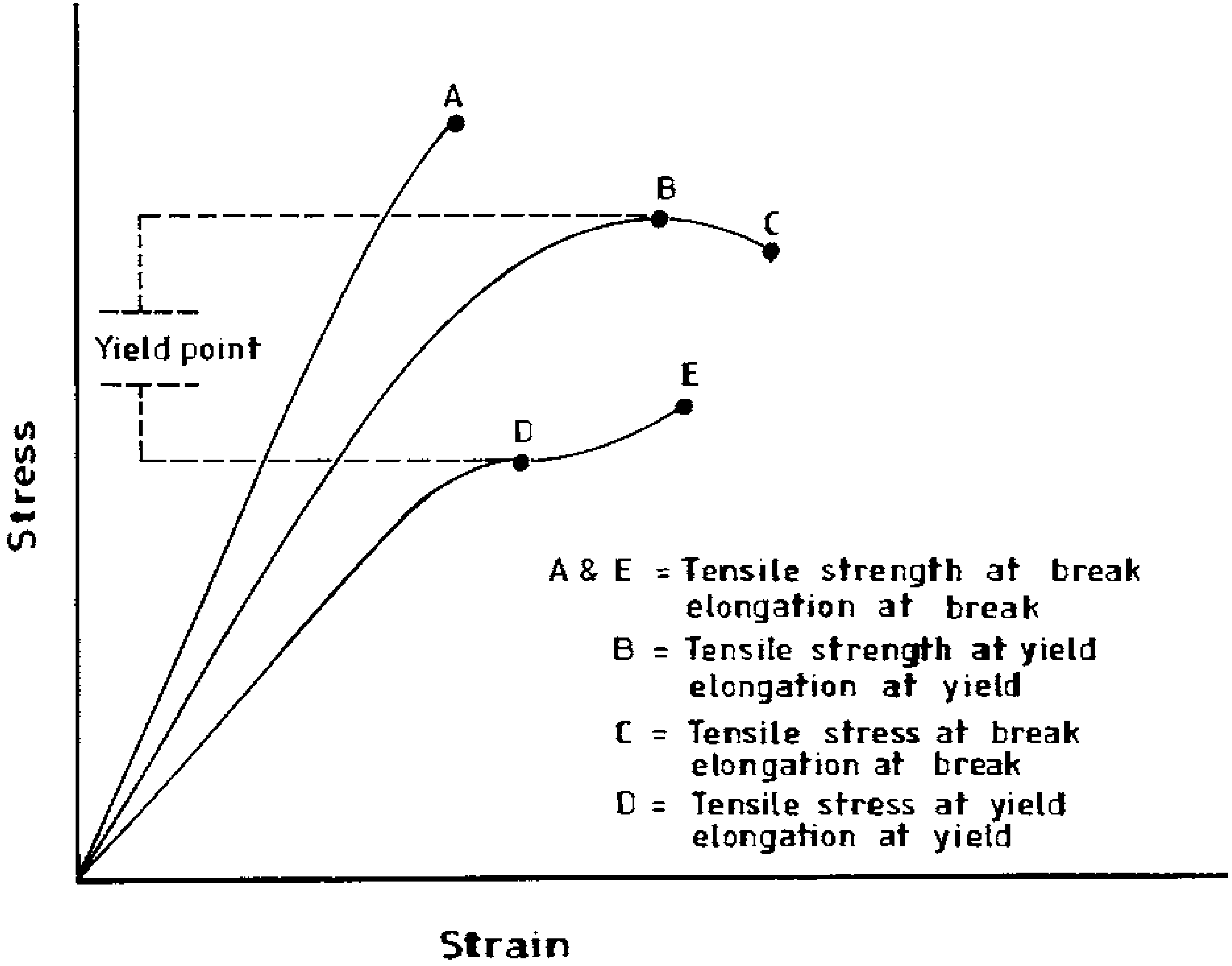
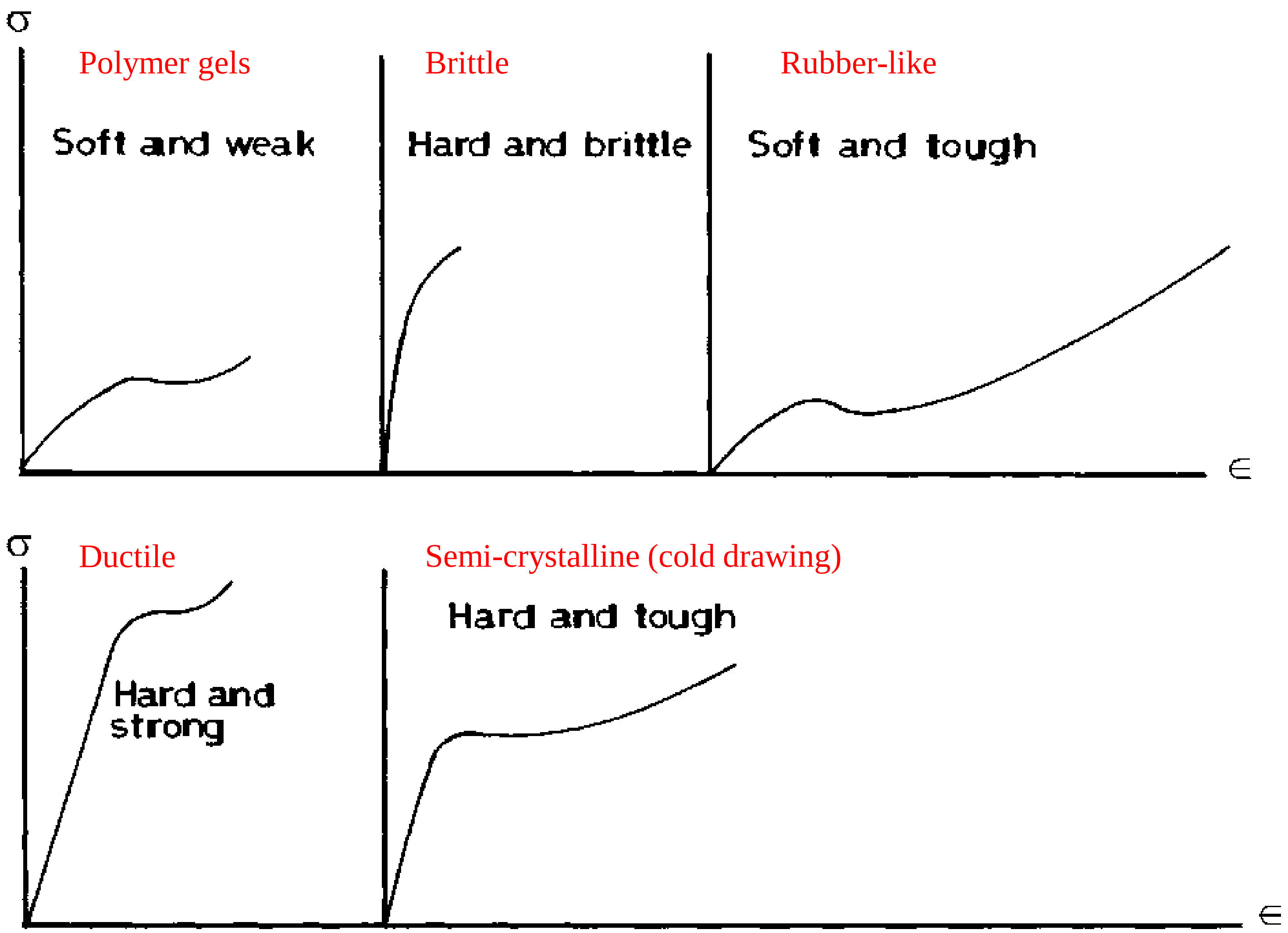
DEFORMATION OF SOLID POLYMERS



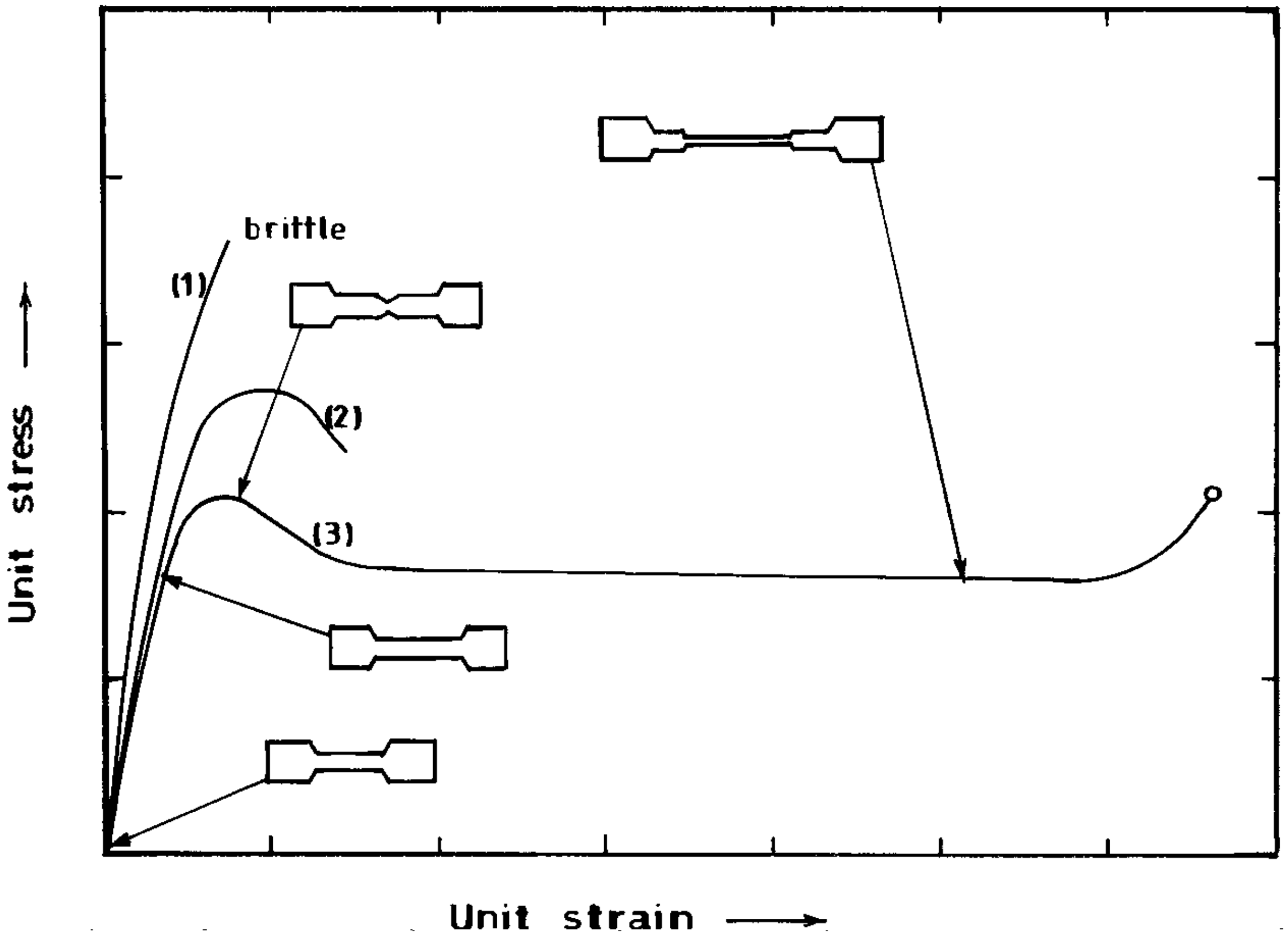
Engineering data from stress–strain tests.

DEFORMATION OF SOLID POLYMERS



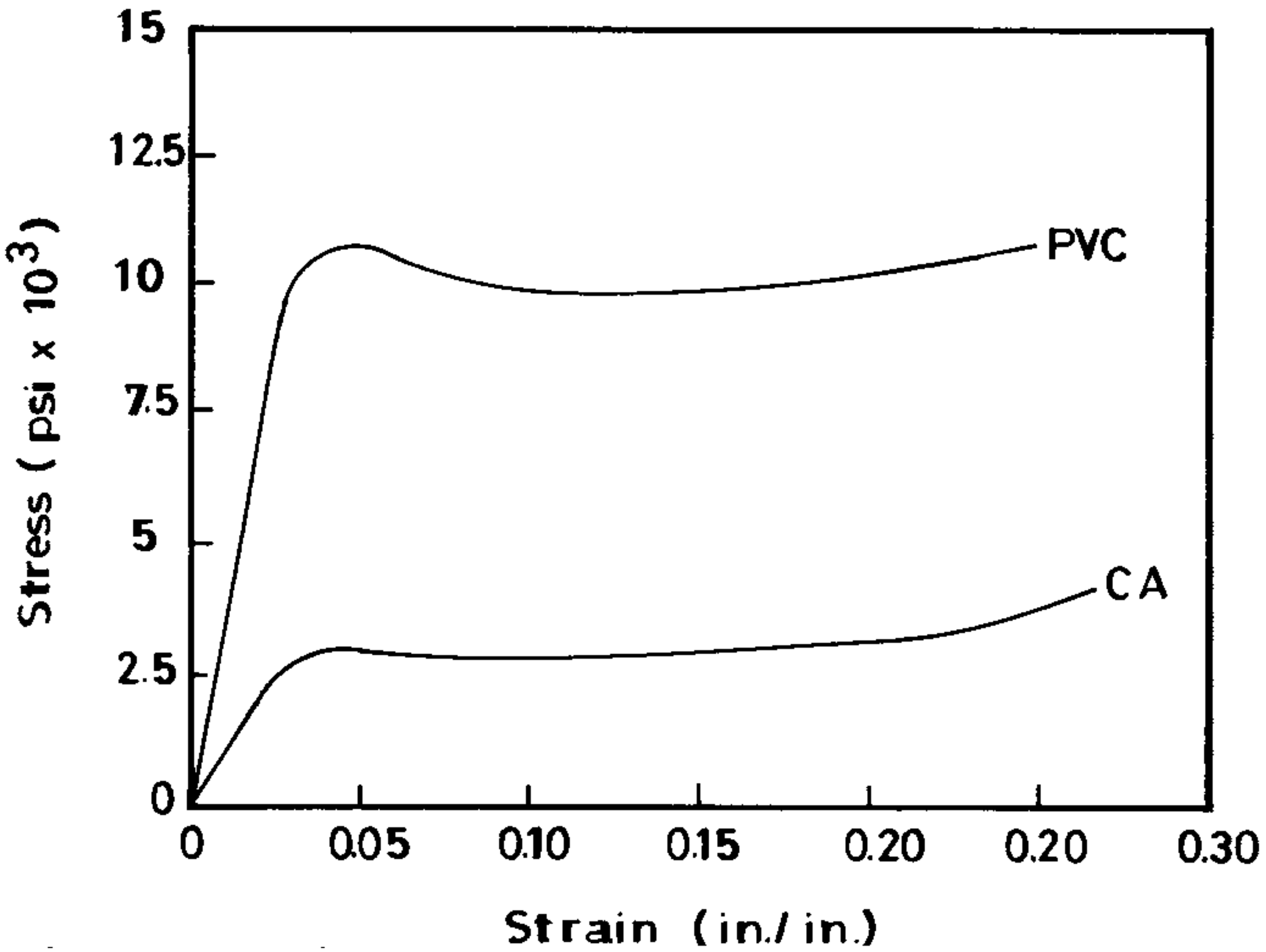
Typical stress–strain curves for polymeric materials.

DEFORMATION OF SOLID POLYMERS



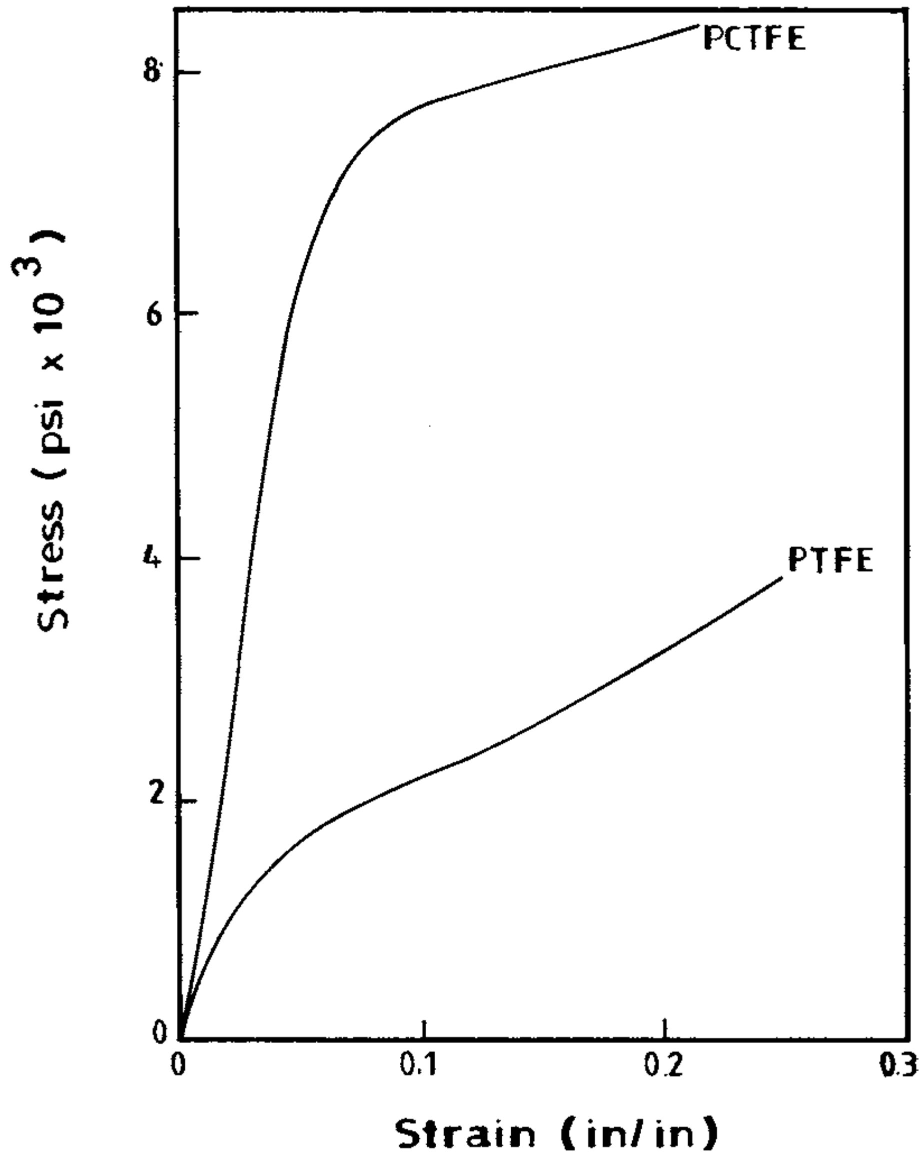
Schematic representation of macroscopic changes in tensile specimen shape during cold drawing.

COMPRESSION VS. TENSILE TESTS



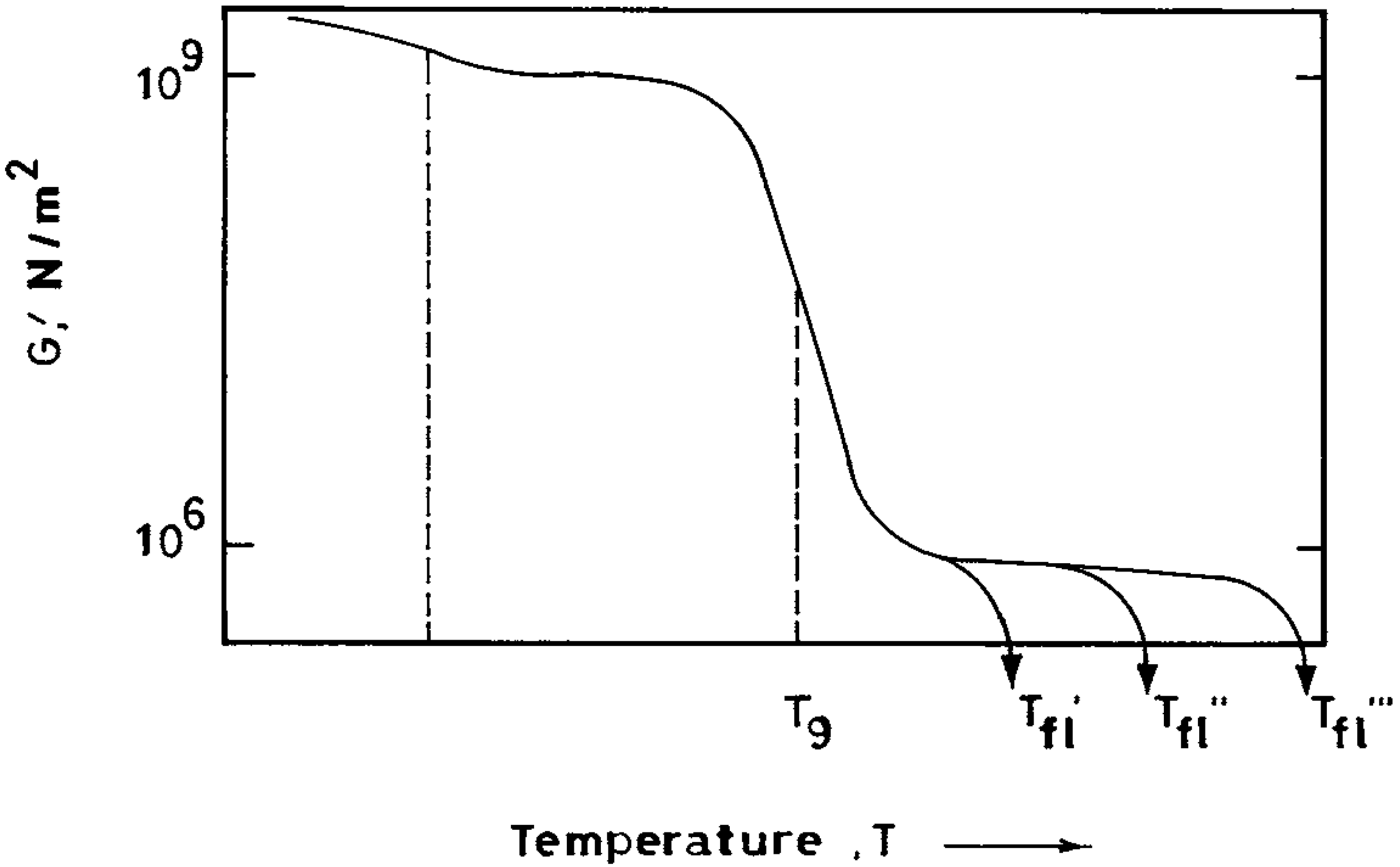
Compressive stress–strain data for two amorphous polymers: polyvinyl chloride (PVC) and cellulose acetate (CA).

COMPRESSION VS. TENSILE TESTS



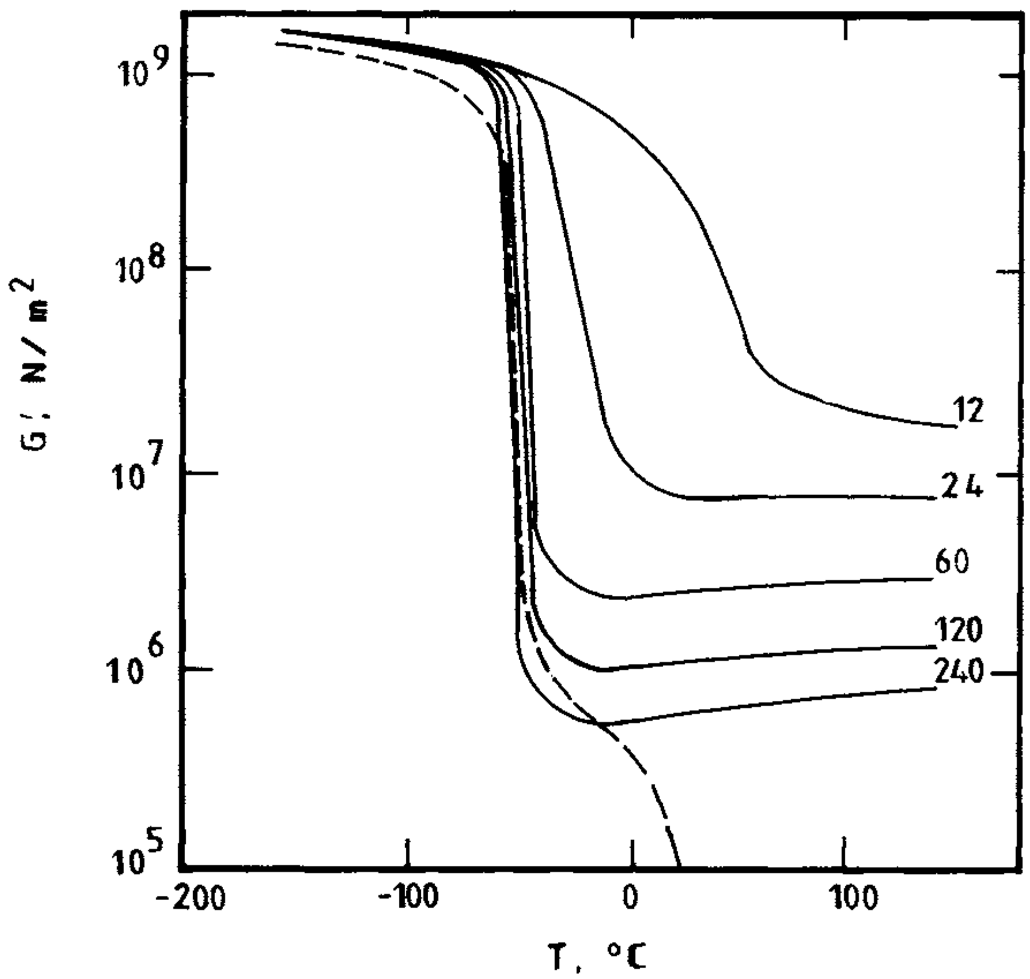
Compressive stress–strain data for two crystalline polymers: polytetrafluoroethylene (PTFE) and polychlorotrifluoroethylene (PCTFE).

Effect of Molecular Weight



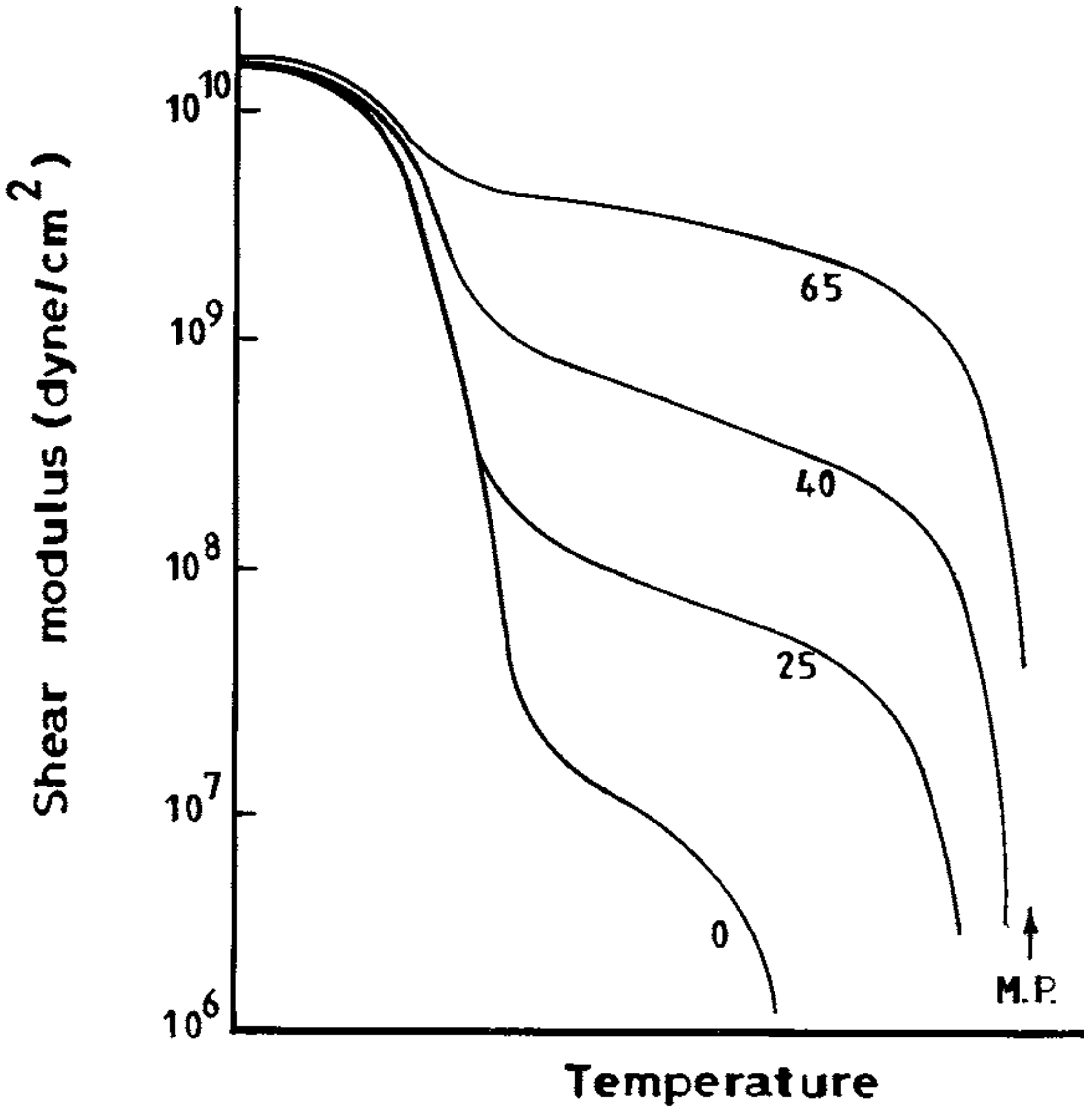
Schematic representation of the effect of molecular weight on shear modulus–temperature curve.
T_g is the glass transition temperature while T_{fl} is the flow temperature. $T_{fl}2$, $T_{fl}3$, T_{fl}- represent low-, medium-, and high-molecular-weight materials, respectively.

Effect of Cross-Linking



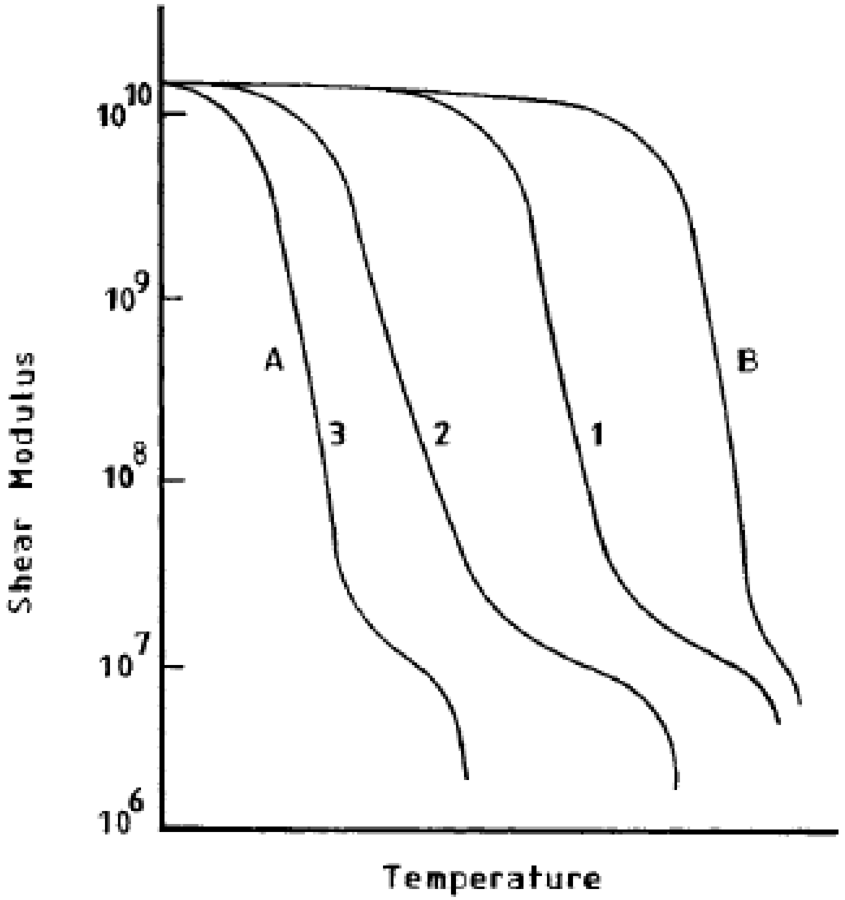
Effect of cross-linking on shear modulus of natural rubber: (———) cross-linked, the approximate mean number of chain atoms between successive cross-links is indicated; (——) noncross-linked.

Effect of Cristallinity



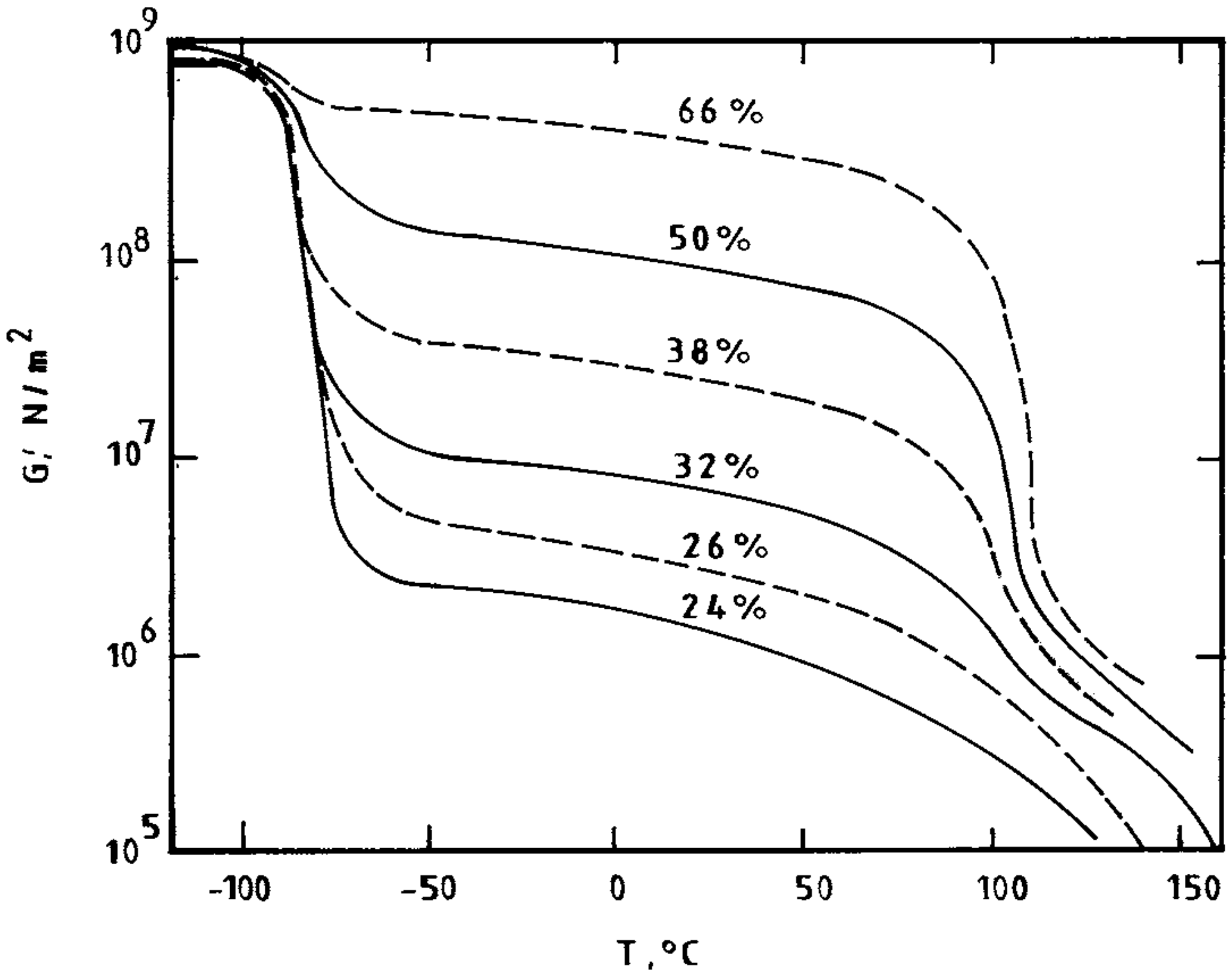
Effect of crystallinity on the modulus–temperature curve. The numbers of the curves are rough approximations of the percentage of crystallinity.

Effect of Copolymerization



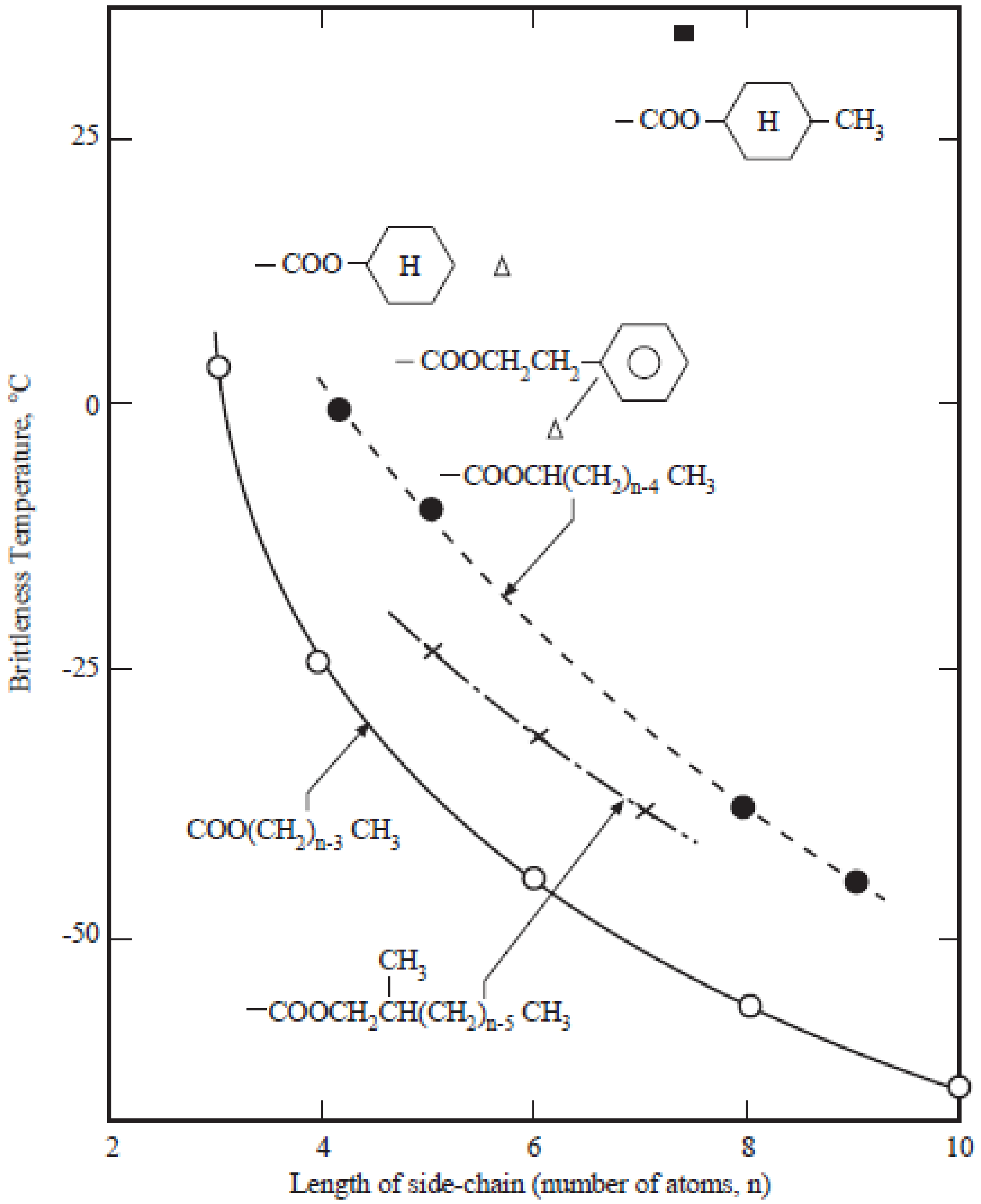
Effect of plasticization or copolymerization on the modulus–temperature curve. The curves correspond to different copolymer compositions. (B) Unplasticized homopolymer; (A) either a second homopolymer or plasticized B.

Effect of Copolymerization

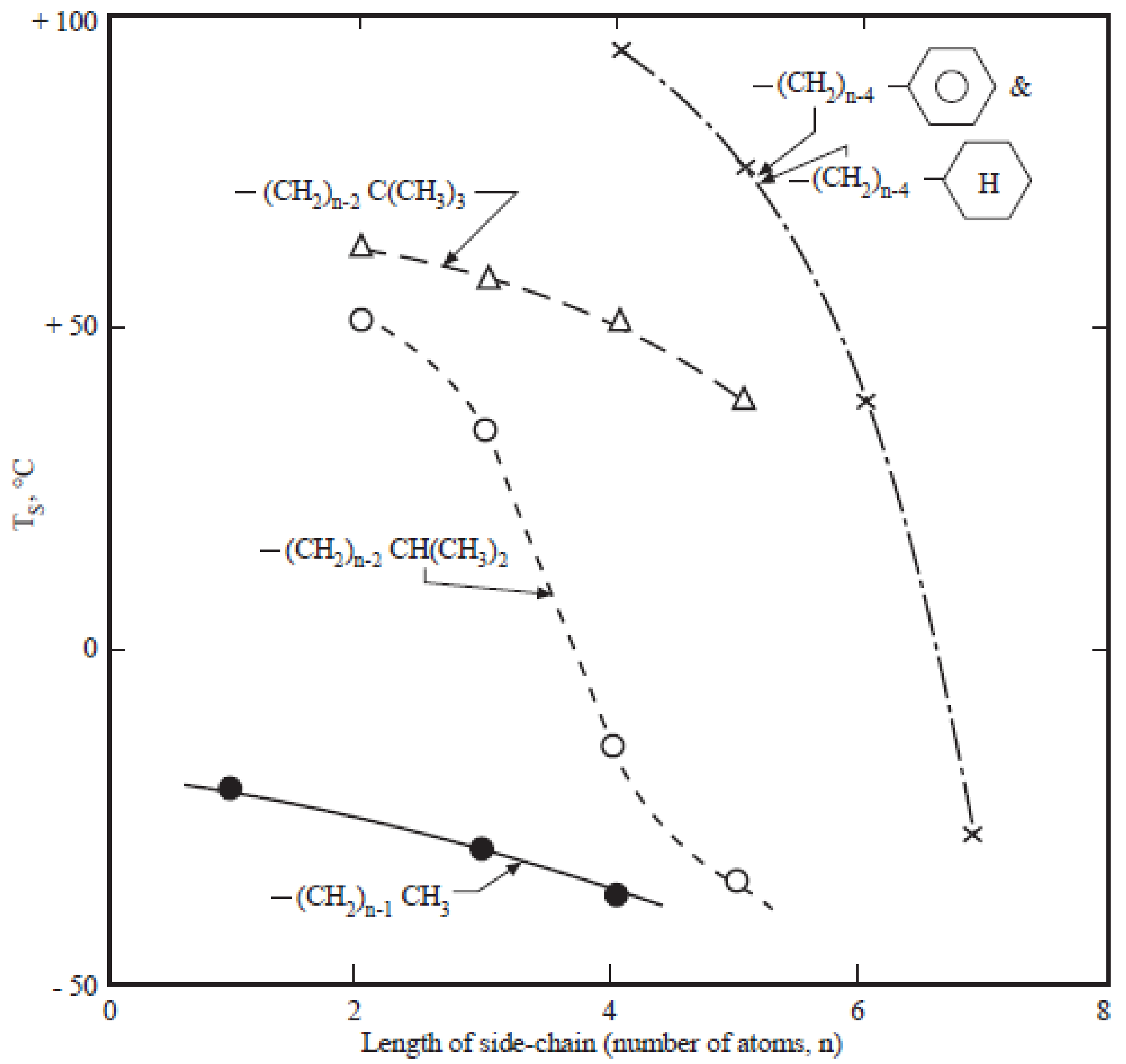


Shear modulus as a function of temperature for styrene–butadiene–styrene block copolymers. Wt.% styrene is indicated on each curve.

Effect of Steric Factors

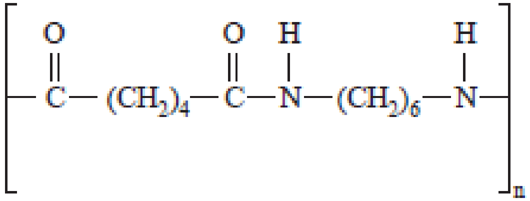
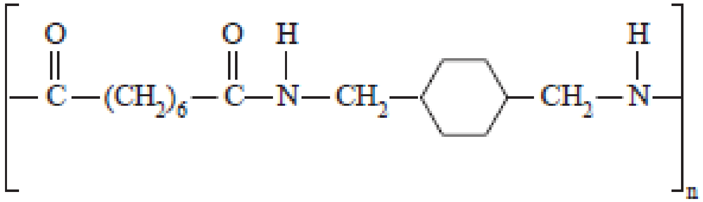
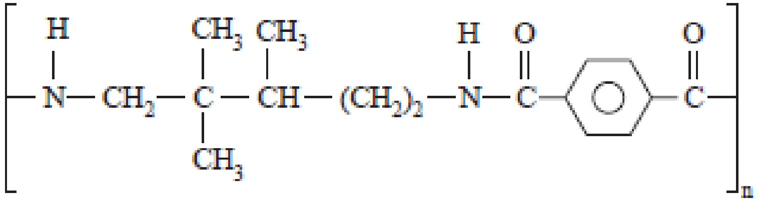


Branched side chains, particularly if the branched point is located close to the main chain, increase the glass transition temperature.



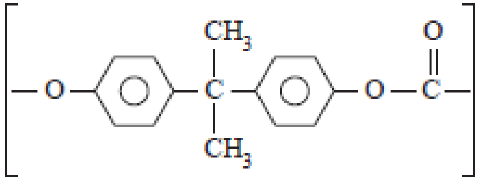
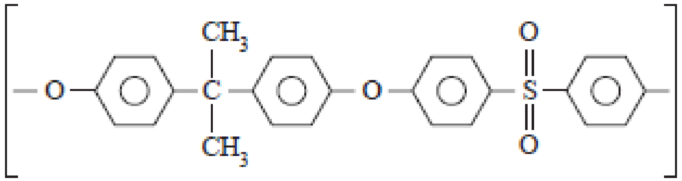
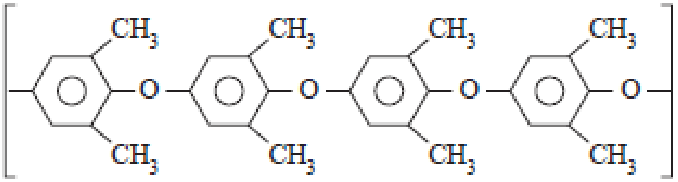
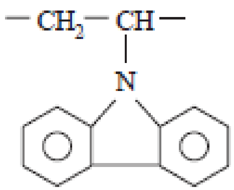
+ 100
+ 50
0
- 50
0
2
4
6
8
T_S, °C
Length of side-chain (number of atoms, n)
—(CH2)n-4
&
—(CH2)n-4
H
— (CH2)n-2 C(CH3)3
—(CH2)n-2 CH(CH3)2
—(CH2)n-1 CH3

Table 13.4 *Effects of the Introduction of Rings into the Main Chain of Some Polyamides*

Polymer	Structure	T_g °C	T_m °C
Nylon 6.6 (Zytel, Du Pont de Nemours)		75	260
Polycyclamide (Q.2 Tennessee Eastman Co.)		125	300
Trogamid T (Dynamit Nobel A.G.)		145	none

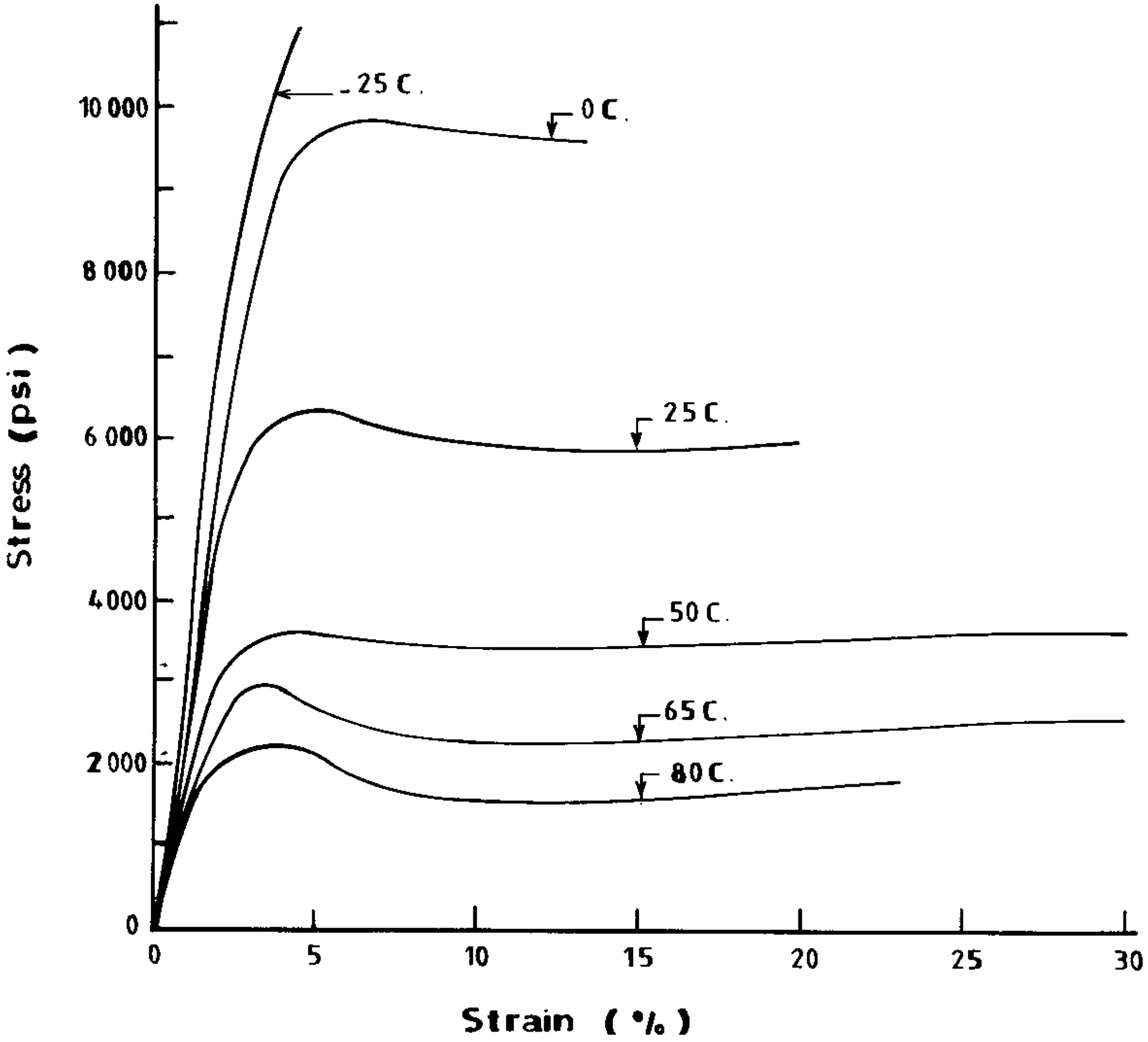
Structural changes within or near the main chain, even if minor, can produce a drastic effect on the mechanical properties of a polymer. Table 13.4 shows the increase in T_g and T_m (for the crystallizable polymers) by the introduction of rings into the main chain.

Table 13.5 *Polymer Stiffening Due to the Introduction of Rings into the Main Chain*

Polymer	Structure	T_g °C
Polycarbonate		150
Polysulfone		190
Poly(phenylene oxide)		220
Poly(vinyl carbazole)		208

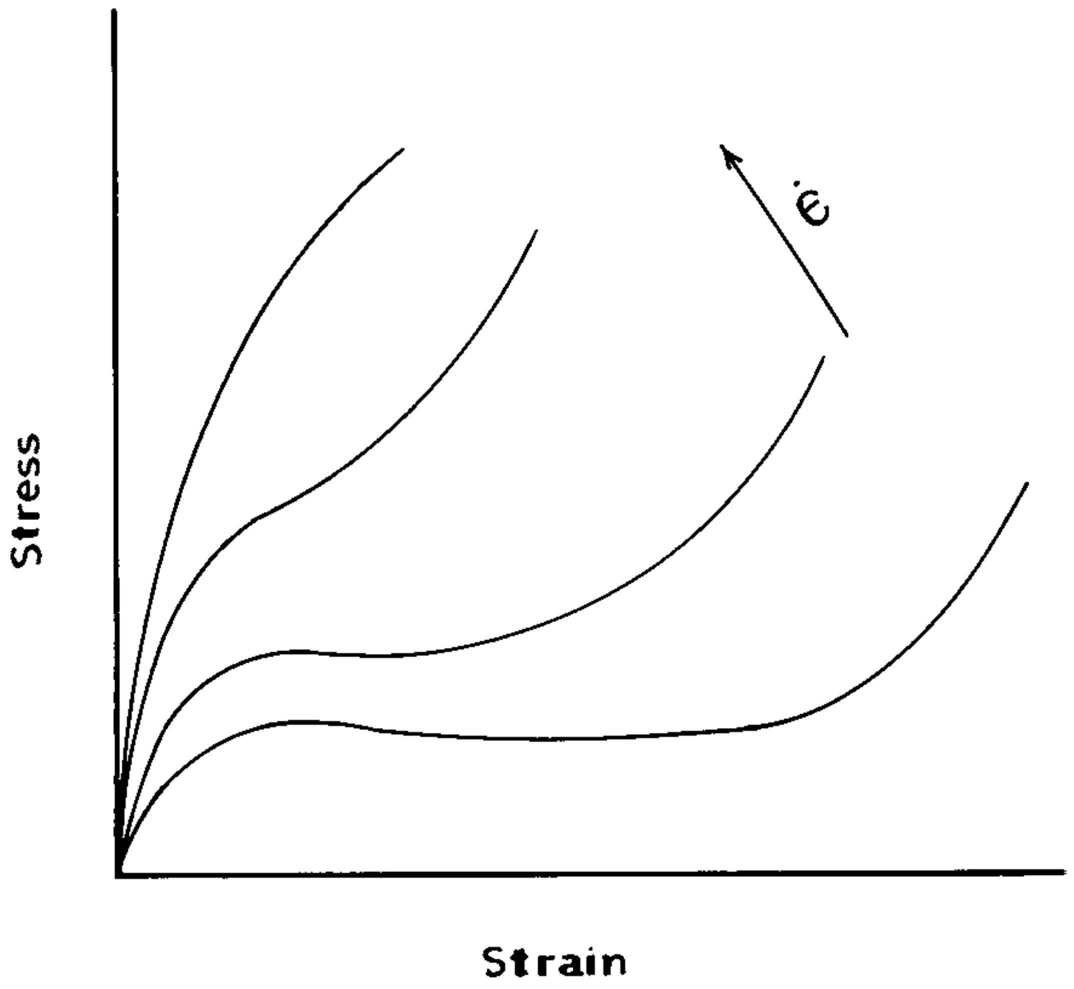
The additional stiffening of the main chain due to the presence of methyl side groups leads to a further increase in the T_g. In general, the introduction of rings into the main chain provides a better structural mechanism for toughening polymers than chain stiffening by bulky side groups.

Effect of Strain Rate



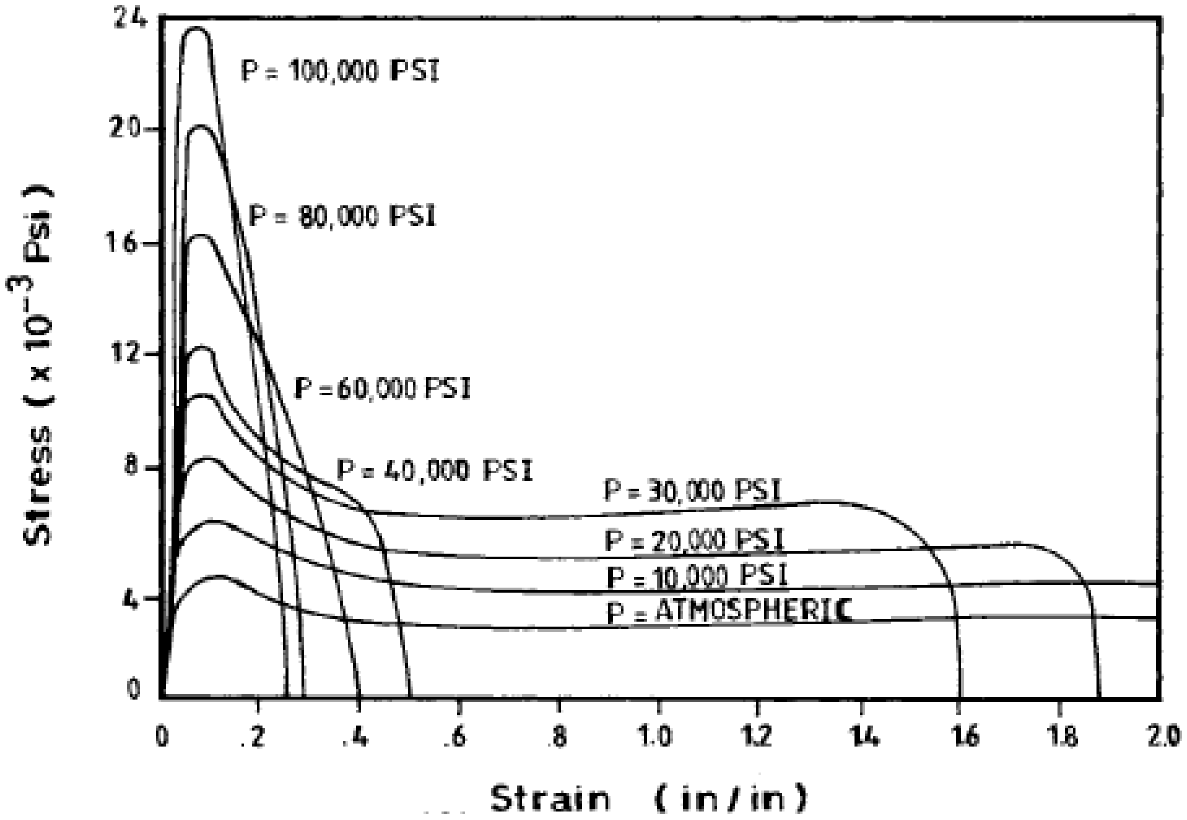
The stress–strain behavior of cellulose acetate at different temperatures.

Polymers are very sensitive to the rate of testing. As the strain rate increases, polymers in general show a decrease in ductility while the modulus and the yield or tensile strength increase.



Schematic illustration of the effect of strain rate on polymers.

Effect of Pressure



The stress–strain behavior of polypropylene at different pressures.

The modulus and yield stress increase with increasing pressure. This behavior is general for all polymers.