Appendix 1

H₂O Models for Identifying the Results of Symmetry Operation Products

The following page contains eight images of H₂O set out in pairs, either side of the vertical line. You should cut out each pair so that you keep the label above each set with it, as indicated by the dotted lines. Then fold each strip of paper along the vertical line and glue the two sides together using paper adhesive. Additional copies of these model templates can be obtained from the Web site associated with this book.

Each model is viewed from the side on which the label can be read correctly. On this side the middle of each atom has a small white circle, pierce a small hole through the middle of the circle on the oxygen atom and then insert a burnt match so that the burnt end is away from the paper. This match represents the x-vector on the atom and the burnt end represents its direction. You should insert the matches so that:

1. The ‘Starting point, E’, model and ‘After σᵥ(XZ)’, models – burnt ends toward you.
2. The ‘After C₂’ and ‘After σ′ᵥ(YZ)’, models – burnt ends away from you, i.e. the match is pushed almost right through the paper because the x-vector is reversed.

There is a model for each of the operations in the point group of H₂O. To perform a product of two operations, start by picking up the model which represents the first part of the product and hold it with the labelled side toward you. To carry out the second operation, do one of the following:

1. E: do nothing. This just demonstrates theXE = EX = X, where X is any operation. This follows from the definition of E.
2. C₂: rotate the model by 180° about the Z-axis.
3. $\sigma(YZ)$: take out the match, reverse it and put it back in the hole at the oxygen atom so that the burnt end is again away from the paper. This effectively reverses the $x$-vector to show it has been reflected in the plane of the molecule. The $y$ and $z$ vectors are in the $YZ$ plane, and so reflection through the plane does not affect them.

4. $\sigma(XZ)$: imagine the model you are holding with the $y$-vector reversed. In this case the $x$ and $z$ vectors are in the mirror plane and so are unaffected by the operation.

After completing the second operation, compare the model you have with the ones left over. Your new model should be identical to one of the other three, and this identical model provides the single symmetry operation corresponding to the product.
Starting point, $E$

After $C_2$

After $\sigma_v(XZ)$

After $\sigma_v'(YZ)$

Starting point, $E$