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

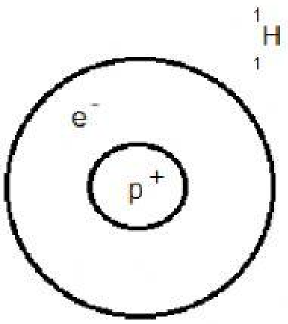
The reactants and products in acid-base reactions can be paired into **conjugate acid-base pairs**. It is easy to identify them if we follow these simple steps.

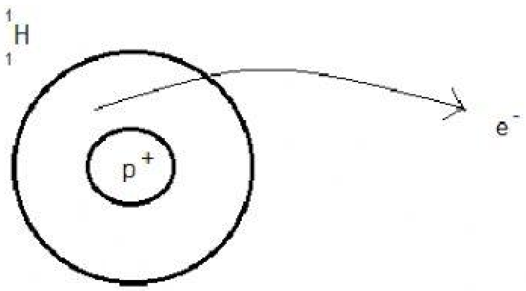
Step 1

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 $HCl_{(g)}$ is dissolved into water.

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

$$\mathbf{HCl - H^+ \rightarrow Cl^-}$$

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 $H_2O_{(\ell)}$ when the $HCl_{(g)}$ was dissolved into it.

The water $H_2O_{(\ell)}$ will accept the proton (H^+) donated by the HCl(g) and form a hydronium ion $H_3O^+_{(aq)}$ according to the equation

$$H_2O + H^+ \rightarrow H_3O^+$$

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

$$HCl_{(g)} + H_2O_{(\ell)} \leftrightarrows H_3O^+_{(aq)} + Cl^-_{(aq)}$$

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

acid 1 base 1

$$HCl_{(g)} + H_2O_{(\ell)} \leftrightarrows H_3O^+_{(aq)} + Cl^-_{(aq)}$$

base 2 acid 2

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

acid 1   base 1

$$NH_4^{+}{}_{(aq)} + CO_3^{2-}{}_{(aq)} \leftrightarrows NH_{3(aq)} + HCO_3^{-}{}_{(aq)}$$

base 2   acid 2

and we can see that the conjugate base of $NH_4^{+}{}_{(aq)}$ is $NH_{3(aq)}$

and the conjugate acid of $CO_3^{2-}{}_{(aq)}$ $HCO_3^{-}{}_{(aq)}$ 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

a) $H_2O + NH_3 \leftrightarrows NH_4^+ + OH^-$

Acid 1

b) $HCl + NH_3 \leftrightarrows NH_4^+ + Cl^-$

c) $CO_3^{2-} + H_2O \leftrightarrows HCO_3^- + OH^-$

d) $HCl_{(aq)} + NH_{3(aq)} \leftrightarrows NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$

e) $CH_3COOH_{(aq)} + H_2O_{(\ell)} \leftrightarrows H_3O^+{}_{(aq)} + CH_3COO^-{}_{(aq)}$

f) $NH_3 + HCl \leftrightarrows NH_4^+ + Cl^-$

g) $CO_3^{2-} + H_2O \leftrightarrows HCO_3^- + OH^-$

h) $NH_4^+ + OH^- \leftrightarrows NH_3 + H_2O$

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 $HPO4^{2-}$

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^-	
$(COOH)_2$	$C_2O_4H^-$	PO_4^{3-}	
H_3O^+		$HCOO^-$	
		HPO_4^{2-}	
		$H_2PO_4^-$	H_3PO_4

AMPHOLYTES

Ampholytes are amphiprotic 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	**H_2O** : $H_2O \rightarrow H^+ + OH^-$	1	**H_2O** : $H_2O + H^+ \rightarrow H_3O^+$
2	**HSO_4^-** : $HSO_4^- \rightarrow H^+ + SO_4^{2-}$	2	**HSO_4^-** : $HSO_4^- + H^+ \rightarrow H_2SO_4$
3	**HCO_3^-** : $HCO_3^- \rightarrow H^+ + CO_3^{2-}$	3	**HCO_3^-** : $HCO_3^- + H^+ \rightarrow H_2CO_3$
4	**$H_2PO_4^-$** : $H_2PO_4^- \rightarrow H^+ + HPO_4^{2-}$	4	**$H_2PO_4^-$** : $H_2PO_4^- + H^+ \rightarrow H_3PO_4$
5	**HPO_4^{2-}** : $HPO_4^{2-} \rightarrow H^+ + PO_4^{2-}$	5	**HPO_4^{2-}** : $HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$

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 $H_2PO_4^{-1}$