PVP

Polyvinylpyrrolidone polymers




Intermediates

Solvents

Monomers

Polymers

Specialty Chemicals

Film Former

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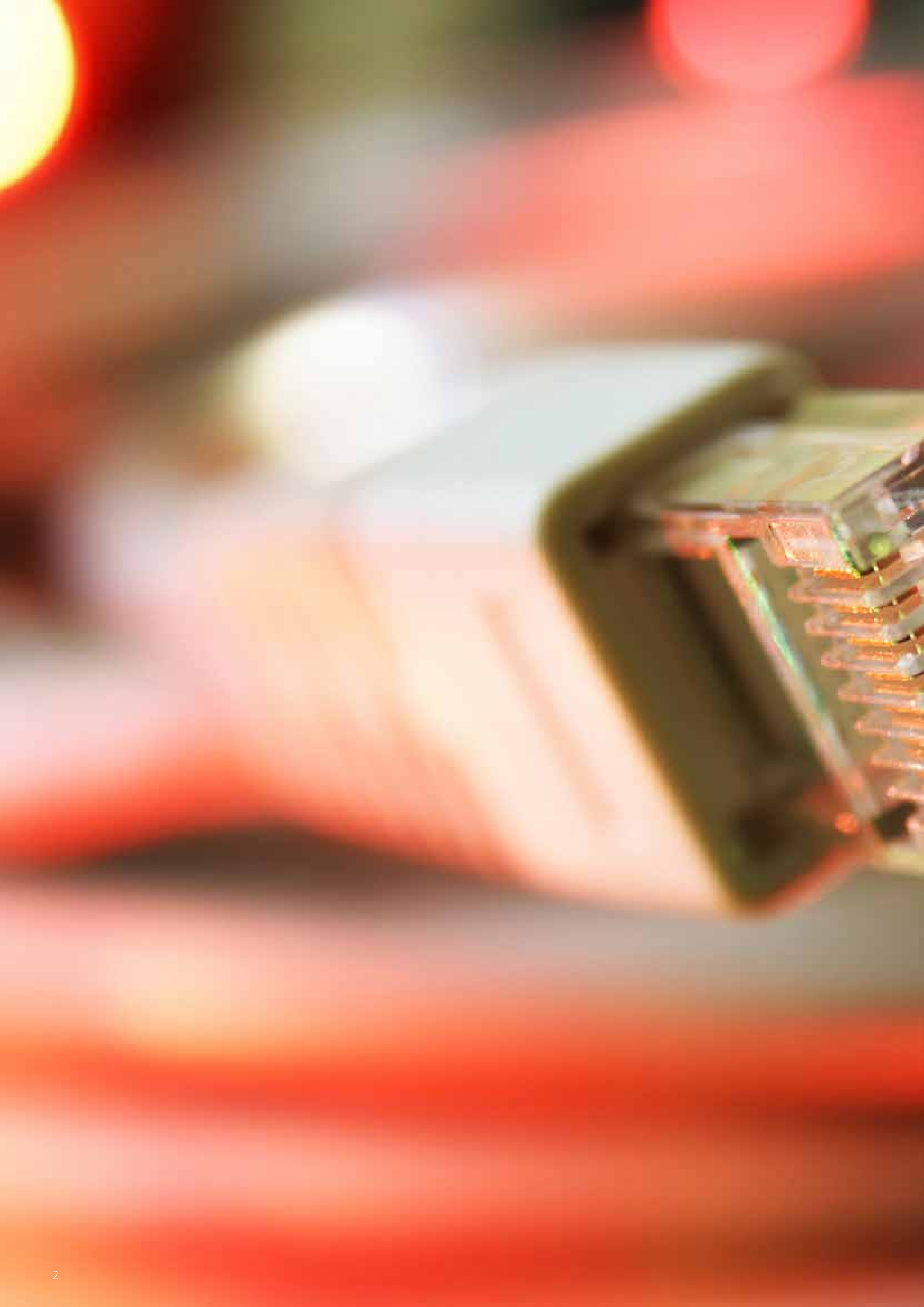
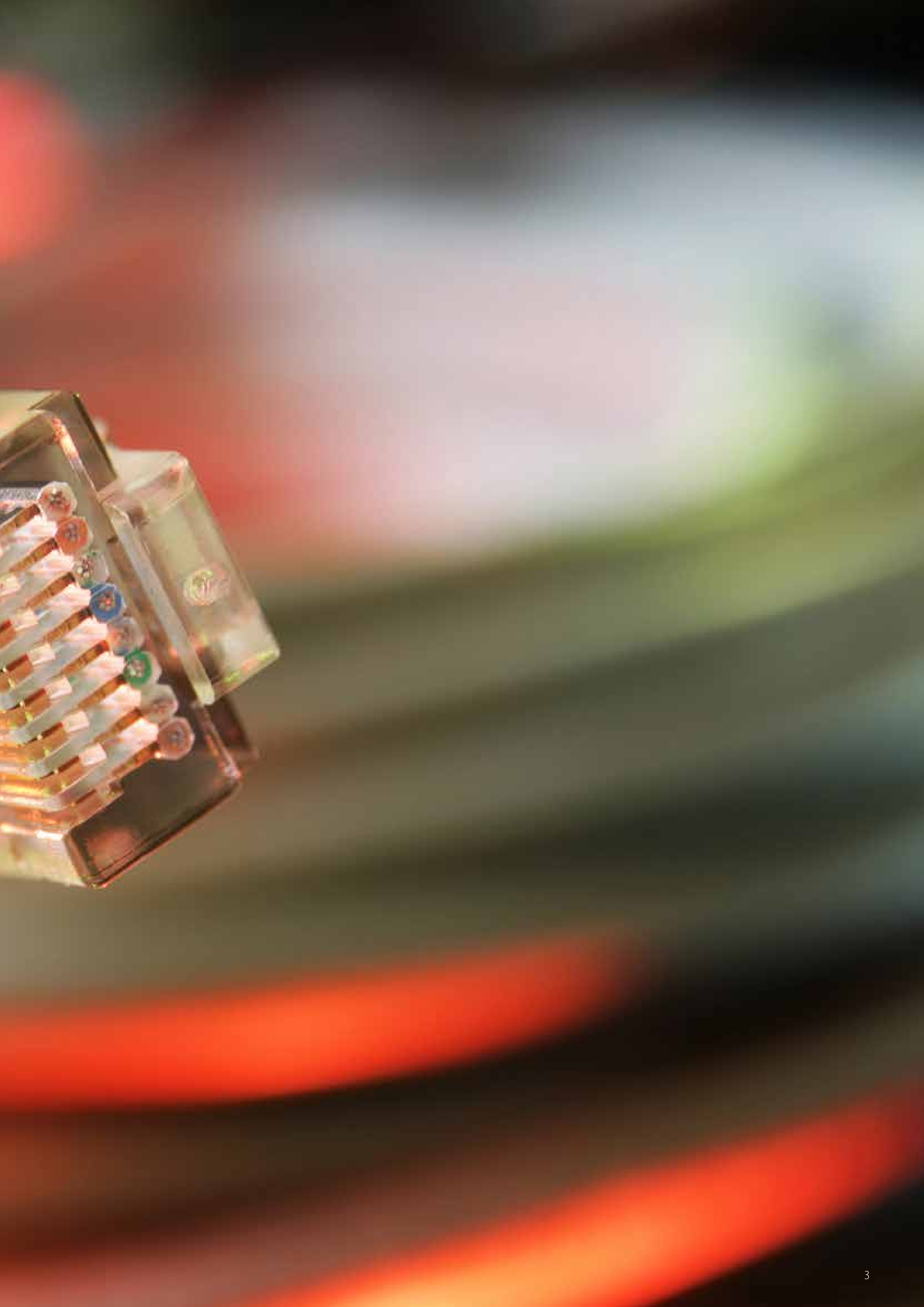




Contents

Commercial Types of PVP polymers

PVP polymers are available in several viscosity grades, ranging from low to high molecular weight. This range, coupled with solubility in aqueous and organic solvent systems combined with its nontoxic character, are some of the properties that gives PVP polymers great flexibility across multiple applications. The industrial applications of PVP polymers include, for example, in adhesives to improve strength and toughness; in paper manufacture to increase strength and as a coating resin; and in synthetic fibers to improve dye receptivity. PVP polymers are also widely employed in inks, imaging, lithography, detergents and soaps, the textile, ceramic, electrical and metallurgical industries and as a polymerization additive.

PVP polymers are supplied in various viscosity grades as a powder and/or aqueous solution. The full line of PVP polymers are also available for personal care applications such as film forming, emulsion stabilization and colorant dispersion. Ashland also offers pharmaceutical and agriculture grades of PVP polymer; our Plasdone™ and Polyplasdone™ polymer products are used in the pharmaceutical industry, Agrimer™ polymers are used by the Agriculture industry.

Tables I, II and III list the PVP polymers commercially available and some typical properties of the same.

Table I: PVP polymers – General Properties

Linear nonionic polymer
High polarity/proton acceptor
Amphiphilic
Compatible with a variety of resins and electrolytes
Soluble in water and polar solvents, insoluble in esters, ethers, ketones and hydrocarbons
Unsuitable for thermoplastic processing
Hard, glossy, transparent, oxygen permeable films which adhere to a variety of substrates
Hygroscopic
Adhesive and cohesive properties
Cross-linkable
Physiologically inert

Table II: PVP polymer Solution and Powder Products

Property	PVP K-12	PVP K-15		PVP K-30		PVP K-60	PVP K-90		PVP K-120	
Appearance @ 25°C	Off-white amorphous powder	Pale yellow aqueous solution	Off-white amorphous powder	Colorless to pale yellow aqueous solution	Off-white amorphous powder	Yellow aqueous solution	Yellow viscous, aqueous solution	Off-white, amorphous powder	Colorless to yellow aqueous solution	Off-white, amorphous powder
K-Value (Viscosity of 1% solution)	10-14[a]	13-19[a]	13 -19[a]	27-33	26-35	50-62	80-100	90-100	110-130	108-130
Color (APHA)	<50[a]	4 max. (VCS)	100 max.[a]	150 max.	80 max.[a]	100 max.[a]	40 max.	60 max.[a]	25 max.[a]	50 max.[a]
%Active	95 min.	28-32	95 min.	29-31	95 min.	45-49	20-24	95 min.	11 - 13	95 min.
%Moisture	5 max.	68-72	5 max.	69-71	5 max.	51-55	76- 80	5 max.	87-89	5 max.
%Ash (combustion)	<0.02	0.012	5 max.	0.012	0.02 max	0.044	0.016	-	0.018	-
pH (5% aqueous solution)	3-5	6-9	3-7	6-9	3-7	3-7	4-9	3-7	6-9	4-8
Brookfield Viscosity, cps (5% solids @ 25°C)	-	-	1	-	3	10	-	150	-	350
Specific Gravity @ 25°C	-	1.061	-	1.062	-	1.122	1.051	-	1.024	-
Bulk Density (g/cc)	0.6-0.7	-	0.6-0.7	-	0.4-0.6	-	-	0.3-0.4	-	0.2-0.3
Film Density (g/cc)	-	1.203	-	1.207	-	-	1.216	-	-	-
Freezing Point °C	-	-4.1	-	-2.7	-	-2.2	-0.9	-	0.3	-
Specific Heat (cal/g/KC)	-	0.819	-	0.803	-	0.738	0.827	-	0.884	-

[a] 5% aqueous solution
NOTE: This data is typical of current production, but are not necessarily specifications.

Table III: PVP polymers properties

PVP polymer Grade	K-Value	Molecular Weight (g/mol)	Tg (°C)	Radius of Hydration (GPC, nm)		Radius of Gyration (MALS, nm)	
				RH Triple Detection	RH DLS	Rg (18 angles)	Rg (2 angles)
K-12	10 – 14	4,000 – 6,000	120	–	2-3	▲	▲
K-15	13 – 19	6,000 – 15,000	130	2	5	▲	▲
K-30	26 – 35	40,000 – 80,000	163	6	10	10	15
K-60	50 – 62	390, 000 –470,000	170	12	20	21	23
K-85	83 – 88	900,000 –1,200,000	172	–	–	–	–
K-90	88 – 100	1,000,000 –1,700,000	174	32	49	58	65
K-120	114 – 130	2,100,000 –3,000,000	174	42	60	66	69

▲ PVP K-12 and K-15 polymer are too small for accurate MALS size readings.

Physical and Chemical Properties

Molecular Weight Determination

There have been many studies that have been devoted to the determination of the molecular weight of PVP polymer. The low molecular weight polymers have narrower distribution curves of molecular entities than the high molecular weight compounds. Some of the techniques for measuring the molecular weight of various PVP polymer products are based on measuring sedimentation, light scattering, osmometry, NMR spectroscopy, ebullimometry, and size exclusion chromatography for determining absolute molecular weight distribution. By the use of these methods, any one of three molecular weight parameters can be measured, namely the number average (Mn), viscosity average (Mv), and weight average (Mw). Each of these characteristics can yield a different answer for the same polymer as illustrated by using these measurement techniques in the analysis of the same PVP K-30 polymer sample. The following results are reported:

Number average (Mn) – 10,000

Viscosity average (Mv) – 40,000

Weight average (Mw) – 55,000

Therefore, in any review of the literature, one must know which molecular average is cited. Conventionally, molecular weights are expressed by their "K-values," which are derived from relative viscosity measurements.

Viscosity

The K-values assigned to various grades of PVP polymer represent a function of the average molecular weight, the degree of polymerization and the intrinsic viscosity. The K-values are derived from viscosity measurements and are calculated according to Fikentscher's formula:

$$\log \frac{\eta_{rel}}{c} = \frac{75K_0^2}{1 + 1.5K_0^2} + K_0$$

$$K = 1000K_0$$

where c = concentration in g/100 ml solution
η rel = viscosity of the solution compared with solvent

The K-value accepted for PVP polymer by pharmacopoeias and other authoritative bodies worldwide is measured by the viscosity technique and calculated by the use of Fikentscher's equation.

In an aqueous solution PVP K-15 and PVP K-30 polymer, particularly in concentrations below 10%, have little effect on viscosity, whereas K-60 and K-90 considerably influence flow properties (Figure 1). In organic solvents the viscosity of the solution is related to that of the solvent, Table IV.

Figure 1: Effect of Concentration of Different Grades of PVP polymer on Viscosity of Aqueous Solutions at 25°C

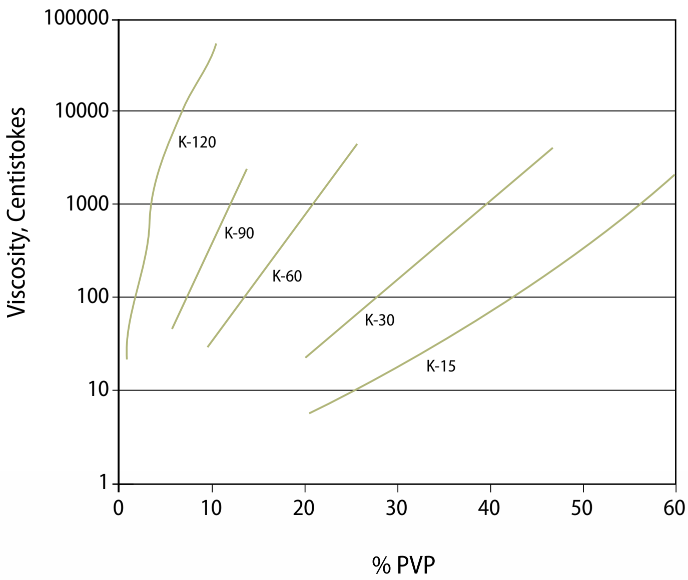


Table IV: Viscosities of PVP K-30 polymers in Various Organic Solvents

Kinematic Viscosities (in centistokes)		
Solvent	2% PVP	10% PVP
Acetic Acid (glacial)	2	12
1,4-Butanediol	101	425
Butyrolactone	2	8
Cyclohexanol	80	376
Diacetone Alcohol	5	22
Diethylene Glycol	39	165
Ethanol (absolute)	2	6
Ethyl Lactate	4	18
Ethylene Glycol	24	95
Ethylene Glycol Monoethyl Ether	3	12

Note: Kinematic Viscosity in centistokes = Absolute Viscosity in centsitokes / Density

Table IV (continued)

Kinematic Viscosities (in centistokes)		
Solvent	2% PVP	10% PVP
Glycerin	480	2,046
Isopropanol	4	12
Methyl Cyclohexanone	3	10
N-Methyi-2-Pyrrolidone	2	8
Methylene Chloride	1	3
Monoethanolamine	27	83
Nitroethane	1	3
Nonylphenol	3,300	-
Propylene Glycol	66	261
Triethanolamine	156	666

Table V: Effect of pH on Viscosity of 5% Aqueous PVP K-30 polymer at 25°C

pH	10	9	7	4	2	1	0.1	conc. HCl
Viscosity (cp)	2.4	2.4	2.4	2.4	2.3	2.3	2.4	4.96

PVP polymer solution viscosity does not change appreciably over a wide pH range, but increases in concentrated HCl. Strong caustic solutions precipitate the polymer, but this precipitate solution redissolves on dilution with water (Table V).

Table VI: Effect of PVP K-30 polymer Concentration on Density in Water

PVP Concentration (%)	10	20	30	40	50
Density at 2s· c (g/ml)	1.02	1.04	1.07	1.09	1.12

The densities of PVP polymer water solutions are only slightly changed despite a significant increase in the concentration of PVP K-30 polymer, Table VI.

The effect of temperature and concentration on viscosity is shown in Figures 2 and 3 for PVP K-30 and K-90 polymer respectively. Any possible effect of high temperatures and concentrations on finished formulations should be determined experimentally.

Figure 2: Brookfield Viscosity of Aqueous PVP K-30 polymer

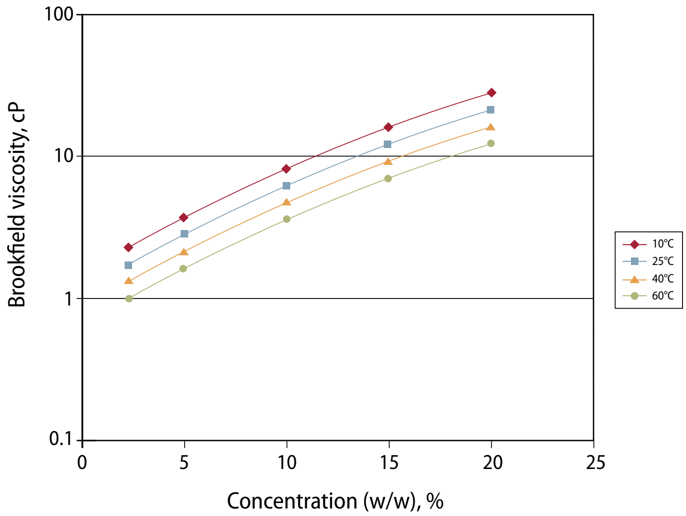


Figure 3: Brookfield Viscosity of Aqueous PVP K-90 polymer

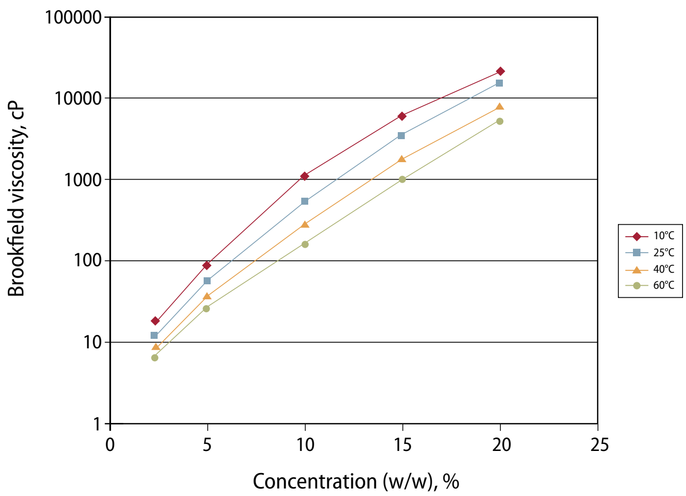
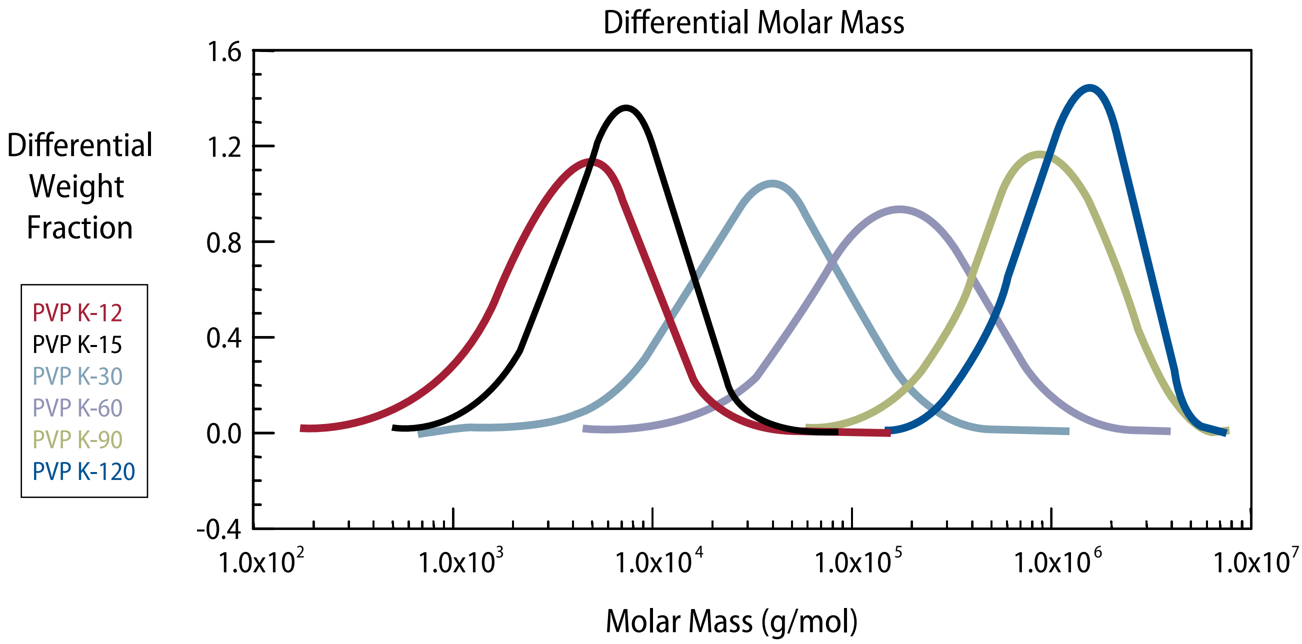
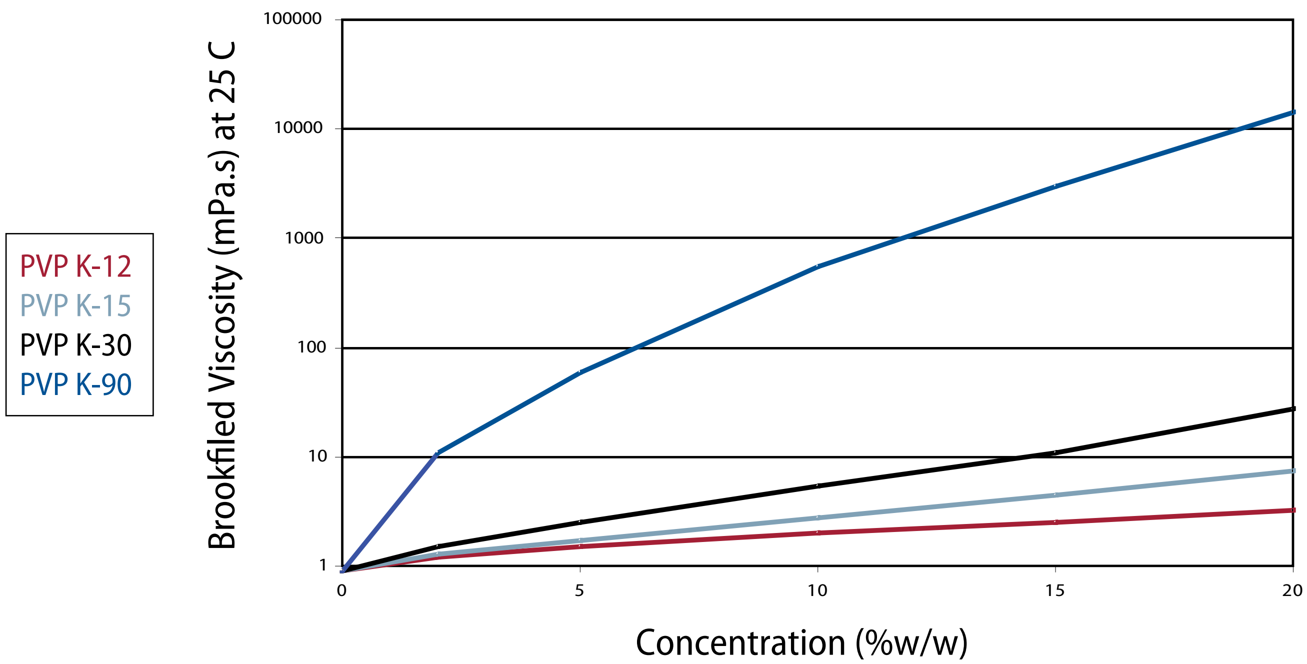


Figure 4: Gel Permeation Chromatograph[1] of PVP polymer grades



1 GPC Conditions: Column: Single Shodex KB-80M, Mobile Phase: Water/Methanol, 50/50, v/v, 0.1 molar LiNO3, Flow Rate: 0.5 ml/min, Injection Volume: 100 µl, Temperature: 30ºC, dn/dc = 0.175 ml/gram.

Figure 5: Brookfield Viscosity of PVP polymer grades



Solubility

PVP polymer is readily soluble in cold water and the concentration is limited only by viscosity. It is possible to prepare free-flowing solutions of PVP K-30 polymer in concentrations up to 60% with only moderate effect on density. PVP K-60 and K-90 polymer are available commercially as 45 and 20 percent aqueous solutions, respectively.

Roughly 0.5 mol water per monomer unit is associated with the polymer molecule in solution. This is of the same order of magnitude as the hydration for various proteins reported in the literature.

PVP K-30 polymer is also freely soluble in many organic solvents, including alcohols, some chlorinated compounds such as chloroform, methylene chloride and ethylene dichloride, nitroparaffins, and amines. It is essentially insoluble in hydrocarbons, ethers, some chlorinated hydrocarbons, ketones and esters.

Dilute solutions of PVP polymer in hydrocarbons may be prepared by the use of a cosolvent, e.g., butanol, N-methyl-2-pyrrolidone, or nonylphenol. Clear 3-5% PVP polymer solutions in aliphatic hydrocarbons may be readily prepared by adding the hydrocarbon to a butyl alcohol solution of the polymer. In oil-based products, solubilization in an alkylphenol, e.g., cetyl- or nonylphenol, is useful. The alkylphenol is first heated to about 100°C and the PVP polymer added slowly with stirring. Then the temperature may be raised to approximately 200°C to accelerate solution.

Table VII: PVP K-30 polymer Solubility

The following representative organic solvents will dissolve 10% or more PVP polymer at room temperature:			
Alcohols	**Acids**	**Ketone**	anline
methanol	formic acid	methylcyclohexanone	ethylenediamine
ethanol	acetic acid		pyridine
propanol	propionic acid	**Chlorinated Hydrocarbons**	morpholine
isopropanol		methylene dichloride	2-aminoethanol
butanol	**Ether-Alcohols**	chloroform	diethanolamine
sec-butanol	glycol ethers	ethylene dichloride	triethanolamine
amyl alcohol	diethylene glycol		aminoethylethanolamlne
2-ethyl-l-hexanol	triethylene glycol	**Lactams**	2-hydroxyethylmorpholine
cyclohexanol	hexamethylene glycol	2-pyrrolidone	2-amino-2-methyl-1-propanol
phenol (50°C)	polyethylene glycol 400	N-methyl-2-pyrrolidone	
ethylene glycol	2,2 -thiodiethanol	N-vinyl-2-pyrrolidone	**Nitroparaffins**
1,3-butanediol			nitromethane
1,4-butanediol	**Lactone**	**Amines**	nitroethane
glycerin	γ-butyrolactone	butylamine	
		cyclohexylamine	
Ketone-Alcohol	**Ester**		
diacetone alcohol	ethyl lactate		
PVP polymer is essentially insoluble in the following solvents under the same conditions of testing:			
Hydrocarbons	mineral oil	methyl ether	**Ketones**
benzene toluene**	cyclohexane	ethyl vinyl ether	methylethylketone
xylene	methylcyclohexane	isobutyl vinyl ether	acetone
petroleum ether	turpentine	tetrahydrofuran	cyclohexanone
hexane			
heptane**	**Ethers**	**Chlorinated Hydrocarbons**	**Esters**
Stoddard solvent**	dioxane	carbon tetrachloride	ethyl acetate
kerosene**	ethyl ether	chlorobenzene	sec-butyl acetate
mineral spirits			

**PVP polymer is soluble in these hydrocarbons in about 5% concentration when added to the solvent as a 25% butanol solution.

Film Forming Properties

Dried unmodified films of PVP polymer are clear, transparent, glossy, and hard. Appearance does not vary when films are cast from different solvent systems, such as water, ethanol, chloroform, or ethylene dichloride.

Compatible plasticizers may be added without affecting clarity or luster of the film. Moisture taken up from the air by PVP polymer can also act as a plasticizer. Among the several commercial modifiers that may be used in concentrations of 10-50% (based on PVP polymer) to control tack and/or brittleness or to decrease hygroscopicity are:

- carboxymethylcellulose
- cellulose acetate
- cellulose acetate propionate
- dibutyl tartrate
- diethylene glycol
- dimethyl phthalate
- 2-ethylhexanediol-1, 3
- glycerin
- glycerylmonoricinoleate
- Igepal C0-430 (Solvay)
- oleyl alcohol
- Resoflex R-363 (Broadview Technologies)
- shellac
- sorbitol

Carboxymethylcellulose, cellulose acetate, cellulose acetate propionate, and shellac effectively decrease tackiness. Dimethyl phthalate is less effective, whereas glycerin, diethylene glycol, and sorbitol increase tackiness. Films essentially tack-free over all ranges of relative humidity may be obtained with 10% arylsulfonamide-formaldehyde resin.

In comparative tests for plasticity at 33% relative humidity, PVP polymer films containing 10% diethylene glycol show an "elongation at break" twice that of PVP polymer films containing 10% glycerin, polyethylene glycol 400, sorbitol, or urea, and four times that of PVP polymer films containing 10% ethylene glycol, dimethyl phthalate. At 70% relative humidity, 25% sorbitol and 25% dimethylphthalate may be used successfully.

Compatibility

PVP polymer shows a high degree of compatibility, both in solution and film form, with most inorganic salt solutions and with many natural and synthetic resins, as well as with other chemicals (Table VIII).

At 25°C the addition of 100 ml of a 10% solution of any of the following salts to 10% PVP K-30 polymer aqueous solution (i.e., 10 parts of the test salt to 1 part of PVP polymer) does not change the appearance of the solution:

aluminum potassium sulfate	$AlK (S0_4)_2 \cdot 12H_20$
aluminum sulfate	$Al_2(SO_4)h \cdot 18H_20$
ammonium chloride	NH_4Cl
ammonium sulfate	$(NH_4)_2S0_4$
barium chloride	$BaCl_2 \cdot H_20$
calcium chloride	$CaCl_2$.
chromium sulfate	$Cr_2(S0_4)_3 \cdot nH_20$
copper sulfate	$CuSO_4 \cdot 5H_20$
ferric chloride	$FeCl_3 \cdot 6H_20$
magnesium chloride	$MgCl_2 \cdot 6H_20$
mercuric acetate	$Hg(C_2H_3O)_2$
nickel nitrate	$Ni(NO_3)_2 \cdot 6H_20$
lead acetate	$Pb(C_2H_3O_2) \cdot 3H_20$
potassium chloride	KCl
potassium sulfate	K_2SO_4
potassium dichromate	$K_2Cr_2O_7$
sodium bicarbonate**	$NaHCO_3$
sodium chloride	NaCl
sodium nitrate	$NaNO_3$
sodium phosphate (primary)	$NaH_2PO_4 \cdot H_2O$
sodium pyrophosphate	$Na_4P_2O_7$
sodium sulfate	Na_2SO_4
sodium sulfite	$Na_2SO_3 \cdot 7H_2O$
sodium thiosulfate	$Na_2S_2O_3 \cdot 5H_2O$
silver nitrate	$AgNO_3$
zinc sulfate	$ZnSO_4 \cdot 7H_2O$

**200 ml if a 5% solution

Table VIII: Compatibility of PVP polymer in Solutions and Films

Class	Compound Tested**	Solvent	% TTL Solids	Solution or Melt Appearance	Film Compatibility
Ether-Alcohols	polyethylene glycol	ethanol	5	S clear, colorless	C
	polyalkylene glycol	ethanol	5	S clear, colorless	IN
Gums	arabic	water	5	PS cloudy, heterogeneous	C
	karaya	water	4	I two-phase	H
	tragacanth	water	4	PS white, homogeneous	H
	sodium alginate	water		S	C
Glycerides	olive oil	chloroform	5	S clear, tight yellow	IN
	castor oil	ethanol	5	S clear, colorless	IN
	lanolin	chloroform	6	S clear, light yellow	H
	lecithin	water	1	I opaque homogeneous IN	(1:3)H(1:1,3:1)
Esters	beeswax	chloroform	5	S clear, colorless	H
	diethylene glycol stearate	propargyl alcohol	3	S clear, yellow	IN
	triethylene glycol bis-alpha-ethylcaproate	ethanol	5	S clear, colorless	IN
	cellulose acetate propionate	chloroform	4	S clear, colorless	C
	cellulose acetate	1:4/ethanol ethylene dichloride	4	S clear, light yellow	C
Phenols	2.2 thiobis-(4,6-dichlorophenot)	ethanol	6	S clear, colorless	
	hexachlorophene [2.2-methytene-bis (3,4,5,-trichlorophenol)]	ethanol	6	S clear, colorless	
Misc. Resins	shellac	ethanol	5	S clear, yellow	C
	ethylcellulose	ethanol	4	PS cloudy, homogeneous	C
	methylcellulose	water		S	C
	carboxymethylcellulose (low viscosity grade)	water	1	S clear, colorless	C
	corn dextrin***	water		S	C
Synthetic Polymers	Saran** B-1155 (vinyildene chloride polymer, Dow)	N-methyl-2-pyrrolidone	3	S yellow	IN
	PVI-C poly (vinylisobutyl ether}	chloroform	4	I two liquid phases	IN
	PVM poly (vinylmethylether)	hot melt	S	C	
	polystyrene	chloroform		S clear, colorless	IN
	polyvinyl alcohol			S	C
Surfactants	Ailpal* C0-436 (ammonium salt of sulfated nonytphenoxypoty (ethylenoxy) ethanol, Solvay)	water	3	S clear, colorless	C
	sodium lauryl sulfate	water	5	S clear, colorless	
	sodium atkytnaphthalene sulfonate	water	3	S hazy, light yellow	IN
Quaternary Ammonium Compounds	Tetrosar** (Stepan)	water	10	S clear, colorless	
	BTC** (alkytidmethytbenzyl ammonium chloride, Stepan)	water	10	S clear, colorless	
	Isothar** (Lauryl isoquinotinium bromide, Stepan)	water	10	S clear, colorless	
	cetylpyridinium chloride	water	10	S clear, colorless	

**Ratio of PVP to compound 1:3, 1:1,3:1

***Ratio of PVP to compound 1:19

Abbreviations:

S	Soluble
PS	Partially soluble
I	Insoluble
IN	Incompatible
H	Homogeneous
C	Compatible

Colloidal suspensions are formed by 10% solutions of the following salts when added to 10% aqueous PVP polymer solutions in the amounts shown:

		Ratio Test Salt: PVP
sodium carbonate	Na_2CO_3	1:85:1
sodium phosphate, dibasic	$Na_2HPO_4 \cdot 7H_2O$	3.7:1
sodium phosphate, tribasic	$Na_3PO_4 \cdot 12H_2O$	1.28:1
sodium metasiticate	$Na_2SiO_3 \cdot 5H_2O$	3:1

When reviewing Table VIII, one should note the general procedure followed in determining compatibility was to dissolve PVP K-30 polymer and the test material separately in a mutual solvent. After mixing the two solutions, appearance was observed. The solution was then cast onto a glass plate and the resulting film examined after the evaporation of the solvent that was air dried.

Protective – Colloid Action

Small amounts of PVP polymer effectively stabilize emulsions, dispersions, and suspensions. Even lyophobic colloids, which exist without significant affinity for the medium, can be protected by PVP polymer. The polymer is adsorbed in a thin molecular layer on the surface of the individual colloidal particles to prevent contact and overcome any tendency to form a continuous solid phase.

The best viscosity grade to use depends on the application. In some cases, the lower molecular weight polymers, PVP K-15 polymer or PVP K-30 polymer, are more efficient than high molecular weight material. For example, PVP K-15 polymer is particularly effective as a dispersant for carbon black and low-bulk density solids in aqueous media. It is used in detergent formulations to prevent soil redeposition on synthetic fibers and as a protective colloid for certain pigments. In viscous systems, on the other hand, PVP K-90 polymer is most suitable, e.g., as a dispersant for titanium dioxide or organic pigments and latex polymers in emulsion paints. PVP K-90 polymer is preferred as the protective colloid in the suspension polymerization of styrene to generate the desired particle size.

Complex Formation/Crosslinking

PVP polymers form molecular adducts with many other substances. This can result in a solubilizing action in some cases or in precipitation in others.

PVP polymer crosslinks with polyacids like polyacrylic or tannic acid to form complexes which are insoluble in water or alcohol but dissolve in dilute alkali. Gantrez™ AN methyl vinyl ether/maleic anhydride copolymer, will also insolubilize PVP polymer when aqueous solutions of polymers are mixed in approximately equal parts at low pH. An increase in pH will solubilize the complex.

Ammonium persulfate will gel PVP polymer in 30 minutes at about 90°C. These gels are not thermoreversible and are substantially insoluble in large amounts of water or salt solution.

The more alkaline sodium phosphates will have the same effect. When dried under mild conditions, PVP polymer gels retain their uniform structure and capacity to swell again by absorption of large amounts water. Resorcinol and pyrogallol also precipitate PVP polymer from aqueous solution, but these complexes redissolve in additional water. In alcoholic solution, no precipitation takes place.

Under the influence of actinic light, diazo compounds and oxidizing agents, such as dichromate, render PVP polymer insoluble.

Heating in air to 150°C will crosslink the PVP polymer and strong alkali at 100°C will permanently insolubilize the polymer.

Stability

PVP polymer powder can be stored under ordinary conditions without undergoing decomposition or degradation. However, since the powder is hygroscopic, suitable precautions should be taken to prevent excessive moisture pickup. Bulk polymer is supplied in tied polyethylene bags enclosed in fiber packs. When not in use, the polyethylene bag should be kept closed at all times in the covered container.

On PVP polymer films, moisture acts as a plasticizer. These films are otherwise chemically stable.

The equilibrium water content of PVP polymer solid or films varies in a linear fashion with relative humidity and is equal to approximately one-third the relative humidity. Samples of dried, powdered PVP polymer, subjected to 20, 52, and 80 percent relative humidity until equilibrium is reached, show a 10, 19, and 31 percent moisture weight gain, respectively.

Exposure to extreme elevated temperatures should be avoided, though PVP polymer powder is quite stable when heated. Some darkening in color and decreased water solubility are evident on heating in air at 150°C. However, PVP polymer appears to be quite stable when heated repeatedly at 110-130°C for relatively short intervals.

Aqueous PVP polymer is stable for extended periods if protected from molds. However, appropriate tests should be made with finished products containing PVP polymer before deciding on a preservative. Steam sterilization (15 lb. pressure for 15 min.) can also be used and this treatment does not appear to change the properties of the solutions.

The PVP polymer has no buffering power, and substantial changes in the pH of solutions are observed upon addition of small amounts of acids or bases. For example, the pH of 100 ml of 3.5% PVP K-30 polymer solution is raised from pH 4 to pH 7 by the addition of 1-2 ml 0.1 N sodium hydroxide.

Industrial Applications of Polyvinylpyrrolidone

Polyvinylpyrrolidone is widely used in a broad variety of industries. This is due to its unique physical and chemical properties, particularly because of its good solubility in both water and many organic solvents, its chemical stability, its affinity to complex both hydrophobic and hydrophilic substances and its nontoxic character. Several hundreds of papers have been published describing the advantages of using PVP polymer in formulas for the following product areas.

Area of Use	*Advantages of PVP polymer*
Adhesives – pressure-sensitive and water-remoistenable types, food packaging (indirect food contact), metal adhesives, abrasives, sandcore binder, rubber to metal adhesives and glue sticks.	Specific adhesive for glass, metal, plastics. Imparts high initial tack, strength, hardness. Particularly suitable for remoistenable adhesive applications. Forms grease-resistant films. Films can be cast from water or organic solvents. Modifies viscosity of polymer-based adhesives. Raises cold-flow temperature. Raises softening point of thermoplastics.
Ceramics – binder in high temperature fire-prepared products such as clay, pottery, porcelain, brick product, dispersant for ceramic media slurries and viscosity modifier.	Binder is completely combustible in the firing process and therefore exerts no influence on the ceramic end product and in addition, is compatible with inorganic materials.
Glass and Glass Fibers – acts as a binder, lubricant and coating agent.	Aids in processing and helps to prevent abrasion of glass.
Coatings/Inks – digital printing coating, ball-point inks, protective colloid and leveling agent for emulsion polymers/ coatings/ printing inks, pigment dispersant, water-colors for commercial art, temporary protective coatings, paper coatings, waxes and polishes.	Suspending agent, flow promoter in inks. Nonthixotropic. Promotes better gloss, high tinctorial strength, more uniform shades. Antiblack agent. Grease resistant. Inkjet dye fixative.
Detergents	Dye transfer inhibition and enzyme stabilization
Electrical Applications – storage batteries, printed circuits, cathode ray tubes, binder for metal salts or amalgams in batteries, gold, nickel, copper and zinc plating, a thickener for solar gel ponds and as an adhesive to prevent leakage of batteries, serves as an expander in cadmium-type electrodes, binder in sintered-nickel powder plates.	Hydrophilic material in electrode separators of microporous film types. Compatible dispersant in printed circuits to improve uniformity. Shadow masks and protects light sensitive material in the CRT. Compatible dispersant for solar collection heat transfer liquids, for gold, nickel, copper and zinc plating baths and cathode ray tubes.

Industrial Applications of Polyvinylpyrrolidone *(continued)*

Area of Use	Advantages of PVP polymer
Lithography and Photography – foil emulsions, etch coatings, plate storage, gumming of litho- graphic plates, dampener roll solutions, photo and laser imaging processes, microencapsulation, thermal recording, carrier, finisher preserver of lithographic plates, thermal transfer recording ribbons and optical recording discs.	Light-hardenable, water-soluble colloid for diazo, dichromate, or silver emulsion layers. Obviates deep-etching of metal plates. Offers uniform viscosity, temperature stability. Nonthixotropic. Defoggant. Adheres tightly to plates in nonimage areas. Grease-proof and water receptive. Chemically inert to ink ingredients. Binder, dispersant carrier and improves adhesion for light absorber dyes and antistick agent. Increases covering power density and contrast as well as speed of emulsions used in photography.
Fiberglass	Sizing agent and helps to prevent abrasion of glass
Fibers and Textiles – synthetic fibers, dyeing and printing, fugitive tinting, dye stripping and dispersant, scouring, delustering, sizing and finishing, greaseproofing aid, soil release agent. Widely used as dye dispersant and to disperse titanium dioxide.	Backbone for grafting monomers. Improves dye receptivity of such hydrophobic fibers as polyolefins, viscoses, rubber latices, poly acrylonitriles and acrylics. Dye fixation improver and dye vehicle in wool transfer printing. Thickener for heat activated textile adhesives, textile finishes and print parts for various types of fabrics. Textile dye stripping and strike rate control through dye complexion. Acts as a dye scavenger in print washing. Contributes enhanced adhesives to glass-fiber sizes.
Inks / Coatings	Viscosity control, suspension stabilization, flow control
Membranes – macroporous, multiporous, desalination, gas separating, liquid ultrafiltration, hemodialysis, selective permeability types of membranes, hollow fiber membranes.	Good compatibility and crosslinking properties Ability to complex with a broad variety of compounds. Strong polar character and hydrophilicity improves selective material separation properties.

Industrial Applications of Polyvinylpyrrolidone *(continued)*

Area of Use	*Advantages of PVP polymer*
Metallurgy – processing for both ferrous and non ferrous metals, coating ingredient to aid or remove material from metal surfaces such as copper, nickel, zinc and aluminum.	Steel quenching bath media. Coating to facilitate the cold forming of metals. Binder for casting molds and cores. Thickener, viscosity controlling agent, adhesion improver, water soluble flux.
Paper – inorganic papers, cellulose papers, rag stock, rag stripping, coloring and beating operations, copying paper, printing paper and electric insulating papers, paper adhesives.	Improves strength and stability. Prevents sliding. Fluorescent whitening agent carrier. Improves luster, binding, absorbency, whitening and gloss. Solubilizes dyes for coloring, dyestripping. Fiber and pigment dispersant. Helps in preventing deposition of pitch. Complexing agent for modifying resins. Binder for inorganic flakes and fibers.
Polymerizations – acrylic monomers, unsaturated polyesters, olefins, including PVC, styrene beads, substrate for graft polymerization, template in acrylic polymerization.	Acts as particle-size regulator, suspending agent and viscosity modifier of emulsion polymers. In polymerization products, improves strength, clarity, color receptivity. Post-polymerization additive to improve dyeability and stability of latices. Pigment dispersant.
Suspensions / Dispersions	PVP polymer is adsorbed on the surface of the colloid particles preventing them from coagulating.
Tableting	Binder agent
Water and Waste Treatment, and Hygiene – clogging of reverse osmosis membranes, water treatment in fish hatchery ponds, removal of oil, dyes from waste water and as an oil-ball forming agent in oil spill removal, flocculant in waste water treatment, waste water clarifier in papermaking, in deodorants for neutralization of irritant and poisonous gas, in air conditioning filters.	Complexes and gels in water to react with undesired water products.

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