C.11.C
Use thermochemical equations to calculate energy changes that occur in chemical reactions and classify reactions as exothermic or endothermic.

Energy Changes in Chemical Reactions

Standard state: reference state for a substance (typically 1 atm, 25°C or 298 K, and 1 mole); defining a property at standard state can allow it to be intensive (independent of size); indicated by a superscript of 0.

Standard molar enthalpy of formation, ΔH^{o}_{f}: difference in energy that occurs when one mole of a substance is formed from its pure elements (all at standard state conditions); **ΔH^{o}_{f} for any element = 0.**

Δ means "change" or "difference"

Enthalpy of reaction, ΔH: energy released or absorbed during a chemical reaction. At standard state, $\Delta H = \sum \Delta H^{o}_{f\,(products)} - \sum \Delta H^{o}_{f\,(reactants)}$, where ∑ means "sum of all" (multiply each $\sum \Delta H^{o}_{f}$ by its coefficient.

Reaction	Enthalpy Change	Description
Exothermic	ΔH < 0 (negative)	Heat is released
Endothermic	ΔH > 0 (positive)	Heat is absorbed

Sample Problem 1:
Calculate the change in energy for the following reaction at standard conditions. Is this reaction **endothermic** or **exothermic**?

$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(g)$$

Substance	ΔH^{o}_{f} (kJ/mol)
CH_4	-74.8
O_2	0
CO_2	-393.5
H_2O	-241.8

Use the following formula to calculate the change in energy:

$$\Delta H = \sum \Delta H^{o}_{f\,(products)} - \sum \Delta H^{o}_{f\,(reactants)}$$

Sample Problem 2:
Calculate the change in energy for the following reaction at standard conditions. Is this reaction **endothermic** or **exothermic**?

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$$

Substance	ΔH°_f (kJ/mol)
$CaCO_3$	-1207
CaO	-635.5
CO_2	-393.5

Use the following formula to calculate the change in energy:

$$\Delta H = \sum \Delta H^\circ_{f\,(products)} - \sum \Delta H^\circ_{f\,(reactants)}$$

C.11.D
Perform calculations involving heat, mass, temperature change, and specific heat.

Heat, Mass, Temperature Change, and Specific Heat

Specific Heat:
Specific heat is an intensive property. It does not vary with the amount of the substance. The **specific heat** of a substance is the amount of heat needed to raise the temperature of one gram of the substance by one degree Celsius.

The **unit of specific heat** is joules per gram-degree Celsius (J/g•°C).

The equation for specific heat is:

$$Q = mc_p\Delta T,$$

Q represents the heat input, m is for mass, c_p is for specific heat, and ΔT is for the change in temperature.

Sample Problem 1:
Given that c_p of copper = 0.385 J/ g•°C, calculate the heat absorbed by a 0.020 kg piece of copper metal that is heated from 25°C to 125°C. *Note: Convert to common units so units will cancel (change kg to g). So, 0.020 kg = 20 g*

	Sample Problem 2: The specific heat of water is 4.179 J/ g•°C. A 1,200 g water sample at 19°C <u>loses</u> 10kJ of heat. What is the final temperature? *Note: Convert to common units so units will cancel (change kJ to J). So, 10kJ = 10,000 J*
C.11.E **Use calorimetry to calculate the heat of a chemical process**	**Calorimetry** **The Science of Measuring Heat Flow** **Calorimeter:** tool used to measure heat of a chemical process (ΔH); heat flows into a substance with known $c_{p\ (\text{specific heat})}$ and the temperature change is recorded: $\Delta H = -Q$; where $Q = mc_p\Delta T$ A calorimeter usually contains a carefully measured mass of a substance of known specific heat, such as water. As the reaction absorbs or releases energy, the temperature of the water will change. From that temperature change, the energy that the water absorbed or released can be calculated. **Energy released by the reaction = Energy absorbed by the solution** **Sample Problem 1:** A student is using a calorimeter to measure the **molar heat** of salvation of calcium chloride ($CaCl_2$). The calorimeter contains 100.0 g of water at 25.1°C. After 10.0 g of $CaCl_2$ is fully dissolved, the temperature of water rises to 42.7°C. (*Hint:* Remember that the specific heat of water is 4.18 J/g•°C.