

GREEN CHEMISTRY OF TAURINE

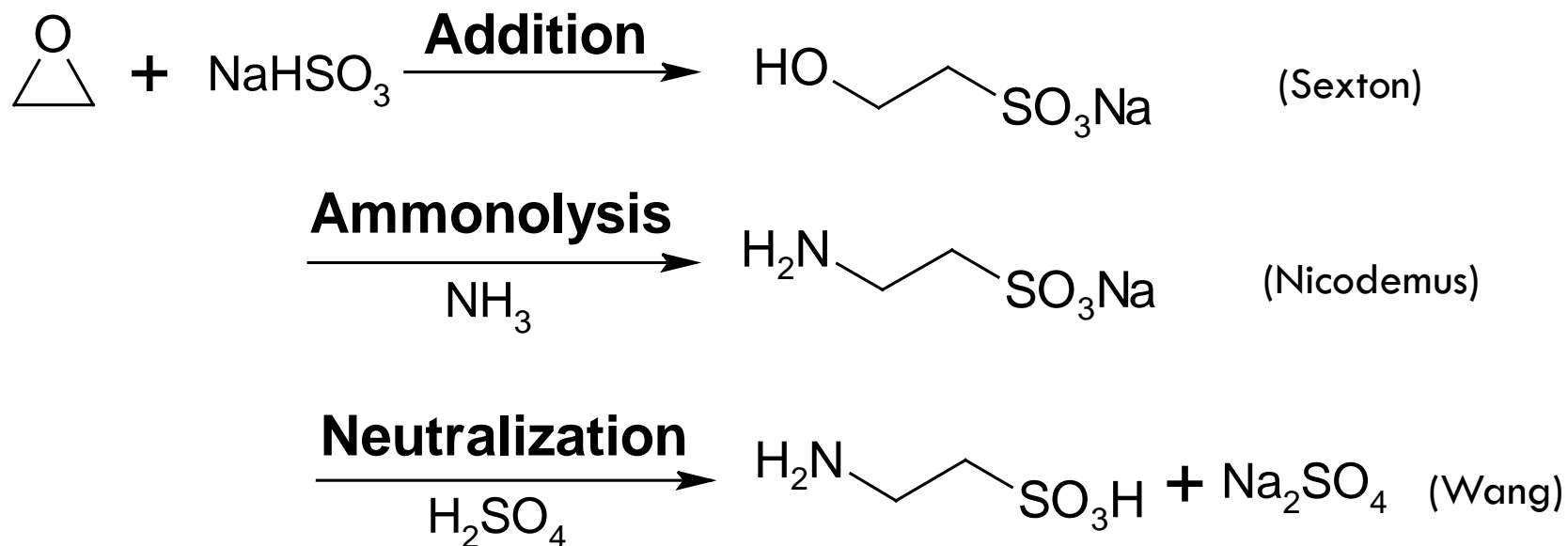
Development of an Atom-Efficient Process

Songzhou Hu, Ph.D

Vitaworks, LLC

Traditional Ethylene Oxide Process

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Sexton, A. R., *U.S. Pat. No. 2,820,818* (1958)

Nicodemus, O.; Schmidt, W., *U.S. Pat. No. 1,932,907* (1933)

Wang, D., *China Pat. Appl. No. 101508657* (2009)

Green Chemistry Metrics of Traditional EO Process

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$$\text{AE (Atom Efficiency)} = \frac{\text{Mol. Wt of Product}}{\text{Mol. Wt of All Substances Formed}}$$

$$\text{E Factor} = \frac{\text{Mass of Raw Materials} - \text{Mass of Product}}{\text{Mass of Product}}$$

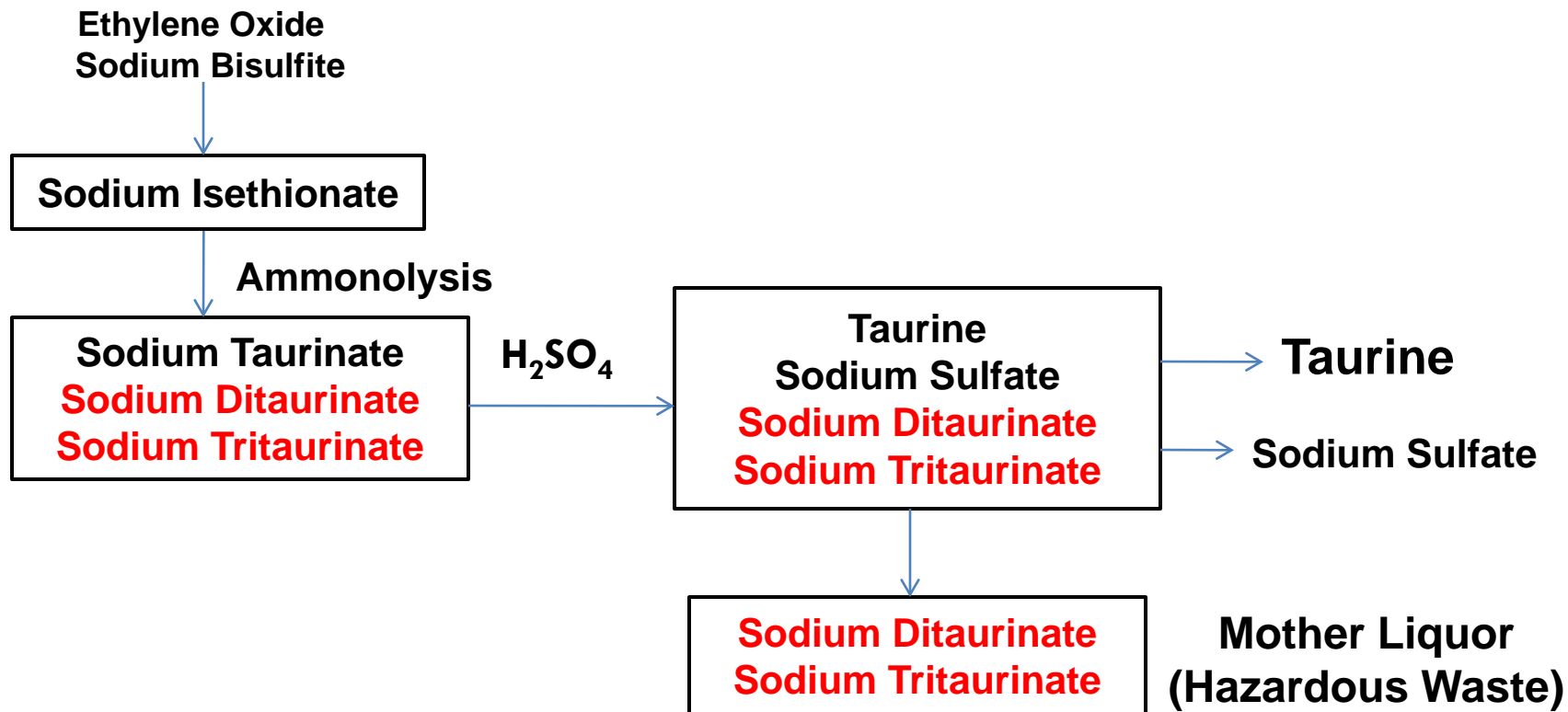
AE: 63.8%

E Factor: 1.28

Overall Yield: 75%

Traditional EO Process (Prior to 2014)

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AE: 63.8% E Factor: 1.28 Overall Yield: 75%

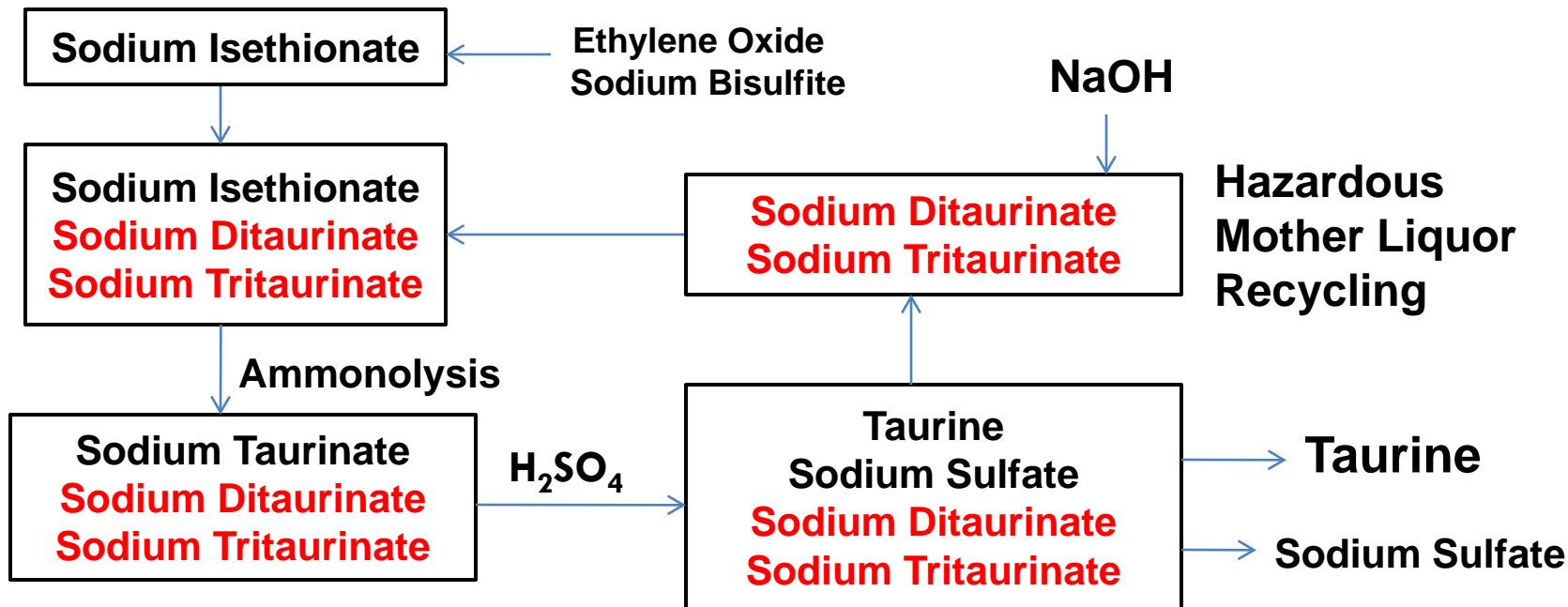
Traditional EO Process: Disadvantages

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- **Low to moderate overall yield**
75% to 80%
- **Large amount of hazardous waste mother liquor**
Containing 25% sodium ditaurinate and tritaurinate
- **Coproduction of large amount of sodium sulfate**
1 Ton sodium sulfate for 1 ton of taurine

Vitaworks GEN 1 Technology (Adopted 2015)

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AE: 63.8% E Factor: 0.65 Overall Yield: >95%

Hu, S. U.S. Pat. No. 9,428,451 B2 (2016)

Hu, S. U.S. Pat. No. 9,573,890 B2 (2017)

Hu, S. U.S. Pat. No. 10,040,755B2 (2018)

Vitaworks GEN 1 Technology

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Advantages

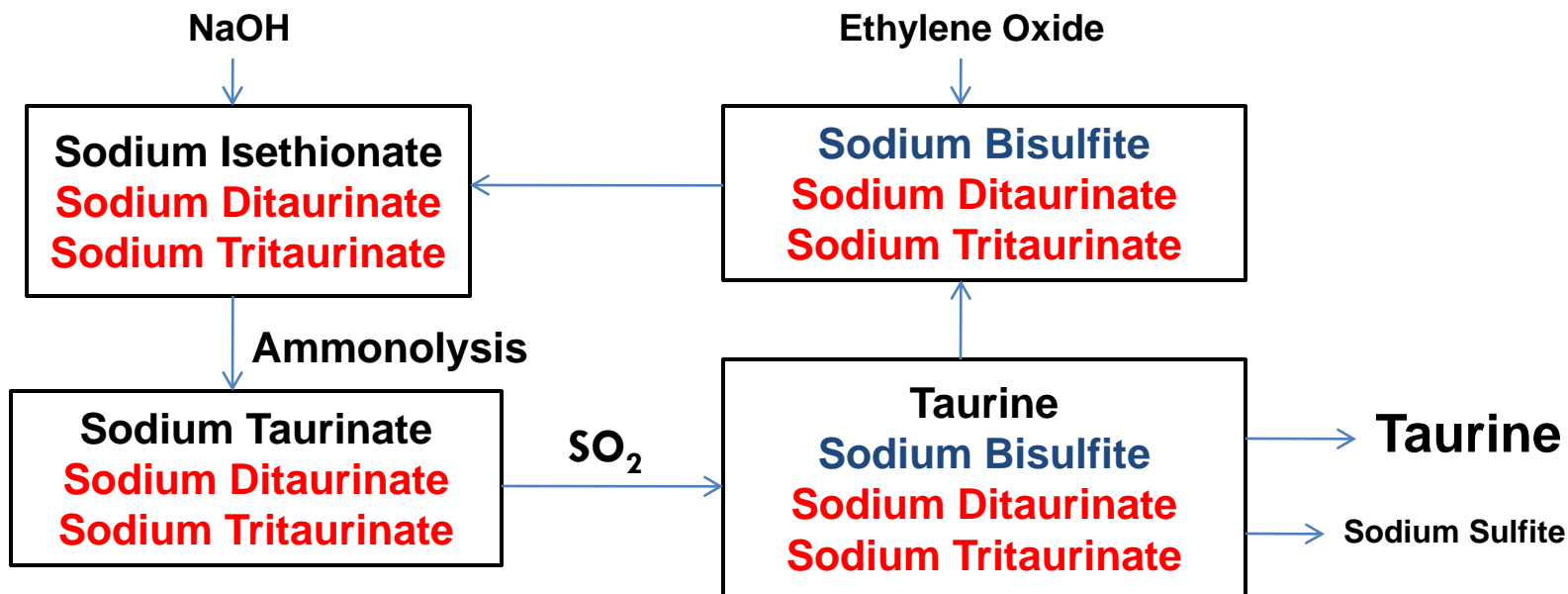
- **High overall yield:** 90% to 95%
- **No waste mother liquor**

Disadvantage

- **Coproduction of large amount of sodium sulfate**
1 Ton sodium sulfate for 1 ton of taurine

Vitaworks GEN 2 Technology (2015)

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AE: 100% E Factor: 0.05 Overall Yield: >95%

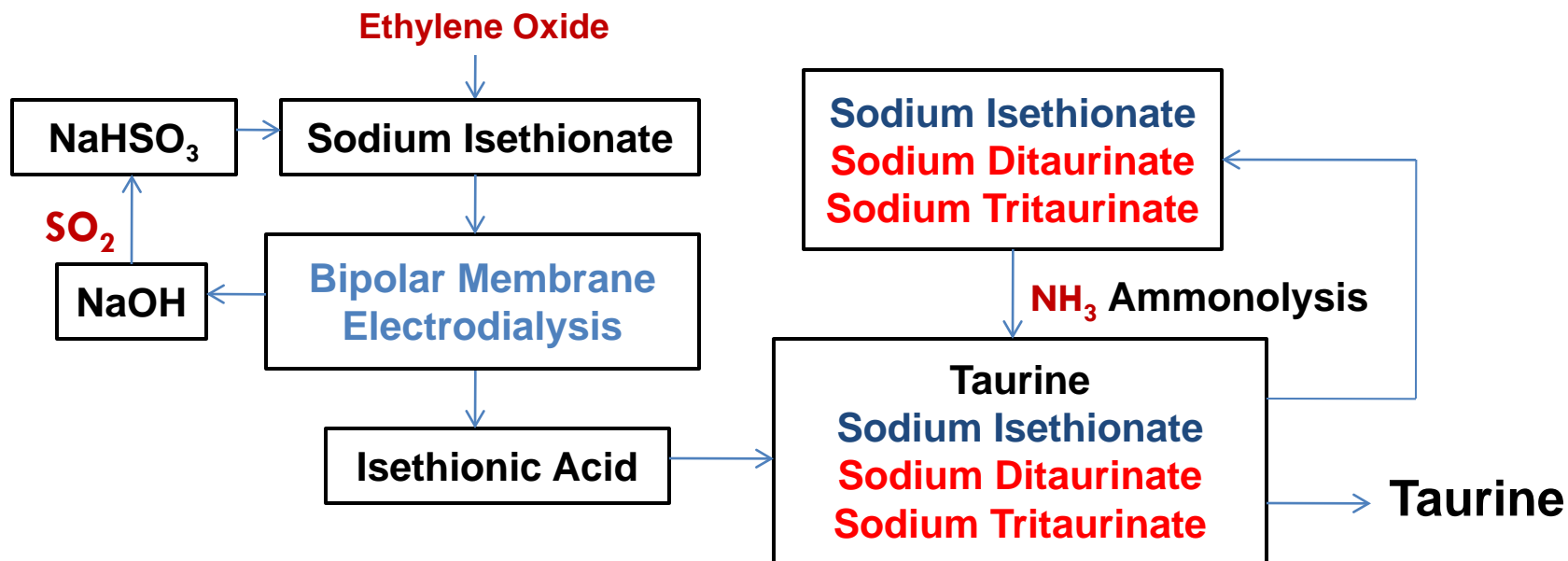
Hu, S. U.S. Pat. No. 8,609,890 B1 (2013)

Hu, S. U.S. Pat. No. 9,061,976 B1 (2015)

Hu, S. U.S. Pat. No. 10,040,755B2 (2018)

Vitaworks GEN 2 Technology (2017)

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AE: 100% E Factor: <0.01 Overall Yield: >99%

Hu, S. U.S. Pat. No. 9,593,076 B2 (2017)

Hu, S. U.S. Pat. No. 10,040,755B2 (2018)

Vitaworks GEN 2 Technology (2017)

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Advantages

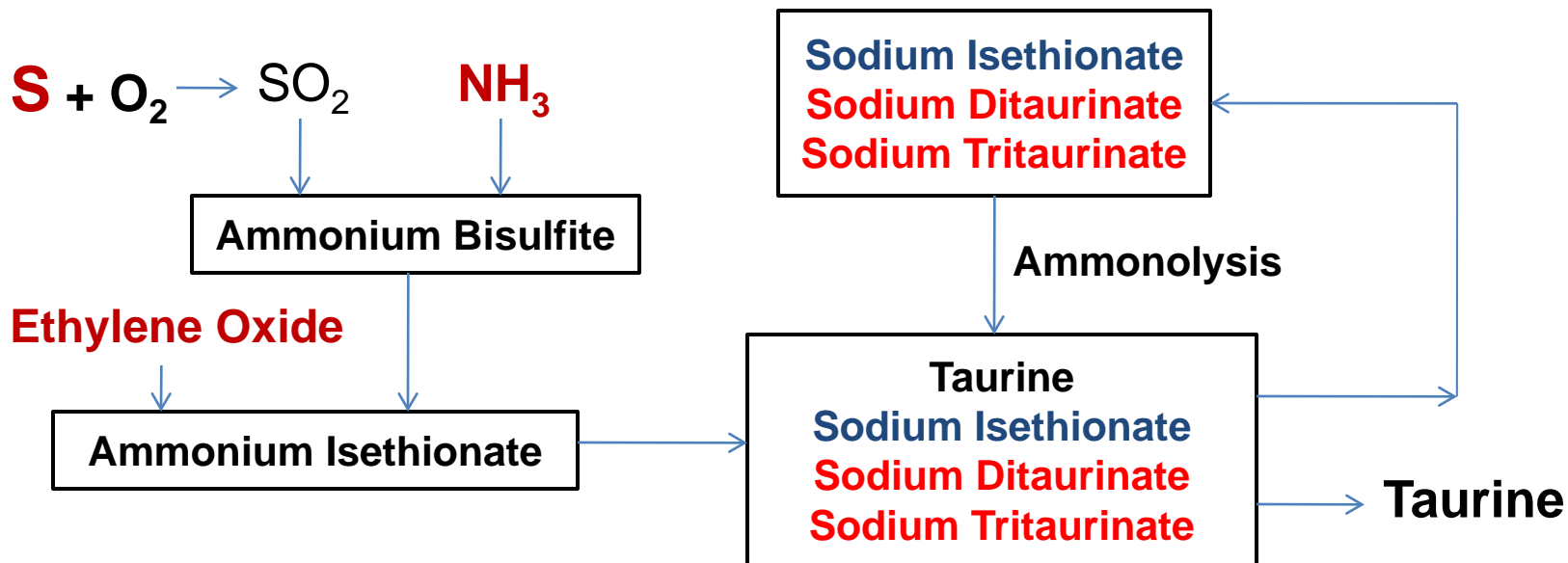
- **High Overall Yield: 95% to 99%**
- **No hazardous waste mother liquor**
- **No inorganic salt**

Disadvantage

- **Problematic recycling process**
- **Foul smell for plant and product**
- **Inconvenient starting material**

Vitaworks GEN 3 Technology (2017)

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AE: 100% E Factor: <0.01 Overall Yield: >99%

Hu, S. U.S. Pat. No. 9,745,258 B1 (2017)

Hu, S. U.S. Pat. No. 9,815,778 B1 (2017)

Hu, S. U.S. Pat. No. 9,926,265 B1 (2018)

Vitaworks GEN 3 Technology (2017)

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Advantages

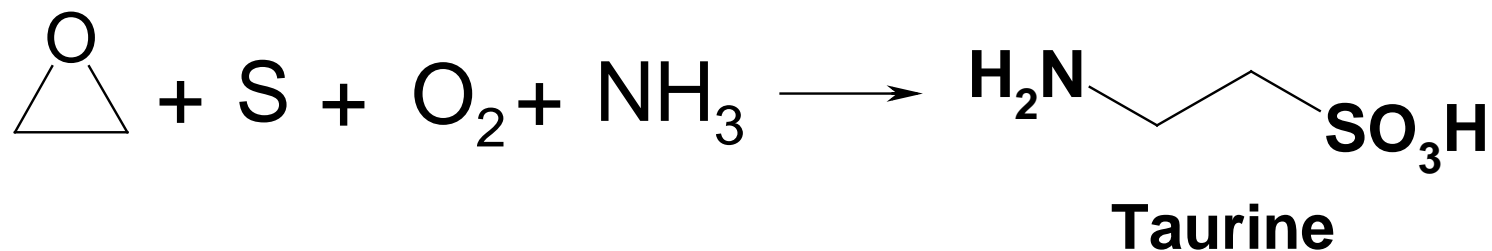
- **High Overall Yield:** 95% to 99%
- **No waste mother liquor**
- **No inorganic salt**

Disadvantage

- **None**

Hu Process of Taurine

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AE: 100% E Factor: <0.01 Overall Yield: >99%

Hu, S. U.S. Pat. No. 9,061,976 B1 (2015)

Hu, S. U.S. Pat. No. 9,593,076 B2 (2017)

Hu, S. U.S. Pat. No. 9,745,258 B1 (2017)

Hu, S. U.S. Pat. No. 10,040,755B2 (2018)