

4th Ed Cpt 2 Polymer Structure

Table 2.1 Typical properties of straight chain hydrocarbons.

Average number of carbon atoms	Boiling range, °C	Name	Physical state at room temp.	Typical uses
1-4	<30	Gas	Gas	Heating
5-10	30-180	Gasoline	Liquid	Automotive fuel
11-12	180-230	Kerosene	Liquid	Jet fuel, heating
13-17	230-300	Light gas oil	Liquid	Diesel fuel, heating
18-25	305-400	Heavy gas oil	Viscous liquid	Heating
26-50	Decomposes	Wax	Waxy	Wax candles
50-1000	Decomposes		Tough waxy to solid	Wax coatings food containers
1000-5000	Decomposes	Polyethylene	Solid	Bottles, containers, films
>5000	Decomposes	Polyethylene	Solid	Waste bags, ballistic wear, fibers, automotive parts, truck liners

Figure 2.1 Simulated structure of high-density polyethylene (HDPE), left, contrasted with the structural formula of linear or normal decane, right.

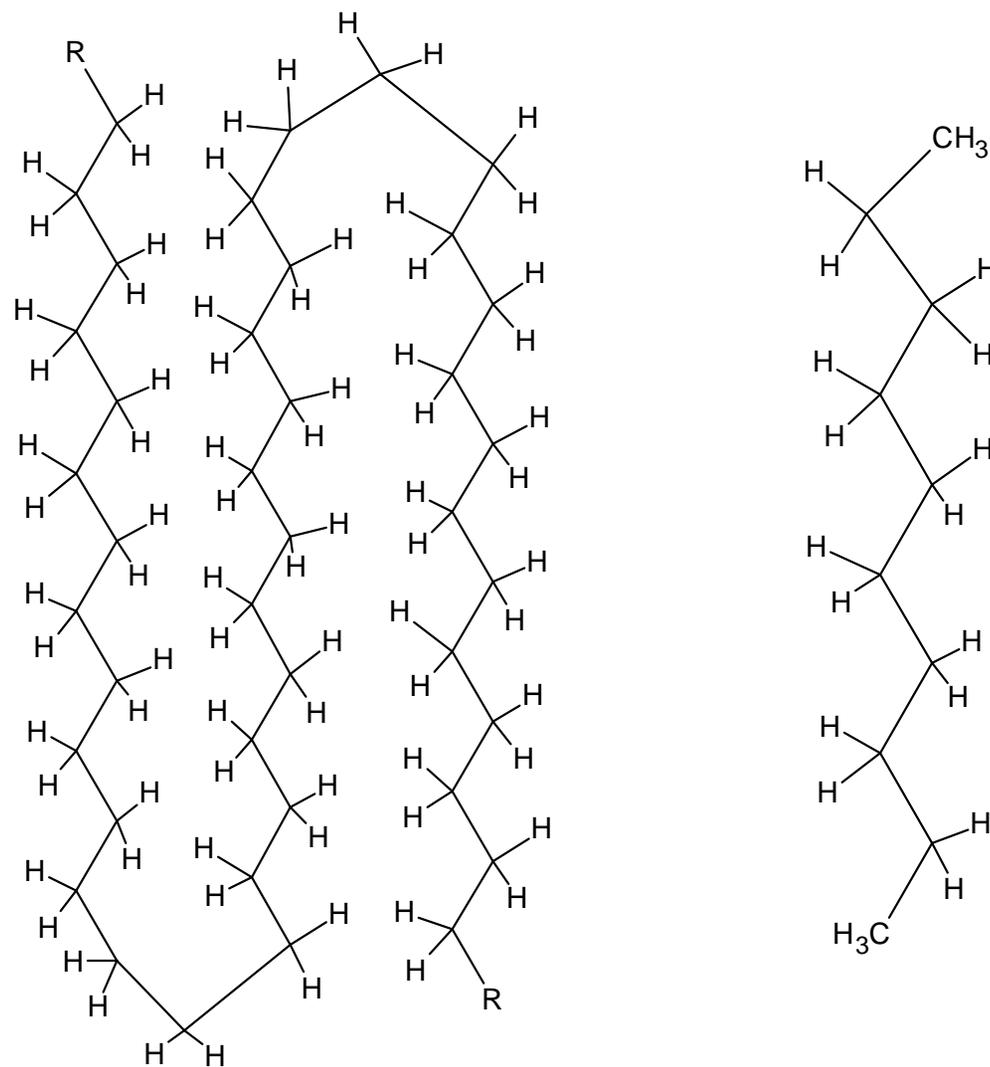


Figure 2.2 Simulated structural formula for branched low-density polyethylene (LDPE); compare with Figure 2.1 for HDPE.

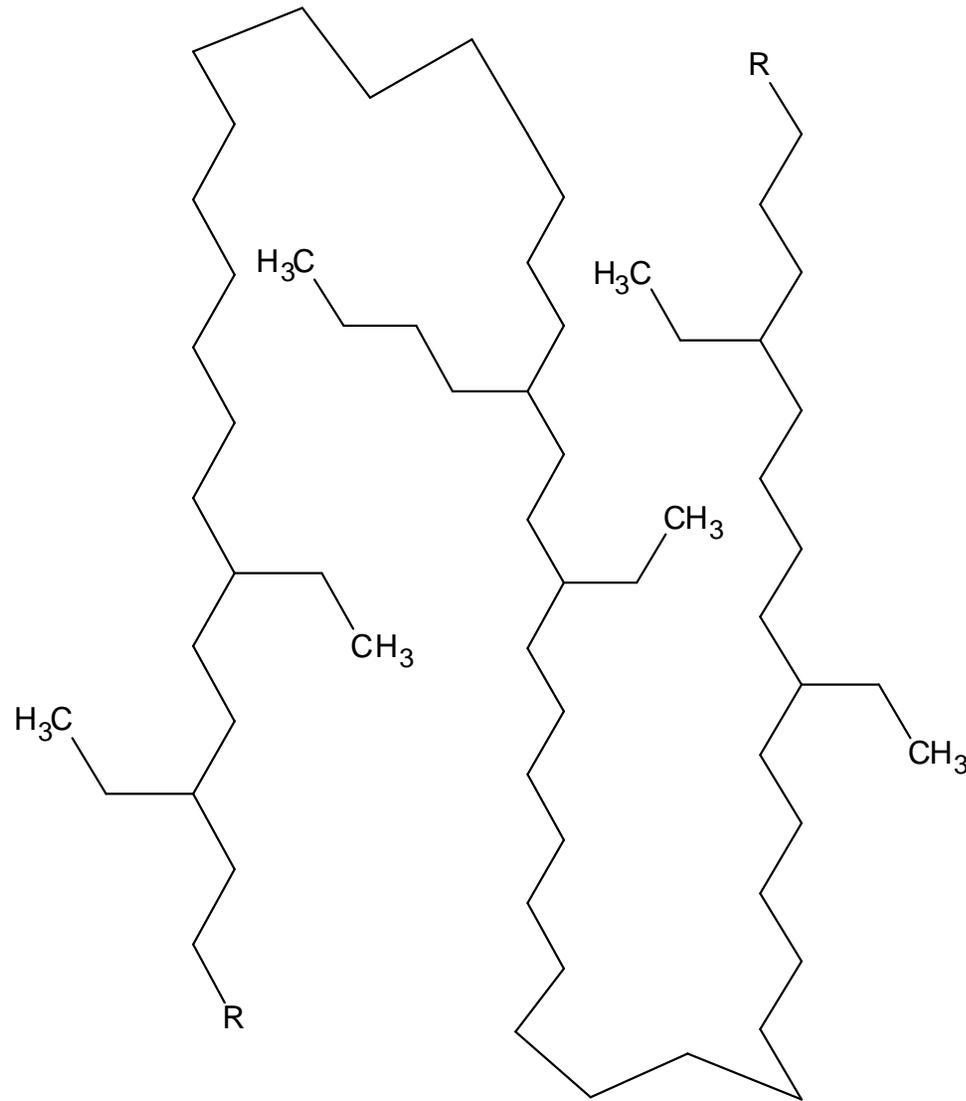


Table 2.2 Types of Commercial Polyethylene

• General structure	%-Crystallinity	Density (g/cc)
• LDPE-Linear with branching	50	0.92-0.94
• LLDPE-Linear with less branching	50	0.92-0.94
• HDPE-Linear with little branching	90	0.95

Figure 2.3 Skeletal structural formulas of a linear polymer (left), and a network (crosslinked) polymer with low crosslinking density (middle) and high density crosslinking (right). Cross-link sites are noted by the non-darkened spheres.

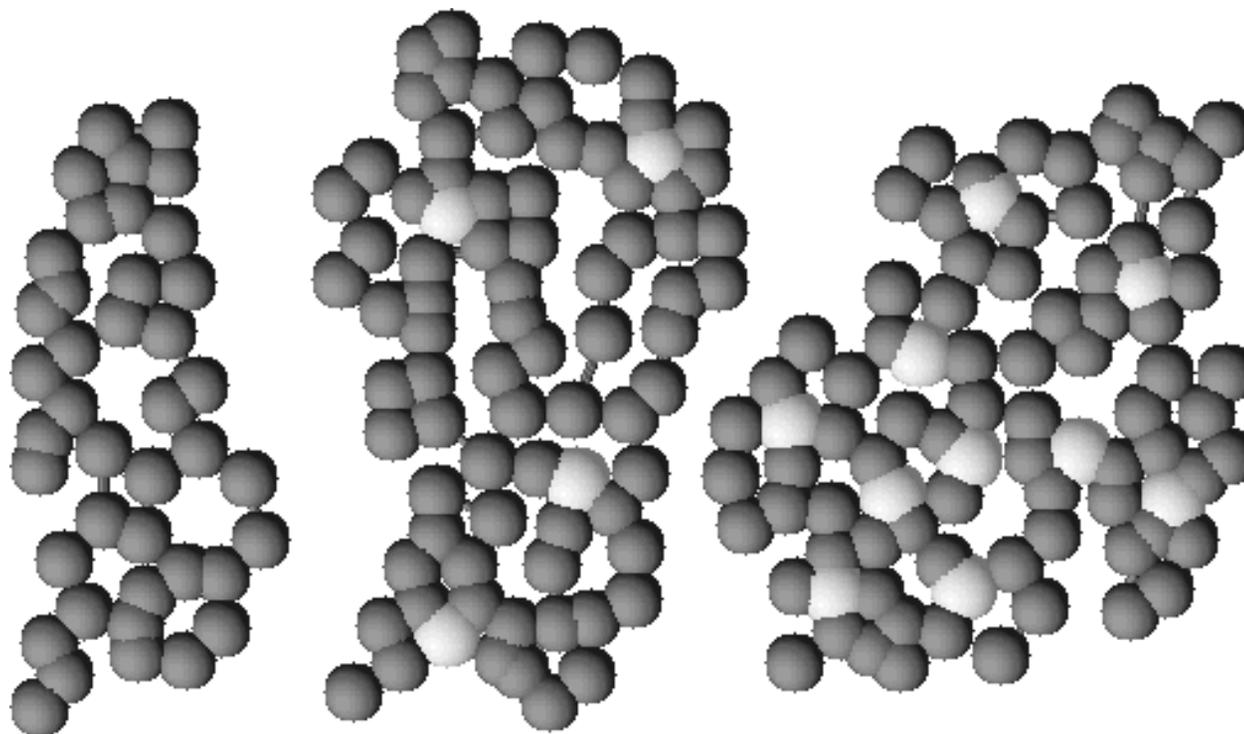


Figure 2.4 Simulated structural formulas showing the usual head-to-tail, middle, and unusual head-to-head, right, configurations of polypropylene.

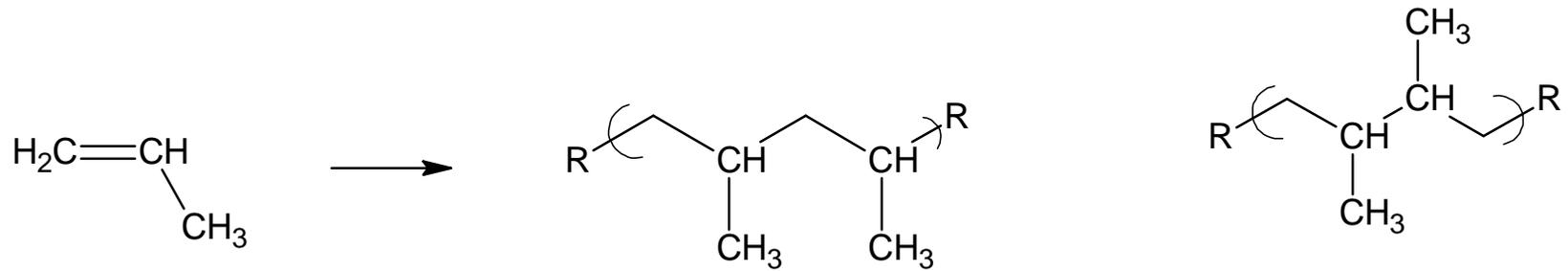
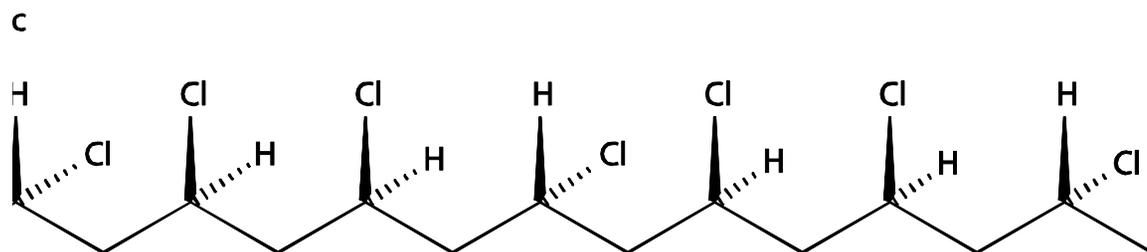
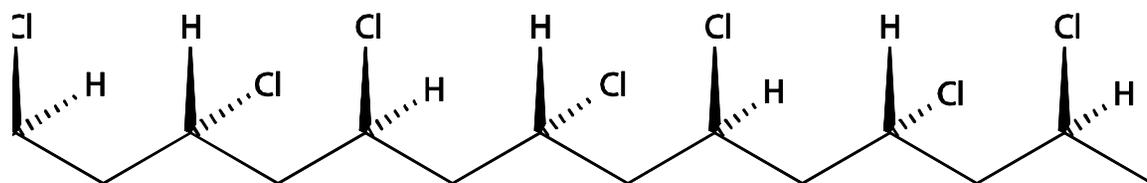
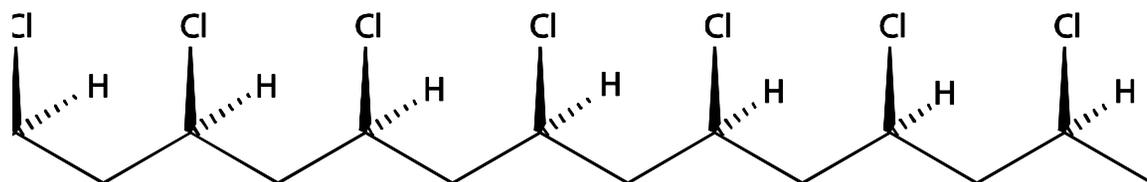
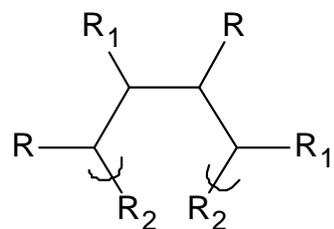
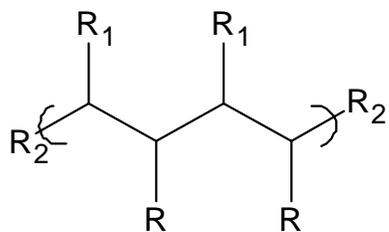


Figure 2.5 Skeletal formulas of isotactic (top), syndiotactic (middle), and atactic (bottom) of poly(vinyl chloride), PVC.

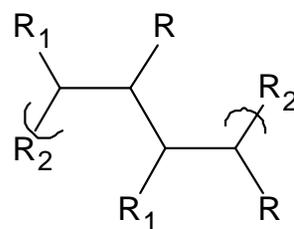




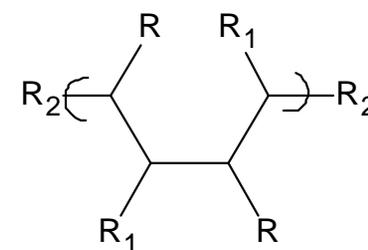
Erythrodiisotactic



Threodiisotactic



Erythrodisyndiotactic



Threodisyndiotactic

Figure 2.6 Simulated formulas of ditactic isomers where R₂ are chain extensions and R and R₁ are not hydrogen.

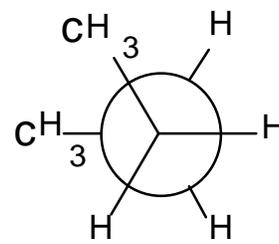
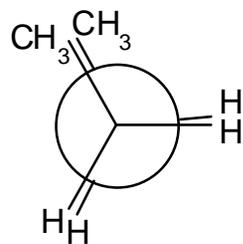
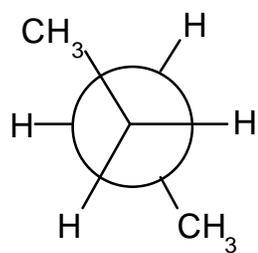


Figure 2.7 Newman projections of designated conformers of n-butane- Anti (left), Eclipsed (middle) and Gauche (right).

Figure 2.8 Representation of a crystalline portion from isotactic polypropylene, left, and an amorphous portion from atactic polypropylene, right.

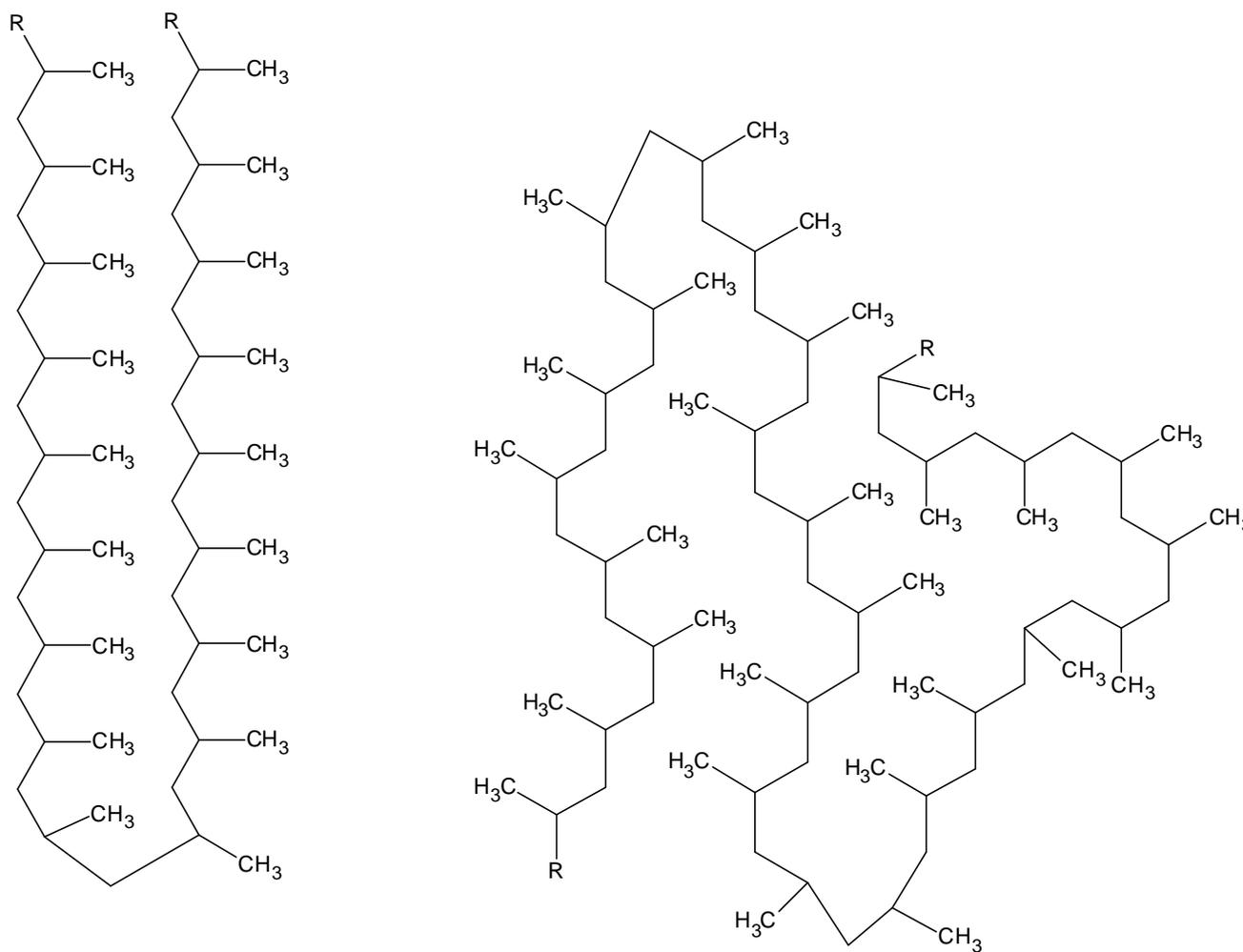


Table 2.2b. General classes of secondary forces.

Type	Relative Strength
• Ion-dipole	Strongest
• Dipole-dipole	
• Dipole-induced dipole	
• Induces dipole-induced dipole	Weakest

Figure 2.9 Typical hydrogen-bonding (shown as “-” between hydrogen on nitrogen and oxygen for nylon 66.

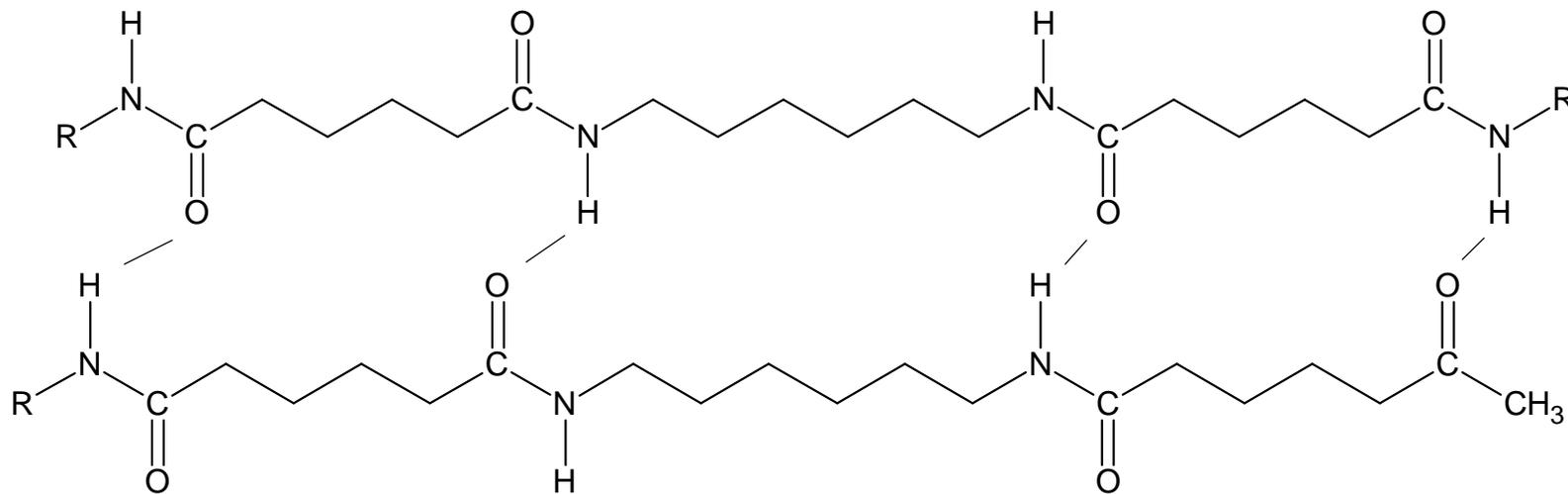


Table 2.3 Critical chain lengths for some common polymers.

Polymer	Critical Chain Length (Number of repeat units)
• Polycarbonate	20
• 1,4-Polybutadiene	110
• Poly(decamethylene adipate)	11
• Polydimethylsiloxane	450
• Polyethylene	150
• Poly(ethylene oxide)	100
• Poly(methyl methacrylate)	160
• Polypropylene	170
• Poly(propylene oxide)	100
• Polystyrene	300
• Poly(vinyl acetate)	250
• Poly(vinyl alcohol)	170
• Poly(vinyl chloride)	175
• modified from L. H. Sperling, Introduction to Physical Polymer Science, 4th Edition, Wiley, Hoboken, NJ,	

Figure 2.10 Determination of T_g by noting the abrupt change in specific volume.

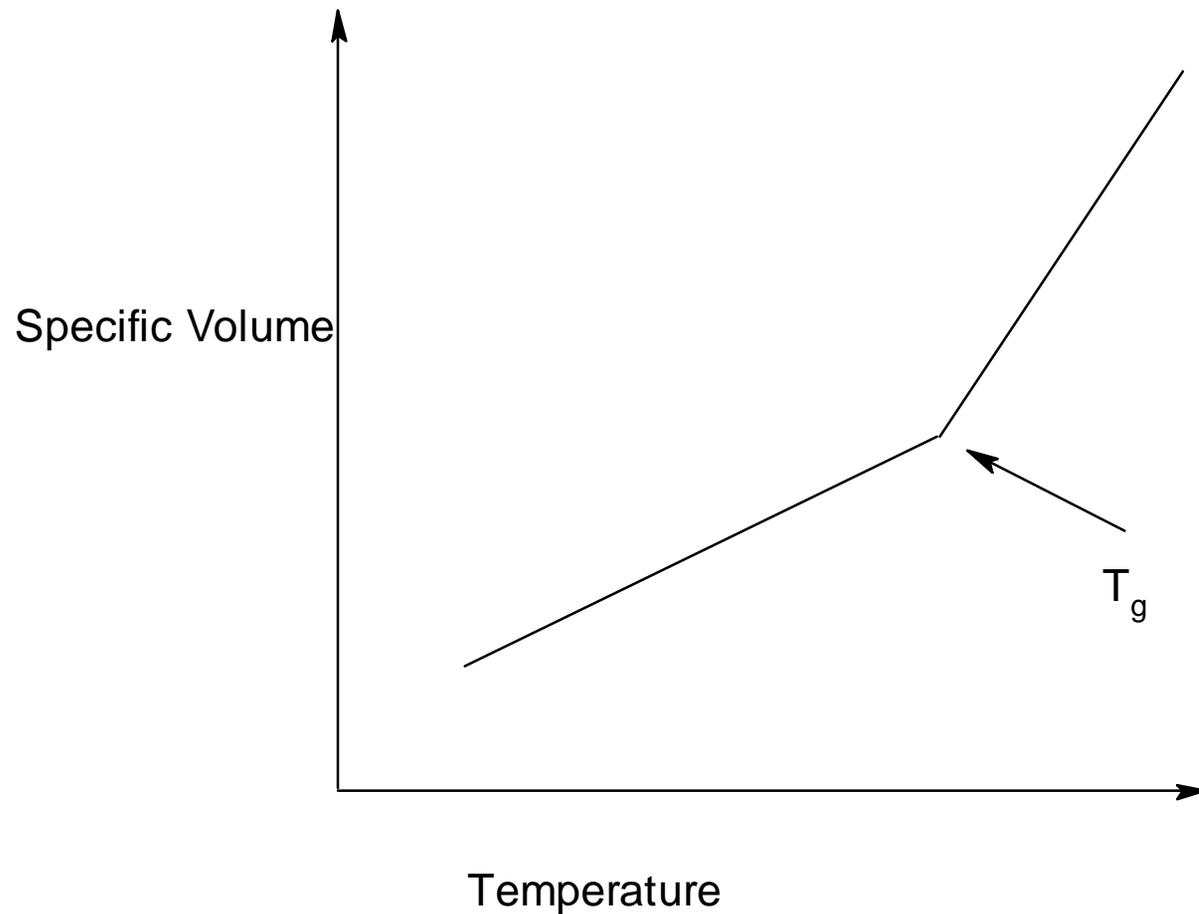


Table 2.4 Approximate Glass Transition Temperatures (T_g) for Selected Polymers

Polymer	T_g (K)	Polymer	T_g (K)
• Cellulose acetate butyrate	323	Cellulose triacetate	430
• Polyethylene (LDPE)	148	Polytetrafluoroethylene	160,400 ^a
• a-Polypropylene	253	Poly(ethyl acrylate)	249
• i-Polypropylene	373	Poly(methyl acrylate)	279
• Polyacrylonitrile	378	alpha-Poly(butyl methacrylate)	339
• Poly(vinyl acetate)	301	alpha-Poly(methyl acrylate)	378
• Poly(vinyl alcohol)	358	Poly(vinyl chloride)	354
• cis-Poly-1,3-butadiene	165	Nylon-66	330
• trans-Poly-1,3-butadiene	255	Poly(ethylene adipate)	223
• Polydimethylsiloxane	150	Poly(ethylene terephthalate)	342
• Polystyrene	373		

a. Two major transitions observed.

Figure 2.11 Typical DSC thermogram of a polymer.

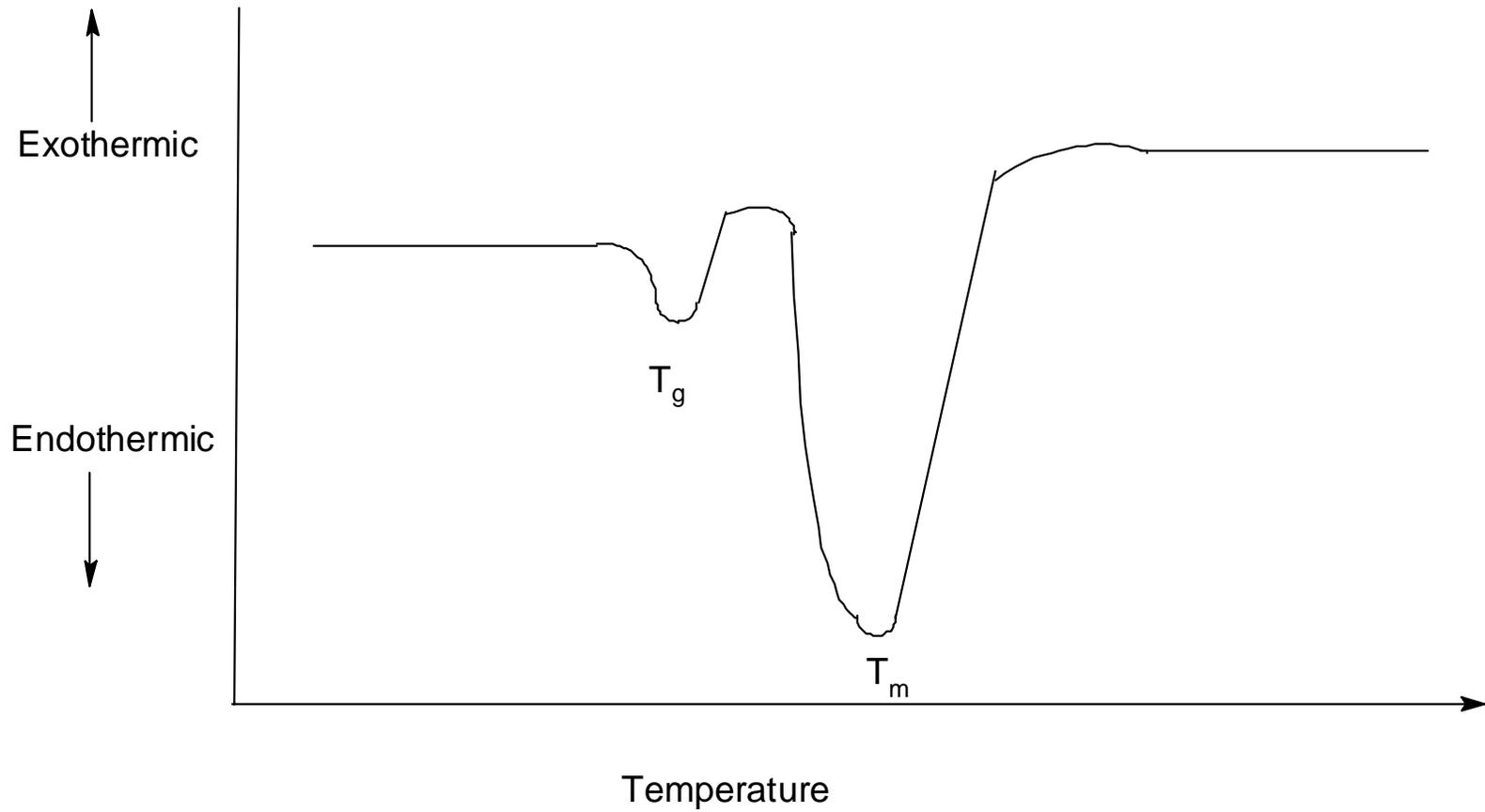


Figure 2.12 End-to-end distances for four 30-unit chains.

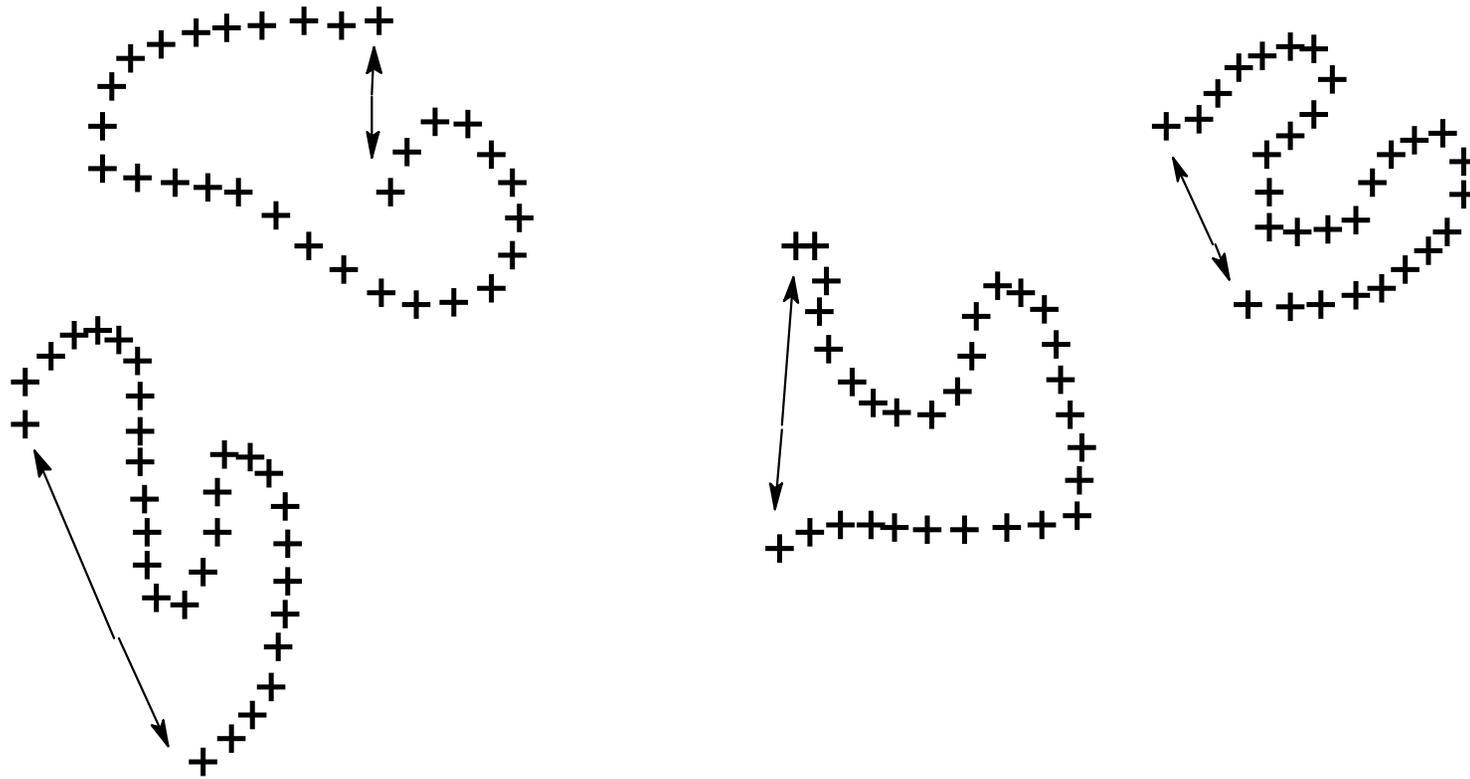


Figure 2.13 Helical conformation of isotactic vinyl polymers. (From N. Gaylord, in *Linear and Stereoregular Addition Polymers* (N. Gaylord and H. Mark, eds.), Wiley, NY, 1959.)

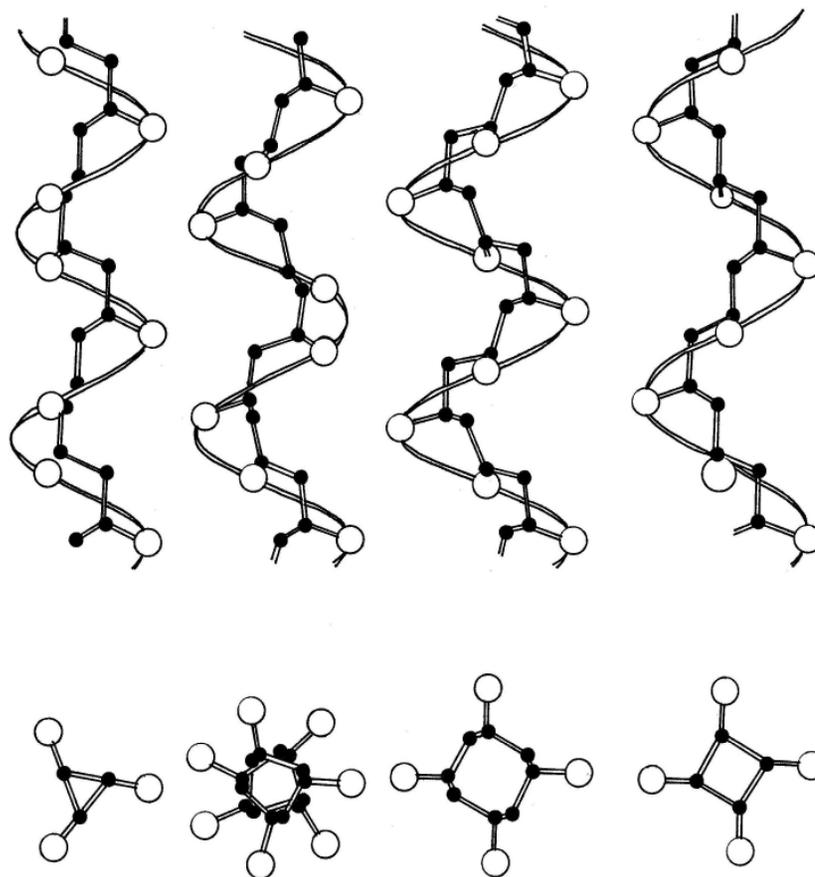


Figure 2.14 Schematic two-dimensional representation of a modified micelle model of the crystalline-amorphous structure of polymers.

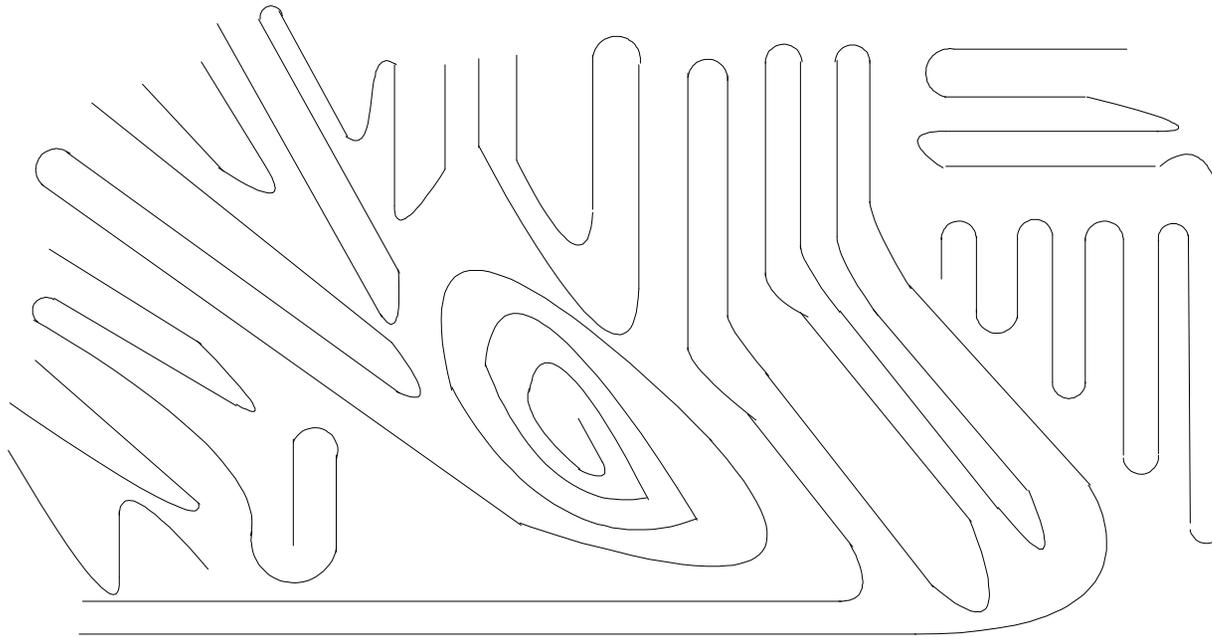


Figure 2.15 Structure of a spherulite from the bulk. Bottom shows a slice of a simple spherulite. As further growth occurs, filling in, branch points, etc. occur as shown above (top). The contour lines are simply the hairpin turning points for the folded chains.

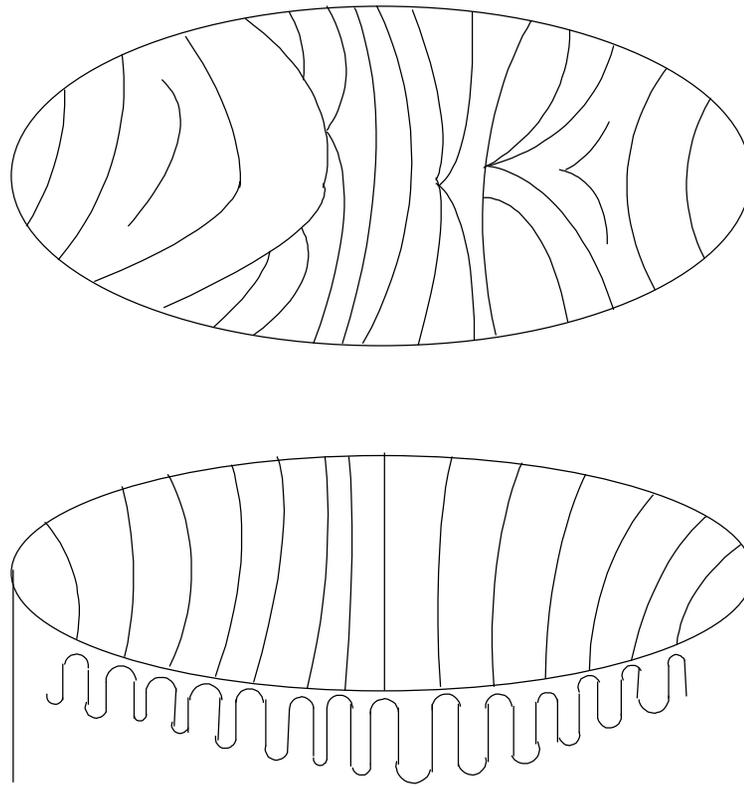


Figure 2.16 Spherulite structure showing the molecular-level lamellar chain-folded platelets and tie and frayed chain arrangements, left, and a more complete model of two sets of three lamellar chain-folded platelets formed from polyethylene, right. Each platelet contains about 850 ethylene units as shown here.

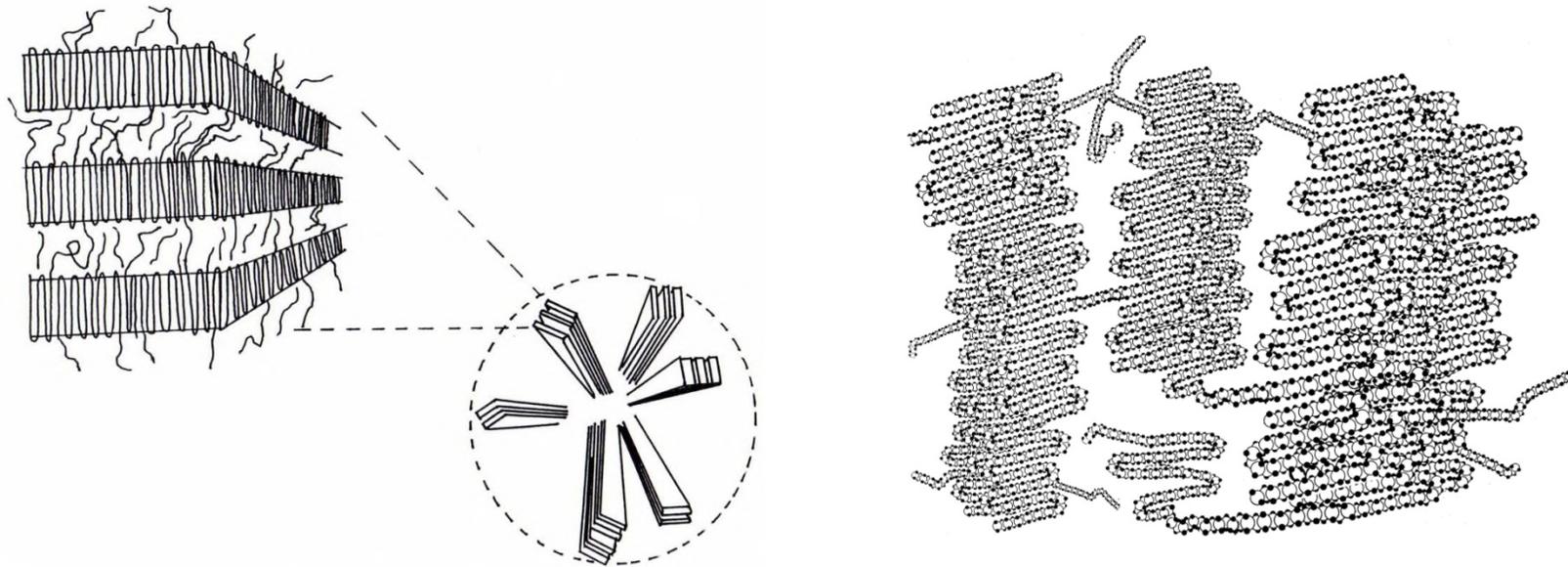


Figure 2.17 Crystalline polymer structures formed under applied tension including flow conditions. Middle shows the tertiary mono-fibrillar structure including platelets and at the left shows these mono-fibrillar structures bundled together forming a quaternary structure fibril. Right shows the distorted shish kebab formed with more rapid flow.

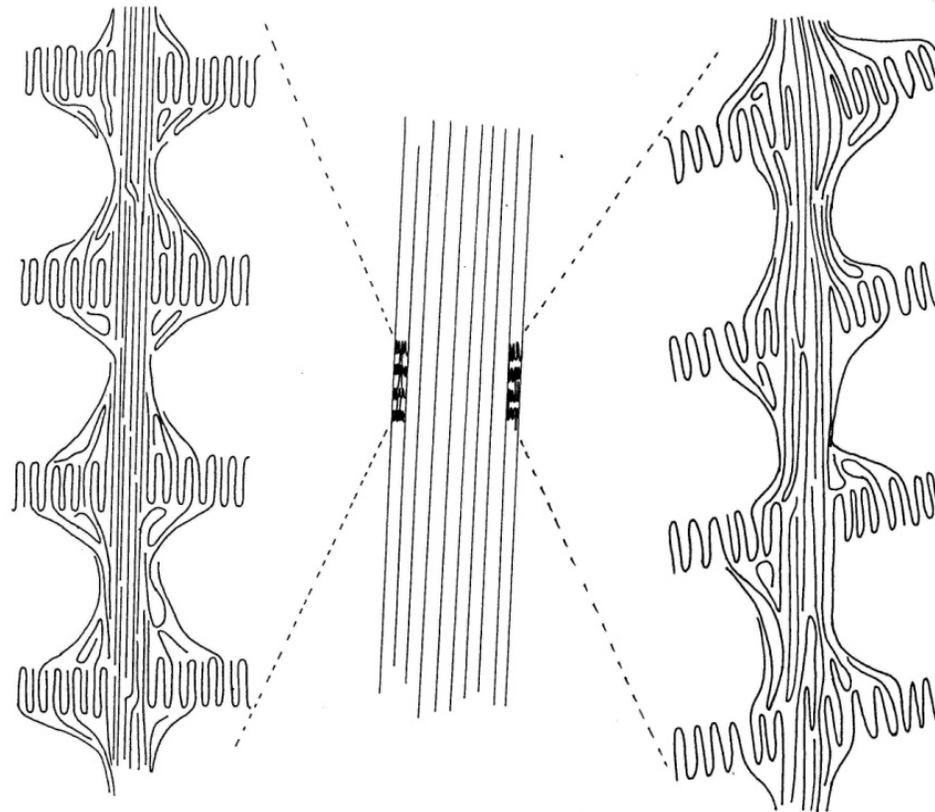


Figure 2.18 Elongation of an elastomer as a function of applied force, stress, where A is the original “relaxed” state, B represents movement to full extension, C is the point at which the elastomer “breaks”, and D represents force necessary to pull two separate pieces of elastomer apart.

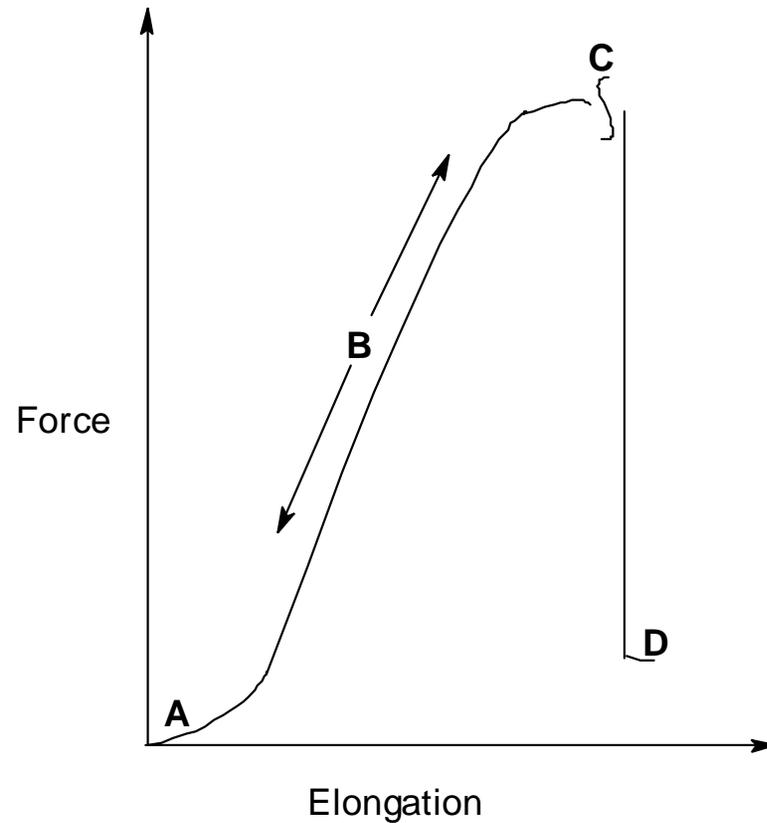


Figure 2.19 Idealized structure illustrating crystalline (ordered) and amorphous (nonordered) regions of lightly branched polyethylene chains for a prestressed and stressed orientation.

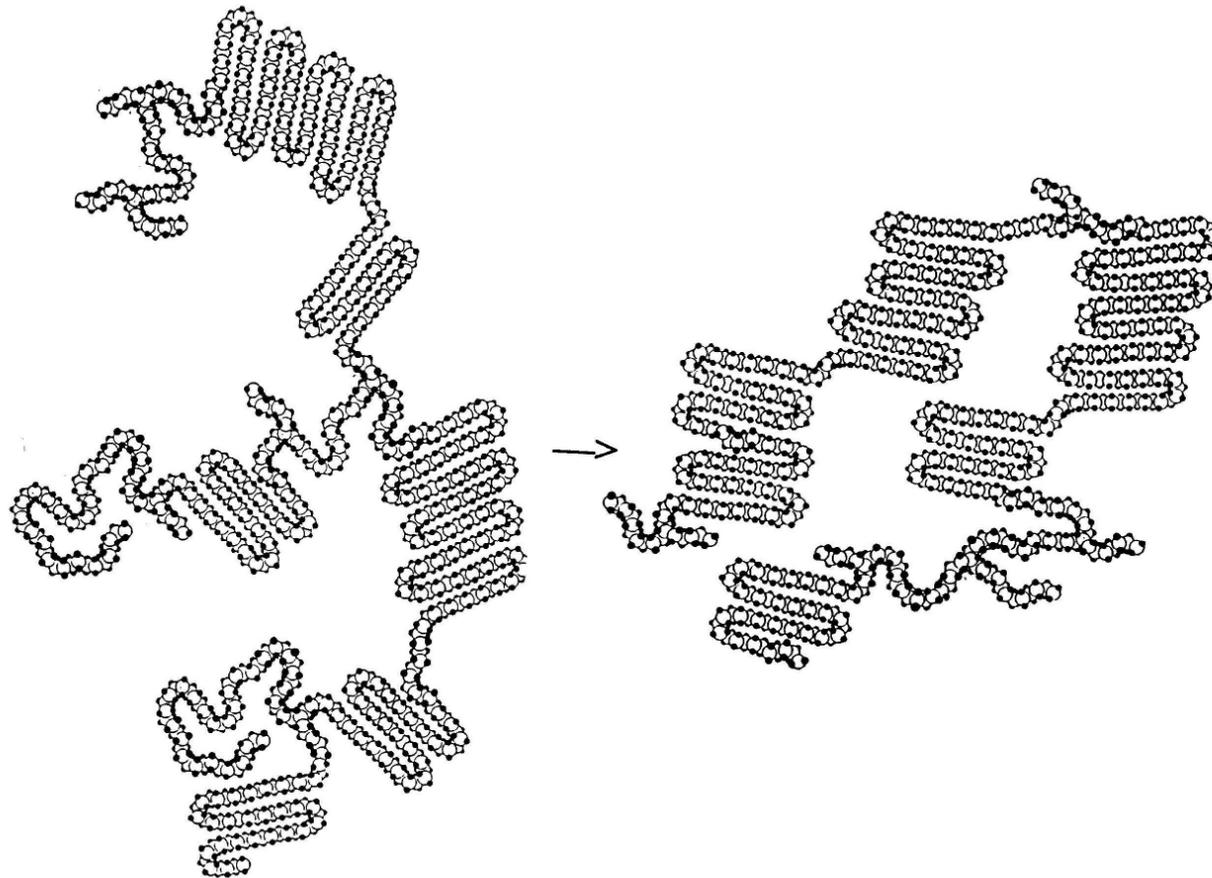


Figure 2.20 General physical states of materials as a function of crystallinity and molecular weight.

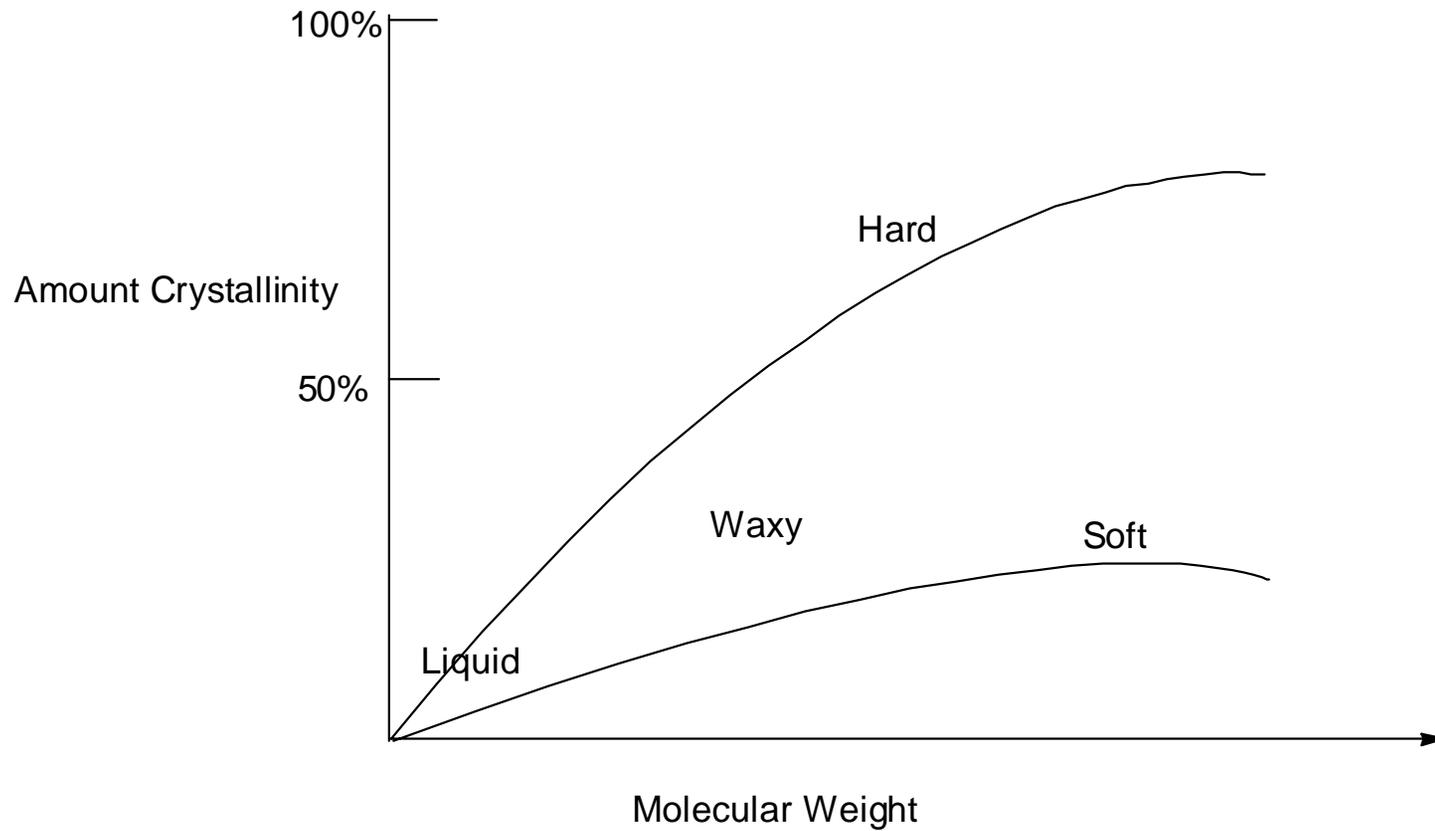


Table 2.6. General property correlations with T_g .

- Cross-linked elastomers Above T_g
- Linear (or branched) amorphous adhesives Above T_g
- Amorphous plastics Generally above T_g
- Largely crystalline plastics Generally above T_g , Below T_m
- Crystalline fibers Below T_m
- Coatings At or near T_g

Figure 2.21 Chemical cross-linking of cis-1,4-butadiene through reaction with sulfur.

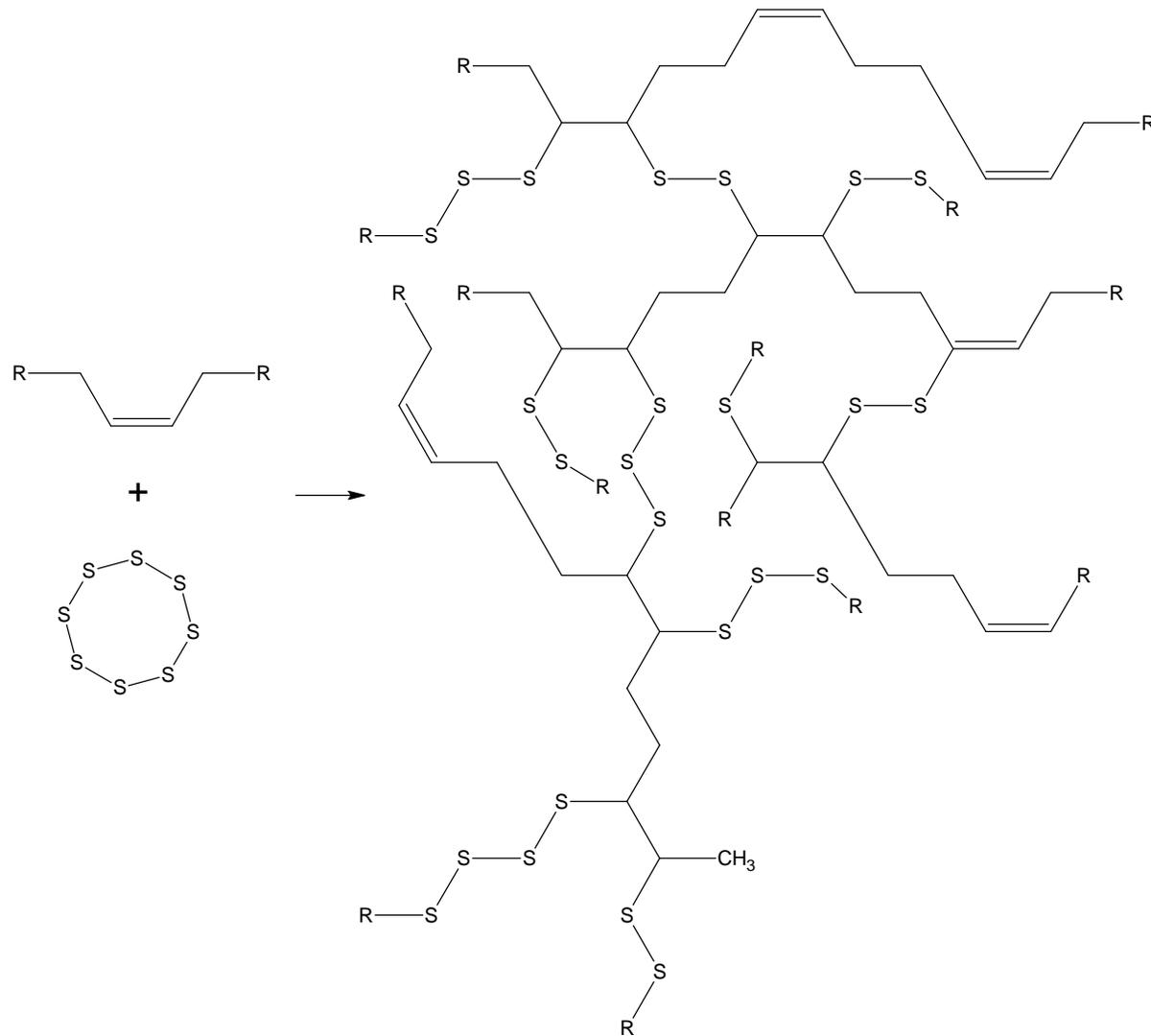


Figure 2.22 Illustration of two types of physical cross-linking-chain entanglement and crystalline regions.

