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Polymer Fundamentals for Coatings

Werner J. Blank

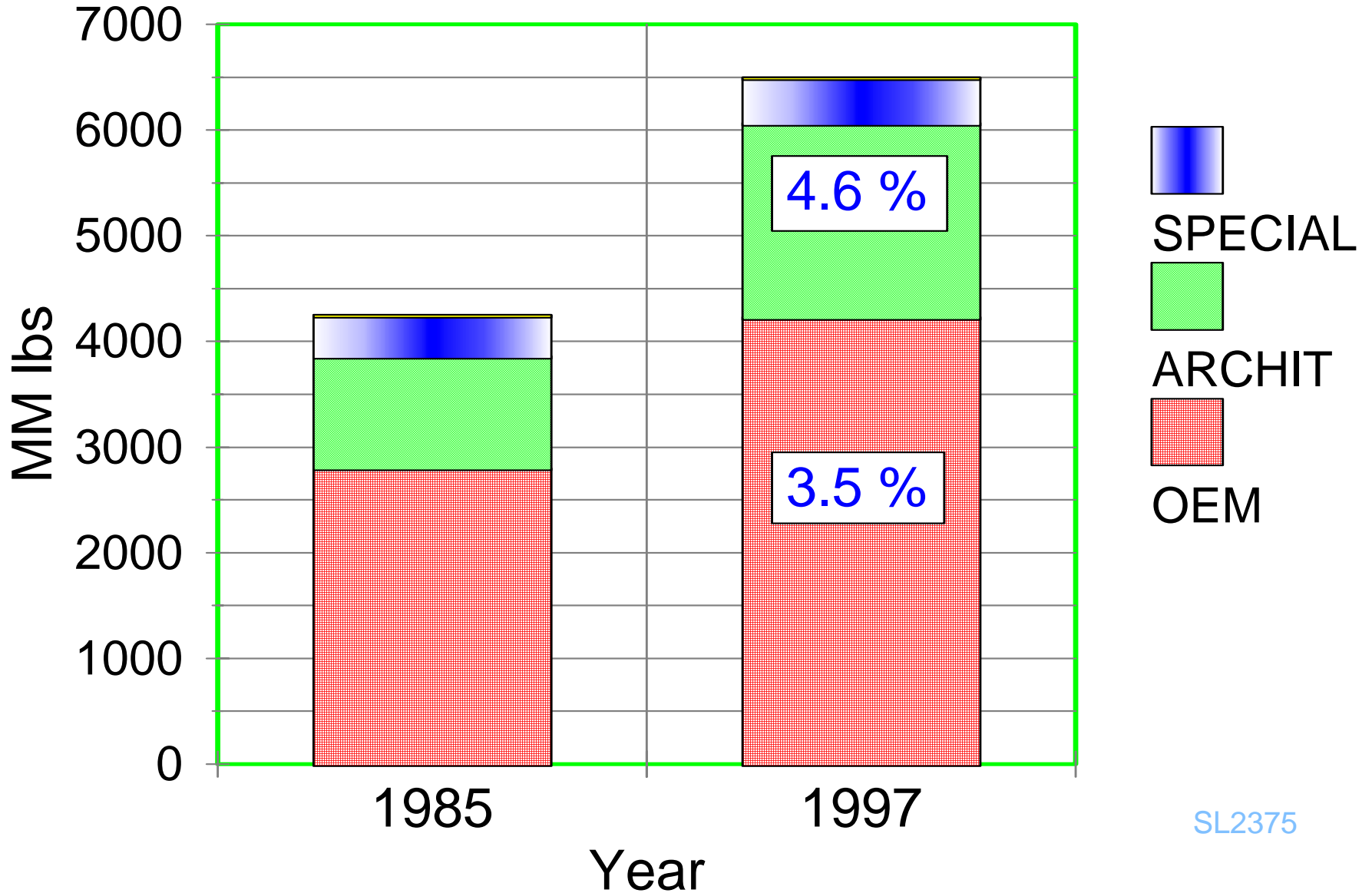
**King Industries Inc
Science Road
Norwalk, CT 06852**



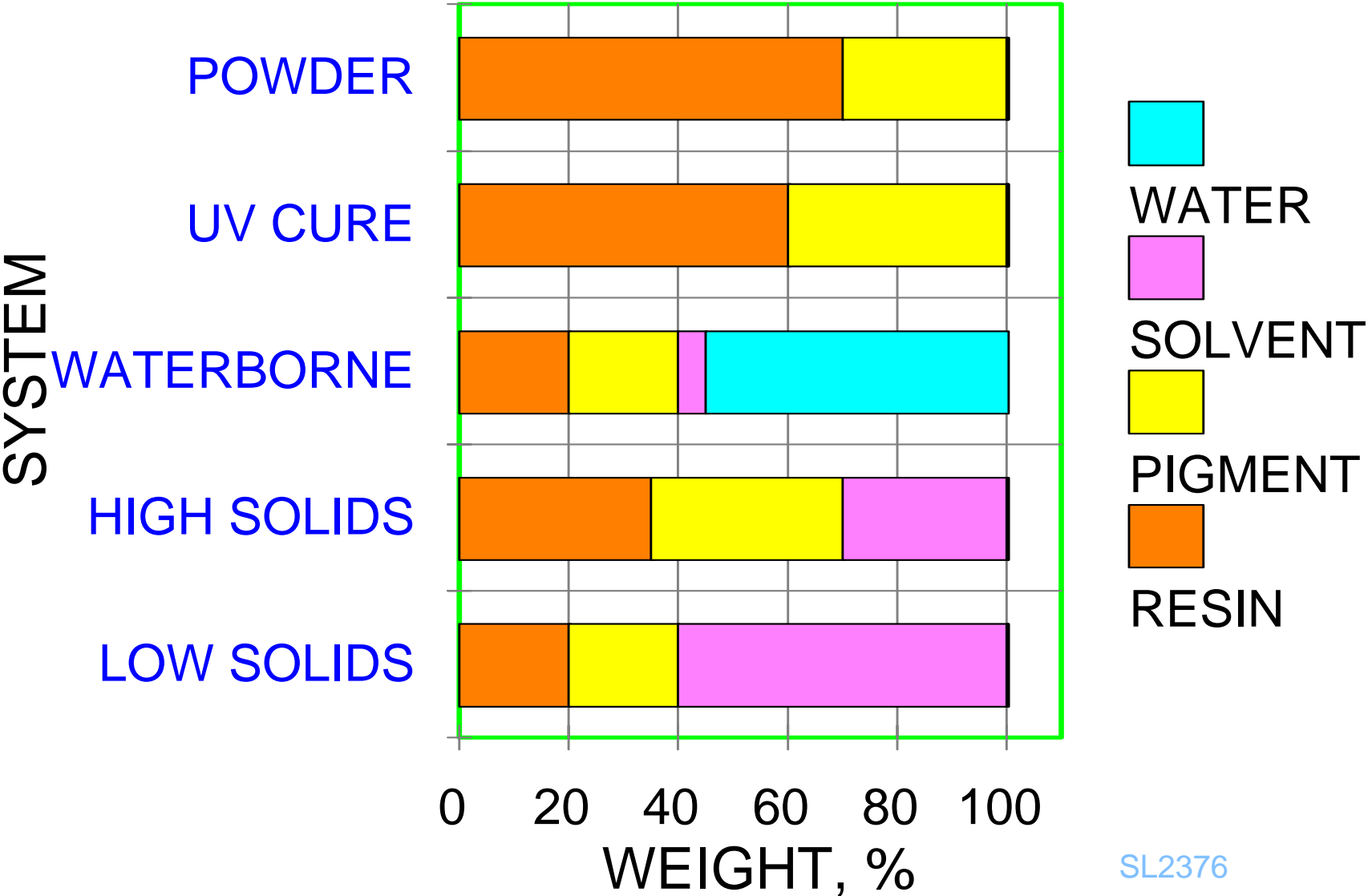
wblank@kingindustries.com
werner@wernerblank.com

RESIN CONSUMPTION

1985 - 1997

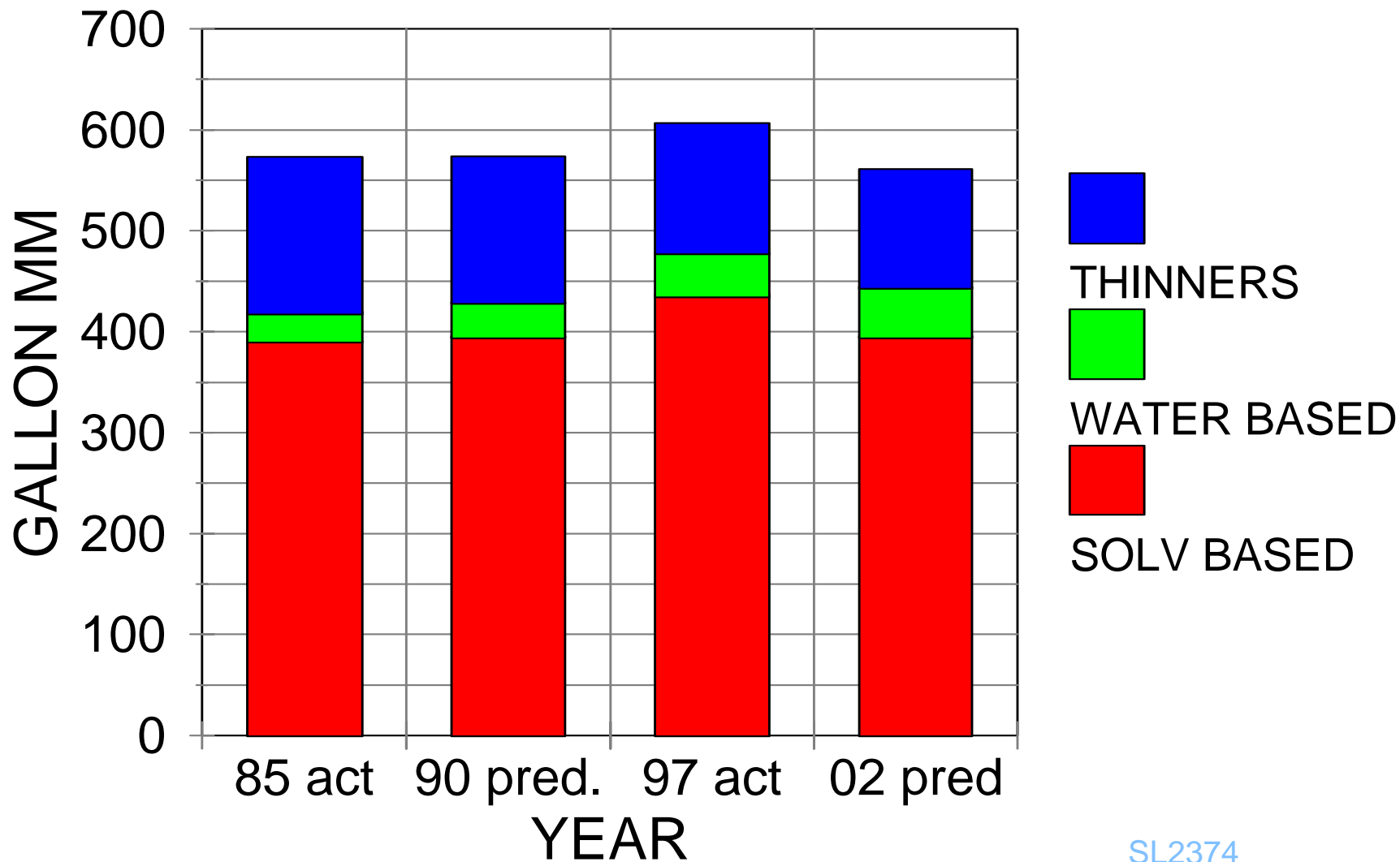


COATING FORMULATIONS

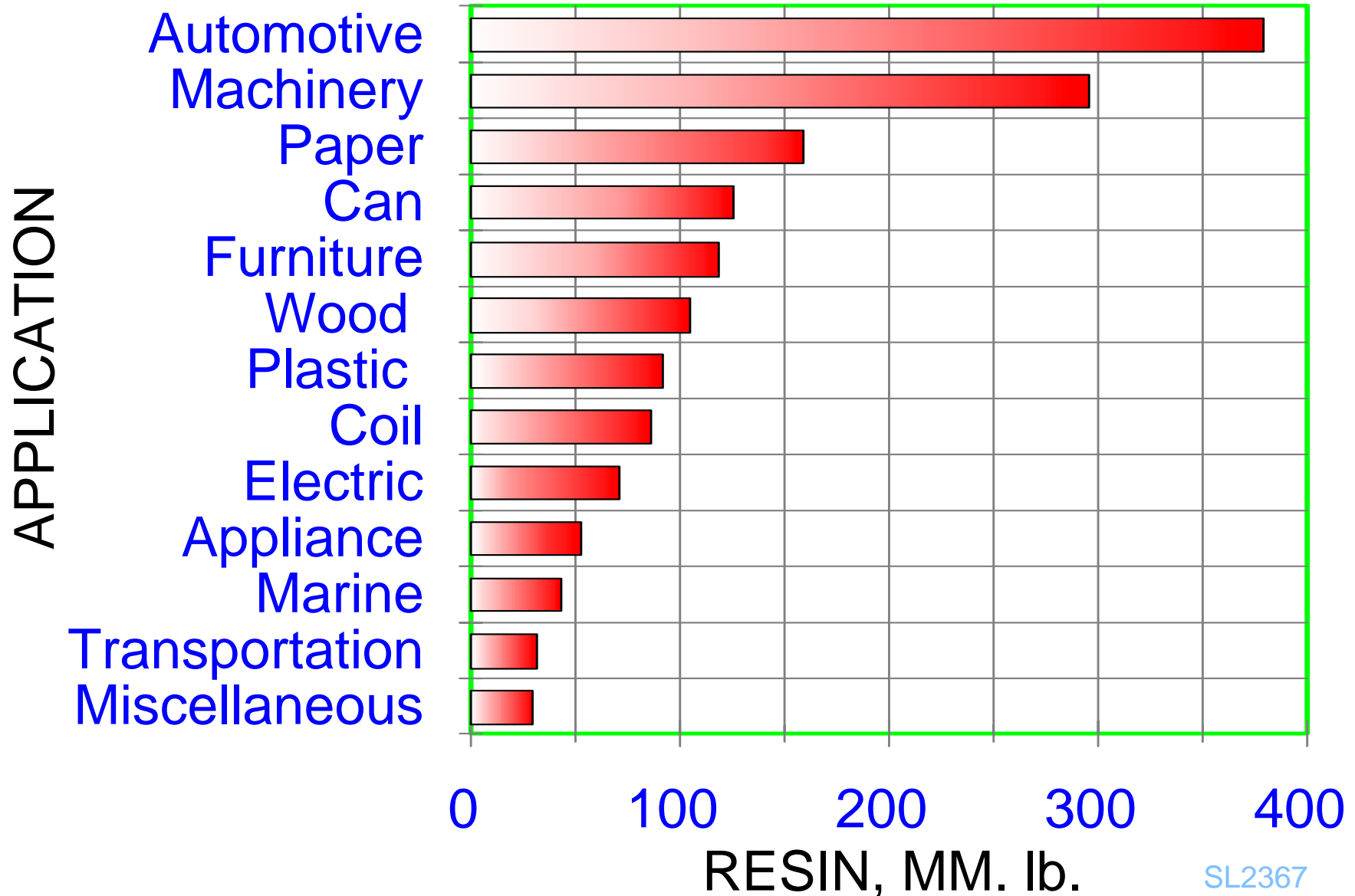


SOLVENT CONSUMPTION

ACTUAL & PREDICTED

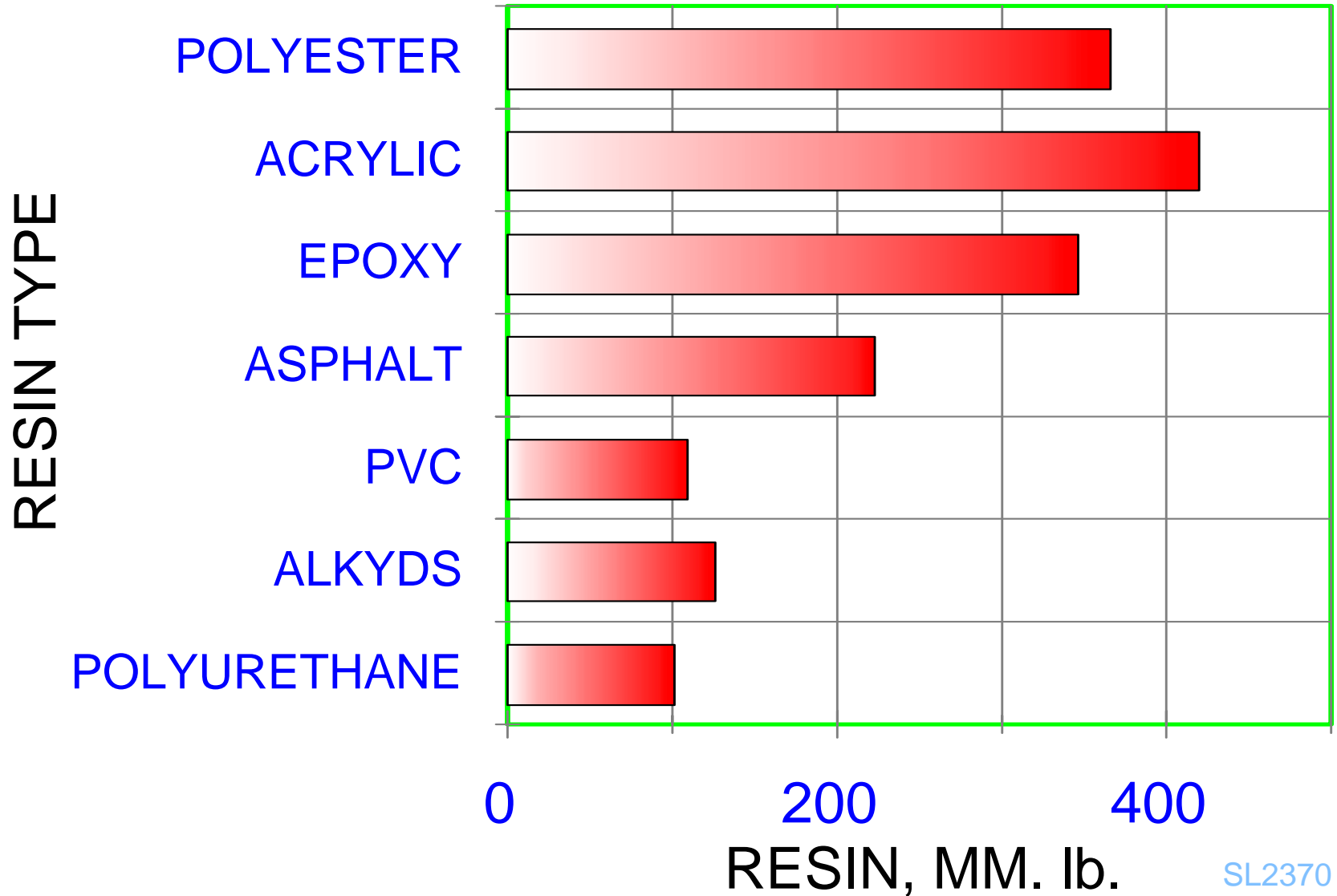


OEM RESINS LBS. 2002



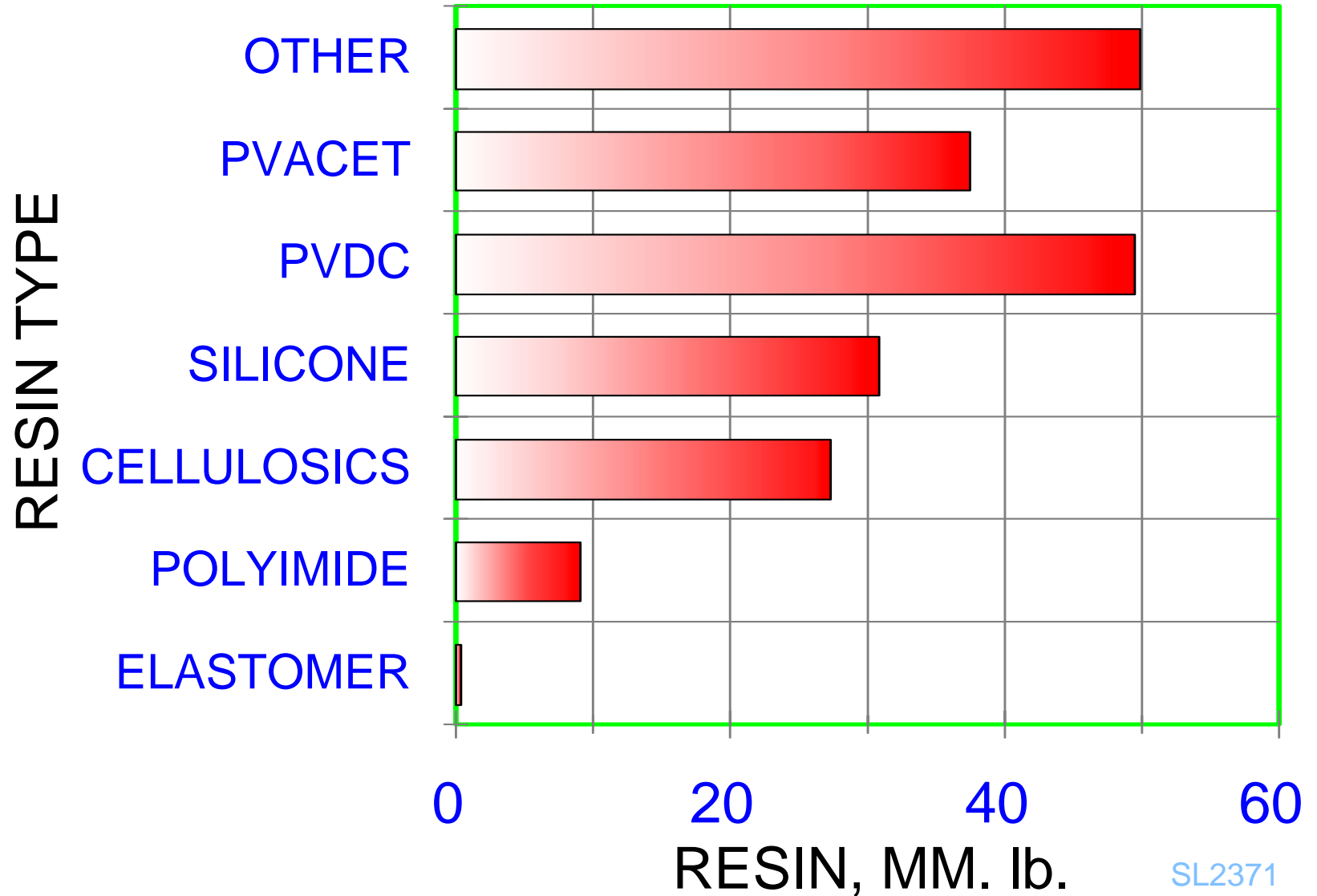
RESINS OEM 2002

MM. LB



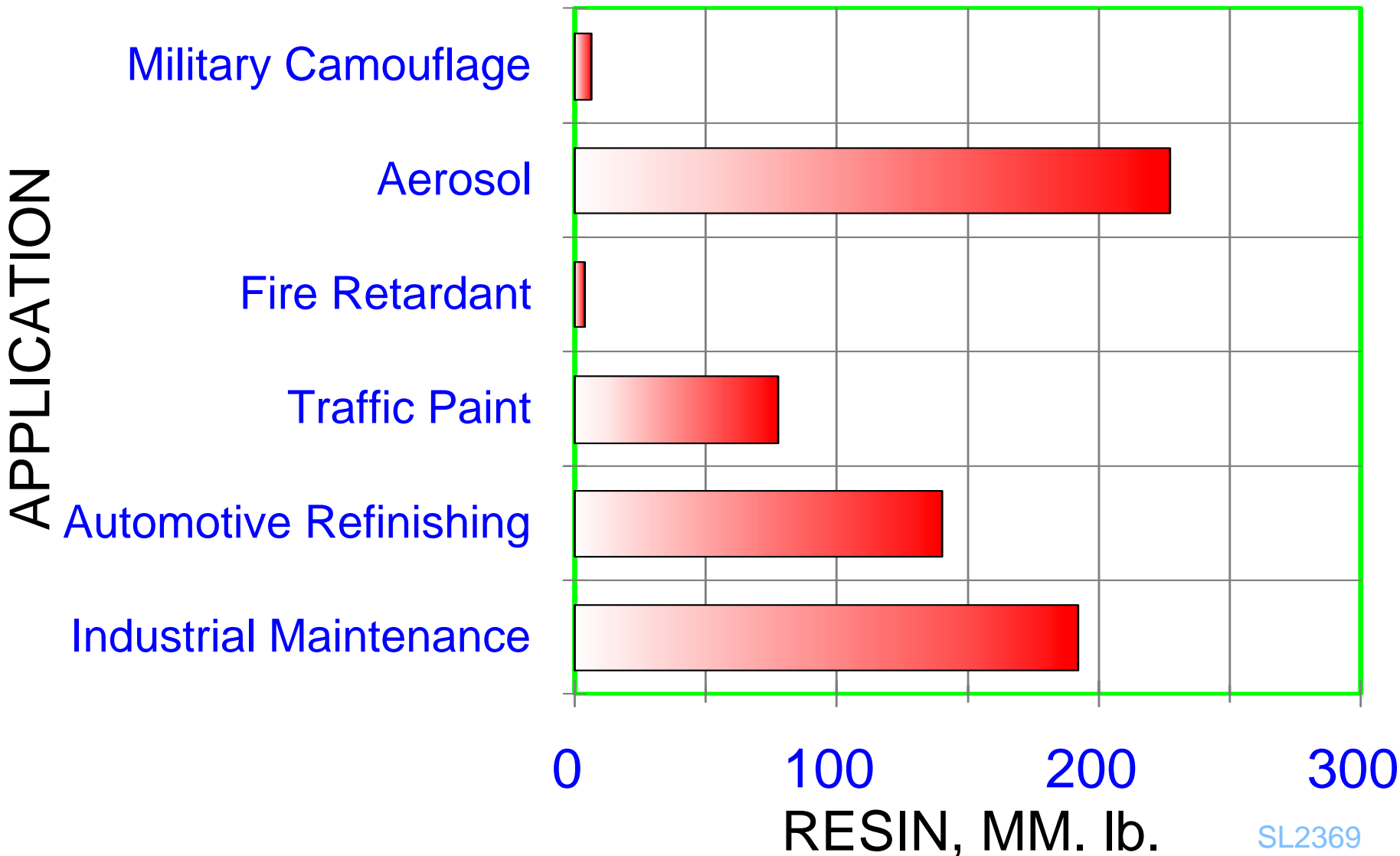
RESINS OEM 2002

MM. LB



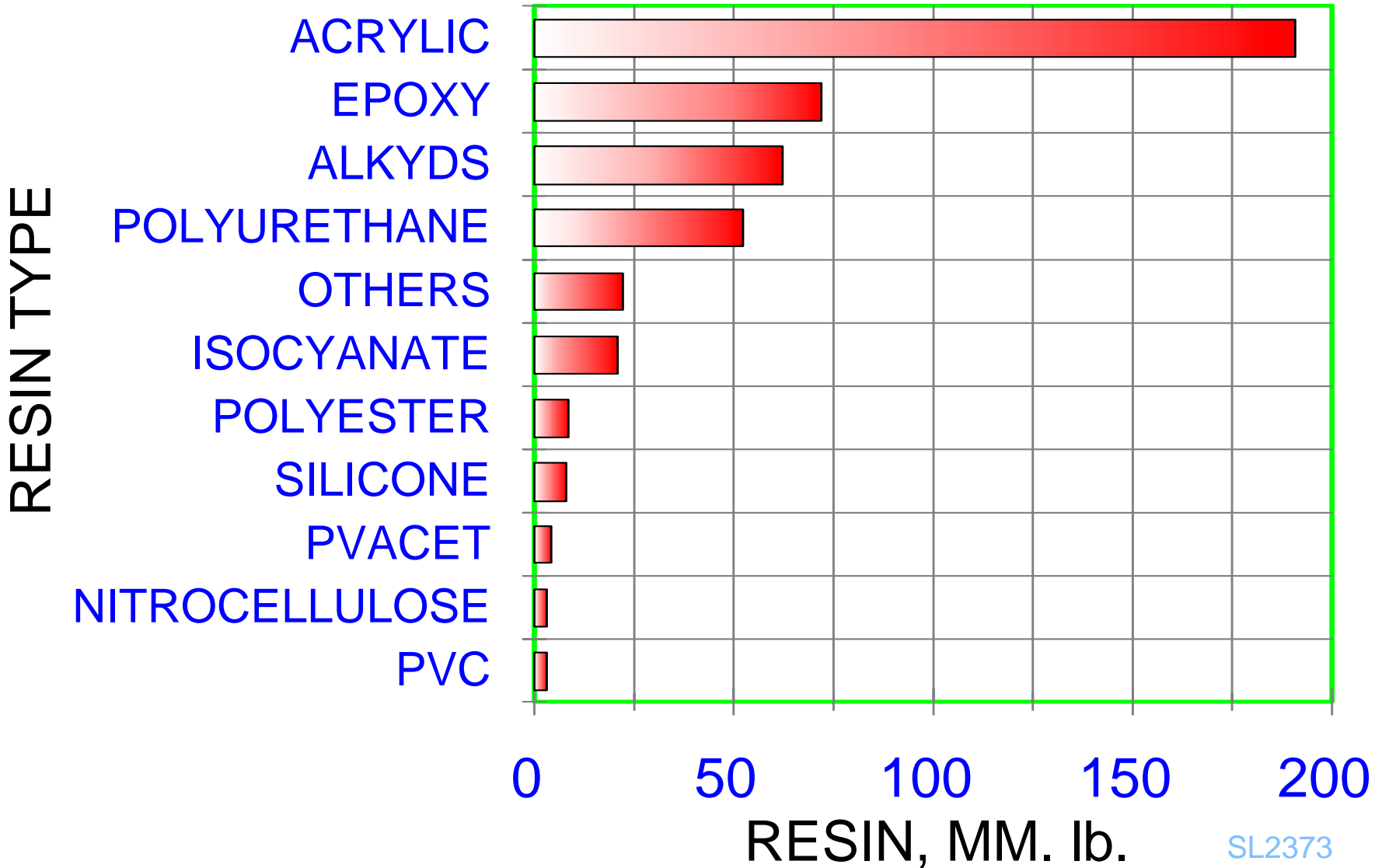
Specialty Coatings 2002

RESINS MM. LB



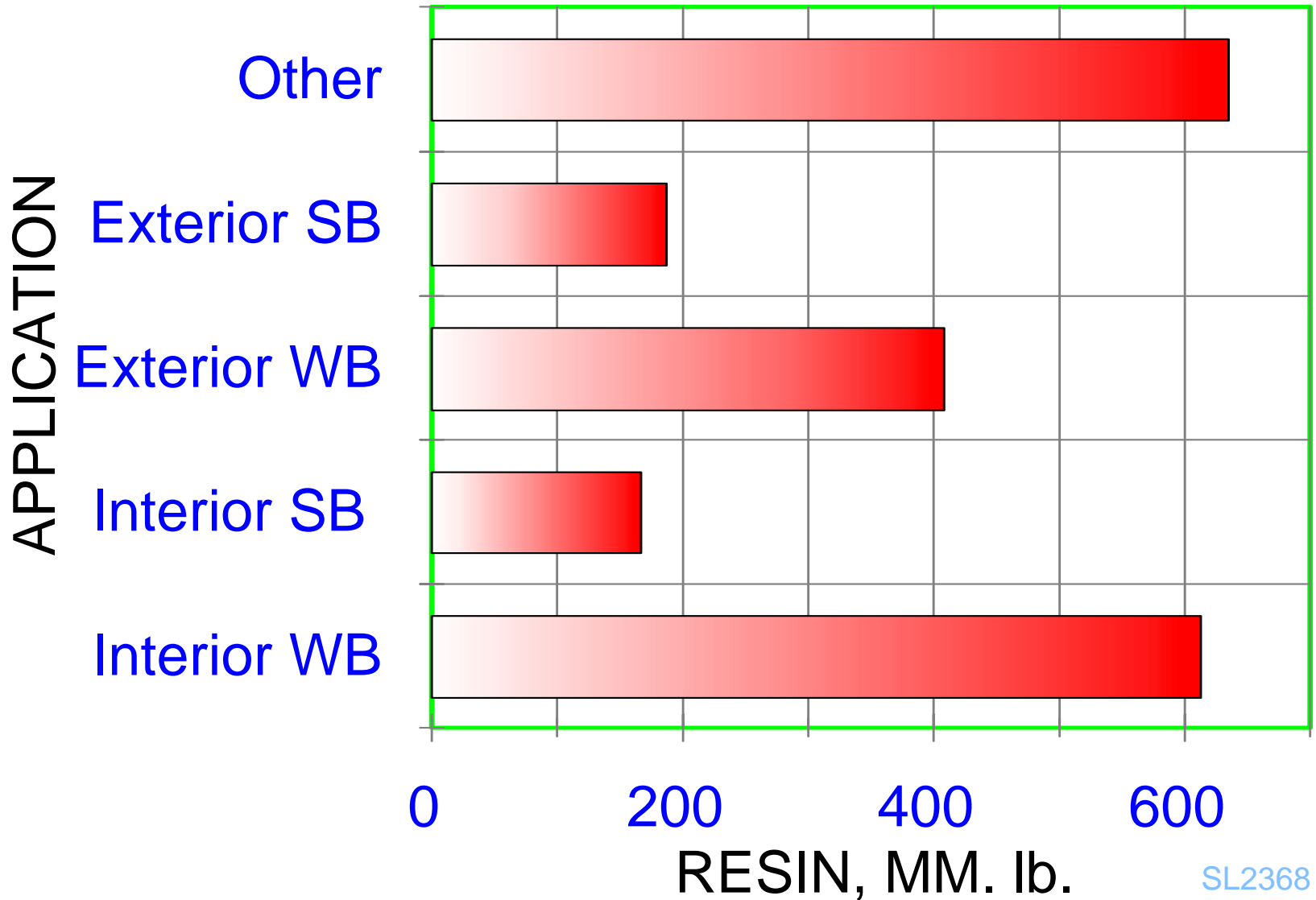
RESINS SPECIALTY 2002

MM. LB



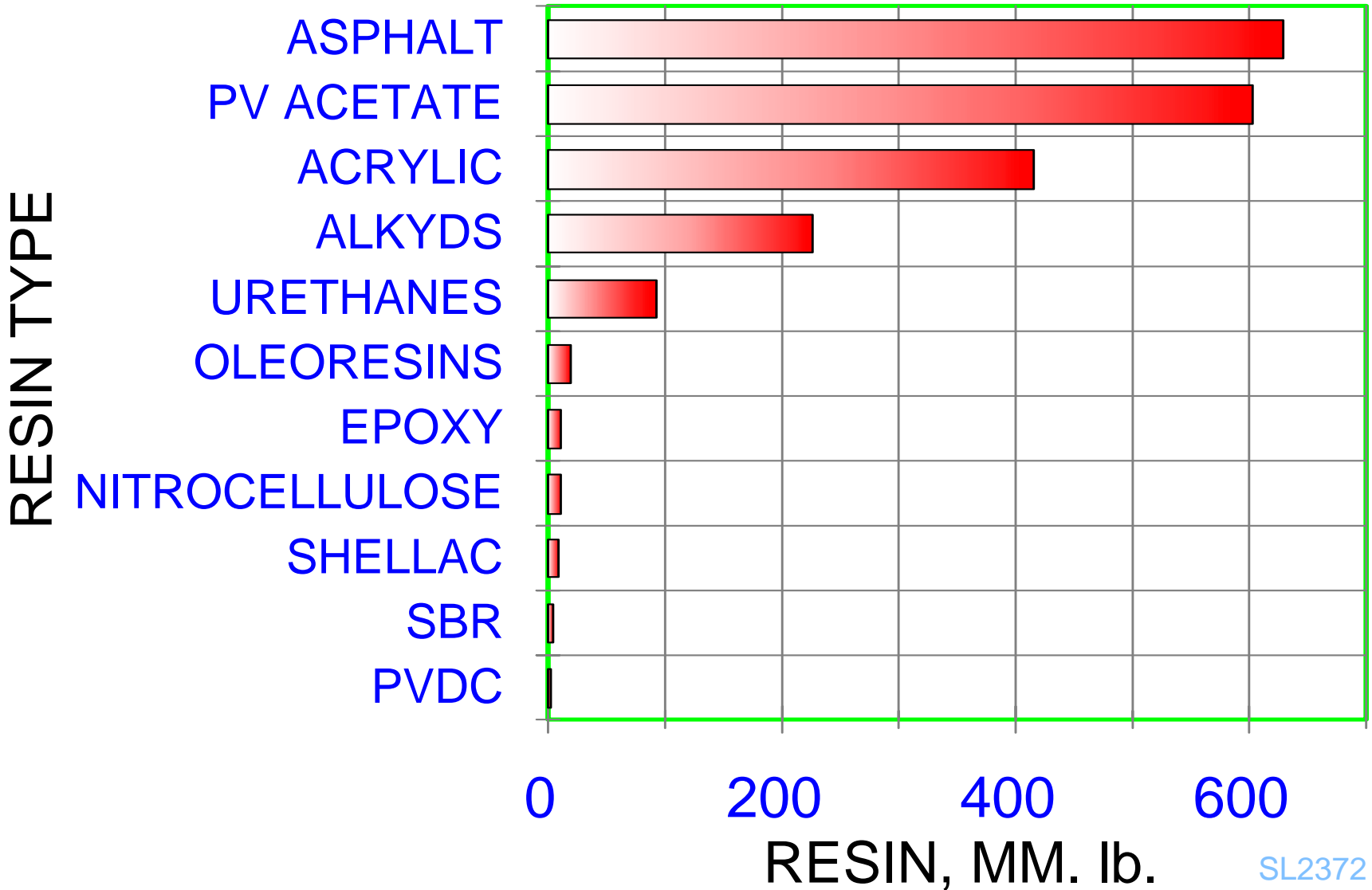
ARCHITECTURAL 2002

RESINS MM. LB



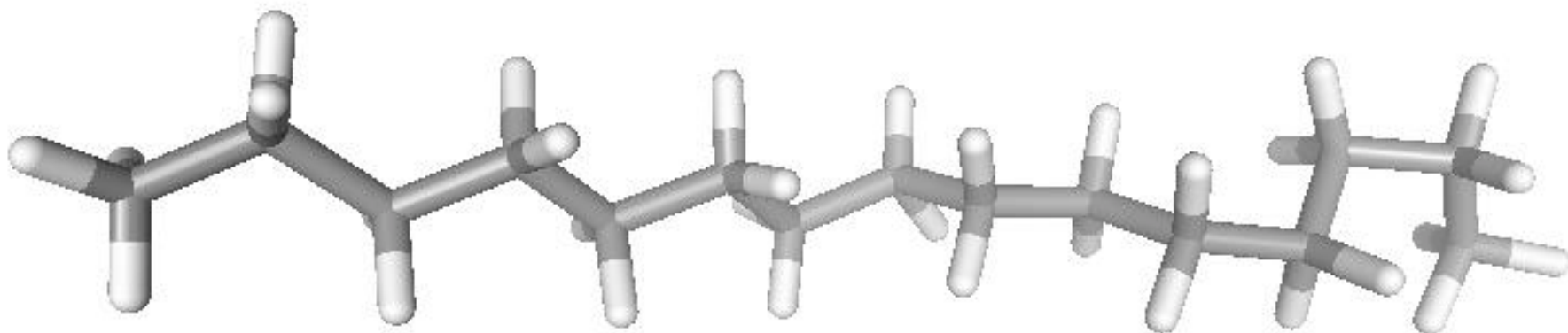
RESINS ARCHITECTURAL 2002

MM. LB

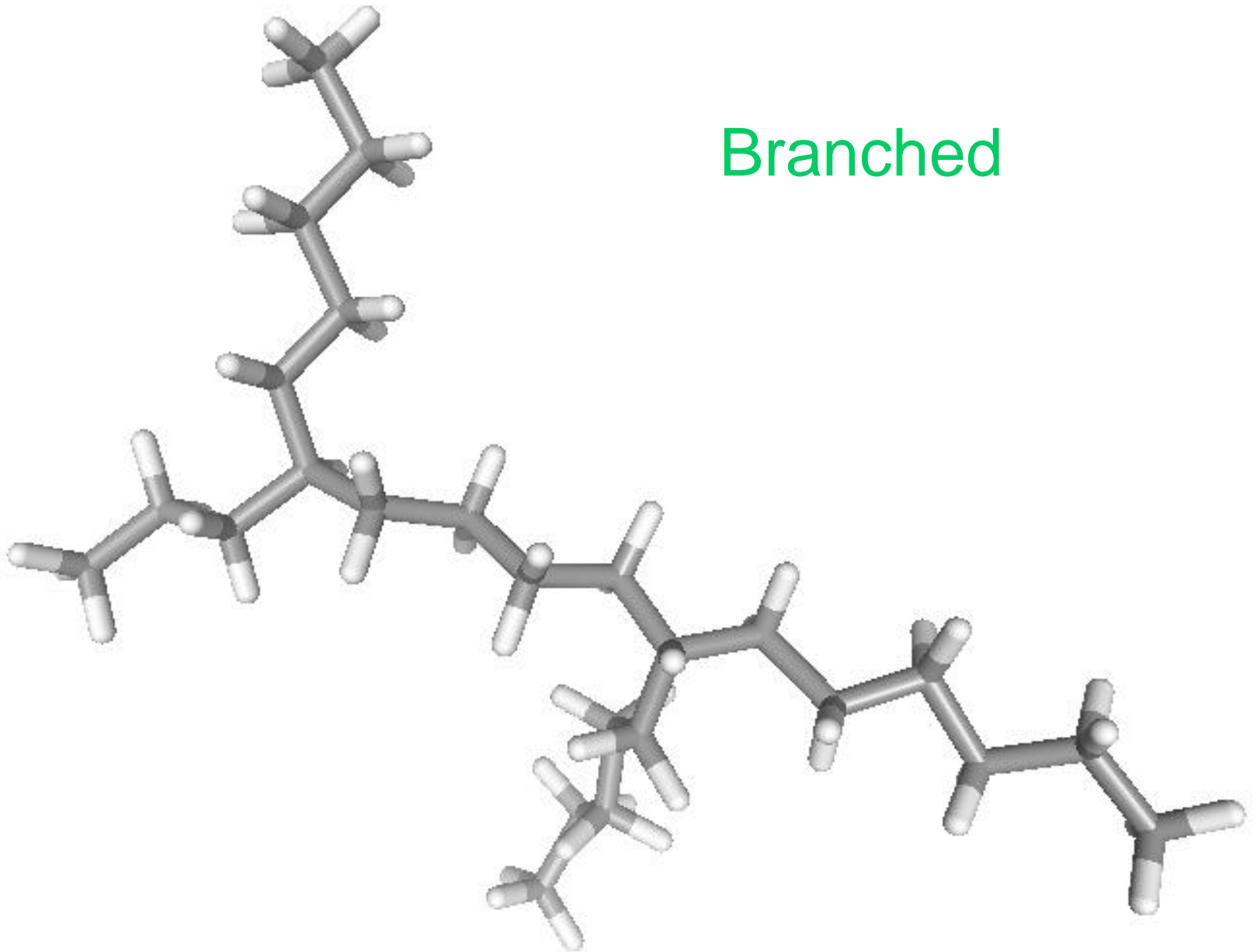


Architecture

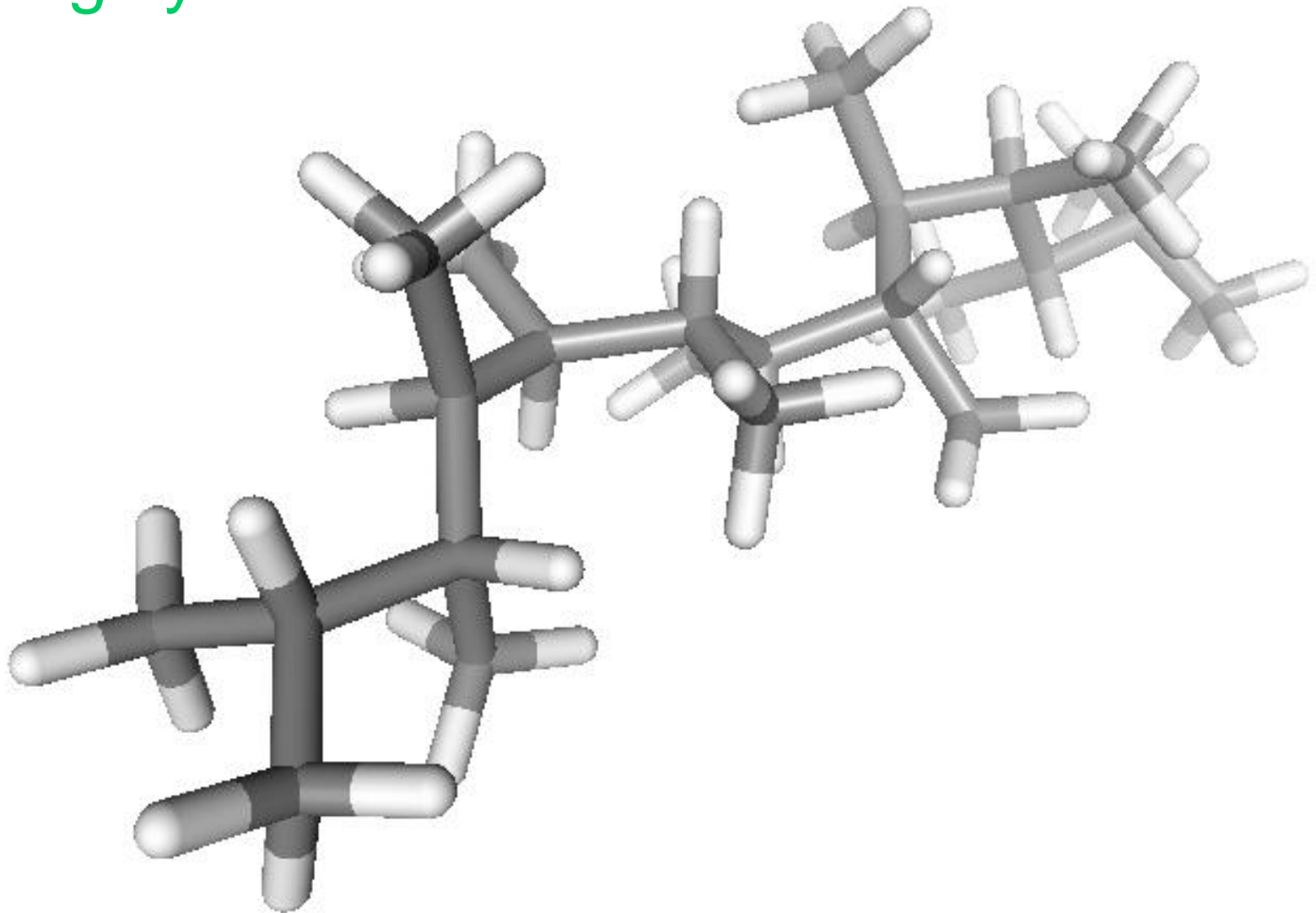
Linear



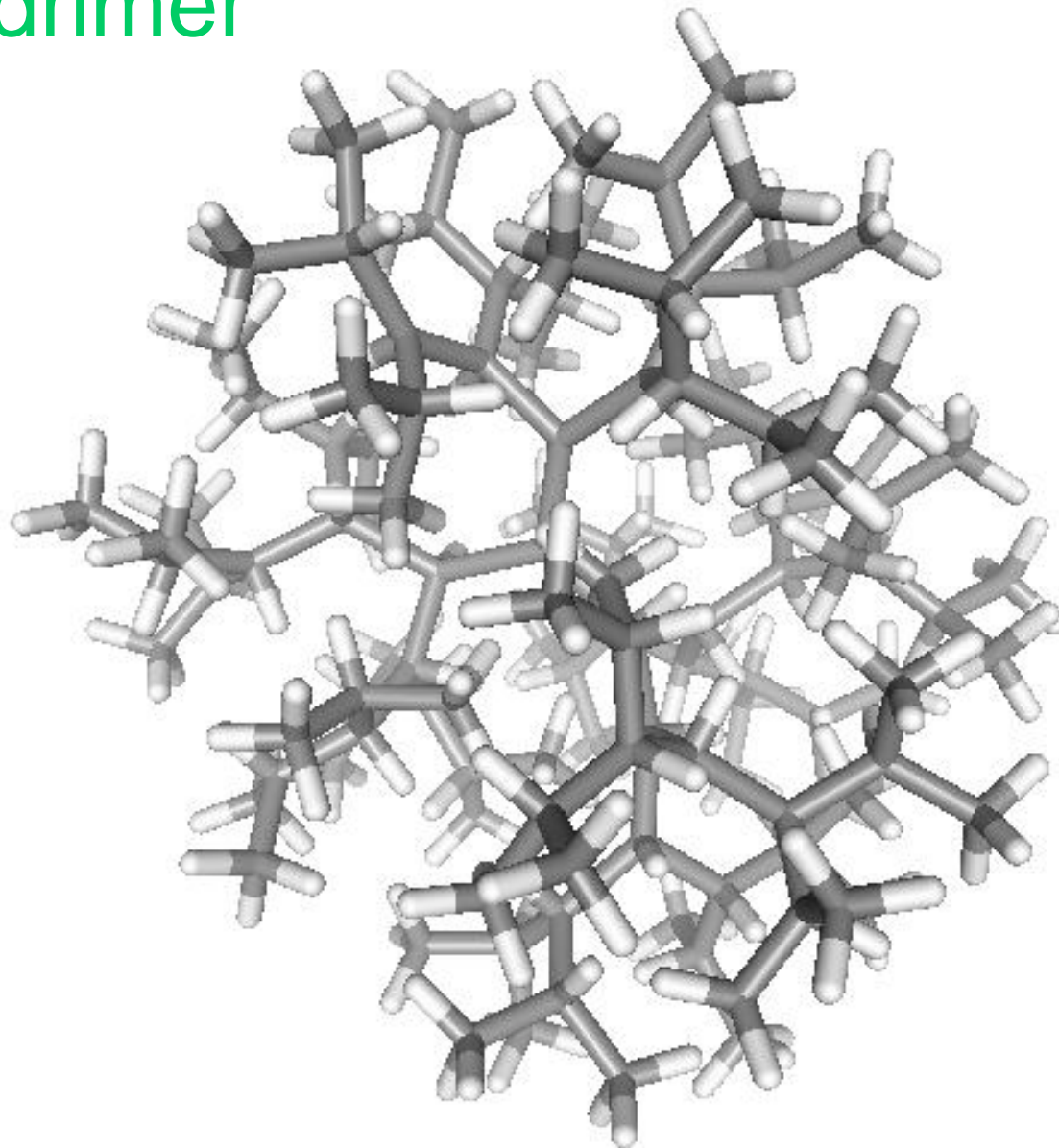
Branched



Highly branched

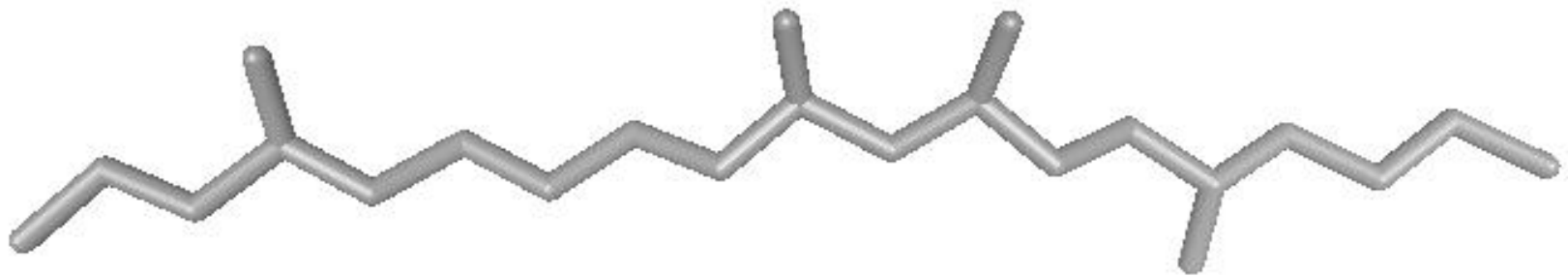


Dendrimer



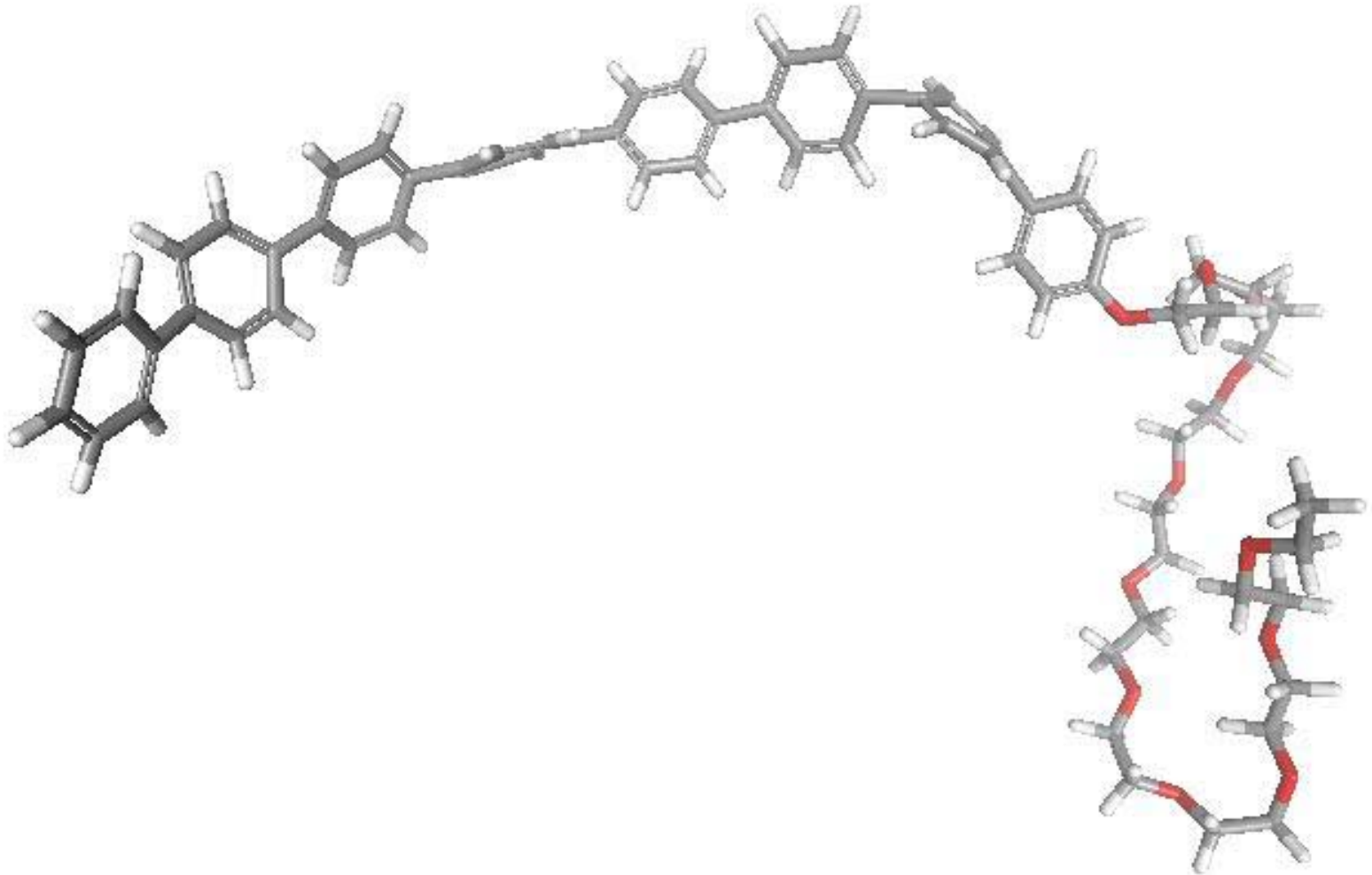
Random Copolymer

Flexible

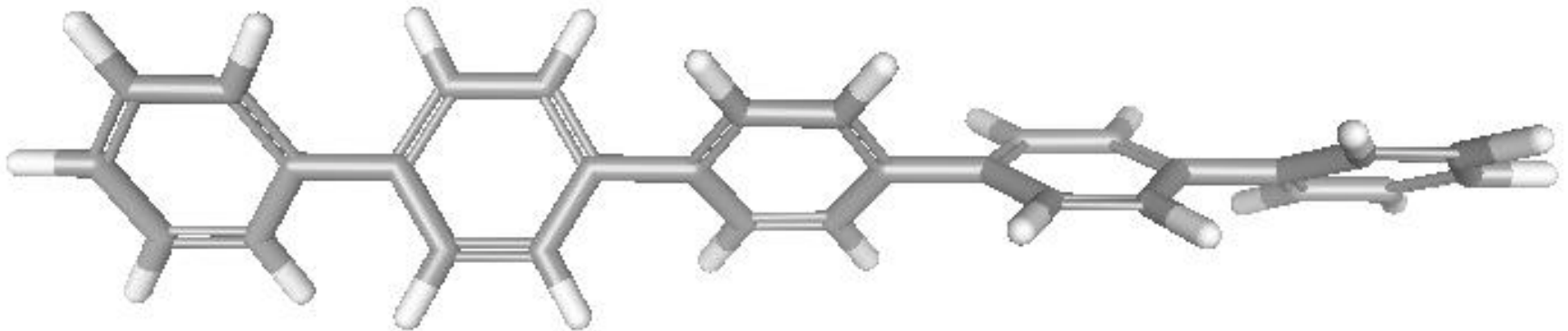


Block

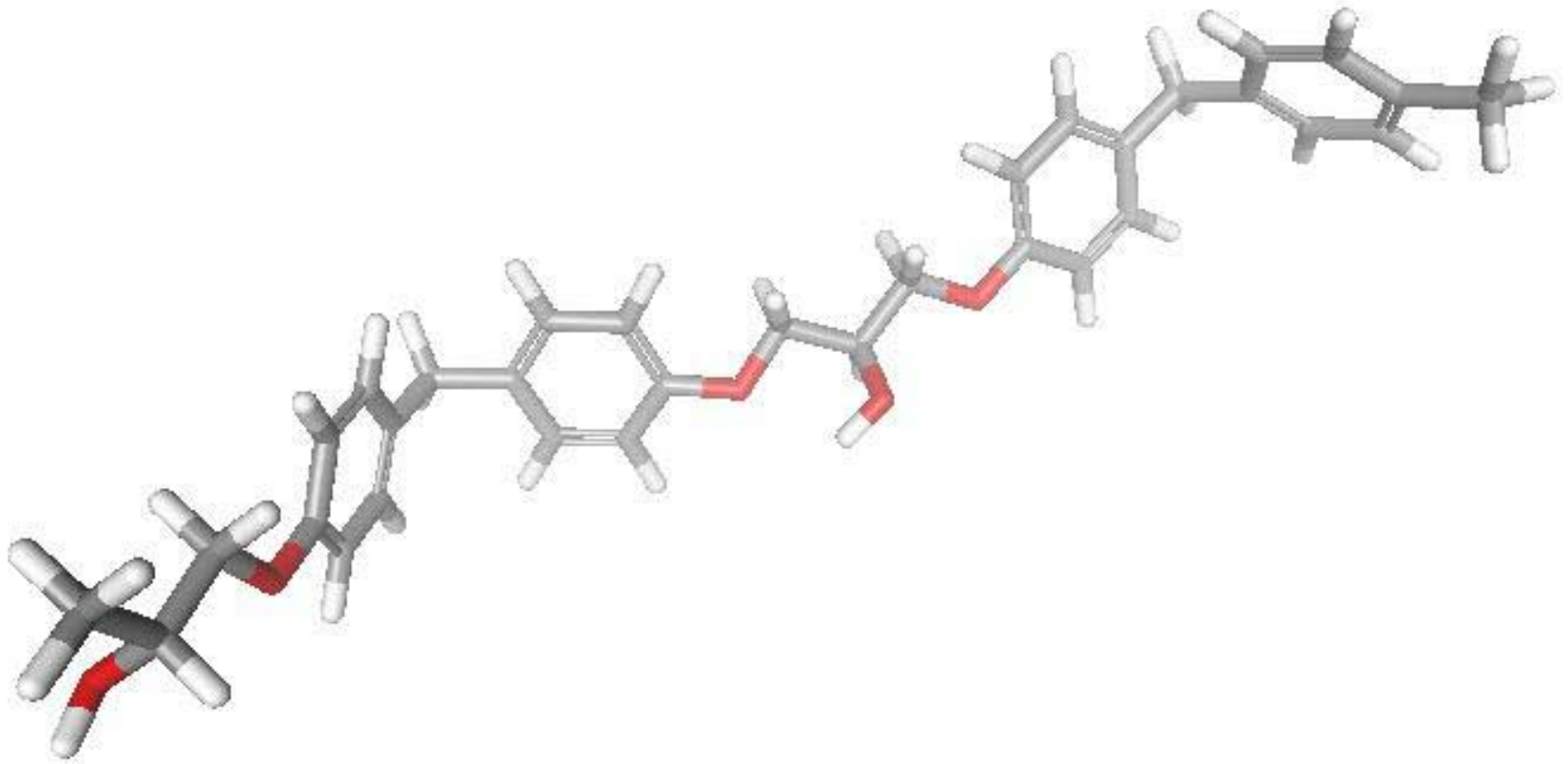
Rigid - flexible



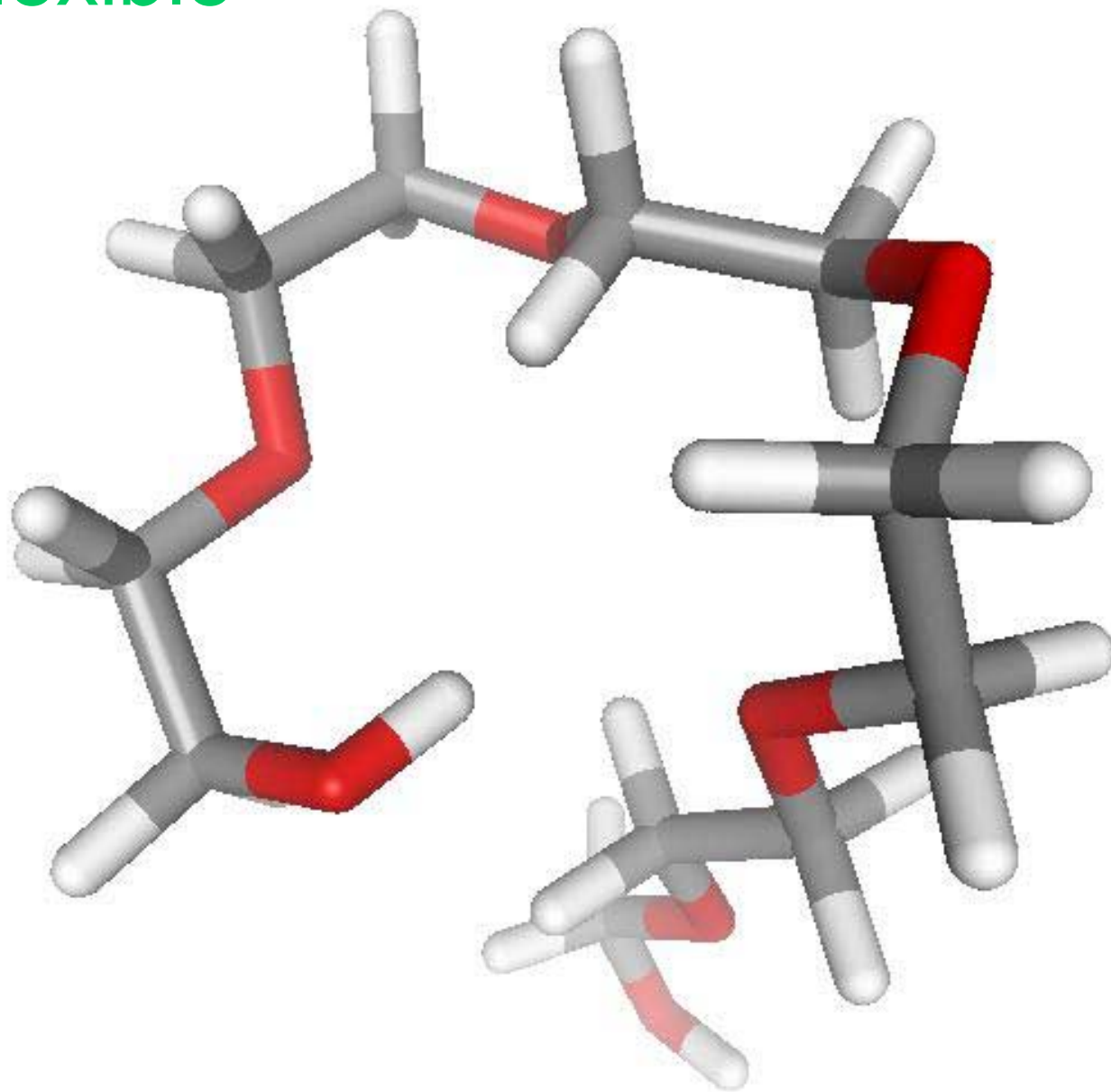
Homo polymer Rigid



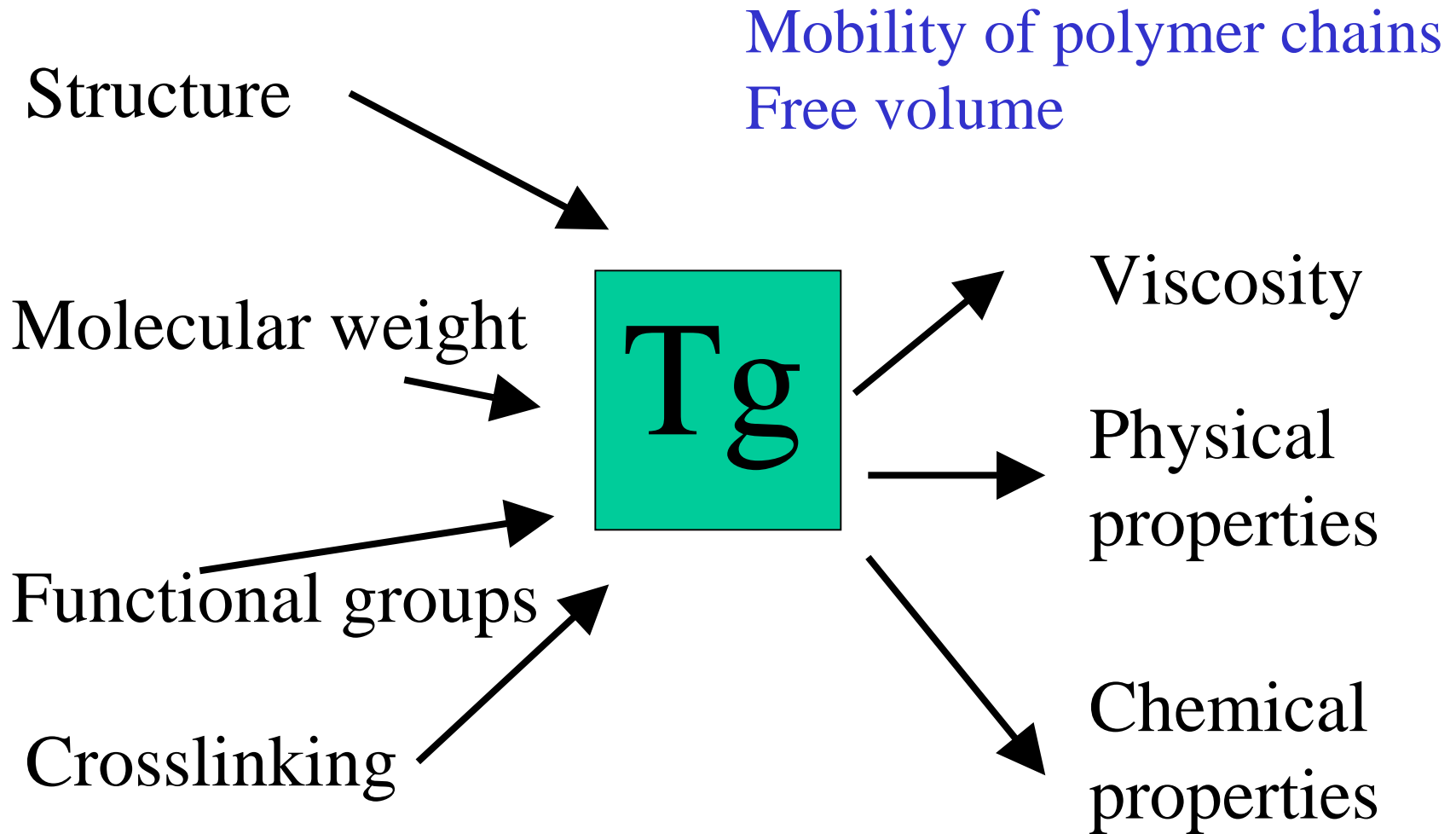
Alternating



Flexible



Glass Transition Temperature



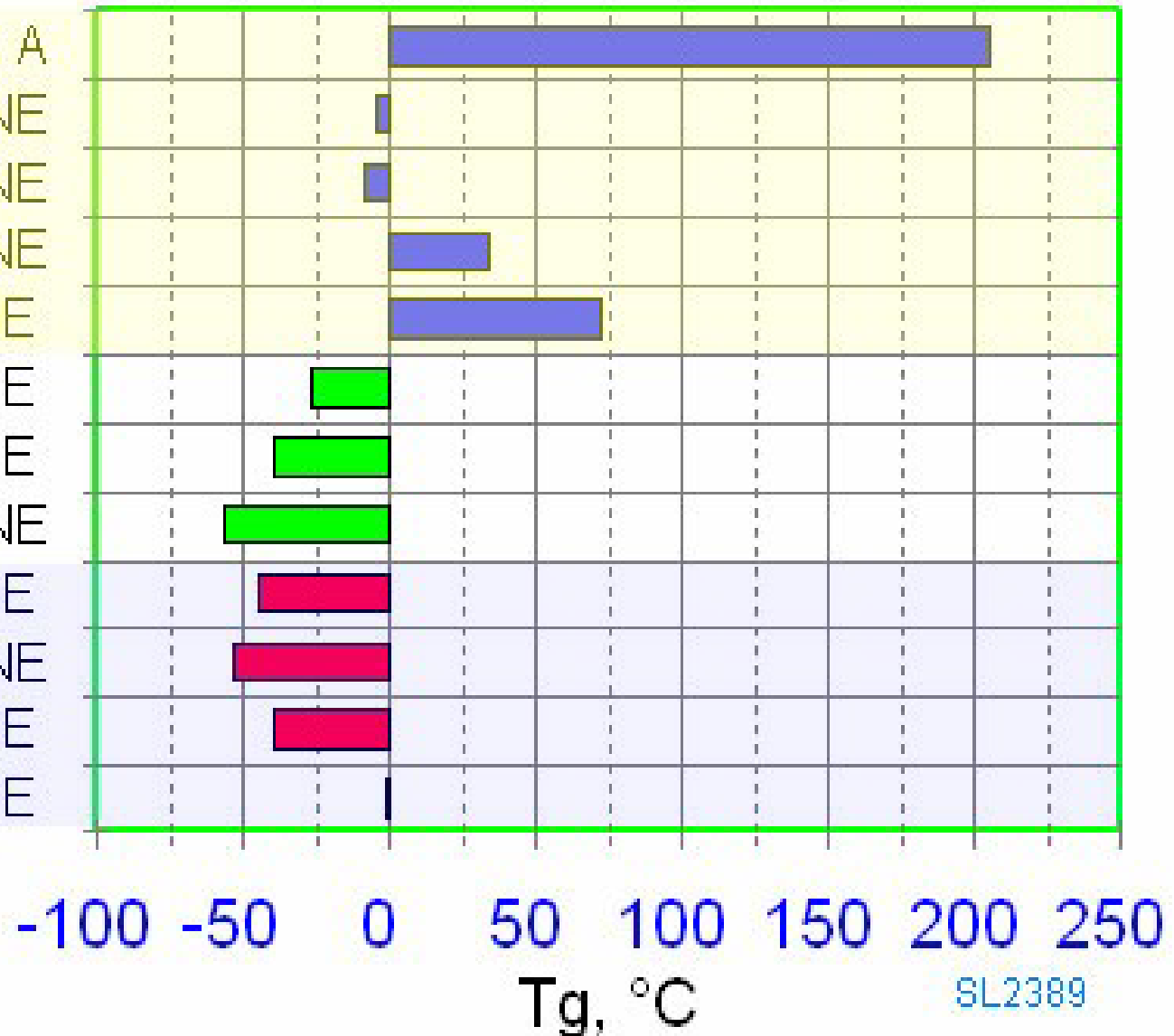
Tg of POLYESTER

TEREPHTHALIC

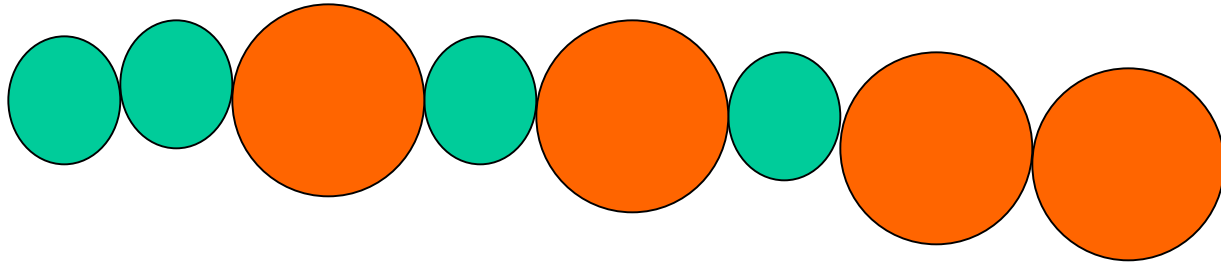
SEBACIC

SUCCINIC

BISPHENOL A
1,10-DODECANE
1,6-HEXANE
1,4-BUTANE
1,2-ETHYLENE
1,4-BUTYNE
1,4-BUTENE
1,4-BUTANE
1,7-HEPTANE
1,6-HEXANE
1,4-BUTANE
1,2-ETHYLENE



Tg of copolymer



$$\frac{1}{T_g} = \frac{W_1}{T_{g1}} + \frac{W_2}{T_{g2}} + \frac{W_n}{T_{gn}}$$

W_n = weight fraction

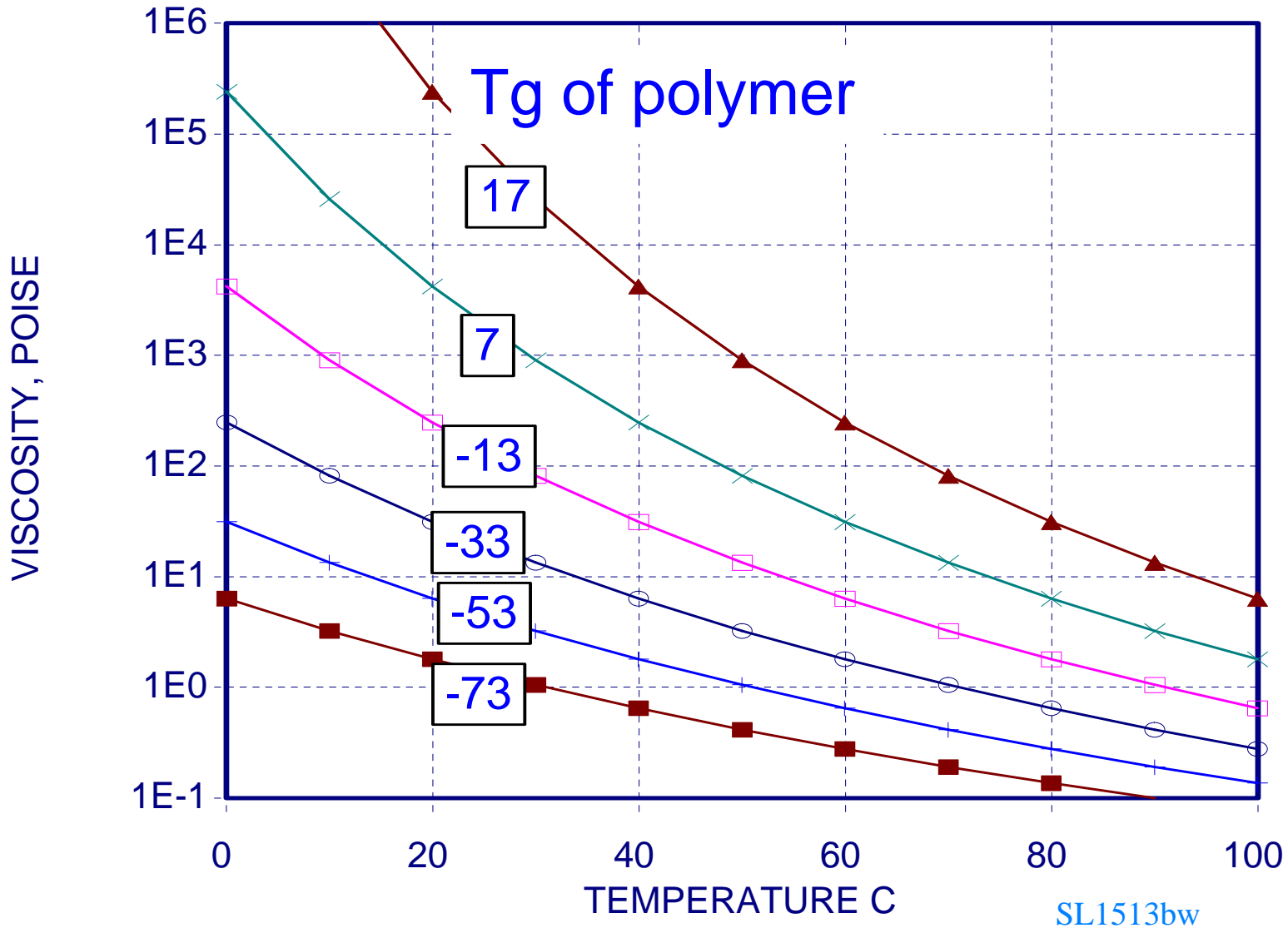
WLF Equation

$$\log \eta_T = 13 - \frac{17.44(T-T_g)}{51.6+(T-T_g)}$$

η = Poise

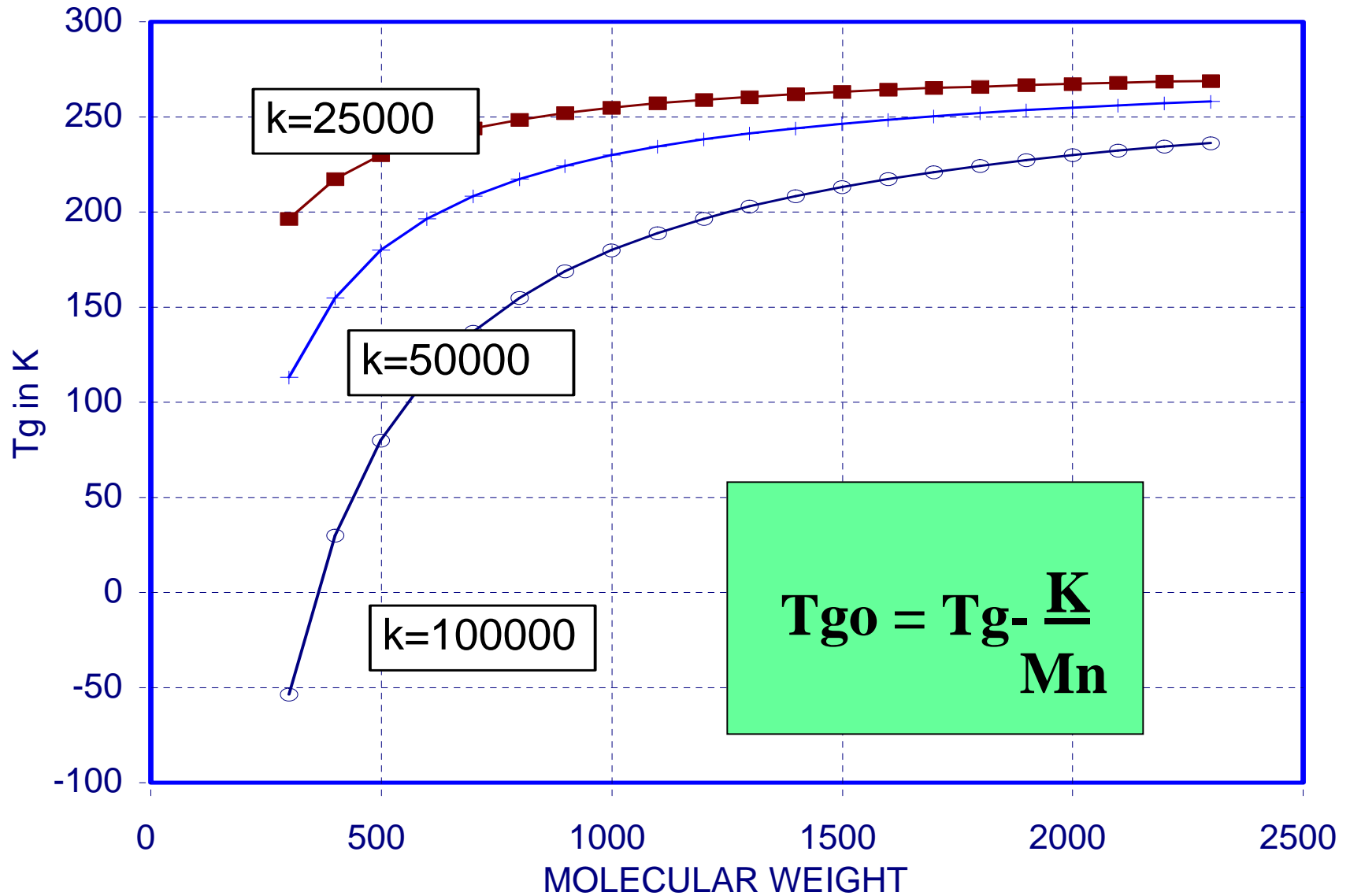
T, T_g = °K or °C

VISCOSITY as a FUNCTION OF Tg WILLIAMS,LANDEL,FERRY EQUATION



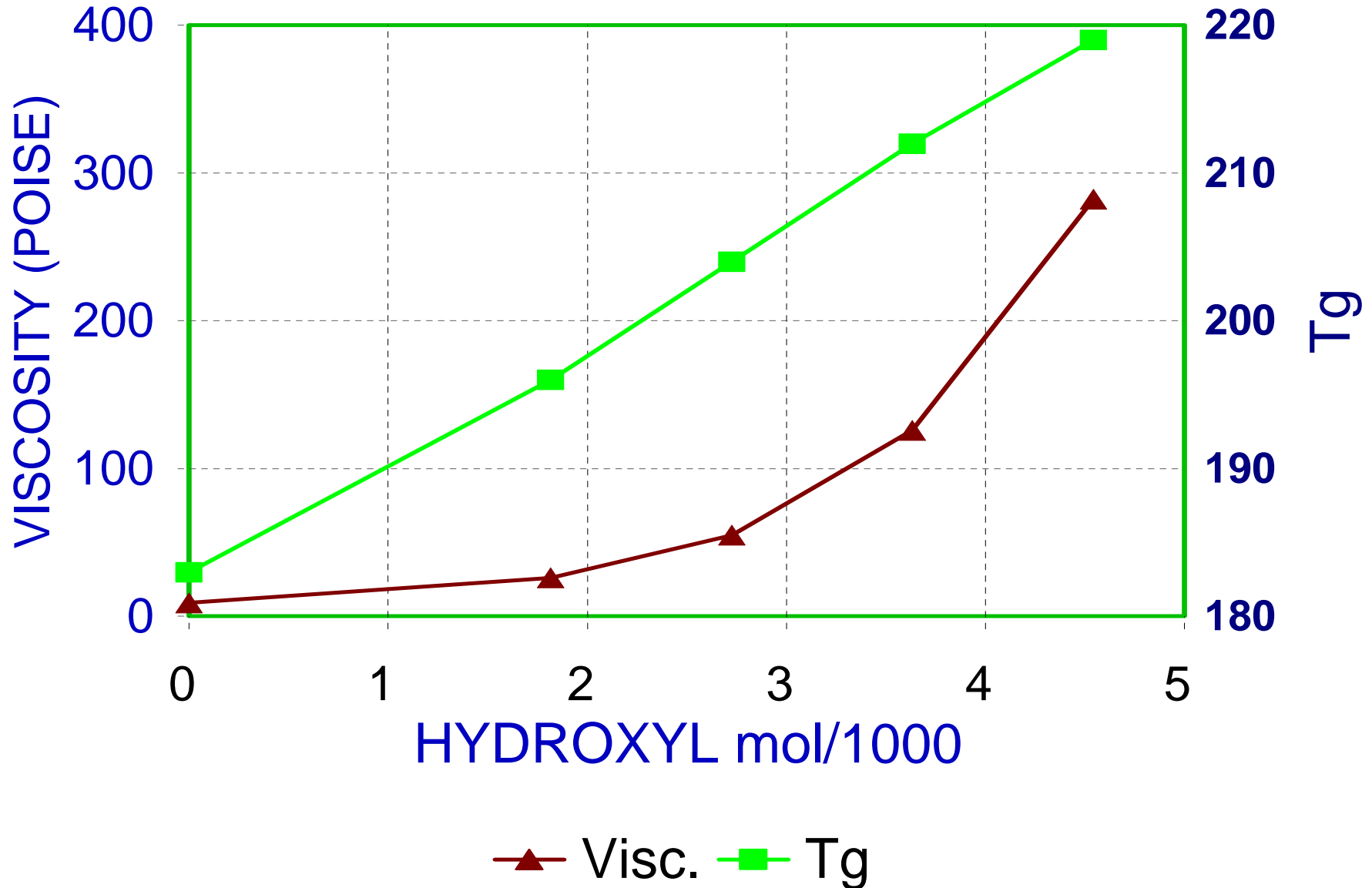
SL1513bw

Tg vs MOLECULAR WEIGHT OF OLIGOMERS



VISCOSITY vs. HYDROXYL CONTENT

NPG/TMP/DIBASIC ACID



WLF Equation

$$\log \eta_T = 13 - \frac{17.44(T-T_g)}{51.6+(T-T_g)}$$

$$T_{g_s} = C_0 - C_1 \times W_s$$

VISCOSITY OF K-FLEX UD-320-100

$$T_{gs} = C_0 - C_1 \times W_s$$

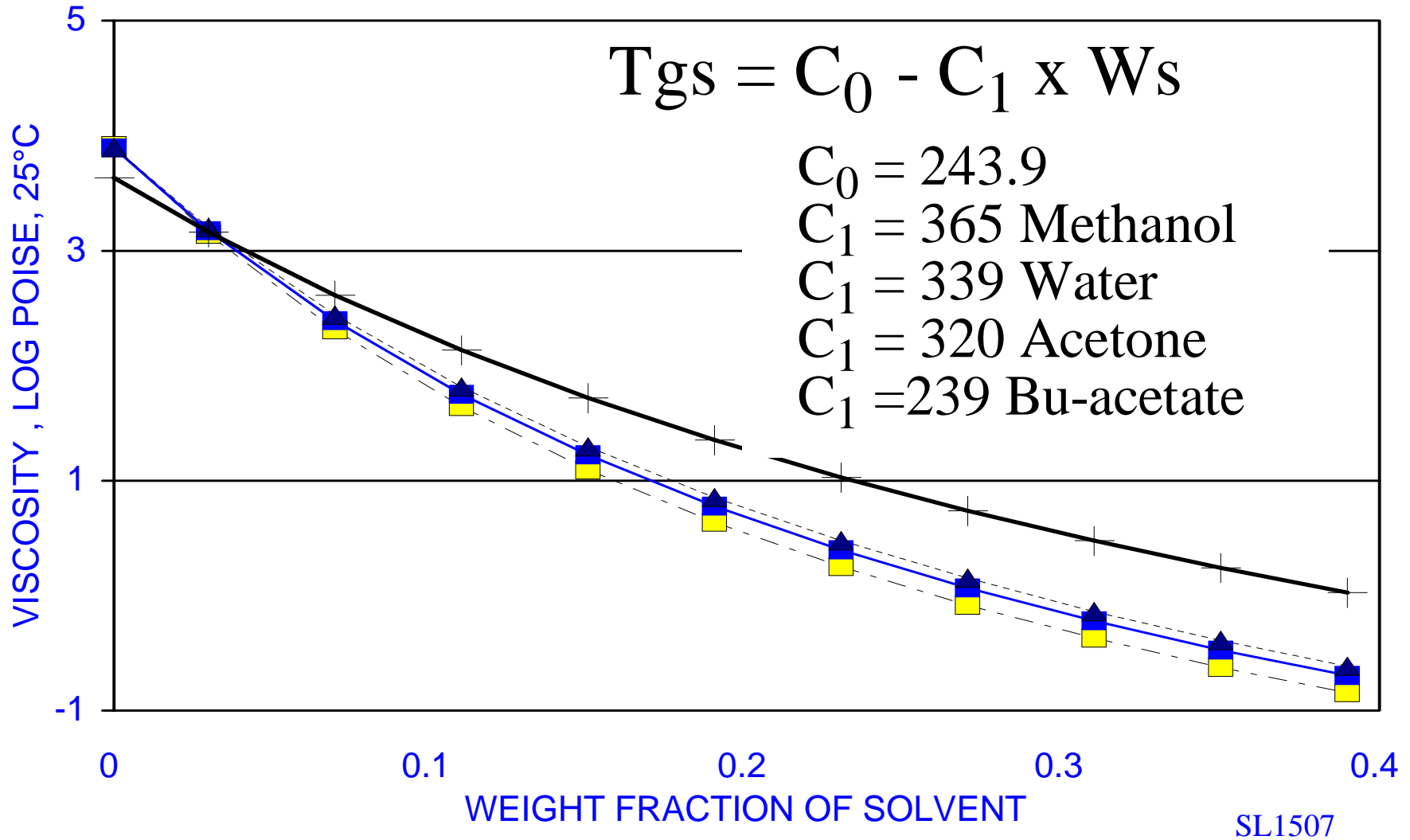
$$C_0 = 243.9$$

$$C_1 = 365 \text{ Methanol}$$

$$C_1 = 339 \text{ Water}$$

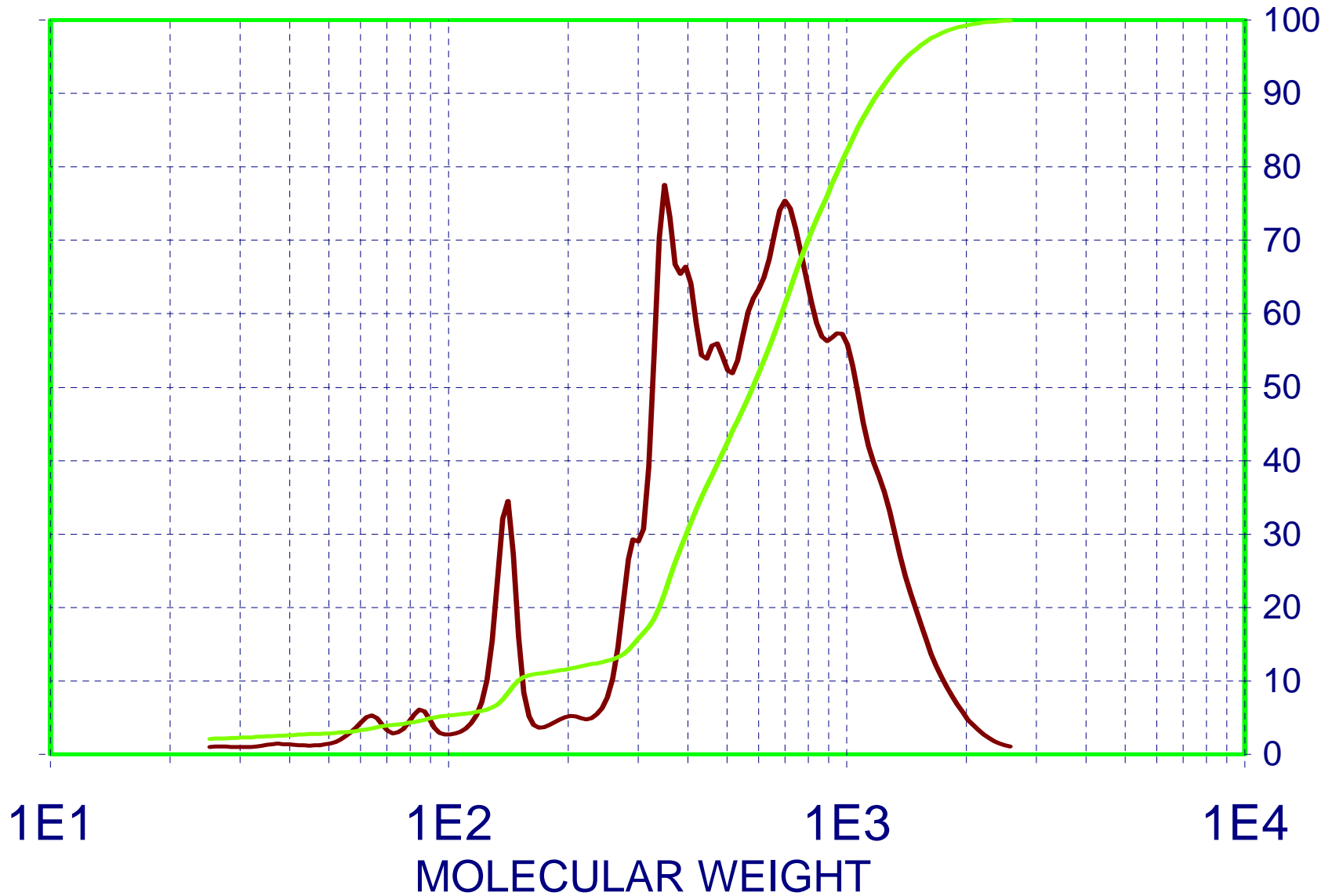
$$C_1 = 320 \text{ Acetone}$$

$$C_1 = 239 \text{ Bu-acetate}$$



—■— METHANOL —■— WATER —▲— ACETONE —+— BU ACETATE

Polyurethane polyol



Viscosity and MW

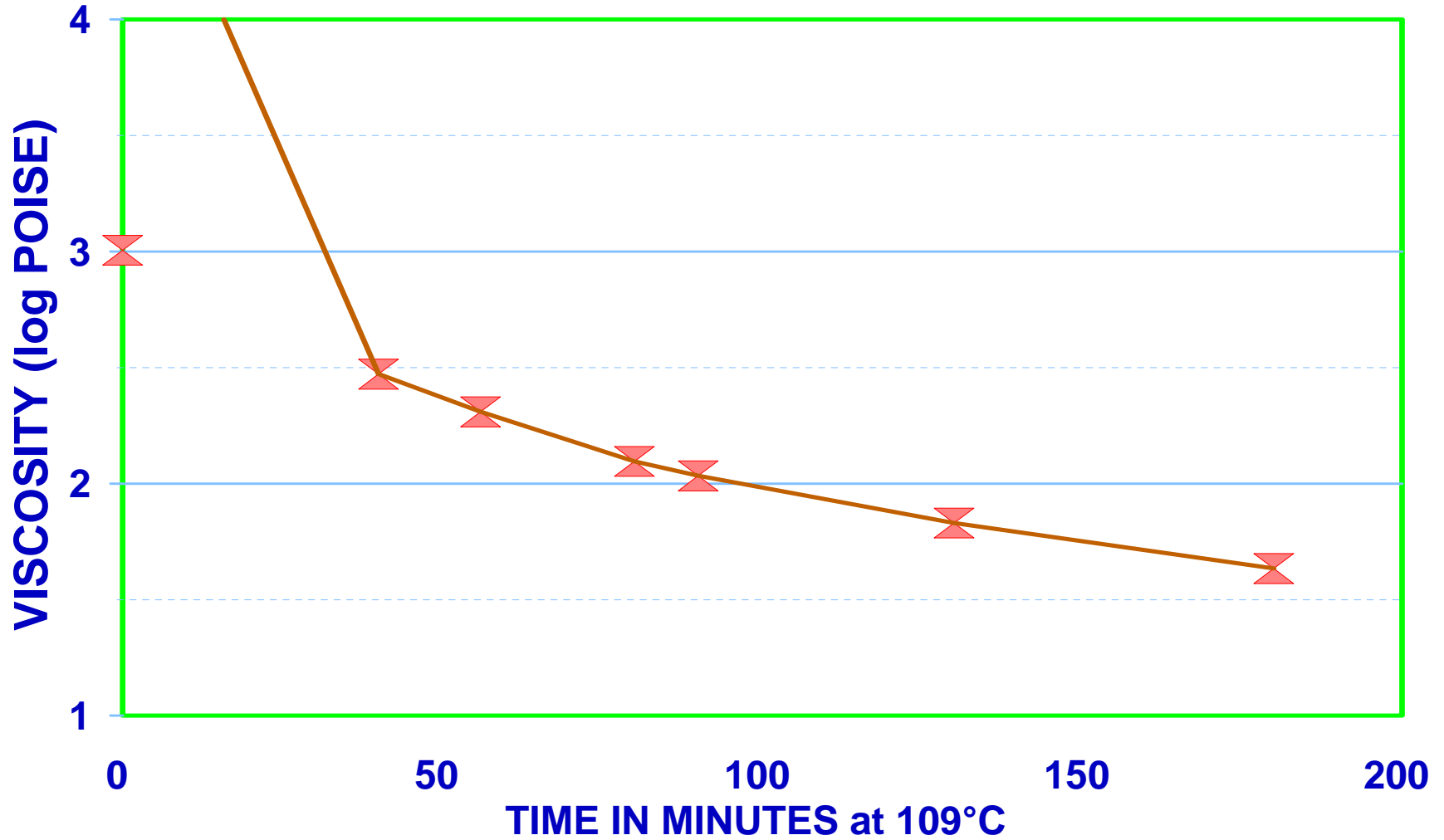
$$\log \eta = A + C \times M_w^{1/2}$$

Number average chain length

P.J.Flory J.Am.Chem..Soc., 62, 1057 (1940)

VISCOSITY OF POLYESTER BLEND

AT 109°C



— MEASURED DATA POINT

Solubility Parameter

Interaction parameter

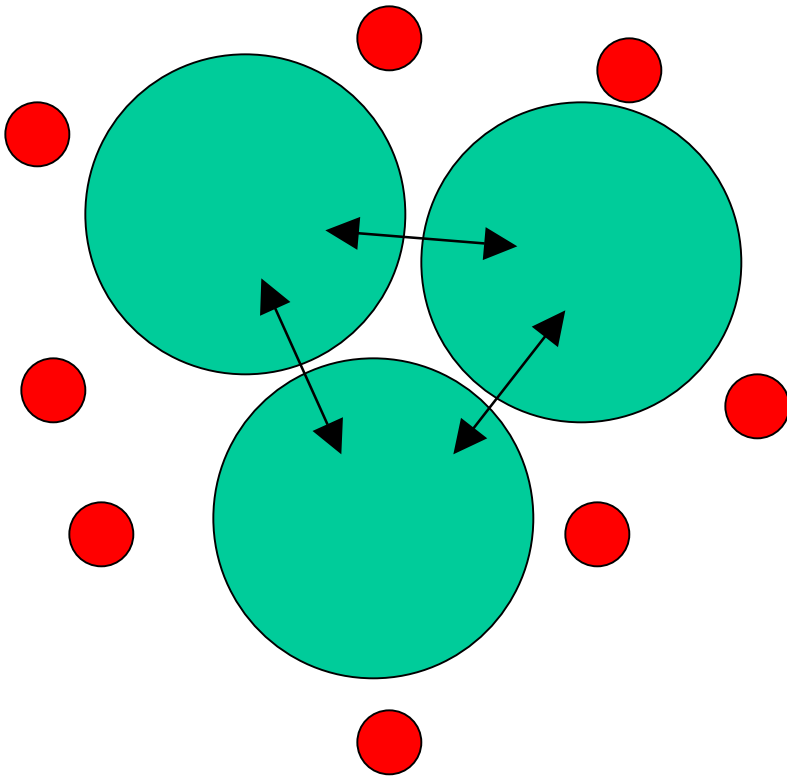
Cohesive energy

Hildebrand, Prausnitz

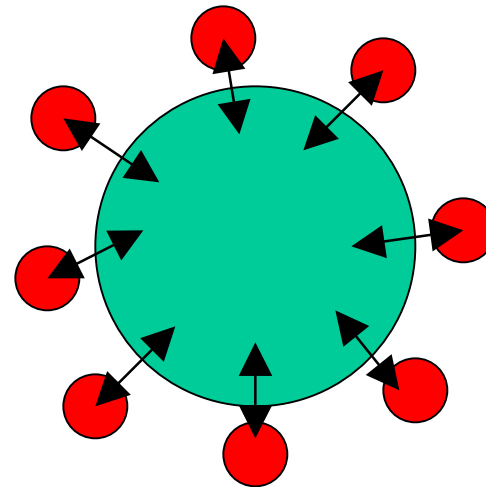
Hansen parameter

$$\delta^2 = \delta_d^2 + \delta_p^2 + \delta_h^2$$

Interaction parameter

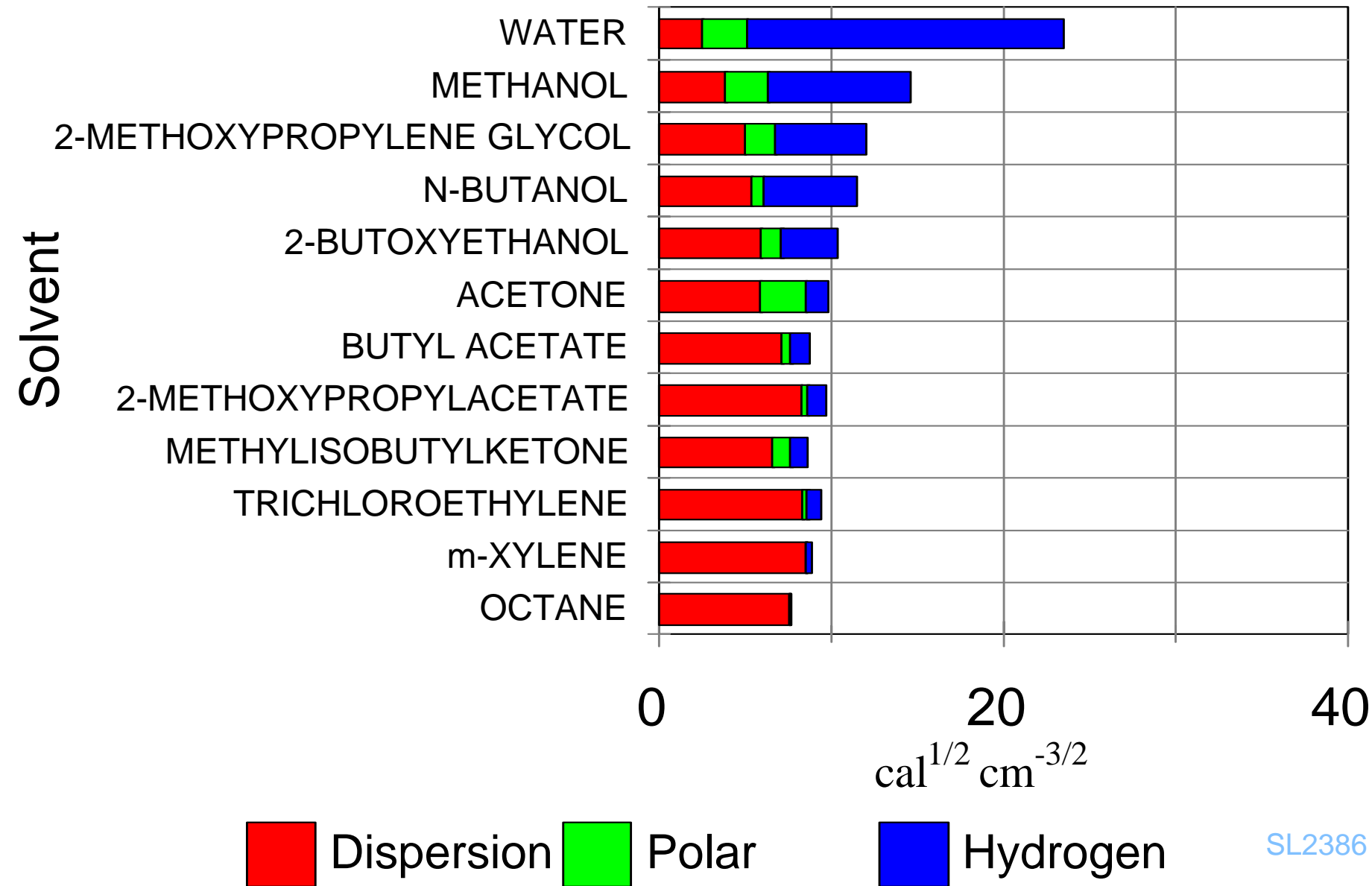


Weak Poly.-Sol.

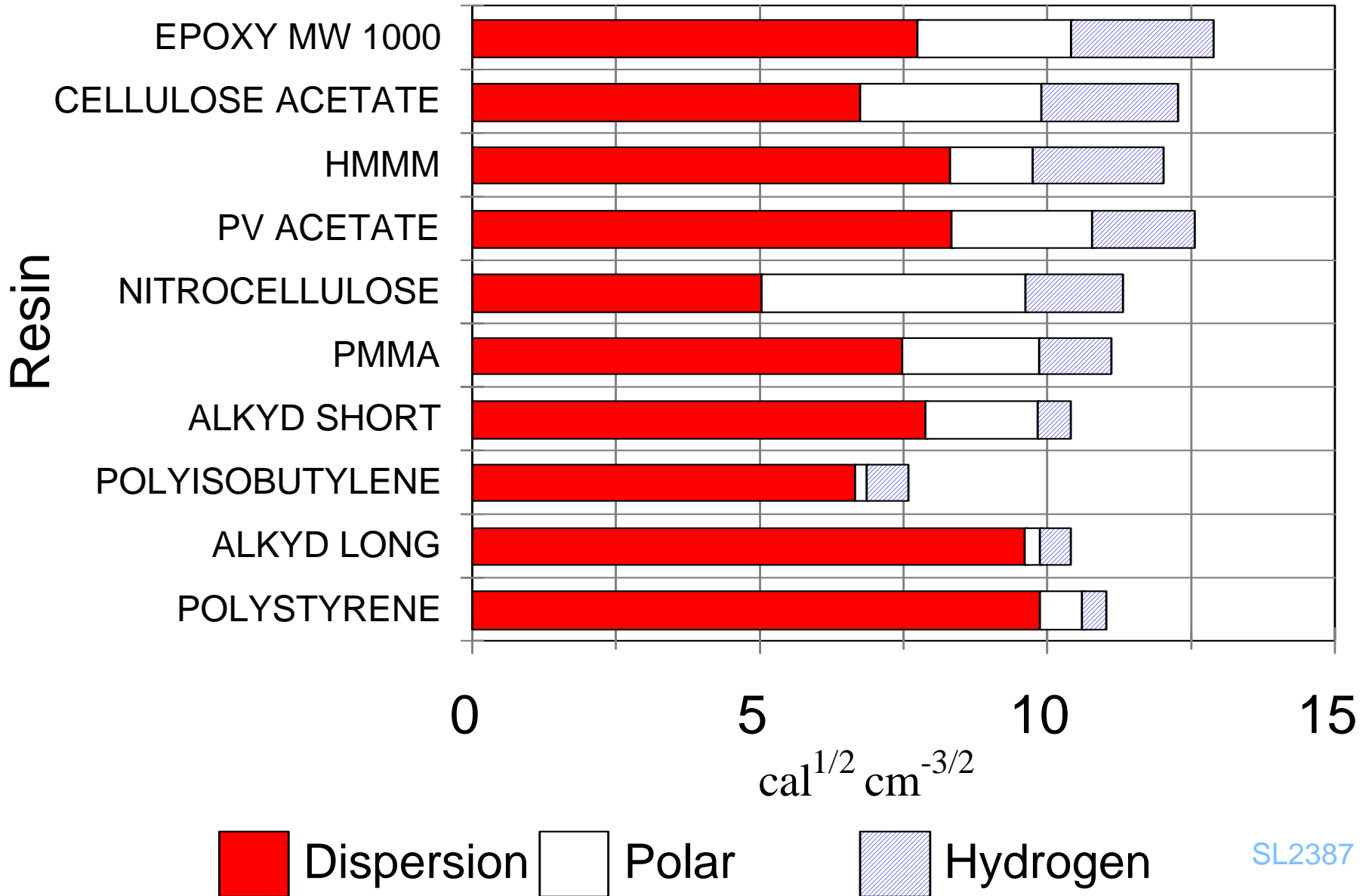


Strong Poly.-Sol.

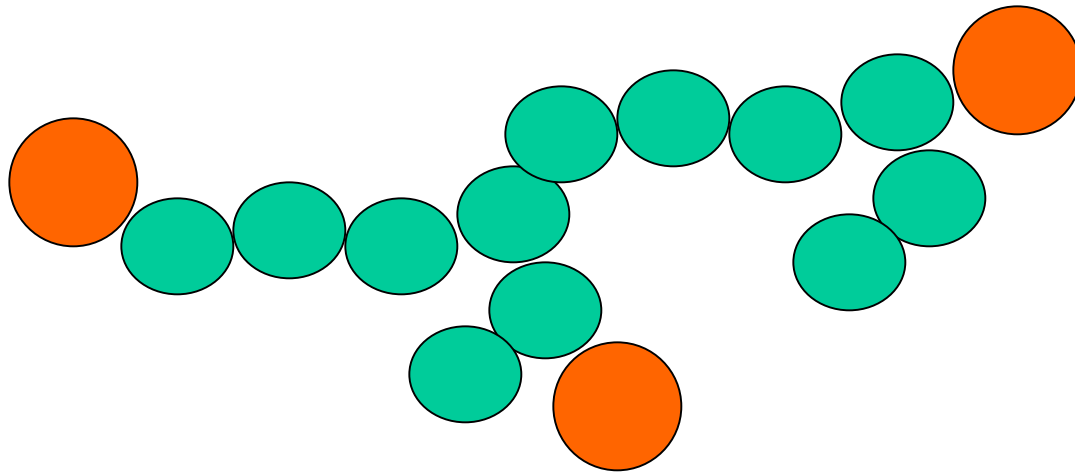
Solubility Parameter



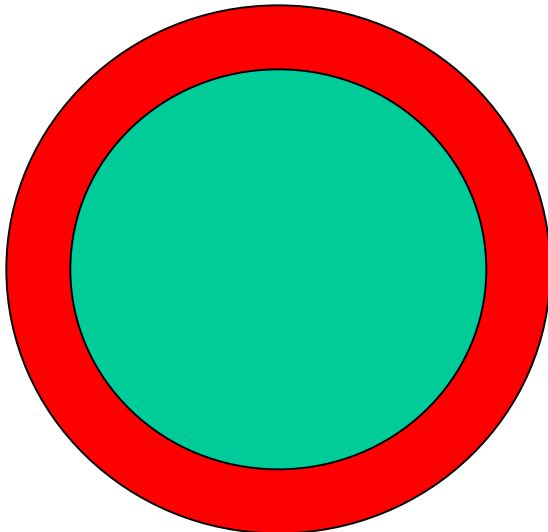
Solubility Parameter



Waterborne Coatings



Soluble

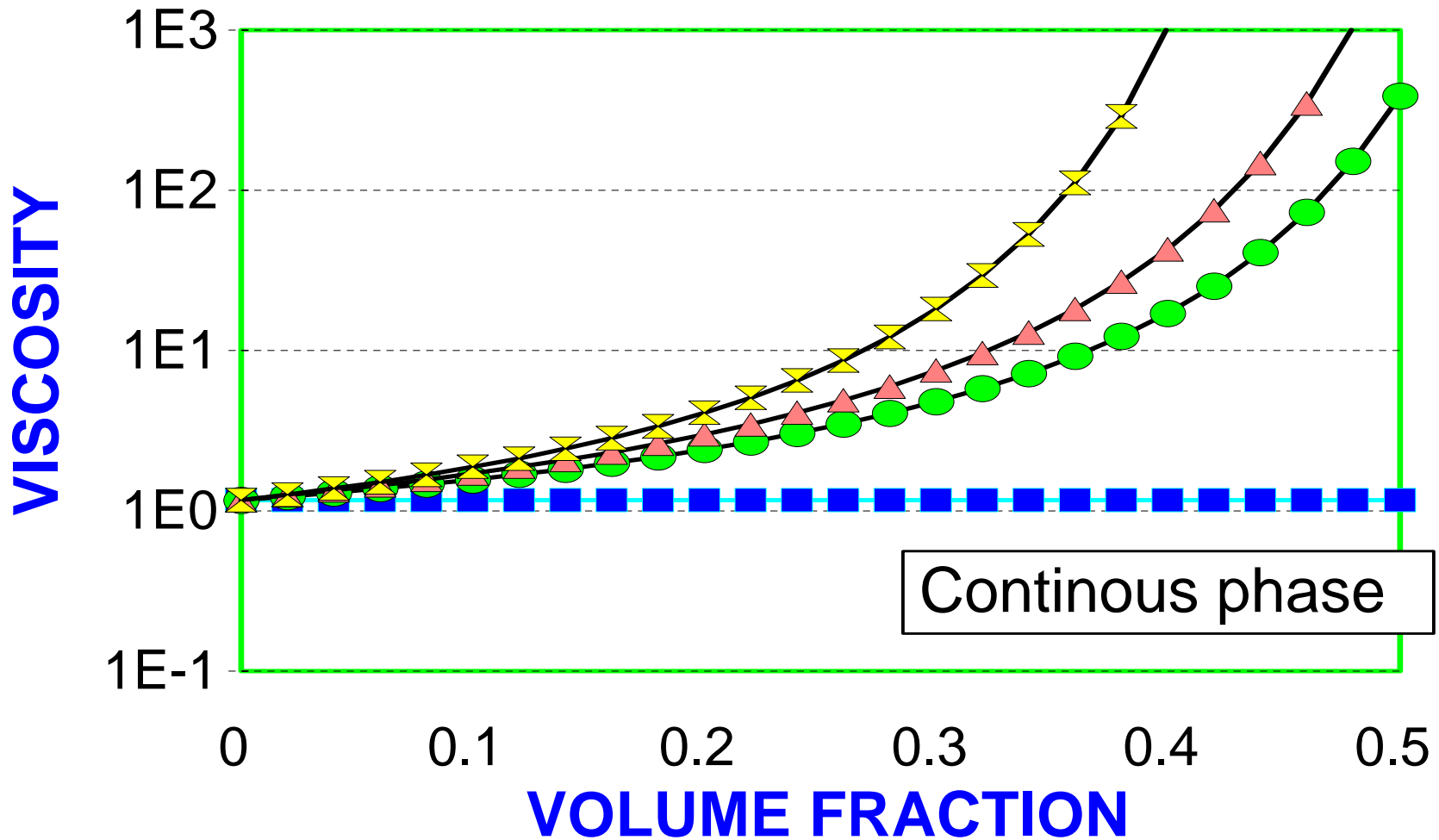


Dispersion

Waterborne coatings

| | Acid number | Appearance |
|------------|-------------|------------|
| Soluble | 50 - 200 | Clear |
| Colloid | 20 - 50 | Turbid |
| Dispersion | 0 - 20 | White |

VISCOSITY OF DISPERSION



—●— SPHERE

—▲— SPH SW

—×— SPH FLOC

Mooney Equation

$$\log \eta = \log \eta_e \frac{k_e V_i}{2.303 (1 - V_i/\theta)}$$

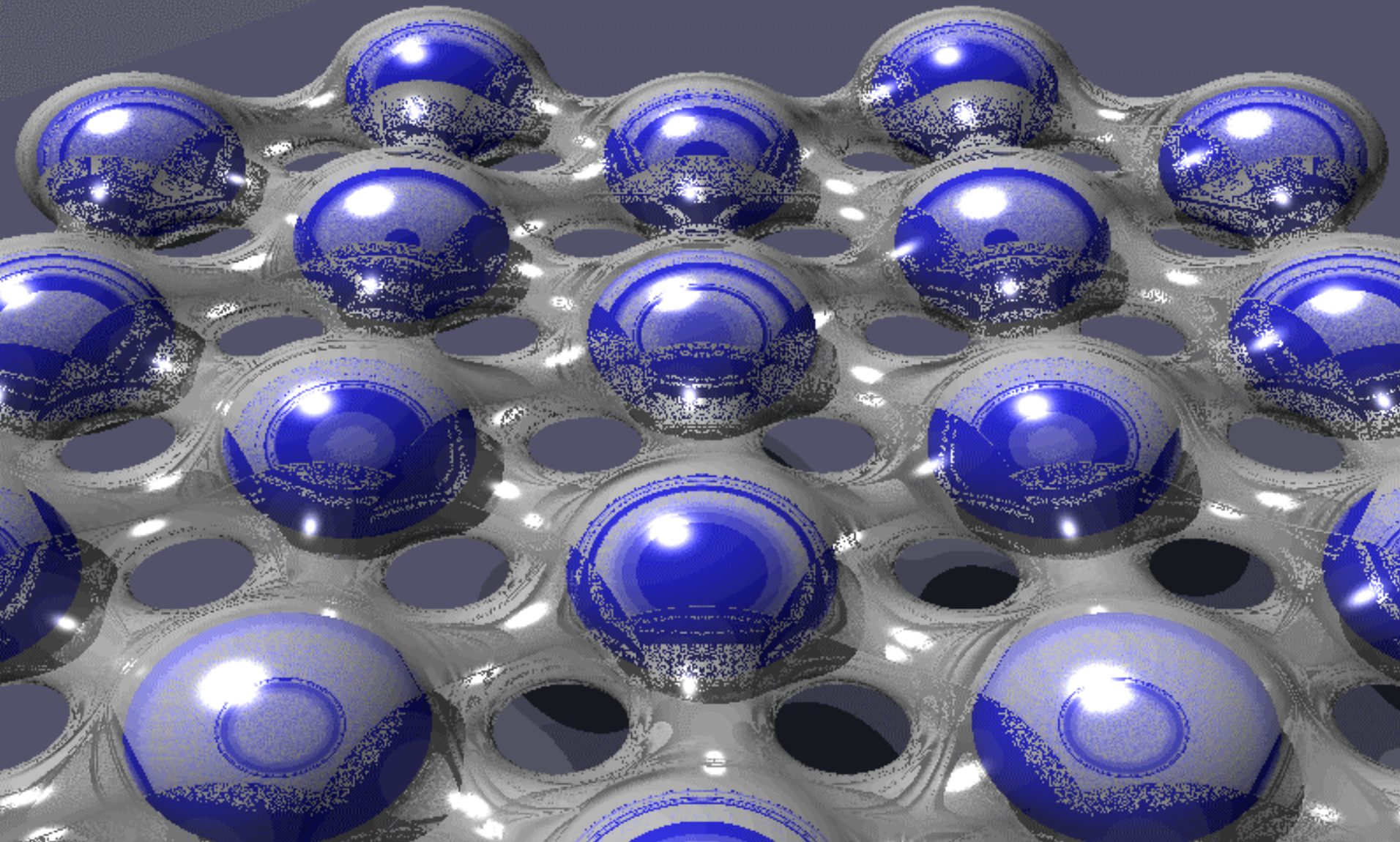
η_e = viscosity of medium

k_e = shape constant (2.5)

θ = packing factor

V_i = volume fraction

Coalescence



Crosslinking Creation of networks

+

-

solvent resistance

elongation

hardness

flexibility

chemical resistance

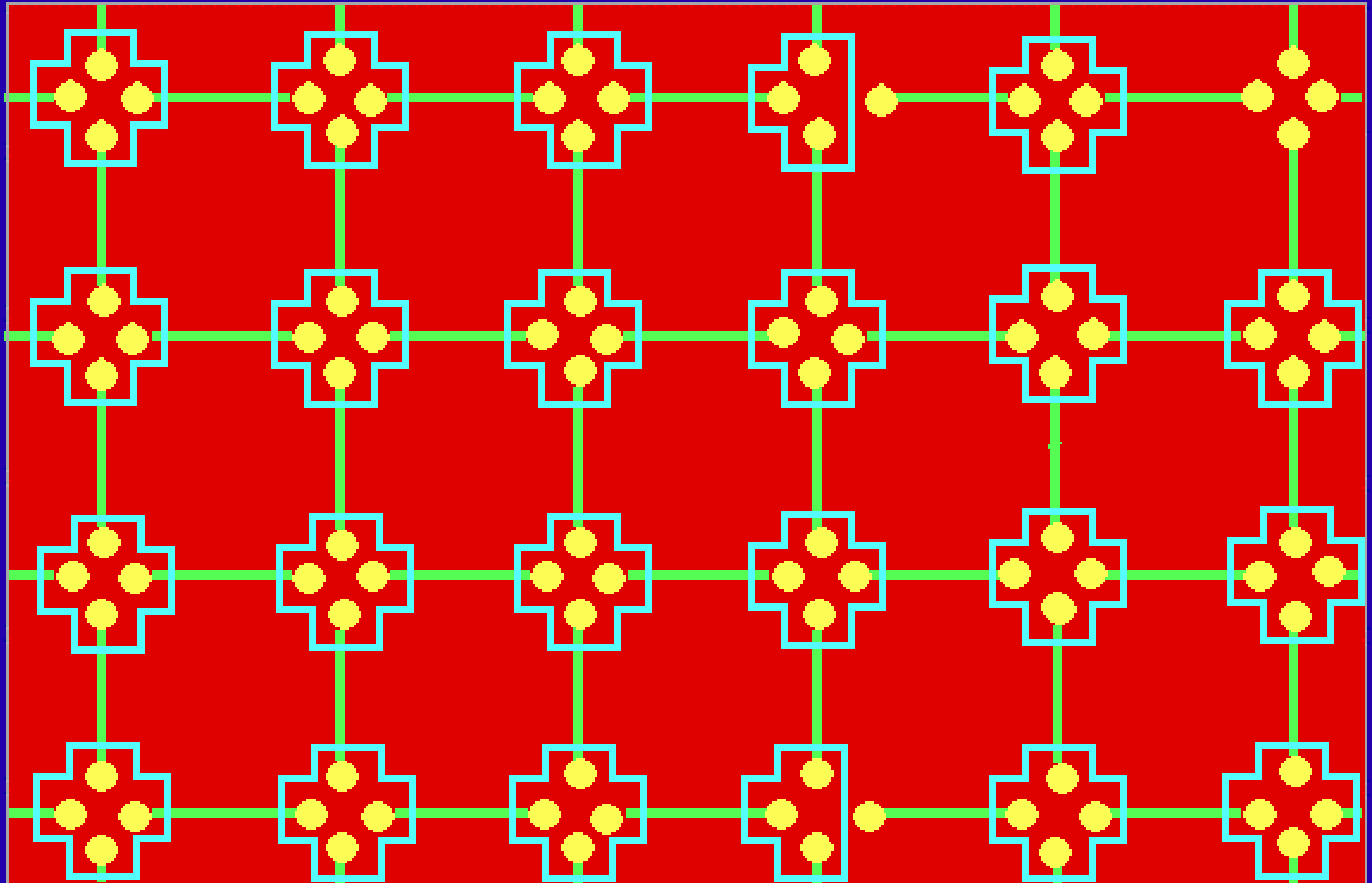
durability

flexibility

T_g

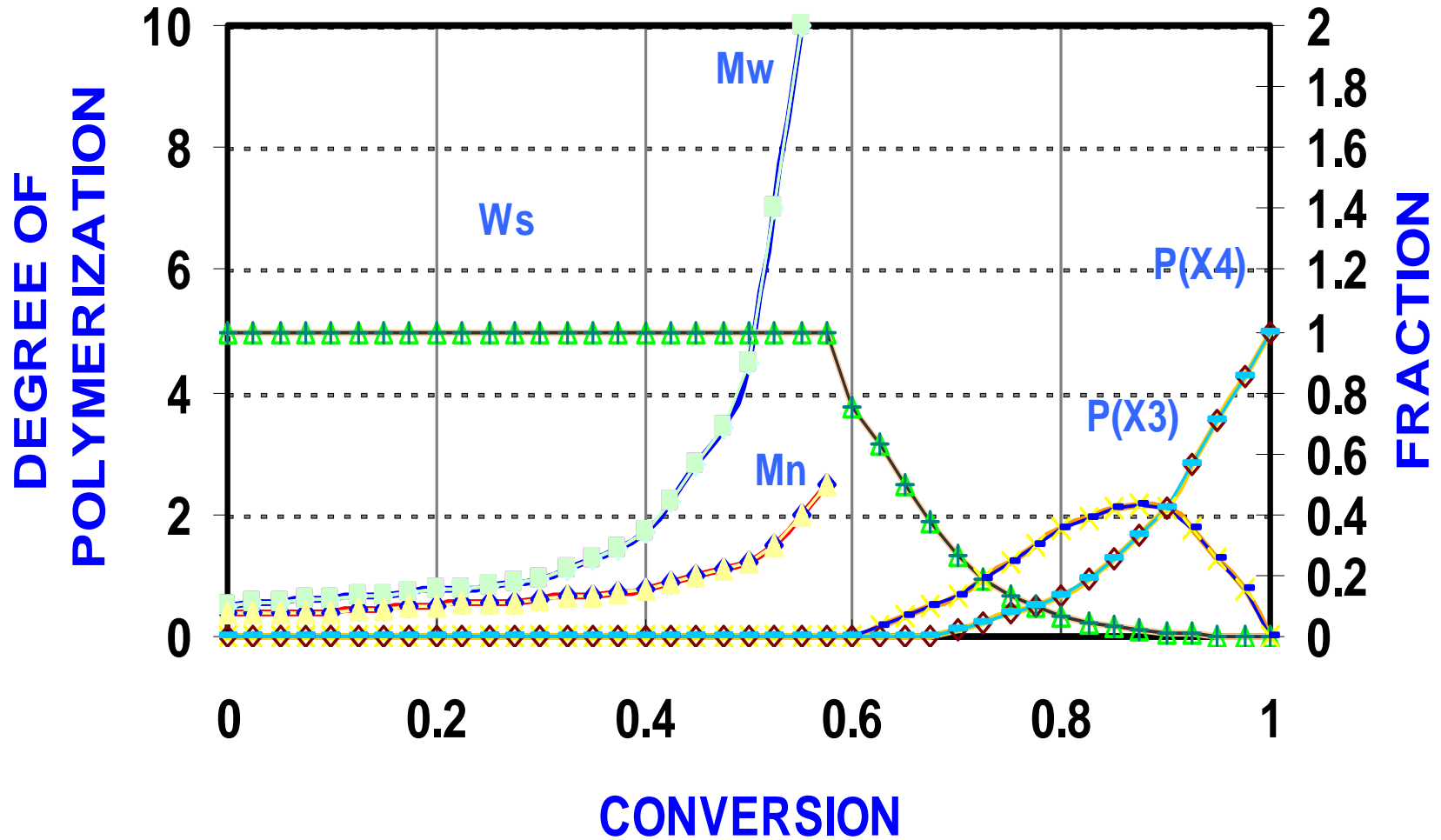
CROSSLINKED NETWORK

TETRAFUNCTIONAL CROSSLINKER



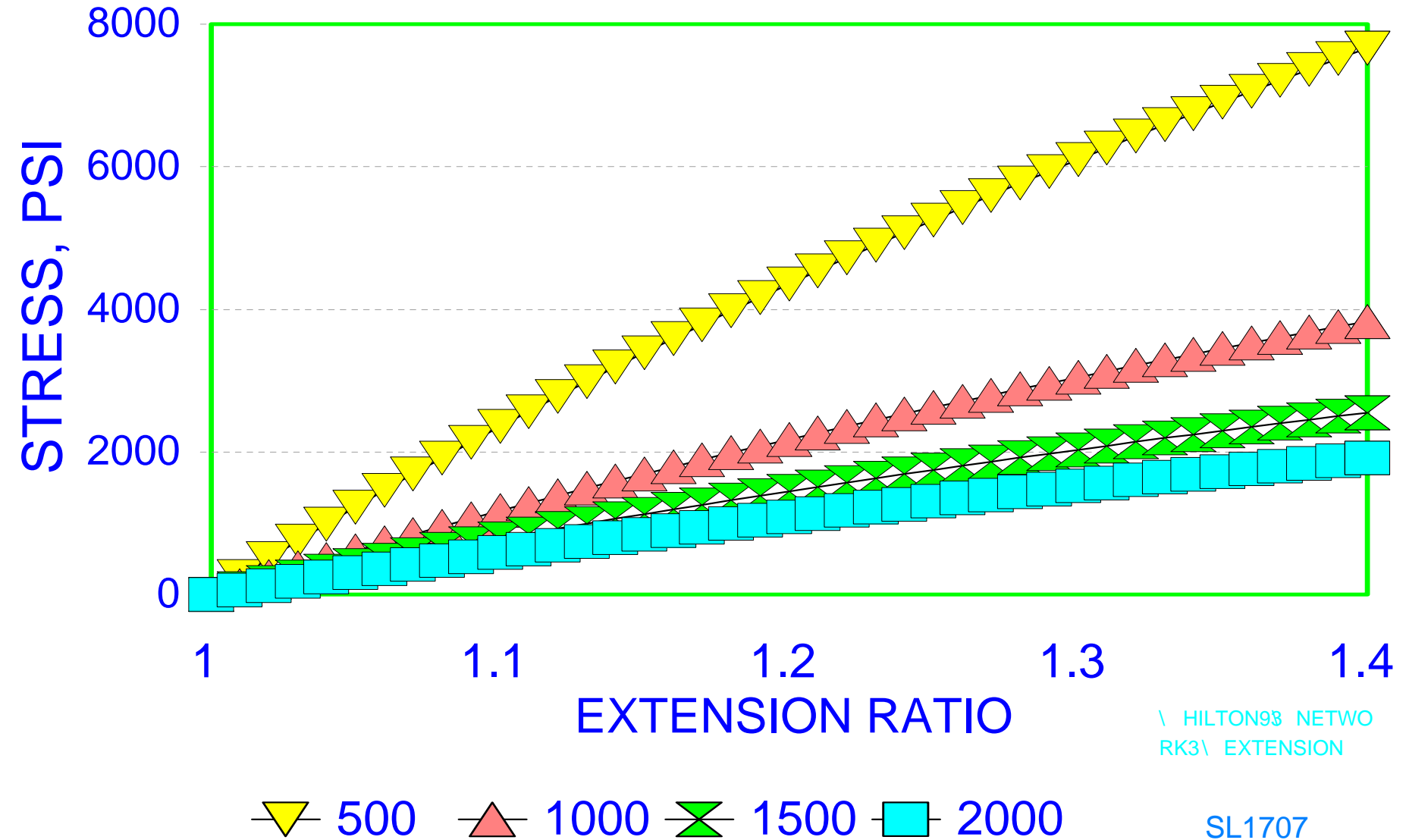
NETWORK FORMATION

A4 + B2



STRESS-STRAIN

FRONT FACTOR = 1



Flory-Rehner Equation

SWELLING OF POLYMERS

$$-\left[\ln(1 - v_2) + v_2 + x_1 v_2^2\right] = V_1 n [v_2^{1/3} - v_2/2]$$

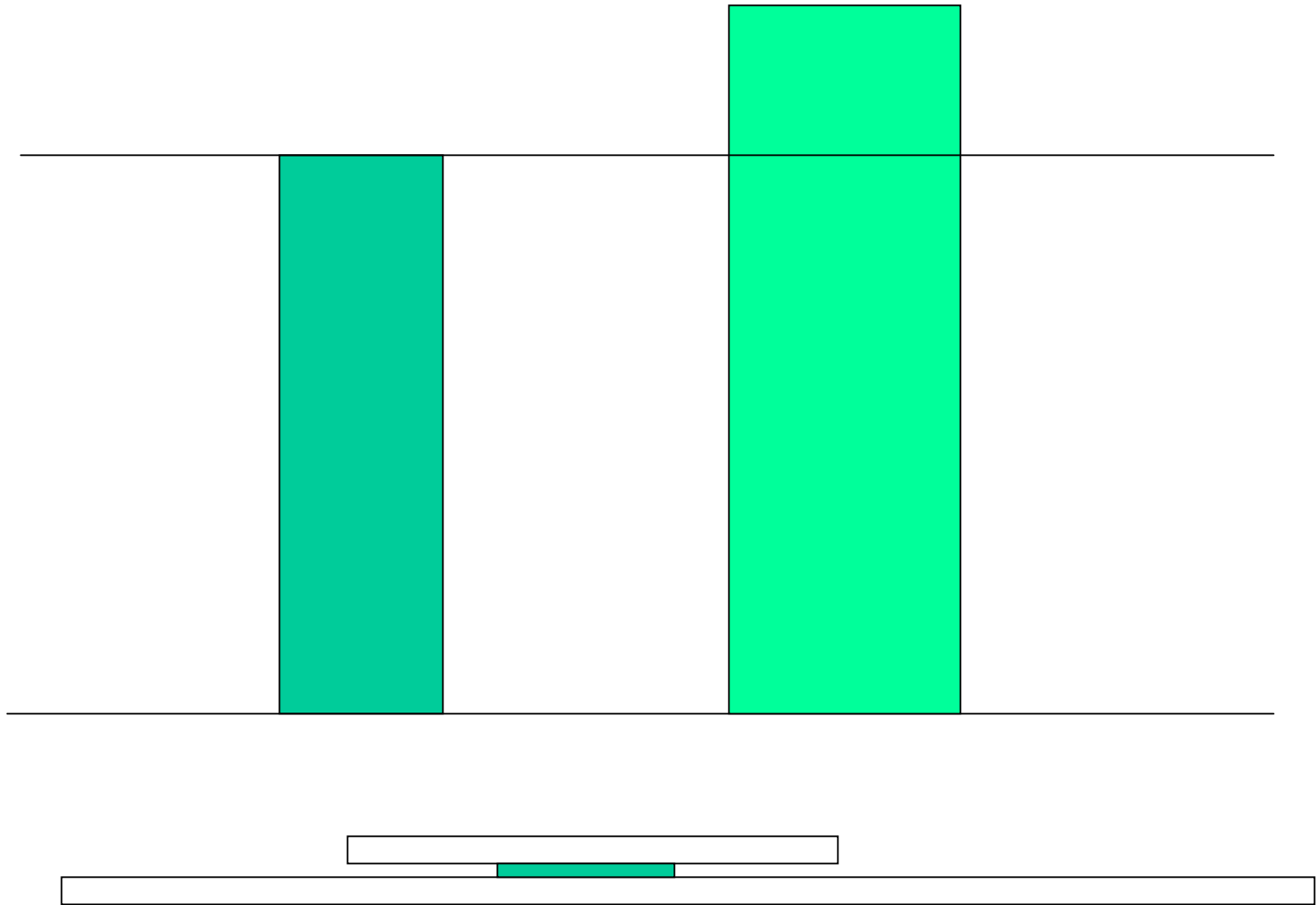
v_2 = Volume fraction of swollen polymer

V_1 = Molar volume of solvent

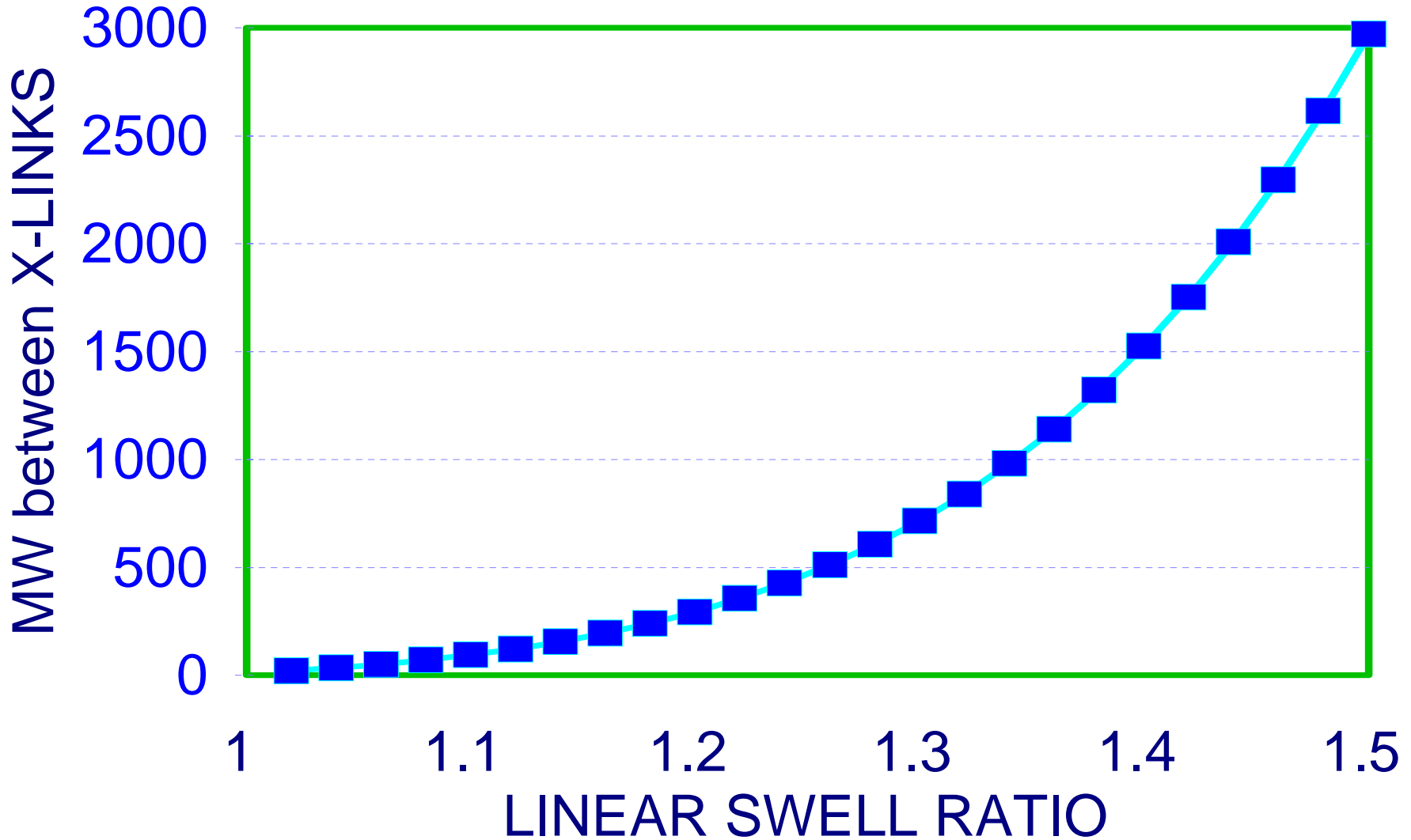
x_1 = Flory-Huggins interaction parameter

n = Number of active chains per volume

SWELL RATIO



SWELL RATIO AND MWxI



HILTON\ SWELCOM1

SL1757

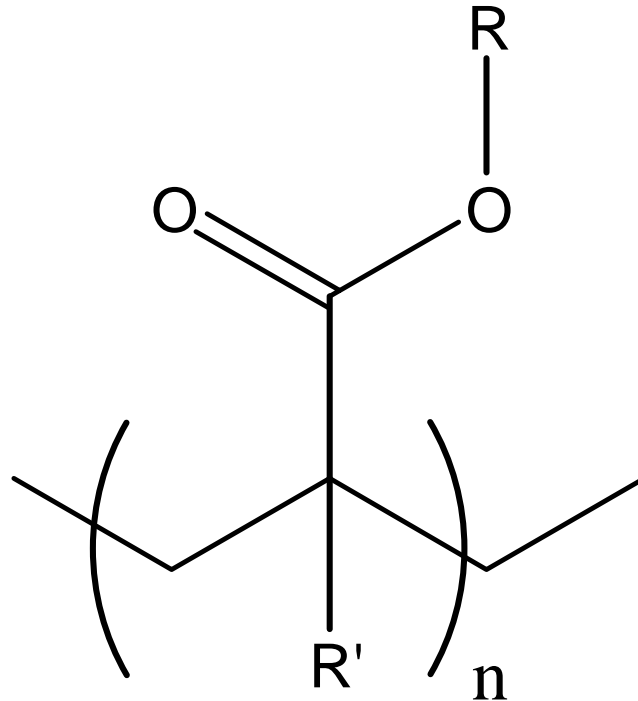
POLYMERS

CHAIN GROWTH FREE RADICALS
ACRYLIC, VINYL

STEP GROWTH CONDENSATION
POLYESTER, ALKYD
EPOXY
MELAMINE

CHAIN GROWTH FREE RADICALS

ACRYLIC, VINYL



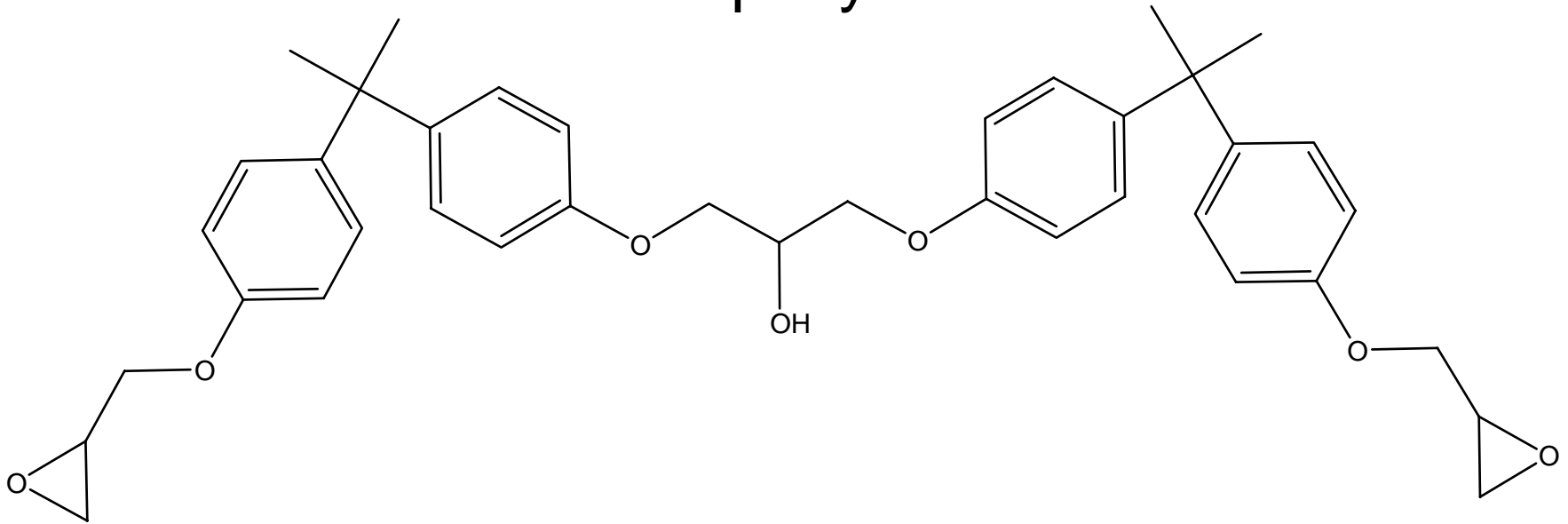
$R = -H, -CH_2CH_2OH, C_1-C_8$

STEP GROWTH CONDENSATION

Polyester



Epoxy



Acknowledgment

King Industries Inc.

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