This section deals with all major aspects which require consideration when proposing to use the common raw materials found in sulphonation.

3.1 Sulphur

Sulphur crystallises in at least two distinct forms, rhombic and monoclinic. Rhombic sulphur, SA, is stable at atmospheric pressure up to 95.5 °C at which temperature transition to monoclinic sulphur, SB, can take place. Monoclinic sulphur is stable up to its natural melting point of 114.5 °C.

The molecular constitution of liquid sulphur undergoes significant and reversible changes with increasing temperature, as evidenced by the characteristic temperature dependence of physical properties, notably viscosity. The sudden increase in sulphur viscosity above 159 °C is attributed to the formation of polymeric sulphur molecules. (see 3.1.4 and figure 3.)

3.1.1 Sulphur quality

Sulphur can be purchased to a wide variety of specifications and standards. The quality, as defined by the level of impurities, depends upon the source and method of production.

Commonly sulphur is obtained from the extraction of native deposits found in unconsolidated volcanic rocks, recovered from hydrogen sulphide present in sour natural gases or produced by the hydrodesulphurisation of crude oil fractions in refinery operations.

The level of impurities in the sulphur used in sulphonation operations should normally not exceed 0.5% and a target minimum sulphur content of 99.7% is preferred. The types of impurity and their effect on sulphonation operations are summarised below. Generally, sulphur analysis is performed very infrequently but in cases where new suppliers appear or processing problems occur, it is advisable to have the sulphur quality checked to ensure that the specification is being met. Because of the low specified levels of some of the impurities, the expertise available in specialised laboratories should be employed for this analysis.

<table>
<thead>
<tr>
<th>Impurity</th>
<th>Maximum level in ppm (Test Method)</th>
<th>Origin &amp; consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>500 (BS4113)</td>
<td>Contaminants picked up in transit. Sludge contamination of heated surfaces requiring manual removal. Physical coating or choking of the catalyst bed or pre-bed filter, increasing pressure drop requiring manual cleaning.</td>
</tr>
<tr>
<td>Acids (as H$_2$SO$_4$)</td>
<td>100 (BS41113)</td>
<td>Acids are formed slowly when sulphur is exposed to moisture or air. Corrosion and reduced equipment life will result, in addition to premature catalyst deactivation.</td>
</tr>
<tr>
<td>Water</td>
<td>100 (BS4113)</td>
<td>See acids.</td>
</tr>
</tbody>
</table>

Hydrocarbons increase the amount of water vapour in the sulphur burner, giving acids. Organic sulphides which can spontaneously ignite may be formed in the presence of sulphuric acid. Hydrocarbons in the form of bitumenous compounds necessitate more frequent cleaning of heating surfaces and can block pump ball valves.

Antimony can have adverse effects on the sulphur filtering process.

Arsenic will poison the vanadium catalyst reducing its service life and requiring premature replacement.

Selenium is similar to arsenic.

Tellurium is similar to arsenic.

Fluorine and chlorine cause catalyst damage by reaction with silica.

Hydrogen sulphide is not only toxic but, if allowed to accumulate in storage systems, can give rise to explosion hazards.

3.1.2 Sulphur storage, handling and safety

This section should be read in conjunction with the raw material hazard data sheet (see 3.1.3.) and the physical property data sheet (see 3.1.4.).

Solid sulphur

Solid elemental sulphur is virtually non-toxic although sulphur dust can cause systemic poisoning if inhaled and can irritate the eyes and mucous membranes of the respiratory tract. No specific exposure limits exist for solid sulphur and therefore it should be considered as a nuisance dust with the following exposure limits:

- 10 mg/m³ (total dust);
- 5 mg/m³ respirable dust.

Adequate ventilation is required.

Because of its low ignition energy and tendency to develop static charges sulphur presents a fire and explosion hazard. In the event of fire, sulphur burns with a slow blue flame, invisible to the naked eye in daylight, and evolves sulphur dioxide (see 3.2).