Capítulo 15

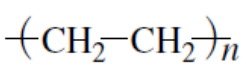
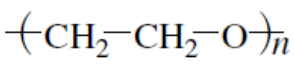
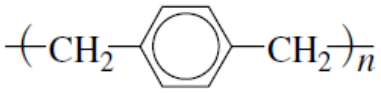
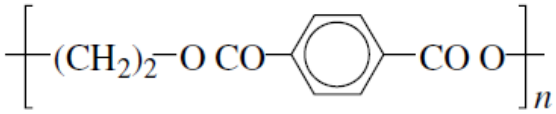
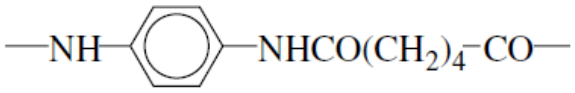
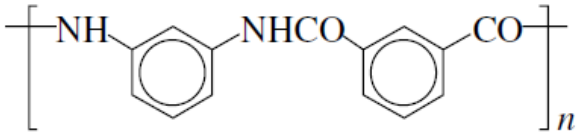
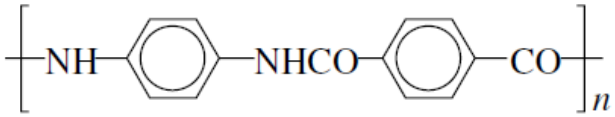
Relação Estrutura - Propriedades

AJF Carvalho

TABLE 15.1
Influence of Various Links on T_m when Incorporated in an All-Carbon Chain

Polymer Group	Repeat Unit	$T_m(K)$				
		m	2	3	4	5	6
Polyethylene	$+(CH_2)_m+$		400	—	—	—	—
Polyester	$+(CH_2)_mCOO+$		395	335	329	335	325
Polycarbonate	$+(CH_2)_m-OCOO+$		312	320	330	318	320
Polyether	$+(CH_2)_m\,CH_2-O+$		308	333	—	—	—
Polyamide	$+(CH_2)_m-CO\,NH+$		598	538	532	496	506
Polysulphone	$+(CH_2)_mCH_2\,SO_2+$		573	544	516	493	—

TABLE 15.2
Effect of Aromatic Rings on Chain Stiffness, as Shown by the Values of T_m and T_g

	Structure	T_g(K)	T_m(K)
1.		188	400
2.		206	339
3.		—	About 653
4.		342	538
5.		320	538
6.		—	613
7.		546	About 635 (decomposition)
8.		—	About 773

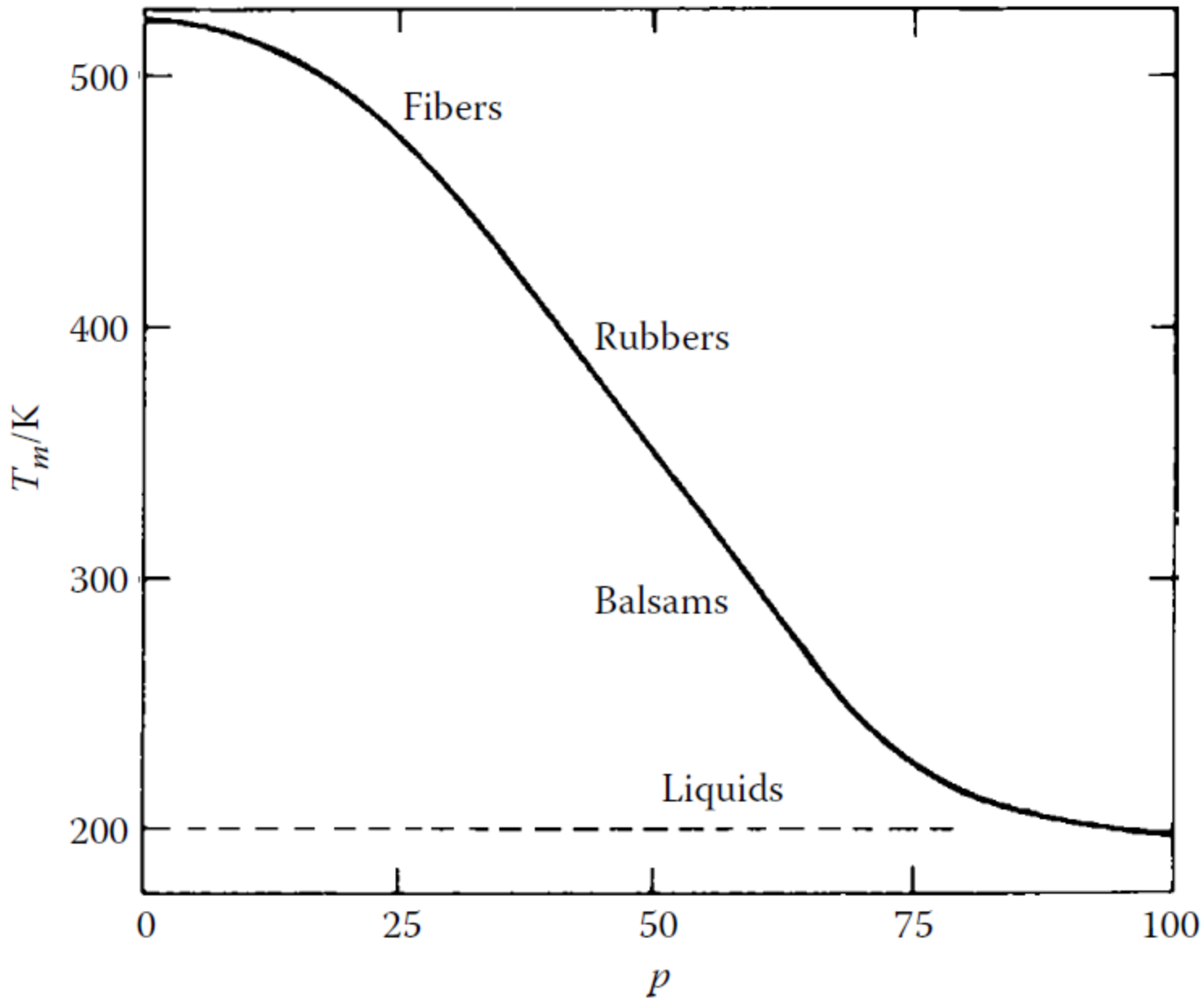
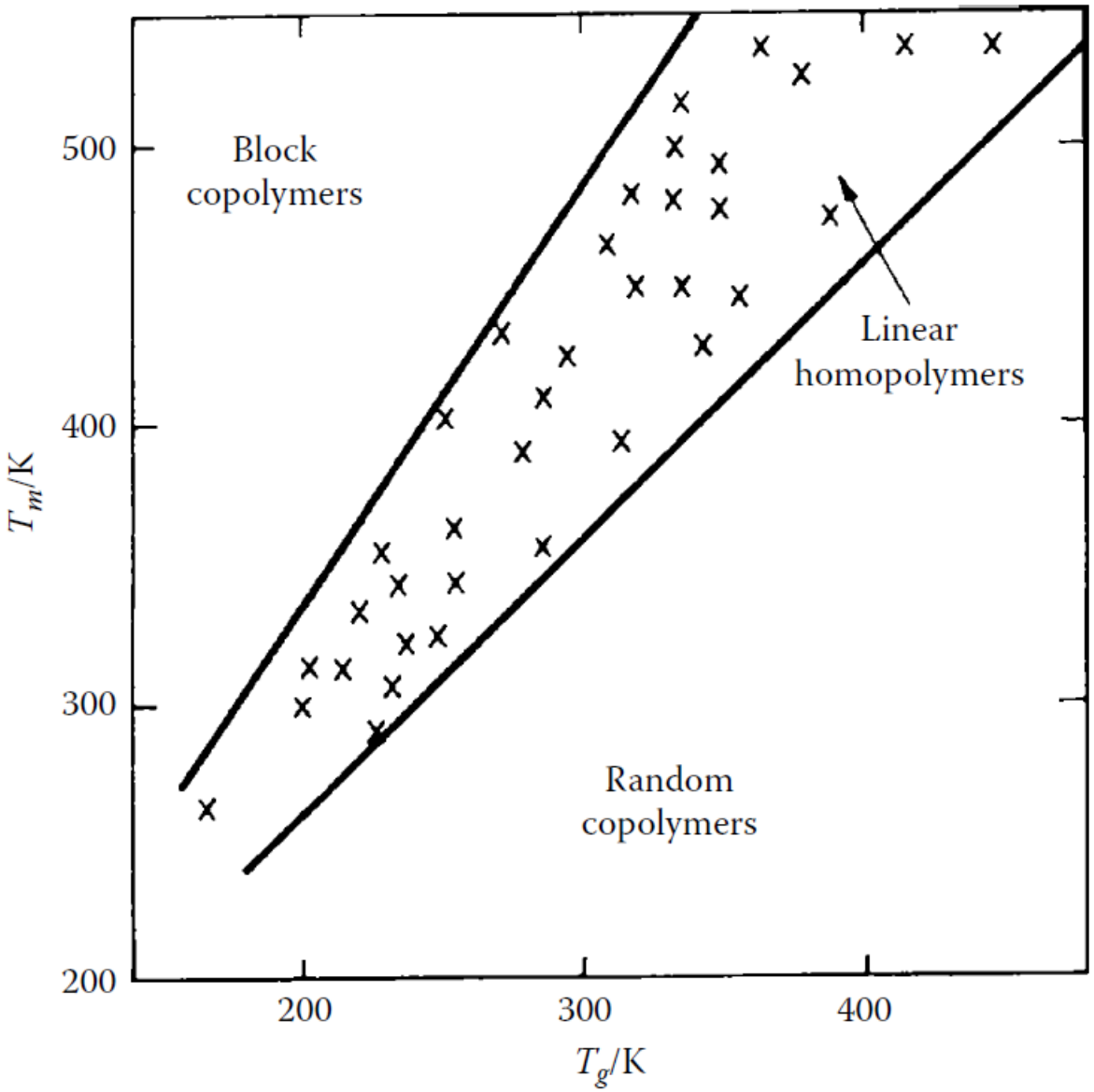
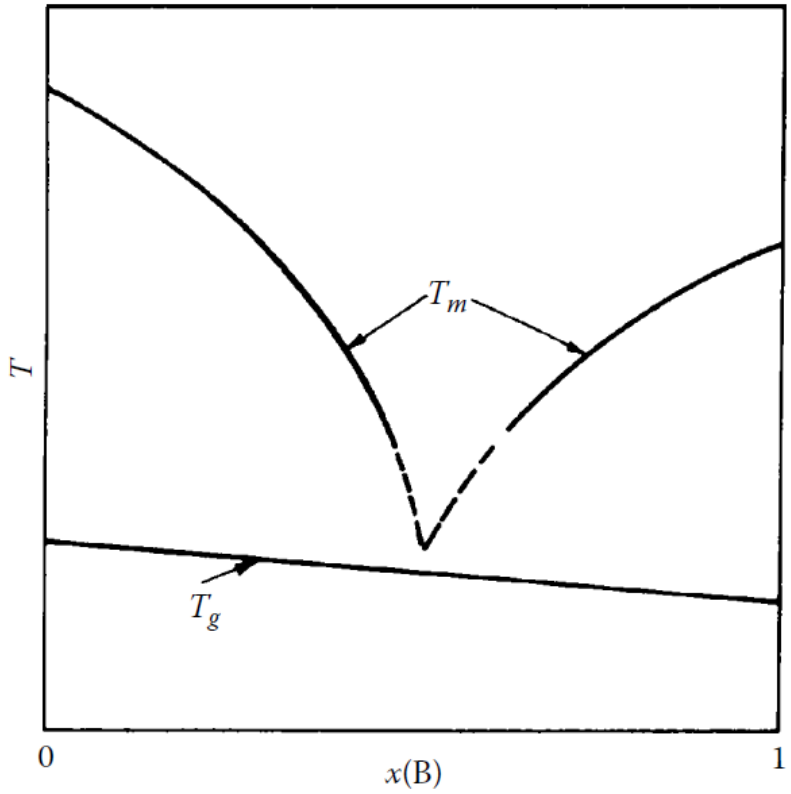
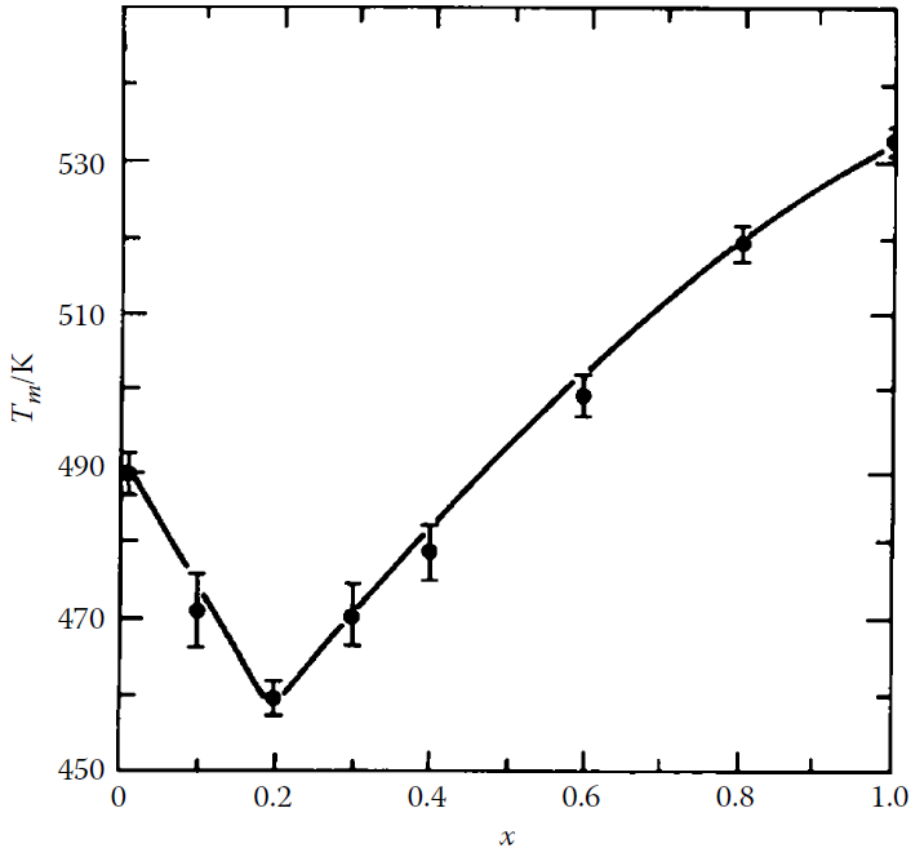

500
400
300
200
T_m/K
Fibers
Rubbers
Balsams
Liquids
0
25
50
75
100
p

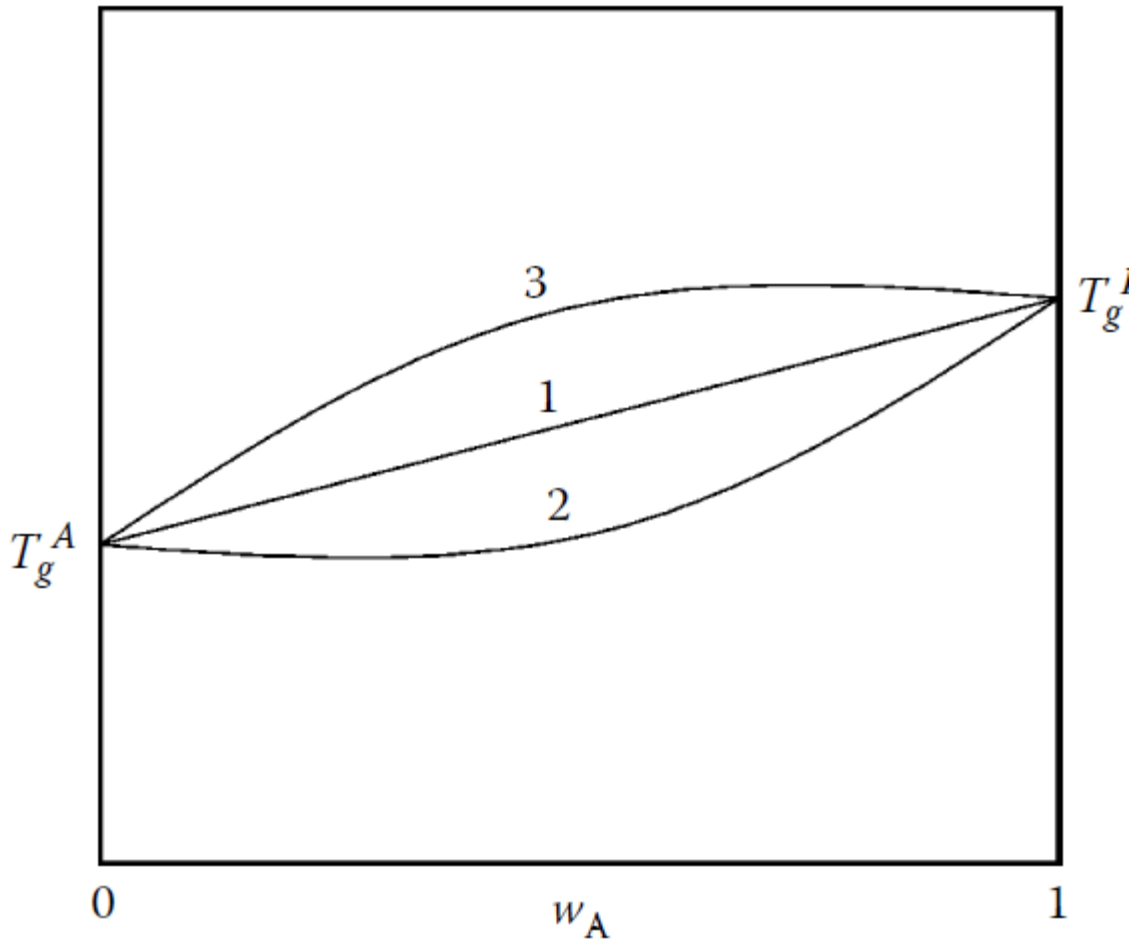
TABLE 15.3
Melting Temperatures T_m of Linear Aliphatic Polyamides

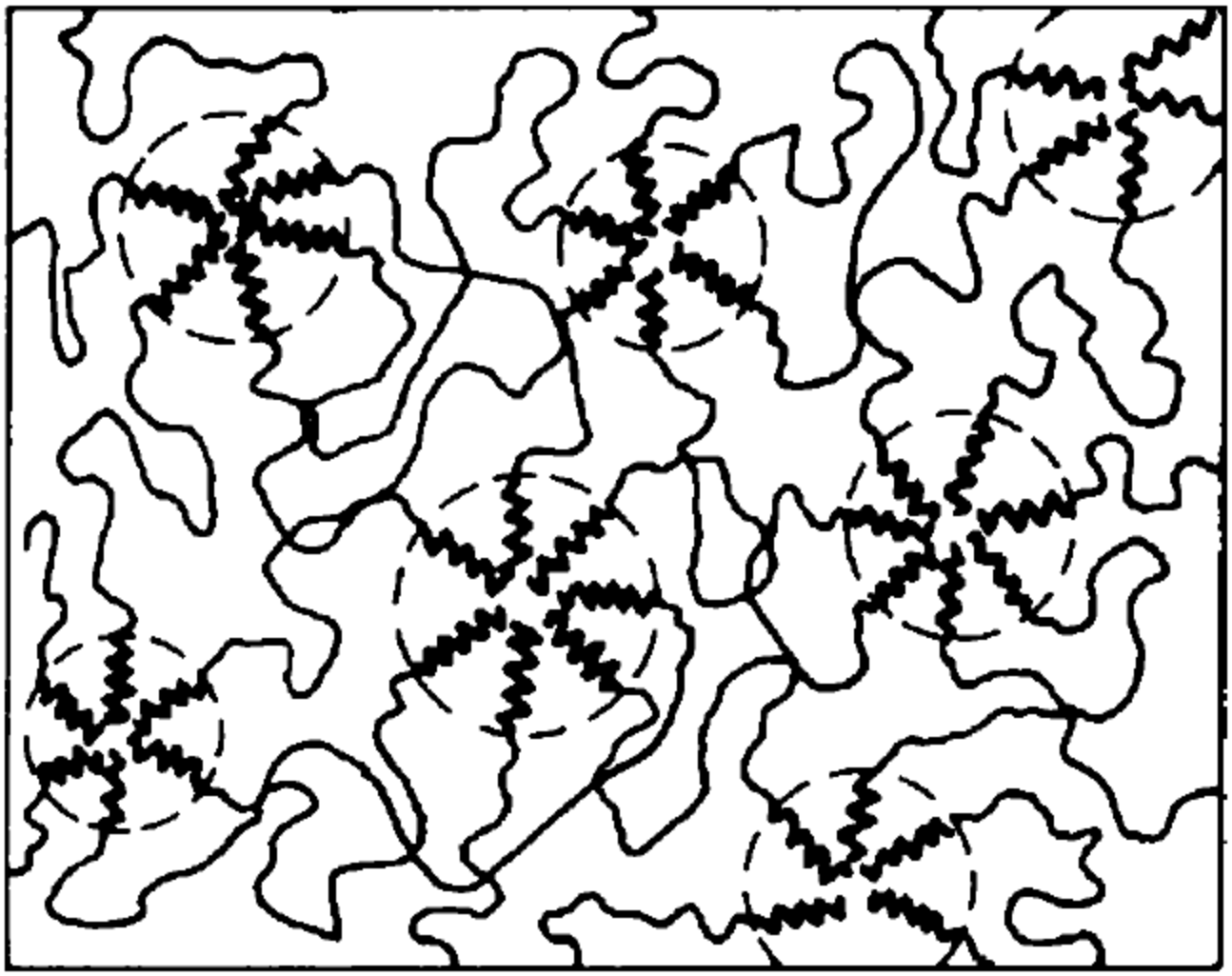
Monadic Nylon	T_m(K)	Dyadic Nylon	T_m(K)
4	533	4,6	581
6	496	5,6	496
7	506	6,6	538
8	473	4,10	509
9	482	5,10	459
10	461	6,10	495
11	463	6,12	482
12	452		

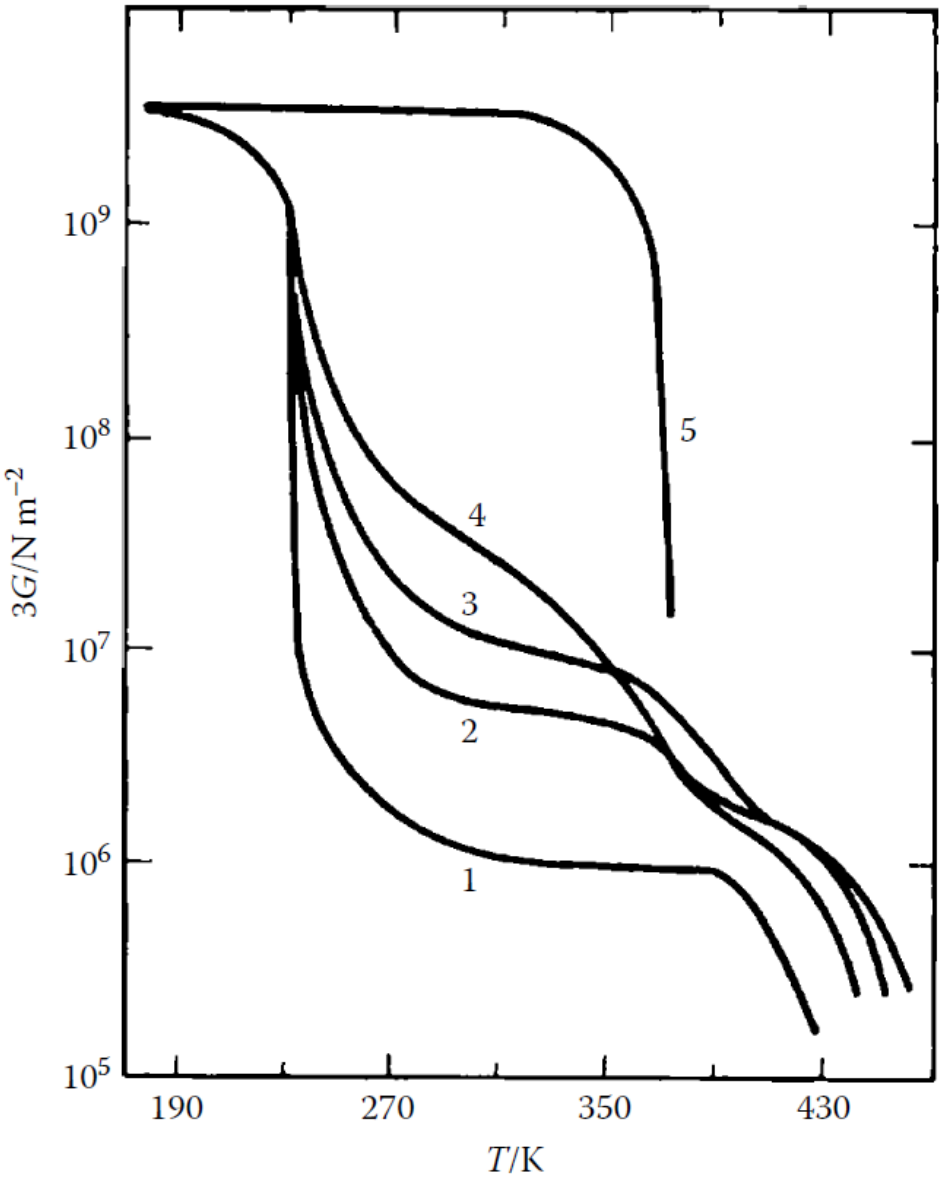

Block
copolymers
Linear
homopolymers
Random
copolymers
500
400
300
200
200
300
400
T_m/K
T_g/K

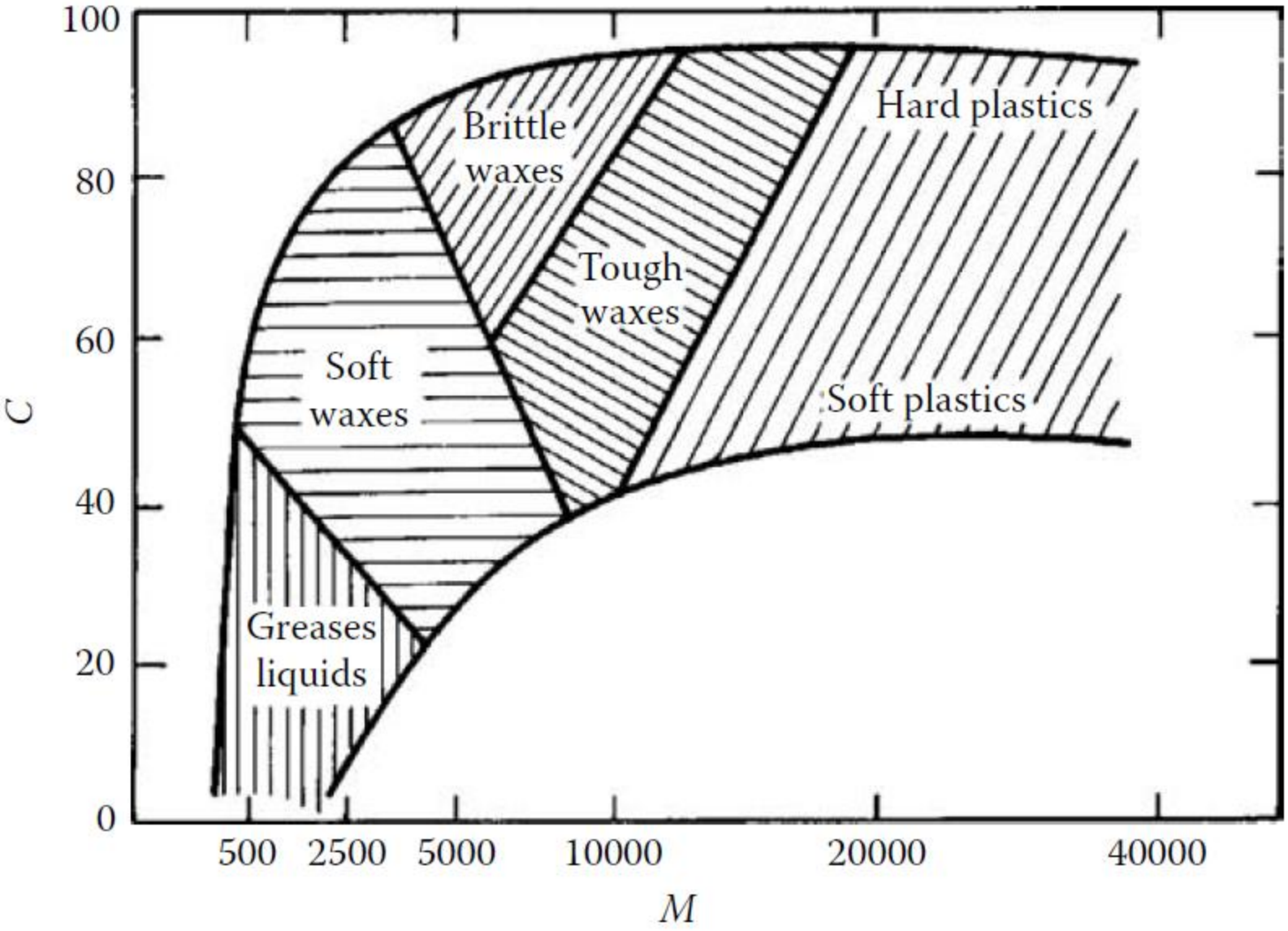

T
T_m
T_g
0
1
x(B)


530
510
490
470
450
T_m/K
0
0.2
0.4
0.6
0.8
1.0
x


3
1
2
T_g^A
T_g^B
0
w_A
1




10^9
10^8
10^7
10^6
10^5
$3G$/N m^{-2}
190
270
350
430
T/K
1
2
3
4
5


100
80
60
40
20
0
C
Brittle
waxes
Tough
waxes
Hard plastics
Soft
waxes
Soft plastics
Greases
liquids
500
2500
5000
10000
20000
40000
M

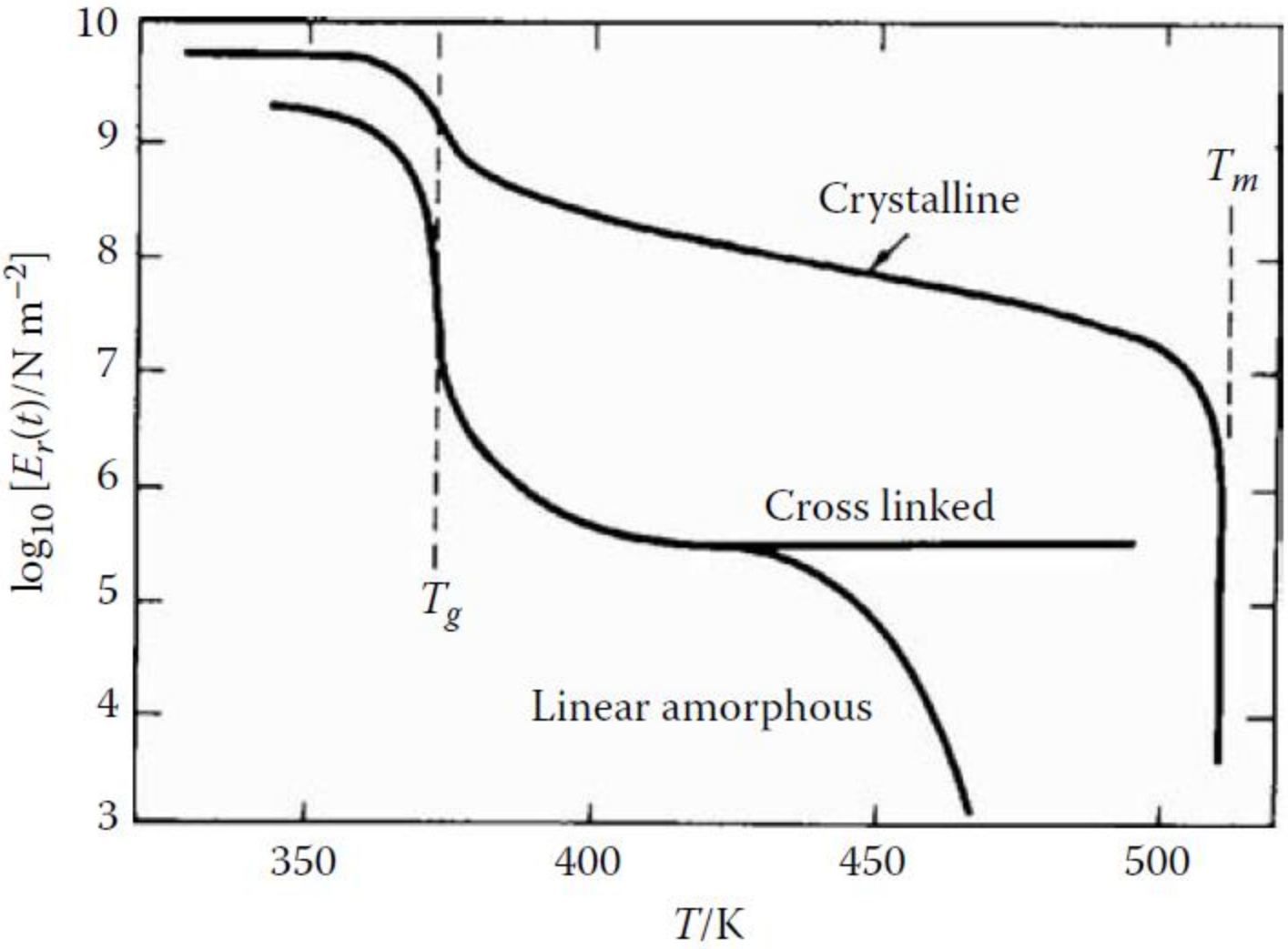
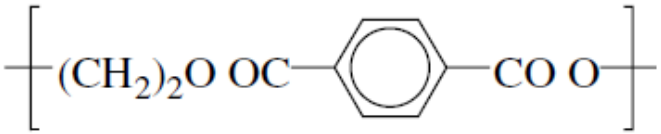
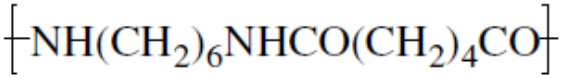
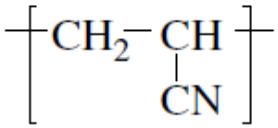
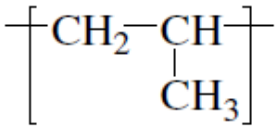
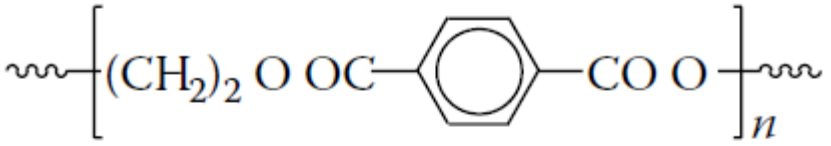
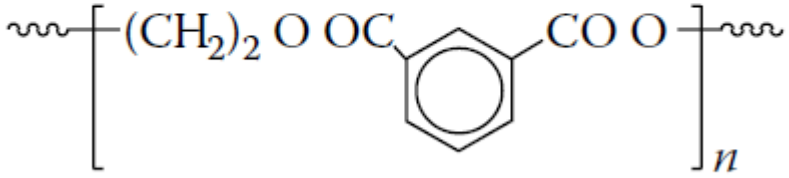

10
9
8
7
6
5
4
3
$\log_{10}[E_r(t)/\mathrm{N\ m^{-2}}]$
Crystalline
T_m
Cross linked
T_g
Linear amorphous
350
400
450
500
T/K

TABLE 15.4
Values of T_m and T_g of Some Typical Fibers

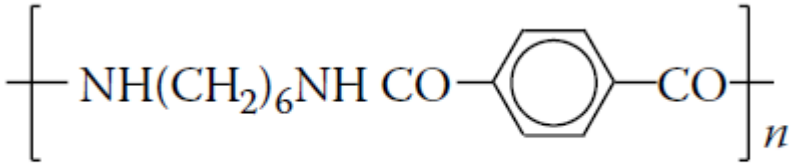
Polymer	Structure	T_g(K)	T_m(K)
Poly(ethylene terephthalate)		343	538
Nylon-6,6		333	538
Polyacrylonitrile		378	590
Polypropylene (isotactic)		268	435


(CH2)2 O OC
CO O
n

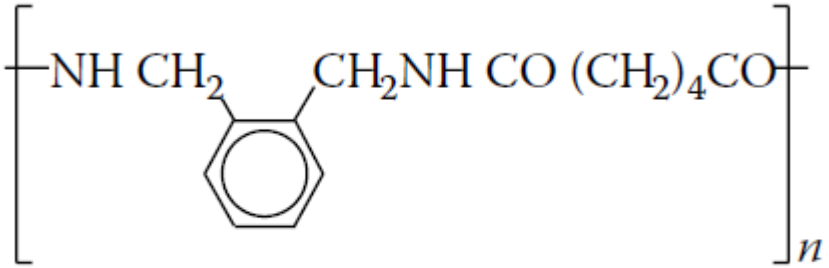
I


(CH2)2 O OC
CO O
n

II

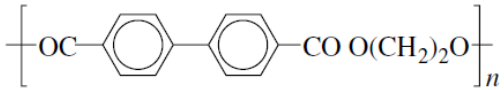
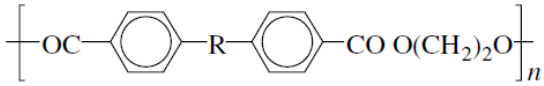
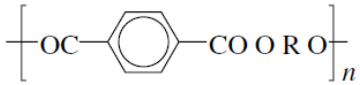
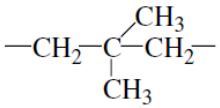
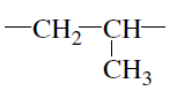
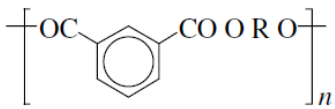
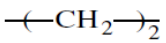
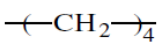
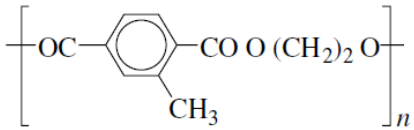
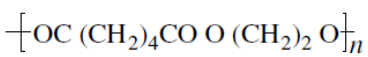

NH(CH2)6NH CO
CO
n

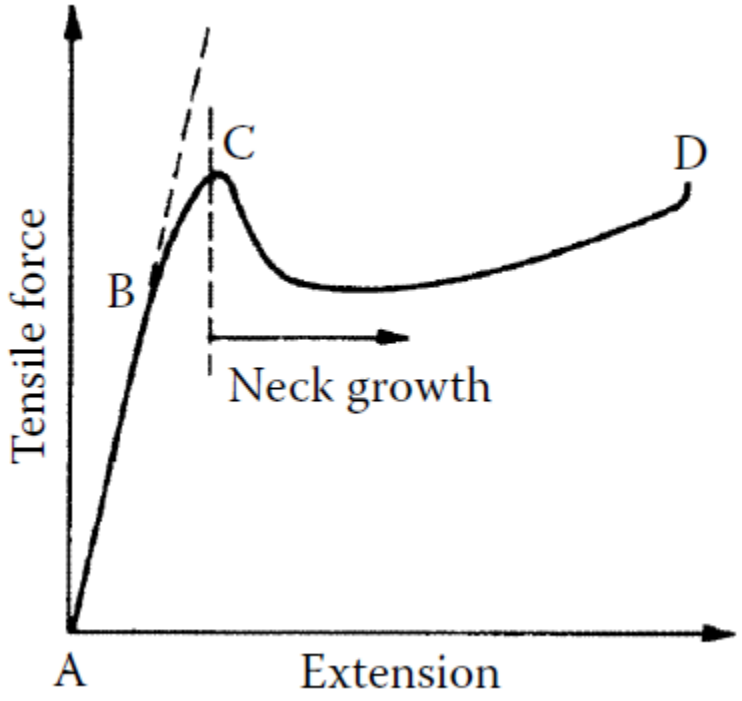
III

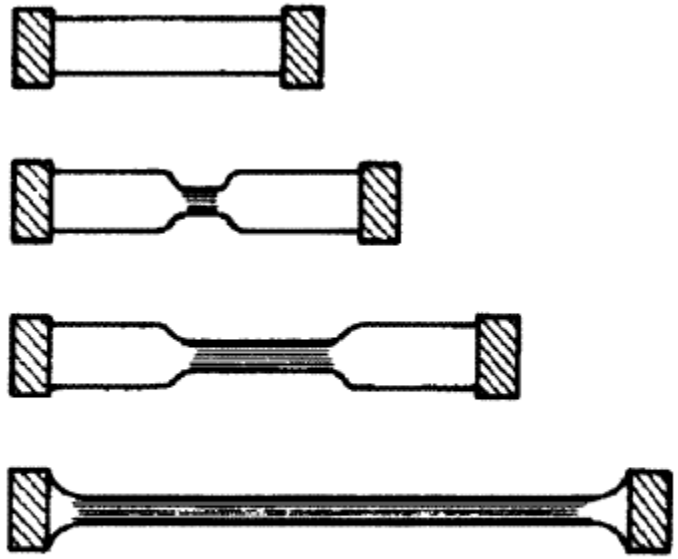

NH CH2
CH2NH CO (CH2)4CO
n

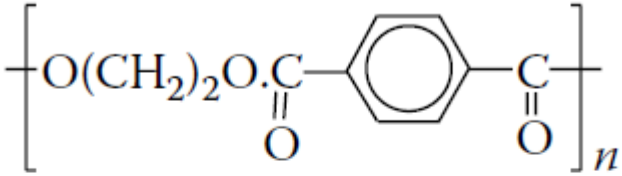
IV

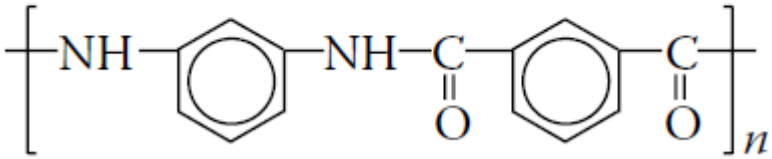
TABLE 15.5
Values of T_m and T_g for Linear Polyesters

Structure	Group R	T_m(K)	T_g(K)
1. 		528	—
2. 	(i) $-(CH_2)_4-$	443	—
	(ii) $-O-(CH_2)_2-O-$	513	—
	(iii) $-NH-(CH_2)_2-NH-$	546	—
3. 	(i) $-(CH_2)_2-$	538	342
	(ii) $-(CH_2)_4-$	503	353
	(iii) 	413	—
	(iv) 	non-crystalline	341
4. 	(i) 	513	324
	(ii) 	426	—
5. 		343	—
6. 		323	—


Tensile force
A
B
C
D
Neck growth
Extension




O(CH2)2O
C
O
C
O
n


NH
NH
C
O
C
O
n

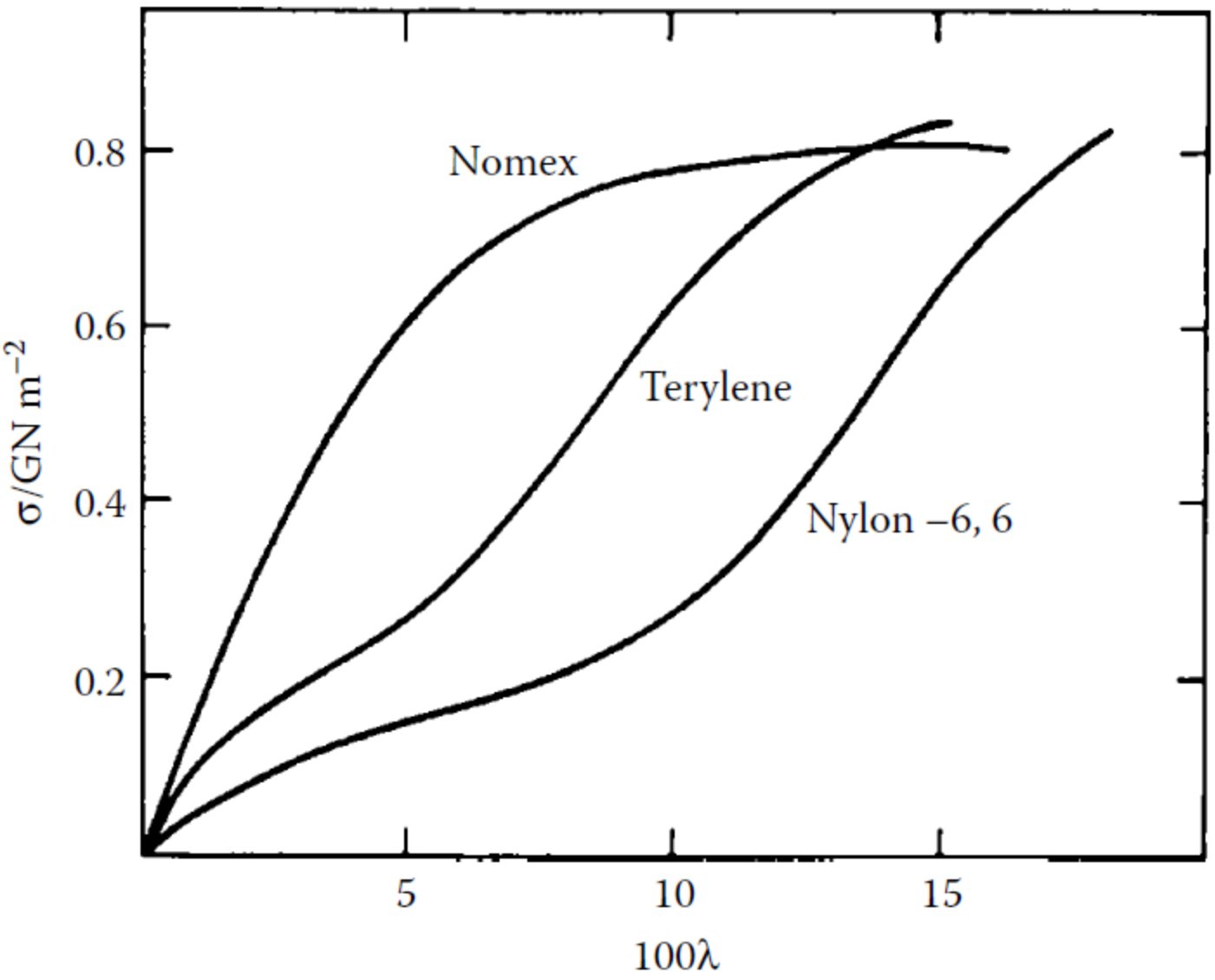
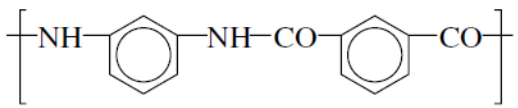
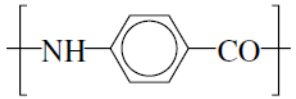
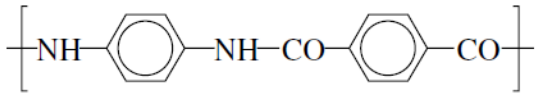
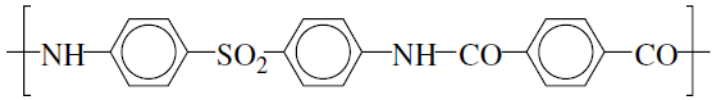
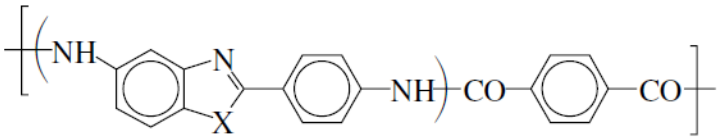
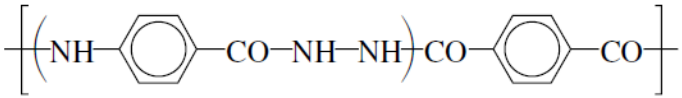
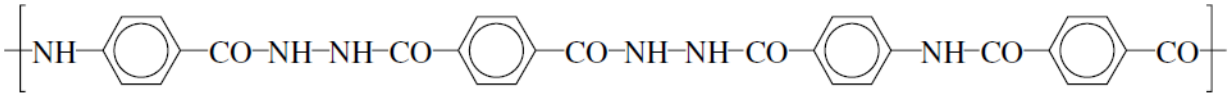
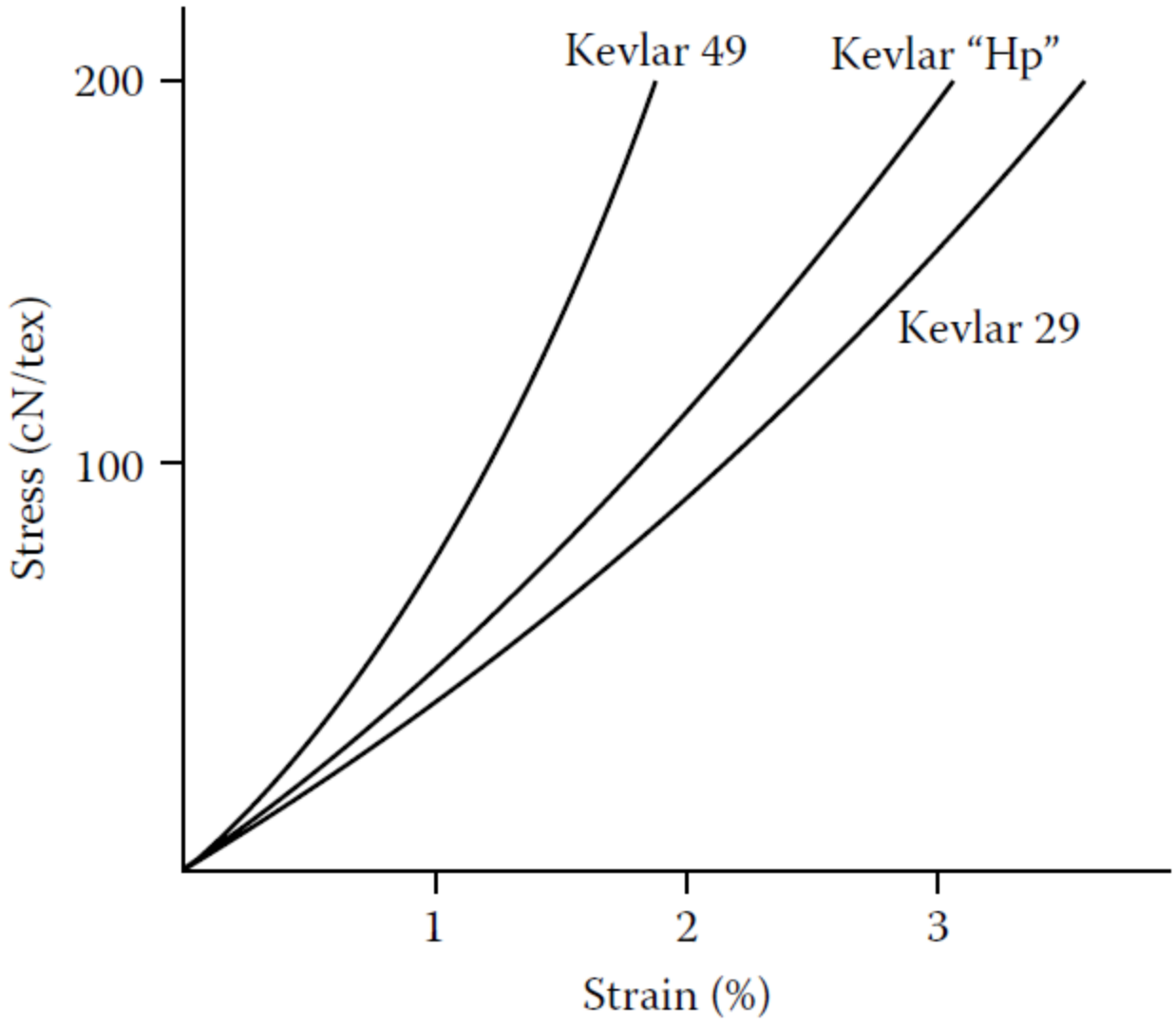
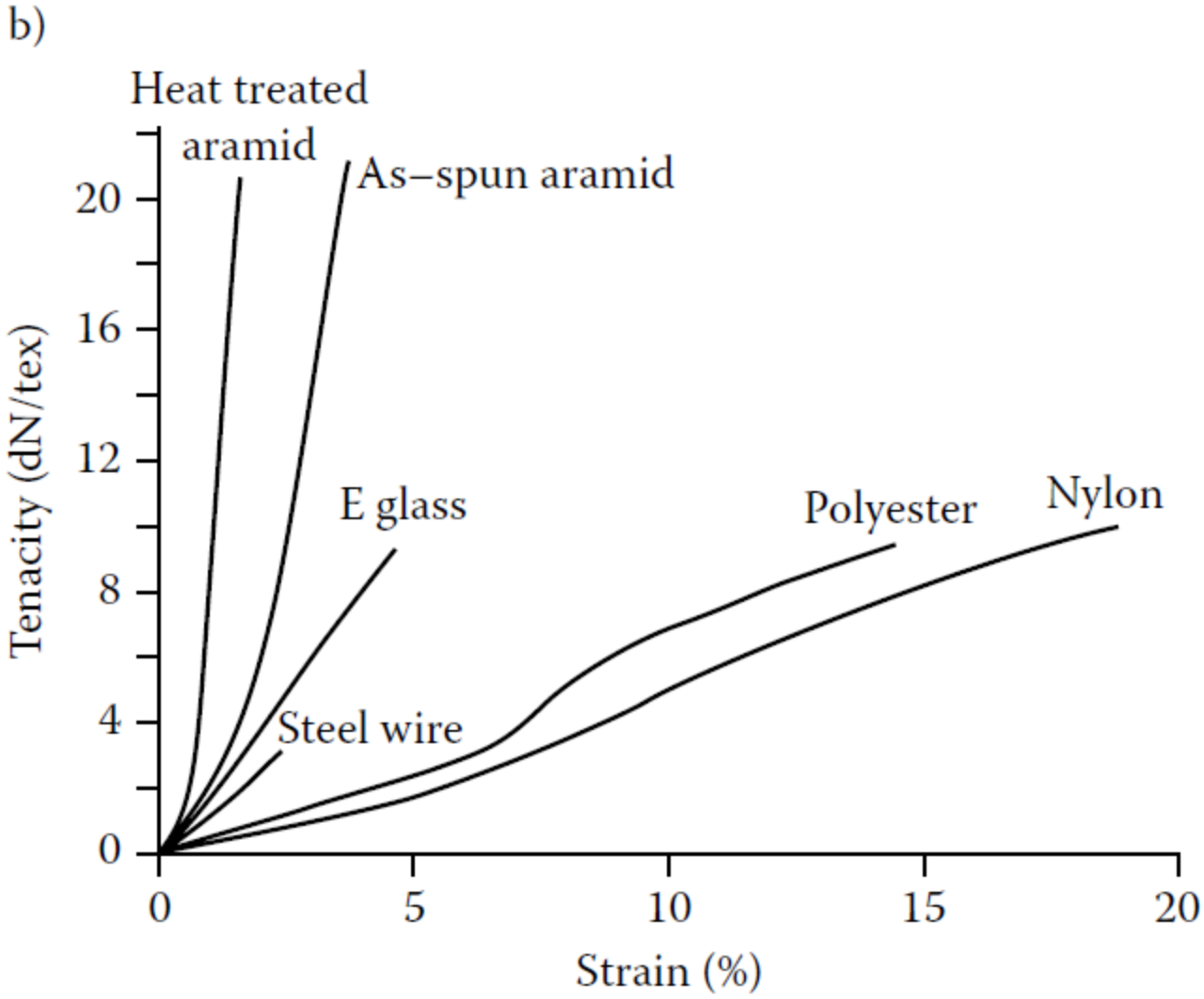
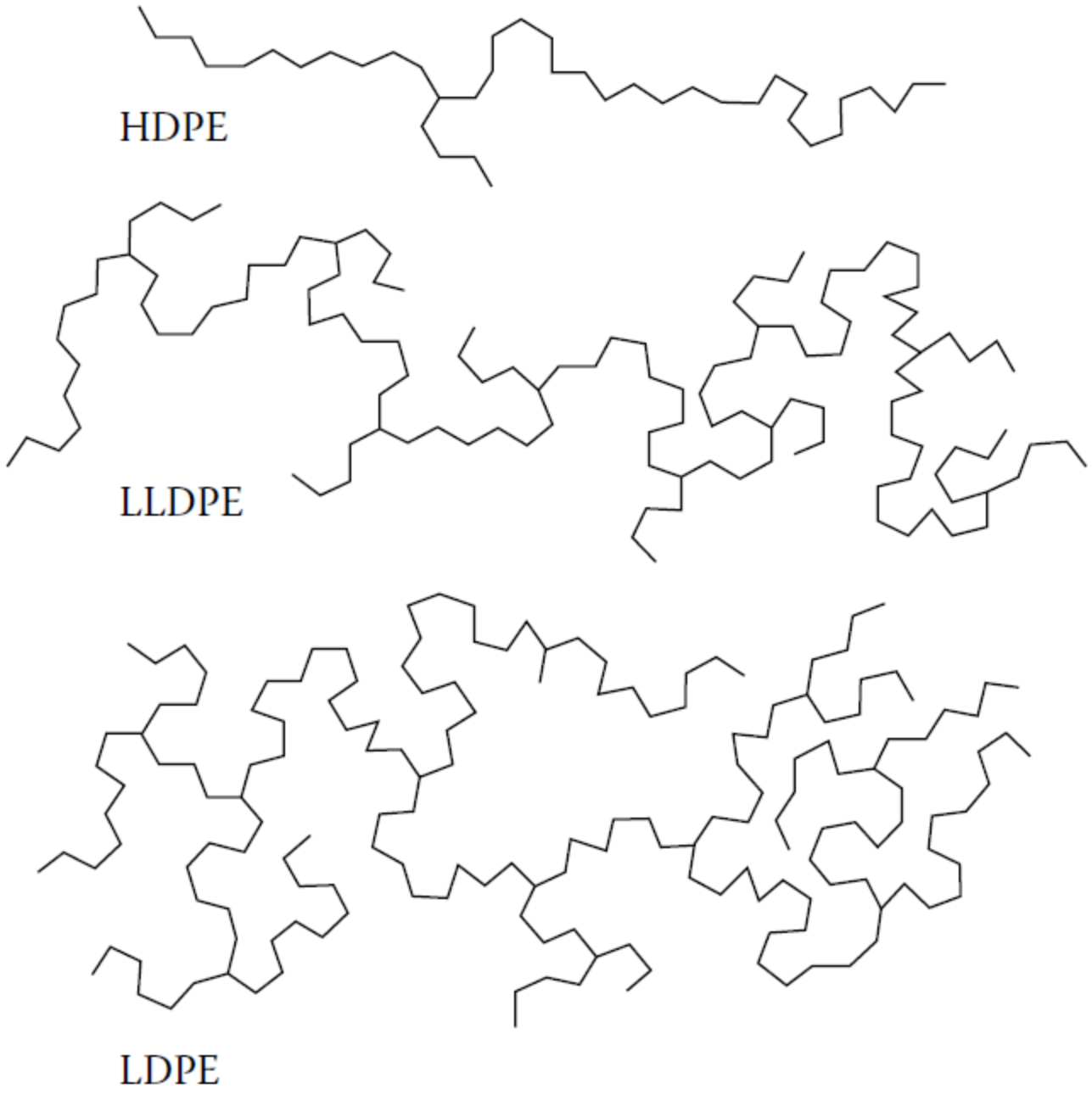

Nomex
Terylene
Nylon –6, 6
0.8
0.6
0.4
0.2
σ/GN m⁻²
5
10
15
100λ

TABLE 15.6
Commercially Important Aramid of Fiber-Forming Polymers

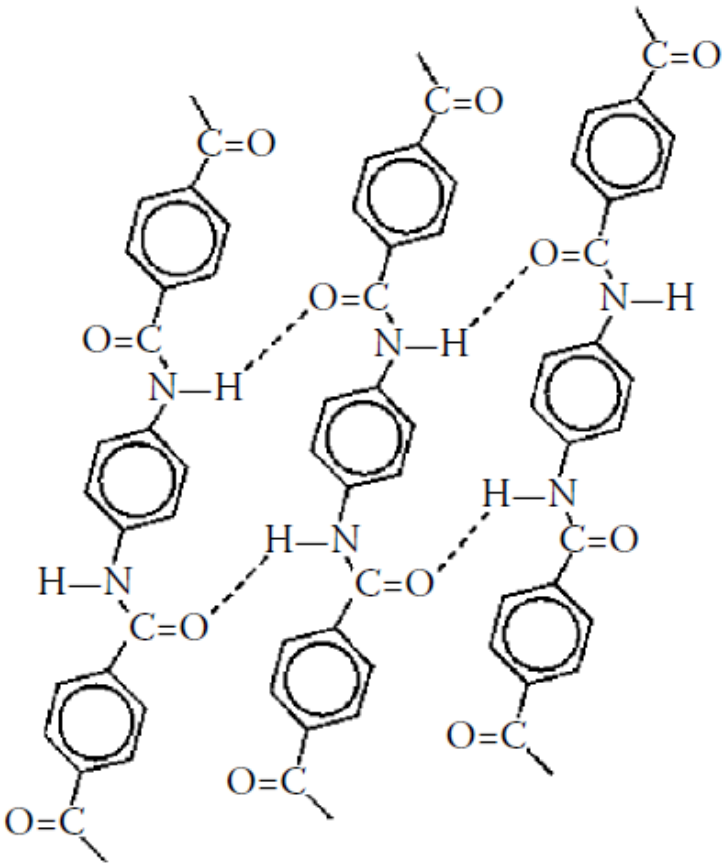
	Polymer		Trade Name
I		MPD-1	Nomex
II		PPB	Fiber B Terlon
III		PPD-T	Kevlar Twaron
IV			Sulfon T
			SVM
	X = —O—, —S—, —NH—		
			X-500-Series
	non-ordered structure		
			
	ordered structure		Flexten


Kevlar 49
Kevlar "Hp"
Kevlar 29
200
100
Stress (cN/tex)
1
2
3
Strain (%)


b)
Heat treated
aramid
As–spun aramid
E glass
Polyester
Nylon
Steel wire
Tenacity (dN/tex)
0
4
8
12
16
20
0
5
10
15
20
Strain (%)


HDPE
LLDPE
LDPE

Hydrogen bonded sheet



Fiber axis

Sheets stack toget

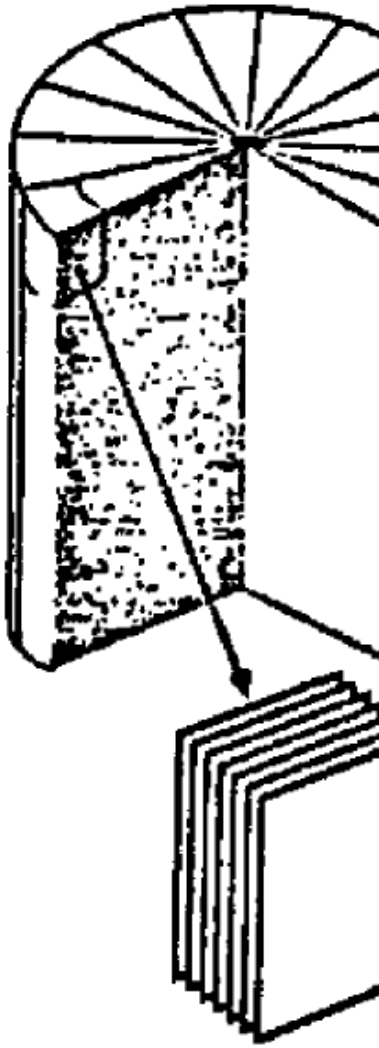
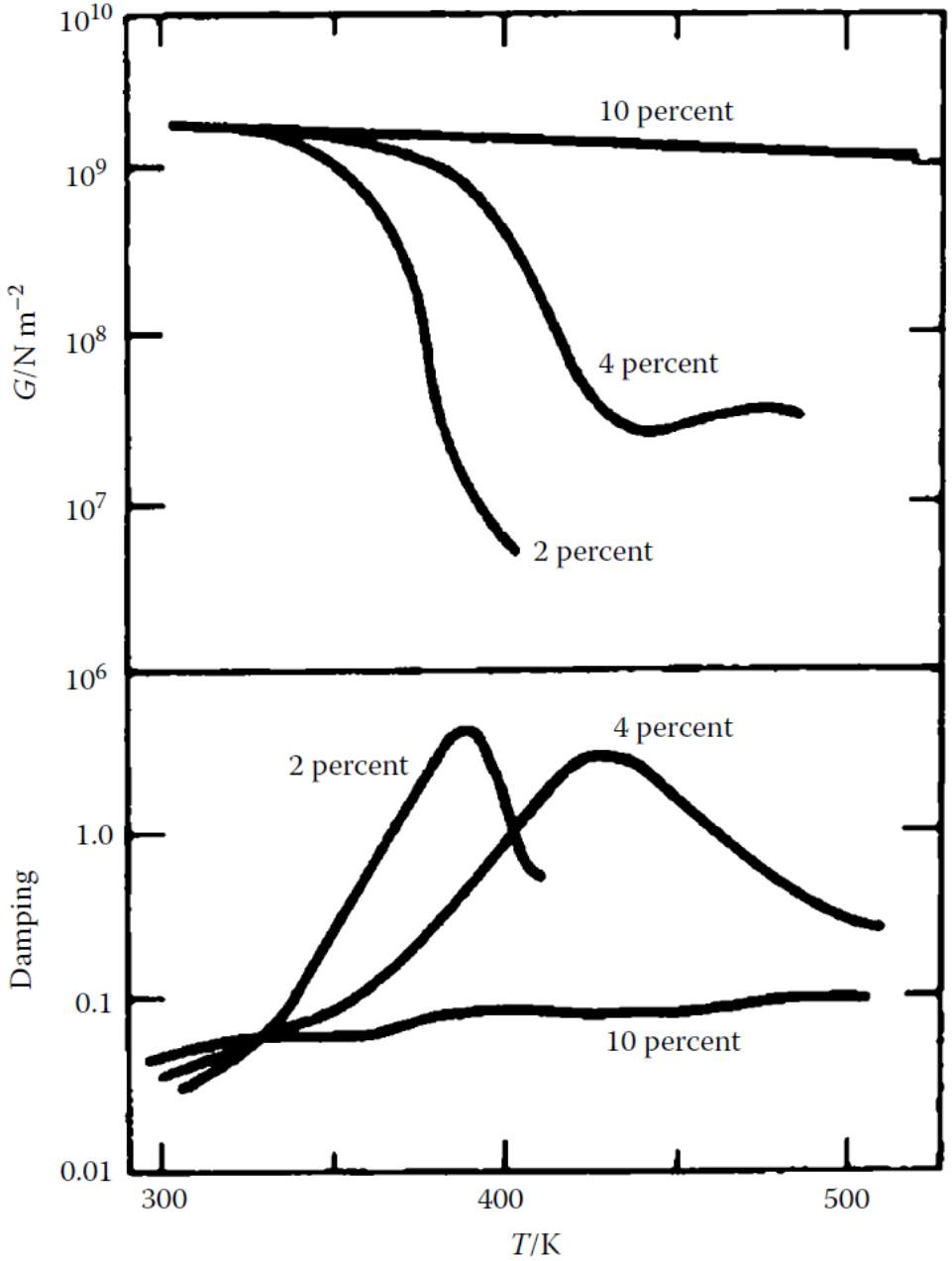
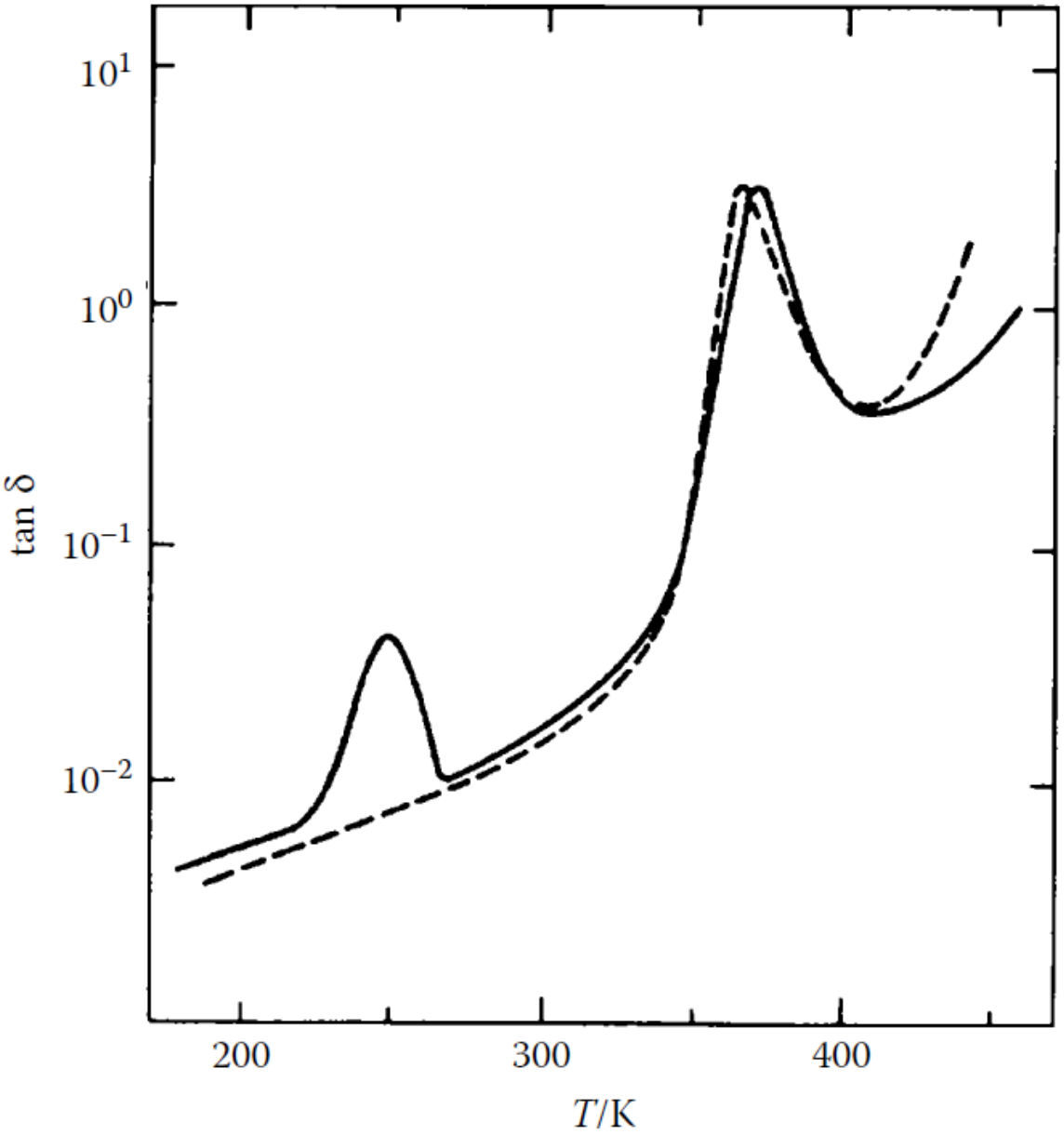


TABLE 15.7
Comparison of Various Polyethylene Grades

Property	LDPE	LLDPE	HDPE
Melting point (K)	383	393–403	>403
Density (g/cm^3)	0.92	0.92–0.94	0.94–0.97
Film tensile strength (MPa)	24	37	43


10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
G/N m^{-2}
10 percent
4 percent
2 percent
Damping
1.0
0.1
0.01
2 percent
4 percent
10 percent
300
400
500
T/K


10^1
10^0
10^{-1}
10^{-2}
tan δ
200
300
400
T/K

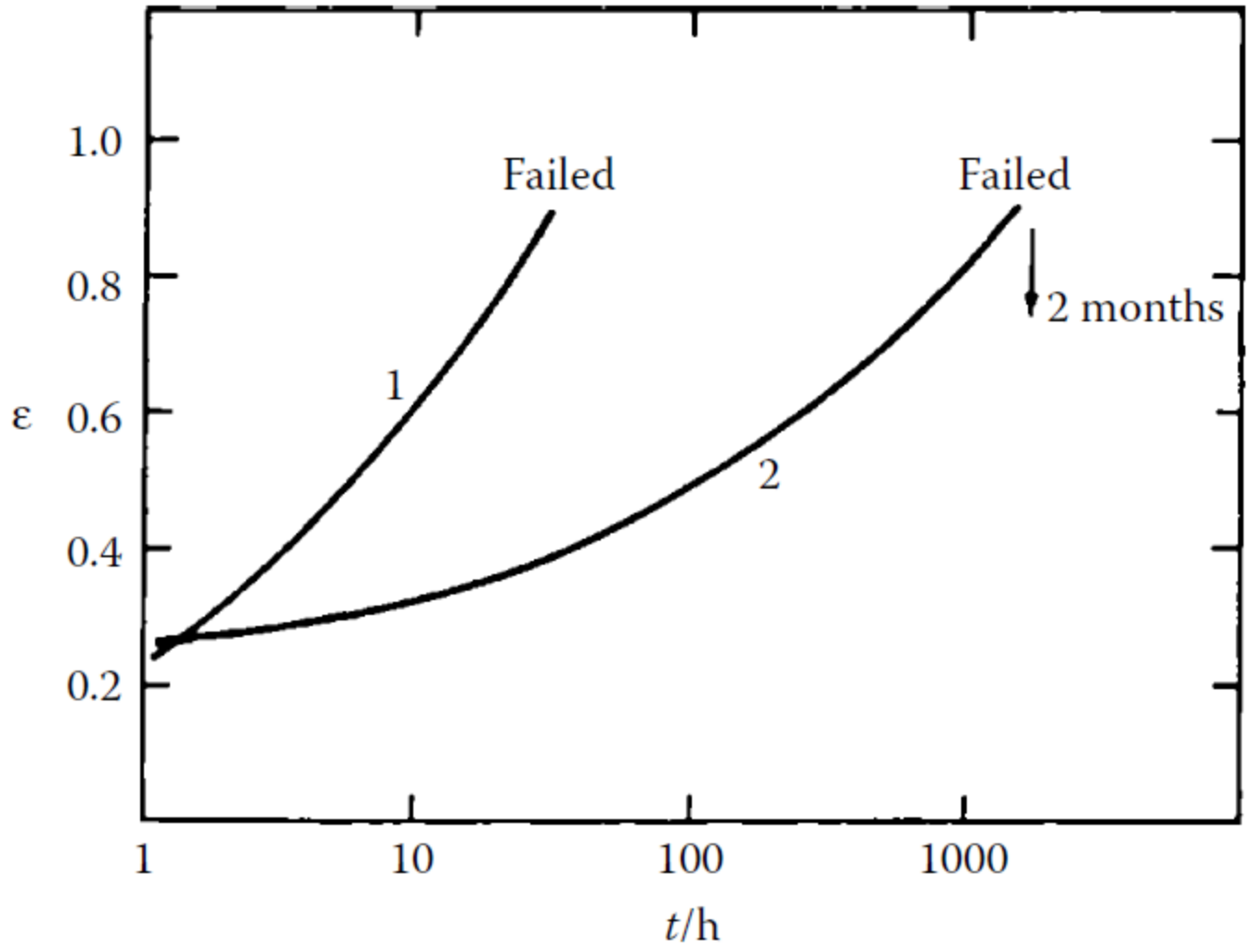
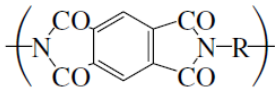
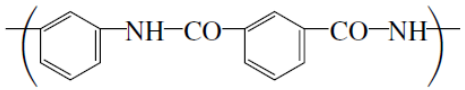
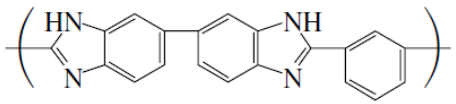
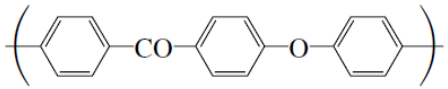
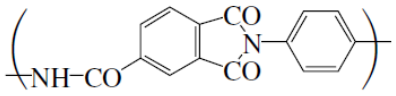
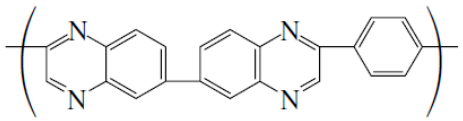
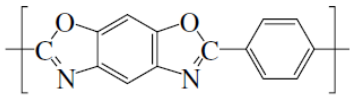
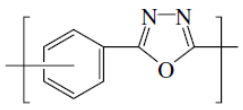
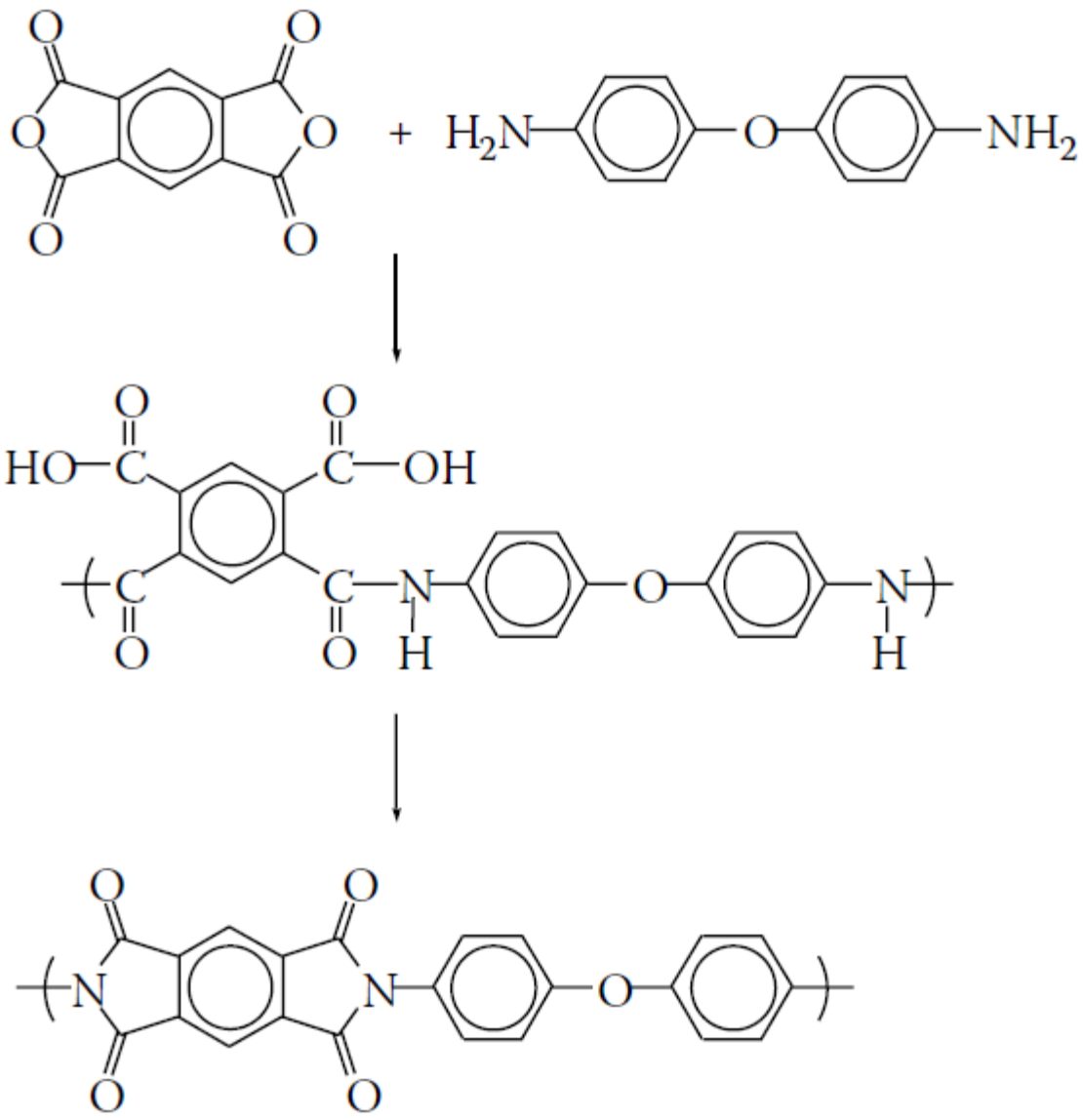
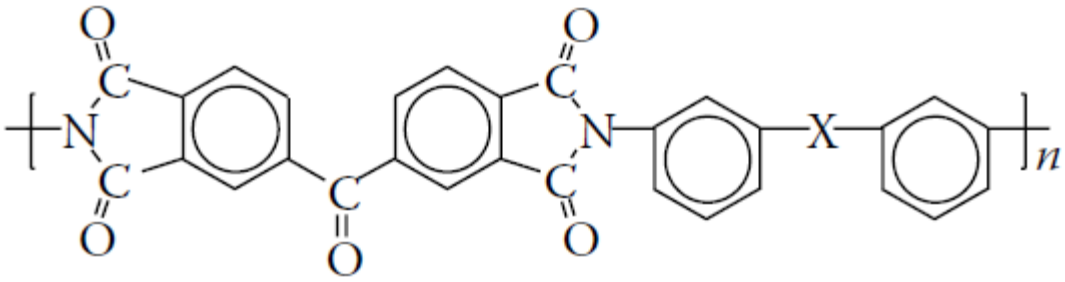
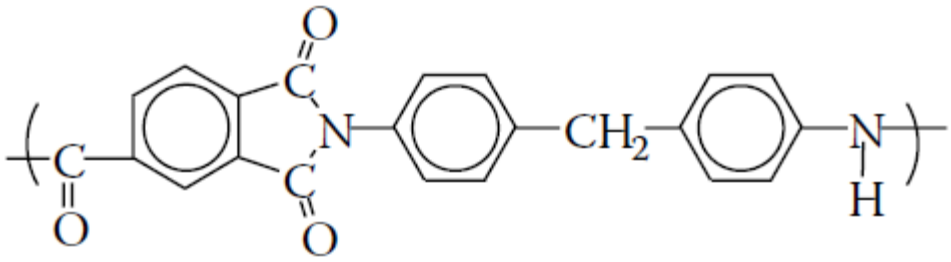

1.0
0.8
0.6
0.4
0.2
ε
Failed
Failed
2 months
1
2
1
10
100
1000
t/h

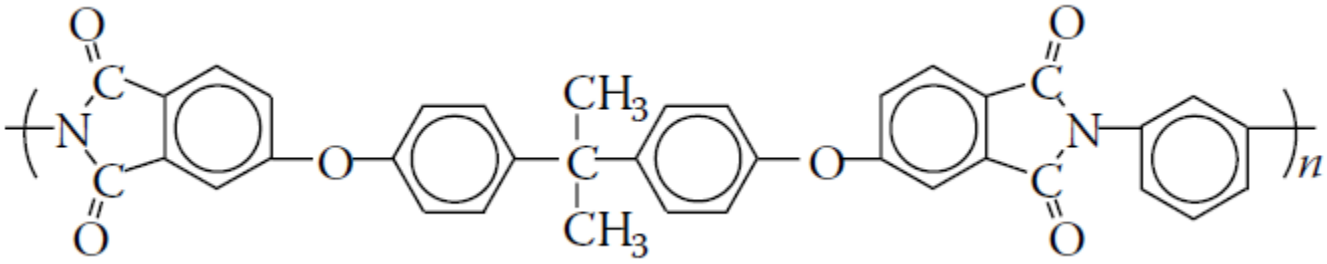
TABLE 15.8
Structures of Polymers with Exceptional High-Temperature Performance

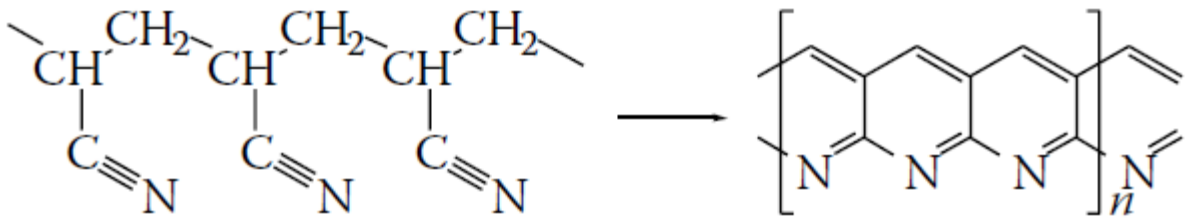
Polymer	Upper Service Temperature [K]
 polyimide	570–620
 aromatic polyamide (aramid)	470–520
 polybenzimidazole	520–570
 polyetheretherketone	510–530
 polyamide-imide	490–510
 polyquinoxaline	670–720
 poly (*p*-phenylene-benzobisoxazole)	600–800
 poly(oxadiazole)s	480–600




O
C
N
C
O
C
O
O
C
N
C
O
X
n

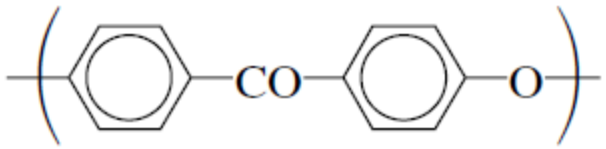

O
C
N
C
O
O
C
O
CH2
N
H



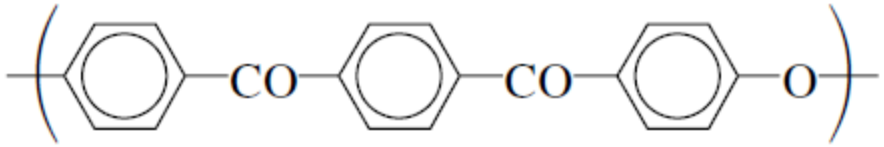


idealized structure

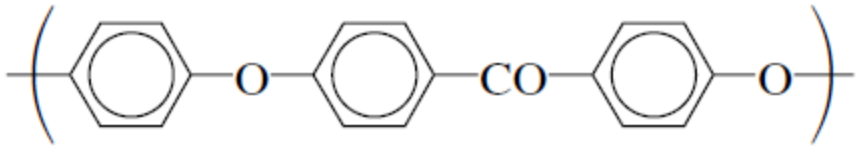
TABLE 15.11
Typical Aromatic Poly(ether ketone)s



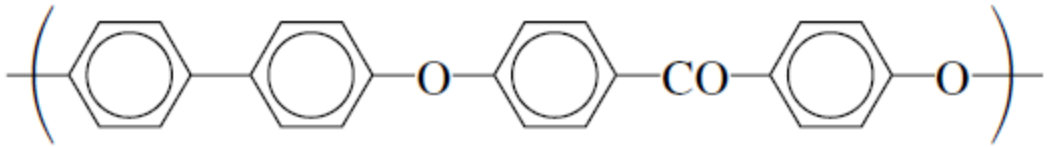
(I) T_g 427K, T_m 640K



(II) T_m 657K



(III) T_g 417K, T_m 628K



(IV) T_m 689K

Fim!