[TP] The enthalpy diagram shows changes associated with the reaction
$Na_2(g) + Br_2(g) \rightarrow 2\ NaBr(g)$.
The uppermost horizontal line corresponds to the species ...

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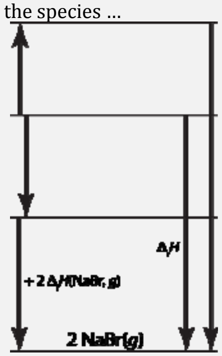
25% 2. $2\ Na(g) + 2\ Br(g)$
25% 3. $Na_2(g) + Br_2(g)$
25% 4. something else



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Lecture 26 CH101 A1 (MWF 9 am)

Wednesday, November 9, 2016

- Hess's law
- Standard states and standard $\Delta_r H$
- Standard enthalpy of formation, $\Delta_f H^o$
- Using $\Delta_f H^o$'s to compute any $\Delta_r H$

Next lecture: [Calorimetry, pp 231–232, done in lab]; Bond enthalpies, $\Delta_b H$; Using $\Delta_b H$'s to *estimate* $\Delta_r H$.

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$\Delta_r H^o$ via Hess's law

Consider

$A \longrightarrow B \quad \Delta_r H^o_1$

$C \longrightarrow B \quad \Delta_r H^o_2$

$A \longrightarrow C \quad \Delta_r H^o_3 = ?$

Since energy is conserved ...

$$\Delta_r H^o_3 = \Delta_r H^o_1 - \Delta_r H^o_2$$

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$\Delta_r H^o$ via Hess's law

Consider

$A \longrightarrow B \quad \Delta_r H^o_1 = +85\ kJ$

$C \longrightarrow B \quad \Delta_r H^o_2 = -52\ kJ$

$A \longrightarrow C \quad \Delta_r H^o_3 = ?$

Since energy is conserved ...

$$\Delta_r H^o_3 = \Delta_r H^o_1 - \Delta_r H^o_2 = +85\ kJ - (-52\ kJ) = +137\ kJ$$

Illustrate with the enthalpy diagram for these processes.

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$\Delta_r H^o$ via Hess's law

Consider

$$C(s) + O_2(g) \longrightarrow CO_2(g) \quad \Delta_r H^o{}_1$$

$$S(s) + O_2(g) \longrightarrow SO_2(g) \quad \Delta_r H^o{}_2$$

$$CS_2(l) + 3\ O_2(g) \longrightarrow CO_2(g) + 2\ SO_2(g) \quad \Delta_r H^o{}_3$$

$$C(s) + 2\ S(s) \longrightarrow CS_2(l) \quad \Delta_r H^o{}_4 = ?$$

Since energy is conserved ...

$$\Delta_r H^o{}_4 = \Delta_r H^o{}_1 + 2\ \Delta_r H^o{}_2 - \Delta_r H^o{}_3$$

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$\Delta_r H^o$ via Hess's law

Consider

$$C(s) + O_2(g) \longrightarrow CO_2(g) \quad \Delta_r H^o{}_1 = -393.5\ \text{kJ}$$

$$S(s) + O_2(g) \longrightarrow SO_2(g) \quad \Delta_r H^o{}_2 = -296.8\ \text{kJ}$$

$$CS_2(l) + 3\ O_2(g) \longrightarrow CO_2(g) + 2\ SO_2(g) \quad \Delta_r H^o{}_3 = -1103.9\ \text{kJ}$$

$$C(s) + 2\ S(s) \longrightarrow CS_2(l) \quad \Delta_r H^o{}_4 = ?$$

Since energy is conserved ...

$$\Delta_r H^o{}_4 = \Delta_r H^o{}_1 + 2\ \Delta_r H^o{}_2 - \Delta_r H^o{}_3 = +116.8\ \text{kJ}$$

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$\Delta_r H^o$ via Hess's law

First, get expression for $\Delta_r H^o$.

Then, substitute in values in the expression for $\Delta_r H^o$ to get its numerical value.

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Standard states and standard $\Delta_r H$

In general $\Delta_r H$ depends on the form of reactants and products.
For this reason we must specify these forms when tabulating values for $\Delta_r H$.

Standard states are defined, for temperature of interest, for ...

- pure substances as the most stable form
- gases as at pressure 1 bar
- aqueous species as at 1 M

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Standard states at 25 °C (http://goo.gl/aljmi)

Bromine?

$Br_2(l)$

Mercury?

$Hg(l)$

Sodium sulfate?

$Na_2SO_4(s)$

Ethanol?

$CH_3CH_2OH(l)$

Hydrated chloride ions in aqueous sodium chloride solution?

1 M $Cl^-(aq)$

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Standard enthalpy of formation, $\Delta_f H°$

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Standard enthalpy of formation, $\Delta_f H°$, of X

Form one mole of X …

… from the elements it contains, …

… each in their standard state.

Recall, the standard state of an element is its most stable form.

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$\Delta_f H°$ of sugar, $C_6H_{12}O_6(s)$

Form one mole of sugar …

$\rightarrow C_6H_{12}O_6(s)$

… from the elements it contains, …

C, H, and O

… each in their standard state,

$C(s)$, $H_2(g)$, and $O_2(g)$

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Lecture 26 CH101 A1 (MWF 9 am) Fall 2016

$\Delta_f H^o$ of sugar, $C_6H_{12}O_6(s)$

The standard enthalpy of formation of sugar is defined as the enthalpy change when one mole of sugar is formed from its elements, each in their standard states.

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Lecture 26 CH101 A1 (MWF 9 am) Fall 2016

$\Delta_f H^o$ of sugar, $C_6H_{12}O_6(s)$

Task: Write down the balanced chemical equation whose enthalpy change is the standard enthalpy of formation of sugar, $C_6H_{12}O_6(s)$

The enthalpy change, $\Delta_r H$, of the chemical reaction

$$6\ C(s) + 6\ H_2(g) + 3\ O_2(g) \to C_6H_{12}O_6(s)$$

is the standard enthalpy of formation of sugar, $\Delta_f H^o$.

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Lecture 26 CH101 A1 (MWF 9 am) Fall 2016

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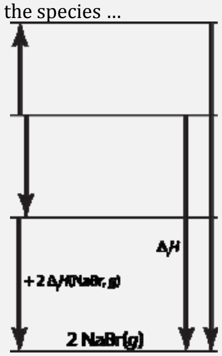

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