Thermal Analysis can damage your ignorance… but save your plant

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Many incidents occurring in the chemical industry are due to lack of knowledge on the process, often under abnormal conditions, but sometimes also during normal operation. A systematic survey of runaway incidents in UK [1] shows that the majority of these incidents are due to secondary reactions, instabilities due to the quality of reactants, and even to the ignorance of the reaction enthalpy. This study is over twenty years old, but more recent incidents show that the situation, even if it has improved, requires a sustained attention. This is illustrated by some examples showing different aspects of process safety.

A semi-batch reaction is performed by addition of a reactant to another, a nitro aromatic compound, that was initially charged in a solvent consisting of a mixture of DMSO and water. Before the start of the addition a failure of the cooling water supply in the plant occurred. It was decided to postpone the addition, leaving the reactor stirring at 60°C. Unfortunately the reactor was left in this stage for longer time until fumes were observed and the reactor finally exploded, the vessel being fragmented in four parts. Fortunately the plant was evacuated in time and nobody was injured. Here a unique DSC analysis of the initially charged mixture would have revealed the energy potential of the mixture and the temperature range in which it is released. With this knowledge the reactor would certainly not have been left stirring at 60°C without temperature monitoring.

A distillation still had to be cleaned to discard a tar consisting of nitro compounds. In order to decrease the viscosity for facilitating cleaning, the vessel was heated, but it was overseen that the temperature probe did not reach the tar. A extremely violent decomposition occurred, destroying the distillation unit, the control room and severely damaging a laboratory building. It resulted in 5 fatalities, 17 injuries and 181 cases of illness due to toxic effects. Here too the energy potential of such compounds was overlooked. A simple DSC analysis would have shown the risk linked with this operation.

A reaction involving sodium was performed as a batch operation [2]. Despite repeating difficulties to keep the batch temperature under control, the production continued, ignoring the energy potential of the main reaction, as well as the fact that the solvent was able to react with sodium increasing the potential. This led to a severe explosion completely destroying the plant and damaging neighboring industrial facilities, causing 4 fatalities and 32 injuries. Here again thermal analysis or calorimetry could have given insight to the thermal problems linked with this reaction.

These are only several examples revealing the lack of awareness about the energy potential that may be linked to the performance of common industrial reactions. One of the problems with the thermal aspects of chemical operations is the lack of “thermal culture”. Thermodynamics suffers from a bad reputation, partially due to the abstract concepts it uses and probably also to bad teaching of these abstract concepts, without link to the reality of industrial operations.

It is surprising, when looking at university syllabus, that reaction hazards, runaway reactions are absent in many important universities or engineering schools. Such omissions can only result in a lack of awareness or even worse, ignorance of these aspects of process safety.

In order to avoid this cultural void, a systematic approach based on thermal analysis and calorimetry is of great help. Such procedures were developed in the past 30 years and spread among different companies in the world. The use of thermal analysis for the determination of energy potentials and thermal stabilities became a standard method in safety laboratories. In parallel reaction calorimetry was establish as well in safety laboratories as in process development, allowing for an early identification of potential hazards and using this knowledge to develop inherently safer processes, which should be the ultimate objective of responsible chemists or chemical engineers

References

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2. Theis A.E., *Case study: T2 Laboratories explosion.* Journal of Loss Prevention in the Process Industries, 2014. **30**(0): p. 296-300.