

## **PROPERTIES AND USES:-**

### **SULFUR:-**

Sulfur is one of the most important raw material used for the production of sulfuric acid. It's insoluble in water and soluble in organic solvents. Its available in the nature in the form of rocks, lumps, ground powder, sublimed powder etc. The various physical properties are mentioned in the table shown

CHEMICAL FORMULA	S
ATOMIC WEIGHT	32.07
MELTING POINT: RHOMBIC	112.8 °C
MONOCLINIC	119.0 °C
BOILING POINT	444.6 °C
SPECIFIC GRAVITY:	
SOLID - RHOMBIC	2.07
MONOCLINIC	1.96
LIQUID	1.803

### **SULFUR TRIOXIDE:-**

Sulfur trioxide at room temperature and atmospheric pressure is a colourless liquid that fumes in air. Trace amounts of water of sulfuric acid can catalyze the formation of polymers. However the polymerization apparently proceeds at a negligible rate so long as the liquid is maintained free of solids ( that is above its freezing point ). Once the solid polymers are present, temperatures of 50 to 75 °C are required to fully convert polymers back to liquid monomers.

There is some controversy about the nature of the polymeric sulfur trioxide. Apparently, polymers can have various molecular weights and degrees or types of cross-linking. The literature generally reports that solid sulfur-trioxide can exist in three trimorphic phases as shown in the table

PHASES	MELTING POINTS
ALPHA SO <sub>3</sub>	62.3 °C
BETA SO <sub>3</sub>	32.5 °C
GAMMA SO <sub>3</sub>	16.8 °C

The alpha and beta forms melt to five liquid gamma SO<sub>3</sub>. The alpha - SO<sub>3</sub> phase has a polymeric cross-linked structure that forms crystals resembling ice-needles, beta - SO<sub>3</sub> consists of polymeric molecules that form white asbestos-like crystals with a silky lusture

and gamma - SO<sub>3</sub> is in a colloidal form that consists of cycle trimer and monomer molecules.

The various properties of Sulfur trioxide are summarized in the following table:-

PROPERTY	NUMERICAL VALUE
CRITICAL TEMPERATURE, C	217.8
CRITICAL PRESSURE, KPa	8208
CRITICAL DENSITY, g/cc	0.630
TRIPLE POINT PRESSURE ( $\gamma$ Phase), KPa	21.13
TRIPLE POINT TEMPERATURE ( $\gamma$ Phase), C	16.80
NORMAL BOILING POINT TEMPERATURE, C	44.80
MELTING POINT, C	16.80
TRANSITION TEMPERATURE, C	-183.0
LIQUID DENSITY ( $\gamma$ Phase at 20 C), g/cc	1.922
SOLID DENSITY ( $\gamma$ Phase at 10 C), g/cc	2.290
LIQUID COEFFICIENT OF THERMAL EXPANSION, / C	0.002
LIQUID HEAT CAPACITY (at 30 C), KJ/Kg C	3.222
HEAT OF FORMATION OF GAS (at 25 C), MJ-Kg/mole	-395.7
FREE ENERGY OF FORMATION (at 25 C) MJ-Kg/mole	-371.1
ENTROPY OF GAS (at 25 C) MJ-Kg/mole/ C	0.256
HEAT OF DILUTION MJ/Kg	2.109
HEAT OF VAPORISATION ( $\gamma$ Phase) MJ/Kg	0.058
DIFFUSION IN AIR (at 80 C), m <sup>2</sup> /s	0.000013
LIQUID DIELECTRIC CONSTANT (at 18 C)	3.11

## **SULFURIC ACID:-**

Sulfuric acid is a strong acid that is in aqueous solution, it is largely changed to hydrogen ions ( $H^+$ ) and sulfate ions ( $SO_4^{4-}$ ). Each molecule gives two hydrogen ions and thus sulfuric acid is dibasic. The general physical properties of the sulfuric are given below:-

EMPIRICAL FORMULA	$H_2SO_4$
MOLECULAR WEIGHT	98.08
MELTING POINT	10.5 °C
BOILING POINT	340 °C (Decomposition)
SPECIFIC HEAT	1.4435 KJ/Kg
SPECIFIC GRAVITY	1.8357
HEAT OF DILUTION	9.304 KJ/Kg water

Commercial sulfuric acid is sometimes colorless but, it is often yellow and its color ranges from pale to dark brown shades. In dilute solution, it is highly corrosive and attacks nearly all metals.

Sulfuric acid, oily, corrosive colorless liquid when mixed with water releases considerable amount of heat. Unless the mixture is well stirred the added water may be heated beyond its boiling point and the sudden formation of steam may blow the acid out of the container. The concentrated acid destroys the skin and flesh and can cause the blindness, if it gets into eyes. The best treatment is to flush away the acid with large amount of water.

Dilute solution of sulfuric acid show all the behavior characteristics of acids. They taste sour, conduct electricity, neutralize alkalies and corrode active metals with the formation of hydrogen gas. From sulfuric acid, one can prepare both normal salts containing the sulfate group ( $SO_4$ ) and acid salts containing hydrogen sulfate groups ( $HSO_4$ ).

Sulfuric acid is not one-function or one purpose product. Its used as drying agent, acidifying agent (pH control), hydrolyzing agent, neutralizing agent, dehydrating agent, oxidizing agent, absorbing agent, purifying agent, leaching agent, catalyst and active reagent is petrochemical industries.

Sulfuric acid need not be one time use product. It can be recovered easily from some phases in the refining of the petroleum and in the manufacture of explosives, petrochemicals, detergents, and dyes. It is often recovered in the form unsuitable for re-use in the same process but of strength and quality suitable for use in another process. Sulfuric acid can also be returned to the producer for the fortification with sulfur trioxide or for the regeneration to strong virgin acid.

Sulfuric acid is not a one-quality product. It is produced and supplied in exact purity for storage batteries, rayon, textiles, dyes, food and pharmaceutical industries, in less pure grade for steel, heavy chemicals, petrochemicals, fertilizers, super phosphates and ammonium sulfate industries.

Sulfuric acid is used in wide range of concentrations from very dilute for pH control to the strong fuming acids used in dyes, explosives, detergents, pharmaceuticals and petrochemical industries.

Standard strengths available in the market are listed below:-

SPECIFIC GRAVITY – 1.250	33.33%
SPECIFIC GRAVITY – 1.400	50.08%
SPECIFIC GRAVITY – 1.500	59.80%
SPECIFIC GRAVITY – 1.550	93.19%
60 BAUME	77.67%
66 BAUME	93.19%
20% OLEUM	104.5%
40% OLEUM	109.0%

GRADES OF SULFURIC ACID:-

CHEMICAL IMPURITIES	COMMERCIAL GRADE (Max ppm)	E-GRADE, BATTERY ACID (Max ppm)	FEDERAL SPECIFICATION CLASS – I (Max ppm)
Ammonium	10.0	10.0	10.0
Antimony	0.02	0.02	1.0
Arsenic	1.0	1.0	1.0
Chloride	10.0	10.0	10.0
Copper	1.0	1.0	50.0
Iron	100.0	50.0	50.0
Manganese	0.2	0.2	0.2
Nickel	1.0	1.0	1.0
Nitrate	20.0	5.0	5.0
Platinum	None	None	None
Selenium	0.05	0.05	20
Sulfurous acid	400.0	40.0	40
Zinc	10.0	10.0	40
Cadmium	1.0	1.0	-
Cobalt	1.0	1.0	-
Chromium	0.75	0.5	-
Lead	0.2	0.1	-
Mercury	1.0	1.0	-
Organic matter	None	None	None
Fixed residue	300.0	300.0	300.0

GRADES OF ACID	% H <sub>2</sub> SO <sub>4</sub>	SPECIFIC GRAVITY (At 18 °C)
50 Be (Fertilizer acid)	62.2	1.525
60 Be (Oil of Vitriol)	93.2	1.833
95 % Acid	95.0	1.840
98% Acid	98.0	1.843
Monohydrate Acid	100.0	1.834
20 % Oleum (fuming)	104.5 (20 % free SO <sub>3</sub> )	1.924
40 % Oleum (fuming)	109.0 (40 % free SO <sub>3</sub> )	1.963
65 % Oleum (fuming)	114.6 (65 % free SO <sub>3</sub> )	1.987

In the past it was popular to report the concentration of sulfuric acid as specific gravity in degrees Baume. In United States, the Baume scale is calculated using the formula

$$^{\circ} \text{Be} = 145 - (145 / \text{Sp gr})$$

The Baume scale only includes the sulfuric acid concentration in the range of 0 to 93.19% H<sub>2</sub>SO<sub>4</sub>. Higher acid concentrations are not covered because of the great difficulty in differentiating between acid concentrations in the range of 93 to 100% H<sub>2</sub>SO<sub>4</sub> by specific gravity measurements.

The graphs shown describe the various properties of the acid namely electrical conductivity, viscosity, surface tension, refractive index, solubility of oxygen in sulfuric acid, solubility of sulfur dioxide in sulfuric acid, normal boiling point, critical temperatures, azeotropic composition of sulfuric acid as a function of pressure, heat of mixing with water, density of oleums, boiling point of oleums, freezing point of oleums, viscosity of oleums, oleums heat capacity, vapors pressure curve for oleum etc.

## **APPLICATION:**

Sulfuric acid is widely used in industry because of its most important chemical and physical properties. Other acids have similar properties but the relative low cost of sulfuric acid makes it the most economical choice for wide variety of chemical application and these operations can be classified by the particular property of sulfuric acid involved.

1. Sulfuric acid is an active acid with a high boiling point. The manufacture of halogen acids namely HCl, HF etc and pickling of still make use this high boiling point. Leaching ores in the manufacture if a metal pigment is more effective with sulfuric acid because high leaching temperatures can be used without loss of acid by volatilization.
2. Sulfuric acid has great affinity for water. It is widely used for drying gases containing moisture (Ex-Cell Chlorine). Virtually complete removal of water vapor from these gases is accomplished by simple scrubbing operation.
3. Sulfuric acid forms hydrolysable sulfates with many organic compounds. Many alkylation operations of petroleum and petrochemical industries depend on the ability of this acid to react with hydrocarbons to form intermediate compounds. Aromatic alkylamines important to dye, photographic and pharmaceutical industries are manufactured with sulfuric acid. The production of industrially important synthetic alcohols is also based on this sulfuric acid property.
4. Sulfuric acid has special catalytic properties, probably related to its affinity for water. These catalytic properties account for its large volume use in the manufacture of aviation gasoline.
5. Oleum is used in the manufacture of organic sulfonates. These materials used in large quantities are major ingredients of the household detergents. Smaller quantities of special sulfonates are used as lubricants and as additives to automotive lubricants.
6. Teamed with relative low cost as a marked advantage of sulfuric acid is the availability. Sulfuric acid in the strengths (99 to 99%) common to commerce, doesnt reacts appreciably with steel. Special containers are needed to transport commercial grades of Hydrochloric acid and Nitric acid, but sulfuric acid can be transported in steel tank cars and tank trucks or shipped in steel drums.
7. Sulfuric acid is widely used in the acidulation and neutralization processes because it is frequently the most economical acid available for a particular purpose. The widespread use of Sulfuric acid for pH control, which can be performed satisfactorily by any acid, is a direct result of its low cost and its availability. The manufacture of phosphate fertilizers is the single largest use of sulfuric acid. Large amounts of sulfuric acid are used in acid Coagulation Process (Ex- GRS Synthetic Rubber) and in the regeneration of cationic exchange equipment. Other major use include as the neutralizing agent is the production of synthetic fibers

Thus the uses of sulfuric acid are so varied that the volume of its production provides an approximate index of general industrial activity. American production of Sulfuric acid

exceeded 29 million tons annually in the early 1970, a figure corresponding to a daily production of 1/3 Kg per person throughout the year. The largest single use of sulfuric acid is for making fertilizers, both superphosphate and ammonium sulfate, organic products, refining petroleum, making paints and pigments, processing metals, making rayon, as car energizer etc. and hence it is difficult to imagine the human survival in absence of Sulfuric Acid