POTENTIAL BENEFITS
OF PROCESS INTENSIFICATION FOR RHODIA

8th MEETING OF THE PROCESS INTENSIFICATION NETWORK

Rhodia

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

Presentation of the RHODIA Group

Process Intensification : principles and devices

Potential Benefits of PI for RHODIA main processes

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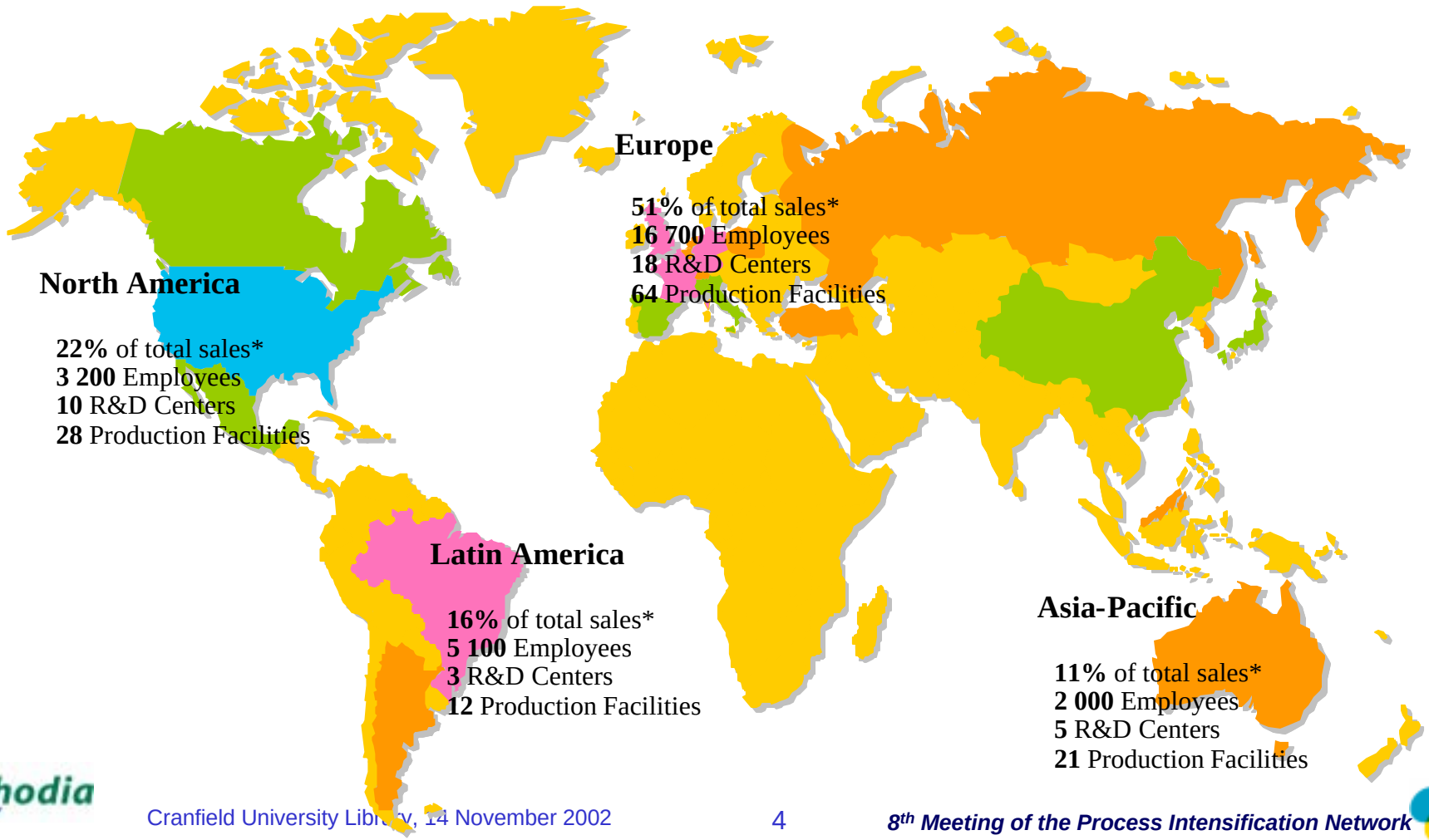
POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

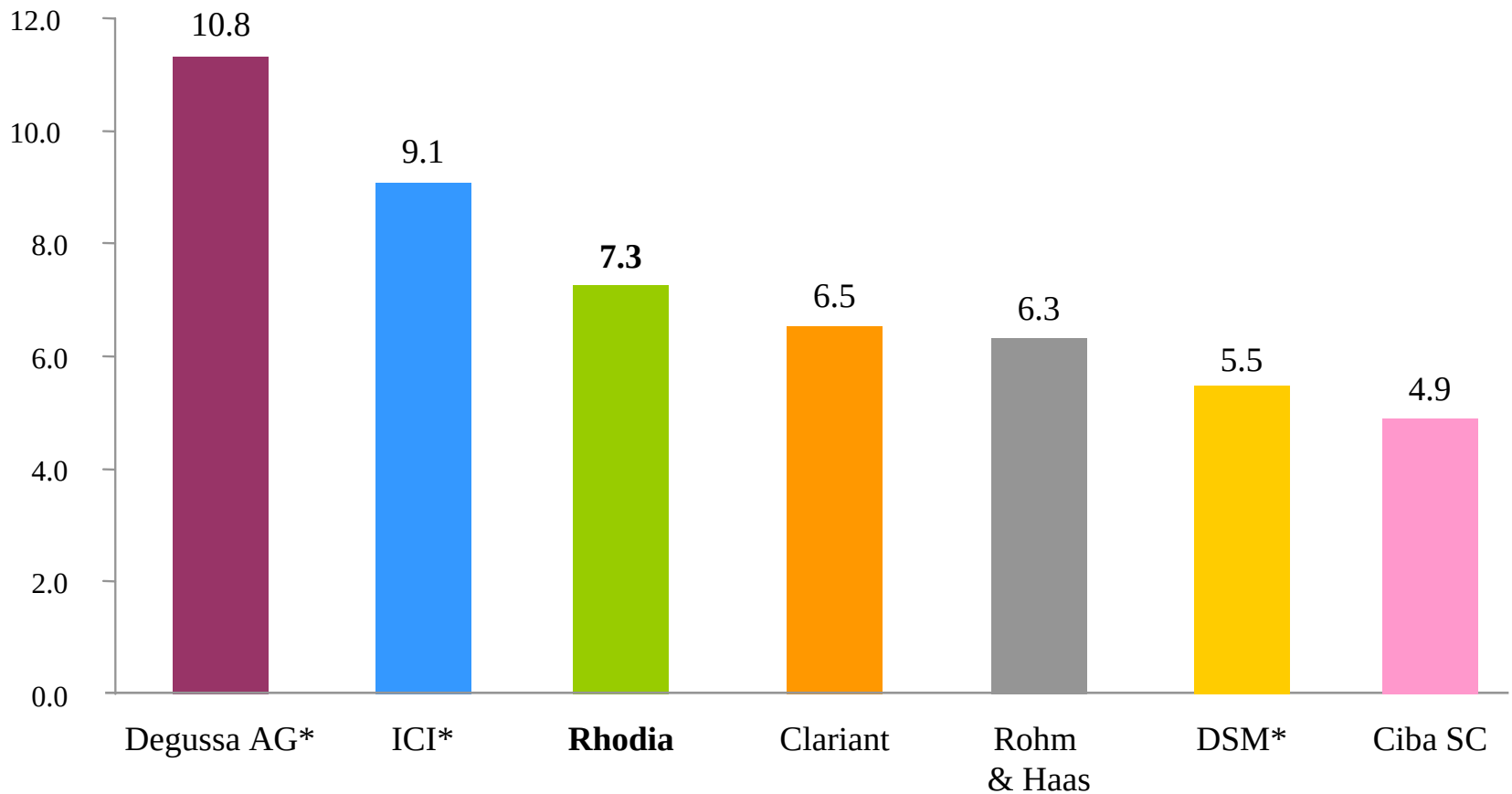
Sales of €7 279 million and 27,000 employees



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

A Key Player in Specialty Chemicals

2001 sales in € billions



* *Specialty chemicals part*

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

Rhodia at a Glance

Sales

€7,279 million

Worldwide employees

27,000

Marketing presence

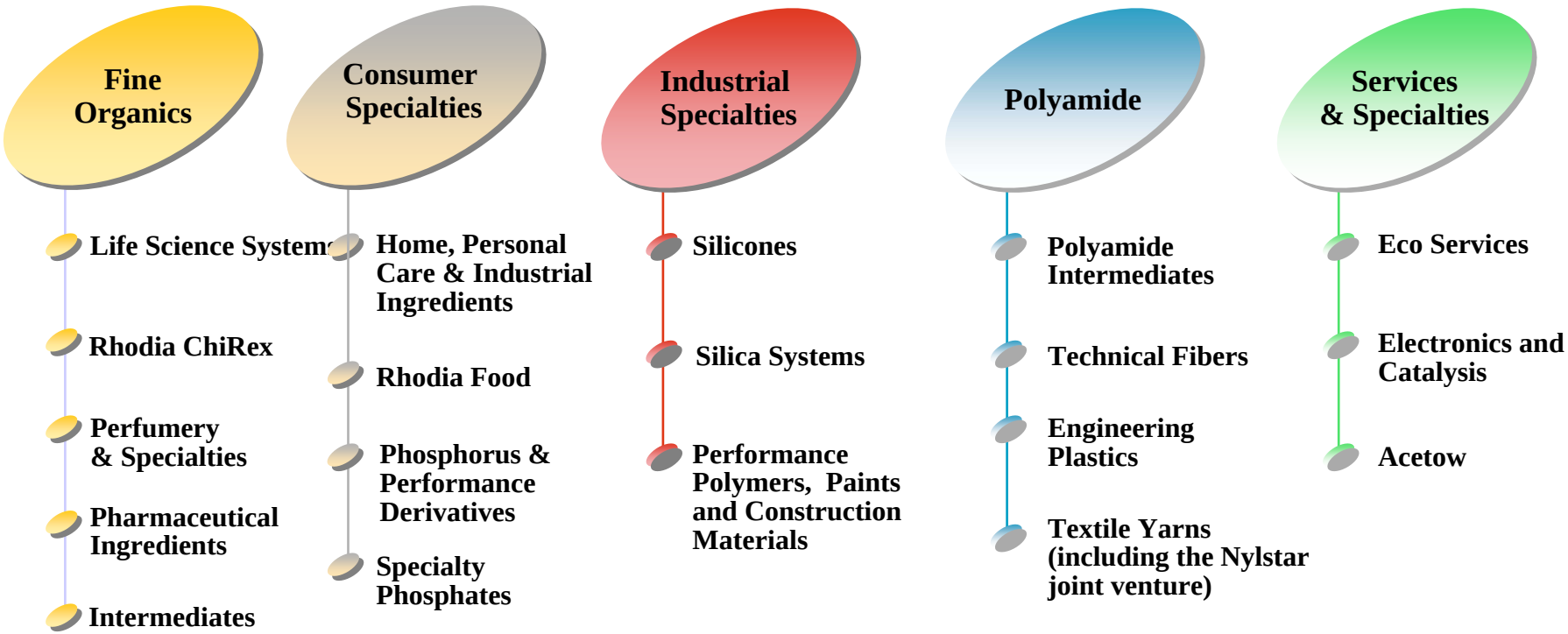
150 countries

R&D budget

€215 million

Market-Driven Enterprises

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Presentation of the RHODIA Group
  - **Different processes by Rhodia**
    - Synthesis of organic compounds
    - Synthesis of inorganic compounds
    - Polymerization

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

Presentation of the RHODIA Group

Process Intensification : principles and devices

Potential Benefits of PI for RHODIA main processes

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

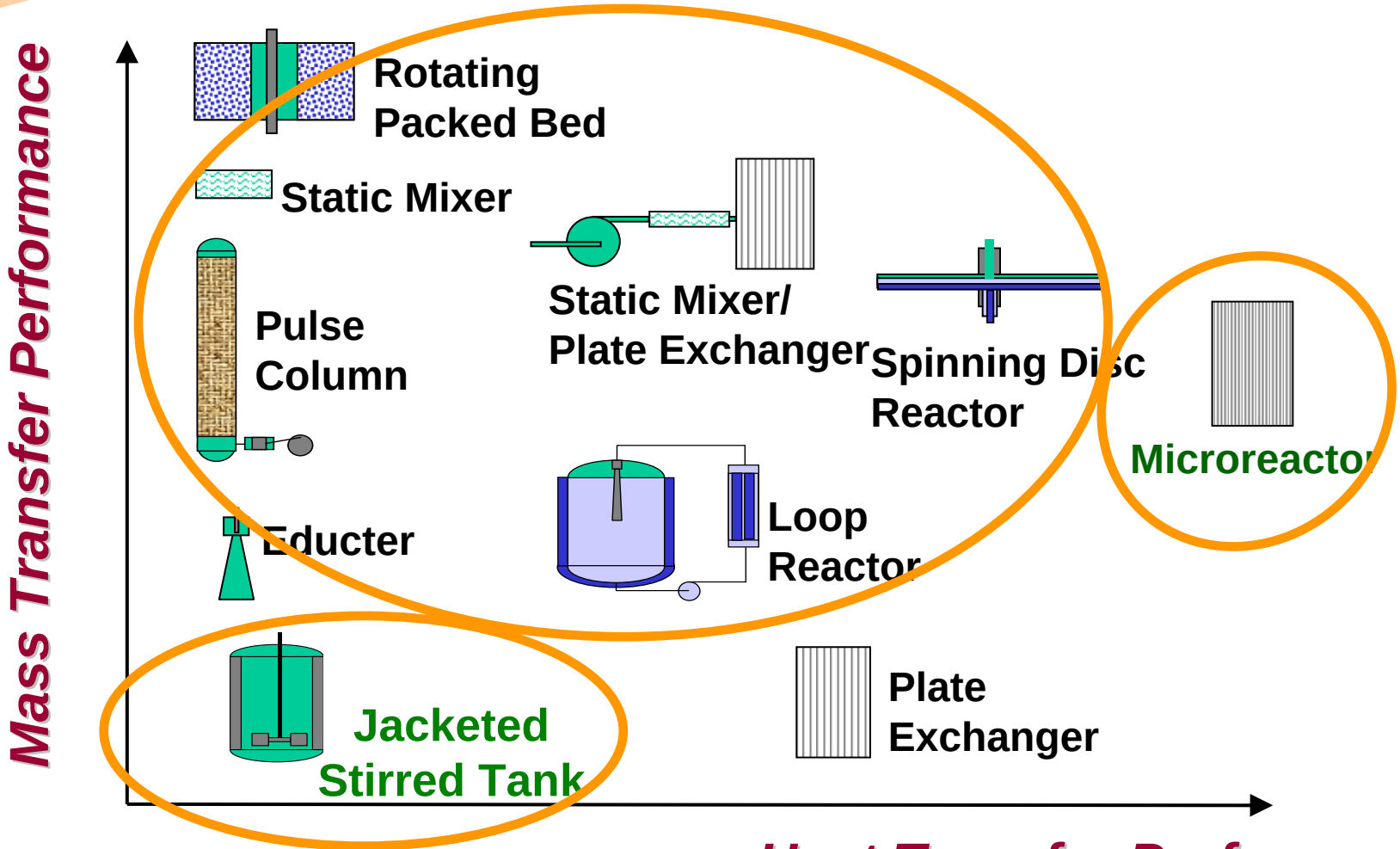
- Process Intensification : principles (R. Jachuck) and devices
  - **Significantly enhances the transport rates**
    - Match mass transfer rate to rate of desired chemical reaction
    - Match heat transfer rate to exothermicity of reaction
  - **Gives every molecule the same processing experience**
    - Match flow behaviour (eg plug flow, backmixed) to reaction scheme
    - Match residence time to desired reaction time

Rather than adapting the operating conditions and chemistry to available classical equipment,

the process structure, architecture and equipment can be adapted to the physico-chemical transformation

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Process Intensification : principles and devices



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

Presentation of the RHODIA Group

Process Intensification : principles and devices

Potential Benefits of PI for RHODIA main processes

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

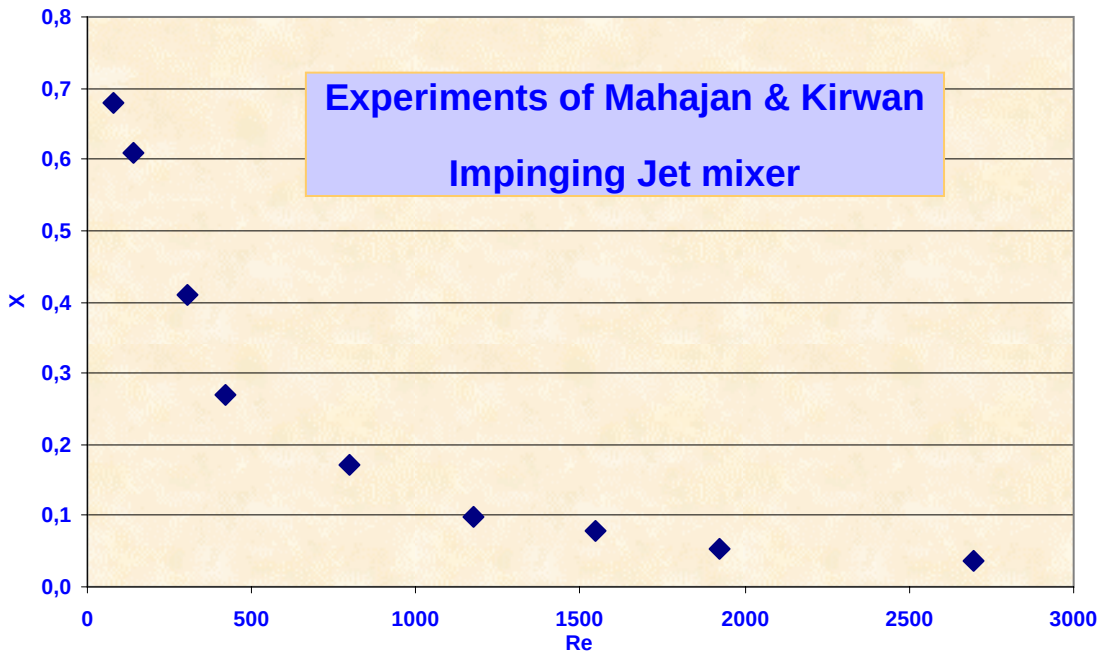
- Potential Benefits of PI for RHODIA main processes
  - Organic Synthesis
    - Case of multiple reactions : influence of mixing (1/2)

- **A + B ⇨ R**
- **B + R ⇨ S**

- **Selectivity of reaction defined by $X = 2C_S/(C_R+2C_S)$**

X ↘ when mixing is improved

Rapid reaction controled by mixing : $k_1 = 12000\ m^3/mol.s$
Slow reaction controled by kinetic : $k_2 = 2\ m^3/mol.s$



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Organic Synthesis
    - Case of multiple reactions : influence of mixing (2/2)
      - **similar schemes as the Bourne exemple exist for Rhodia organic products, even more complicated but the principle is the same**
        - **PI can raise the selectivity of reaction, that is to say the yield of the desired product and diminish secondary products**

          => higher yield of desired product

          => easier or no separation required
    - Case of exothermic reactions
      - **introduction rates are limited by the speed of heat removal (risk of degradation of product, risk of hot points)**
        - **PI can allow quicker introductions and better temperature homogeneity**

          => improvement of productivity

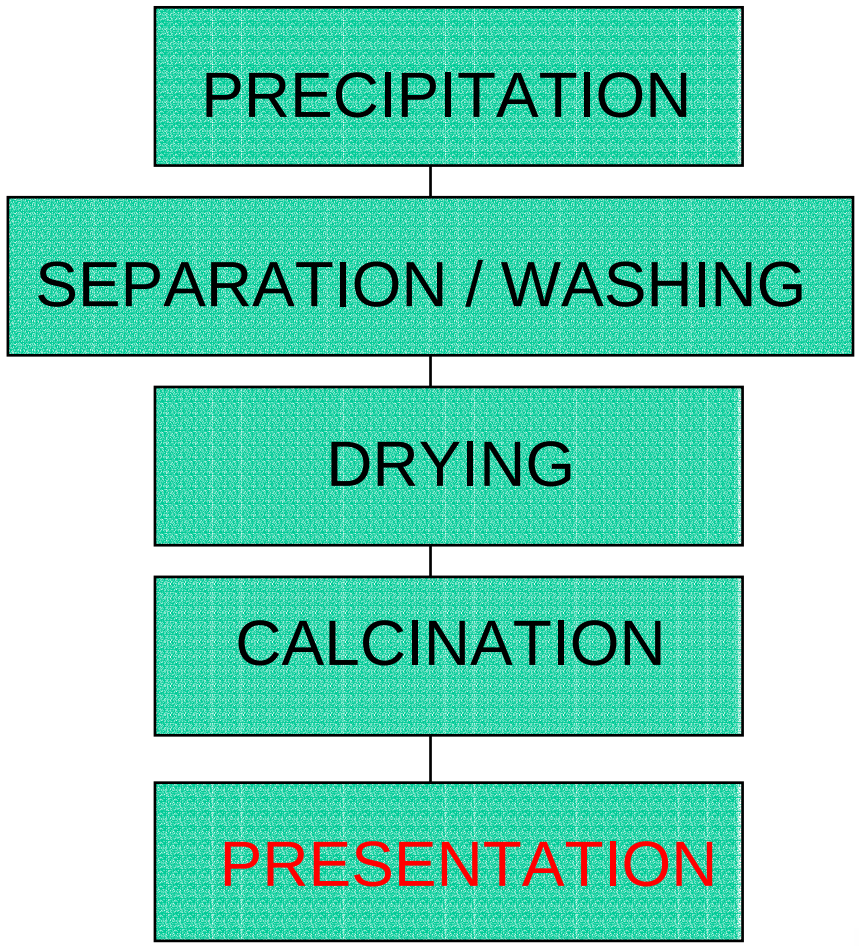
          => improvement of quality

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis

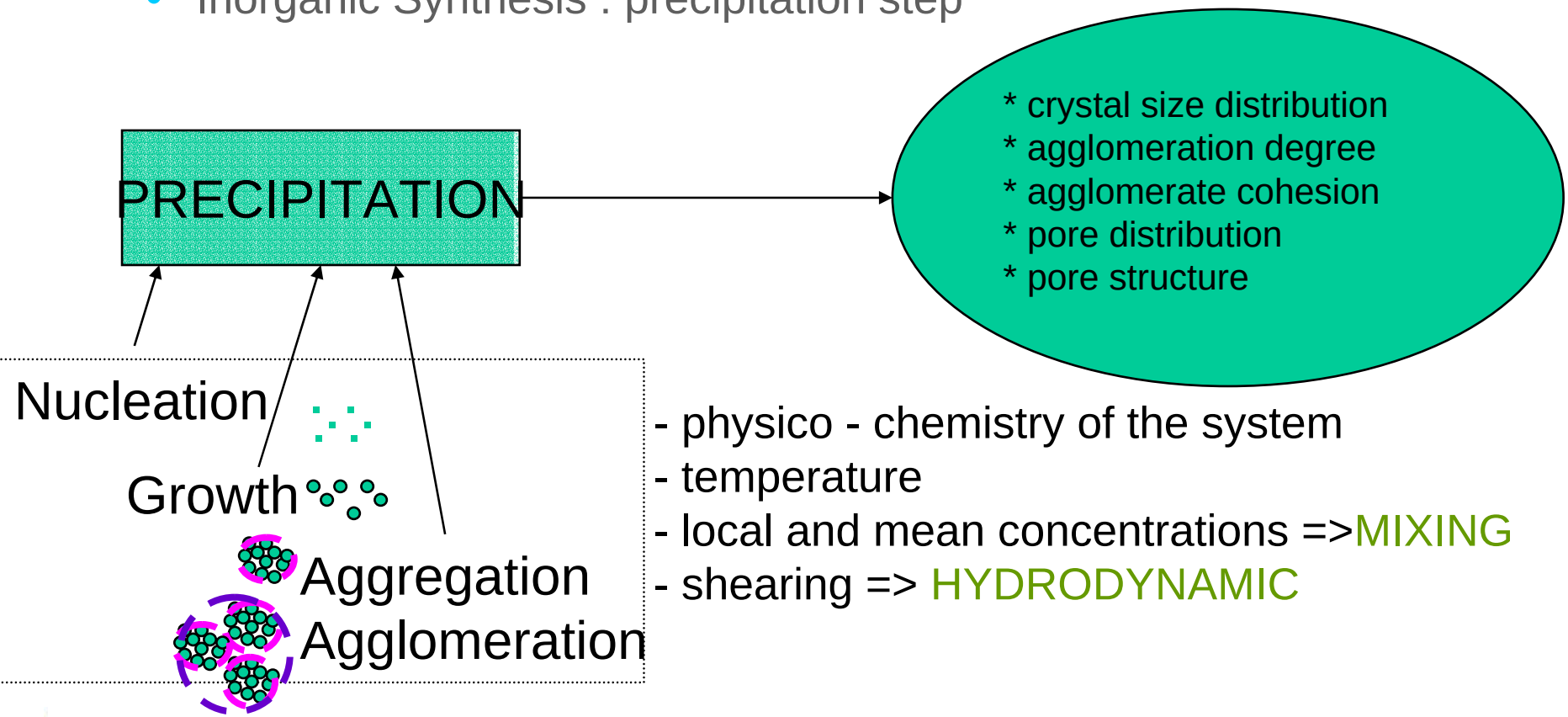
    different steps

    => Improvement of productivity to improve significantly the productivity of the process, all the steps must be intensified



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis : precipitation step



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis
    - Actual state
      - Agitated batch or semi-batch reactors, with big volumes and moderated specific power input and complex hydrodynamic

Limitations and potential difficulties :

- semi-batch and especially continuous case : all the particles don ’t have the same history => large particle size distribution
- scale up
  . limitated specific power input : limited mass and heat transfer
  . difficulty of determination of scale up criteria : empirical way

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis
    - How will PI help?

PRECIPITATION kinetics = *f* (physico-chemistry, hydrodynamic)

Accelerated heat and mass transfer
Better contact of reactants
Better hydrodynamic control

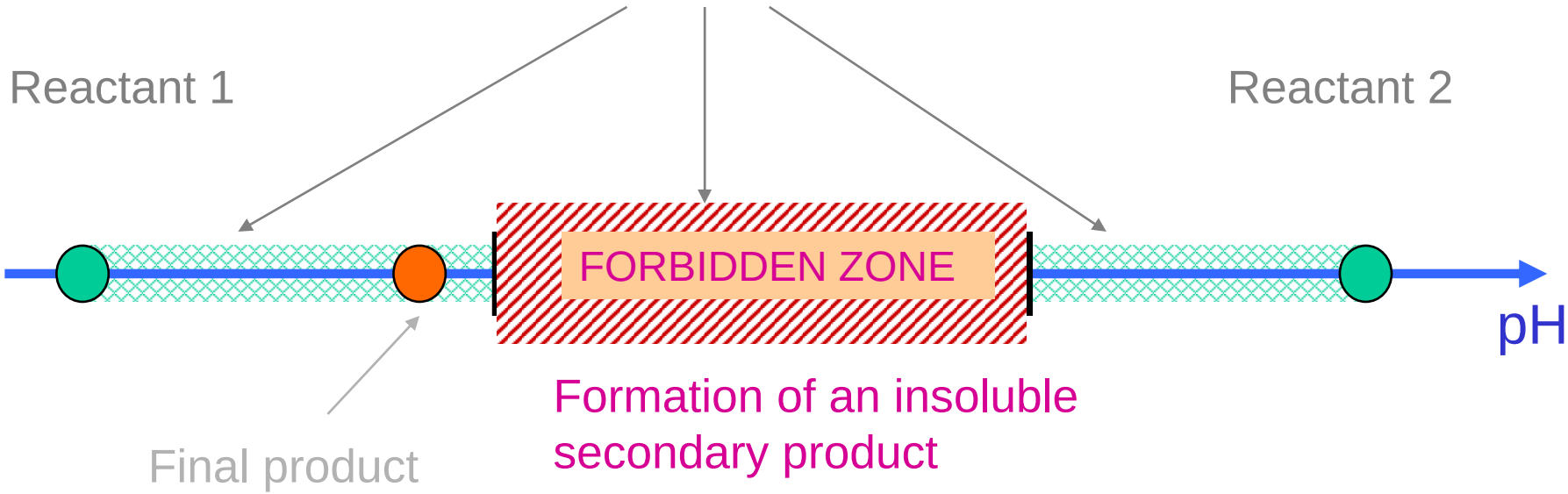
If $t_{mixing} < t_{précipitation\ induction}$, no impact of hydrodynamic control by physico-chemistry

=> NEW PRODUCTS MORE EASILY SCALABLE

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis
    - Example of PI application (RHODIA patent 1994)

Potentially accessible zone during mixing of reactants



$$Al(OH)_xCl_y + Na\ Al(OH)_4 \rightarrow Al(OH)_{x'}Cl_{y'}$$

PAC ALUMINATE AQ S x '>x et y '<y

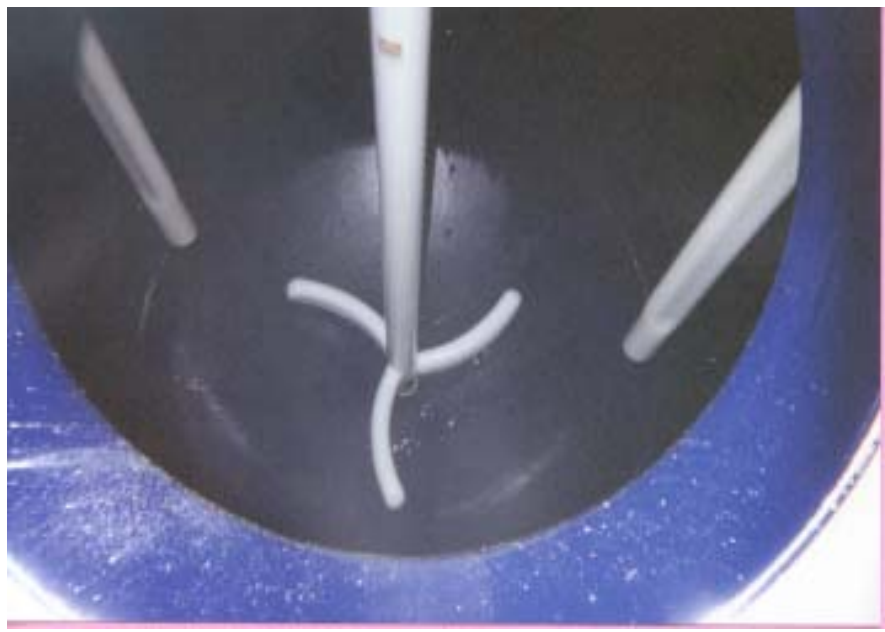
POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis
    - Example of PI application

FIRST INDUSTRIALIZATION TRIAL

Classical semi-batch reactor

Scale : 14 m^3



- Initial introduction : reactant 1

- Introduction of reactant 2

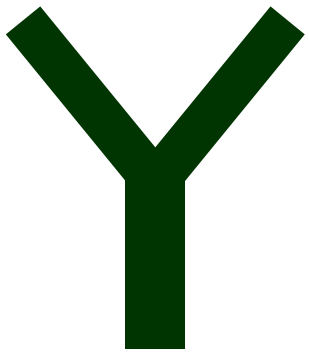
- Ripening

=> formation of undesired secondary product

impossible separation

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Inorganic Synthesis
    - Example of PI application



Installation of a quick mixer for reactants 1 and 2

- no formation of undesired products anymore

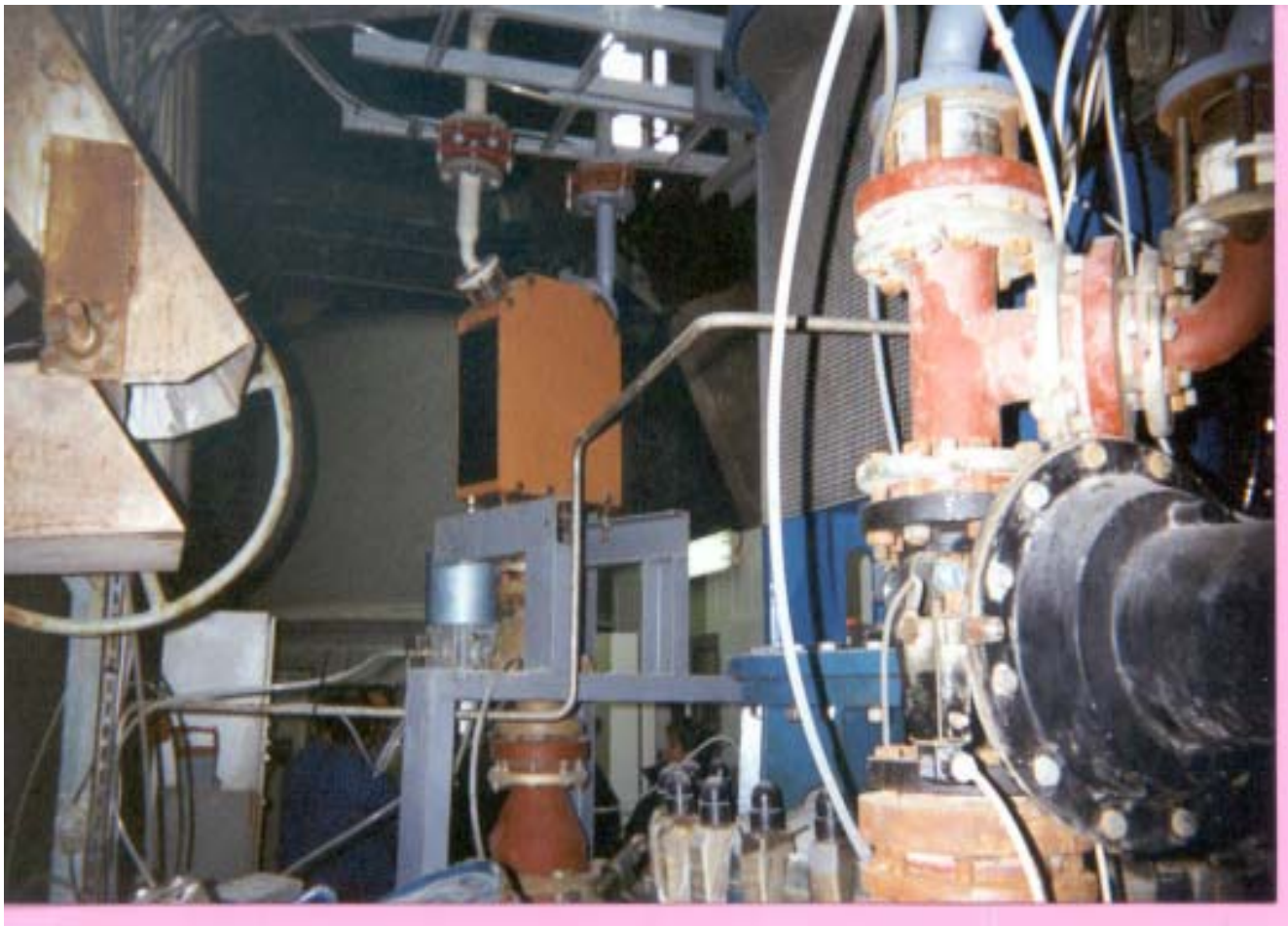
- final composition all the time in the mixer

- rapid homogeneization

Rapid scale-up

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

INDUSTRIALISATION



POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - Polymerization
    - A way of improving productivity
      - **Conversion of batch or semi-batch process to continuous process raise the productivity because of gain of time in feeding and discharge, but problems of intermediates products**
        - **PI, in the case of reactions limited by mass or heat transfer, will decrease the size of equipement, so the quantity of intermediates**

          => raise of productivity

          => decrease of undesired intermediates
    - Example of devolatilization
      - **an important step in producing polymers, limited by mass transfer**
        - **PI can allow quicker exchanges of mass, especially for highly viscous products**

          => acceleration of product devolatilization

POTENTIAL BENEFITS OF PROCESS INTENSIFICATION FOR RHODIA

- Potential Benefits of PI for RHODIA main processes
  - CONCLUSIONS
    - RHODIA believes that PI is really an opportunity especially for
      - improving productivity
      - diminishing investment cost
      - improving quality of products
      - accelerating speed of developpement