Ludox® -- Technical Literature

Product Description

- *Ludox® HS40 and HS30*
  Ludox® HS is available in two silica concentrations: 40% and 30%. The 30% concentration is convenient to investment casting customers because the material can be used as an investment casting binder as supplied, without dilution. Ludox® HS has been broadly used in the formulation of coatings, catalysts, antislips, and anti-soil treatments as well as a high temperature binder for refractory fibers, stool coatings, investment castings, etc.
- *Ludox® TM*
  The larger particle size of Ludox® TM allows it to be used for friction and anti-sheer applications on textiles such as delustering and as an antislip to avoid seam slippage during fabric cutting and sewing. The larger size promotes long-term stability.
- *Ludox® SM*
  Ludox® SM is used almost exclusively in the investment casting of metals. Its high surface area makes it a very efficient binderÐvery economical when properly diluted for use.
- *Ludox® AM*
  The use of sodium aluminate instead of sodium hydroxide in stabilizing Ludox® AM gives it broader stability against variation of pH. In applications where a colloidal silica needs to be incorporated at a neutral or acid pH, Ludox® AM has been the grade of choice.
- *Ludox® AS*
  Ammonium hydroxide is used to stabilize Ludox® AS instead of sodium hydroxide. Where the presence of sodium is detrimental, such as in very high temperature applications or some catalyst applications, Ludox® AS is preferred.
- *Ludox® LS*
  Low sodium content is the hallmark of this grade. It is often used in formulations where organic solvents are used. Low pH and low sodium levels promote improved stability of these mixtures.
- *Ludox® CL-X*
  Ludox® CL-X is formulated to be more easily cleanable than the other grades of Ludox® and is especially recommended for paper frictionizing applications.
- *Ludox® SK*
  Ludox® SK is a family of patented products which combine a stable, deionized colloidal silica with water soluble polymers. New combinations are being developed to meet special needs. We suggest you contact DuPont to more fully discuss the properties and grades available.
  Ludox® SK was originally developed as an investment casting binder. It gives very long life and stable properties in investment casting slurries with many refractories. Its low sodium levels improve its high temperature properties compared to standard alkaline colloidal silicas. Because Ludox® SK binders do not depend on being kept alkaline to maintain stability, no pH adjustments are necessary. Slurry maintenance consists of replacing evaporated water only.
  Conventional grades of colloidal silica are not good film formers. The film-forming characteristics of Ludox® SK binders suggest that they may have utility in coating applications, especially in high temperature coatings such as ceramic or catalyst applications.
- *Ludox® TMA*
  Ludox® TMA is deionized to remove most of the sodium normally present in an alkali stabilized colloidal silica. The pH of Ludox® TMA is slightly acidic to neutral, yet the stability is excellent. Ludox® TMA is used where alkaline counter ions are not wanted such as in combinations with polar organic solvents, catalyst applications, or where the presence of sodium or other alkalis would destabilize other components of a proposed mixture. Ludox® TMA has been found to be very useful in the preparation of "hybrid" colloidal-ethyl silicate binder combinations for the investment casting industry.
- *Ludox® CL*
  Ludox® CL is colloidal silica in which each particle is coated with a layer of alumina. This converts the charge of the particle from negative to positive. The stabilizing counter-ion is chloride. Many surfaces are negatively charged and therefore Ludox® CL is often readily adsorbed on surfaces producing a stable layer which is not easily removed.
  Ludox® CL is a good high temperature binder. The alumina coating of the particles causes them to act similar to colloidal alumina. However, the low temperature strength developed by Ludox® CL is usually

intermediate between colloidal alumina and colloidal silica. The alumina coating retards the conversion of the underlying silica from amorphous to crystalline at high temperatures. The fired strengths are usually observed to be superior to conventional colloidal silicas of similar particle size.
Because it is positively charged it is not compatible with other grades of Ludox® and will gel other grades on contact. Unlike most grades of Ludox® CL is freeze stable and can be recovered after being frozen by thawing and remixing.

Chemical and Physical Properties

- *Stability and Compatibility*
  Stability is an important consideration in formulations containing Ludox® or Syton® and other components. The time required for gelation is usually used as a measure of stability. For some applications, however, gelation is a required step during processing. The stability of systems that contain Ludox® or Syton® depends on several variables: silica solids content; temperature; size or surface area of the silica particles; pH; particle charge; salt concentration; and the compatibility with various additives such as surfactants, freeze-thaw stabilizers and organic solvents.
- *Shelf Life*
  The question of shelf life comes up quite often. Generally, unopened drums of most grades can be stable for many years. However, DuPont limits its claims for shelf life to one year from the date of manufacture.
- *Silica Solids Content*
  The stability of systems containing Ludox® or Syton® increases with dilution provided other conditions (such as temperature, pH and concentration of additives) remain constant. The figure below shows the stability (indicated by gel time) as a function of pH at various levels of silica concentration for Ludox® HS, AM and TM. Sodium chloride was added to these sols in order to accelerate the comparison. Water can be added directly to Ludox® and Syton® in any amount to reduce the silica content to a desired level.
- *Temperature*
  Most applications of Ludox®/Syton® involve the use of sols at room temperature, thereby minimizing concentration by evaporation. Higher temperatures not only increase the loss of water by evaporation but also the movement of the colloidal particles in suspension and the dissociation of electrolytes present in the system. Each of these factors contributes to gelation or to the formation of aggregates of silica.
  Freezing temperatures cause crystals of ice to form in Ludox® and Syton®, which increases the concentration of silica in the unfrozen portion. This accelerates gelation of the silica-rich fraction. On thawing, the gelled silica does not redisperse but remains as a sediment in the melted ice. As a result, the melted material also contains a reduced concentration of dispersed silica particles and is usually unsuitable for use.
  Ludox® and Syton® containing a freeze-thaw stabilizer are available on request. On freezing, this material also tends to separate into silica-rich and silica-deficient fractions but remains unaggregated on thawing. For use, the thawed sol only requires remixing of the concentrated bottom layer with the more dilute material in the top of the container.
  Ludox® PGE, CL, and CL-X are freeze-thaw stable as received. If frozen, they may be thawed and remixed to give useful product.
- *Particle Size*
  The relative stability of various grades of Ludox® and Syton® increases with increasing particle size, other variables remaining constant. Thus, at pH 6.0 for sols containing 30% silica and adjusted to 0.1 N in sodium chloride, Ludox® SM (about 7 nm in diameter) gels in 45 minutes, Ludox® HS (about 12 nm in diameter) gels in 400 minutes and Ludox® TM (about 22 nm in diameter) gels in 1 800 minutes. The greater stability of Ludox® TM over that of Ludox® HS is also shown in the figure below. For example, at pH 7.5 in the presence of 0.1 N sodium chloride, Ludox® TM, containing 30% silica, gels in about 20 days whereas Ludox® HS-30 gels in only one day.

Effect of Silica Concentration, Salt Content, and pH on Gel Time

- *Effect of pH*

  The tendency of Ludox® HS or TM, Syton® X or W to gel is greatest at pH 5-6. The same is true for Ludox® LS, SM and AS. As the pH is further reduced, these sols all become more stable. They can be effectively used in acidic media where temporary stability is sufficient. To acidify Ludox® or Syton® acid should be added with agitation in such a manner that the pH moves rapidly through the critical range of pH 5-6.

  Ludox® AM does not exhibit a minimum in stability versus pH but increases continuously in stability with decreasing pH as shown in the figure above. Therefore Ludox® AM is preferred in applications at pH 4-6 (as discussed in the next section).

  Above about pH 10.7, the silica in Ludox® and Syton® becomes increasingly solubilized and the alkali silicate acts like any other soluble salt in destabilizing the remaining colloidal silica (See discussion under "Salt Concentration"). However, high concentrations of sodium hydroxide also cause coagulation of silica. Therefore, in adding sodium hydroxide to Ludox®/Syton®, vigorous mixing must be maintained during addition to prevent local gelation even though high pH is not finally reached.

- *Particle Charge*

  Ludox®/Syton® colloidal silica sols are stabilized against gelation by causing the silica particles to become negatively charged so they repel each other. This is done by addition of small amounts of alkali (ammonia in the case of Ludox® AS and Syton® T40AS and sodium hydroxide for the other grades) which react with the silica surface to produce the negative charge.

  The unique behaviour of Ludox® AM results from the novel means used to create the negative charge on the particles of this sol. A comparison of the particle charges on the various grades helps in understanding the advantages of each.

  In all of the alkaline types of Ludox®/Syton®, hydroxyl ions have two important effects:

  1. They react with surface silanol groups to create negative surface charges which cause the particles to repel each other. This inhibits aggregation or gel formation.
  2. They also directly catalyze the formation of siloxane cross- linkages or gel formation. Thus, at high pH, Ludox® and Syton® are stable because of high particle charge.

  As pH drops, particle charge decreases but sufficient hydroxyl ions remain to catalyze cross linking, and stability reaches a minimum at pH 5-6. At still lower pH, hydroxyl ions essentially disappear and even though the particles become uncharged, interparticle bonding decreases and the sol becomes more stable.

  In Ludox® AM, trivalent aluminum atoms have been substituted for part of the tetravalent silicon atoms in the surface of the particles, creating a fixed negative charge which is independent of pH. For this sol, lowering of pH reduces the amount of charge attributable to reaction between hydroxyl ions and surface silanol groups, but not that arising from the aluminum substitution. Consequently the stability of Ludox® AM increases continuously with decreasing pH as shown in the figure above.

- *Salt Concentration*

  Figure D also illustrates the effect of salt additives on the gelation of sols of Ludox® HS and AM. In a salt-free sol, the positive counter ions balancing the negative surface charge are diffusely oriented around the particle. Thus, the repelling forces between particles extend for some distance out from the particle surface.

  As salt is added, the counter ions move much closer to the particle surface which reduces the distance through which the repelling forces act. This causes a reduction in sol stability by increasing the probability of interparticle collision. Polyvalent cations are more effective in shrinking the diffuse layer, and are therefore more effective gelling agents for Ludox® and Syton®. However, salt-induced gelation is most frequently accomplished by addition of sodium or ammonium chloride.

  The electrolyte selected to induce gelation of Ludox®/Syton® depends on the system involved. Solutions of sodium chloride are widely applicable. Where the presence of sodium is undesirable (e.g., where sodium would cause fluxing in a ceramic slip with Ludox®/Syton® as binder), ammonium chloride, acetate or nitrate can be used.

- *Surfactants*

  Surfactants can be added to formulations containing Ludox®/Syton® to improve wetting properties. Certain types of anionic surfactants, such as those having sodium as the cation and a sulfated fatty alcohol or sulfonated alkyl or aryl hydrocarbon radical as anion, are

pH Adjustment Required for Stable Mixture[a]

[a] Adjustment of sol pH required to form mixture which does not gel or flocculate for at least 24 hours.
[b] Mixtures which remained stable at least 1 day formed in the pH range 8.5-9.5 and at pH 4.0.
[c] "ND" signifies that the pH needed to form a stable mixture was not determined.

Solvent	Dielectric Constant	Ludox® HS40 pH 9.7	Ludox® HS30 pH 9.8	Ludox® LS pH 8.4[a]	Ludox® SM pH 9.9	Ludox® TM pH 8.9	Ludox® AM pH 9.0
Formamide	109	None	None	None	None	None	None
Glycerol	42.5	None	None	None	None	None	None
Ethylene glycol	37.7	None	None	None	None	None	None
Dimethylformamide	36.7	9.3	None	None	4.0	None	None
Methanol	32.7	[b]	None	None	4.0	None	None
Ethanol	24.3	4.0	7.5	None	4.0	4.0	8.0
Acetone	20.1	7.1	8.3	None	4.0	7.4	None
Isopropyl alcohol	18.3	ND[c]	ND[c]	None	ND[c]	ND[c]	ND[c]

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