AQUIVION™ IONOMER DISPERSION

AQUIVION™ Low-EW PFSA Dispersion Product Description

Solvay Solexis Aquivion dispersions are based on the unique Short Side Chain (SSC) copolymer of Tetrafluoroethylene and a Sulfonyl Fluoride Vinyl Ether (SFVE) $F_2C=CF-O-CF_2CF_2-SO_2F$ of low molecular weight produced by Solvay Solexis. The ionomer dispersions contain its acid form and are available in various solvent systems and concentrations.

Solvay Solexis Aquivion dispersions can be used for the production of PEM fuel cell electrodes, electrochemical cell electrodes, manufacture or repair of ion exchange membranes, super-acid catalyst production or surface treatment of PTFE membranes to improve wetting behavior. The following grades are available:

Product Code	Equivalent Weight (EW)	Polymer Concentration	Solvent System (% w/w)
D83-06A	830	6 % w/w	20 % Water, 40 % 1-Propanol , 40 % 2-Propanol
D83-10E	830	10 % w/w	36 % Water, 51 % 1-Propanol , 13 % 2-Propanol
D83-15C	830	15 % w/w	58 % Water, 21 % 1-Propanol , 21 % 2-Propanol
D83-20B	830	20 % w/w	>99 % Water, free of ethers

HEALTH SAFETY AND ENVIRONMENT

Solvay Solexis Aquivion dispersions are not harmful if used and handled according to standard processing procedures (see for example the "Guide to the Safe Handling of Fluoropolymer Resins" issued by the Society of the Plastics Industry). If handled inappropriately, the dispersions may release harmful toxic chemicals.

Solvay Solexis Aquivion dispersion grades A, C and E are flammable. Please refer to the corresponding Material Safety Data Sheets for more information on handling and safety.

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PACKAGING, SHIPMENT AND STORAGE

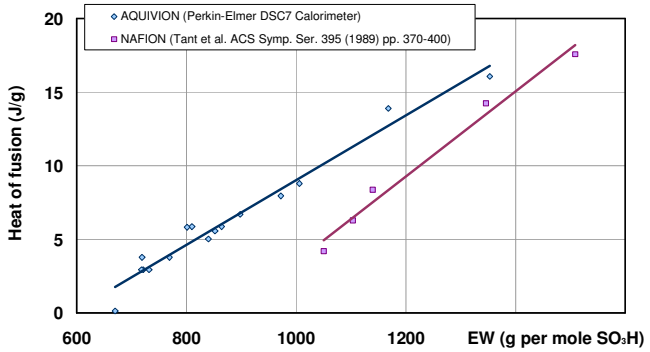
Solvay Solexis Aquivion dispersions are available in 0.5 ltr, 5 ltr and 60 liter containers. It is recommended to store the product at 25 °C (77 °F) in a clean temperature-controlled and well ventilated environment, protected from direct sunlight or other sources of heat or irradiation. Containers should be kept tightly closed to avoid solvent evaporation.
Solvay Solexis ionomer dispersion grades A, C and E should be kept away from sparks and flames or any other possible source of ignition.


MOLECULAR STRUCTURE

Solvay Solexis' Aquivion ionomer is a copolymer produced from Tetrafluoroethylene, C_2F_4, and Ethanesulfonyl fluoride,1,1,2,2-tetrafluoro-2-[(trifluoroethenyl)-oxy], C_2F_3-O-$(CF_2)_2$-SO_2F. The section between the ether bridge and the functional unit SO_2F is typically called the "side chain". The characteristic of Aquivion™ to have a very short and light side chain incurs a number of advantageous factors for the end user. The co-monomer content typically varies between 14 and 19 %-mole in the EW range of 700-900.

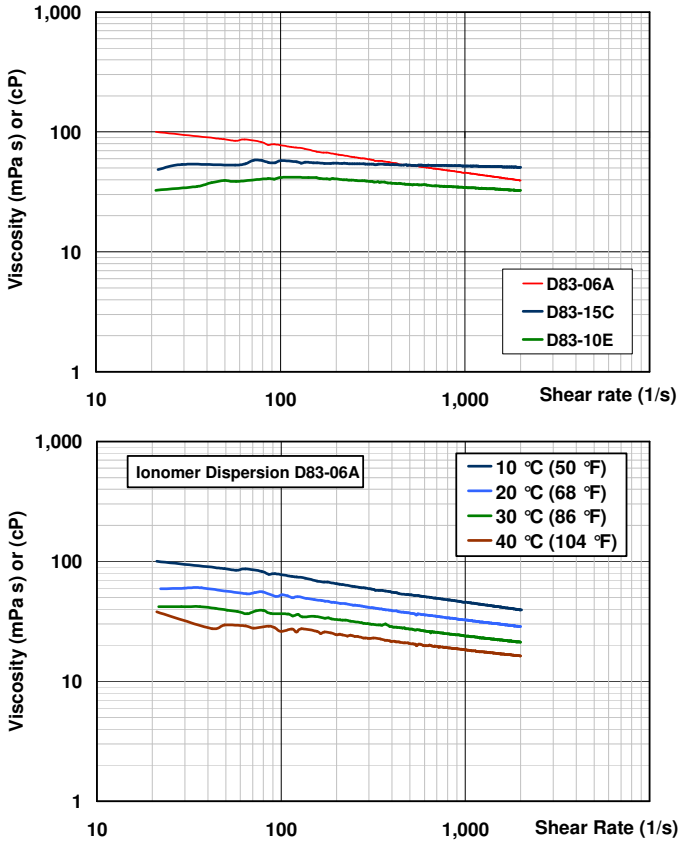
DIFFERENTIAL SCANNING CALORIMETRY

The Aquivion ionomer exhibits a higher level of crystallinity compared to other PFSA ionomers with longer side chains. This is observed through comparison of the heat of fusion determined from DSC analyses. Additionally, the Solvay Solexis ionomer retains crystallinity down to approximately EW 600.



DISPERSION REOLOGY

Important for formulations such as catalyst inks, where ionomer dispersion becomes part of the suspension. It can be noted that C or E-type dispersions exhibit a medium viscosity level around 50-70 mPa·s (cP) which is rather independent from the shear rate applied (Newtonian characteristic). A-type Aquivion dispersions reveal a more pronounced shear-thinning behavior and their viscosity is also more temperature-dependent compared to B, C or E grades.



DISPERSION MORPHOLOGY

Aquivion ionomer dispersions contain non-spherical polymeric particles of different characteristic dimensions. Small-angle X-ray Scattering (SAXS) was performed to determine their distribution. On the basis of the intermediate data obtained one can say that C-type dispersion (and accordingly also B and E) have a higher fraction smaller particles, whereas the A-type material of higher concentration regarding larger particles. No particles are larger than one micron.

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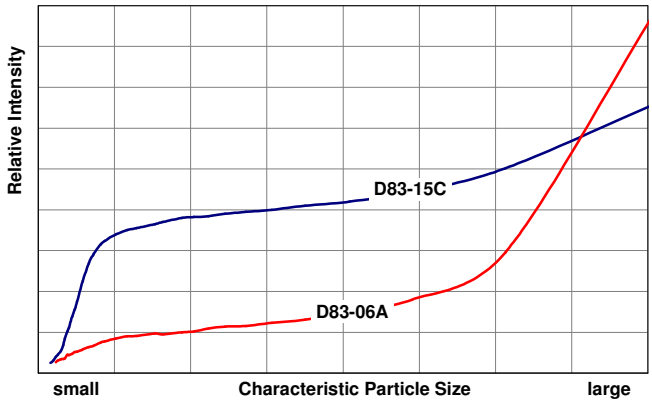
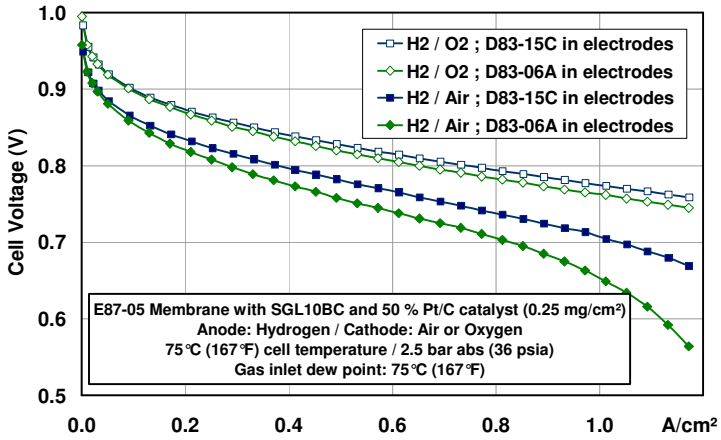


IN-CELL DISPERSION PERFORMANCE

The different characteristics between the dispersion grades can be exploited to maximize performance under certain operation conditions, for example in fuel cell applications. A comparison of four different single cell operations of which in two cases electrodes were prepared with D83-06A and other two with D83-15C reveals the two major effects.



D83-15C avoids water-entrapment inside the electrode structure which is advantageous for cathodes where oxygen (from air) must diffuse to reactive sites. At high current densities D83-15C efficiently avoids diffusion limitation caused through blocking of gas transport channels by product water.

A significant increase of the cathodic oxygen concentration removes the diffusion limitation and reveals a second benign effect of dispersions such as D83-15C: The electrode structure becomes more homogeneous and has a lower ionic resistance compared to electrodes made from a standard dispersion such as D83-06A.

GENERAL PROCESSING REMARKS

Though no particle maturation has been observed so far, stratification over extended periods of time can not be fully excluded since dispersions are colloidal in nature. It is therefore recommended to shake the dispersion well before use. Ultrasound can be applied additionally if available.
After long storage periods additionally check the dispersion's dry content on a small sample before use. Evaporation of organic solvents may have incurred increasing ionomer concentration or dispersion viscosity. If this is the case, add DI-water quantitatively to recover the initial concentration.
Being superacids, Aquivion ionomer dispersions constitute reactive systems. Solvay Solexis is not responsible of incorrect formulations. The following sections give illustrative examples of possible solvent modifications.

D83-06A: SUBSTITUTION OF PROPANOL WITH WATER

To transfer D83-06A to a 6 wt% aqueous dispersion, the dispersion can be held under slight heating respecting the following points:

- Keep the dispersion under stirring
- Do not exceed 50 °C (122 °F) during operation
- Continuously add water to maintain the polymer concentration ≤ 6 % w/w
- Operate at ambient pressure if low viscosity is desired
- Inert gas flow accelerates solvent removal
  Nitrogen is recommended due to the nature of solvents involved
- Avoid vacuum operation

D83-06A: INCREASE OF IONOMER CONCENTRATION

To increase the concentration of water-based dispersions up to around 25 % w/w, water can be slowly evaporated while:

- Maintaining the dispersion under stirring
- Optionally adding inert gas flow to accelerate solvent removal

Polymer precipitation or viscosity increase are not expected if alcohols are removed properly - or if D83-20B is used.

D83-20B: INCREASE OF IONOMER CONCENTRATION

To increase the concentration of water-based dispersions up to 40 % w/w, water can be slowly evaporated while respecting the following:

- Recommended temperature is 50 °C.
- Maintain dispersion under stirring at ambient pressure
  Avoid vacuum operation
- Inert gas flow accelerates solvent removal
- The process is reversible
  Water addition for re-dilution is possible if necessary

Polymer precipitation is not expected, though non-uniform agitation can result in reversible formation of solids. Exponential increase in viscosity will occur, depending on polymer concentration.

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AQUIVION™ IONOMER DISPERSION

AQUIVION™ IONOMER DISPERSION – TYPICAL PROPERTIES

	Test Method	Units	D83-06A	D83-10E	D83-15C	D83-20B
Physico-Chemical Properties						
Visual aspect			transparent liquid	transparent liquid	transparent liquid	transparent liquid
Flammability at ambient conditions			YES	YES	YES	NO
Polymer Content	TGA analysis	% w/w	6±0.2	10 ± 0.2	15 ± 0.2	20 ± 0.2
Equivalent Weight (eq = mol SO_3H)	PF 87/21e	g/eq	830 ± 20	830 ± 20	830 ± 20	830 ± 20
Total Acid Capacity	PF 87/21e	meq/g	1.17-1.23	1.17-1.23	1.17-1.23	1.17-1.23
Density at 25°C (77°F)	PF	g/cm^3	0.875	0.927	1.005	1.115
Solvent water content			25 %	36 %	58 %	100 %
Viscosity at 25°C (77°F)	(*)	mPa·s cP	80-100	30-40	50-60	5-10

PF = Solvay Solexis Internal Test Method

(*) Dynamic Mechanical Spectrometer Rheometric RFS III
Geometry: Couette
Mode: Steady Rate Sweep Test
Value at 40 s^{-1}

*For any further information on Solvay Solexis AQUIVION product line contact your regional Solvay Solexis representative, send us an email directly to solexis.ionomers@solvay.com or go to **www.solvaysolexis.com***

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