration as well as the exchanges with the surroundings and the production /destruction processes which may occur within the system;

1.2 - *recognize* the role of the differences of generalized potentials as "driving forces" for the transfer processes of a conductive nature;

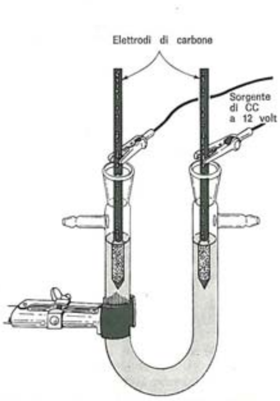


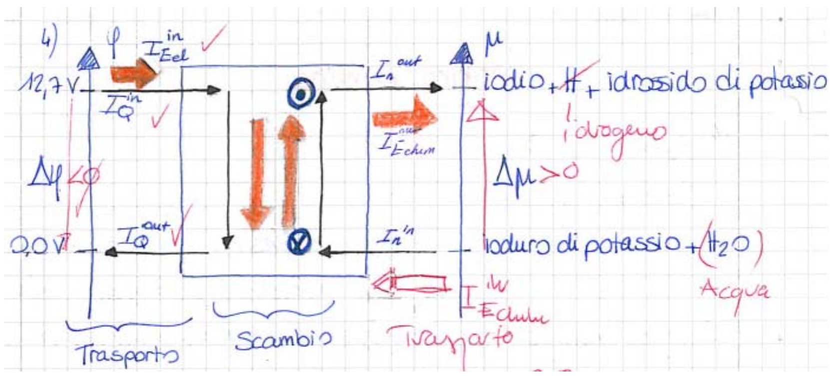
Δp

1.3 - *use* the concepts of capacity and resistance to interpret qualitatively the development observed over a period of time;

1.4 - *outline* the energy balance in terms of incoming and outgoing energy flows; in particular *single out*, in a given process, the transfer of energy from one energy carrier to another;

1.5 - *recognize*, how one potential difference can be used to create another one by releasing energy used by the second process, both in nature and in technical artefacts;



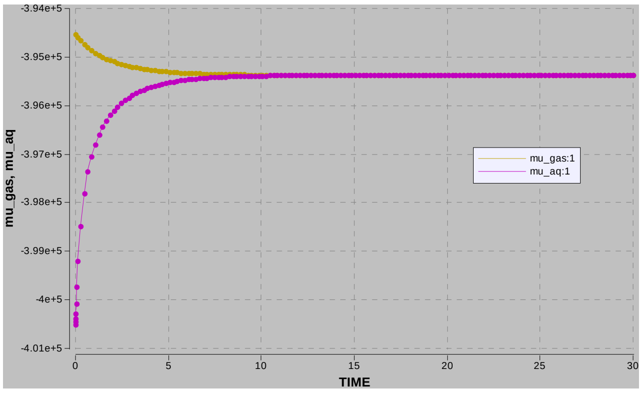


1.6 - *identify* those processes in which entropy is typically produced, as well as the link between entropy production and irreversibility.

2 - With respect to the quantitative treatment of different fields, the student must be able to:

2.1 - *know and use* the extensive and intensive quantities, their units of measurement (SI) and the basic relationships which link them (constitutive laws for some simple systems);

2.2 - *characterize* equilibrium in terms of intensive quantities;



2.3 - *set up* accurately the balance equation (both in its instantaneous and integrated forms) and *apply* it to describe situations observed and to predict the development of the system;

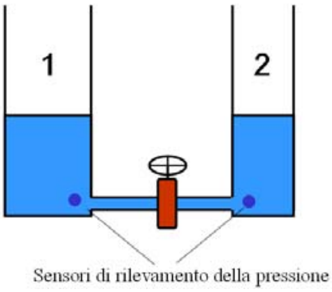
2.4 - *know and use* the connection between the magnitude of the flows and the level of the potentials at which the transport occurs and the magnitude of the energy flows and of the power released and/or required in a given process;

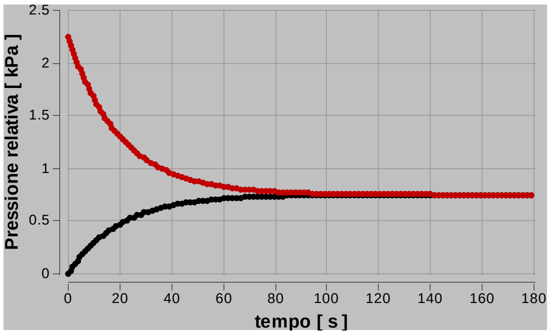
2.5 - *know and use* the relation between the dissipation rate of energy and the production rate of entropy.

$$\pi_S = \frac{\mathcal{P}_{el}}{T_{heater}}$$

3 - The student must also be able to:

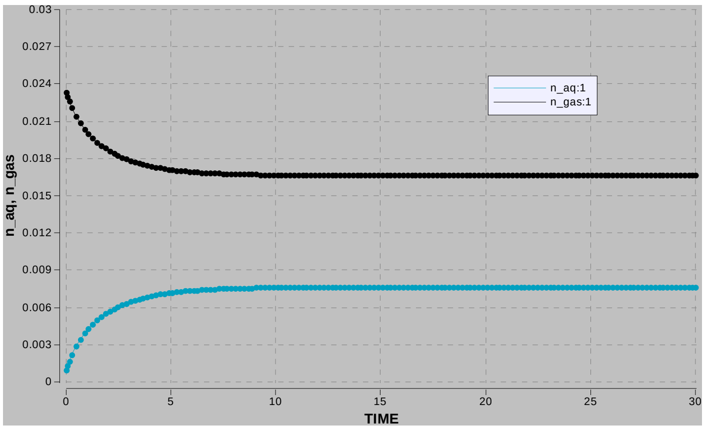
3.1 - *obtain and use* quantitative data from diagrams plotting the relationships between physical quantities (particularly in connection with time elapsed);





Quale dei due vasi era stato riempito con acqua all'inizio dell'esperimento?

3.2 - *deduce* from diagrams of stored quantities as functions of time information about the magnitudes of incoming and outgoing flows and vice versa;

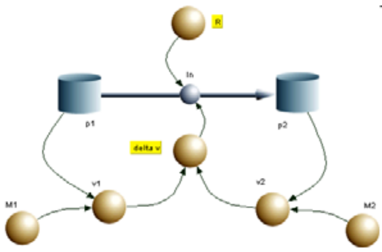


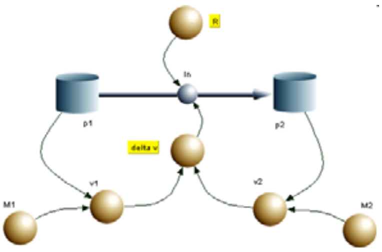
$$CO_{2(g)} \rightleftharpoons CO_{2(aq)}$$

3.3 - *read and use* process diagrams that graphically represent various processes;

3.4 - *recognize and make explicit* the analogies between situations in different fields of study;

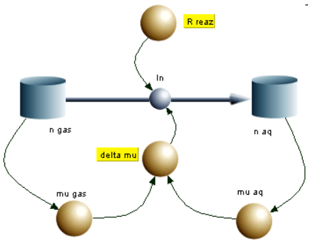
$$dV/dt = I_V$$



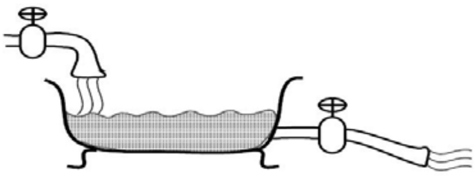


$$d\mathbf{p}/dt = \boldsymbol{F}$$

$$dn/dt = I_n + \pi_n$$



3.5 - *imagine and describe* experimental situations by analogy.



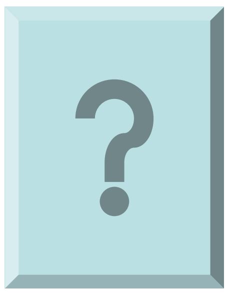
Hydraulik

Elektrizität

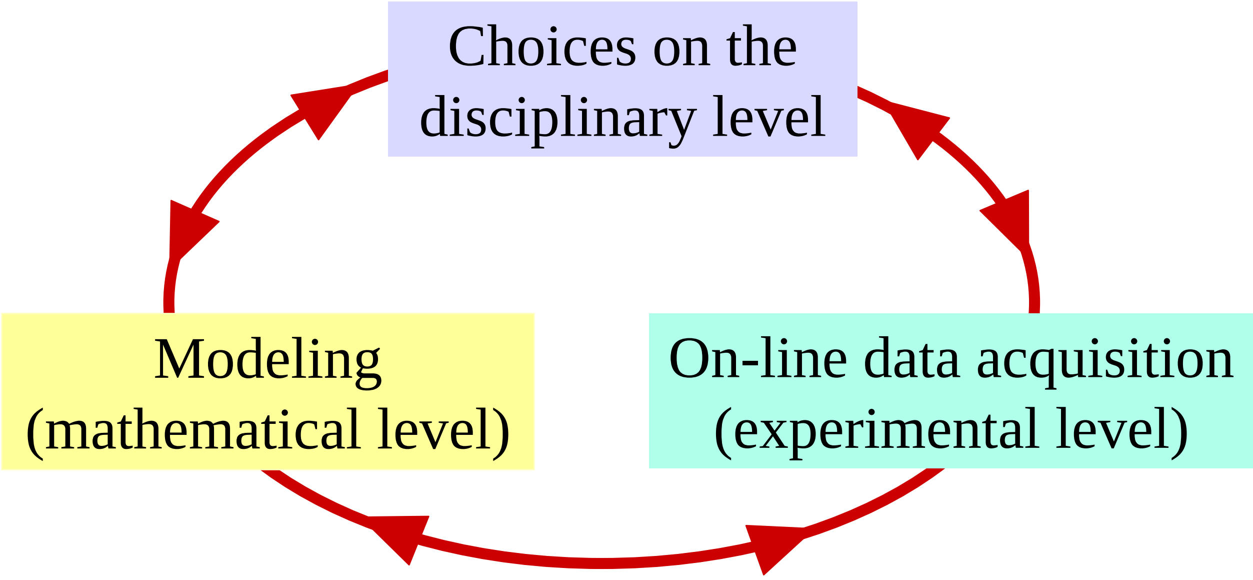
Mechanik

Wärmelehre

Chemie

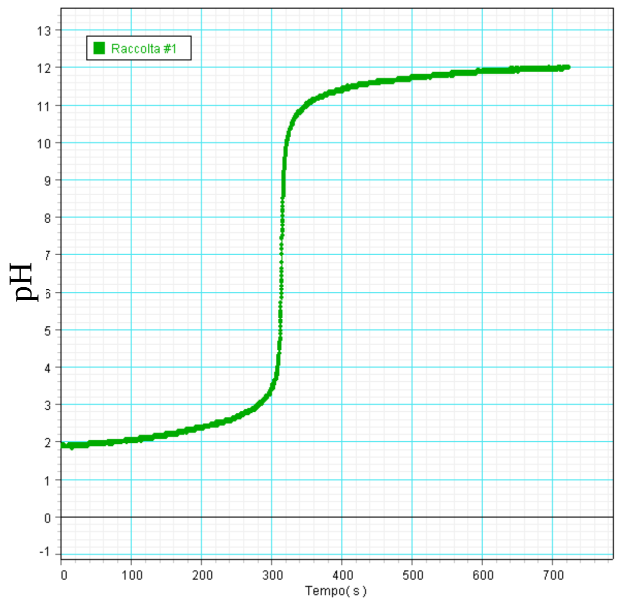


5 – Conclusions and perspectives

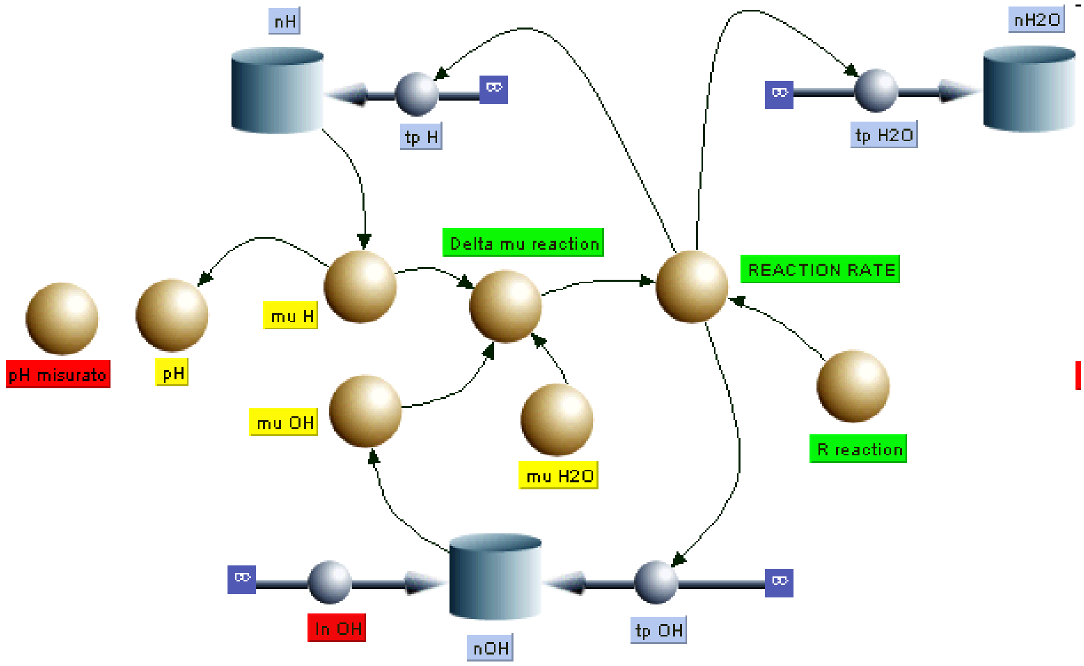


An example: a titration experiment – description and interpretation

$$HCl_{(aq)} + NaOH_{(aq)} \longrightarrow H_2O_{(l)} + NaCl_{(aq)}$$

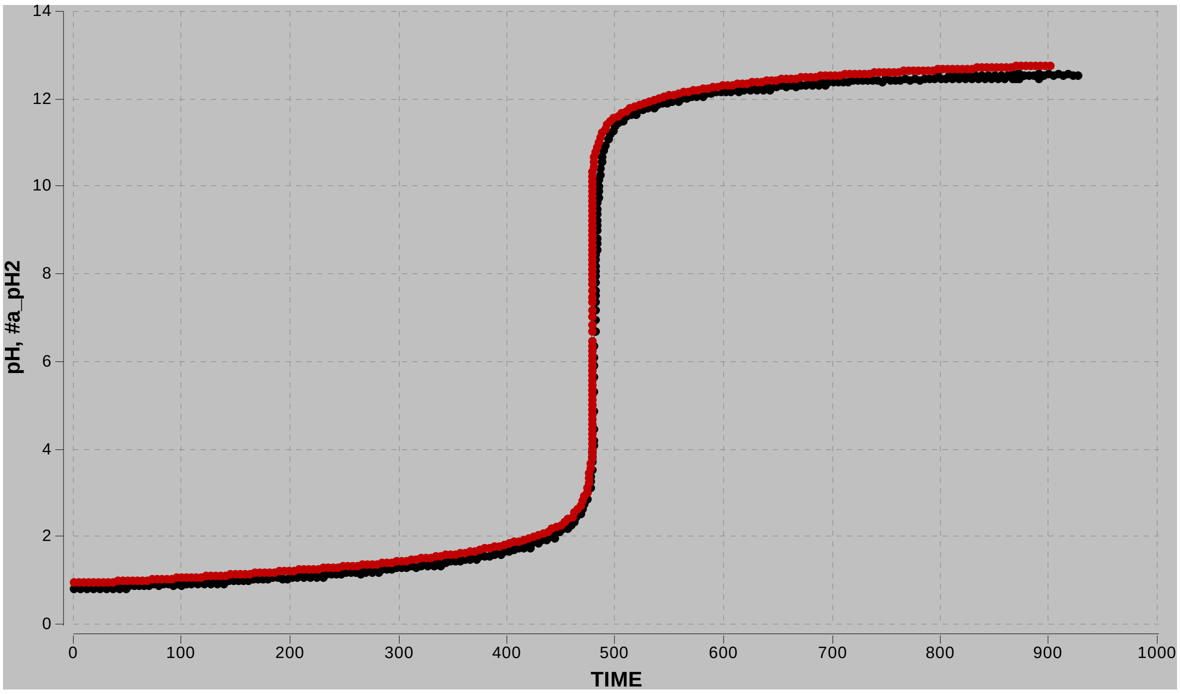


A model with chemical potential



$$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$$

Measured values (black) vs. model results (red)



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Besten Dank

für Ihre Aufmerksamkeit!

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Gruppo di ricerca September 2007
L'insegnamento della termodinamica nella scuola medio superiore

Skills concerning the reference model (preliminary version for the 2007-2008 activity)

1. When faced with a given experimental situation, the student must be able to:

1.1 *sketch out* the description on a phenomenological level, singling out accurately the physical system to be examined, the fundamental quantities to be taken into consideration as well as the exchanges with the surroundings and the production/destruction processes which may occur within the system;

1.2 *recognize* the role of the differences of generalized potentials as "driving forces" for the transfer processes of a conductive nature;

1.3 *use* the concepts of capacity and resistance to interpret qualitatively the development observed over a period of time;

1.4 *outline* the energy balance in terms of incoming and outgoing energy flows; in particular *single out* , in a given process, the transfer of energy from one energy carrier to another;

1.5 *recognize,* how one potential difference can be used to create another one by releasing energy used by the second process, both in nature and in technical artefacts;

1.6 *identify* those processes in which entropy is typically produced, as well as the link between entropy production and irreversibility.

2. With respect to the quantitative treatment of different fields, the student must be able to:

2.1 *know and use* the extensive and intensive quantities, their units of measurement (SI) and the basic relationships which link them (constitutive laws for some simple systems);

2.2 *characterize* equilibrium in terms of intensive quantities;

2.3 *set up* accurately the balance equation (both in its instantaneous and integrated forms) and *apply* it to describe situations observed and to predict the development of the system;

2.4 *know and use* the connection between the magnitude of the flows and the level of the potentials at which the transport occurs and the magnitude of the energy flows and of the power released and/or required in a given process;

2.5 *know and use* the relation between the dissipation rate of energy and the production rate of entropy.

3. The student must also be able to:

3.1 *obtain and use* quantitative data from diagrams plotting the relationships between physical quantities (particularly in connection with time elapsed);

3.2 *deduce* from diagrams of stored quantities as functions of time information about the magnitudes of incoming and outgoing flows and vice versa;

3.3 *read and use* process diagrams that graphically represent various processes;

3.4 *recognize and make explicit* the analogies between situations in different fields of study;

3.5 *imagine and describe* experimental situations by analogy.