MORE ON CONJUGATE ACID-BASE PAIRS:

\[ \text{HSO}_4^- (aq) + \text{HOH} (aq) \rightleftharpoons \text{H}_3\text{O}^+ (aq) + \text{SO}_4^{2-} (aq) \]

\[ \text{H}_2\text{CO}_3 + \text{SO}_3^{2-} \rightleftharpoons \text{HSO}_3^- + \text{HCO}_3^- \]

\[ \text{NH}_3 + \text{NH}_3 \rightleftharpoons \text{NH}_4^+ + \text{NH}_2^- \]

NOTE THAT AMMONIA IS ALSO AMPHOTERIC!!

WHAT IS THE CONJUGATE BASE FOR:

Answers

a) HI
b) H\text{3PO}_4
c) HSO_4^-
d) H_2

WHAT IS THE CONJUGATE ACID FOR:

Answers

a) HO_2^-
b) SO_4^{2-}
c) C_2H_3O_2^-
e) NH_2^-

Note: NEUTRALIZATION:

\text{Arrhenius: \ ACID + BASE \ ⇌}

\text{Bronsted: \ ACID + BASE \ ⇌}

\text{Or...more identifiably.... ACID 1 + BASE 2 \ ⇌}
ACIDIC AND BASIC ANHYDRIDES

AN OXYGEN-CONTAINING COMPOUND THAT REACTS WITH WATER PRODUCING AN ACIDIC SOLUTION IS CALLED AN ACIDIC ANHYDRIDE.

eg.
SO₃ + H₂O →

AN OXYGEN-CONTAINING COMPOUND THAT REACTS WITH WATER PRODUCING A BASIC SOLUTION IS CALLED A BASIC ANHYDRIDE.

eg.
Na₂O + H₂O →

WHEN A BASIC ANHYDRIDE AND AN ACIDIC ANHYDRIDE COMBINE, THEY FORM A SALT.

eg.
N₂O₅ + Na₂O →

THE REACTION (as written above) IS A NEUTRALIZATION WITHOUT THE FORMATION OF WATER. Use your knowledge of Unit 3 solubility and dissociation to reason why…

N₂O₃ IS THE ACIDIC ANHYDRIDE OF HNO₃

eg.
2HNO₃ →
acid

ANHYDRIDE MEANS WITHOUT WATER SO A BASIC ANHYDRIDE IS A BASE WITHOUT WATER

eg.
Ca(OH)₂ →
base

Interesting fact: Grass thrives in alkaline soil. Adding Lime, CaO, increases the alkalinity or basicity of the soil by the following reaction:

CaO + H₂O →
anhydride water

SOME COMPOUNDS CAN BE AMPHIPROTIC ANHYDRIDES:

eg. BeO Al₂O₃ GeO₂ As₄O₆
Ga₂O₃ SnO₂ Sb₄O₆
PbO₂
STRONG / WEAK / CONCENTRATED / DILUTE

STRONG BASE:
- any metallic hydroxide that is very soluble in water is a strong base.
- if it is not soluble it is a weak base.

GROUP I hydroxides: LiOH, NaOH, KOH, RbOH, CsOH, FrOH since they are 100% soluble hydroxides. 
_and also other hydroxides are considered strong bases:
Mg(OH)₂, Ba(OH)₂, Sr(OH)₂ even though only Sr²⁺ is designated as soluble with hydroxide.
Ca(OH)₂ is sometimes referred to as a strong base, even though it’s solubility is extremely low.
It would be more accurate to talk about CaO as a strong base. (refer back to the ANHYDRIDES section).

Other GROUP 2 hydroxides are only slightly soluble & are therefore weak bases.

STRONG ACID:
- the strongest acid is always the one in which the ionizable hydrogen can be most easily removed
_dissociate ~100% in water at RTP

HClO₄       PERCHLORIC ACID
HI          HYDROIODIC ACID
HBr         HYDROBROMIC ACID
HCl         HYDROCHLORIC ACID
HNO₃        NITRIC ACID
H₂SO₄       SULPHURIC ACID

Look closely at the data table and be sure you understand how strong acids / bases are displayed.
Take special note: OH⁻ O₂⁻ NH₂⁻

STRONG IS NOT THE SAME AS CONCENTRATED!!!

Concentrated: proportion of solute to solvent molecules is near the maximum value
_there are a lot of moles of acid/base solute compared to the solvent in the solution

Strong:              dissociates well and has MANY ions; favours formation of products
                   (conducts current well)

DILUTE IS NOT THE SAME AS WEAK!!!

Dilute:      low proportion of solute to solvent (nowhere near the max)
               (not many moles of acid/base relative to solvent in the solution)

Weak:        dissociates poorly and has FEW ions; favours reactants
               (conducts current poorly in water)

eg. 0.010 M HCl is a dilute strong acid
Consider the ARRHENIUS definitions of NEUTRALIZATION:

\[ \text{H}_2\text{SO}_4 + 2\text{KOH} \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O} \]

\text{strong} acid + \text{strong} base \rightarrow \text{neutral salt} \quad \text{pH} \approx 7

\[ \text{HCl} + (\text{NH}_3 \text{ (aq)}) \rightarrow \text{NH}_4\text{Cl} + \text{H}_2\text{O} \]

\text{strong} acid + \text{weak base} \rightarrow \text{acidic salt} \quad \text{pH} < 7

\[ 3\text{HC}_2\text{H}_3\text{O}_2 + \text{Fe(OH)}_3 \rightarrow \text{Fe(C}_2\text{H}_3\text{O}_2)_3 + 3\text{H}_2\text{O} \]

\text{weak} acid + \text{weak base} \rightarrow \text{neutral salt} \quad \text{pH} \approx 7

\[ \text{H}_2\text{CO}_3 + 2\text{KOH} \rightarrow \text{K}_2\text{CO}_3 + 2\text{H}_2\text{O} \]

\text{weak} acid + \text{strong base} \rightarrow \text{basic salt} \quad \text{pH} > 7

\textbf{Strongest acid in water: hydronium ion}

\textbf{Strongest base in water: hydroxide ion}

ALL OF CHAPTER NINE HAS BEEN COMPLETED!!!

NOW DO WORKSHEET 4.2 FOR HOMEWORK
Wkst 4.2: Arrhenius and Brønsted-Lowry Acids
Using Brønsted-Lowry definitions, identify…

a) the missing conjugate…

<table>
<thead>
<tr>
<th>ACID</th>
<th>BASE</th>
<th>ACID</th>
<th>BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>F⁻</td>
<td>HPO₄⁻²</td>
<td>SO₃⁻²</td>
<td>H₂O</td>
</tr>
<tr>
<td>NH₃</td>
<td>HNO₂</td>
<td>HCO₃⁻</td>
<td>PH₄⁺</td>
</tr>
<tr>
<td>H₂O</td>
<td>HC₂O₄⁻</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) the ACID-BASE conjugate pairs in the following reactions…

\[
\begin{align*}
HBr + Cl^- & \rightleftharpoons HCl + Br^- \\
CO_3^{\text{-2}} + H_2O & \rightleftharpoons HCO_3^- + OH^- \\
HS^- + H_3O^+ & \rightleftharpoons H_2S + H_2O \\
HSO_3^- + HSO_4^- & \rightleftharpoons H_2SO_3 + SO_4^{\text{-2}} \\
HNO_2 + NH_3 & \rightleftharpoons NH_4^+ + NO_2^- \\
HS_2O_3^- + PH_2^- & \rightleftharpoons PH_3 + S_2O_3^{\text{-2}}
\end{align*}
\]
c) Using ARRHENIUS Definitions: Neutralization and salt pH

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Salt pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{HCl}<em>{(aq)} + \text{Cu(OH)}</em>{2(aq)} \rightarrow \text{H}<em>2\text{O}</em>{(l)} + \text{CuCl}_{2(aq)}$</td>
<td>pH&lt;7</td>
</tr>
<tr>
<td>$\text{H}_3\text{PO}<em>4(aq) + \text{NaOH}</em>{(aq)} \rightarrow$</td>
<td>+</td>
</tr>
<tr>
<td>$\text{H}_2\text{CO}<em>3(aq) + \text{Pb(OH)}</em>{4(aq)} \rightarrow$</td>
<td>+</td>
</tr>
<tr>
<td>$\text{H}_2\text{SO}<em>4(aq) + \text{Fe(OH)}</em>{3(aq)} \rightarrow$</td>
<td>+</td>
</tr>
<tr>
<td>$\text{HClO}<em>4(aq) + \text{LiOH}</em>{(aq)} \rightarrow$</td>
<td>+</td>
</tr>
<tr>
<td>$\rightarrow \text{H}<em>2\text{O}</em>{(l)} + \text{ZnI}_2(aq)$</td>
<td></td>
</tr>
<tr>
<td>$\rightarrow \text{H}<em>2\text{O}</em>{(l)} + \text{AlF}_3(aq)$</td>
<td></td>
</tr>
<tr>
<td>$\rightarrow \text{H}<em>2\text{O}</em>{(l)} + \text{KBr}_{(aq)}$</td>
<td></td>
</tr>
</tbody>
</table>
Wkst 4.2: Arrhenius and Brønsted-Lowry Acids

Using Brønsted-Lowry definitions, identify…

a) the missing conjugate…

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<th>ACID</th>
<th>BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>F^-</td>
<td>HPO_4^-^2</td>
<td>PO_4^-^3</td>
</tr>
<tr>
<td>HSO_3^-</td>
<td>SO_3^-^2</td>
<td>H_2O</td>
<td>OH^-</td>
</tr>
<tr>
<td>NH_4^+</td>
<td>NH_3</td>
<td>HNO_2</td>
<td>NO_2^-</td>
</tr>
<tr>
<td>H_2CO_3</td>
<td>HCO_3^-</td>
<td>PH_4^+</td>
<td>PH_3</td>
</tr>
<tr>
<td>H_3O_+</td>
<td>H_2O</td>
<td>HC_2O_4^-</td>
<td>C_2O_4^-^2</td>
</tr>
</tbody>
</table>

b) the ACID-BASE conjugate pairs in the following reactions…

\[
\begin{align*}
\text{HBr} & \quad + \quad \text{Cl}^- & \quad \Leftrightarrow \quad \text{HCl} & \quad + \quad \text{Br}^- \\
\text{Acid} & & \text{Base} & & \text{Acid} & & \text{Base} \\
\text{CO}_3^-^2 & \quad + \quad \text{H}_2\text{O} & \quad \Leftrightarrow \quad \text{HCO}_3^- & \quad + \quad \text{OH}^- \\
\text{Base} & & \text{Acid} & & \text{Acid} & & \text{Base} \\
\text{HS}^- & \quad + \quad \text{H}_3\text{O}^+ & \quad \Leftrightarrow \quad \text{H}_2\text{S} & \quad + \quad \text{H}_2\text{O} \\
\text{Base} & & \text{Acid} & & \text{Acid} & & \text{Base} \\
\text{HSO}_3^- & \quad + \quad \text{HSO}_4^- & \quad \Leftrightarrow \quad \text{H}_2\text{SO}_3 & \quad + \quad \text{SO}_4^-^2 \\
\text{Base} & & \text{Acid} & & \text{Acid} & & \text{Base} \\
\text{HNO}_2 & \quad + \quad \text{NH}_3 & \quad \Leftrightarrow \quad \text{NH}_4^+ & \quad + \quad \text{NO}_2^- \\
\text{Acid} & & \text{Base} & & \text{Acid} & & \text{Base} \\
\text{HS}_2\text{O}_3^- & \quad + \quad \text{PH}_2^- & \quad \Leftrightarrow \quad \text{PH}_3 & \quad + \quad \text{S}_2\text{O}_3^-^2 \\
\text{Acid} & & \text{Base} & & \text{Acid} & & \text{Base}
\end{align*}
\]
c) Using ARRHENIUS Definitions: Neutralization and salt pH

<table>
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<th>Salt pH</th>
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<tbody>
<tr>
<td>$2 \text{HCl}<em>{(aq)} + \text{Cu(OH)}</em>{2(aq)} \rightarrow 2 \text{H}<em>2\text{O}</em>{(l)} + \text{CuCl}_{2(aq)}$</td>
<td>pH&lt;7 Acidic salt</td>
</tr>
<tr>
<td>$\text{H}<em>3\text{PO}<em>4</em>{(aq)} + 3 \text{NaOH}</em>{(aq)} \rightarrow 3 \text{H}<em>2\text{O}</em>{(l)} + \text{Na}_3\text{PO}<em>4</em>{(aq)}$</td>
<td>pH&gt;7 Basic salt</td>
</tr>
<tr>
<td>$2 \text{H}<em>2\text{CO}<em>3</em>{(aq)} + \text{Pb(OH)}</em>{4(aq)} \rightarrow 4 \text{H}<em>2\text{O}</em>{(l)} + \text{Pb(CO}<em>3\text{)}</em>{2(aq)}$</td>
<td>pH~7 Neutral salt</td>
</tr>
<tr>
<td>$3 \text{H}<em>2\text{SO}<em>4</em>{(aq)} + 2 \text{Fe(OH)}</em>{3(aq)} \rightarrow 6 \text{H}<em>2\text{O}</em>{(l)} + \text{Fe}_2\text{(SO}<em>4\text{)}</em>{3(aq)}$</td>
<td>pH&lt;7 Acidic salt</td>
</tr>
<tr>
<td>$\text{HClO}<em>4</em>{(aq)} + \text{LiOH}_{(aq)} \rightarrow \text{H}<em>2\text{O}</em>{(l)} + \text{LiClO}<em>4</em>{(aq)}$</td>
<td>pH~7 Neutral salt</td>
</tr>
<tr>
<td>$2 \text{HI}<em>{(aq)} + \text{Zn(OH)}</em>{2(aq)} \rightarrow 2 \text{H}<em>2\text{O}</em>{(l)} + \text{ZnI}_2(aq)$</td>
<td>pH&lt;7 Acidic salt</td>
</tr>
<tr>
<td>$3 \text{HF}<em>{(aq)} + \text{Al(OH)}</em>{3(aq)} \rightarrow 3 \text{H}<em>2\text{O}</em>{(l)} + \text{AlF}_3(aq)$</td>
<td>pH~7 Neutral salt</td>
</tr>
<tr>
<td>$\text{HBr}<em>{(aq)} + \text{KOH}</em>{(aq)} \rightarrow \text{H}<em>2\text{O}</em>{(l)} + \text{KBr}_{(aq)}$</td>
<td>pH~7 Neutral salt</td>
</tr>
</tbody>
</table>
SOME COMMON ACIDS:

Chemical name: oil of vitriol, battery acid

Properties:
- cheap to make (raw materials needed are sulphur, oxygen and hydrogen)
- good dehydrating agent (removes water from substances)
- good neutralizer of bases (strong acid)
- strong exothermic reaction when mixed with water
- good oxidizing agent
- strong electrolyte (this is why it is used in car batteries)

Common uses:
- fertilizers, explosives, dyes, insecticides, detergents, plastics, car batteries

Chemical name: muriatic acid

Properties:
- choking odour in concentrated solutions
- good electrolyte
- does not produce sulphates with ions, like sulphuric acid does

Common uses:
- metal oxide cleaners, removing "scale" from kettles, stomach acid, catalyst

Chemical name: none

Properties:
- suffocating odour
- yellow stain on skin (due to the action of the acid on protein)
- very reactive with almost all metals

Common uses:
- ammonium and phosphate fertilizers, explosives, plastics, dyes, lacquers

Chemical name: vinegar (if <5% aqueous solution)

Properties:
- only affects highly reactive metals
- weak electrolyte when diluted

Common uses:
- food preservation, manufacture of textiles and plastics
### SOME COMMON BASES:

<table>
<thead>
<tr>
<th>Chemical name:</th>
<th>Chemical Formula:</th>
<th>Commercial/common name:</th>
<th>Properties:</th>
<th>Common uses:</th>
</tr>
</thead>
</table>
|                |                   | caustic soda, lye         | - very corrosive  
|                |                   |                          | - strong exothermic reaction when mixed with water  
|                |                   |                          | - good dehydrating agent (RAPIDLY removes water from air)  
|                |                   |                          |             | soap, oven cleaner, drain cleaner |

<table>
<thead>
<tr>
<th>Chemical name:</th>
<th>Chemical Formula:</th>
<th>Commercial/common name:</th>
<th>Properties:</th>
<th>Common uses:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>caustic potash</td>
<td>- similar to NaOH but lower MP</td>
<td>electrolyte in alkaline batteries, liquid soaps (due to lower MP)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical name:</th>
<th>Chemical Formula:</th>
<th>Commercial/common name:</th>
<th>Properties:</th>
<th>Common uses:</th>
</tr>
</thead>
</table>
|                |                   |                          | - colourless, highly toxic, corrosive gas with strong odour  
|                |                   |                          | - strong exothermic reaction when mixed with water  
|                |                   |                          | - very soluble in water  
|                |                   |                          |             | manufacture of nitric acid, explosives, fertilizers, synthetic fibers, refrigerant gas |

<table>
<thead>
<tr>
<th>Chemical name:</th>
<th>Chemical Formula:</th>
<th>Commercial/common name:</th>
<th>Properties:</th>
<th>Common uses:</th>
</tr>
</thead>
</table>
|                |                   | Non-Caustic version:     | - very soluble in water  
|                |                   |                          | - caustic (can cause chemical burns)  
|                |                   |                          | - strongly exothermic when mixed with water  
|                |                   |                          |             | increasing the alkalinity of your soil / lawn |