CHAPTER 62

Definitions

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Adherend A body that is held to another body by adhesion.

Adhesion The state in which two surfaces are held together by interfacial forces of attraction.

Adhesive An adhesive is a linear or branched amorphous polymer applied in a fluid state. It must contain molecular moieties that are attracted to each of two surfaces being joined together.

Aging A long-term deleterious change in properties of a polymer composition during its service life.

Amorphous Orientation Oriented amorphous regions in a polymeric material where shear, etc., have caused elongational flow.

Amorphous Polymer A polymer in which the molecular chains exist in the random coil conformation since there is no regular three-dimensional arrangement of molecules or subunits of molecules extending over distances that are large compared to atomic dimensions, i.e., there is no long-range order. There is no crystallinity in an amorphous polymer.

Amorphous Region A region in a material or a portion of a property versus temperature curve in which the polymer chains exist in the random coil conformation.

Anelastic Mechanical behavior in which the stress and strain are not single-valued functions of each other. This occurs particularly when a periodic stress is applied due to internal friction in a viscoelastic material.

Anisotropy The dependence of the properties of a material on the direction in which they are being observed. In polymers, anisotropy occurs when the polymer molecules are oriented or when anisotropically shaped and oriented fillers are present.

Annealing The improvement of crystallinity by heating to temperatures below the melting temperature due to a certain amount of molecular rearrangement. A molecular process that allows relaxation of frozen-in stresses and strains in a bulk material.

Beta Transition A subsidiary glass transition occurring at a temperature, T_β, lower than that of the α-transition.

Biaxial Birefringence Birefringence resulting from biaxial orientation.

Bimodal Distribution A molecular-weight distribution in which the differential weight distribution function has two maxima.

Biodegradation Degradation induced by the physiological environment.

Biopolymers Biopolymers include all naturally occurring, large, polymeric molecules, such as polypeptides and proteins, nucleic acids, and polysaccharides.

Biplanar Fracture Fracture in which crack propagation takes place on two parallel planes.

Birefringence The difference between the refractive indices of two perpendicular directions as measured with polarized light along these directions.

Branched Polymer A branched polymer has side chains, or branches, of significant length, which are bonded to the main chain at branch points.

Brittle–Ductile Transition The temperature at which the mode of fracture changes from brittle to ductile fracture.

Brittle Fracture Fracture that occurs without significant plastic deformation of the material at the crack tip.

Cellular Polymer A polymer whose apparent density is decreased substantially by the presence of numerous cells dispersed throughout its mass.

Cellulose The most abundant natural polymer. It is composed of glucose, being the major cell-wall material in land plants and their main structural component.

Chain Flexibility The ability of polymer chain molecules to assume a variety of configurations, arising from freedom of segments to rotate around C–C bonds. Polar side groups generally hinder rotation, making chain stiffer, while alkyl side chains tend to increase flexibility.

Characteristic Ratio A measure of the expansion of a polymer chain due to steric interactions and valence-bond angle restrictions. It is defined as

$$C_\infty = \langle r^2 \rangle_0 / nl^2,$$

where $\langle r^2 \rangle_0$ is the unperturbed mean square end-to-end distance and n is the number of links of length l in the chain.

Chemical Cross-link The existence of a retaining force between polymer chains, brought about by covalent bonding.

Chemical Degradation Degradation induced by chemical attack on polymers.

Chemisorption Adsorption, especially when irreversible, by means of chemical, rather than physical, forces.

Circular Birefringence Birefringence due to the different velocities of propagation of light polarized circularly in the clockwise and anticlockwise directions in an optically active material.

Contact Angle The angle between the edge of a liquid drop and the solid surface with which it is in contact.

Complex Modulus A representation of the dynamic mechanical properties of viscoelastic materials. The real part of the complex modulus, the component in phase with the measuring frequency, is called the storage modulus and the imaginary part, the component out of phase with the measuring or driving frequency, is called the loss modulus.

Composite Material A material that consists of a combination of two or more materials and in which the individual components retain their separate identities. Usually one component is drastically more rigid than the other. If both components are similar, it is referred to as a blend.

Conducting Polymer A polymer that exhibits electrical conductivity, i.e., greater than about 10^{-10}S cm^{-1}.

Configuration Configuration denotes the stereochemical arrangements of the atoms in the polymer chain. The configuration of a polymer chain cannot be altered without breaking and reforming chemical bonds.

Conformation Conformation of a polymer molecule describes the geometrical arrangements of the atoms in the polymer chain achieved through rotations about or stretching of its chemical bonds and bending of its valence angles.

Constitutive Equation Any equation relating stress, stress rate, and strain rate.

Contour Length The length of a fully extended polymer chain along its backbone.

Controlled Release The systems that can provide some control, whether this be of a temporal or spatial nature, or both, of drug release in the body.

Copolymer A polymer that is derived from more than one species of monomer. There are several categories of copolymers, each being characterized by a particular form of arrangement of the repeat units along the polymer chain. A *random* copolymer is a special type of statistical polymer in which the distribution of repeat units is truly random. An *alternating* copolymer has only two different types of repeat units, which are arranged alternatively along the polymer chain. A *block* copolymer is a linear copolymer in which the repeat units exist only in long sequences, or blocks, of the same type. A *graft* copolymer is a branched polymer in which the branches have a different chemical structure from that of the main chain.

Coupling Agent A material applied as a thin layer to the surface of a reinforcing filler to improve the adhesion between the filler and a polymer matrix in a filler–polymer composite.

Crazing A localized form of plastic deformation due to internal stresses or solvents modifying a chemical structure.

Creep The progressively increasing strain over a period of time of a viscoelastic material when subject to a continuously applied stress.

Cross-link A structure chemically or physically bonding two or more chains together.

Crystal–Crystal Transition The transformation of one crystal structure of a polymer to a different crystal structure, for example, below 19 °C Teflon is triclinic and above 19 °C the packing is hexagonal.

Crystalline Orientation The component of the overall orientation due to the crystalline regions of a crystalline polymer.

Crystallinity The long-range regular ordering of atoms or molecules in unit cells on a three-dimensional crystalline lattice.

Crystallization The process of formation of a crystalline (ordered) material from a disordered aggregate of molecules.

Degree of Polymerization The number of repeat units in a polymer chain.

Dielectric Constant The ratio of the capacitance of the capacitor with the material in place to its capacitance with vacuum between the plates.

Dielectric Spectroscopy The determination of dielectric properties such as the loss factor and the dielectric constant as a function of frequency at different fixed temperatures.

Differential Scanning Calorimetry A thermal analysis technique that measures the energy required to maintain the temperature of the sample equal to that of an inert reference material.

Domain A region in a material that has homogeneous properties, e.g., a phase-separated block copolymer where aggregates of blocks of one type are incompatible with blocks of the second type.

Ductile Fracture Fracture in which significant plastic deformation occurs before fracture.

Dynamic Mechanical Behavior The stress–strain behavior of a material when subject to an applied sinusoidally varying stress or strain.

Dynamic Mechanical Spectroscopy The determination of dynamic mechanical behavior over a range of frequency or temperature.

Elasticity The reversible stress–strain behavior by which a body resists and recovers from deformation produced by a force.

Elastic Modulus A constant of proportionality in the generalized Hooke's law relationship between stress and strain.

Elastic–Plastic Transition The change from recoverable elastic behavior to nonrecoverable plastic strain, which occurs on stressing a material beyond its yield point.

Elastic Scattering The scattering of radiation by a medium in which the scattered radiation has the same wavelength as the incident radiation. There is conservation of energy and momentum.

Elastomers Elastomers are chemically or physically cross-linked rubbery polymers (i.e., rubbery networks) that can be easily stretched to high extensions and rapidly recover their original dimensions when the applied stress is released. Use temperatures are above T_g in the rubbery plateau region.

End-To-End Distance The distance separating the two ends of a polymer chain.

Engineering Polymer A processable polymeric material, capable of being formed to precise and stable dimensions, exhibiting high performance at the continuous use temperature above 100 °C and having tensile strength in excess of 40 MPa.

Environmental Stress Cracking A type of cracking in which the polymer fails by breaking when subject to mechanical stress in the presence of an organic liquid or an aqueous solution of a soap or other wetting agent.

Excluded Volume The volume in a solution, in addition to the volume physically necessarily occupied by the solute molecules, from which other molecules are excluded due to the fact that the distance between two molecules cannot be less than the sum of their radii.

Fatigue In general, the progressive weakening of a material component with increasing time under load, such that the load that would not produce failure at short times does produce failure at long times.

Fiber A solid material in the form of a piece whose length is very much greater than its diameter (typically a micron), and characterized by its fineness and flexibility. Often called a filament.

Filler A relatively inert additive for a polymer composition to modify the physical properties of a polymer, thus forming a composite.

Flory–Huggins Interaction Parameter A measure of polymer–solvent interaction energy.

Fractal Geometry Fractal geometry is concerned about the quantitative description of complex structures and the ways in which these structures transform under a change of length scales.

Fracture A stress-biased material disintegration through the formation of new surfaces within a body.

Free Volume The volume of the vacant sites or holes present in a amorphous solid, not occupied by the molecules of the polymer.

Freely Jointed Chain A simple model of a polymer chain consists of n links of length l joined in a linear sequence with no restrictions on the angles between successive bonds.

Gaussian Chain A chain whose statistical distribution of chain end-to-end distances is a Gaussian distribution.

Gel A polymer network that contains solvent.

Gelation Any process in which a gel is formed.

Glass Transition Temperature The temperature at which polymers transform abruptly from the glassy state (hard) to the rubbery state (soft), symbolized as T_g. This transform corresponds to the onset of chain motion. Below the glass transition temperature, the thermal energy available for chain motion is inadequate to allow much relative motion between chains.

Head-to-Head Structure A structure in a vinyl or related polymer that has the form $\sim CH_2{-}CHR{-}CHR{-}CH_2 \sim$, R being designated the head.

Head-to-Tail Structure A structure in a vinyl or related polymer that has the form $\sim CHR{-}CH_2{-}CHR{-}CH_2 \sim$, R being designated the head.

Heterogeneous Nucleation Primary nucleation in the presence of a foreign surface that enhances nucleation by reducing the critical size needed for crystal growth.

Homogeneous Nucleation Primary nucleation without the presence of preformed nuclei or crystalline surfaces.

Homopolymer A polymer whose structure can be represented by multiple repetition of a single type of repeat unit.

Hydrogel A slightly cross-linked polymer that is highly swollen by water.

Ideal Solution A mixture of molecules that are identical in size and for which the energies of like and unlike molecular interactions are equal.

Impact Resistance A measure of the ability of a material or structure to withstand the application of a sudden load.

Interface A surface separating dissimilar materials in intimate contact.

Interpenetrating Polymer Network An intimate combination of two polymer networks, not chemically bonded to each other, at least one of which is synthesized and/or cross-linked in the immediate presence of the other.

Ionic Polymer A polymer that carries electrostatic charges.

Ionomer A generic term for a class of thermoplastics containing ionizable carboxyl groups that can create ionic cross-links between chains.

Kinetic Chain Length The number of monomers consumed per active center.

Lamella The platelike crystal or crystallite that is the characteristic crystal habit of most crystalline polymers and polymer single crystals.

Linear Polymer A polymer in which the molecules consist of single unbranched chains of atoms.

Liquid-Crystalline Polymer A polymer that is capable of forming a liquid-crystalline phase (a mesophase).

Living Polymer A polymer in which the active centers of the polymerization are retained even if all the monomer has been consumed.

Mechanochemical Degradation A chain scission type of degradation induced by mechanical shear.

Melting Temperature The temperature at which the thermal energy in a solid material is just sufficient to overcome the intermolecular forces of attraction in the

crystalline lattice so that the lattice breaks down and the material becomes a liquid, i.e., it melts.

Membrane A thin barrier that permits selective mass transport.

Molecular-Weight Average Several different averages, all ratios of the moments of the distribution, are used. They are given by

$$M = \sum N_i M_i^{n+1} \Big/ \sum N_i M_i^n,$$

where there are N_i molecules of molecular weight M_i for each molecular species i. In the number-average weight (M_n), $n = 1$; in the weight-average molecular weight (M_w), $n = 2$; in the Z-average molecular weight (M_z), $n = 3$.

Molecular-Weight Distribution The distribution of molecular sizes in a polydisperse polymer.

Monolithic Device A device in which the drug of interest is uniformly dispersed within a polymeric matrix.

Monomers Small molecules that combine with each other to form polymers.

Nanotechnology The technology that creates functional materials, devices, and systems with novel properties and phenomena through control of matter on the scale of 1–100 nm

Neutron Scattering The interaction of neutrons with a material such that they are deflected.

Nonlinear Optics Nonlinear optics is basically concerned about the interaction of optical frequency electromagnetic fields with materials, resulting in the alteration of the phase, frequency, or other propagation characteristics of the incident light.

Nucleating Agent An additive that provides nuclei for heterogeneous crystallization, raising the crystallization rate and temperature. More and smaller spherulites are consequently produced.

Permeability The proportionality constant in the general equation for mass transport of a penetrant across the barrier, i.e., the product of permeance and thickness.

Permeation The rate at which a gas or vapor passes through a barrier material.

Photoconductive Polymer A polymer that exhibits a relatively high electrical conductivity when irradiated with visible or ultraviolet light.

Photodegradation Degradation induced by exposure to ultraviolet radiation.

Photoresist A photosensitive polymer system, which, when applied as a coating to a substrate, after interaction with ultraviolet or visible light undergoes a change in solubility.

Physical Cross-Link The existence of a retaining force between polymer chains, brought about by noncovalent bonding.

Piezoelectric Polymer A polymer whose polarization changes under strain, due either to a change in dimensions or to electrostriction.

Polymer A polymer is a large molecule built up by the repetition of small, simple units, which are linked to each other through primary covalent bonds.

Polymer Alloy Polymer blend having a modified interface and/or morphology.

Polymer Blend An intimate combination of two or more polymer chains of constitutionally or configurationally different features that are not bonded to each other.

Polymerization A process by which monomer molecules are linked to form polymers.

Pyroelectric Polymer A polymer whose polarization changes on heating.

Radius of Gyration A parameter characterizing the size of a polymer random coil. It is given by

$$R_G^2 = \sum m s_i^2 \Big/ \sum m = \sum s_i^2 / n,$$

where the polymer chain consists of n segments, each of mass m, located at distance s from the center of gravity of the coil.

Raman Scattering An inelastic process with a shift in wavelength due to chemical absorption or emission.

Rayleigh Scattering Elastically scattered light, usually measured as a function of scattering angle.

Relaxation Time The time required to respond to a change in temperature or pressure.

Repeat Unit The smallest structural unit of a polymer chain.

Reservoir Device A device in which the drug to be released is surrounded by an appropriate polymer membrane.

Rheo-Optics The use of optical methods to study flow and deformation in materials.

Second Virial Coefficient The coefficient of the most important term of the virial equation that accounts for the nonideality of behavior of a system, in particular of the colligative and other properties of dilute solutions. Generally, the virial equation is of the form.

$$P = RT(c_2/M_2 + A_2 c_2^2 + \dots),$$

where P is the colligative property, c_2 is the concentration of solute, M_2 is the molecular weight of solute, and A_2 is the second virial coefficient.

Self-Assembly A method of integration in which the components spontaneously assemble, typically by bouncing around in a solution or gas phase until a stable structure with minimum energy is reached.

Semiconducting Polymer A polymer having an electrical conductivity in the range 10^{-10}–10^{2}S cm^{-1}.

Semicrystalline Polymer A polymer that has both crystalline and amorphous regions.

Semi-Interpenetrating Polymer Network A combination of two polymers, not chemically linked to each other, one cross-linked and one linear, at least one of which is synthesized and/or cross-linked in the immediate presence of the other.

Sequence Length The number of repeat units of a specific type joined to each other contiguously in a polymer chain.

Solubility A measure of the extent to which two pure components can be mixed homogeneously.

Spherulite An aggregation of crystallites as a spherical cluster, consisting of fibrillar crystalline lamellae radiating from the center of the spherulite.

Spinodal The line on a temperature versus composition phase diagram of a mixture of two components that separates the two phase region from a metastable single phase region between the binodal and spinodal.

Spinodal Decomposition A process of phase separation that occurs when the temperature of a homogeneous mixture of two components is rapidly changed, so that the system is brought to a state in which both the spinodal and binodal have been crossed.

Star Polymer Three or more chains linked at one end through a central moiety.

Stress Intensity Factor A factor relating the magnitude of the stress components in the vicinity of a crack tip to the crack and specimen geometry and the overall stress.

Stress Relaxation The relatively slow decay of the stress when a viscoelastic material is held at a constant strain after being rapidly stressed initially.

Supercooling The temperature difference between the equilibrium melting temperature and the temperature of crystallization.

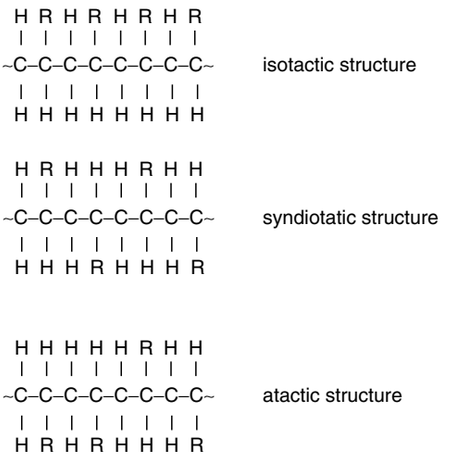
Supermolecular Structure Polymer structure features observable at a level above that of individual polymer molecules. These include crystal structure, crystallite, multilayer, crystalline, fibrillar, spherulitic, and fibrous morphologies.

Surface Tension The force per unit length acting in the surface of a liquid that opposes spreading.

Sustained Release The systems that only prolong therapeutic blood or tissue levels of the drug for an extended period of time.

Swelling The first step in the solubilization of a polymer. The degree of swelling depends on the polymer–solvent interaction parameter and the molecular weight of the polymer. In the case of a cross-linked polymer, solubilization cannot take place, and an equilibrium degree of swelling is attained.

Tacticity The tacticity of the polymer is concerned with the different possible spatial arrangements. In *isotactic* polymers, all the repeat units have the same configuration, whereas in *syndiotactic* polymers, the configuration alternates from one repeat unit to the next. *Atactic* polymers have a random placement of the two configurations. For example, in a vinyl polymer, $\sim [CH_2CHR]_n \sim$, where R is a substituent group, three distinct configurational arrangements of the repeat unit exist as follows:



Terpolymer A polymer consisting of three different monomers.

Thermal Conductivity The ratio of the heat flow across unit area of a surface to the negative of the temperature gradient in the direction of flow.

Thermal Degradation Degradation induced by exposure to an elevated temperature.

Thermogravimetric Analysis A dynamic thermal analysis technique in which the weight loss of a sample is measured continuously while its temperature is increased at a constant rate.

Thermoplastic Elastomers Polymers capable of behaving as elastomers with the domains having physical cross-links. They are thermoformable, i.e., moldable and remoldable.

Thermoplastics Thermoplastics are linear or branched polymers that can be melted upon the application of heat. They can be molded and remolded into virtually any shape.

Thermosets Thermosets are rigid materials having short network polymers in which chain motion is greatly restricted by a high degree of cross-linking. They are intractable once formed and degrade rather than melt upon the application of heat.

Theta (Θ) Solvent A solvent for a polymer system that exhibits a theta temperature.

Theta (Θ) Temperature (Flory Temperature) The temperature at which, for a given polymer–solvent pair, the polymer exists in its unperturbed dimensions. Under these conditions, the long-range forces between polymer molecular segments that cause contraction are just balanced by the polymer–solvent interactions that cause the polymer molecular coil to expand.

Tie Molecule The intervening section in a polymer molecule that has started to crystallize independently in two different crystals.

Toughness The ability of a material to withstand fracture.

Unit Cell The basic unit for describing the ordered arrangement of atoms in a crystal.

Unperturbed Dimensions The dimension of a polymer coil in dilute solution at the θ temperature.

Viscoelasticity The ability for a material to exhibit viscous and elastic responses to deformation simultaneously.

Viscosity The ability of a fluid to resist flow.

Wetting The process in which a liquid spontaneously adheres to and spreads on a solid surface.

CHAPTER 63

Units and Conversion Factors

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TABLE 63.1. *SI prefixes.*

Multiplication factor			Prefix	Symbol
1 000 000 000 000 000 000 000 000	=	10^{24}	yotta	Y
1 000 000 000 000 000 000 000	=	10^{21}	zetta	Z
1 000 000 000 000 000 000	=	10^{18}	exa	E
1 000 000 000 000 000	=	10^{15}	peta	P
1 000 000 000 000	=	10^{12}	tera	T
1 000 000 000	=	10^{9}	giga	G
1 000 000	=	10^{6}	mega	M
1 000	=	10^{3}	kilo	k
100	=	10^{2}	hecto	h
10	=	10^{1}	deca	da
0.1	=	10^{-1}	deci	d
0.01	=	10^{-2}	centi	c
0.001	=	10^{-3}	milli	m
0.000 001	=	10^{-6}	micro	μ
0.000 000 001	=	10^{-6}	nano	n
0.000 000 000 001	=	10^{-9}	pico	p
0.000 000 000 000 001	=	10^{-15}	femto	f
0.000 000 000 000 000 001	=	10^{-18}	atto	a
0.000 000 000 000 000 000 001	=	10^{-21}	zepto	z
0.000 000 000 000 000 000 000 001	=	10^{-24}	yocto	y

TABLE 63.2. *SI base and supplementary units.*

Quantity	SI unit	SI symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd
Plane angle	radian	rad
Solid angle	steradian	sr

TABLE 63.3. *Derived units of SI that have special names.*

Quantity	Unit	Symbol	Formula
Absorbed dose	gray	Gy	J/kg
Conductance	siemens	S	A/V
Electric capacitance	farad	F	C/V
Electric charge	coulomb	C	A s
Electric potential	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Energy, work, heat	joule	J	N m
Force	newton	N	$(\text{kg m})/\text{s}^2$
Frequency	hertz	Hz	1/s

TABLE 63.3. *Continued.*

Quantity	Unit	Symbol	Formula
Illuminance	lux	lx	lm/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	cd sr
Magnetic flux	weber	Wb	V s
Magnetic-flux density	tesla	T	Wb/m^2
Pressure, stress, vacuum	pascal	Pa	N/m^2
Power, radiant flux	watt	W	J/s

TABLE 63.4. *Additional commonly derived SI units.*

Quantity	Unit	Symbol
Acceleration (linear)	meter per second squared	m/s^2
Acceleration (angular)	radian per second squared	rad/s^2
Area	square meter	m^2
Concentration	mole per cubic meter	mol/m^3
Current density	ampere per square meter	A/m^2
Density (mass)	kilogram per cubic meter	kg/m^3
Electric-charge density	coulomb per cubic meter	C/m^3
Electric-field strength	volt per meter	V/m
Energy density	joule per cubic meter	J/m^3
Entropy	joule per kelvin	J/K

TABLE 63.4. *Continued.*

Quantity	Unit	Symbol
Heat capacity	joule per kelvin	J/K
Luminance	candela per square meter	cd/m^2
Magnetic-field strength	ampere per meter	A/m
Molar energy	joule per mole	J/mol
Molar entropy	joule per mole-kelvin	J/(mol K)
Molar heat capacity	joule per mole-kelvin	J/(mol K)
Moment of force	newton-meter	N m
Permeability	henry per meter	H/m
Permittivity	farad per meter	F/m
Radiance	watt per sq. meter-steradian	$W/(m^2 sr)$
Radiant intensity	watt per steradian	W/sr
Specific-heat capacity	joule per kilogram-kelvin	J/(kg K)
Specific energy	joule per kilogram	J/kg
Specific entropy	joule per kilogram-kelvin	J/(kg K)
Specific volume	cubic meter per kilogram	m^3/kg
Surface tension	newton per meter	N/m
Thermal conductivity	watt per meter-kelvin	W/(m K)
Velocity (angular)	radian per second	rad/s
Velocity (linear)	meter per second	m/s
Viscosity (dynamic)	pascal-second	Pa s
Viscosity (kinematic)	sq. meter per second	m^2/s
Volume	cubic meter	m^3

TABLE 63.5. *Some quantities and units commonly used in polymer science.*

Quantity	Notation	Commonly used unit
Second and third virial coefficient	A_2, A_3	mol cm^3/g^2
Chain transfer constant for monomer	C_m	—
Chain transfer constant for solvent	C_s	—
Chain transfer constant for polymer	C_p	—
Characteristic ratio	C_∞	—
Diffusion coefficient	D	1/s
Tensile storage compliance	D'	1/Pa
Tensile loss compliance	D''	1/Pa
Complex tensile compliance	D^*	1/Pa
Young's modulus	E	Pa
Tensile storage modulus	E'	Pa
Tensile loss modulus	E''	Pa
Complex tensile modulus	E^*	Pa
Shear modulus	G	Pa
Shear storage modulus	G'	Pa
Shear loss modulus	G''	Pa
Complex shear modulus	G^*	Pa
Free energy of mixing	ΔG_m	kJ/mol
Enthalpy of mixing	ΔH_m	kJ/mol

TABLE 63.5. *Continued.*

Quantity	Notation	Commonly used unit
Shear compliance	J	1/Pa
Shear storage compliance	J'	1/Pa
Shear loss compliance	J''	1/Pa
Complex shear compliance	J^*	1/Pa
Molecular weight per cross-linked unit	M_c	g/mol
Number average molecular weight	M_n	g/mol
Molecular weight of a polymer chain unit	M_o	g/mol
Viscosity average molecular weight	M_v	g/mol
Weight average molecular weight	M_w	g/mol
z-average molecular weight	M_z	g/mol
Refractive index	n	—
Reactivity ratio of monomer A	r_A	—
Permeability coefficient	P	$cm^3 cm/(cm^2$ s Pa)
Mean-square end-to-end distance	$< r^2 >$	A^2
Unperturbed mean-square end-to-end distance	$< r^2 >_0$	A^2
Radius of gyration	s	A
Sedimentation coefficient	S	1/s
Solubility coefficient	S	$cm^3/(cm^3$ Pa)
Configurational entropy	S_{conf}	kJ/(mol K)
Entropy of mixing	ΔS_m	kJ/(mol K)
Brittleness temperature	T_B	°C
Crystallization temperature	T_c	°C
Temperature of fusion	T_f	°C
Glass transition temperature	T_g	°C
Melting temperature	T_m	°C
Supercooling	ΔT	°C
Molar volume	v	cm^3/mol
Volume fraction of species *i*	v_i	—
Weight fraction of species *i*	w_i	—
Mole fraction of species *i*	x_i	—
Number average degree of polymerization	x_n	—
Weight average degree of polymerization	x_w	—
z-average degree of polymerization	x_z	—
Elongation, linear deformation	α	—
Shear strain	γ	—
Birefringence	Δ	—
Solubility parameter	δ	$(MPa)^{1/2}$
Loss angle	δ	rad
Tensor strain	ε	—
Apparent viscosity, dynamic viscosity	η'	Pa s
Complex viscosity	η^*	Pa s
Intrinsic viscosity	$[\eta]$	ml/g
Theta temperature	θ	°C
Thermal conductivity	κ	W/(m K)
Deformation ratio	λ	—
Poisson ratio	υ	—
Osmotic pressure	π,Π	Pa
Stress	σ	Pa
Shear stress	τ	Pa
Relaxation time	τ	s
Retardation time	τ'	s
Flory–Huggins parameter	χ,ξ	—

TABLE 63.6. *Conversion factors for commonly used qualities.*

Acceleration (linear)	m/s^2	km/(hr s)	mil/(hr s)	ft/s^2	cm/s^2	
	1	3.600	2.237	3.281	1.000×10^2	
Acceleration (rotational)	rad/s^2	rad/min^2	$revol/s^2$	revol/(min s)	$revol/min^2$	
	1	3.600×10^3	1.592×10^{-1}	9.549	5.730×10^2	
Area	m^2	sq. in.	sq. ft	sq. yd	area	
	1	1.550×10^3	1.076×10	1.196	1.000×10^{-2}	
Coefficient of expansion	$kg/(m^3\ K)$	$kg/(m^3\ ^\circ C)$	$kg/(cm^3\ ^\circ C)$	$g/(cm^3\ ^\circ C)$	lb/(cu. ft °F)	
	1	1.000	1.000×10^{-6}	1.000×10^{-3}	3.468×10^{-2}	
Concentration (mass/volume)	kg/m^3(or g/l)	grains/gal(US)	grains/gal(UK)	ppm	lb/gal(US)	
	1	5.842×10^1	7.016×10^1	1.001×10^3	8.345×10^{-4}	
Concentration (mole/volume)	mol/m^3	$kmol/m^3$	(lb mol)/gal(US)		(lb mol)/gal(UK)	
	1	1.001×10^{-3}	8.345×10^{-3}		1.002×10^{-2}	
Density (mass)	kg/m^3	lb/cu. ft	lb/cu. in.	lb/gal(UK)	lb/gal(US)	
	1	6.243×10^{-2}	3.613×10^{-5}	1.002×10^{-2}	8.345×10^{-3}	
Electric charge	C (or A s)	Electronic charge		Statcoulomb		
	1	6.241×10^{18}		2.998×10^9		
Energy, heat, work	J (or N m)	kcal	Btu	kgf m	erg	
	1	2.388×10^{-4}	9.478×10^{-4}	1.020×10^{-1}	1.000×10^7	
Force	N	kgf	lbf	dyn	tonf(US)	
	1	1.020×10^{-1}	2.248×10^{-1}	1.000×10^5	1.124×10^{-4}	
Luminous intensity	cd	candle(UK)	carcel unit	hefner unit	lumen/steradian	
	1	9.600×10^{-1}	1.041×10^{-1}	1.111	1.000	
Length	m	in.	ft	yd	mil	angstrom
	1	3.937×10^1	3.281	1.094	3.937×10^4	1.000×10^{10}
Mass	kg	lb	ton(UK)	ton(US)	once	
	1	2.205	9.842×10^{-4}	1.102×10^{-3}	3.527×10^1	
Power	W (or J/s)	Btu/h	HP(UK)	erg/s	kcal/hr	
	1	3.412	1.341×10^{-3}	1.0×10^7	8.598×10^{-1}	
Pressure, vacuum, stress	Pa (or N/m^2)	bar	atm	torr (or mmHg)	psi (or lbf/sq. in)	
	1	1.0×10^{-5}	9.869×10^{-6}	7.501×10^{-3}	1.450×10^{-4}	
Surface tension	N/m	lbf/in.	kgf/m	dyn/cm		
	1	5.710×10^{-3}	1.020×10^{-1}	1.0×10^3		
Temperature	K	$^\circ C + 273.15$	$^\circ F + 459.67$	R		
	1	1.000	1.800	1.800		
Thermal conductivity	W/(m K)	kcal/(m h °C)	Btu/(ft h °F)	Btu/(in. h °F)	Btu in./(sq. ft h °F)	
	1	8.598×10^{-1}	5.778×10^{-1}	4.815×10^{-2}	6.933	
Time	s	min	h (or hour)	day	year (365day)	
	1	1.667×10^{-2}	2.778×10^{-4}	1.157×10^{-5}	3.171×10^{-8}	
Torque	N m	N cm	dyne cm	kgf m	in. lbf	
	1	1.000×10^2	1.000×10^7	1.02×10^{-1}	8.851	
Velocity (linear)	m/s	km/h	mile/h	ft/min	ft/s	
	1	3.600	2.237	1.969×10^2	3.281	
Viscosity (dynamic)	Pa s (or $N\ s/m^2$)	poise	centipoise	dyne s/cm^2	g/(cm s)	
	1	1.000×10^1	1.000×10^3	1.000×10^1	1.000×10^1	
Viscosity (kinematic)	m^2/s	cm^2/s	stoke	sq. ft/s	sq. ft/hr	
	1	1.000×10^4	1.000×10^4	1.076×10^1	3.875×10^4	
Volume	m^3	l(or litre)	cu. in.	gal(US)	gal(UK)	
	1	1.000×10^3	6.102×10^4	2.642×10^2	2.200×10^2	

TABLE 63.7. *General data and constants.*

Quantity	Symbol and equation	Value	
Atomic mass unit	$1u = 10^{-3}$ kg mol^{-1} L^{-1}	1.66057×10^{-27}	kg
Avogadro's number	L, N_a	6.02204×10^{23}	mole^{-1}
Bohr magneton	$\mu_B = eh/2m_e$	9.27408×10^{-24}	J T^{-1}
Bohr radius	$a_0 = \alpha/4\pi R_\infty$	5.29177×10^{-11}	m
Boltzmann constant	$k = R/L$	1.38066×10^{-23}	J K^{-1}
Electronic charge	e	1.60219×10^{-19}	C
Electron magnetic moment	μ_e	9.284832×10^{-24}	J T^{-1}
Electron mass	m_e	9.10953×10^{-31}	kg
Electronvolt	eV	1.60219×10^{-19}	J
Faraday constant	$F = Le$	9.64846×10^{4}	C mole^{-1}
Gravitational constant	G	6.6720×10^{-11}	N m^2 kg^{-2}
Gyromagnetic ratio of proton	γ_p	2.67520×10^{8}	s^{-1} T^{-1}
Neutron mass	m_n	1.67495×10^{-27}	kg
Nuclear magneton	$\mu_N = eh/2m_p$	5.05082×10^{-27}	J T^{-1}
Permeability of vacuum	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
Permittivity of vacuum	$\varepsilon_N = (\mu_0 c^2)^{-1}$	$8.85418782 \times 10^{-12}$	F m^{-1}
Planck constant	h	6.62618×10^{-34}	J s
	$\bar{h} = h/2\pi$	$1.0545887 \times 10^{-34}$	J s
Proton mass	m_p	1.67265×10^{-27}	kg
Rydberg constant	$R_\infty = \mu_0^2 m_e e^4 c^3/8h^3$	1.09737×10^{7}	m^{-1}
Speed of light in vacuum	c	2.99792×10^{8}	m s^{-1}
Universal/molar gas constant	R	8.31441	J K^{-1} mol^{-1}
		1.98717	cal K^{-1} mol^{-1}
Standard molar volume of ideal gas	$V_0 = RT_0/P_0$	2.241383×10^{-2}	m^3 mol^{-1}

TABLE 63.8. *Greek alphabet.*

A	α	alpha	N	ν	nu
B	β	beta	Ξ	ξ	xi
Γ	γ	gamma	O	o	omicron
Δ	δ	delta	Π	π	pi
E	ε	epsilon	P	ρ	rho
Z	ζ	zeta	Σ	σ	sigma
H	η	eta	T	τ	tau
Θ	θ	theta	Υ	υ	upsilon
I	ι	iota	Φ	ϕ	phi
K	κ	kappa	X	χ	chi
Λ	λ	lambda	Ψ	ψ	psi
M	μ	mu	Ω	ω	omega