Bindersystems
for
HE-Charges

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Requirements for HE Bindersystems

- Phlegmatisation
- Wetting
- Mechanical properties
  - Low Young‘s Modulus with high elongation
- Long life stability
- Temperature resistent > 120°C

Binder for HE

Absorbents	HE	Product
Bentonite	NG	Dynamite
Kieselgur	NG	Dynamite
Rubber	NG	Dynamite
Charcoal	O_2liq.	Oxyliquit

Binder for HE

- Asphalt
- Bitumen
- Dextrin
- Flour
- Starch
- TNT

- Glue
- Gelatine
- Milk sugar
- Shellack
- Sugar
- Wax

PBX Formulation

80 - 90 %		RDX, HMX, AP, Al
10 - 20 %		HTPB (Resin)
0 - 10 %		IDP (Plasticizer)
1 - 2 %		IPDI (Curing agent)
0,05 - 0,2 %		bonding agent
10^{-4} - 10^{-2} %		Catalyst
0 - 0,5 %		Antioxydant
0 - 0,2 %		Lecithin

Viscosity	500 - 1500 [Pas]
Density	1,6 - 1,7 [g/cm^3]

Binder Systems

- **Type of binder**
- **Antioxidans**
- **Plasticizer**
- **Bonding agent**

Mechanical

Properties

Aging behaviour

Binder Desensitizing Factors

- Wettability of and Adhesion to the Explosive
- Elasticity
- Heat Capacity
- Heat of Fusion
- Heat of Vaporisation
- Decomposition Products (Quenchers)
- Reaction with any initial Explosive

  Decomposition Products (also as Quenchers)

Specification Raw Materials

Plasticizer:

- Moisture
- Free Hydroxyl and Carboxyl
- Species
- Impurities

Curing Agents:

- Moisture
- Impurities
- Homopolymers
- Differences in Reactivity

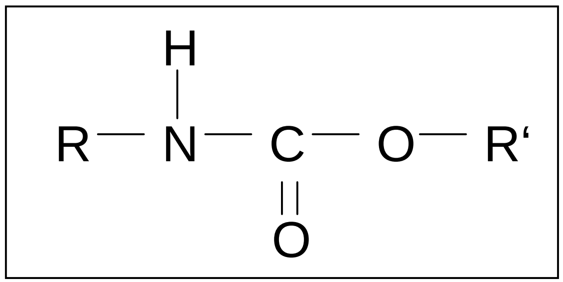
Catalysts:

- Reactivity
- Physical Properties
- Impurities
- Moisture

Urethane Reaction

$$R - NCO \quad + \quad R' - OH \longrightarrow$$

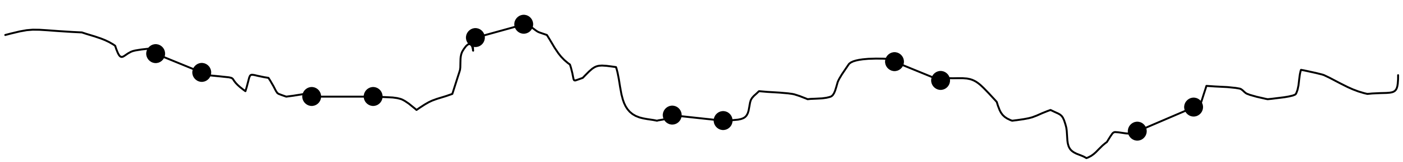
Isocyanate — Alcohol



Urethane

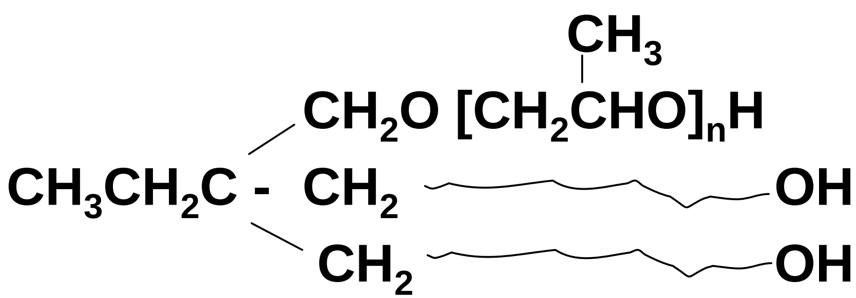
Requirements

Bifunctional molecules

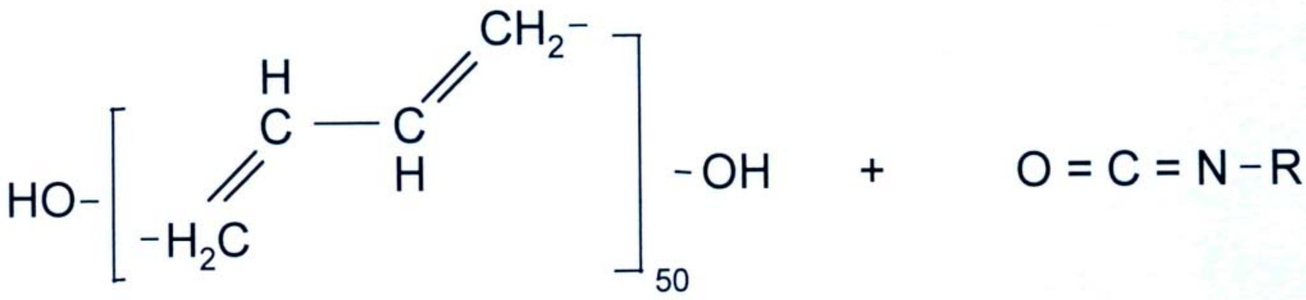


Polyoles

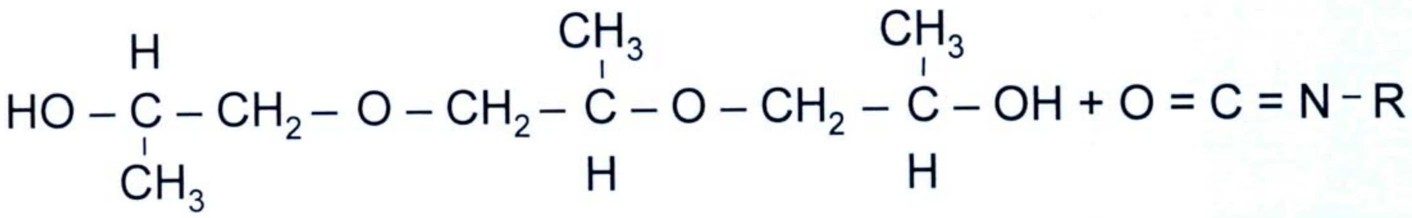
$HO\,[CH_2CH_2O]_nH$	**Polyethylenglycole**
$HO\,[CH_2CH(CH_3)O]_nH$	**Polypropylenglycole**
$HO\,[(CH_2)_4O]_nH$	**Polytetramethylenglycole**



Binder Systems Polyurethanes

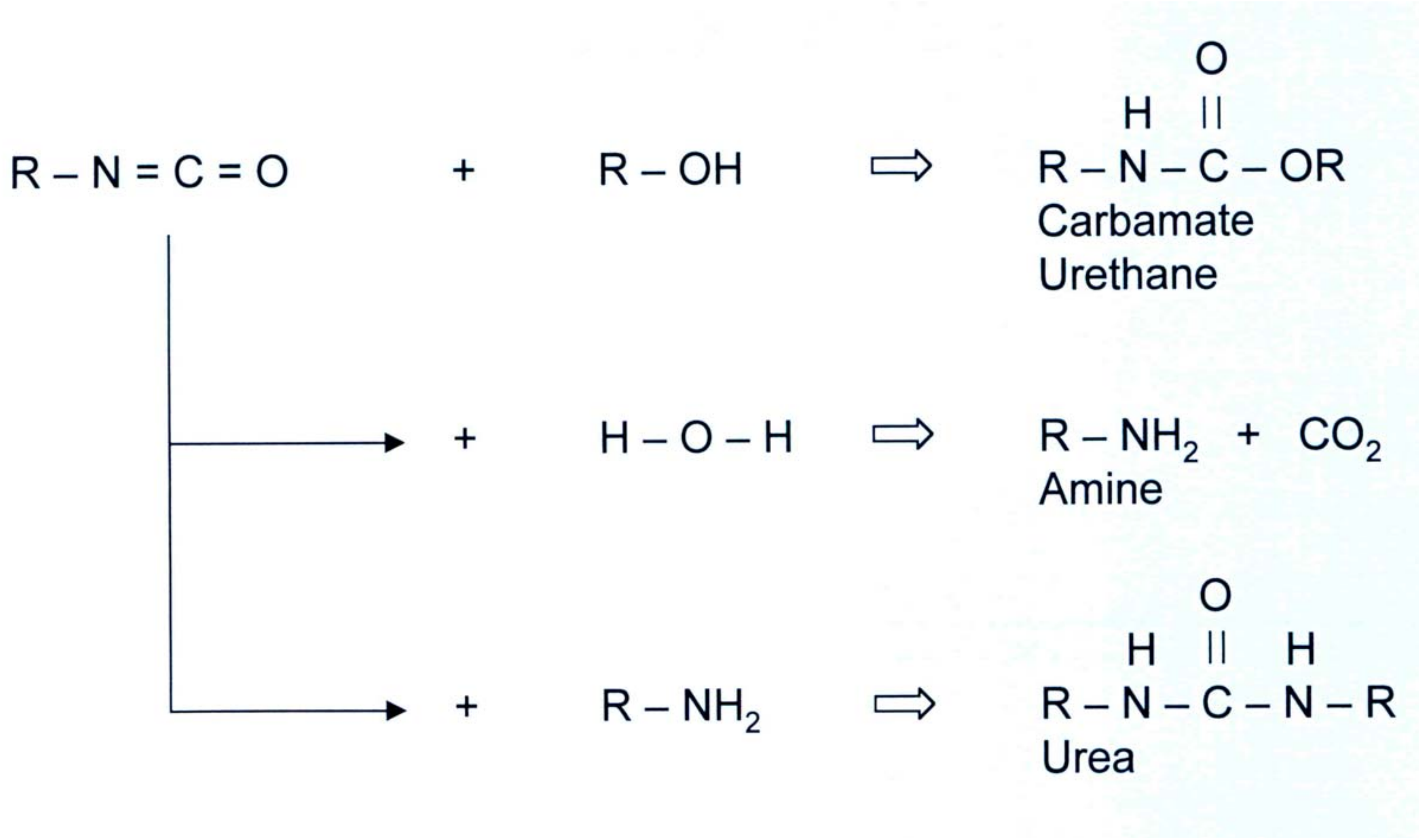


Polybutadiene



Polyether

Binder Systems Isocyanates Reactions



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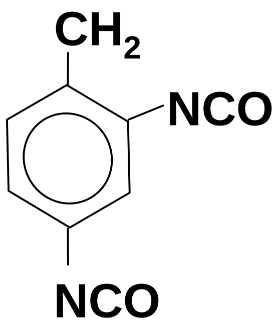
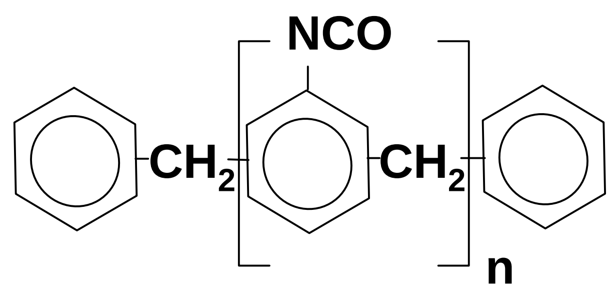
Isocyanates

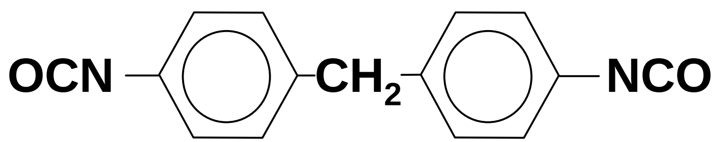


TDI



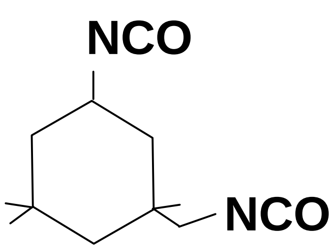
PAPI

End of chain: NCO

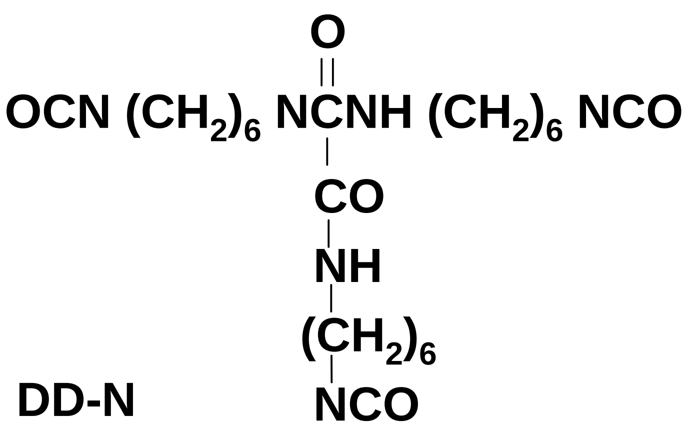


MDI

OCN $(CH_2)_6$ NCO HDI

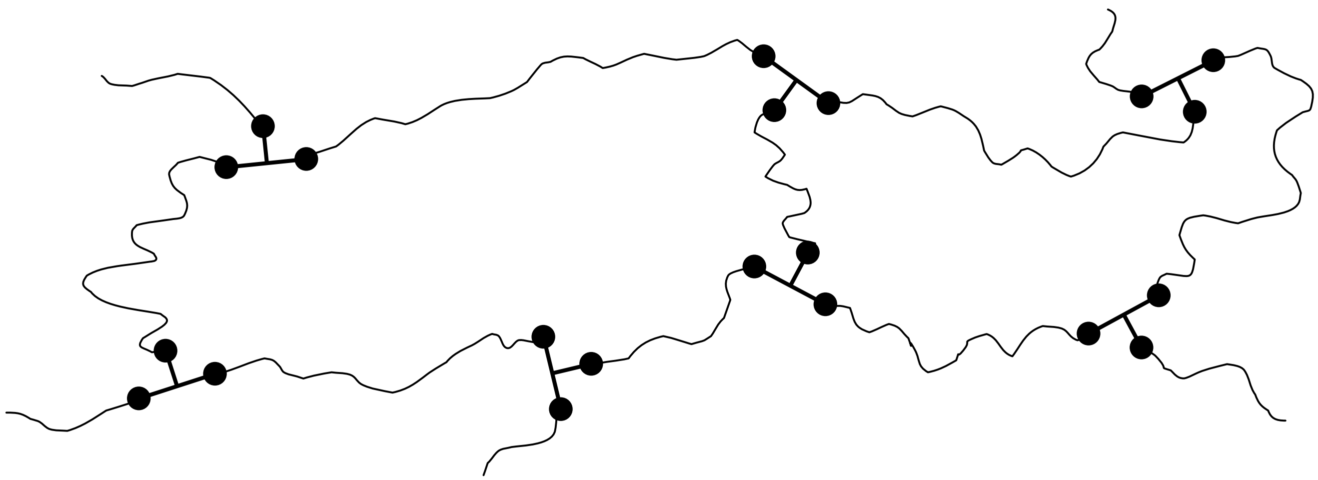


IPOI



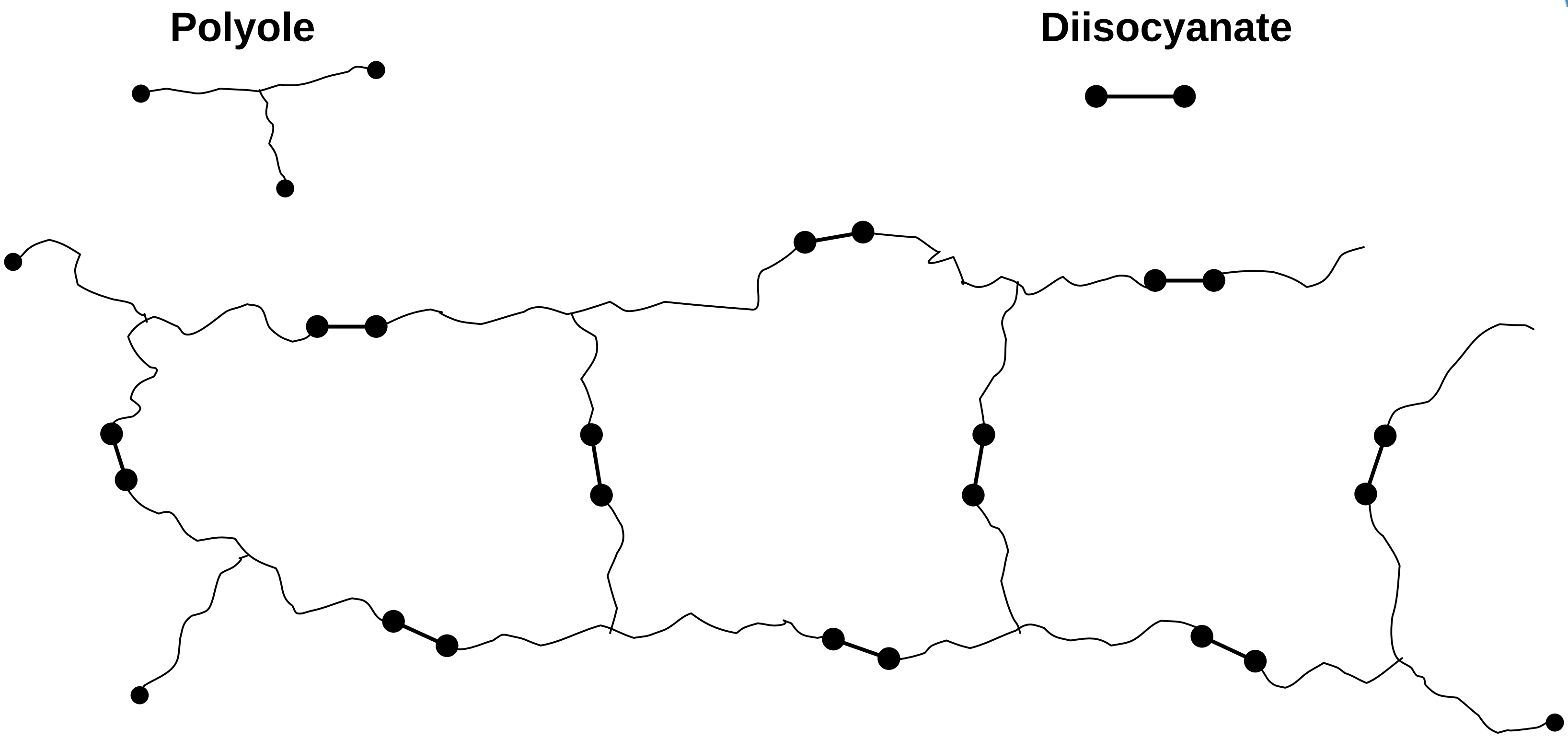
DD-N

Polyurethanes

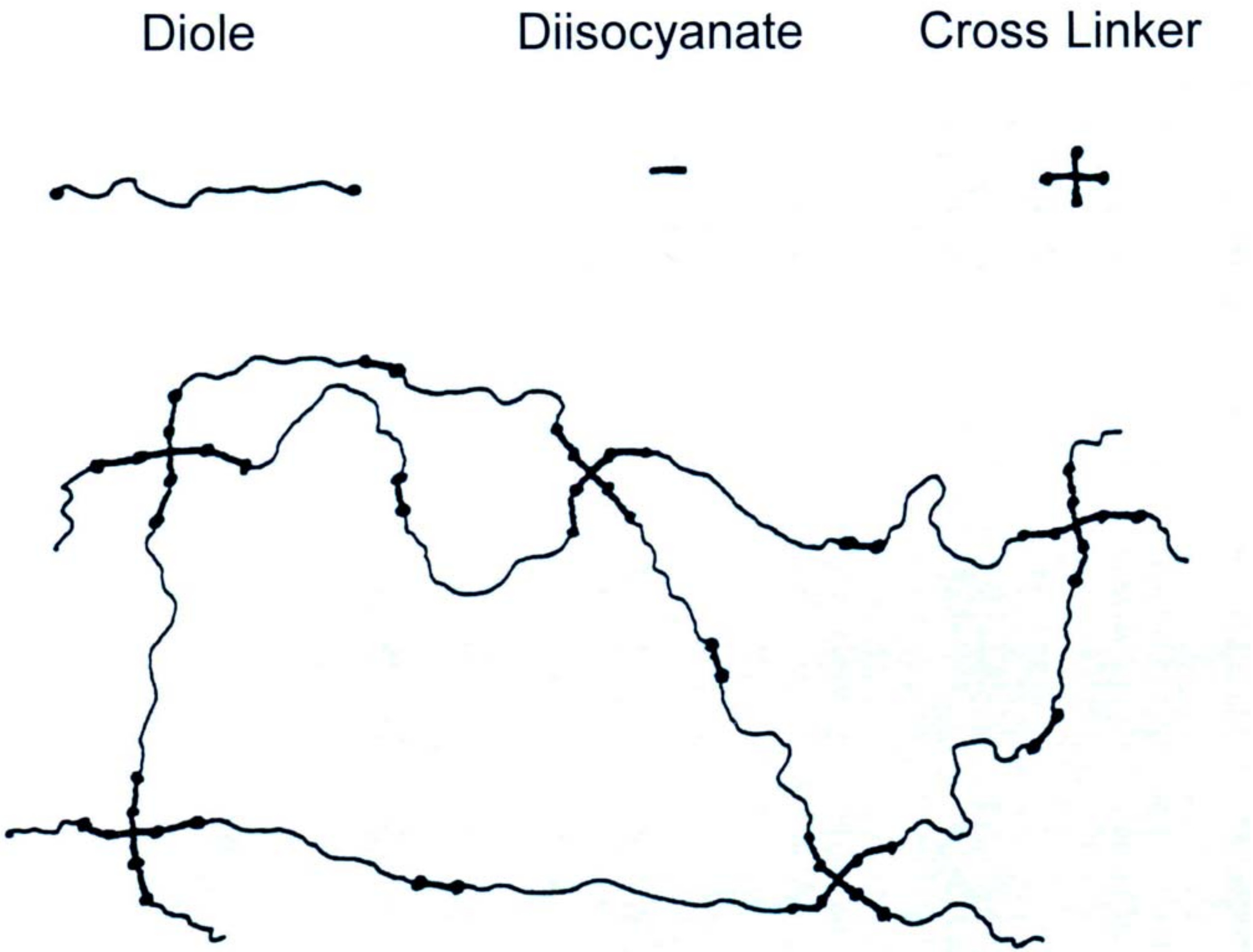


NCO/OH - Relation

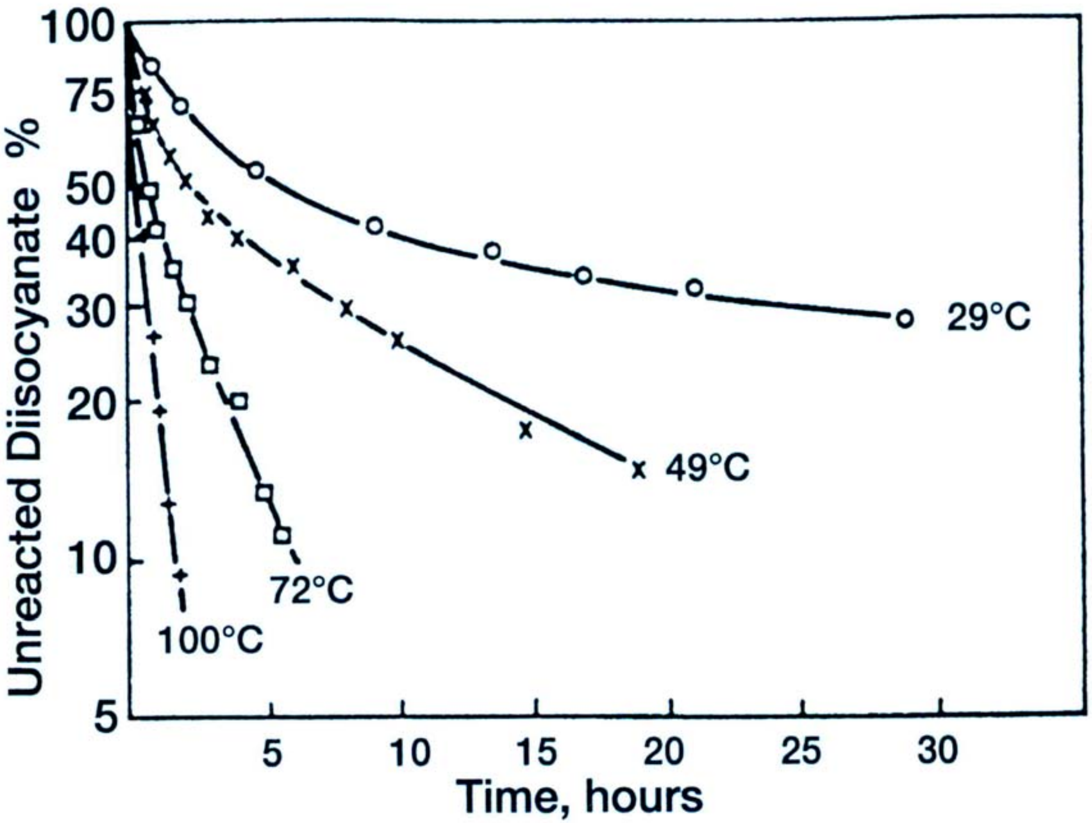
Polyurethanes



Polyurethanes

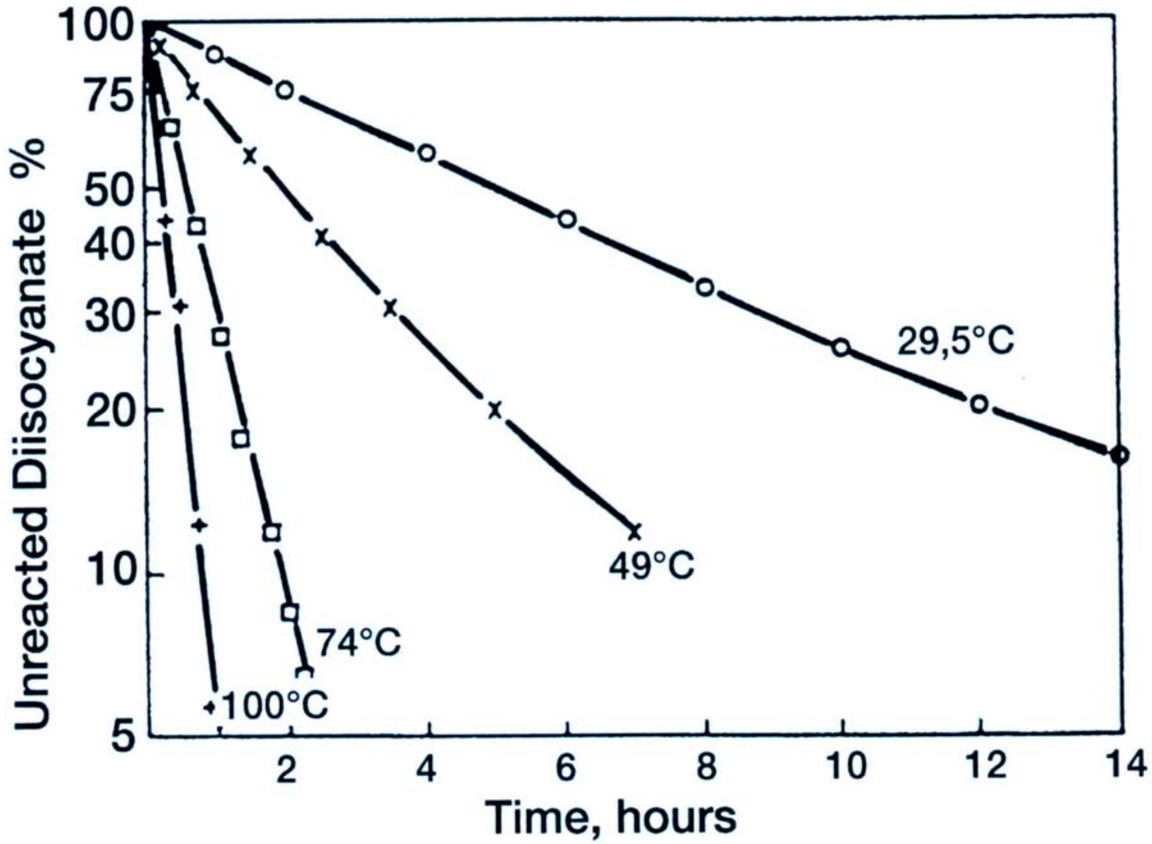


Kinetics and Catalysis of Reactions



Reaction of 2,4-tolylene diisocyanate
with diethylene glycol adipate polyester in chlorobenzene

Kinetics and Catalysis of Reactions

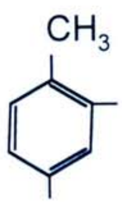
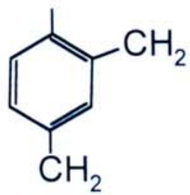


Reaction of 4,4-diphenylmethane diisocyanate
with diethylene glycol adipate polyester in chlorobenzene

Relative Reaction Rates of Three Different Diisocyanates

$$OCN-R-NCO + R'OH \xrightarrow{k_1} OCN-R-NH-CO_2R'$$

$$OCN-R-NH-CO_2R' + R'OH \xrightarrow{k_2} R'O_2C-NH-R-NH-CO_2R'$$

—R—	k_1	k_2
	400	33
	27	10
$-(CH_2)_6-$	1	0,5

Catalyst Tests with Three Different Isocyanates

	Gelation time (min.) at 70°C with:		
Compound tested	Tolylene diisocyanate	M-Xylylene diisocyanate	Hexamethylene diisocyanate
Blank	> 240	> 240	> 240
Triethylamine	120	> 240	> 240
Triethylenediamime	4	80	> 240
Stannous octoate	4	3	4
Dibutyltin di (2-ethylhexoate)	6	3	3
Lead 2-ethylhexoate (24% Pb)	2	1	2
Sodium o-phenylphenate	4	6	3
Potassium oleate	10	8	3
Bismuth nitrate	1	½	½
Tetra (e-ethylhexyl) titanete	5	2	2
Stannic chloride	3	½	½
Ferric chloride	6	½	½
Ferric 2-ethylhexoate (6% Fe)	16	5	4
Cobalt 2-ethylxoate (6% Co)	12	4	4
Zinc naphthenate (14,5 % Zn)	60	6	10
Antimony trichloride	13	3	6

Binder Systems Polyurethanes Catalyst Reactivity

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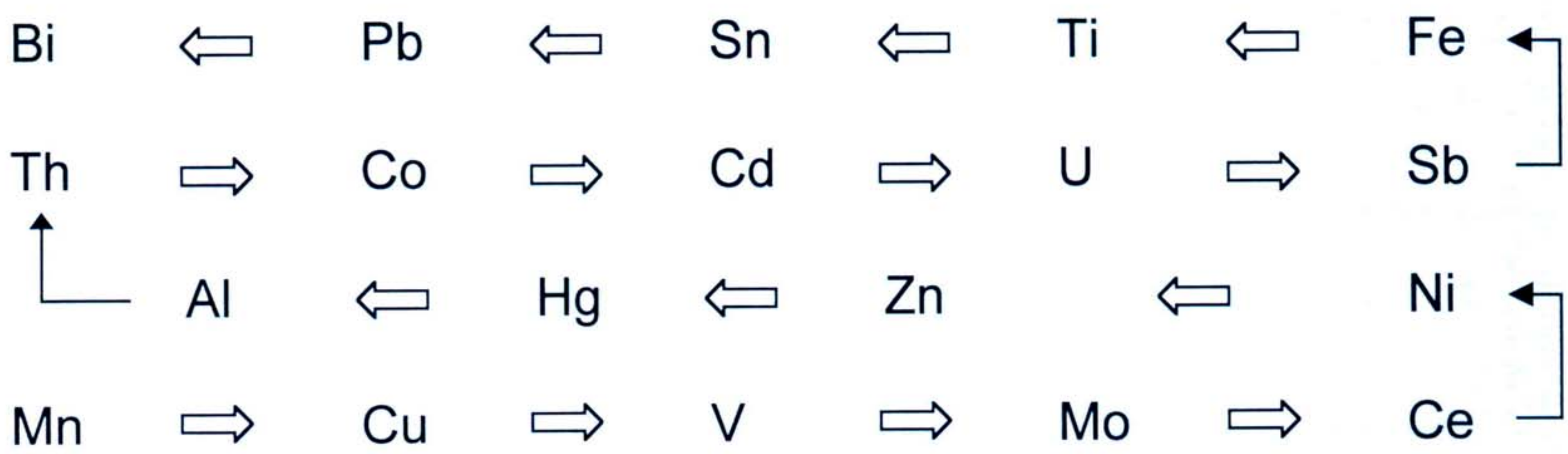
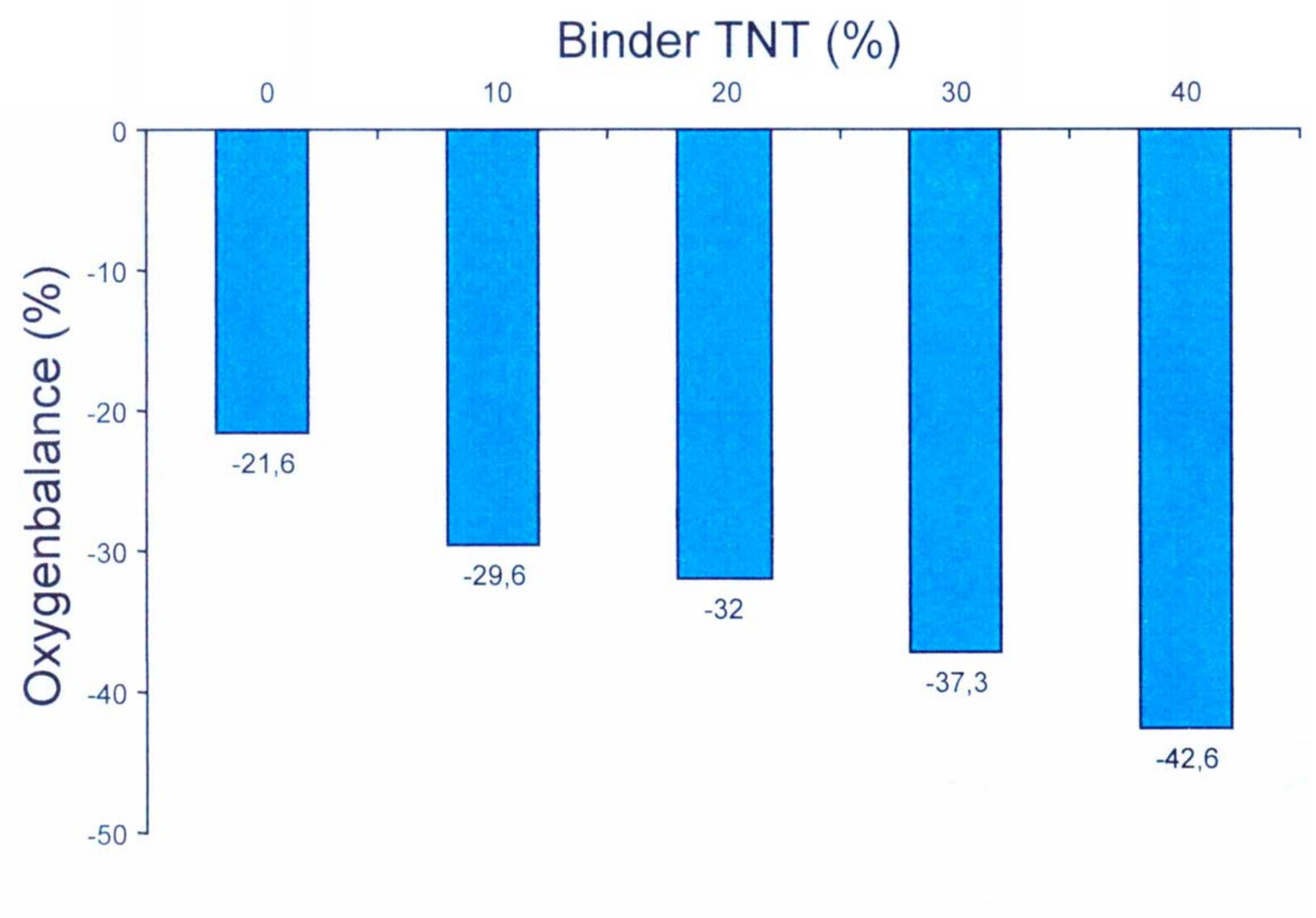


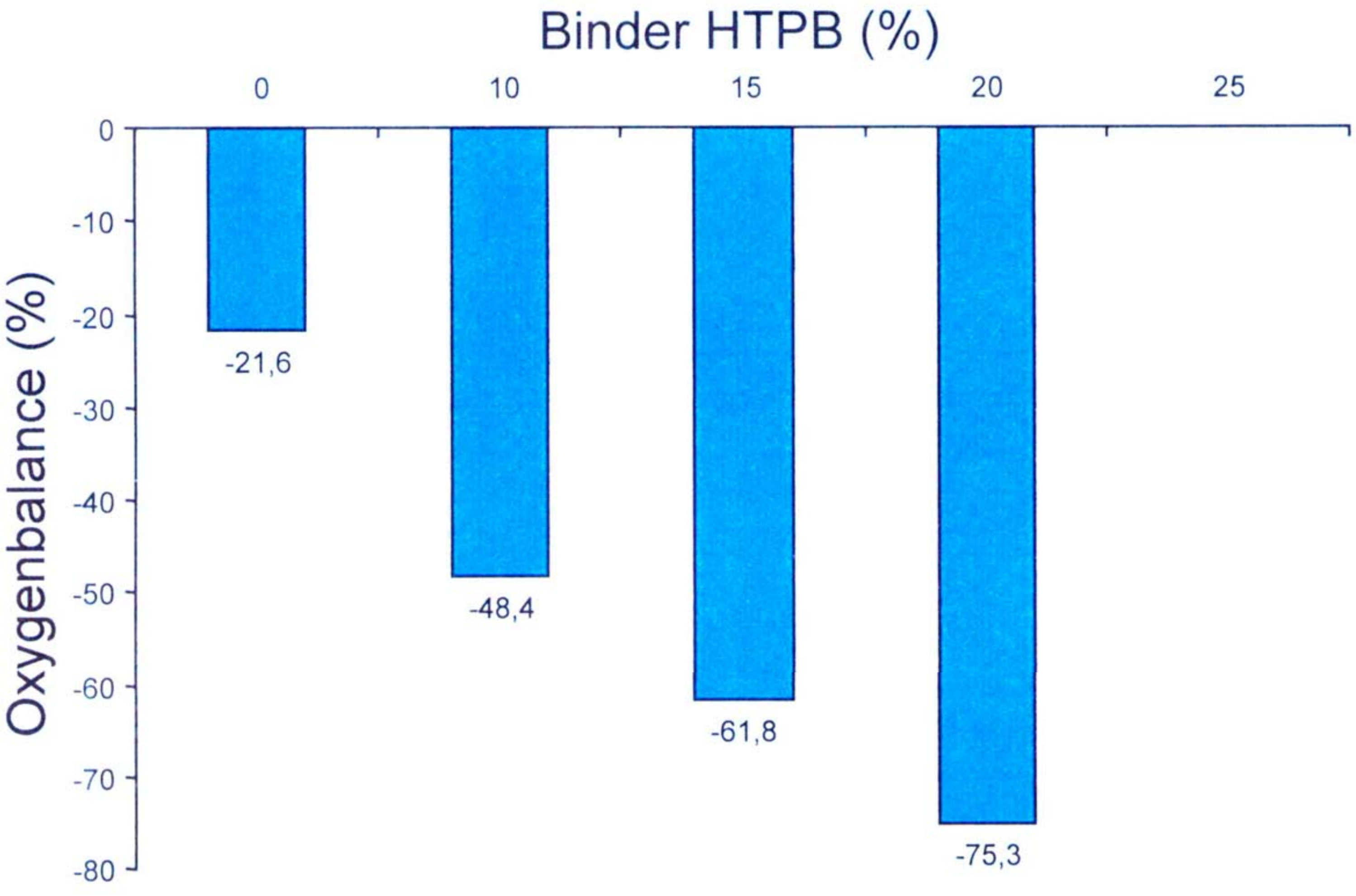
No catalytic activity

As, B, Ca, Ba

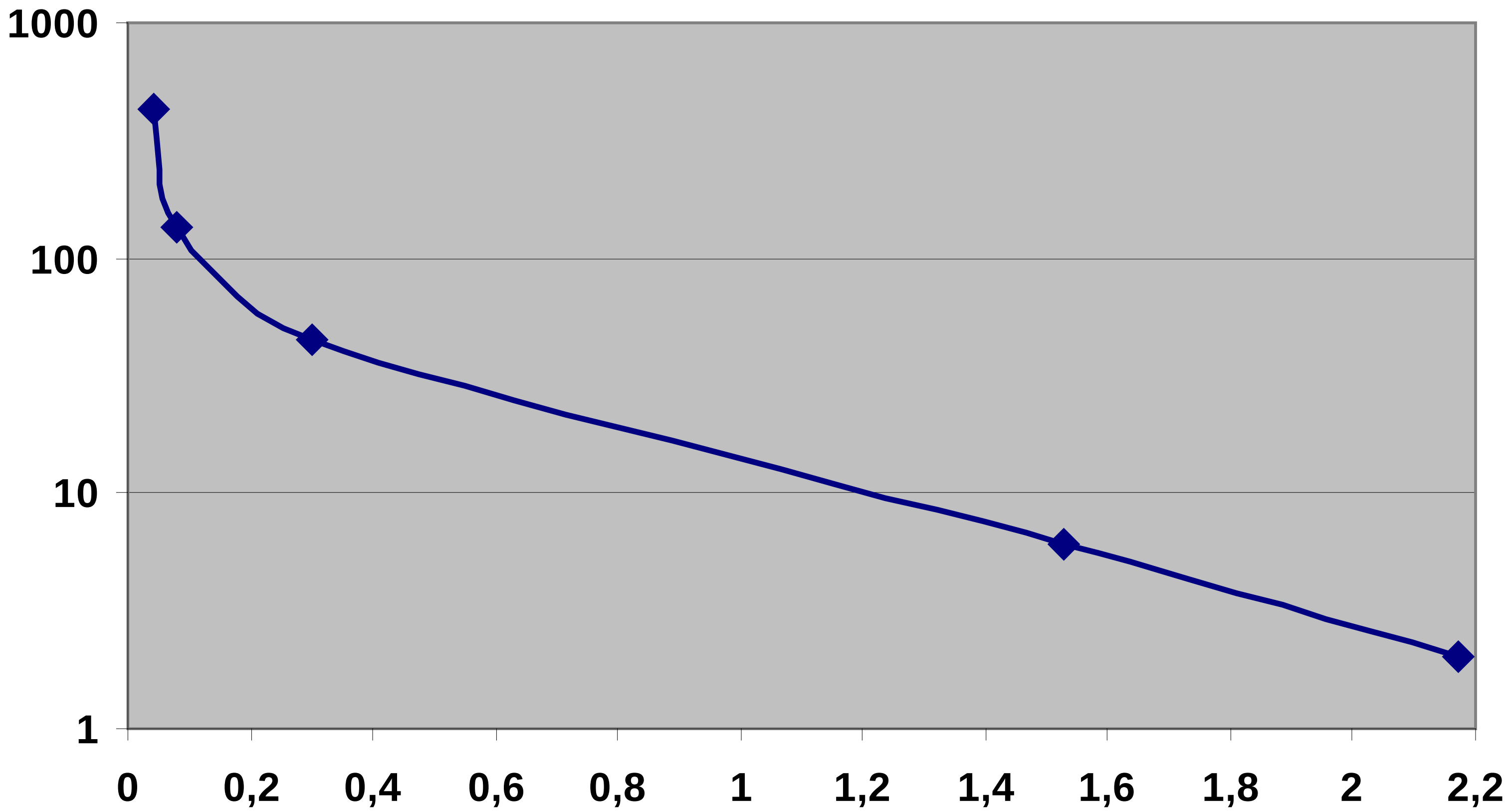
RDX/HMX/Binder vs. Oxygenbalance



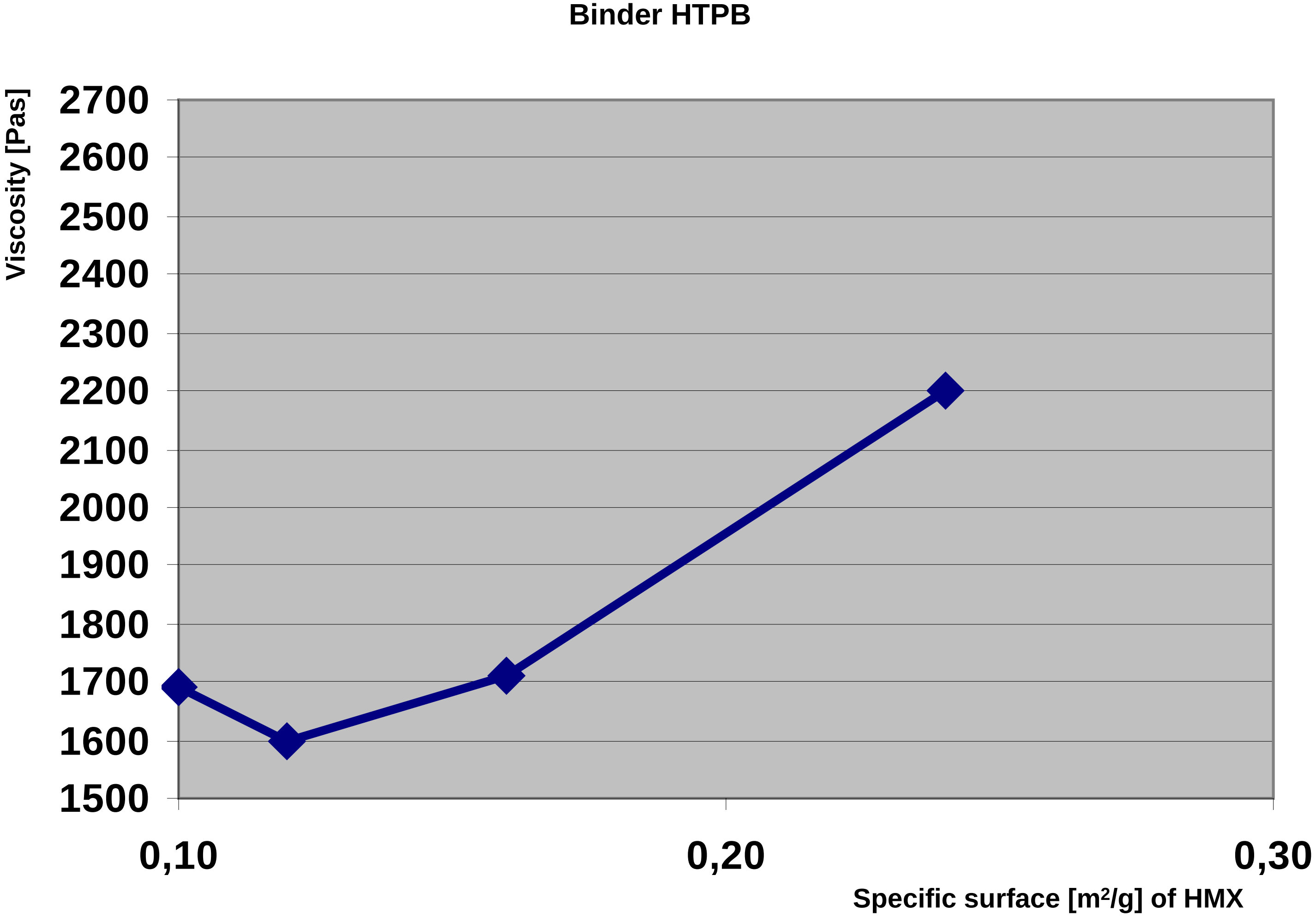
RDX/HMX/Binder vs. Oxygenbalance



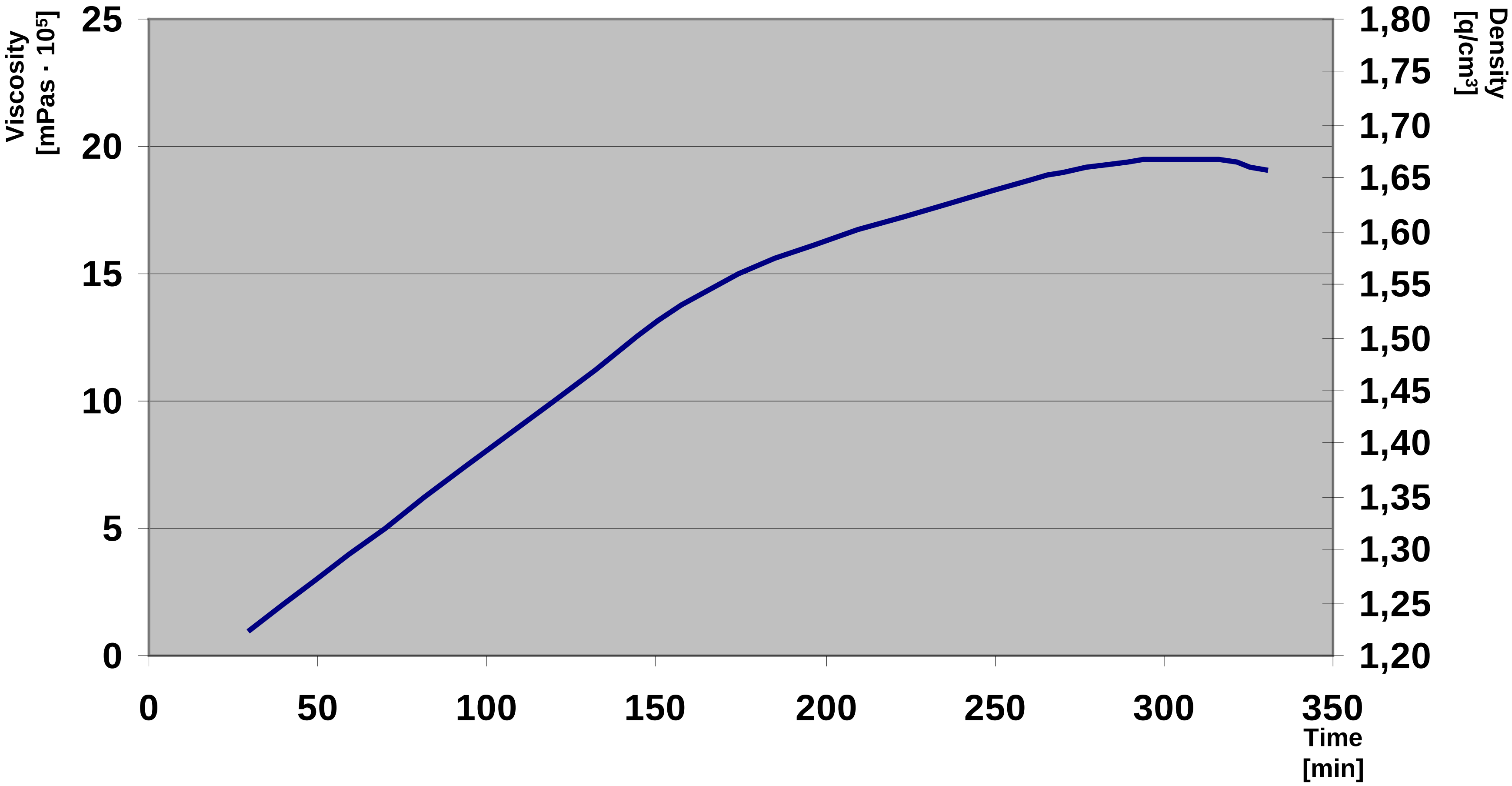
Specific Surface vs grain size HMX



Viscosity vs Specific Surface of HMX



PBX – Density, Viscosity 90% HMX / 10 % HTPB



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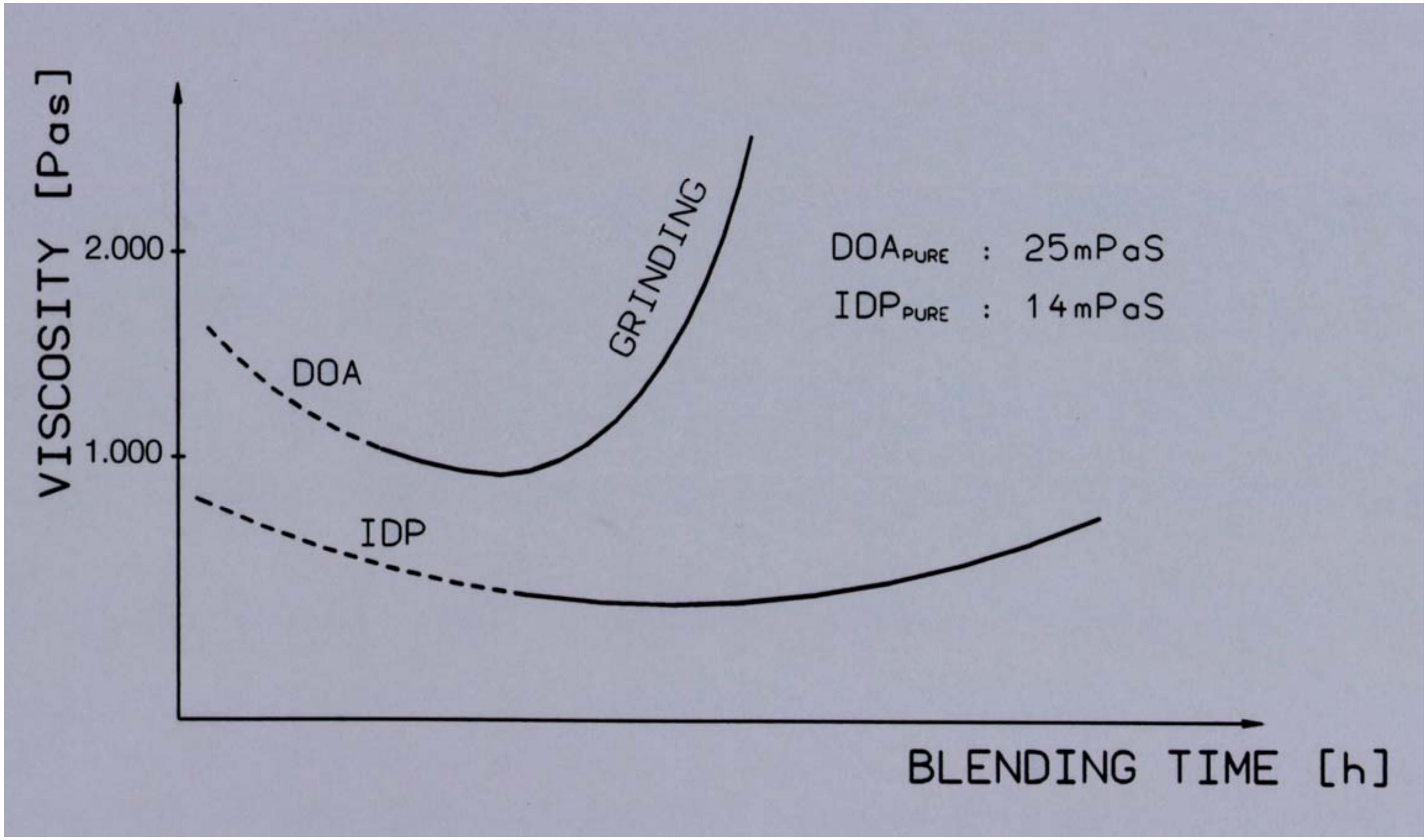
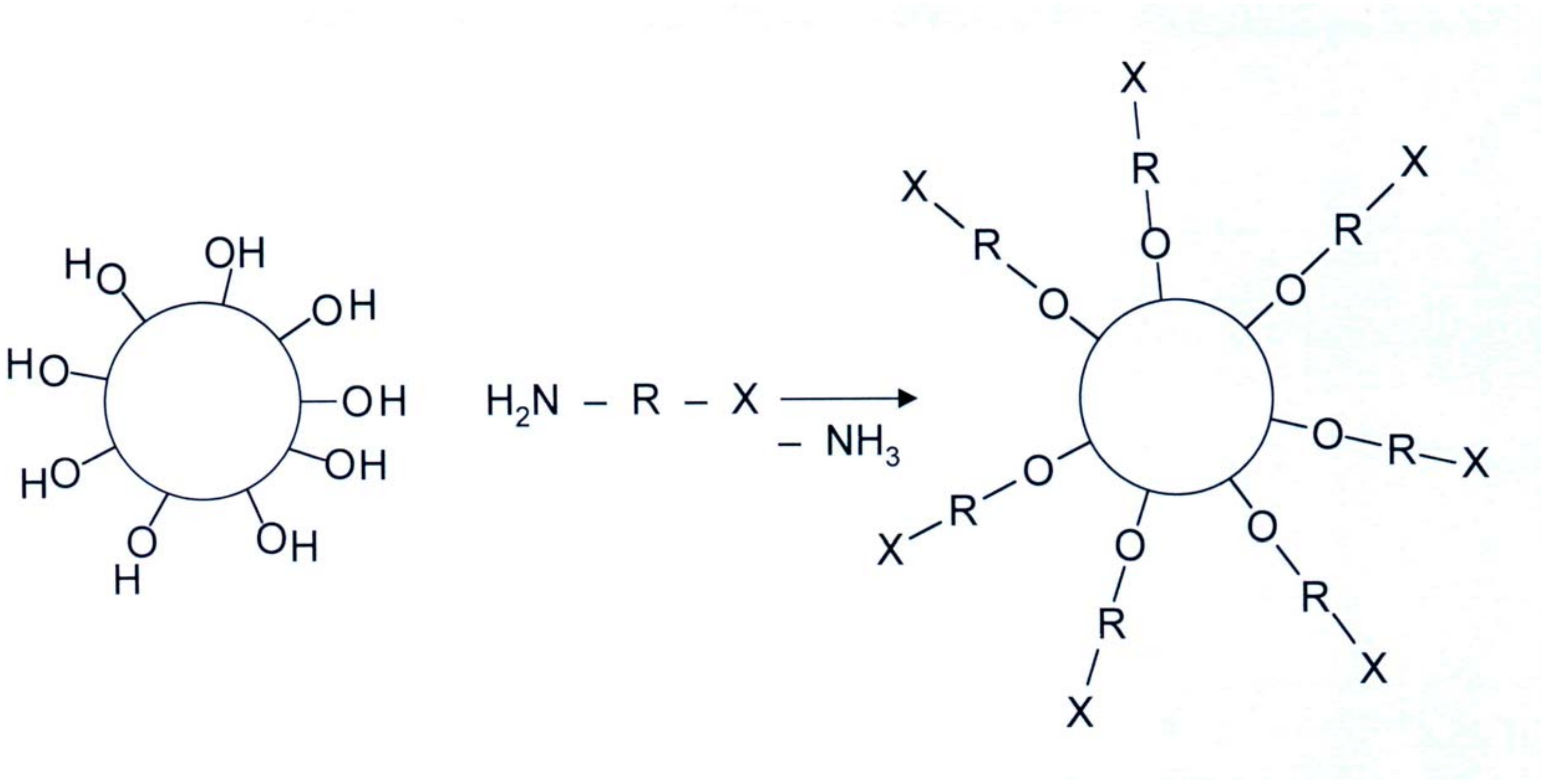
TYPICAL PLASTICIZERS			
Compound	**Boiling Point °C/mm Hg**	**Melting Point °C**	**Density 25 °C g/cm^3**
IDP	150/2.5	-80	0.860
DOS	258/4	-55	0.912
DOA	214/6	-70	0.920
Nitroglycerin	Dec	13.2	1.601
BDNPF	150/0.01	33/34	1.366
BDNPA	152/0.01	31	1.411
FEFO	122/3	14	1.596

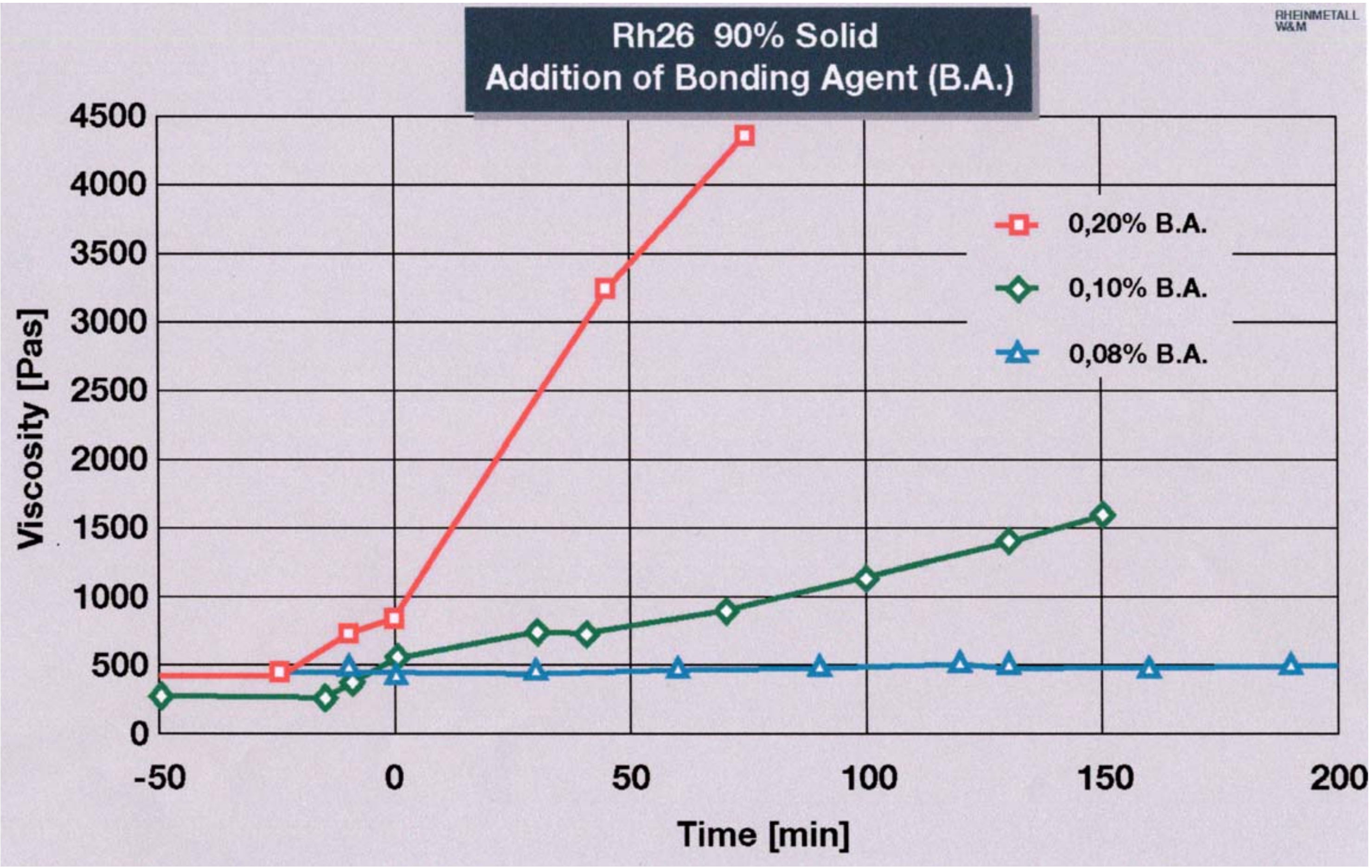
Influence of Plasticizer



Bonding Agents



Rheology Flow curve at 50°C



Glass Transition Temperature

Tg

Glass

Elastomer

Molecular segments
are frozen

Molecular segments
are rotaring

Not constant
Strong influenced by pressure

Glass Transition Temperature

Changing

- Coeffizient of Thermal expansion

- Heat capacity

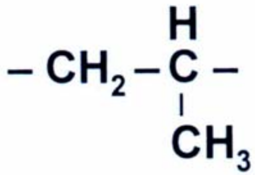
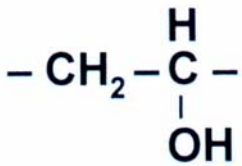
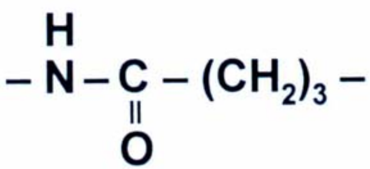
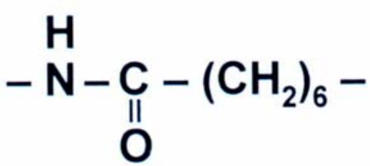
- Electrical resistance

Glass Transition Temperature

Determination

-Torsion	
-Thermal Mechanical Analysis	TMA
-Differential Thermal Analysis	DTA
-Differential Scanning Calorimetry	DSC
-Ultrasonic Absorption	US
-Nuclear Magnetic Resonance	NMR

Glass Transition Temperature

Segment	Tg {°K}
	260
	358
	384
	325
	580

Glass Transition Temperature

Decreasing	Increasing
Reduction in cross linking	Increase in cross linking
Reduction intermolecular forces	High molecular weight
Plasticizers	Bulky and stift
	Groups hindering rotation
	Fillers

Mechanical Properties of HE Charges

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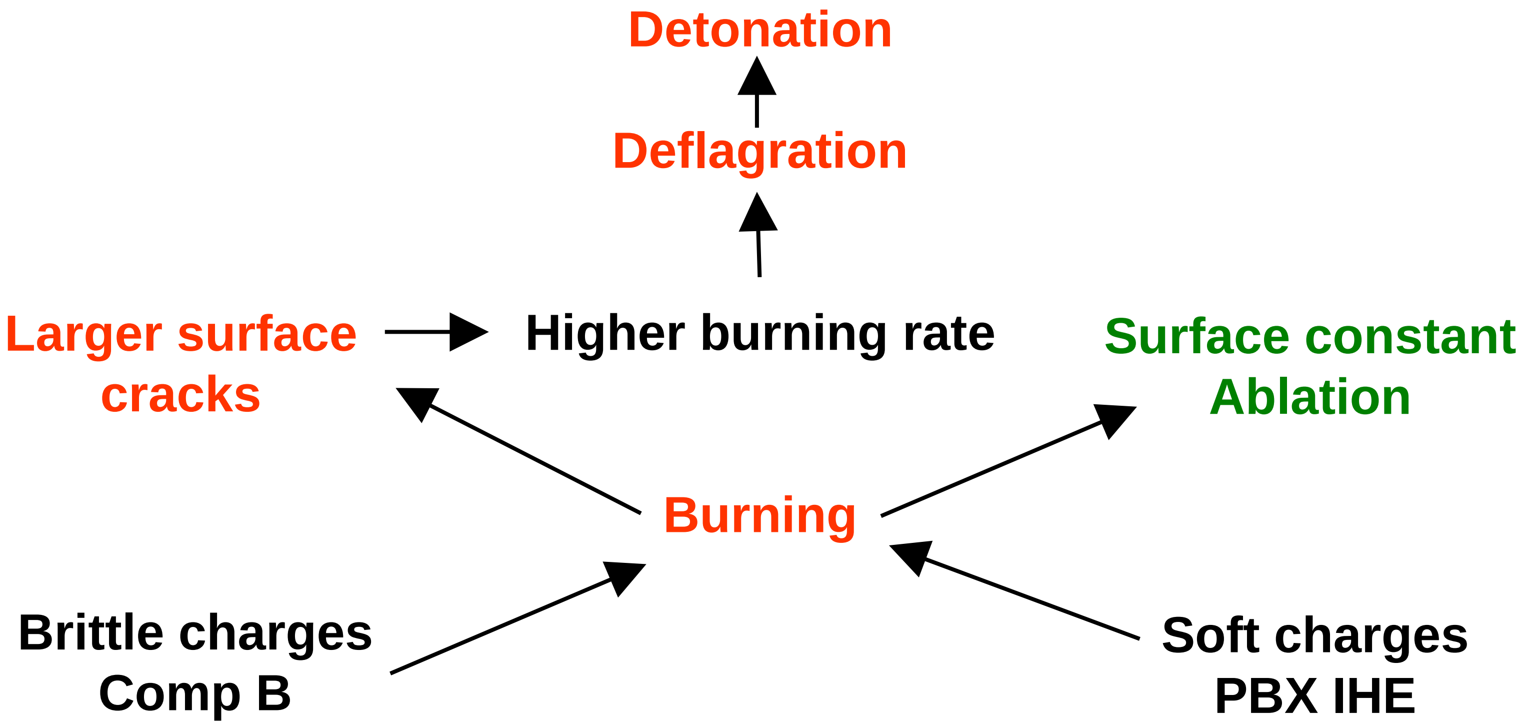
Charge	Young's modulus [N/mm²]	Tensile strength [N/mm²]	Elongation %	Coeffizient of thermal expansion	Hardness Shore A
Comp B	2200 ± 500	10 – 15	< 0,1	5 x 10 – 5	> 100
RDX/wax		12 – 14	< 0,1	7 x 10 – 5	> 100
PBX-cast	6 – 8	0,3 – 0,5	5 – 7	1 x 10 – 4	60 – 70
PBX pressed	130 - 400	10 – 15	1	5 x 10 - 5	> 100

Vulnerability



Coating of small particles

- **Saturation of polar surfaces with a chemical agent**
- **Decreasing specific surface**
- **Decreasing viscosity**
- **Lubrification effect**
- **Protection for**
  - **Oxygen**
  - **Water**