

A New Perspective on Hydrogen Chloride Scavenging at High Temperatures for Reducing the Smoke Acidity of PVC Cables in Fires. II: Some Examples of Acid Scavengers at High Temperatures in the Condensed Phase

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1) Materials

Table S1: The identification of commercial additives in Tables 1-3 of the paper

Inovyn 271 PC: PVC S K70 produced by Inovyn. https://www.ineos.com/businesses/inovyn/
Diplast N: Di Iso Nonyl Phthalate produced by Polynt S.p.A.. https://www.polynt.com/it/
Reaflex EP/6: Epoxidized Soy Bean Oil in the product portfolio of Reagens. https://www.reagens-group.com/
Arenox A10: Pentaerythritol tetrakis(3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate) in the product portfolio of Reagens. https://www.reagens-group.com/
RPK B-CV/3037: Thermal stabilizer for PVC. One pack in the product portfolio of Reagens. https://www.reagens-group.com/
Riochim: Ground Calcium Carbonate produced by Umbria Fillers s.r.l.: https://umbriafiller.com/
Apyral 40 CD: Synthetic Aluminum tri hydroxide, produced by Nabaltec. https://nabaltec.de/
Ecopiren 3.5: Brucite in the product portfolio of Europiren. https://europiren.com/it/catalog/ecopiren/
Winnofl S: Precipitated Calcium Carbonate in the product portfolio of Imerys: https://www.imerys.com/

2) Sample preparation

PVC compounds in tables 1, 2, and 3 are prepared by weighing the stabilizers' ingredients in the 0.001 g readability balance. PVC, plasticizers, fillers, flame retardants, and acid scavengers are weighed in the 0.1 g readability balance. All solid ingredients have been introduced into the turbo mixer. Liquids such as ESBO and DINP were added when the temperature reached 80°C, and the mixing stopped at 105°C. The dry blends have been dropped in PE bags and stored for 24 hours at 23°C to get the proper "maturation" of the dry blends.

60 g of dry blends have been processed in plasticorder for 10 minutes, at a temperature cell of 160°C, with a blade speed of 30 g/min. The kneaders have been pressed in the hydraulic press to wanted thicknesses plaques (0.5 mm, 1 mm, and 6 mm) with the following cycles:

160°C per 1.5 minutes, pressure 0 bars

160°C per 1.5 minutes, pressure 60 bars

160°C per 1 min, pressure 100 bars

Cooling cycles, pressure 150 bars

3) Measurements of the main properties

Table S2: Data of the formulations in table 7

Formulation	F50.0	F50.1	F50.2	F50.3	F50.4	F50.5
Specific Gravity [g/cm ³]	1.542 +/- 0.012	1.505 +/- 0.021	1.503 +/- 0.004	1.542 +/- 0.007	1.445 +/- 0.014	1.446 +/- 0.009
Shore Hardness [type A, 15"]	88 +/- 1	89 +/- 1	89 +/- 1	88 +/- 1	90 +/- 1	90 +/- 1
Tensile strength [N/mm ²]	13.0 +/- 0.8	11.8 +/- 0.5	11.7 +/- 0.8	13.4 +/- 1.1	13.0 +/- 1.0	13.1 +/- 0.7
Elongation at break [%]	246.4 +/- 3.8	236.1 +/- 4.9	233.1 +/- 2.5	240.1 +/- 2.4	221.5 +/- 1.7	225.5 +/- 1.5
Thermal Stability [min]	104 +/- 3	79 +/- 2	73 +/- 4	76 +/- 5	291 +/- 11	299 +/- 12

Table S3: Data of the formulations in table 12 of the paper

Formulation	F50.6	F50.7	F50.8	F50.9	F50.10
Specific Gravity [g/cm ³]	1.644 +/- 0.011	1.590 +/- 0.014	1.627 +/- 0.002	1.853 +/- 0.007	1.946 +/- 0.007
Hardness [SHA 15"]	91 +/- 1	92 +/- 1	91 +/- 1	97 +/- 1	98 +/- 1
Tensile strength [N/mm ²]	8.2 +/- 0.5	5.8 +/- 0.3	7.5 +/- 0.7	2.3 +/- 1.3	1.2 +/- 1.3
Elongation at break [%]	210.3 +/- 3.2	195.1 +/- 5.2	205.0 +/- 1.1	177.0 +/- 7.5	172.0 +/- 8.5
Thermal Stability [min]	76 +/- 5	71 +/- 3	61 +/- 2	57 +/- 4	38 +/- 3

Specific Gravity: 3 measures for mean value and standard deviation have been carried out. The measurements are taken after conditioning the test specimens for 24 h at 23°C. The measurements have been derived manually from weighing in water and air the test specimens, following the indications of ISO 1183. After weighing the test specimens in water, they are gently dried using laboratory paper strips.

Hardness: 10 measures have been carried out for getting mean values and standard deviations, following ISO 868 (Manual Digital Hardness Tester, Gibitre Instruments). The measurements are taken after conditioning test specimens for 24 h at 23°C. The surface of the test specimens is carefully checked to verify the flatness and the absence of bubbles or imperfections affecting the measure.

Tensile and elongation: 5 measures have been carried out for getting mean values and standard deviations, following ISO 527 (Hounsfield, model H10KS). Specimen type 1B has been used for determining the mechanicals. The aspect of the test specimens is carefully checked to verify the absence of defects or imperfections affecting the measure. The measurements are taken after conditioning the test specimens for 24 h at 23°C. The measurements are performed at 23°C. The adopted testing speed is 500 mm/min.

Thermal Stability: 3 measures have been carried out for getting mean values and standard deviations, following EN 60811-405 procedures. The measurements are taken after conditioning 0.5 mm plaques for 24 h at 23°C. The test specimens are cut from 0.5 mm plaques and introduced in test tubes with comparable dimensions, specifically with a length of less than 2 cm. The thermostat is a metalblock thermostat Liebisch Labortechnik, model LT-PVC-210-36-5, with 36 positions. The test temperature, set at 200,0°C+/-0.5 °C, has been checked by a calibrated thermocouple. The congo red test paper has been utilized to identify the end point of Thermal Stability, expressed in minutes

4) pH and conductivities measurements

Table S4: Data of the formulations in table 8 of the paper

Method 2 @ 400 °C	F50.0	F50.1	F50.2	F50.3	F50.4	F50.5
pH	2.48 +/- 0.06	2.37 +/- 0.06	2.81 +/- 0.07	3.71 +/- 0.03	4.03 +/- 0.19	3.88 +/- 0.12
Conductivity [μ S/mm]	142.9 +/- 3.6	179.4 +/- 1.5	88.7 +/- 3.5	8.1 +/- 0.3	4.0 +/- 0.1	5.3 +/- 0.1
Method 2 at 500 °C	F50.0	F50.1	F50.2	F50.3	F50.4	F50.5
pH	2.48 +/- 0.04	2.41 +/- 0.03	2.41 +/- 0.09	3.73 +/- 0.10	3.70 +/- 0.15	3.69 +/- 0.13
Conductivity [μ S/mm]	139.1 +/- 1.2	177.2 +/- 2.5	177.3 +/- 6.2	7.7 +/- 0.3	8.2 +/- 0.4	8.6 +/- 0.3
Method 2 at 600 °C	F50.0	F50.1	F50.2	F50.3	F50.4	F50.5
pH	2.51 +/- 0.02	2.30 +/- 0.01	2.31 +/- 0.03	3.69 +/- 0.07	3.70 +/- 0.10	3.65 +/- 0.05
Conductivity [μ S/mm]	132.6 +/- 3.7	201.7 +/- 4.1	195.7 +/- 5.0	9.2 +/- 0.4	7.8 +/- 0.3	9.5 +/- 0.2
Method 2 at 800 °C	F50.0	F50.1	F50.2	F50.3	F50.4	F50.5
pH	2.63 +/- 0.13	2.30 +/- 0.09	2.29 +/- 0.09	3.26 +/- 0.11	3.52 +/- 0.02	3.20 +/- 0.03
Conductivity [μ S/mm]	100.4 +/- 4.4	206.4 +/- 2.5	208.9 +/- 7.8	23.7 +/- 0.6	13.5 +/- 0.2	25.7 +/- 0.6
Method 2 at 950 °C	F50.0	F50.1	F50.2	F50.3	F50.4	F50.5
pH	2.62 +/- 0.03	2.27 +/- 0.10	2.27 +/- 0.02	2.74 +/- 0.06	2.89 +/- 0.08	2.79 +/- 0.02
Conductivity [μ S/mm]	97.3 +/- 3.7	221.5 +/- 8.4	224.3 +/- 3.1	74.0 +/- 1.6	70.1 +/- 0.7	70.1 +/- 2.0

Table S5: Data of the formulations in table 12 of the paper

Formulation	F50.6	F50.7	F50.8	F50.9	F50.10
pH	2.93 +/- 0.06	2.34 +/- 0.02	3.32 +/- 0.06	3.75 +/- 0.08	3.75 +/- 0.09
Conductivity [μ S/mm]	49.4 +/- 6.1	183.8 +/- 9.0	20.7 +/- 2.6	8.4 +/- 1.0	8.4 +/- 1.0

Table S6: Data of the formulations in table 13 of the paper

Formulation	F50.6	F50.7	F50.18	F50.9	F50.19	F50.20	F50.21	F50.22	F50.23
pH	2.93 +/- 0.06	2.34 +/- 0.04	3.19 +/- 0.11	3.75 +/- 0.08	2.65 +/- 0.02	2.51 +/- 0.04	2.90 +/- 0.01	2.89 +/- 0.00	2.33 +/- 0.02
Conductivity [μ S/mm]	49.4 +/- 1.4	183.8 +/- 9.0	28.8 +/- 0.3	8.4 +/- 0.3	106.2 +/- 4.2	133.5 +/- 6.2	56.9 +/- 2.3	51.6 +/- 1.8	193.0 +/- 3.0

pH and conductivity measurements: the tube furnace (SA Associates, standard model) has a touch screen temperature controller through which the heating regime of EN 60754-2 has been selected. The final temperature has been checked and adjusted with a calibrated external thermocouple. The air flux has been set at 300 ml/min according to the quartz tube dimensions, as requested by EN 60754-2. Before the first run, a preliminary test of the presence of bubbling in the bubbling devices has been done. That aimed to verify that all connections were well tightened and that no HCl leak could affect the measurements.

0.5 mm plaques have been conditioned for 24 h at 23°C. The plaques have been cut in slices with similar dimensions for all runs (approximately 1 mm x 1 mm). The slices have been weighed into the combustion boat and arranged into the tube furnace when the temperature is stable at 950 +/- 5 °C.

Smokes have been collected in the bubbling devices containing double deionized water of the quality required by EN 60754-2 for 30 minutes. The two quotes are collected in a 1 L volumetric flask, cleaning all connectors and bubbling devices well to recover as much as possible all HCl.

pH and conductivity have been measured simultaneously by inserting the electrodes in two different vessels. pH and conductivity measures are taken at 25 °C +/- 1 with the following procedure: the multimeter has been calibrated with standard solutions before each measurement: pH at two points (4.01 and 7.00) and conductivity at 1 point at 141.3 μ S/mm. The solutions closer to the measured value have been chosen as correction standards, and the measurements are corrected accordingly through a correction factor. pH and conductivity electrodes have a reference thermocouple that adjusts the fluctuation of temperature.

Ashes analysis: the combustion boat has been extracted from the tube furnace, left to cool down, and put in a PE zip lock bag. Before the measurement, the combustion boat and standards are dried for two h in the oven at 105 °C.

FTIR measurement: After dried ashes, they were analyzed in an FTIR-ATR spectrometer (IS 20, Thermo, Software Omnic). The measurements have been taken as fast as possible due to the high hygroscopicity of the analytes. Different levels of water uptake can bring different hydration states and severely modify the spectra of analytes. The spectra have been corrected to transmission using the integrated algorithm of Omnic.

XRF measurements: After dried ashes, the ashes have been weighed and melted in glass beads (Equilab, F1 induction fluxer). They have been analyzed in a WD-XRF spectrometer (Perform'x, Thermo).