

## Calculating Heats of Reaction

Sometimes it is hard to measure the enthalpy change for a reaction. We can still measure enthalpy change indirectly through Hess's Law.

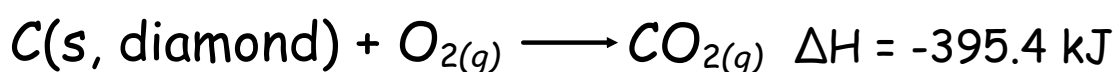
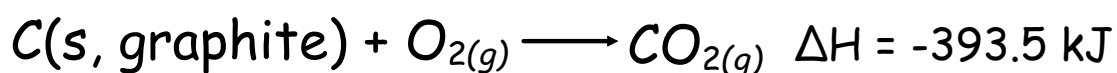
Hess's law states that if you add two or more thermochemical equations to give a final equation, then you can also add the heats of reaction to give the final heat of reaction.

Diamonds are a form of carbon that exist at 25°C. Another type is graphite.



The conversion of diamond to graphite takes millions of years. This enthalpy change cannot be observed because the reaction is far too slow.

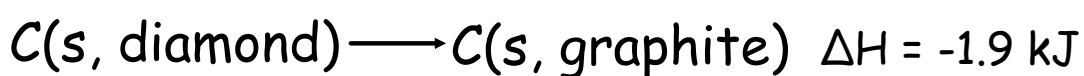
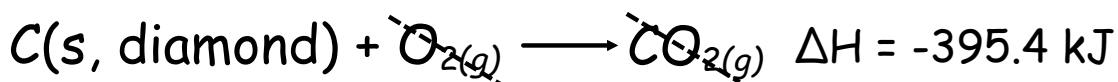
We can use Hess's law to find the enthalpy change for the conversion of diamond to graphite by using the following combustion reactions.



Write the first equation in reverse...



... and add the new equation to the second.

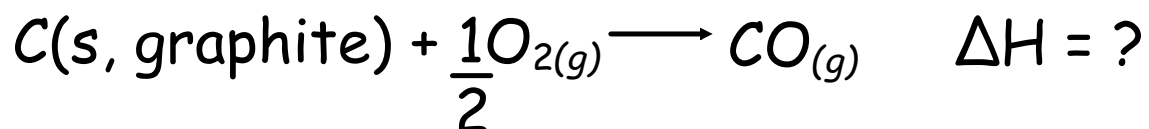


*Terms on opposite sides of the equation will cancel out when added.*

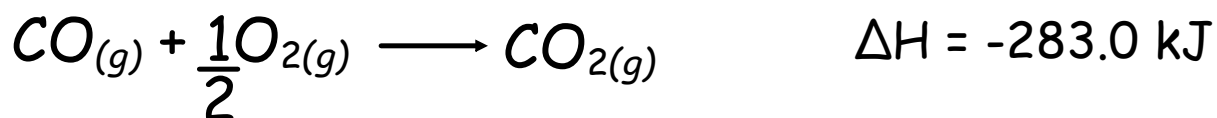
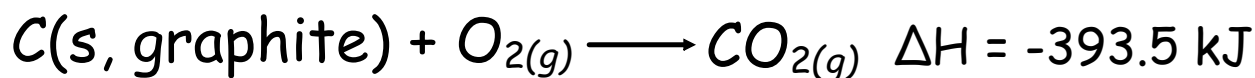
The conversion of diamond to graphite is an exothermic process, releasing 1.9 kJ of energy.

## Example

Calculate the enthalpy change ( $\Delta H$ ) in kJ for the following reaction.



Use the following enthalpy changes to calculate  $\Delta H$  above.



## Standard Heats of Formation

Enthalpy changes generally depend on specific conditions as reference points. These conditions refer to the stable form of the substance at 25°C and 101.3 kPa

The standard heat of formation ( $H_f^\circ$ ) of a compound is the change in enthalpy that accompanies the formation of one mole of a compound.

$H_f^\circ$  of a free element in its standard state is set at zero.

Table 17.4 (pg. 530) lists  $H_f^\circ$  for some common substances. NOTE: Ignore the ' $\Delta$ ' the textbook uses as this talks about kJ/mol.

For a reaction that occurs at standard conditions, you can calculate the heat of reaction by using standard heats of formation.

This type of enthalpy change is called the *standard heat of reaction* ( $\Delta H^\circ$ ).

The standard heat of reaction is the difference between the standard heats of formation of all the reactants and products.

$$\Delta H^\circ = \Delta H_f^\circ (\text{products}) - \Delta H_f^\circ (\text{reactants})$$

## Example

What is the standard heat of reaction ( $\Delta H^\circ$ ) for the reaction of  $\text{CO}_{(g)}$  with  $\text{O}_{2(g)}$  to form  $\text{CO}_{2(g)}$ ?

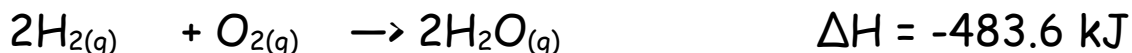
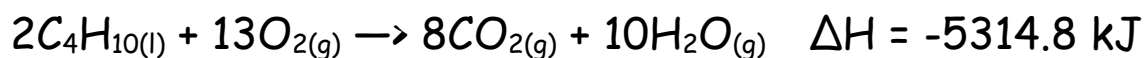
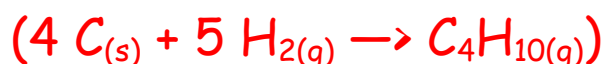
Try questions on pages 531-532 #32-37



## Extending Hess's Law and Heats of Reactions.

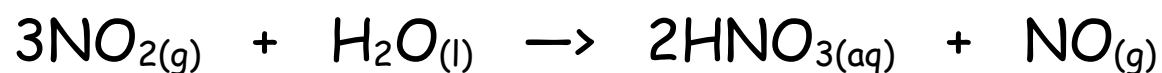
### Example:

Use the evidence of the following reactions to find the standard molar enthalpy of formation of butane?



### Example

Find the molar enthalpy of reaction ( $H^\circ$ ) of nitrogen dioxide in the following reaction:  
(note:  $\Delta H_f^\circ(\text{HNO}_{3(\text{aq})}) = -174.1 \text{ kJ/mol}$ )



## Heats of Reaction Worksheet