NBR acrylonitrile-butadiene elastomer

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	acrylonitrile-butadiene elastomer, nitrile rubber	
CAS name	-	2-propenenitrile, polymer with 1,3-butadiene; nitrile rubber	
Acronym	-	NBR	
CAS number	-	9003-18-3; 9005-98-5	
HISTORY			
Person to discover	-	Semon, W L	Semon, W L, US Patent 2,380,551, BF Goodrich, July 31, 1945.
Date	-	1941	
Details	-	patent for copolymerization of butadiene and acylonitrile in water emulsion in reactor composed of nickel, chromium, and iron	
SYNTHESIS			
Monomer(s) structure	-	CH_2=CHCN; CH_2=CHCH=CH_2	
Monomer(s) CAS number(s)	-	107-13-1; 106-99-0	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	53.06; 54.09	
Acrylonitrile content	%	15-51	
Formulation example	-	AC – 32, butadiene – 68, water – 180, PMHP – 0.223, $FeSO_4 \cdot H_2O$ – 0.0056, SFS – 0.12, Dresinate – 1.25, Tamol – 2.85, mercaptan – 0.42	Washington, I D; Duever, T A; Penlidis, A, J. Macromol. Sci. A, 47, 747-69, 2010.
Method of synthesis	-	NBR is produced by an emulsion polymerization. The water, emulsifier/soap, monomers (butadiene and acrylonitrile), radical generating activator, and other ingredients are introduced into the polymerization vessels. The emulsion process yields a polymer latex that is coagulated using calcium chloride or aluminum sulfate to form crumb rubber that is dried and compressed into bales.	Minari, R J; Gugliotta, L M; Vega, J R; Meira, G R, Computers Chem. Eng., 31, 1073-80, 2007.
Number average molecular weight, M_n	dalton, g/mol, amu	58,00-75,000	
Mass average molecular weight, M_w	dalton, g/mol, amu	199,000-600,000	
Polydispersity, M_w/M_n	-	2-6	
STRUCTURE			
Crystallinity	%	amorphous	
Tacticity	%	78 (trans in butadiene segments), 12 (cis), 10 (1,2-sites)	
COMMERCIAL POLYMERS			
Some manufacturers	-	Lanxess	
Trade names	-	Krynac, Baymod N	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	0.92-1.01	
Odor	-	slight rubbery	
Thermal decomposition	°C	>200 (begins with excessive hardening due to croisslinking)	
Storage temperature	°C	<35	
Glass transition temperature	°C	-60 to -10	

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Specific heat capacity	$J\ K^{-1}\ kg^{-1}$	0.25	
Specific enthalpy of T_g	$J\ g^{-1}$	1.43	Ong, H T; Julkapli, N M; Hamid, S B A; Boondamnoen, O; Tai, M F, J. Magnetism Magnetic Mater., 395, 173-9, 2015.
Latent heat of crystallization	$J\ g^{-1}$	808.33	Ong, H T; Julkapli, N M; Hamid, S B A; Boondamnoen, O; Tai, M F, J. Magnetism Magnetic Mater., 395, 173-9, 2015.
Maximum service temperature	°C	-45 to 125	
Long term service temperature	°C	-40 to 108	
Hansen solubility parameters, δ_D, δ_P, δ_H	$MPa^{0.5}$	17.2, 8.6, 4.3	Zhu, L; Cheung, C S; Zhang, W G; Huang, Z, Fuel, 158, 288-92, 2015.
Hildebrand solubility parameter	$MPa^{0.5}$	17.90-21.38	
Permeability to nitrogen, 25°C	$cm^3\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1} \times 10^{12}$	0.0177-0.189 (decreases with acrylonitrile concentration increasing)	
Permeability to oxygen, 25°C	$cm^3\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1} \times 10^{12}$	0.0721-1.44 (decreases with acrylonitrile concentration increasing)	
Diffusion coefficient of nitrogen	$cm^2\ s^{-1}\ x10^6$	0.25-0.064	
Diffusion coefficient of oxygen	$cm^2\ s^{-1}\ x10^6$	0.79-13.6	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	3.1-6.5 (pure rubber)	
Tensile modulus	MPa	20.1-29.4	
Elongation	%	300-600	
Young's modulus	MPa	2-5	
Tear strength	$kN\ m^{-1}$	42-65	
Compression set	%	9 (1 day at 23°C); 25-35 (1 day at 70°C); 12-54 (70 h at 100°C)	Cook, S; Patel, J; Tinker, A J, 1680-84, 2000.
Shore A hardness	-	25-95	
Brittleness temperature (ASTM D746)	°C	-28 to -55	
Mooney viscosity	-	30-120	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	very good	
Alcohols	-	good	
Alkalis	-	very good	
Aliphatic hydrocarbons	-	good	
Aromatic hydrocarbons	-	poor	
Esters	-	poor	
Greases & oils	-	good	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
Θ solvent	-	butanone/isopropanol, cyclohexane/MEK=1/1	

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PARAMETER	UNIT	VALUE	REFERENCES
Lifetime in aviation kerosene	day/temp	11,113/20, 6467//25, 3831/30, 2309/35, 1414/40	Xiong, Y; Chen, G; Guo, S; Li, G, J. Ind. Eng. Chem., 19, 1611-16, 2013.
FLAMMABILITY			
Ignition temperature	°C	>300	
Limiting oxygen index	% O_2	29-31 (different FRs)	Moon, S C; Jo, B W; Farris, R J, Polym. Compos. 30, 1732-42, 2009.
Heat release	MJ m^{-2}	2.6-17.9 (different FRs)	Moon, S C; Jo, B W; Farris, R J, Polym. Compos. 30, 1732-42, 2009.
Volatile products of combustion	-	CO, CO_2, HCN, hydrocarbons, soot	
WEATHER STABILITY			
Spectral sensitivity	nm	262 (isolated C=C)	Sreeja, R; Najidha, S; Jayan, S R; Predeep, P; Mazur, M; Sharma, P D, Polymer, 617-23, 2006.
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	1/1/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
PROCESSING			
Typical processing methods	-	coating, molding, vulcanization	
Additives used in final products	-	Fillers: calcium carbonate, carbon black, cellulose fibers, graphite, kaolin, montmorillonite, talc, zinc oxide; Plasticizers: dibenzyl ether, dioctyl adipate, dioctyl phthalate, fatty acid ester, and polyglycol ether; Antistatics: conductive carbon black, high styrene resin; Release: silicone resin surface coating; Slip: crosslinking of nitrile rubber, stearic acid; Dusting agent: calcium stearate, silica, PVC (powder grades); Crosslinker: sulfur	
Applications	-	aerospace (airplane components, cockpit display components, fighter jet components, fighter pilot headgear, guided missiles electrical connectors, etc.), automotive hoses, belt covers, electronics (buttons, connectors, keypads, power supply gaskets, satellite, etc.), footwear, gaskets, hose jackets, industrial hoses, medical (angioplasty balloons, blood pumps, dialysis, insulin pumps, needle-less syringes, etc.), o-rings, precision diaphragms, printing rolls, polymer modification, seals, tires	
BLENDS			
Suitable polymers	-	BR, EPDM, epoxy, EVA, LDPE, PA, PANI, PEDOT, PP, PSU, PVC, SBR, UHMWPE	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	2260-2236 – cyano; 1540-1530 – C=C	Sreeja, R; Najidha, S; Jayan, S R; Predeep, P; Mazur, M; Sharma, P D, Polymer, 617-23, 2006.