Pressure Swing Adsorption as an Efficient Tool for the Separation of Carbon Dioxide from Flue Gases

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1. **Introduction**
    - **fossil fuels – the CO_2 problem**
    - **abatement options**
2. **Pressure swing adsorption**
    - **basic principles**
    - **equilibria**
    - **kinetics**
3. **Scope of the study**
    - **adsorbent selection**
    - **simulations**

4. **Experimental**
   - **equilibria**
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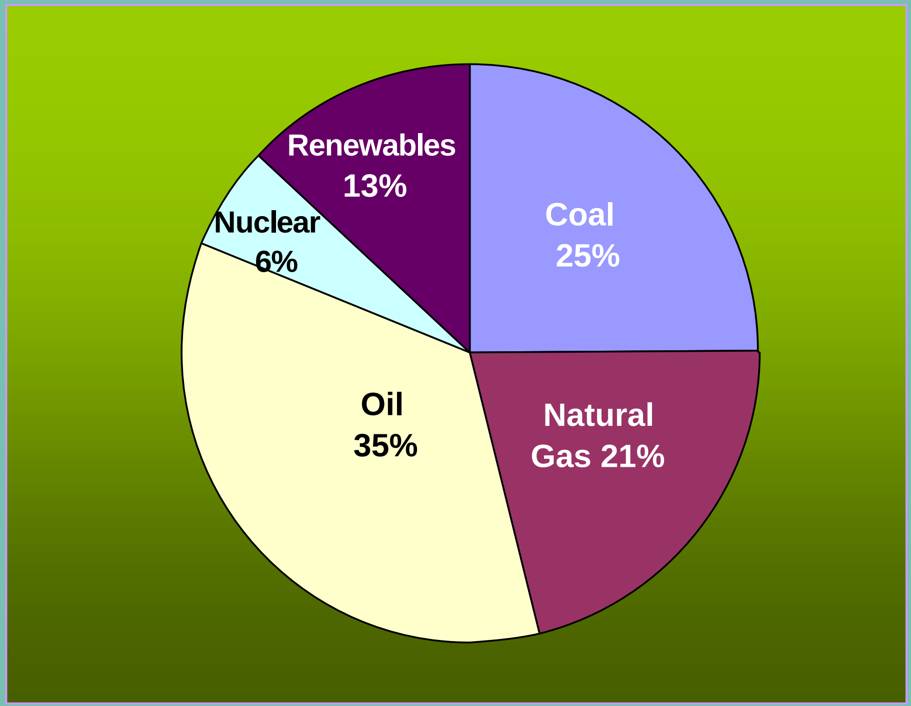
   - **kinetics**
   - **PSA separation experiments**

5. **Mathematical modelling**

6. **Development of an efficient PSA cycle**
   - **CO_2 purity**
   - **CO_2 recovery**

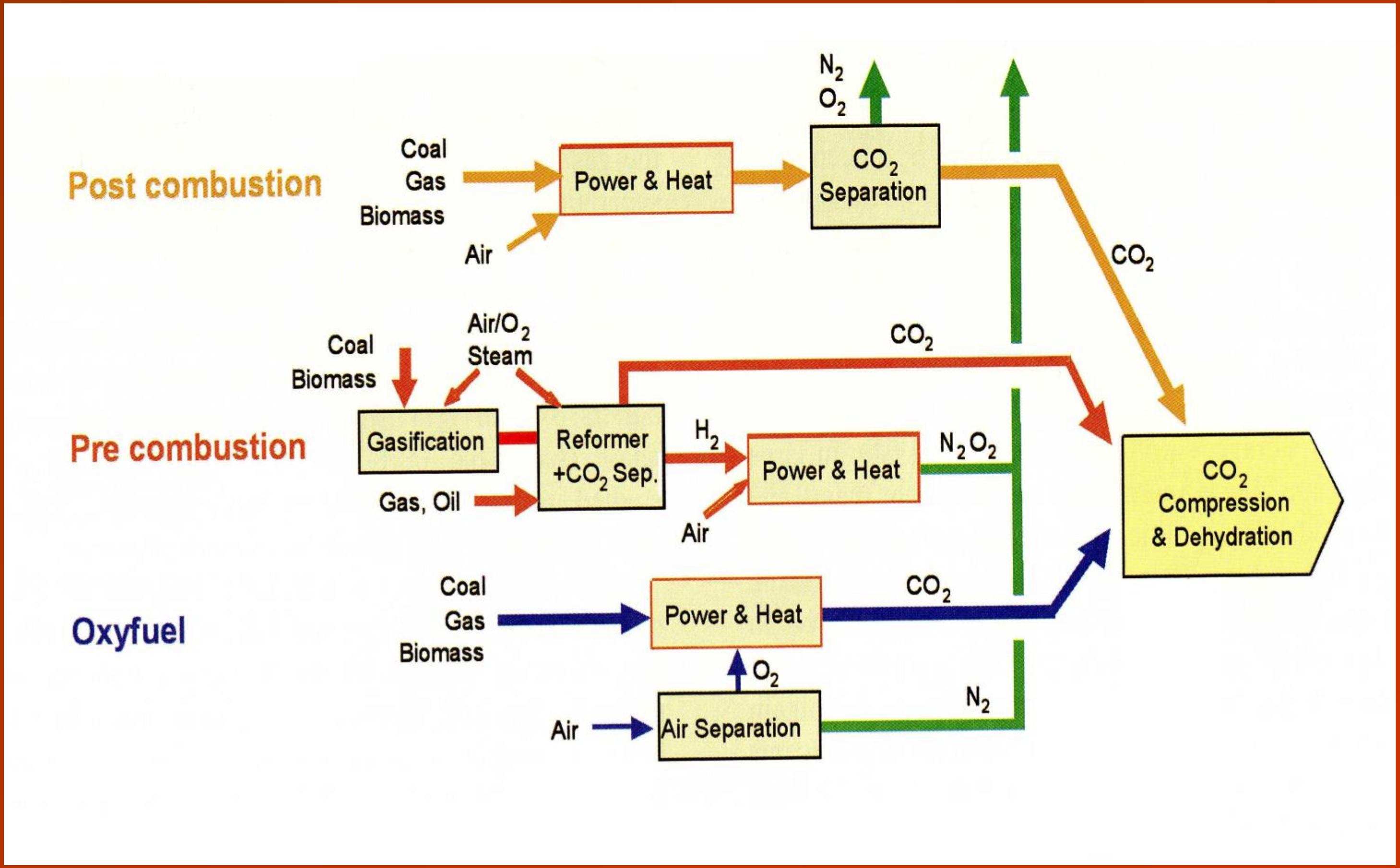
7. **Conclusions**

Fossil fuels provide over 80% of primary energy

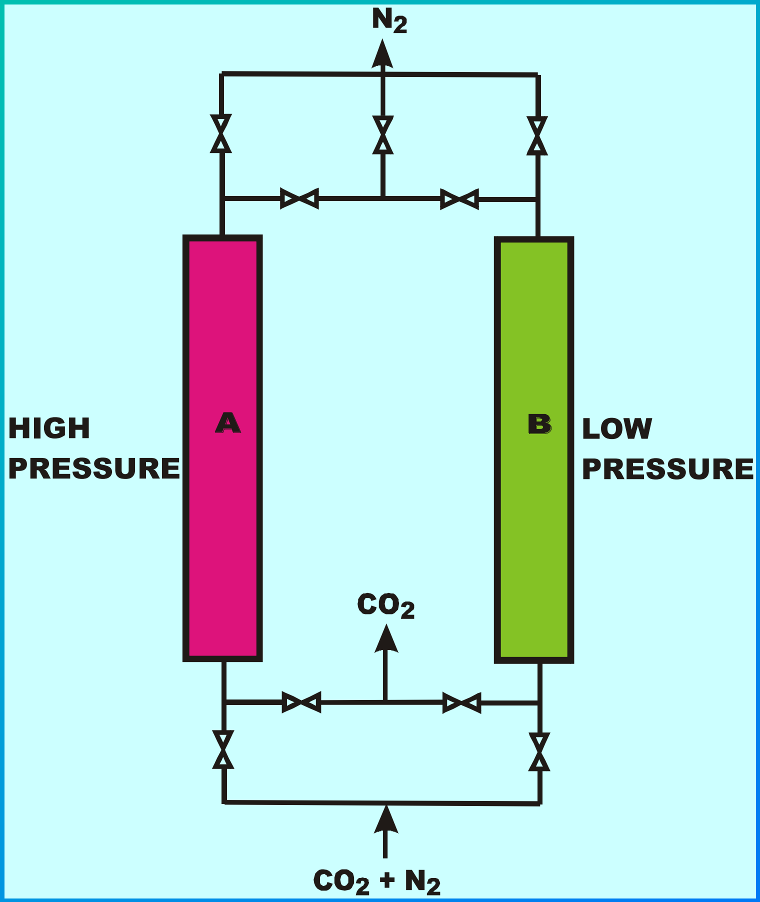


Today, almost 30 billion tonnes of CO_2 are emitted every year as a result of using fossil fuels

Carbon dioxide capture systems



The principle of pressure swing adsorption



Adsorption equilibrium

- how **much** of a given species can be adsorbed

Adsorption kinetics

- how **fast** a species is being adsorbed

Objectives of the present study

- to select the best adsorbent for the separation of CO_2/N_2 mixtures (based on experiments)

- to develop an efficient PSA cycle for the separation of CO_2/N_2 mixtures (based on experiment, modelling and simulations)

Adsorbents studied

- BA-10
- GAC CECA
- Norit Vapure

} activated carbons

- Molsiv 13X
- Grace 13X

} zeolite molecular sieves

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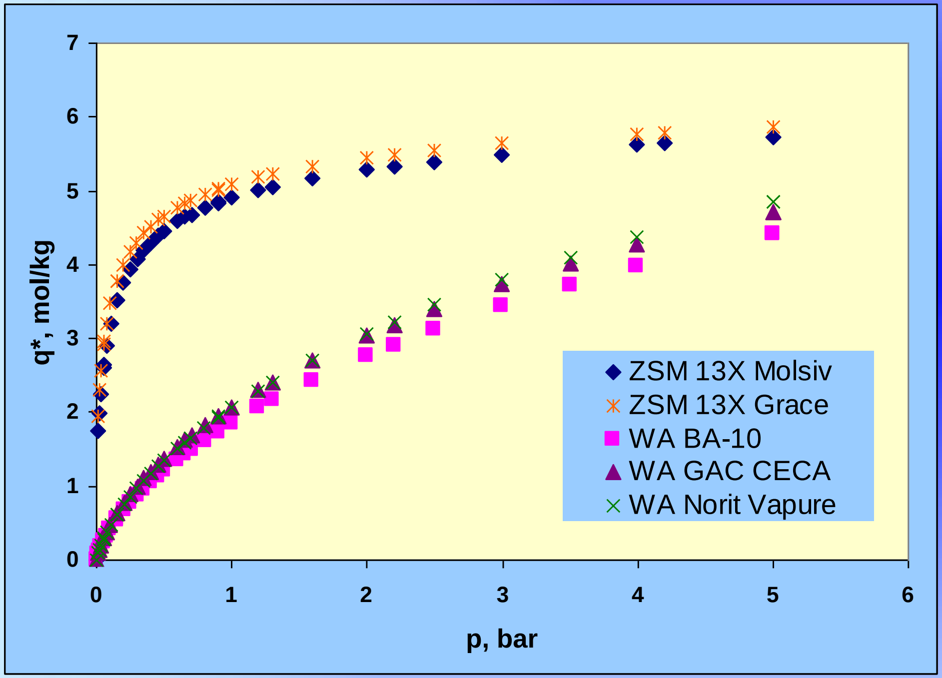
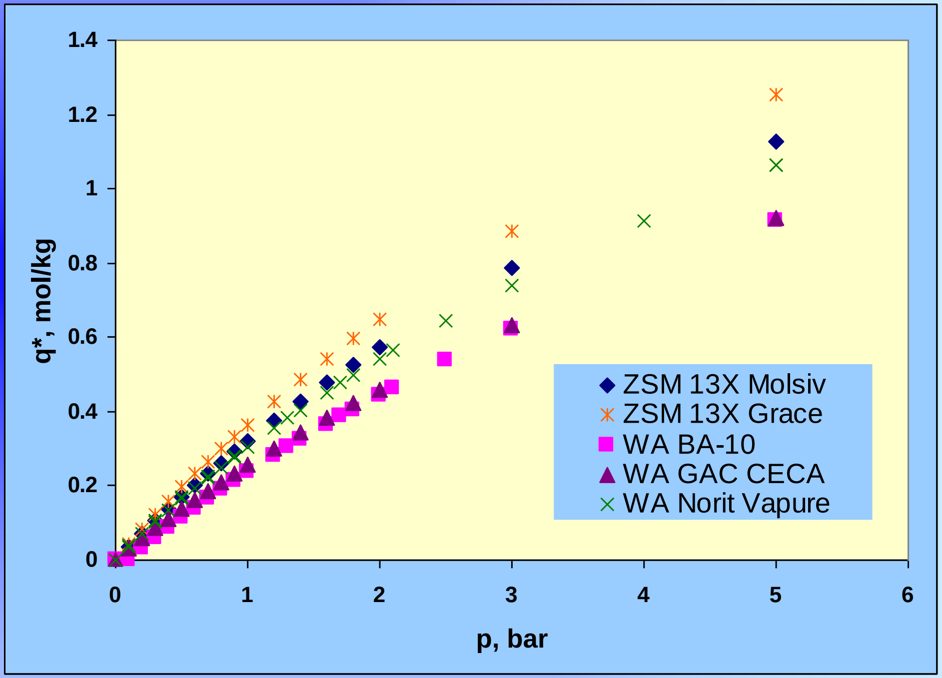
Representative adsorption isotherms for CO_2 and N_2 at 20°C





CARBON DIOXIDE

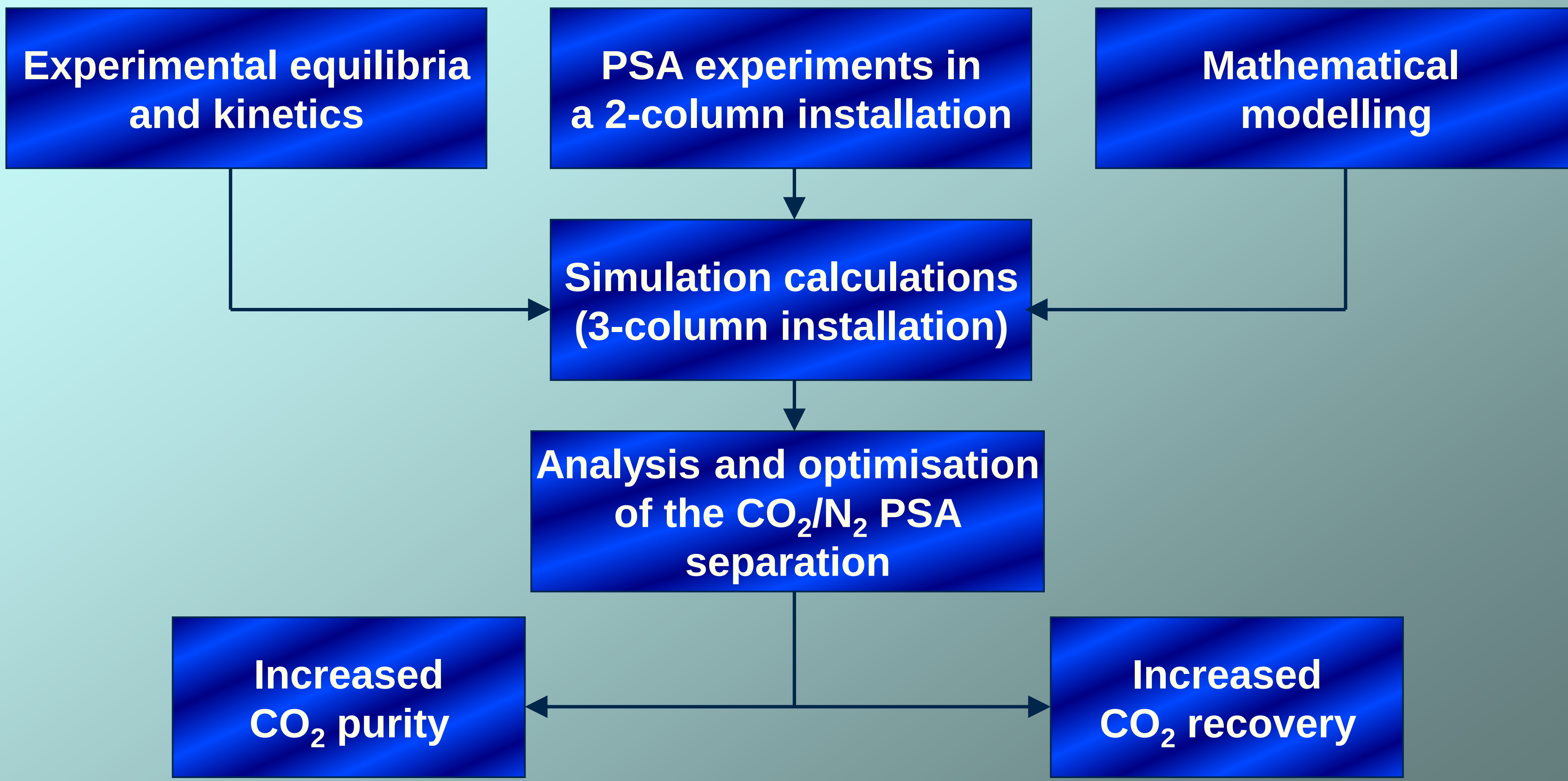
NITROGEN

Adsorbent selected: ZMS 13X (Grace)

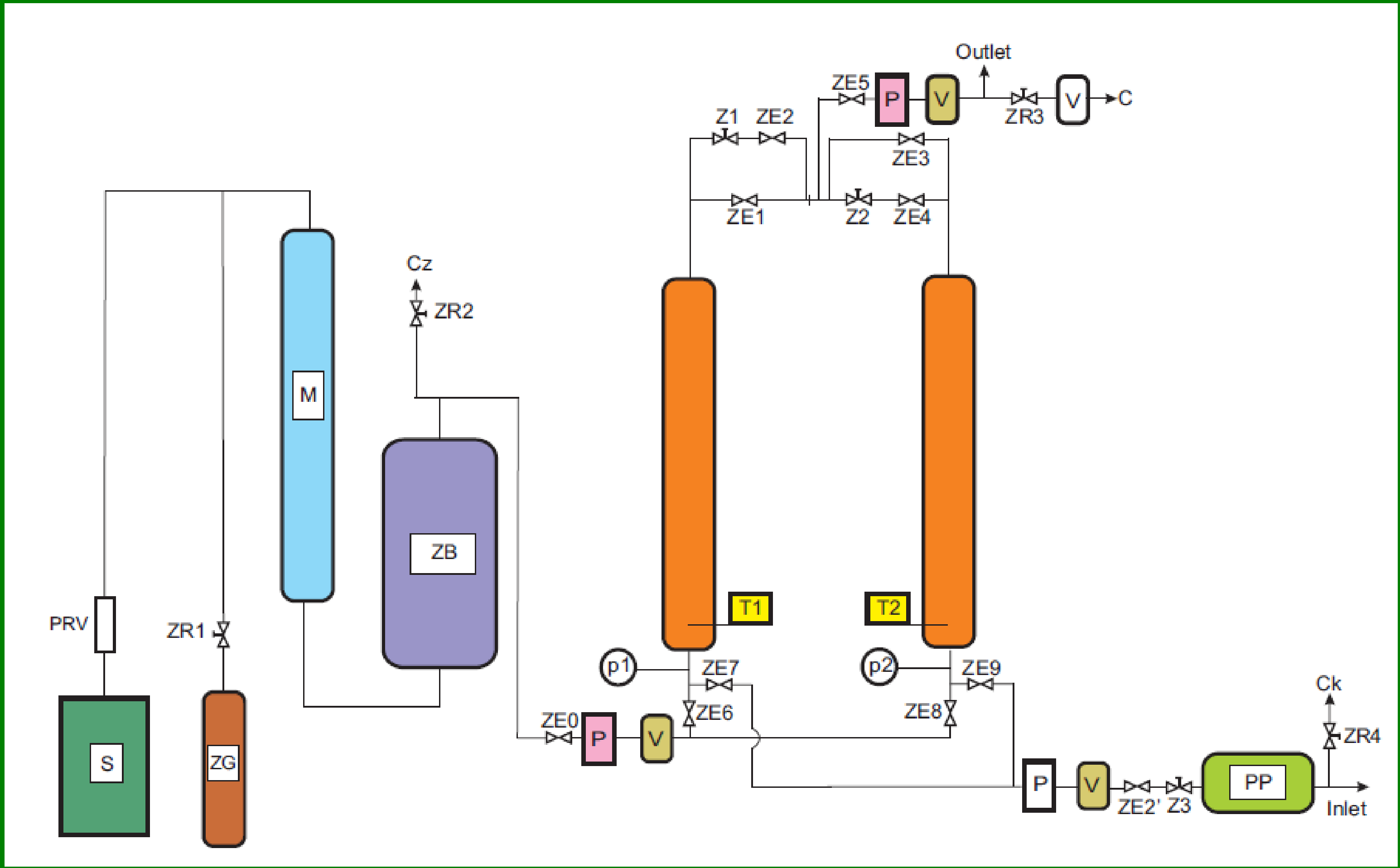
Kinetic constants for CO_2 and N_2 over the adsorbent selected

Gas	D/r^2, s^{-1}			
	20°C	40°C	60°C	80°C
CO_2	$9.06 \cdot 10^{-4}$	$1.07 \cdot 10^{-3}$	$1.33 \cdot 10^{-3}$	$1.59 \cdot 10^{-3}$
N_2	$4.08 \cdot 10^{-3}$	$4.79 \cdot 10^{-3}$	$4.65 \cdot 10^{-3}$	$4.86 \cdot 10^{-3}$

Development of an efficient PSA cycle



Experimental PSA installation



Basic assumptions of the model

- thermal equilibrium between the gas and the solid phase
- plug flow with axial dispersion
- negligible pressure drop over the adsorbent
- the fluid phase is an ideal gas

PSA cycle in the 3-column installation

Stage \ Column	1			2			3		
1	F↑			D↑	Pu↑		D↓	R↓	P↓
2	D↓	R↓	P↓	F↑			D↑	Pu↑	
3	D↑	Pu↑		D↓	R↓	P↓	F↑		

F – feed, D – depressurisation, P – pressurisation
Pu – purge, R – vacuum regeneration
↑ – cocurrent flow, ↓ – countercurrent flow

Feed

- 15% CO_2, 85% N_2

Improved process conditions

- optimised flow rates during purge and vacuum regeneration

Results

- CO_2 recovery close to 100%
- CO_2 purity in excess of 80%

Conclusions

The improved PSA process can enrich the 15/85 CO_2/N_2 mixture to a level of over 80% of CO_2, with an almost complete recovery of this species. Such efficiency can be achieved by a suitable selection of flow rates during purge with the enriched gas and vacuum regeneration.

Thank you