

Which segment of the chemical industry has the highest E factor (kg of waste generated/kg of product)?

**A. Pharmaceuticals** B. Oil Refining C. Fine Chemicals D. Bulk Chemicals

*Reference:* Sheldon, R. A. Atom efficiency and catalysis in organic synthesis. *Pure Appl. Chem.* **2000**, 72, 1233–1246

*URL:* <https://www.degruyter.com/view/j/pac.2000.72.issue-7/pac200072071233/pac200072071233.xml>

The magnitude of the waste problem is readily apparent from a consideration of the waste generated per kg of product, designated as the E factor, in various segments of the chemical industry. Chemical waste, defined as everything produced in the process except the desired product, consists primarily of inorganic salts (e.g., sodium chloride, sodium sulfate, ammonium sulfate), formed in the reaction or subsequent neutralization steps, or derived from stoichiometric inorganic reagents (e.g., a stoichiometric metal oxidant).

The E factor increases dramatically on going downstream from oil refining ( $E < 0.1$ ) to bulk chemicals ( $E < 1-5$ ) to fine chemicals ( $E = 5 - >50$ ) and specialties such as pharmaceuticals ( $E = 25 - >100$ ). This is partly owing to the fact that the production of fine chemicals and pharmaceuticals involves multi-step syntheses but is also a reflection of the use of stoichiometric reagents rather than catalytic methodologies.

<b>Industry segment</b>	<b>Product tonnage</b>	<b>kg waste/kg product</b>
Oil refining	$10^6 - 10^8$	$< 0.1$
Bulk Chemicals	$10^4 - 10^6$	$< 1-5$
Fine Chemicals	$10^2 - 10^4$	$5 - > 50$
Pharmaceuticals	$10 - 10^3$	$25 - > 100$