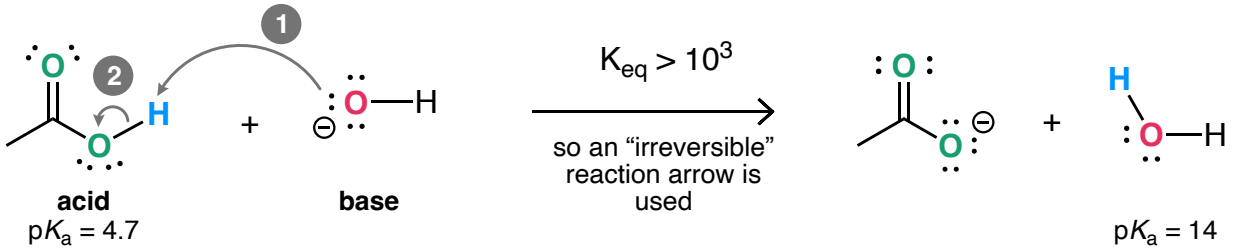
Arrows

This worksheet should help reinforce the physcal meaning of the curved-arrow reaction mechanisms you learn in organic chemistry 1.

Example

An acid-base reaction is shown with the curved-arrow mechanism. The table below describes the physical meaning of each arrow in the mechanism.



Arrow	Bonds broken	Bonds formed
1	none	O—H sigma bond
2	O—H sigma bond	none

Description of curved-arrow mechanism:

The first arrow indicates the use of a lone pair on the negatively charged oxygen atom (red) to deprotonate the H in the acid, forming a new O—H sigma bond

The second arrow indicates that the O—H sigma bond in the acid breaks and the electrons become a lone pair on the oxygen atom (green).

Use of irreversible reaction arrow: The forward reaction was described using an irreversible reaction arrow (⟶).

The irreverible reaction arrow is used above because the reaction is highly favorable: reacting an acid with pKa of 4.7 and forming an acid with pKa of 14. Typically, going from something more reactive to less reactive (more stable) constitutes a favorable process.

1. S_N2 Reaction

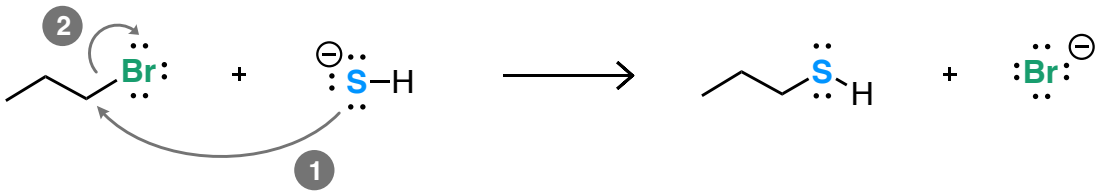
An S_N2 reaction is shown below with starting materials and products. Answer each item below.

A. Provide the curved arrow mechanism

B. Fill in the table with the meaning of each curved arrow using the example above as a guideline

C. Describe the mechanism in your own words

D. Describe the use of the irreversible or reversible forward reaction arrow



Arrow	Bonds broken	Bonds formed
1	none	C—S sigma bond
2	C—Br sigma bond	none

Description of curved-arrow mechanism:

The first arrow indicates the use of a lone pair on the negatively charged sulfur atom (blue) to to form a new C—S sigma bond

The second arrow indicates that the C—Br sigma bond breaks and the electrons become a lone pair on the bromine atom, making bromide (Br^{1-})

Use of irreversible reaction arrow: The forward reaction was described using an irreversible reaction arrow (⟶). Describe why.

The irreversible reaction arrow is appropriate to use because the reaction would not be favorable in the reverse direction. Bromide is a better leaving group and, therefore, worse nucleophile than $^{1-}$SH.

2. E2 Reaction

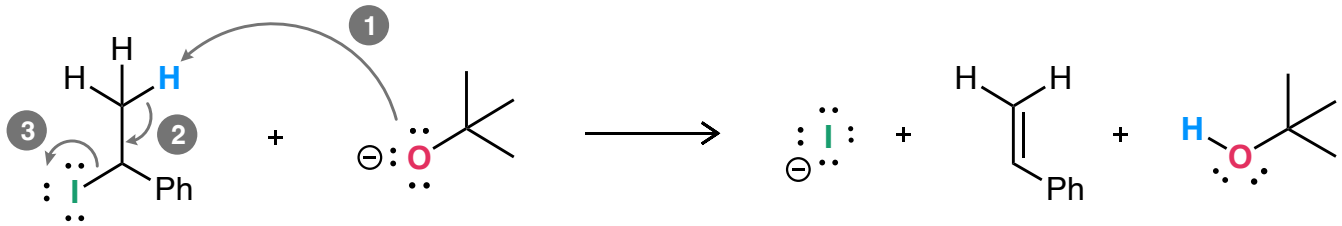
A curved arrow mechanism for an E2 reaction is shown below and involves three arrows, labeled 1-3.

A. Provide the curved arrow mechanism

B. Fill in the table with the meaning of each curved arrow using the example above as a guideline

C. Describe the mechanism in your own words

D. Describe the use of the irreversible or reversible forward reaction arrow



Arrow	Bonds broken	Bonds formed
1	none	O—H sigma bond
2	C—H sigma bond	C=C pi bond
3	C—I sigma bond	none

Description of curved-arrow mechanism:

The first arrow indicates the use of a lone pair on the negatively charged oxygen atom (red) to deprotonate the *beta*-H and make a new O—H sigma bond

The second arrow indicates that the C—H sigma bond breaks and the electrons are used to form a C=C pi bond

The third arrow indicates that the C—I sigma bond breaks and the electrons become a lone pair on the iodine atom, making iodide (I^{1-})

Use of irreversible reaction arrow: The forward reaction was described using an irreversible reaction arrow (⟶). Describe why.

The irreversible reaction arrow is appropriate to use because the product (alkene) is more stable than the starting material and would not react with the alcohol by-product or iodide.

3. Addition Reaction

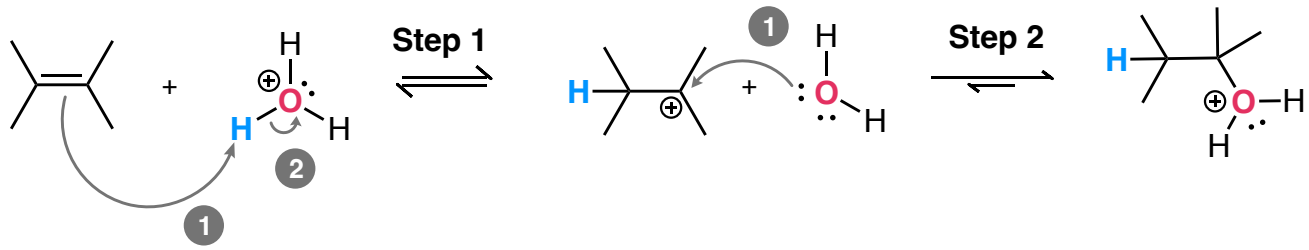
Two steps of an addition reaction to a carbon-carbon double bond (alkene) are shown below.

A. Provide the curved arrow mechanism

B. Fill in the table with the meaning of each curved arrow using the example above as a guideline

C. Describe the mechanism in your own words

D. Describe the use of the irreversible or reversible forward reaction arrow



Step 1

Arrow	Bonds broken	Bonds formed
1	C=C pi bond	C—H sigma bond
2	O—H sigma bond	none

Step 2

Arrow	Bonds broken	Bonds formed
1	none	O—C sigma bond

Description of curved-arrow mechanism in step 1:

The first arrow indicates the pi bond breaking and C—H bond formation to one of the carbons of the double bond

The second arrow indicates the O—H bond in hydronium breaking as a consequence of hydronium being deprotonated.

Description of curved-arrow mechanism in step 2:

The first arrow indicates the use of a lone pair on the oxygen atom in water to form a C—O bond to the open-shell carbocation

Use of reversible reaction arrow in step 1: Step 1 of the reaction above was described using an reversible reaction arrow (⇌). Describe why.

The reversible reaction arrow is appropriate to use here because you are starting with a stable, closed shell alkene and forming an open-shell carbocation as a product. This process would not be considered favorable and would be best described as a process that is *reversible*.