

Lecture 26 CH101 A1 (MWF 9:05 am) Fall 2017 Copyright © 2017 Dan Dill dan@bu.edu

[TP] The enthalpy diagram shows changes associated with the reaction
 $\text{Na}_2(g) + \text{Br}_2(g) \rightarrow 2 \text{NaBr}(g)$.
 The uppermost horizontal line corresponds to the species ...

25% 1. $2 \text{Na}(s) + \text{Br}_2(l)$
 25% 2. $2 \text{Na}(g) + 2 \text{Br}(g)$
 25% 3. $\text{Na}_2(g) + \text{Br}_2(g)$
 25% 4. something else

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Lecture 26 CH101 A1 (MWF 9:05 am)
 Wednesday, November 8, 2017

For today ...

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

Next lecture: [[Calorimetry, pp 231–232, done in lab](#)]; Bond enthalpies, $\Delta_b H$; Using $\Delta_b H$ to *estimate* $\Delta_r H$; If some substances are not gases, using $\Delta_b H$ works poorly

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

Consider

$$A \rightarrow B \quad \Delta_r H^\circ_1$$

$$C \rightarrow B \quad \Delta_r H^\circ_2$$

$$A \rightarrow C \quad \Delta_r H^\circ_3 = ?$$

Since energy is conserved ...

$$\Delta_r H^\circ_3 = \Delta_r H^\circ_1 - \Delta_r H^\circ_2$$

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

Consider

$$A \rightarrow B \quad \Delta_r H^\circ_1 = +85 \text{ kJ}$$

$$C \rightarrow B \quad \Delta_r H^\circ_2 = -52 \text{ kJ}$$

$$A \rightarrow C \quad \Delta_r H^\circ_3 = ?$$

Since energy is conserved ...

$$\Delta_r H^\circ_3 = \Delta_r H^\circ_1 - \Delta_r H^\circ_2 = +85 \text{ kJ} - (-52 \text{ kJ}) = +137 \text{ kJ}$$

Illustrate this result with the enthalpy diagram for these processes.

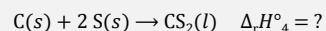
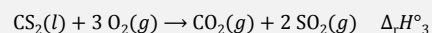
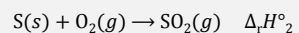
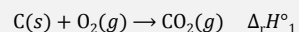
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 $\Delta_r H^\circ$ via Hess's law

Consider



Since energy is conserved ...

$$\Delta_r H^\circ_4 = \Delta_r H^\circ_1 + 2 \Delta_r H^\circ_2 - \Delta_r H^\circ_3$$



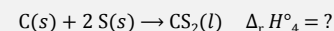
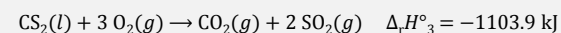
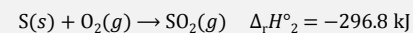
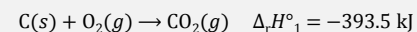
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 $\Delta_r H^\circ$ via Hess's law

Consider



Since energy is conserved ...

$$\Delta_r H^\circ_4 = \Delta_r H^\circ_1 + 2 \Delta_r H^\circ_2 - \Delta_r H^\circ_3 = +116.8 \text{ kJ}$$



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 $\Delta_r H^\circ$ via Hess's law**First**, get expression for $\Delta_r H^\circ$.**Then**, substitute in values in the expression for $\Delta_r H^\circ$ 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 atm**
- aqueous species as at **1 M**



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Standard states at 25 °C


Bromine?
 $\text{Br}_2(l)$

Mercury?
 $\text{Hg}(l)$

Sodium sulfate?
 $\text{Na}_2\text{SO}_4(s)$

Ethanol?
 $\text{CH}_3\text{CH}_2\text{OH}(l)$

Hydrated chloride ions in aqueous sodium chloride solution?
 $1 \text{ M Cl}^-(aq)$


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Standard enthalpy of formation, $\Delta_f H^\circ$, 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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$\Delta_f H^\circ$ of sugar, $\text{C}_6\text{H}_{12}\text{O}_6(s)$


Form **one mole** of sugar ...
 $\rightarrow \text{C}_6\text{H}_{12}\text{O}_6(s)$
 from the **elements** it contains, ...
 C, H, and O
 each in their **standard state**, ...
 $\text{C}(s)$, $\text{H}_2(g)$, and $\text{O}_2(g)$

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$\Delta_f H^\circ$ of sugar, $\text{C}_6\text{H}_{12}\text{O}_6(s)$

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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$\Delta_f H^\circ$ 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

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

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

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What is the standard state at 25 °C?

From tables of enthalpies of formation, such as <http://goo.gl/aljmi>, ... the standard state will have value 0.

Dinitrogen pentoxide	Gas	N_2O_5	11.3
Oxygen			
Monatomic oxygen	Gas	O	249
Oxygen	Gas	O_2	0
Ozone	Gas	O_3	143
Phosphorus			
White phosphorus	Solid	P_4	0

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