1. If the pH < $pK_a$ of an ionisable group, then it will be predominantly in the conjugate acid form. If the pH > $pK_a$, then it will be predominantly in the conjugate base form.

The pI is the mean of the two $pK_a$ values associated with the formation of the +1 and −1 species. It is the pH at which the predominant species has a net charge of zero. In this case, the mean is $\frac{1}{2} (2.10 + 4.07) = 3.09$.

If the pH = $pK_a$, then 50% will be in the conjugate acid form and 50% in the conjugate base form.

(a) pH = 1.0:

$pK_a$ (sidechain) > pH so it will exist in the protonated (-COOH) form.
pK$a$ (α-COOH) > pH so it will also exist in the protonated (-COOH) form.
p$K_a$ (NH$₃^+$) > pH so it will also exist in the protonated (-NH$₃^+$ form).

(b) pH = 4.0:

$pK_a$ (sidechain) > pH so it will exist in the protonated (-COOH) form.
p$K_a$ (α-COOH) < pH so it will exist in the deprotonated (-COO$^-$) form.
p$K_a$ (NH$₃^+$) > pH so it will exist in the protonated (-NH$₃^+$ form).

(b) pH = 12.0:

$pK_a$ (sidechain) < pH so it will exist in the deprotonated (-COO$^-$) form.
p$K_a$ (α-COOH) < pH so it will exist in the deprotonated (-COO$^-$) form.
p$K_a$ (NH$₃^+$) > pH so it will exist in the deprotonated (-NH₂ form).

<table>
<thead>
<tr>
<th>pH 1.0</th>
<th>pH 4.0</th>
<th>pH 12.0</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="HOOCCOONH3" /></td>
<td><img src="image2" alt="HOOCCOONH3" /></td>
<td><img src="image3" alt="HOOCCOONH3" /></td>
</tr>
<tr>
<td>+1 charge</td>
<td>0 charge</td>
<td>-1 charge</td>
</tr>
<tr>
<td><img src="image4" alt="HOOCCOONH3" /></td>
<td><img src="image5" alt="HOOCCOONH3" /></td>
<td><img src="image6" alt="HOOCCOONH3" /></td>
</tr>
<tr>
<td><img src="image7" alt="HOOCCOONH3" /></td>
<td><img src="image8" alt="HOOCCOONH3" /></td>
<td><img src="image9" alt="HOOCCOONH3" /></td>
</tr>
<tr>
<td>-1 charge</td>
<td>-1 charge</td>
<td>-1 charge</td>
</tr>
</tbody>
</table>
2. (a) 

- hydroxyl
- ammonium
- amide
- carboxylate

(b) 

\[
\begin{align*}
\text{Cl} & \quad \text{H}_3\text{N} - \text{CH} - \text{C} - \text{NH} - \text{C} - \text{CO}_2 \\
\text{CH}_2\text{OH} & \quad \text{CH}_3
\end{align*}
\]

(c) 

\[
\begin{align*}
\text{H}_2\text{N} - \text{CH} - \text{C} - \text{NH} - \text{C} - \text{CO}_2 \\
\text{CH}_2\text{OH} & \quad \text{CH}_3 \\
\text{Na} & \quad \text{C} - \text{O}
\end{align*}
\]

(d) 

\[
\begin{align*}
\text{Cl} & \quad \text{H}_3\text{N} - \text{CH} - \text{CO}_2 \\
\text{CH}_2\text{OH} & \quad \text{CH}_3 \\
\text{Cl} & \quad \text{NH}_3 - \text{CH} - \text{CO}_2
\end{align*}
\]

(e) 

\[
\begin{align*}
\text{H}_3\text{N} - \text{CH} - \text{C} - \text{NH} - \text{CH} - \text{CO}_2
\end{align*}
\]

3. **By convention, the N-terminal is on the left:**
4. Note that this tetrapeptide has a modified C-terminus, which has been converted to an amide with ammonia. On acid hydrolysis this will be converted to the acid and ammonium ion.

\[
\begin{align*}
\text{Absolute configuration} & \quad \text{Absolute configuration} - L & \quad \text{Absolute configuration} - L & \quad \text{Absolute configuration} - \text{not applicable}
\end{align*}
\]

5.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Tautomer</th>
<th>Compound</th>
<th>Tautomer</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="Image1" alt="Image" /></td>
<td><img src="Image2" alt="Image" /></td>
<td><img src="Image3" alt="Image" /></td>
<td><img src="Image4" alt="Image" /></td>
</tr>
</tbody>
</table>

6. (a) U is

\[
\begin{align*}
\text{CHO} \\
\text{H--H} \\
\text{H--OH} \\
\text{H--OH} \\
\text{CH}_2\text{OH}
\end{align*}
\]

(b) The Haworth stereoformula for V is:

\[
\begin{align*}
\text{CH}_2\text{OH} \\
\text{O} \\
\text{H--H} \\
\text{H--OH} \\
\text{OH} \\
\text{H--OH} \\
\text{OH}
\end{align*}
\]

(c) T is β-2-deoxy-D-ribofuranose. V is α-2-deoxy-D-ribofuranose
7. It is a fragment of RNA: the sugar component is ribose (rather than 2'-deoxy ribose) and it contains the base uracil (rather than thymine).