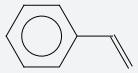
SBR poly(styrene-co-butadiene)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(styrene-co-butadiene)	
CAS name	-	benzene, ethenyl-, polymer with 1,3-butadiene	
Acronym	-	SBR	
CAS number	-	9003-55-8	
RTECS number	-	WL6478000	
HISTORY			
Date	-	1935; 1942	
Details	-	production in IG Farben, Germany; production in US	
SYNTHESIS			
Monomer(s) structure	-	 $H_2C{=}CHCH{=}CH_2$	
Monomer(s) CAS number(s)	-	100-42-5; 106-99-0	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	104.15; 54.09	
Styrene content	%	5-43	Martinez-Barrera, G; Lopez, H; Castano, V M; Rodriguez, R, Radiat. Phys. Chem., 69, 155-62, 2004.
Formulation example	-	styrene – 25, butadiene – 75, water – 180, emulsifier – 5, dodecyl mercaptan – 0.2-0.8, cumene hydroperoxide – 0.17, $FeSO_4$ – 0.017, EDTA – 0.06	Maruyama, K; Kawaguchi, M; Kato, T, Colloids Surfaces, A189, 211-23, 2001.
Method of synthesis	-	emulsion polymerization in water medium initiated by peroxide or peroxydisulfate; also solution polymerized grades are available; typically produced by cold emulsion polymerization	Dube, M A; Li, L, Polym. Plast. Technol. Eng., 49, 648-56, 2010; Godoy, J L; Minari, R J; Vega, J R; Marchetti, J L, Chemometrics Intelligent Lab. Systems, in press, 2011.
Number average molecular weight, M_n	dalton, g/mol, amu	28,000-307,000	Rivera-Gastelum, M J; Puig, J E; Monroy, V M; Garcia Garduno, M; Castano, V M, Mater. Lett., 15, 253-59, 1992.
Mass average molecular weight, M_w	dalton, g/mol, amu	64,000-313,000	Rivera-Gastelum, M J; Puig, J E; Monroy, V M; Garcia Garduno, M; Castano, V M, Mater. Lett., 15, 253-59, 1992.
Polydispersity, M_w/M_n	-	1.04-3.31	Rivera-Gastelum, M J; Puig, J E; Monroy, V M; Garcia Garduno, M; Castano, V M, Mater. Lett., 15, 253-59, 1992.
STRUCTURE			
Tacticity	%	*cis* – 9-38, *trans* – 53-75, vinyl – remainder	Martinez-Barrera, G; Lopez, H; Castano, V M; Rodriguez, R, Radiat. Phys. Chem., 69, 155-62, 2004.
COMMERCIAL POLYMERS			
Some manufacturers	-	Lanxess	
Trade names	-	Buna SE	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	0.91-0.96	

SBR poly(styrene-co-butadiene)

PARAMETER	UNIT	VALUE	REFERENCES
Color	-	light amber to yellow to brown	
Refractive index, 20°C	-	1.53-1.56	
Odor	-	characteristic	
Decomposition temperature	°C	180	
Storage temperature	°C	0-35	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.3-0.361	
Glass transition temperature	°C	-25 to -55	
Specific heat capacity	J K^{-1} kg^{-1}	1,895	Grieco, E; Bernardi, M; Baldi, G, J. Anal. Appl. Pyrolysis, 82, 304-11, 2008.
Maximum service temperature	°C	-40 to 100	
Long term service temperature	°C	65-70	
Vicat temperature VST/A/50	°C	92	
Hildebrand solubility parameter	$MPa^{0.5}$	17.4	
Coefficient of friction	-	1.5-2.5 (PE/SBR)	McNally, G M; Clarke, J L; Small, C M; Skelton, W J; Monroe, V, Antec, 2001.
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	13-28.5	
Tensile stress at yield	MPa	9.4-18	
Elongation	%	380-750	
Young's modulus	MPa	2.-2.3	
Tear strength	kN m^{-1}	20.4-43	
Poisson's ratio	-	0.5 (or variable)	Starkova, O; Aniskevich, A, Polym. Test., 29, 310-18, 2010.
Compression set, 24h 105°C	%	34	Chakraborty, S; Kar, S; Dasgupta, S; Mukhopadhyay, R; Bandyopadhyay, S; Joshi, M; Ameta, S C, Polym. Test., 29, 679-84, 2010.
Shore A hardness	-	30-90	
Mooney viscosity	-	30-120	
Water absorption, equilibrium in water at 23°C	%	5	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	poor	
Alcohols	-	good-fair	
Alkalis	-	poor	
Aliphatic hydrocarbons	-	poor	
Aromatic hydrocarbons	-	soluble	
Esters	-	poor	
Greases & oils	-	good-poor	
Halogenated hydrocarbons	-	poor	
Ketones	-	fair-poor	
Θ solvent, Θ-temp.=46, 21°C	-	methyl isobutyl ketone, methyl n-propyl ketone, n-octane	

SBR poly(styrene-co-butadiene)

PARAMETER	UNIT	VALUE	REFERENCES
FLAMMABILITY			
Autoignition temperature	°C	320	
Volatile products of combustion	-	CO, CO_2, styrene, butadiene, aromatic tars	Grieco, E; Bernardi, M; Baldi, G, J. Anal. Appl. Pyrolysis, 82, 304-11, 2008.
UL 94 rating	-	HB	
WEATHER STABILITY			
Spectral sensitivity	nm	295-360	
Important initiators and accelerators	-	ozone	
Products of degradation	-	hydroperoxides, hydroxyl, carboxyl, ketone, and epoxy groups; butadiene is degraded	Arantes, T M; Leao, K V; Tavares, M I B; Ferreira, A G; Longo, E; Camargo, E R, Polym. Test., 28, 490-94, 2009.
Stabilizers	-	Screener: carbon black, zinc oxide, talc; Phenolic antioxidant: ethylene-bis(oxyethylene)-bis(3-(5-tert-butyl-4-hydroxy-m-tolyl)-propionate); 2,6,-di-tert-butyl-4-(4,6-bis(octylthio)-1,3,5,-triazine-2-ylamino) phenol; 2-(1,1-dimethylethyl)-6-[[3-(1,1-dimethylethyl)-2-hydroxy-5-methylphenyl] methyl-4-methylphenyl acrylate; 2',3-bis[[3-[3,5-di-tert-butyl-4-hydroxyphenyl]propionyl]]propionohydrazide; isotridecyl-3-(3,5-di-tert-butyl-4-hydroxyphenyl) propionate; 3,5-bis(1,1-dimethyethyl)-4-hydroxy-benzenepropanoic acid, C13-15 alkyl esters; 2,2'-isobutylidenebis(2,4-dimethylphenol); Phosphite: trinonylphenol phosphite; Thiosynergist: 4,6-bis(octylthiomethyl)-o-cresol; 4,6-bis(dodecylthiomethyl)-o-cresol; 2,2'-thiodiethylene bis[3-(3,5-ditert-butyl-4-hydroxyphenyl)propionate]; Amine: nonylated diphenylamine	
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	1/1-3/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
ENVIRONMENTAL IMPACT			
Aquatic toxicity, *Daphnia magna*, LC_{50}, 48 h	mg l^{-1}	23	
Aquatic toxicity, *Bluegill sunfish*, LC_{50}, 48 h	mg l^{-1}	25.05	
Aquatic toxicity, *Fathead minnow*, LC_{50}, 48 h	mg l^{-1}	46.4-59.3	
PROCESSING			
Typical processing methods	-	calendering, coating, compression molding, mixing, vulcanization	
Additives used in final products	-	Fillers: barium sulfate, carbon black, carbon fiber, carbon nanotubes, clay, crosslinked PS beads, lead oxide (g-radiation shields), kaolin, magnesium hydroxide, mica, rectorite, silica, sodium aluminum silicate; Plasticizers: aromatic mineral oil, paraffinic mineral oil, rosin esters, terpene resins; Antistatics: carbon black, steel fibers, trineoalkoxy amino and trineoalkoxy sulfonyl zirconate; Release: zinc stearate	

SBR poly(styrene-co-butadiene)

PARAMETER	UNIT	VALUE	REFERENCES
Applications	-	automotive goods, belts, caulking, coated fabrics, conveyor belts, flooring, gaskets, lamination, mastics, pressure-sensitive adhesives, sealants, sheet, shoe products, sponge, sporting goods, tank and caterpillar tracks, tires, toys, tubing, wire & cable	
BLENDS			
Suitable polymers	-	CMC, EVA, LDPE, NBR, NR, PE, PC, PMMA, PS, PVC, SBS	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	aromatic hydrogen – 3025, 3061; CH_2 – 2917, 2847; *trans* C=C – 965; $C=CH_2$ – 913; phenyl – 699	Lei, Y; Tang, Z; Zhu, L; Guo, B; Jia, D, Polymer, 52, 1337-44, 2011.
Raman (wavenumber-assignment)	cm^{-1}/-	C-H – 2915, 1000; C=C – 1438, 620	Martinez-Barrera, G; Lopez, H; Castano, V M; Rodriguez, R, Radiat. Phys. Chem., 69, 155-62, 2004.
NMR (chemical shifts)	ppm	C NMR: C1 aromatic – 143.8, CH=CH vinyl – 141.2; C2 and C4 aromatic – 130.0; C3 – 128.6; CH=CH 1,4 – 126.7; C4 aromatic – 124.8; $=CH_2$ vinyl – 113.1; CH_2 styrene – 44.3, 41.9; CH_2 vinyl – 36.8, 31.4; CH_2 1,4 *trans* – 34.5, 26.2; CH_2 1,4 *cis* – 32.8, 28.9, 23.8	Arantes, T M; Leao, K V; Tavares, M I B; Ferreira, A G; Longo, E; Camargo, E R, Polym. Test., 28, 490-94, 2009.