The element boron forms a series of hydrides, which includes \( \text{B}_2\text{H}_6 \), \( \text{B}_4\text{H}_{10} \), \( \text{B}_5\text{H}_9 \), \( \text{B}_6\text{H}_{10} \) and \( \text{B}_{10}\text{H}_{14} \). Which one of these hydrides consists of 85.63% boron by mass?

The molar mass of the boranes are:

- molar mass of \( \text{B}_2\text{H}_6 \) = \( (2 \times 10.81 \text{ (B)) + (6 \times 1.008 \text{ (H)) g mol}^{-1} = 27.668 \text{ g mol}^{-1} \)
- molar mass of \( \text{B}_4\text{H}_{10} \) = \( (4 \times 10.81 \text{ (B)) + (10 \times 1.008 \text{ (H)) g mol}^{-1} = 53.32 \text{ g mol}^{-1} \)
- molar mass of \( \text{B}_5\text{H}_9 \) = \( (5 \times 10.81 \text{ (B)) + (9 \times 1.008 \text{ (H)) g mol}^{-1} = 63.122 \text{ g mol}^{-1} \)
- molar mass of \( \text{B}_6\text{H}_{10} \) = \( (6 \times 10.81 \text{ (B)) + (10 \times 1.008 \text{ (H)) g mol}^{-1} = 74.94 \text{ g mol}^{-1} \)
- molar mass of \( \text{B}_{10}\text{H}_{14} \) = \( (10 \times 10.81 \text{ (B)) + (14 \times 1.008 \text{ (H)) g mol}^{-1} = 122.212 \text{ g mol}^{-1} \)

The percentage of boron = \( \frac{\text{mass of boron in one mole of hydride}}{\text{molar mass of hydride}} \times 100\% \)

- percentage boron in \( \text{B}_2\text{H}_6 \) = \( \frac{2 \times 10.81}{27.668} \times 100\% = 78.14\% \)
- percentage boron in \( \text{B}_4\text{H}_{10} \) = \( \frac{4 \times 10.81}{53.32} \times 100\% = 81.10\% \)
- percentage boron in \( \text{B}_5\text{H}_9 \) = \( \frac{5 \times 10.81}{63.122} \times 100\% = 85.63\% \)
- percentage boron in \( \text{B}_6\text{H}_{10} \) = \( \frac{6 \times 10.81}{74.94} \times 100\% = 86.55\% \)
- percentage boron in \( \text{B}_{10}\text{H}_{14} \) = \( \frac{10 \times 10.81}{122.12} \times 100\% = 88.45\% \)

Answer: \( \text{B}_5\text{H}_9 \)

Complete the following table.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{K}_2\text{SO}_4 )</td>
<td>potassium sulfate</td>
</tr>
<tr>
<td>( \text{CuCl}_2 )</td>
<td>copper(II) chloride</td>
</tr>
<tr>
<td>( \text{SF}_4 )</td>
<td>sulfur(IV) fluoride (or sulfur tetrafluoride)</td>
</tr>
<tr>
<td>( \text{K}_2\text{CrO}_4 )</td>
<td>potassium chromate</td>
</tr>
</tbody>
</table>
Solid sodium hydroxide reacts with carbon dioxide to produce sodium carbonate and water. Calculate the mass of sodium hydroxide required to prepare 53.0 g of sodium carbonate.

The chemical reaction is:

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

The molar mass of Na$_2$CO$_3$ is:

$$\text{molar mass} = (2 \times 22.99 \text{ (Na)}) + 12.01 \text{ (C)} + (3 \times 16.00 \text{ (O)}) \text{ g mol}^{-1}$$

$$= 105.99 \text{ g mol}^{-1}$$

The number of moles of this in 53 g is therefore:

$$\text{number of moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{53.0 \text{ g}}{105.99 \text{ g mol}^{-1}} = 0.50 \text{ mol}$$

For every 1 mole of Na$_2$CO$_3$ produced, 2 moles of NaOH are required. To make 0.50 mol therefore requires 1.00 mol of NaOH. The molar mass of NaOH is:

$$\text{molar mass} = (22.99 \text{ (Na)} + 16.00 \text{ (O)} + 1.008 \text{ (H)}) \text{ g mol}^{-1} = 39.998 \text{ g mol}^{-1}$$

As 1.00 mol is required, the mass required is 40.0 g.

Answer: 40.0 g

Analysis of an unknown compound returned the following percentage composition by weight:

- nitrogen: 26.2%;
- chlorine: 66.4%
- hydrogen 7.5%

What is the empirical formula of this compound?

<table>
<thead>
<tr>
<th>Amount in 100 g</th>
<th>N</th>
<th>Cl</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>26.2</td>
<td>66.4</td>
<td>7.5</td>
</tr>
<tr>
<td>Ratio (divide by atomic mass)</td>
<td>14.01</td>
<td>35.45</td>
<td>1.08</td>
</tr>
<tr>
<td></td>
<td>1.87</td>
<td>1.87</td>
<td>7.44</td>
</tr>
<tr>
<td>Divide by smallest</td>
<td>1.00 ~1</td>
<td>1.00 ~1</td>
<td>3.98 ~ 4</td>
</tr>
</tbody>
</table>

Answer: NClH$_4$
- The active ingredient in superphosphate fertilizer is calcium dihydrogenphosphate, Ca\((H_2PO_4)_2\). It is made by treating insoluble rock phosphate, Ca\(_3\)(PO\(_4\))\(_2\) with sulfuric acid. The other product of the reaction is calcium sulfate. Write the molecular equation for the reaction.

\[
\text{Ca}_3\text{(PO}_4\text{)}_2 + 2\text{H}_2\text{SO}_4 \rightarrow 2\text{CaSO}_4 + \text{Ca}(\text{H}_2\text{PO}_4)_2
\]

What mass of sulfuric acid is needed to convert 1.0 tonne (1000 kg) of rock phosphate to superphosphate?

The molar mass of Ca\(_3\)(PO\(_4\))\(_2\) is:

\[
\text{molar mass} = (3 \times 40.08 \text{ (Ca)}) + 2(30.97 \text{ (P)} + (4 \times 16.00 \text{ (O)}) \text{ g mol}^{-1} = 310.18 \text{ g mol}^{-1}
\]

The number of moles of this in 1000 g is therefore:

\[
\text{number of moles} = \frac{\text{mass (in g)}}{\text{molar mass (in g mol}^{-1})} = \frac{1000 \times 10^3 \text{ g}}{310.18 \text{ g mol}^{-1}} = 3224 \text{ mol}
\]

For every 1 mole of Ca\(_3\)(PO\(_4\))\(_2\) used, 2 moles of H\(_2\)SO\(_4\) is required. For 3224 mol of Ca\(_3\)(PO\(_4\))\(_2\), 6448 mol of H\(_2\)SO\(_4\) is needed. The molar mass of H\(_2\)SO\(_4\) is:

\[
\text{molar mass} = (2 \times 1.08 \text{ (H)}) + 32.07 \text{ (S)} + (4 \times 16.00 \text{ (O)}) \text{ g mol}^{-1} = 98.23 \text{ g mol}^{-1}
\]

The mass of H\(_2\)SO\(_4\) in 6448 mol is therefore:

\[
\text{mass} = \text{number of moles (in mol) } \times \text{ molar mass (in g mol}^{-1}) = (6448 \text{ mol}) \times (98.23 \text{ g mol}^{-1}) = 633400 \text{ g} = 0.63 \text{ tonne}
\]

Answer: 0.63 tonne

- Analysis of an unknown compound returned the following percentage composition by weight:
  
  nitrogen: 26.2%;  
  chlorine: 66.4%  
  hydrogen 7.5%

What is the empirical formula of this compound?

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<tr>
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<td>1.87</td>
<td>1.87</td>
</tr>
</tbody>
</table>

Answer: NCl\(_4\H_4\)