To put all the information together, we may now draw the cycle:

![Graph of the Born-Haber cycle]

Thus,

\[
2H^\circ - (2H^\text{sub} + H^\text{vap} + 2IP + D) = 2EA + 2E_{\text{cryst}}
\]

Note that we have used two moles of \(\ce{NaBr}\) in the above diagram.

This scheme shows that we can calculate the lattice energy of \(\ce{NaBr}\) from some known thermodynamic data. The same can be calculated from reaction equations and their associated energies. This is illustrated below:

<table>
<thead>
<tr>
<th>Equation</th>
<th>Reaction Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\ce{2 Na(s) + Br_2(l) \rightarrow 2 NaBr(s)})</td>
<td>(2 H^\circ)</td>
</tr>
<tr>
<td>(\ce{2 Na^+(g) + 2e^- \rightarrow 2 Na(g)})</td>
<td>(- 2, IP)</td>
</tr>
<tr>
<td>(\ce{Br_2(g) \rightarrow Br_2(l)})</td>
<td>(- H^\text{vap})</td>
</tr>
<tr>
<td>(\ce{Br^-_2(g) \rightarrow 2 Br(g) + 2 e^-})</td>
<td>(- 2, EA)</td>
</tr>
<tr>
<td>(\text{Add all the above equations leading to} )</td>
<td></td>
</tr>
</tbody>
</table>

Add all the above equations leading to
Thus,

\[2 \text{H}_{\text{f}} - 2 \text{H}_{\text{sub}} - 2 \text{IP} - \text{H}_{\text{vap}} - D - 2 \text{EA} = 2 \text{E}_{\text{cryst}}\]

This is the same result as shown in the diagram.

\begin{align*}
E_{\text{cryst}} &= H_{\text{f}} - H_{\text{sub}} - \text{IP} - \frac{(H_{\text{vap}} + D)}{2} - \text{EA} \\
&= -788 \text{ kJ/mol} \\
U &= -E_{\text{cryst}} \\
&= 788 \text{ kJ/mol (lattice energy)}
\end{align*}

**Discussion**

The value calculated for \(U\) depends on the data used. Data from various sources differ slightly, and so does the result. The lattice energies for \(\text{NaCl}\) most often quoted in other texts is about 765 kJ/mol.

Compare with the method shown below

\[\text{Na}_{} + 0.5 \text{Cl}_2 \rightarrow \text{NaCl} \]

- 411

\[\text{Na}_{} \rightarrow \text{Na}_{} \]

- 108
\[ \text{Na}^+_{\text{(g)}} + e^- \rightarrow \text{Na}_{\text{(g)}} \] - 496 \text{ kJ/mol} = -\text{IP}

\[ \text{Cl}_{\text{(g)}} \rightarrow 0.5 \times \text{Cl}_2_{\text{(g)}} \] - 0.5 \times 244 = -0.5 \times \text{D}

\[ \text{Cl}^-_{\text{(g)}} \rightarrow \text{Cl}_{\text{(g)}} + 2 e^- \] 349 = -\text{EA}

Add all the above equations leading to

\[ \text{Na}^+_{\text{(g)}} + \text{Cl}^-_{\text{(g)}} \rightarrow \text{NaCl}_{\text{(s)}} \] -788 kJ/mol = \text{E}_{\text{cryst}}

There is another method based on principles of physics to evaluate the lattice energy, and some examples are given in the discussion enthalpy of hydration and lattice energy.

The Born-Haber cycle enables us to calculate lattice energies of various compounds. For salts containing polyatomic ions, the Born-Haber cycle is not as useful. Some other means have to be used to evaluate the lattice energy or energy of crystallization.

### Comparison of Lattice Energies (\(U\) in kJ/mol) of Some Salts

<table>
<thead>
<tr>
<th>Solid</th>
<th>(U)</th>
<th>Solid</th>
<th>(U)</th>
<th>Solid</th>
<th>(U)</th>
<th>Solid</th>
<th>(U)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiF</td>
<td>1036</td>
<td>LiCl</td>
<td>853</td>
<td>LiBr</td>
<td>807</td>
<td>LiI</td>
<td>757</td>
</tr>
<tr>
<td>NaF</td>
<td>923</td>
<td>NaCl</td>
<td>786</td>
<td>NaBr</td>
<td>747</td>
<td>NaI</td>
<td>704</td>
</tr>
<tr>
<td>KF</td>
<td>821</td>
<td>KCl</td>
<td>715</td>
<td>KBr</td>
<td>682</td>
<td>KI</td>
<td>649</td>
</tr>
<tr>
<td>MgF(_2)</td>
<td>2957</td>
<td>MgCl(_2)</td>
<td>2526</td>
<td>MgBr(_2)</td>
<td>2440</td>
<td>MgI(_2)</td>
<td>2327</td>
</tr>
</tbody>
</table>

The lattice energies of some salts are given in the table on the right here.

Among the mono-valent salts, the lattice energies decrease when the sizes of the ions increase.

Comparing the lattice energy for salts with one divalent ion leads to the same conclusion. The lattice energies decrease when the sizes of the ions increase.

The lattice energy of salts involving a divalent ion are much higher than those of monovalent salts, because much more energy is required to separate these ions.

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**Contributors and Attributions**

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