Mnemonic use for aiding students to determine erythro vs threo stereochemistry in additions to internal alkenes

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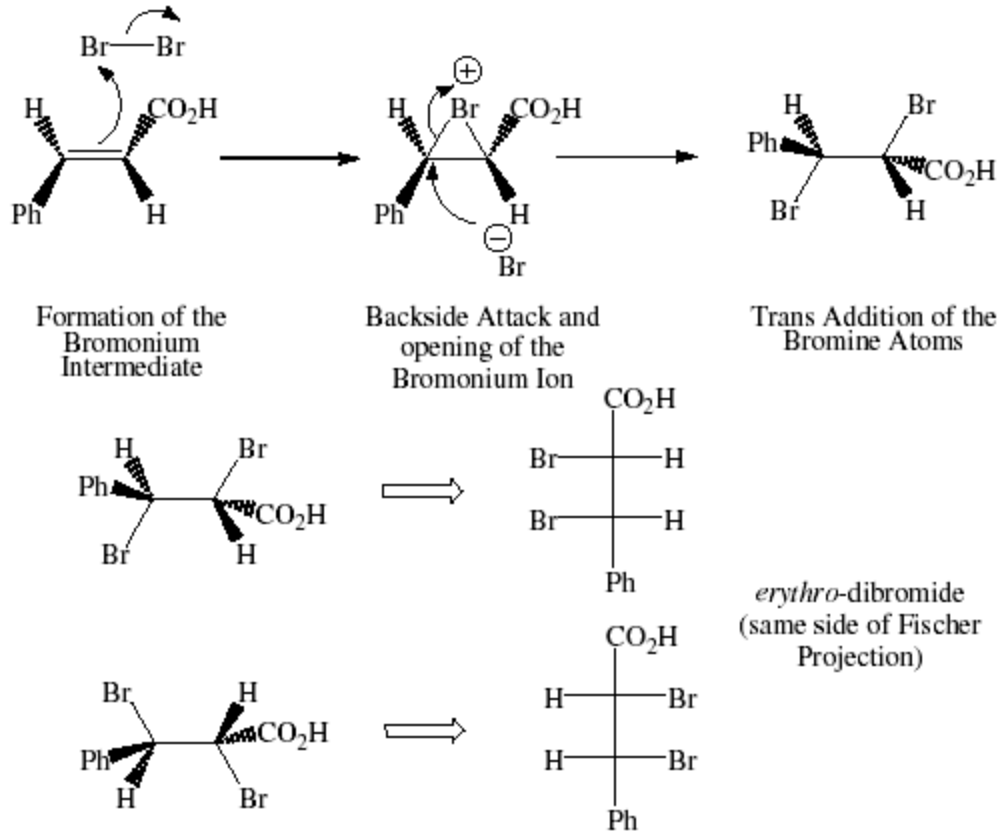
Abstract:

Use of the TOES mnemonic allows organic chemistry students to quickly write the correct Fischer projections and erythro vs threo nomenclature for additions to the double bonds of internal alkenes.

Many organic chemistry students have great difficulty visualizing stereochemistry or predicting outcomes on paper based upon Fischer projections or wedge and dot format. In particular, determining erythro vs threo stereochemistry for adducts of cis or trans alkenes with reagents adding cis or trans is troublesome. Even for those who can write the Fischer

projection correctly, many are confused as to whether it represents erythro or threo. I have found that use of the TOES minemonic clears the confusion and always gives correct answers both for Fischer projections and erythro vs threo nomenclature. Students easily remember TOES. Just think "what is on your feet besides shoes and socks", or "what are at the front of your feet"? In this mneomic, T = opposite, where T represents three parameters 1, configuration of the alkene versus mode of addition, 2, orientation of the added group in the resulting Fischer projection, and 3, threo. For example, trans cinnamic acid adds 2 OH groups cis on reaction with osmium tetroxide., which is opposite, and the resulting two Fischer projection have the two OH groups opposite, and the nomenclature is threo. In this mneomic, E = same. For example, trans cinnamic acid adds bromine trans, which is the same, and the resulting two Fischer projections have the two Br groups on the same side, and the nomenclature is erythro. See the example below for trans cinnamic acid adding trans with bromine (same), yielding dibromide enantiomers on the same side with erythro nomenclature



If the alkene has two identical groups on the double bond and the mode of addition is the same as the alkene configuration, the mnemonic predicts erythro nomenclature, with both adding groups on same side in the Fischer projection. While technically correct, the student has learned that enantiomers with an internal plane of symmetry are actually a single MESO form. See the reaction below giving MESO dibromostilbene from trans bromination of trans stilbene with pyridinium bromide perbromide.

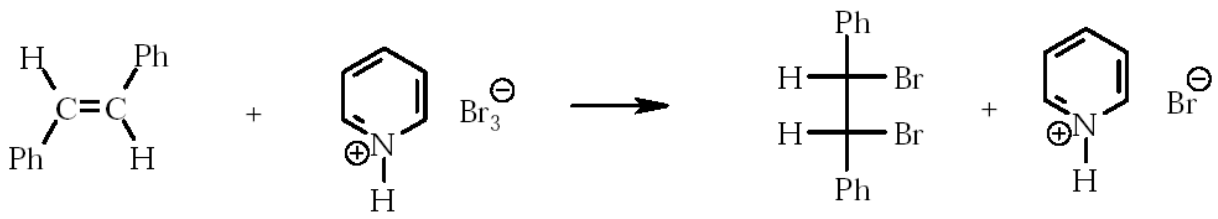


Table-1 lists all possible combinations using this mnemonic.

TABLE 1

THINK OF	THE "TOES" ON	YOUR FEET	T = OPPOSITE	E = SAME			
ALKENE STEREOCHEM	ALKENE TYPE	STEREOCHEM OF ADDITION	TOES	RESULT	FISCHER	PROJECTION	
1) CIS	SYMMETRICAL	CIS	SAME	MESO COMPOUND (ERYTHRO)	INTERNAL	PLANE OF	SYMMETRY
2)CIS	SYMMETRICAL	TRANS	OPPOSITE	THREO ENANTIOMERS	H OPPOSITE	SIDES ON	FISCHER
3))TRANS	SYMMETRICAL	CIS	OPPOSITE	THREO ENANTIOMERS	H OPPOSITE	SIDES ON	FISCHER
4)TRANS	SYMMETRICAL	TRANS	SAME	MESO COMPOUND (ERYTHRO)	INTERNAL	PLANE OF	SYMMETRY
5)CIS	UNSYMMETRICAL	CIS	SAME	ERYTHRO ENANTIOMERS	H SAME	SIDES ON	FISCHER
6)CIS	UNSYMMETRICAL	TRANS	OPPOSITE	THREO ENANTIOMERS	H OPPOSITE	SIDES ON	FISCHER
7)TRANS	UNSYMMETRICAL	CIS	OPPOSITE	THREO ENANTIOMERS	H OPPOSITE	SIDES ON	FISCHER
8)TRANS	UNSYMMETRICAL	TRANS	SAME	ERYTHRO ENANTIOMERS	H SAME	SIDES ON	FISCHER

Table-11 lists the TOES result for modes 1-8 above and a reaction illustrating each mode.

TABLE-11

MODE	"TOES"	EXAMPLES
1	SAME	CIS STILBENE WITH DEUTERIUM
2	OPPOSITE	CIS STILBENE WITH BROMINE
3	OPPOSITE	TRANS STILBENE WITH OsO_4
4	SAME	TRANS STILBENE WITH BROMINE
5	SAME	CIS CINNAMIC ACID WITH OsO_4
6	OPPOSITE	CIS CINNAMIC ACID WITH BROMINE
7	OPPOSITE	TRANS CINNAMIC ACID WITH DEUTERIUM
8	SAME	TRANS CINNAMIC ACID WITH BROMINE

References:

1) John McMurry, "Organic Chemistry, 7th Edition", Brooks-Cole Publishing Co., 2007.
2) Paula Bruice, "Organic Chemistry, 5th Edition", Prentice Hall., 2007.