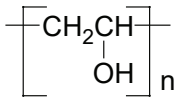
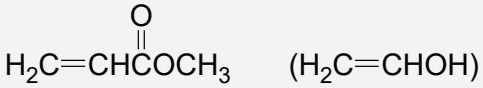
PVAl poly(vinyl alcohol)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(vinyl alcohol)	
Acronym	-	PVAl, PVOH	
CAS number	-	9002-89-5	
RTECS number	-	TR8100000, TR8101000	
Formula			
HISTORY			
Person to discover	-	Kuehn, E; Hopff, H	Kuehn, E; Hopff, H, US Patent 2,044,730, IG Farben, June 16, 1936.
Date	-	1936	
SYNTHESIS			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	108-05-4 (557-75-5)	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	86.09 (44.053)	
Monomer ratio	-	100% (hydrolysis to a varying degree: 98.0-99.8 (fully hydrolyzed); 90-97 (intermediately hydrolyzed); 87-89 (partially hydrolyzed))	
Method of synthesis	-	because of instability of vinyl alcohol, poly(vinyl alcohol) is produced by polymerization of vinyl acetate (see more in PVAc) and its subsequent hydrolysis	
Typical impurities	ppm	sodium acetate, methanol and methyl acetate	
Number average molecular weight, M_n	dalton, g/mol, amu	7,000-101,000	
Mass average molecular weight, M_w	dalton, g/mol, amu	1,750-186,000	
Polydispersity, M_w/M_n	-	1.19	
Polymerization degree (number of monomer units)	-	150-2,200	
Molar volume at 298K	$cm^3 mol^{-1}$	33.6 (crystalline)	
Van der Waals volume	$cm^3 mol^{-1}$	25.1 (crystalline)	
Radius of gyration	nm	31 (PVAc 37.6% saponified)	Ahmed, I; Pritchard, J G; Blakely, C F, Polymer, 25, 4, 543-50, 1984.
Chain-end groups	-	OH	
STRUCTURE			
Crystallinity	%	25-35 (syndiotactic); 30-60 (atactic); 18-24 (isotactic)	
Cell type (lattice)	-	monoclinic	
Cell dimensions	nm	a:b:c=0.781-0.784:0.543-0.552:0.252-0.253	
Unit cell angles	degree	γ=91-93	
Crystallite size	nm	3.4-12.1	

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Spacing between crystallites	nm	8.5-18.2	
Tacticity	%	78 (isotactic); 69.2 (syndiotactic)	Ohgi, H; Yang, H; Sato, T; Horii, F, Polymer, 48, 3850-57, 2007; Nagara, Y; Nakano, T; Okamoto, Y; Gotoh, Y; Nagura, M, Polymer, 42, 9679-86, 2001.
Avrami constants, k/n	-	n=4.54 (syndiotactic); n=1.48 (atactic)	Nagara, Y; Nakano, T; Okamoto, Y; Gotoh, Y; Nagura, M, Polymer, 42, 9679-86, 2001.
COMMERCIAL POLYMERS			
Some manufacturers	-	DuPont; Sekisui; Kuraray	
Trade names	-	Elvanol; Celvol; melt moldable	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.19-1.31	
Bulk density at 20°C	g cm^{-3}	0.3-0.7	
Color	-	clear, white to yellow	
Refractive index, 20°C	-	1.49-1.51	
Birefringence	-	0.0.55 (syndiotactic); 0.0353 (atactic)	Nagara, Y; Nakano, T; Okamoto, Y; Gotoh, Y; Nagura, M, Polymer, 42, 9679-86, 2001.
Odor	-	odorless	
Melting temperature, DSC	°C	178; 230 (fully hydrolyzed), 180-190 (partially hydrolyzed)	
Decomposition temperature	°C	100 (color change); 150 (rapid darkening); 200 (rapid decomposition)	Prosanov, I Y; Matvienko, A A, Phys. Solid State, 52, 10, 2203-6, 2010.
Fusion temperature	°C	0.2	
Thermal expansion coefficient, 23-80°C	$°C^{-1}$	0.7-1.2E-4	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.2	
Glass transition temperature	°C	calc.=84; exp.=34-85	
Specific heat capacity	J K^{-1} kg^{-1}	1,500-1,650	
Heat of fusion	J g^{-1}	40.9-48.4	Zhang, W; Zhang, Z; Wang, X, J. Colloid Interface Sci., 333, 346-53, 2009.
Hansen solubility parameters, δ_D, δ_P, δ_H	$MPa^{0.5}$	14.7, 14.1, 14.9	
Interaction radius		10.5	
Molar volume	kmol m^{-3}		
Hildebrand solubility parameter	$MPa^{0.5}$	21.7-25.78	
Surface tension	mN m^{-1}	calc.=37.0	
Dielectric constant at 100 Hz/1 MHz	-	2.6	
Volume resistivity	ohm-m	3.1-3.8E5	
Permeability to oxygen, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	0.000665	

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PARAMETER	UNIT	VALUE	REFERENCES
Permeability to water vapor, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	0.525	
Diffusion coefficient of water vapor	cm^2 s^{-1} $x10^6$	0.746	
Contact angle of water, 20°C	degree	51-72	Zhang, W; Zhang, Z; Wang, X, J. Colloid Interface Sci., 333, 346-53, 2009.
Surface free energy	mJ m^{-2}	44.2	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	23-55; 1,430 (drawn syndiotactic fiber); 1,490 (drawn atactic fiber)	Nagara, Y; Nakano, T; Okamoto, Y; Gotoh, Y; Nagura, M, Polymer, 42, 9679-86, 2001.
Young's modulus	MPa	38,100 (drawn syndiotactic fiber); 25,200 (drawn atactic fiber)	Nagara, Y; Nakano, T; Okamoto, Y; Gotoh, Y; Nagura, M, Polymer, 42, 9679-86, 2001.
Tenacity (fiber) (standard atmosphere)	cN tex^{-1} (daN mm^{-2})	20-65 (25-80)	Fourne, F, Synthetic Fibers. Machines and Equipment Manufacture, Properties. Carl Hanser Verlag, 1999.
Tenacity (wet fiber, as % of dry strength)	%	65-85	Fourne, F, Synthetic Fibers. Machines and Equipment Manufacture, Properties. Carl Hanser Verlag, 1999.
Fineness of fiber (titer)	dtex	1.5-10	Fourne, F, Synthetic Fibers. Machines and Equipment Manufacture, Properties. Carl Hanser Verlag, 1999.
Length (elemental fiber)	mm	38-200	Fourne, F, Synthetic Fibers. Machines and Equipment Manufacture, Properties. Carl Hanser Verlag, 1999.
Melt index, 190°C/21.6 kg	g/10 min	31-47	
Water absorption, 24h at 23°C	%	5	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	good-poor	
Alcohols	-	poor	
Alkalis	-	good	
Aromatic hydrocarbons	-	poor	
Esters	-	poor	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
Θ solvent, Θ-temp.=25, 97°C	-	ethanol/water=41.5/58.5, water	
Good solvent	-	acetamide, DMF, DMSO, glycerol (hot), piperazine; hot water (fully hydrolized); cold water (partially hydrolyzed)	
Non-solvent	-	carboxylic acids, chlorinated hydrocarbons, esters, hydrocarbons, ketones, lower alcohols, THF	
FLAMMABILITY			
Ignition temperature	°C	79	
Autoignition temperature	°C	450	
Limiting oxygen index	% O_2	20-22.5	

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Char at 500°C	%	3.3	Lyon, R E; Walters, R N, J. Anal. Appl. Pyrolysis, 71, 27-46, 2004.
Heat of combustion	J g^{-1}	23,310	Walters, R N; Hacket, S M; Lyon, R E, Fire Mater., 24, 5, 245-52, 2000.
Volatile products of combustion	-	CO_2, H_2O, CO, organic acids, aldehydes, alcohols	
WEATHER STABILITY			
Spectral sensitivity	nm	<280	
Activation wavelengths	nm	310, 326 (in the course of degradation)	
Transmittance	%	100 nm – 59; 300 nm – 20.6	
Stability to sunlight	-	excellent	
Important initiators and accelerators	-	products of thermal degradation, carbonyl groups, unsaturations, sensitizers (polynuclear aromatic compounds, benzophenones)	
Products of degradation	-	free radicals, unsaturations, carbonyl groups, hydroperoxides, chain scissions, water, polyenes	
BIODEGRADATION			
Colonized products		hydrogel, nanofiber, preparations	
Typical biodegradants	-	oxidase and dehydrogenase give β-hydroxylketone as well as 1,3-diketone moieties	
Stabilizers	-	Kathon LX; Dowicil 75, paraquat dichloride, quaternized chitosan	
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	0-1/1/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
OSHA	mg m^{-3}	5 (respirable), 15 (total)	
Oral rat, LD_{50}	mg kg^{-1}	>20,000; 23,854	
ENVIRONMENTAL IMPACT			
Aquatic toxicity, *Daphnia magna*, LC_{50}, 48 h	mg l^{-1}	8.3	
Aquatic toxicity, *Bluegill sunfish*, LC_{50}, 48 h	mg l^{-1}	10	
Aquatic toxicity, *Fathead minnow*, LC_{50}, 48 h	mg l^{-1}	40	
PROCESSING			
Typical processing methods	-	casting, coating, electrospinning, extrusion; molding	
Processing temperature	°C	183-188 (extrusion)	
Additives used in final products	-	Fillers: aluminum oxide, calcium carbonate, clay, carbon black, ferrite, graphite, magnesium oxide, nanocellulose, sand, silica, titanium dioxide, zinc oxide, zirconia; Plasticizers: benzyl butyl phthalate, dipropylene glycol dibenzoate, glycerin, monostearyl citrate, polyethylene and polypropylene glycols, triacetin; Antistatics: alkyl aryl sulfonate, cadmium sulfide, ethoxylated fatty acid amine, tetraammonium salt; Antiblocking: talc; Release: silane modified PVOH; Slip: PTFE beads; Crosslinkers; Defoamers	

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PARAMETER	UNIT	VALUE	REFERENCES
Applications	-	adhesives, belts, binders, cementitious laminate, coatings, controlled drug delivery, electroconductive film, film, food, magnetic nanocomposite, membranes, paper (with pigments and optical brighteners), photographic papers, printing rolls, protective colloids, sanitary pads, seed tapes, sizing agents, toners, water-soluble laundry bags, warp sizing, wood glue	
Outstanding properties	-	fibers	
BLENDS			
Suitable polymers	-	chitosan, starch, NR, PAA, PCL, PEEK, PEG	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	O-H – 3550-3200; C-H – 2840-3000; C=O – 1750-1735; C-O – 1141; C-O-C – 1150-1085	Mansur, H S; Sadahira, C M; Souza, A N; Mansur, A A P, Mater. Sci. Eng., C28, 539-48, 2008.
Raman (wavenumber-assignment)	cm^{-1}/-	CH_2 – 2912; OH – 1440	Uddin, A J; Araki, J; Gotoh, Y, Composites, A42, 741-47, 2011.