



Analysis of T2 Incident Jacksonville Florida, December 2007

Answers: Part 1

- **Considering the chemistry above, what hazards need to be handled in order to run the process safely?**

- Chemicals – sodium (highly reactive, flammable solvent), carbon monoxide (toxic and flammable).
- Hydrogen – extremely flammable.
- High temperature and gases means possible high pressures.
- Heterogeneous reaction mixture (at least initially) – potential mixing issues

- **What are the merits of telescoping or ‘one pot’ reactions?**

No isolation or downstream processing between single reaction steps; lower solvent use ; lower number of vessels required – less capital investment; simple process flow.

- **In the case of the T2 process, was this a good or bad idea? Why?**

Reagents ‘all in ‘ meant that in the event of an incident, nothing could be done to arrest or stop the chemical/thermal runaway; no possibility of safe interruption or quenching of the reaction mixture.

- **Ultimately, what do you think led to the uncontrolled reaction and explosion at T2?**

For example: at first pass, the failure of the cooling system, with no back up, or safe way to intervene/quench the reaction once the runaway reaction had commenced. But investigations after the event showed that the reaction was regularly taken into temperature regions where a runaway thermal decomposition of the solvent could occur. Ultimately, this process should never have been designed to run as it was at T2 –it was fundamentally unsafe. On previous occasions, unexplained temperature rises had been noted, but brought under control. The root cause of these temperature deviations was never investigated – if it had been, the T2 disaster may have been averted.

For further details see the full investigation report into the T2 Laboratories, Inc. runaway reaction from the U.S. Chemical Safety and Hazard Investigation Board.¹



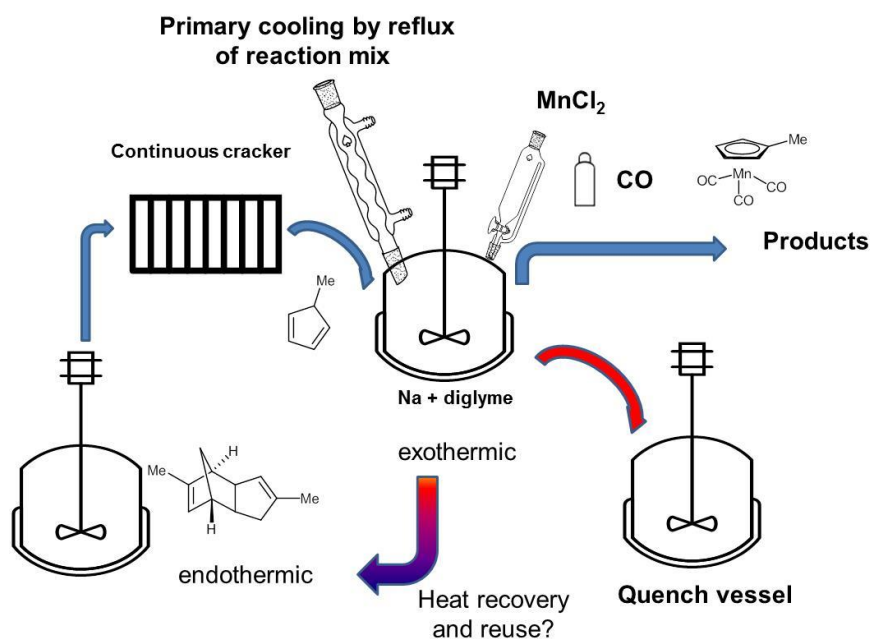
Answers: Part 2

- Given the same input chemicals, what would you do to make this process safer to run at scale?

The idea of running an exothermic reaction and an endothermic reaction in the same pot may seem like a good idea, but in the T2 case proved fatal since the temperature needed to drive the cracking of the methyl cyclopentadiene (MCPD) into monomer pushed the Na/Diglyme combination into a region of thermal instability. A better option would be to separate the reactions. The cyclopentadiene monomer could be produced by continuous cracking in a high temperature plate reactor then charged to the diglyme/ Na to produce the anion which is then sequentially reacted with $MnCl_2$ and CO.

Any excess heat from the exothermic reaction could be used to pre-heat the MCPD and a quench vessel could also be employed as a precaution in case of difficulties with the Na/diglyme reaction.

Conceptual ECOTANE process



- What chemicals could you substitute to make the process safer?

Looking at the list of chemicals used:

- Na – this acts as a base, so could be replaced by an alternative like Li or Na HMDS – or any base strong enough to deprotonate methylcyclopentadiene. This would have the advantage of making the reaction more homogeneous and avoiding the generation of H_2 gas. The disadvantage would be higher cost, poor atom economy and maybe the need to remove side products after the reaction.
- MCPD - crucial & difficult to substitute.
- Diglyme – could possibly choose another solvent – diglyme is reprotoxic and restricted under REACH legislation in the EU. Normally diglyme is stable to strong bases if used at lower temperatures.
- $MnCl_2$ – crucial & difficult to substitute.
- CO – crucial & difficult to substitute.



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1. Investigation report T2 laboratories, http://www.csb.gov/assets/1/19/T2_Final_Copy_9_17_09.pdf, (accessed April 2016).