IFP : a research and industrial development and training center

Active in the fields of :

- oil, gas and coal, their uses, in particular in transport,
- the new energy and environmental technologies

IFP's staff : 1,125 researchers
239 doctoral and post doctoral researchers

An applied research : a portfolio of more than 12,000 living patents

A policy of commercial development of the results through the licensing of processes, software, equipment, etc.

In refining-petrochemicals

Objectives are :

- to design refining and petrochemical processes that are clean and efficient
- to diversify sources of energy for the production of fuels and hydrogen
- to control emissions of CO_2

Skill areas :

catalysis, separation technologies, analysis and physico-chemical characterization, thermodynamics, chemical engineering, modeling of processes, molecular modeling, high-flow tests and experiments

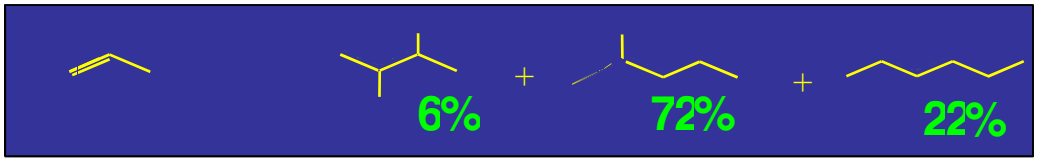
1,800 industrial units worldwide

Recent achievements :

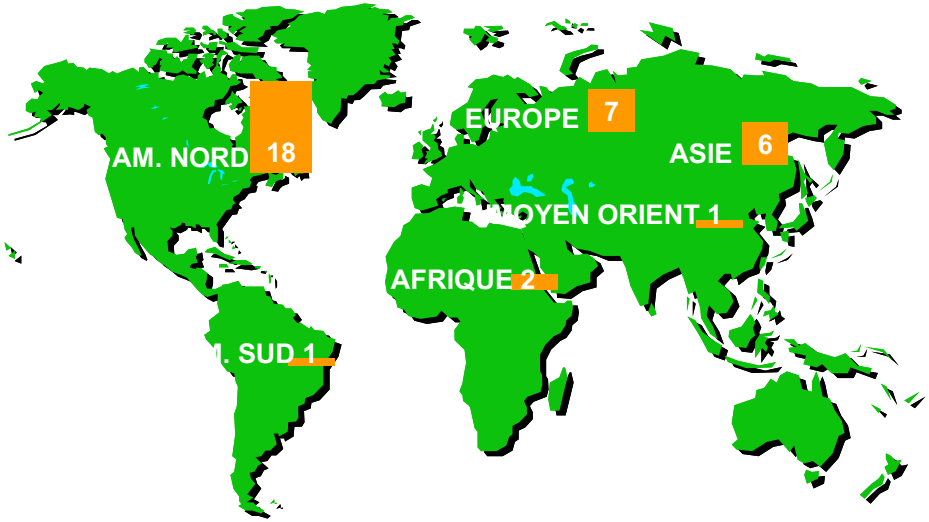
Esterfip-H: biodiesel production process by transesterification of vegetable oils. Marketed by Axens.

Esterfip-H unit under construction in Sète, France.

Dimersol Process : for gasoline

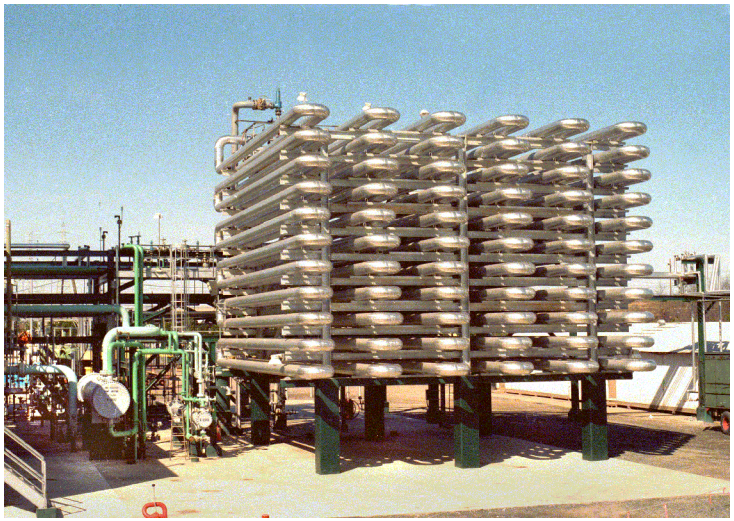


Dimerization of propylene into isohexenes : octane booster for gasoline

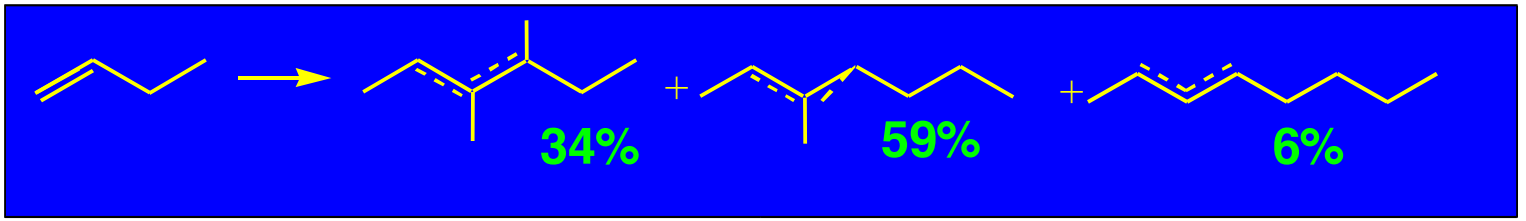


- One of the first examples of application of homogeneous catalysis in refining industry

- First industrial unit in 1977
- 35 units in operation worldwide
- 3.5 Mt products / year



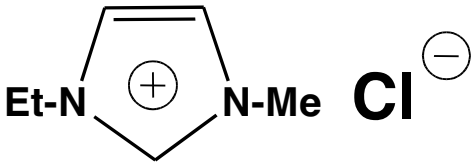
Dimersol Process : for chemistry



Dimerization of butenes into octenes : raw materials for the production of PVC phthalate plasticizers

- **First industrial unit in 1980**
- **0.4 Mt products / year**

Non-Aqueous Ionic Liquids



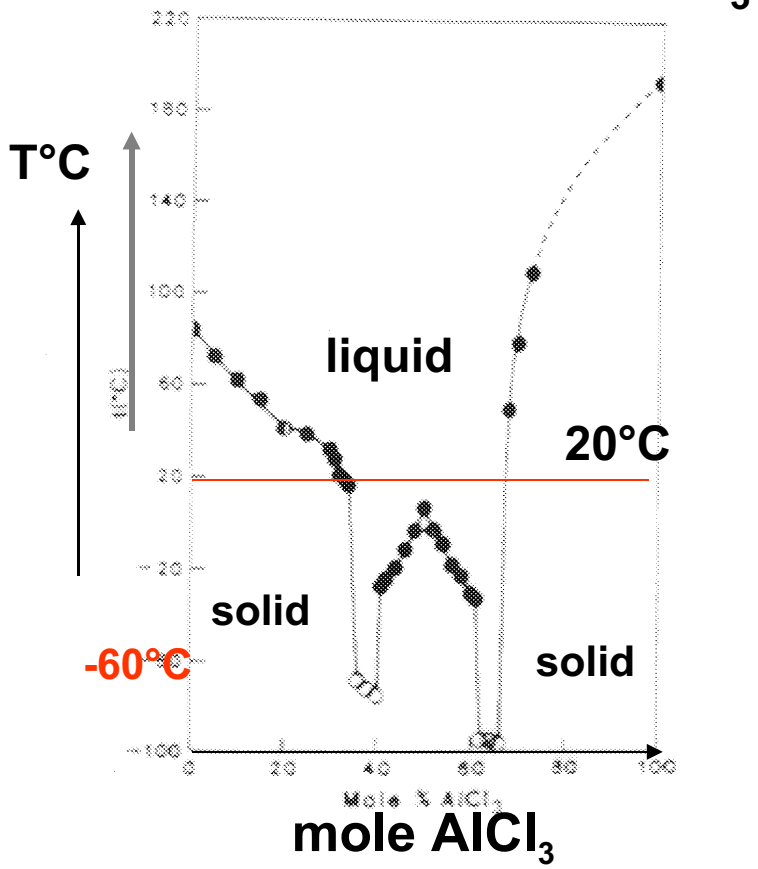
EMIC

Ethyl Methyl Imidazolium Chlorure

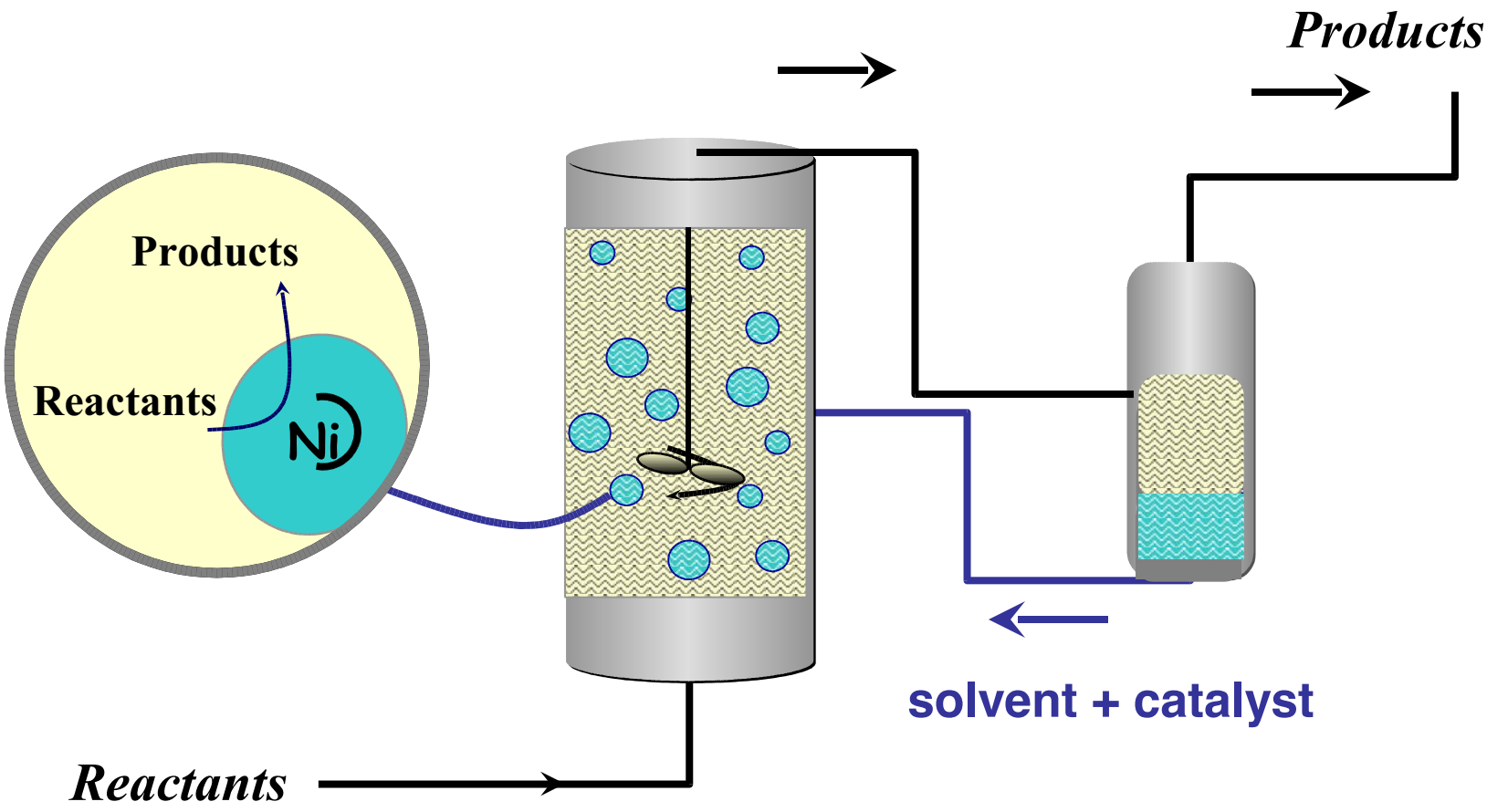
From non aqueous electrolytes for batteries

...to a new class of solvents for catalysis

Diagramme de phases



Liquid-Liquid Biphasic Catalysis



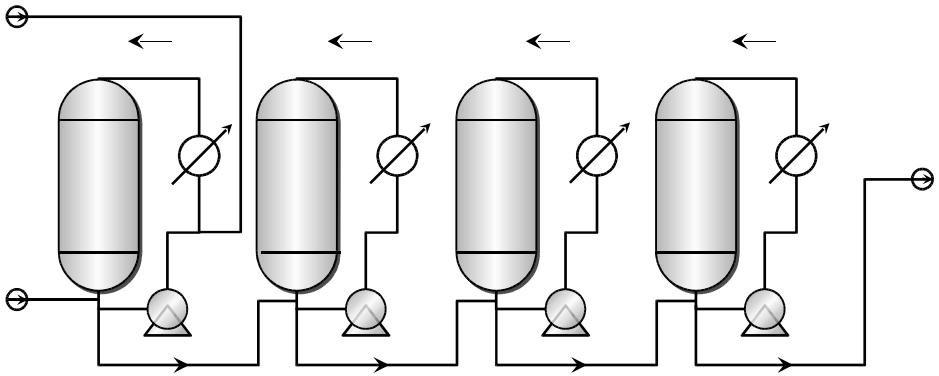
Dimersol process

4 reactors of 120 m³

Catalyst

20t/h feed rate

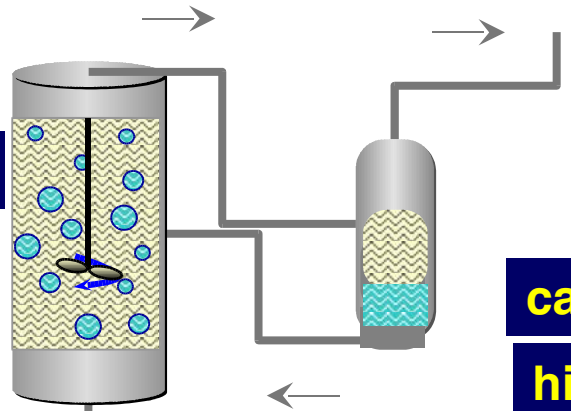
Butenes



toward washing and distillation section

Difasol process

reactor of 50 m³



Products

toward distillation section

catalyst consumption divided by 10

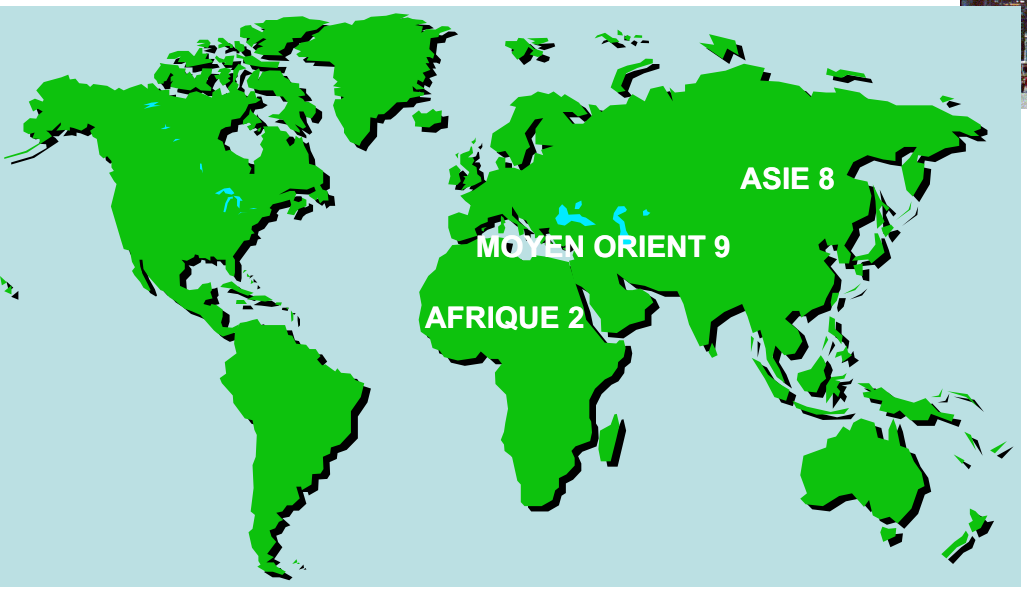
higher yield in dimers

Reactants

Active Phase containing the catalyst

Alphabutol process

- Dimerization of ethylene into 1-butene (Ti homogeneous catalyst)
- 1-Butene is used as co-monomer for polyethylene manufacture

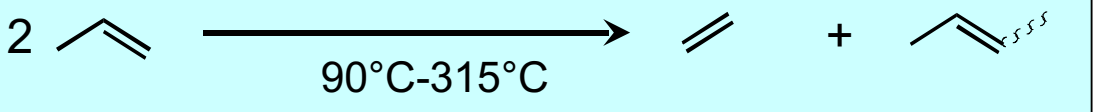


- First industrial unit in 1987
- 20 units in operation
- 0.4 Mt/Y

- 2005 : 3 new units 110 000t/Y total capacity

Heterogeneous catalysis...

$M(CO)_6/Al_2O_3$ (**M** = **Mo**, **W**)

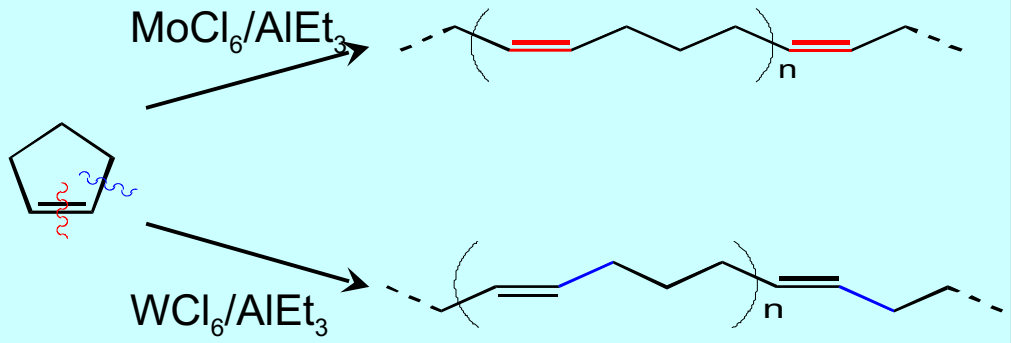


Propylene — Ethylene — 2-Butene (*trans* et *cis*)

Banks et Bailey (Philips Petroleum Co.)
I. & E. C. Product Research and Development
1964, *3*, 170-173.

1964 :
a magic year...

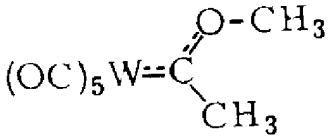
Homogeneous catalysis



G. Natta *Angew. Chem. Int. Ed. Engl.* **1964**, *3*, 723

Metallocarbene

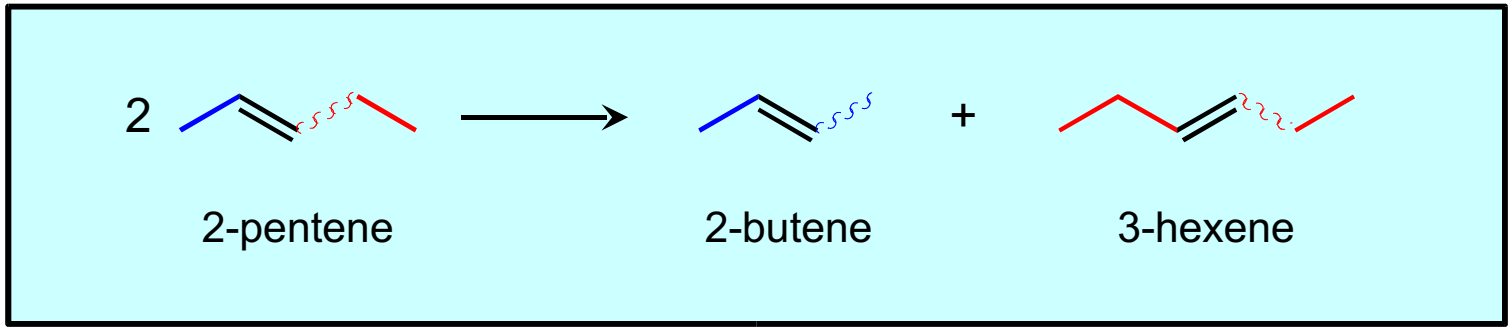
Wir glauben daher für $W(CO)_5(COCH_3)(CH_3)$ eine Struktur folgender Art annehmen zu dürfen.

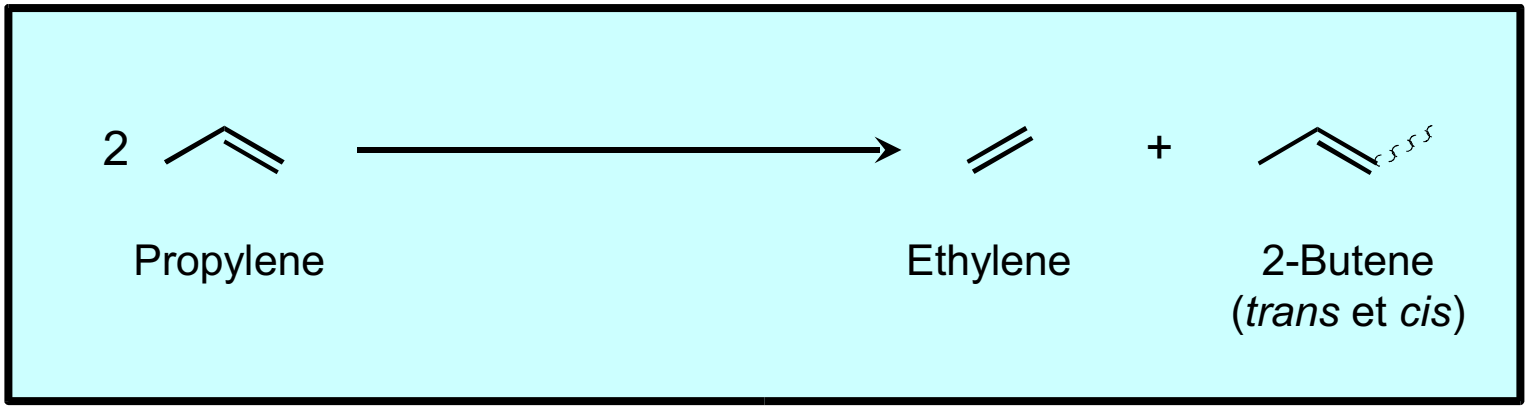


E. O. Fischer *Angew. Chemie* **1964**, *76*, 645

a new metal–carbon bond

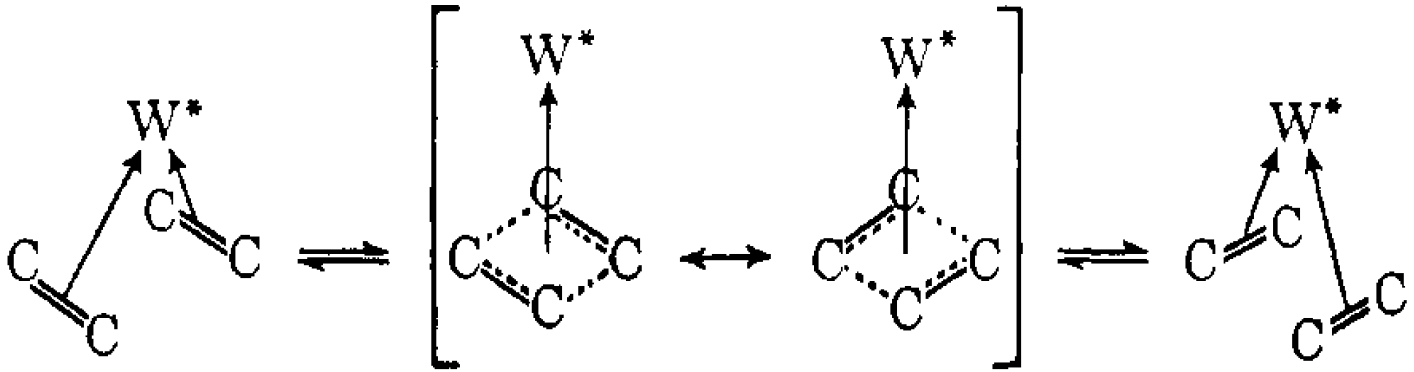
Disproportionation of olefins





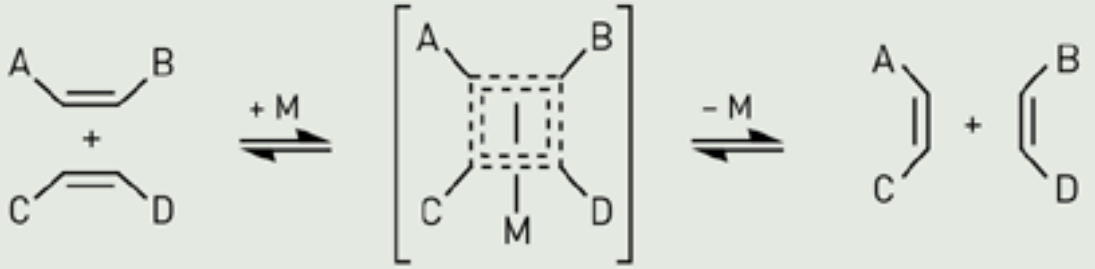
"Pairwise" mechanism

Transalkylidenation

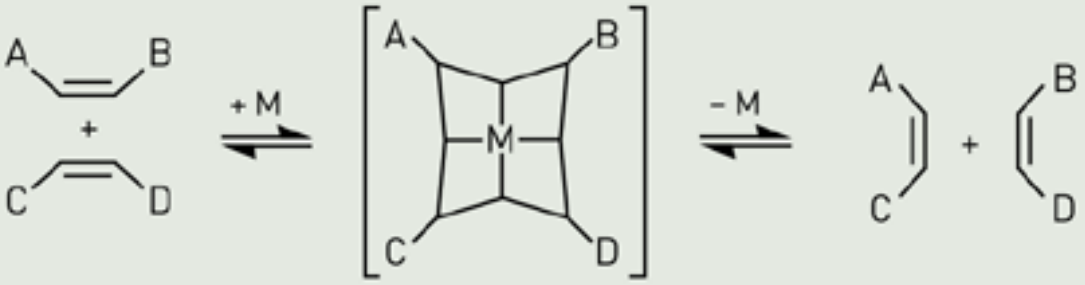


WRONG TURNS

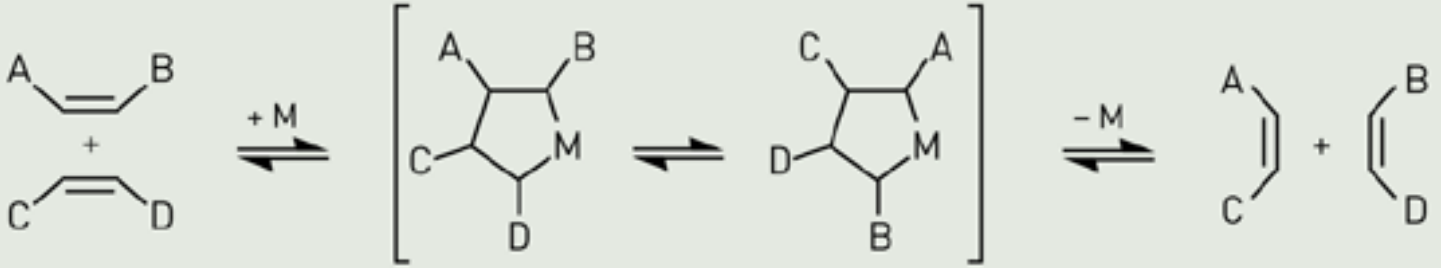
Unusual intermediates proposed initially have since been rejected



Cyclobutane intermediate



Tetramethylene complex

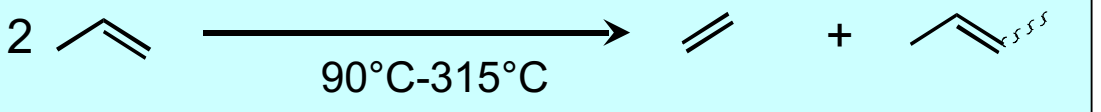


M = metal

Rearranging metallacyclopentane

Heterogeneous catalysis...

$M(CO)_6/Al_2O_3$ (**M** = **Mo**, **W**)



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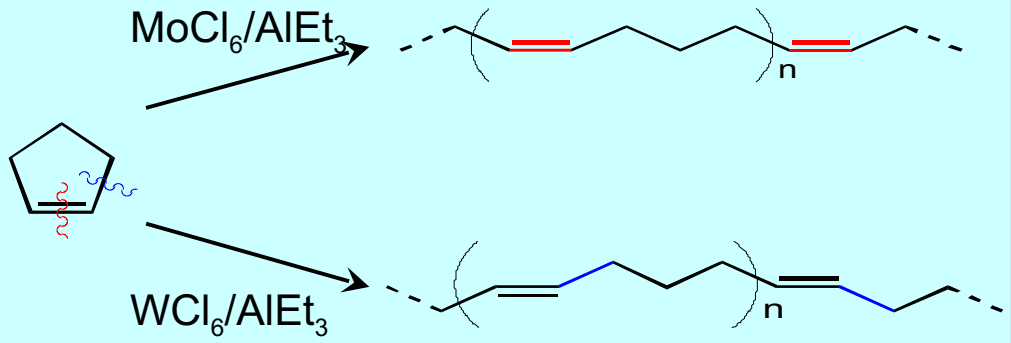

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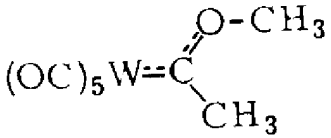
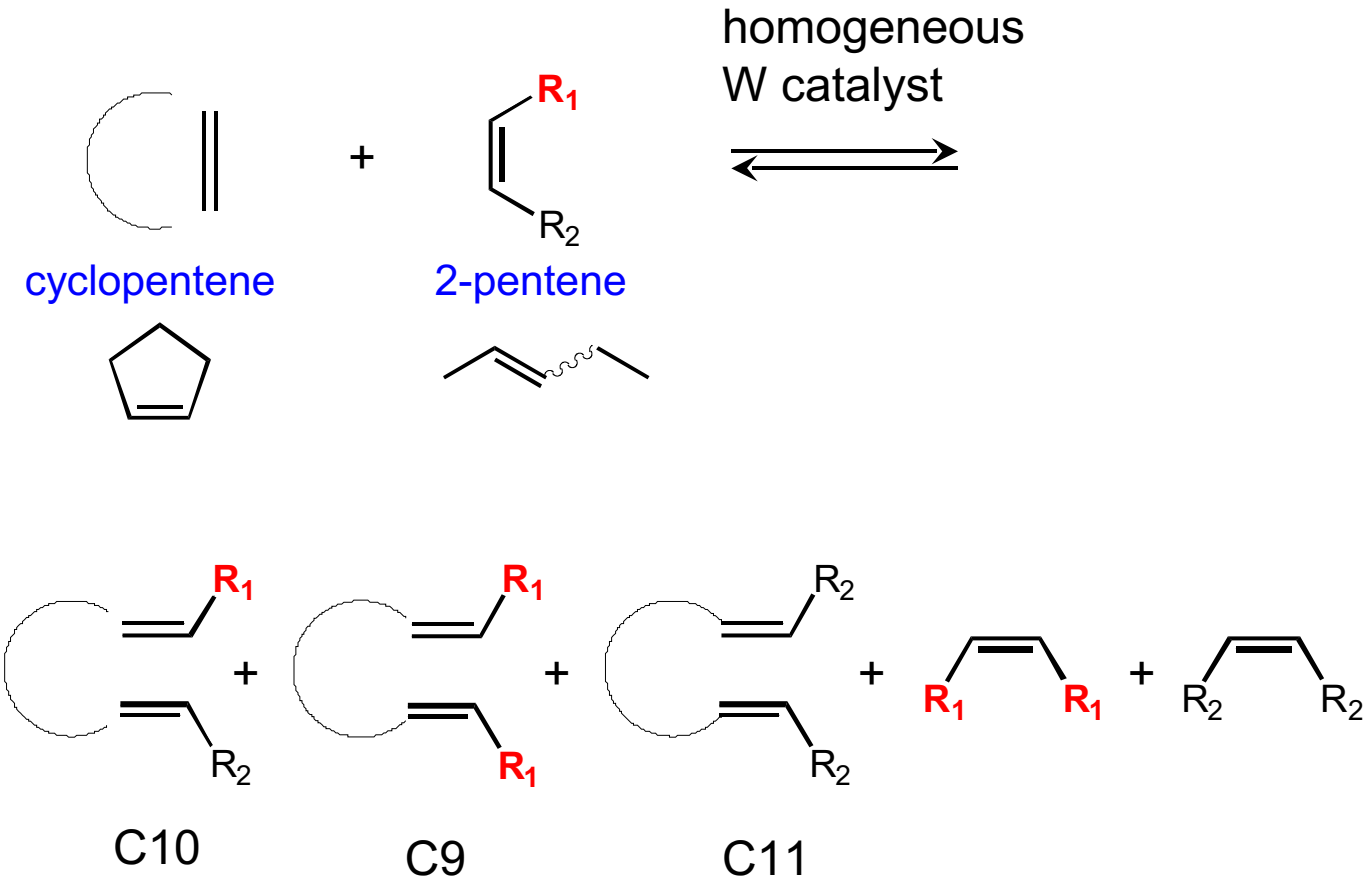


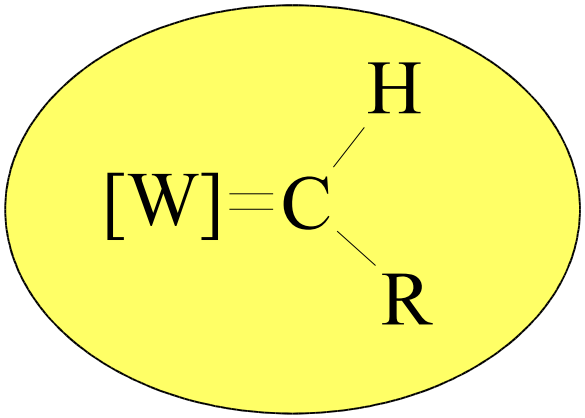
E. O. Fischer *Angew. Chemie* **1964**, *76*, 645

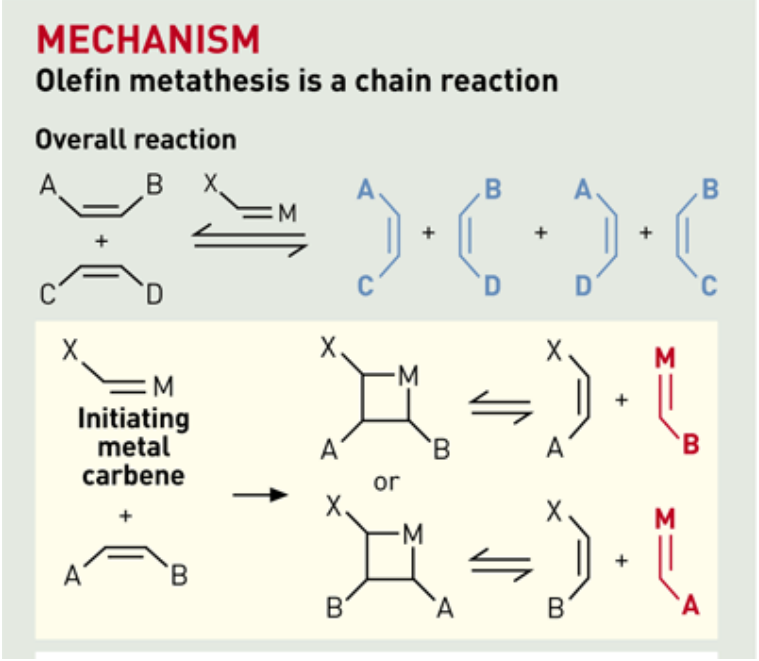
a new metal–carbon bond

Co-reaction of cyclopentene with 2-pentene



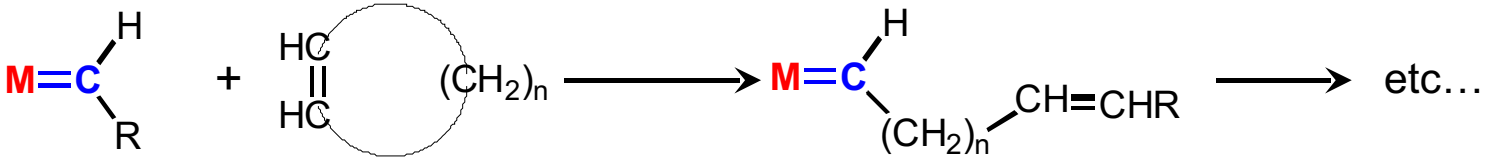
Hérisson et Chauvin *Die Makromolekular Chemie* **1971**, *141*, 161-176.





Carbene mechanism

Linear polymers with high molecular weight : observed at the beginning of the reaction



Formation of the metallocarbene : $WCl_6 + Sn(CH_3)_n$

TABLEAU

Produits de réaction entre $W(Cl)_6$, $M(CH_3)_n$ *et une oléfine*

Oléfine	$W(Cl)_6$ (g)	Coréactif (**)	Solvant	T (°C)	Oléfine / $W(Cl)_6$	% molaires par rapport au tungstène mis en œuvre : Méthane + éthane	Propylène	Butène-1
Butène-2	0,5	$LiCH_3$	Benzène (15 ml)	4	10	22	6,3	–
Butène-2	0,5	$Sn(CH_3)_4$	Benzène (15 ml)	4	10	3,5	3,6	–
Hexène-3	0,2	$Sn(CH_3)_4$	Benzène (30 ml)	4	10	n. d.	–	2,6
Pentène-2 (*) ...	0,5	$LiCH_3$	Benzène (15 ml)	4	10	22	4,4	4,7
	0,2	$Sn(CH_3)_4$	Benzène (30 ml)	4	10	10	9,6	10,4
	0,2	$Sn(CH_3)_4$	Chloro-benzène (30 ml)	—20	10	n. d.	8,5	6,4
	0,4	$Sn(CH_3)_4$	Chloro-benzène (30 ml)	—20	2,5	n. d.	6,8	6,9

(*) On observe la formation de butène-2 et d'hexène-3 issus de la disproportion du pentène-2 en excès.

(**) Sn/W = 2; Li/W = 2.

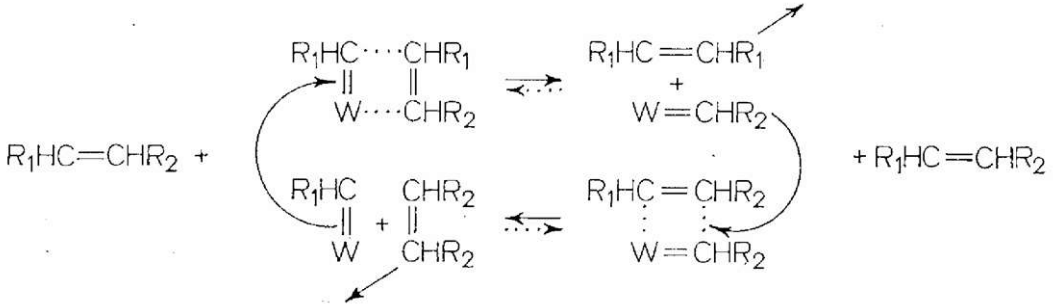
$[W]=CH_2$

$R_1CH=CHR_2$

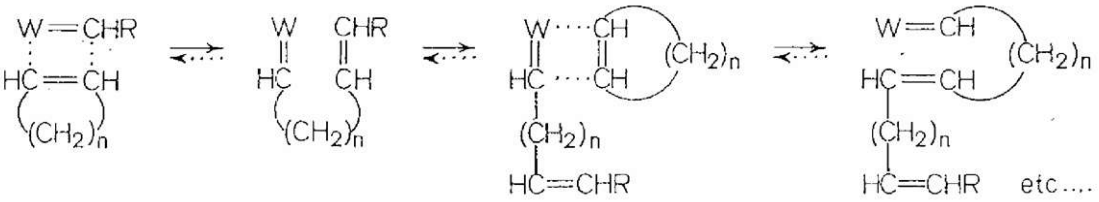
formation of α-olefins

Soufflet, Commereuc et Chauvin *C. R. Acad. Sc.* **1973**, *276*, 169-171

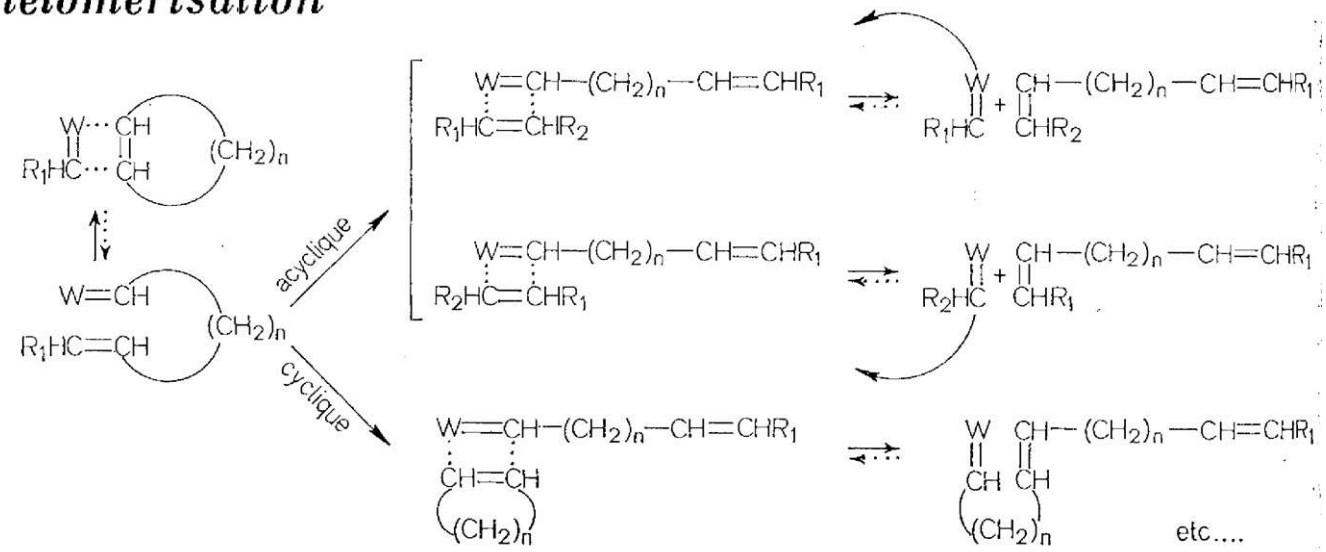
Réaction de disproportion



Réaction de polymérisation



Réaction de télomérisation



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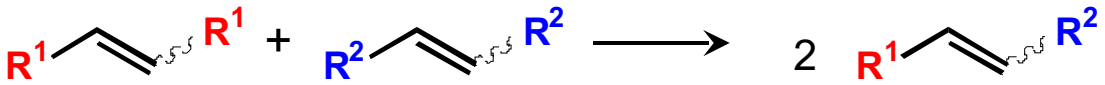
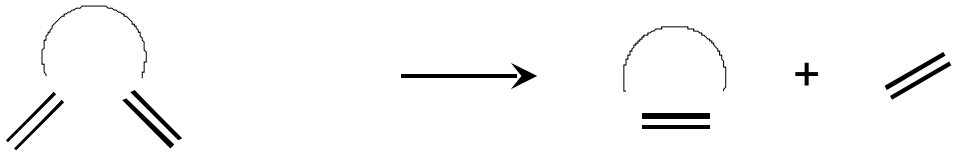
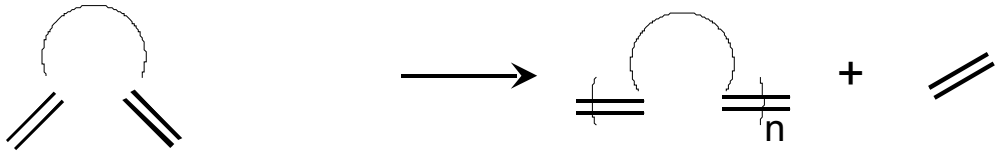
Cross Metathesis (CM)



Ring Closing Metathesis (RCM)



Acyclic Diene Polymerization (ADMET)



Ring Opening Metathesis (ROMP)