

CONJUGATE ACID- BASE PAIRS

BRÖNSTED – LOWRY THEORY (1923)

Named for both the Danish chemist Brönsted and the British chemist Lowry, who were working independently, this theory provides a definition of acids and bases that can be used to deal both with solutions that contain no water and solutions that contain water.

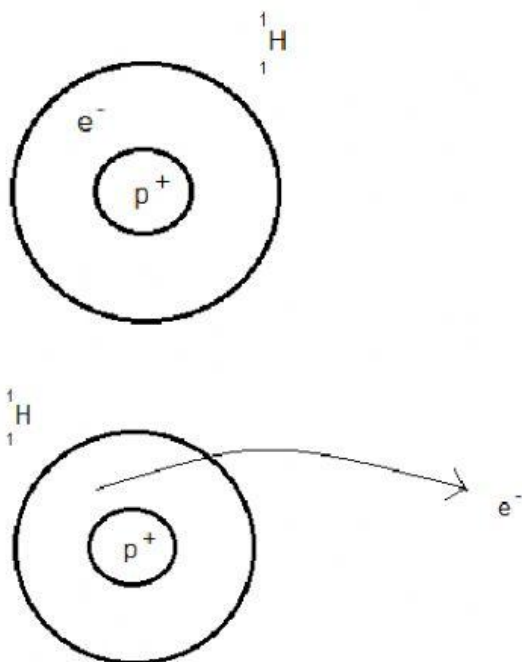
	BRONSTED-LOWRY
ACID	A substance that donates a proton (H^+) i.e. a proton donor
BASE	A substance that accepts a proton (H^+) i.e. a proton acceptor

The reactants and products in acid-base reactions can be paired into **conjugate acid-base pairs**. It is easy to identify them if we follow these simple steps.

Step 1

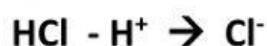
The acid in the conjugate pair will always donate (lose) a proton, and will form its conjugate base when it does.

A proton in this case refers to a hydrogen atom that has lost its electron. Remember hydrogen starts off with only 1 proton and 1 electron. When it then loses the one electron and becomes H^+ , all that is left over in the otherwise empty atom is one proton.



Let's look at what happens when $\text{HCl}_{(g)}$ is dissolved into water.

The hydrochloric acid $\text{HCl}_{(g)}$ will donate a proton (H^+) and form a chloride ion Cl^- _(aq) according to the equation



So the conjugate base for HCl is Cl^- .

Step 2

The base in the conjugate pair will always accept (gain) a proton, and will form its conjugate acid when it does.

Let's look at what happens to the water $\text{H}_2\text{O}_{(l)}$ when the $\text{HCl}_{(g)}$ was dissolved into it.

The water $\text{H}_2\text{O}_{(l)}$ will accept the proton (H^+) donated by the $\text{HCl}_{(g)}$ and form a hydronium ion $\text{H}_3\text{O}^+_{(aq)}$ according to the equation



So the conjugate acid for H_2O is H_3O^+

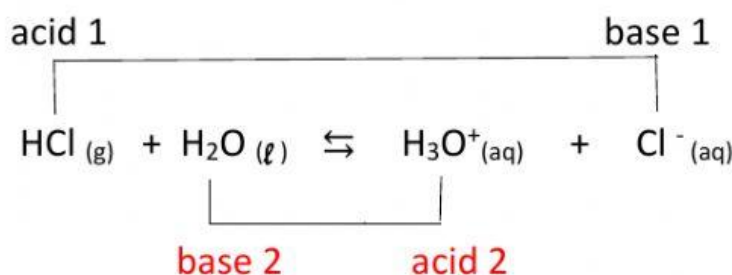
(it is interesting to note that here, water is behaving as a base)

Step 3

Putting the two equations together



So we can see that there are two acid-base conjugate pairs in the equation as follows:



Acid – always loses a proton/ H^+

Base – always gains a proton/ H^+

Thus what happened here:

If you look only at the forward reaction (read it from left to right)-

HCl gave off a H^+ ion in order to become Cl^- , and thus acted like an acid.

Whereas H_2O gained a H^+ and acted like a base.

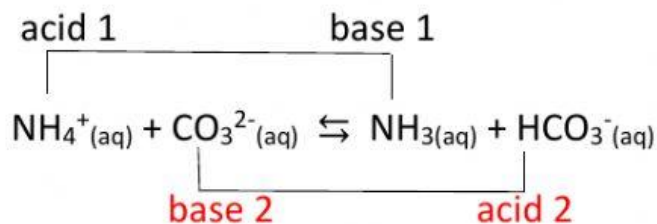
If you read the reaction in reverse (from right to left)

The Cl^- to become HCl would have to gain a H^+ and thus acts as a base.

The H_3O^+ in order to become H_2O would have to lose a H^+ and thus acts as an acid.

***It doesn't matter which pair you decide to make pair one and pair two- as long as the correct substances are grouped together.**

Similarly



and we can see that the conjugate base of $\text{NH}_4^+_{(\text{aq})}$ is $\text{NH}_3_{(\text{aq})}$

and the conjugate acid of $\text{CO}_3^{2-}_{(\text{aq})}$ $\text{HCO}_3^-_{(\text{aq})}$ is

A **strong acid** always has a **weak conjugate base**

e.g. a strong acid, HCl , has a weak conjugate base, Cl^- .

A **weak acid** always has a **strong conjugate base**

e.g. a weak acid, H_2CO_3 , has a strong conjugate base, HCO_3^- .

A **strong base** always has a **weak conjugate acid**

e.g. a strong base, OH^- , has a weak conjugate acid, H_2O .

A **weak base** always has a **strong conjugate acid**

e.g. a weak base, NH_3 , has a strong conjugate acid, NH_4^+ .

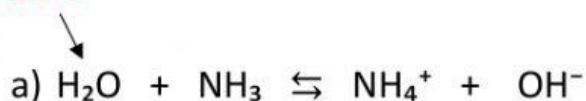
Here is a table of acid base conjugate pairs. You don't need to memorize them.

QUESTION 3

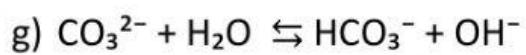
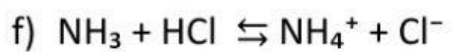
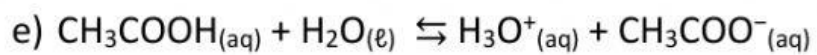
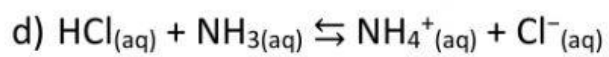
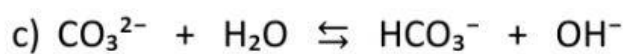
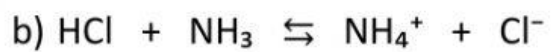
Identify the conjugate acid-base pairs:

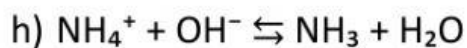
Just type acid 1, acid 2, base 1 or base 2 into the block provided – and for the purpose of this worksheet – always make the first substance the acid or base

no 1



Acid 1





Question 4

Complete the table by typing in the conjugate acid or base of the given substance: {type the substance into the block and the charge into the little block above it. If there is no charge – type a 0}

*keep in mind – that when an acid gives away a positive H^+ ion, it will leave the product will have a charge that is less negative one:

Eg. H_2SO_4 becomes HSO_4^{-1}

HNO_3 becomes NO_3^{-}

HPO_4^{2-} becomes PO_4^{3-}

And when a base gains a positive H^+ the product will have a charge that is +1 greater.

Eg. CO_3^{2-} becomes HCO_3^{-1}

NO_3^{-1} becomes HNO_3

PO_4^{3-} becomes HPO_4^{2-}

ACID	CONJUGATE BASE	BASE	CONJUGATE ACID
H_2PO_4^-		HCO_3^-	
HPO_4^{2-}		OH^-	
H_2CO_3		NH_3	
HCO_3^-		SO_4^{2-}	
CH_3COOH		HSO_4^-	
$(\text{COOH})_2$	$\text{C}_2\text{O}_4\text{H}^-$	PO_4^{3-}	
H_3O^+		HCOO^-	
		HPO_4^{2-}	
		H_2PO_4^-	H_3PO_4

AMPHOLYTES

Ampholytes are amphoteric substances. This means that they can accept and donate protons thereby acting as both an acid or a base, depending on what they are mixed with.

Water is a good example of this.

The H_2O molecule contains both H^+ and OH^-

Other examples include HSO_4^- , HCO_3^- , H_2PO_4^- and HPO_4^{2-}

as an acid (proton donor)		as a base (proton acceptor)	
1	$\text{H}_2\text{O} : \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$	1	$\text{H}_2\text{O} : \text{H}_2\text{O} + \text{H}^+ \rightarrow \text{H}_3\text{O}^+$
2	$\text{HSO}_4^- : \text{HSO}_4^- \rightarrow \text{H}^+ + \text{SO}_4^{2-}$	2	$\text{HSO}_4^- : \text{HSO}_4^- + \text{H}^+ \rightarrow \text{H}_2\text{SO}_4$
3	$\text{HCO}_3^- : \text{HCO}_3^- \rightarrow \text{H}^+ + \text{CO}_3^{2-}$	3	$\text{HCO}_3^- : \text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3$
4	$\text{H}_2\text{PO}_4^- : \text{H}_2\text{PO}_4^- \rightarrow \text{H}^+ + \text{HPO}_4^{2-}$	4	$\text{H}_2\text{PO}_4^- : \text{H}_2\text{PO}_4^- + \text{H}^+ \rightarrow \text{H}_3\text{PO}_4$
5	$\text{HPO}_4^{2-} : \text{HPO}_4^{2-} \rightarrow \text{H}^+ + \text{PO}_4^{2-}$	5	$\text{HPO}_4^{2-} : \text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-$

Question 1

State whether the following are ampholytes or not:

{Just type yes or no next to the substance}

1.1 HSO_4^-

1.2 H_2O

1.3 H_2SO_4

1.4 H_2CO_3

1.5 HCO_3^{-1}

1.6 H_3PO_4

1.7 $\text{H}_2\text{PO}_4^{-1}$