Innovation ... Delivered.

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"1,2,4-Butanetriol Production at ATK – A Sustainable Solution"

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ATK Energetic Systems

Why Synthesis at ATK Energetic Systems

A premier aerospace and defense company

✓ History

- ATK has operated RFAAP since inception and intends to be the operating contractor of the future
- Recent history has shown small companies to be a risk of single point failure

✓ Commitment

- ATK is dedicated to safety, quality, and excellence in all that we do
- ATK has and will continue to support the DoD and NTIB contractors
- ATK has invested heavily in upgrading & expanding facility capabilities

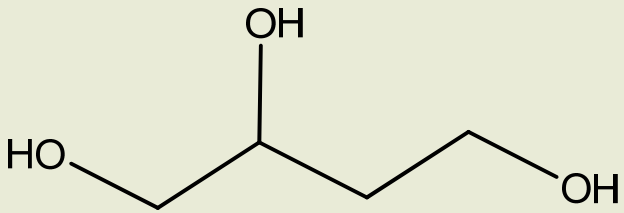
✓ Quality

- ATK has a world class Specialty and Flexible Energetics Facilities
- We met all quality requirements for BT every time
  - From initial small scale lab synthesis to 10l scale
- Systems and talent in place to ensure quality is maintained through scale up

ATK Energetic Systems is committed to serving the warfighter: past, present, and future!

BT – What is it?

A premier aerospace and defense company



1,2,4-butanetriol (BT)

- **1,2,4-butanetriol (BT) is a straight chain polyol (similar to glycerin)**
- **Multiple synthetic routes to BT are known, but purification is key**
- **BT is the precursor to BTTN**
- **BTTN is an energetic plasticizer used in several propellants**
- **BTTN is lower melting and less sensitive than NG**

BT is a simple molecule that is not so simple to obtain

BT – Background

The sad story of BT – an orphaned chemical

- **Pre-2002: Avecia is qualified CONUS BT supplier**
- **2002: Copperhead Chemical is re-qualified as BTTN supplier**
- **2002-2003: Avecia sells business segment that produces BT to Cytec**
    - **Cytec assures Copperhead that BT production will continue**
- **2003: Cytec discontinues BT production;**
- **May 2008: ATK Energetic Systems answers Sources Sought with a BT production solution**
- **November 2008: ATK Energetic Systems delivers high purity BT sample for evaluation**
    - **Purest BT ever evaluated by Copperhead Chemical**
- **March 2009: ATK begins BT process development and scale-up activities**

Reliance on commercial sources outside of the NTIB puts the government at risk

ATK BT requirements

Meet or exceed Mil Spec requirements

High Purity >98% (GC)

Boiling point ca. 170C at 8-10mmHg

No new trace contaminants

Optically inactive

Low cost reagents

Robust synthesis

- History of NG explosions from impure glycerin

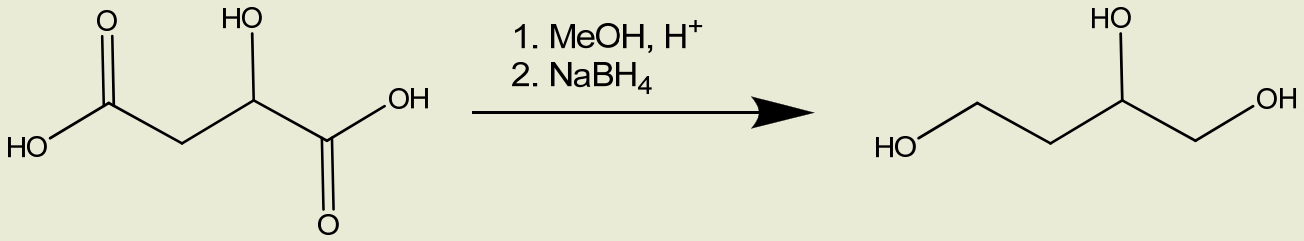
Readily available materials and reagents

Readily scaled up in NTIB facilities

Plan to Identify and Meet Requirements First Time

ATK BT Process Summary

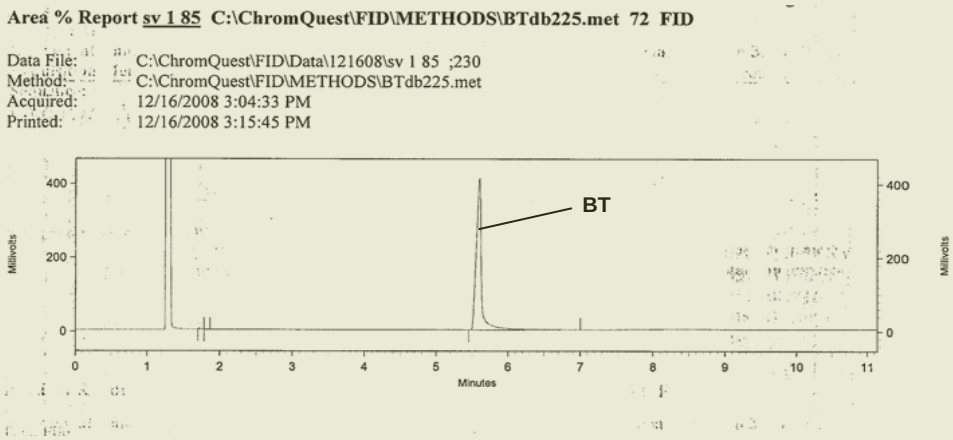
A premier aerospace and defense company



DL-malic acid

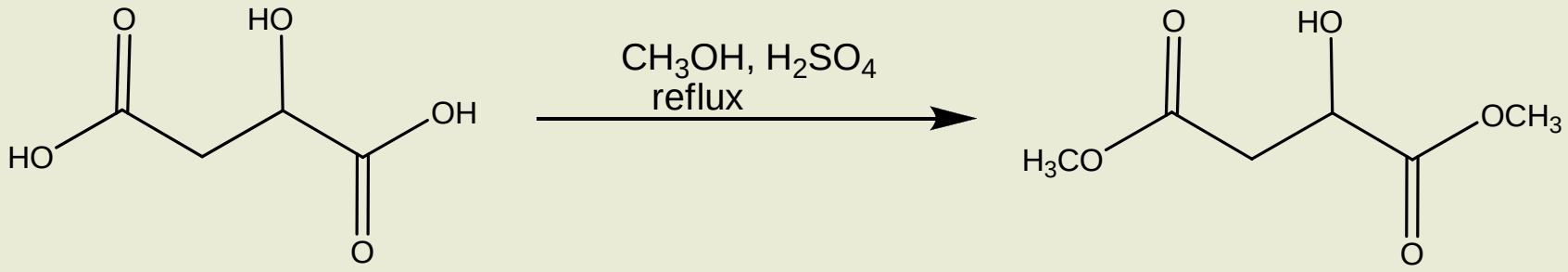
1,2,4-butanetriol (BT)

- ✓ **Two step process is amenable to scale-up**
  - -Robust process with good yields
- ✓ **BT from AES meets internal requirements**
- ✓ **BT process development and scale-up ongoing**
  - -Leveraging extensive ATK resources
  - -Partnering with ABL on scale-up effort



- ✓ **Rapid development at lab scale**
  - -Key proprietary purification step has been developed at AES
  - -Several pounds of BT purified

Esterification



Malic acid

Dimethyl malate

Acid catalyzed esterification

- Choice of starting material, alcohol (methanol/ethanol) , catalyst and reaction conditions

Desire

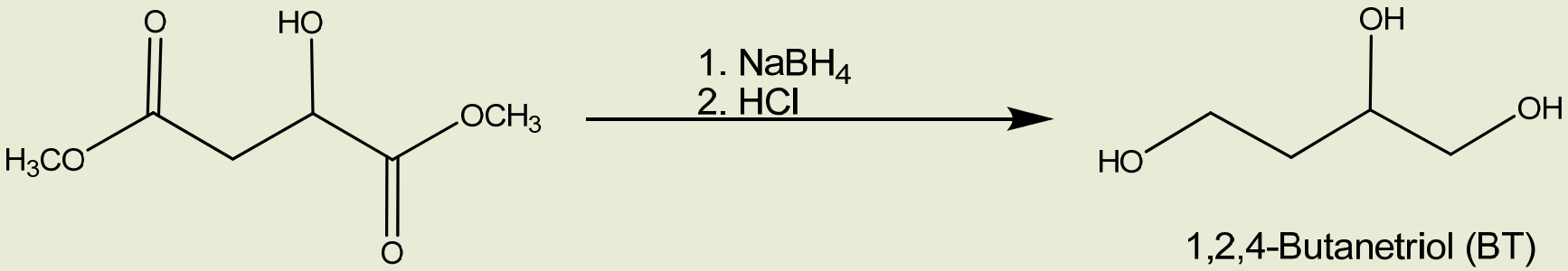
- Low cost reagents
- Rapid and complete reaction
- High reactor loading
- Simple work up

Result

- Low cost four carbon optically inactive natural product
- Clean reaction under simple conditions

Reaction optimized to rapidly give high isolated yield of pure ester

Reduction



1,2,4-Butanetriol (BT)

Hydride reduction

- Choice of reagents and conditions
- Wide range of solvents in literature

Desire

- Safe and complete reaction
- High reactor loading
- Simple work up

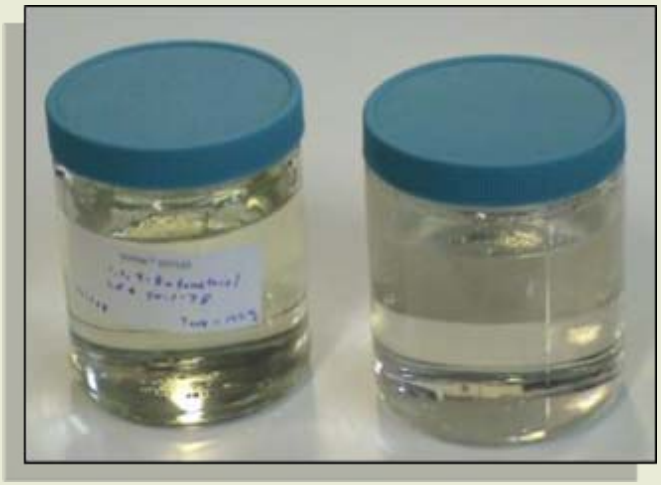
Reaction optimized to give high purity in crude mixture and moderate isolated yield of pure BT

- Crude BT may contain boron from reduction
- Expect yield to increase at larger scale

Status and plans

Lab studies complete

- Optimization of esterification at lab scale
- Optimization of reduction of ester at lab scale
- Purification of crude alcohol at lab scale



Scale up in pilot plant

- Esterification already conducted in pilot plant
  - No changes anticipated moving to 100 gallon reactor
- Reduction already conducted in pilot plant
  - Potential for further improvement in Pfaudler reactors
- Purification scale up to be done

Will scale all steps to 100 gallon by July 2009

All BT Requirements Met

Acknowledgements

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