

Chapter 5 Part 3

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Internal Energy (U)

- Internal energy (U) is the sum of all kinds of energy present in a substance

$$\Delta U = q + w$$

- ▣ ΔU is change in internal energy
- ▣ q is heat
- ▣ w is work

Internal energy

Heat Energy (q)

- q is positive when heat flows into the system (endothermic reaction)
- q is negative when heat flows out of the system (exothermic reaction)

Work (w)

- w is positive when the system has work done on it
- w is negative when the system does work on the surroundings

Internal Energy

A gas, while expanding, absorbs 25 J of heat and does 243 J of work.
What is ΔU for the gas?

Internal Energy

Two gases, A(g) and B(g), are confined in a cylinder-and-piston arrangement. Gases A and B react to form a solid product C: $A(g) + B(g) \rightarrow C(s)$. As the reaction occurs, the system loses 1150 J of heat to the surroundings. The piston moves downward as the gases react to form a solid. As the volume of the gas decreases under the constant pressure of the atmosphere, the surroundings do 480 J of work on the system. What is the change in the internal energy of the system?

- A. 1630 J
- B. 670 J
- C. -670 J
- D. -1630J

Enthalpy (H)

- For processes that occur at a constant pressure, enthalpy is equal to heat
- For a chemical reaction:

$$\Delta H = \text{Energy of products} - \text{Energy of reactants}$$

- Enthalpy can be thought of as a measure of the thermal energy produced or absorbed by a chemical reaction
- If a reaction is endothermic, ΔH will be positive
- If a reaction is exothermic, ΔH will be negative

Burning Firewood

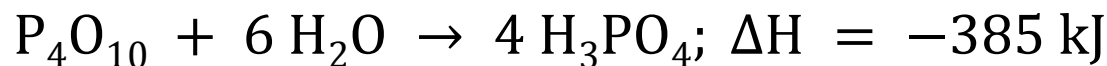
- If firewood is burned in the presence of oxygen gas, is thermal energy released or absorbed?

Burning Firewood

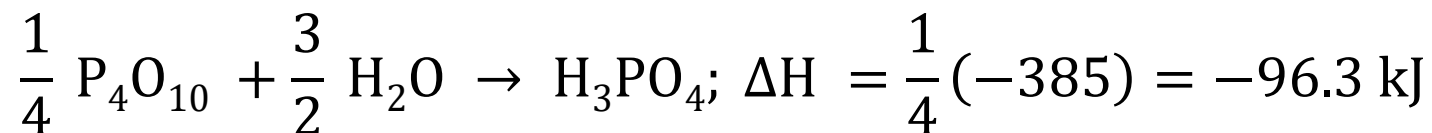
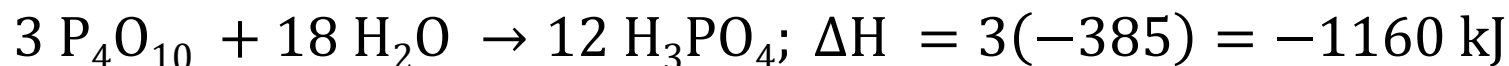
- If one increases the amount of firewood being burned, will the amount of thermal energy produced increase or stay the same?

Enthalpy as an extensive property

- Consider the following reaction:

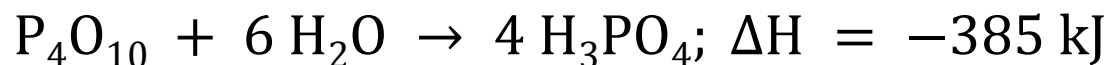


- When a chemical reaction is multiplied by a constant, the enthalpy change is also multiplied by that constant



Enthalpy as an extensive property

- When the reactants and products in a chemical equation are reversed, the magnitude of ΔH is identical, but the sign of ΔH is reversed



State Functions



- State functions are functions that depend only on the state that a system is in and not the path to how that state was reached

State Functions

Examples of state functions

- Altitude
- Enthalpy
- Entropy
- Free Energy

Examples path functions

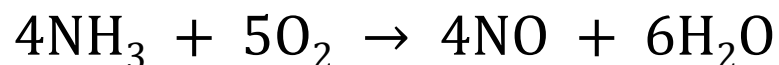
- Distance
- Heat
- Work

Hess's Law

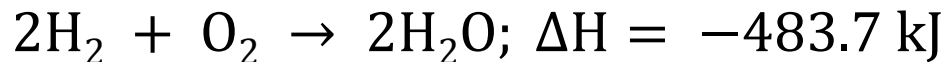
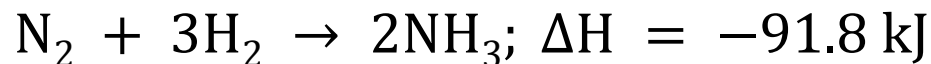
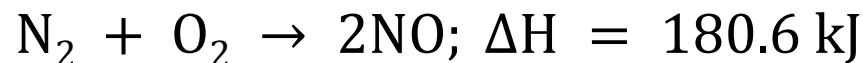
- Hess's law states that if a process can be written as the sum of several stepwise processes. The enthalpy change of the total process equals the sum of the enthalpy changes of the various steps
- This is true because enthalpy is a state function

Hess's Law

Ammonia will burn in the presence of a platinum catalyst to produce nitric oxide, NO.

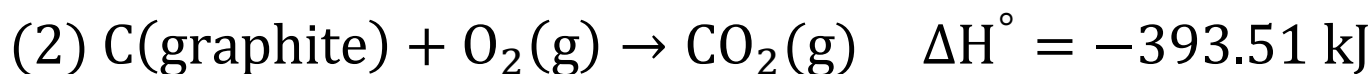
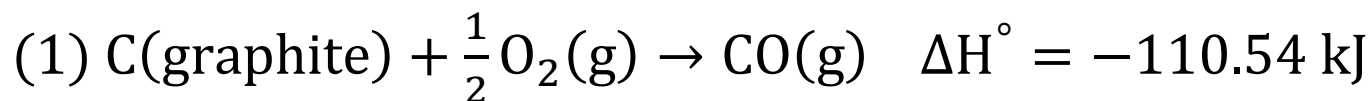
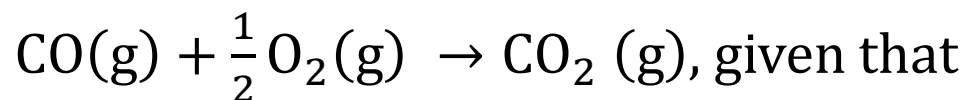


What is the heat of reaction at constant pressure? Use the following thermochemical equations:



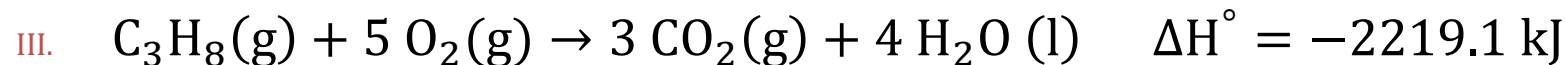
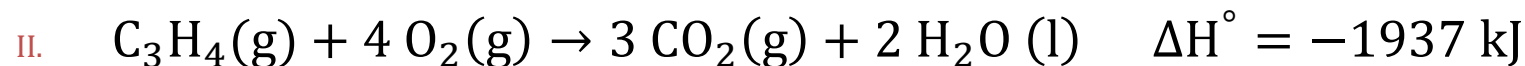
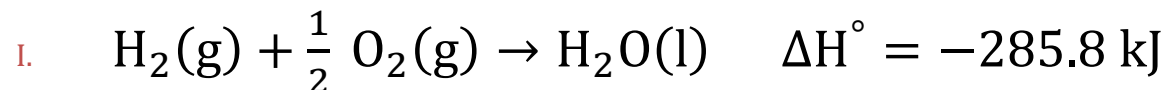
Hess's Law

Use Hess's Law to determine ΔH° for the reaction

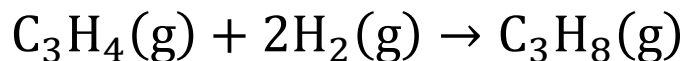


Hess's Law

Given the following data



Use Hess's Law to determine ΔH° for the reaction in kJ



Standard State Conditions (°)

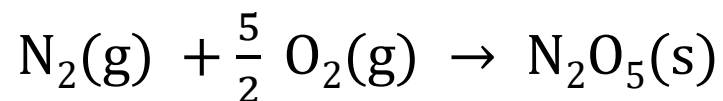
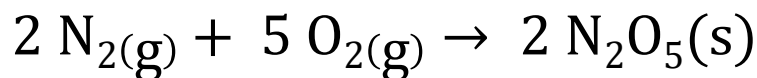
- A standard state is a commonly accepted set of conditions used as a reference point for the determination of properties under other conditions
- Standard states are denoted by a "°" after the property symbol (H°)
- Since the enthalpy for a reaction varies with changes in experimental conditions such as temperature, pressure, and solution concentration, it is helpful to specify a standard state of conditions

Standard State Conditions (°)

- Standard state conditions
 - ▣ Gases, liquids, and solids must be in their pure form
 - ▣ Pressure is 1 bar
 - ▣ All solutions are 1 M
- Temperature for standard enthalpies are normally given at 25°C, but this is not a requirement

Standard Enthalpy of Formation

- Standard enthalpy of formation (ΔH_f°) for a species is the enthalpy change of one mole of a species from its constituent elements in their most stable form



Standard Enthalpy of Formation

- Rules for standard heats of formation
 - ▣ ΔH_f° values have units of kJ/mol because each is the enthalpy change is for the formation of one mole of a chemical species.
 - ▣ The ΔH_f° value for an element in its standard state is equal to 0 kJ/mol.
 - ▣ Most ΔH_f° values are negative. This indicates that for most species, the formation from elements in their standard states is an exothermic process.

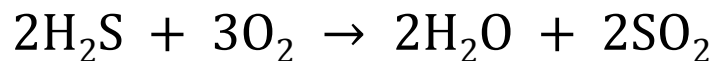
Standard enthalpies of reactions

Standard enthalpies of a reaction are the enthalpy change for a reaction under standard conditions and are found using the equation below

$$\Delta H_{\text{rxn}}^{\circ} = \sum \Delta H_{\text{f}}^{\circ}(\text{products}) - \sum \Delta H_{\text{f}}^{\circ}(\text{reactants})$$

Standard enthalpy of reaction

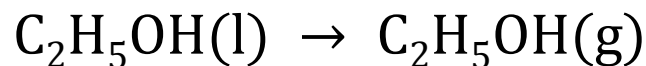
Hydrogen sulfide gas is a poisonous gas with the odor of rotten eggs. It occurs in natural gas and is produced during the decay of organic matter, which contains sulfur. The gas burns in oxygen as follows:



Calculate the standard enthalpy change for this reaction using standard enthalpies of formation. The standard enthalpy of formation of H_2S , H_2O , and SO_2 are -20.50 , -285.8 , and -296.8 kJ/mol, respectively.

Standard enthalpy of reaction

The cooling effect of alcohol on the skin is due to its evaporation. Calculate the heat of vaporization of ethanol, $\text{C}_2\text{H}_5\text{OH}$.

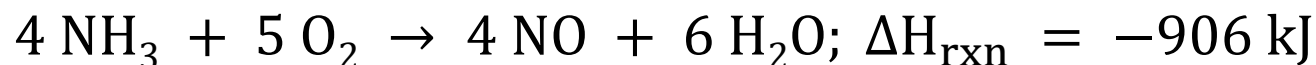


The standard enthalpy of formation of $\text{C}_2\text{H}_5\text{OH}(\text{l})$ is -277.7 kJ/mol and that of $\text{C}_2\text{H}_5\text{OH}(\text{g})$ is -235.4 kJ/mol .

- A. -277.7 kJ/mol
- B. -235.4 kJ/mol
- C. 42.3 kJ/mol
- D. -42.3 kJ/mol

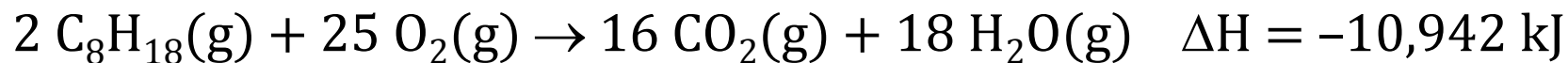
Thermstoichiometry

A mixture containing 10.0 g of NH_3 and 20.0 g of O_2 reacts by the following equation. (A) Determine which reactant is limiting. (B) How much heat will be released by the reaction?



Thermstoichiometry

The reaction for the combustion of octane, C_8H_{18} , is shown below.



Determine the amount of heat released when 0.2430 mol of C_8H_{18} reacts with excess O_2 .

- A. -10942 kJ
- B. -5471 kJ
- C. -1329 kJ
- D. -2659 kJ
- E. -3371 kJ

Thermstoichiometry

Gaseous hydrogen iodide, HI, is formed from the reaction of hydrogen and iodine gas.

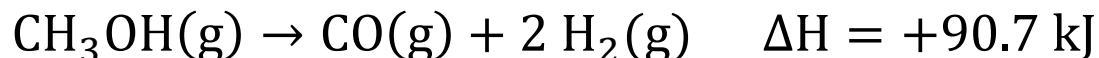


Determine the enthalpy of the reaction per mole of HI produced.

- A. 52.96 kJ/mol
- B. 26.48 kJ/mol
- C. 37.76 J/mol
- D. 018.88 J/mol

Thermostoichiometry

Consider the following reaction:



(A) Is this reaction endothermic or exothermic? (B) Calculate the amount of heat absorbed when 45.0 g of CH_3OH is decomposed at a constant pressure. (C) How many grams of H_2 are produced during an enthalpy change of 25.8 kJ?