

HEAT REACTIONS

- **Exothermic vs. Endothermic Reactions**

- SUMMARY:

ENDOTHERMIC	EXOTHERMIC
Energy (heat) is absorbed	Energy (heat) is emitted
Heat enters the system	Heat exits the system
Feels Cold	Feels Hot
Heat is a <i>reactant</i> : Reactants + heat → Products	Heat is a <i>product</i> : Reactants → Products + heat
+ ΔH	- ΔH

- The amount of heat gained/lost by the system must be equal to that gained/lost by the surroundings according to the _____.

- **Practice:** Classify the following reactions as exothermic or endothermic:

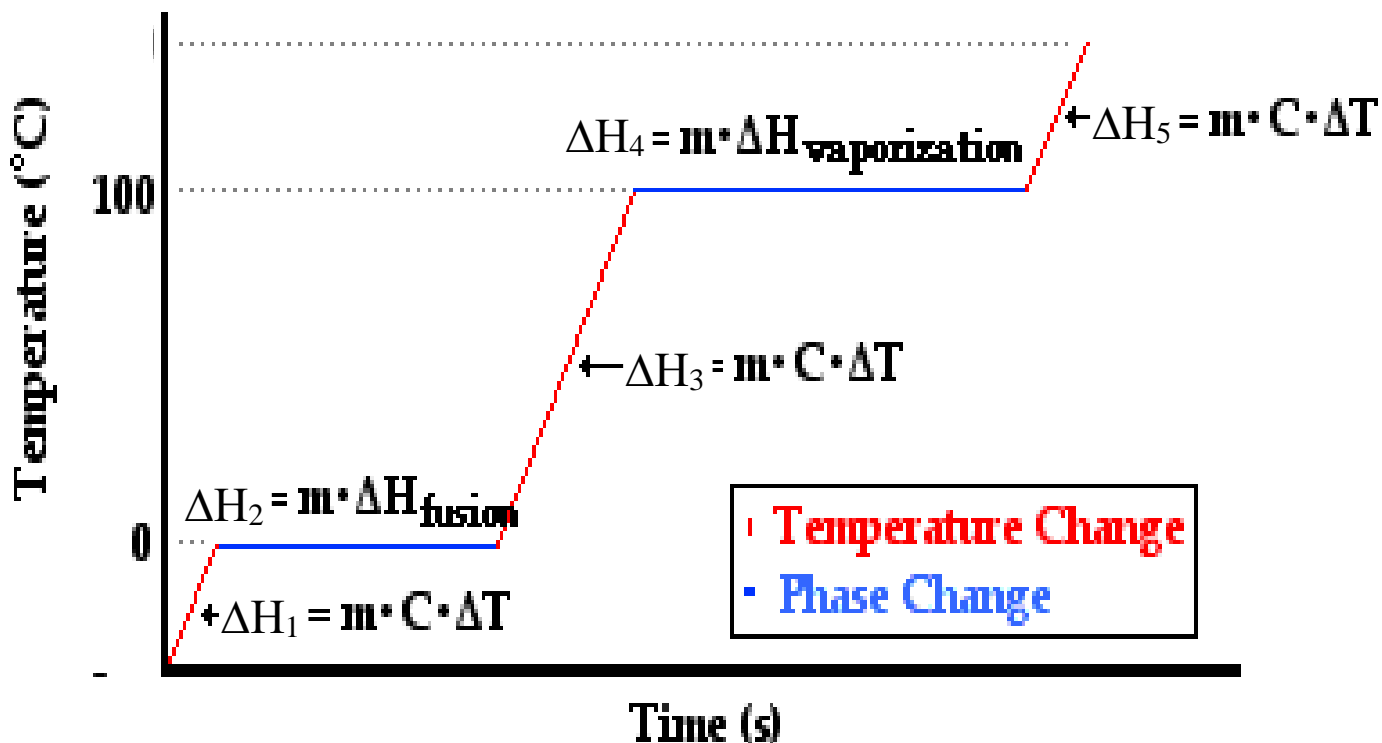
- A system gives off heat over time. _____
- The surroundings get warmer. _____
- The change in heat is positive. _____
- There is a $-\Delta H$. _____
- The test tube feels warm to the touch. _____
- The energy of the products is greater than the energy of the reactants. _____

SPECIFIC HEAT CAPACITY

- **Specific heat, C_p** –

- C_p units are usually: J/g•°C or cal/g•°C or (J/g•K or cal/g•K)

HEATING/COOLING CURVE FOR WATER



TEMPERATURE CHANGE EQUATION

- On steps 1, 3, and 5 of the five-step diagram the temperature is changing!
- $\Delta H = m \times C_p \times \Delta T$ (ΔH is usually in units of Joules)
 - ΔH – change in heat (also listed as q)
 - m – mass in grams
 - C – specific heat; selected from reference table
 - ΔT – change in temperature
- *See Part A on worksheet for example calculations*

PHASE CHANGE EQUATION

- On Steps 2 and 4 of the five-step diagram the phase is changing so the temperature is constant – that means we can't use the Temperature Change Equation (because $\Delta T = 0!$).
- The heat involved in phase changes is called _____.
- **Molar heat of fusion** (ΔH_{fus}) – the energy that must be _____ to convert one mole of a _____ to a _____ at the _____.
- **Molar heat of solidification** (ΔH_{solid}) – the energy that must be _____ to convert one mole of a _____ to a _____ at the _____.
- **Molar heat of vaporization** (ΔH_{vap}) – the energy that must be _____ to convert one mole of a _____ to a _____ at the _____.
- **Molar heat of condensation** (ΔH_{cond}) – the energy that must be _____ to convert one mole of a _____ to a _____ at the _____.
- $\Delta H = \text{mol} \times \Delta H_{\text{phase change}}$ (ΔH is usually in units of kilojoules)
 - ΔH – change in heat (also listed as q)
 - mol – moles of the substance
 - $\Delta H_{\text{phase change}}$ – selected from reference table
- *See Part B on worksheet for example calculations*

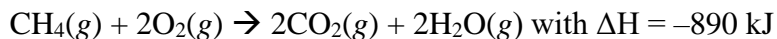
CALCULATING ΔH ACROSS MULTIPLE STEPS

- When a problem asks you to calculate heat evolved over multiple steps (*phase changes and temperature changes*), **use both equations** as you would normally. Then, at the end, make sure all equations are in the **same units** and then **add** them together.
- Decide which of the two equations apply for each step:
 - Enthalpy change, **no phase change** (*Steps 1, 3, and 5*)
 - $\Delta H = m \times C_p \times \Delta T$ (answer typically in J for ΔH)
 - Enthalpy change, **no temperature change** (*Steps 2 and 4*)
 - $\Delta H = \text{mol} \times \Delta H_{\text{phase change}}$ (answer typically in kJ for ΔH)
 - Add the total energy together, **in the SAME units!**
 - $1000 \text{ J} = 1 \text{ kJ}$
- *See Part C on worksheet for example calculations*

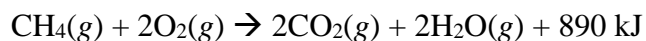
THERMOCHEMICAL EQUATIONS

- Thermochemical equation –

- *Example:* The combustion of 1 mole of methane (CH₄) releases 890 kJ of heat energy

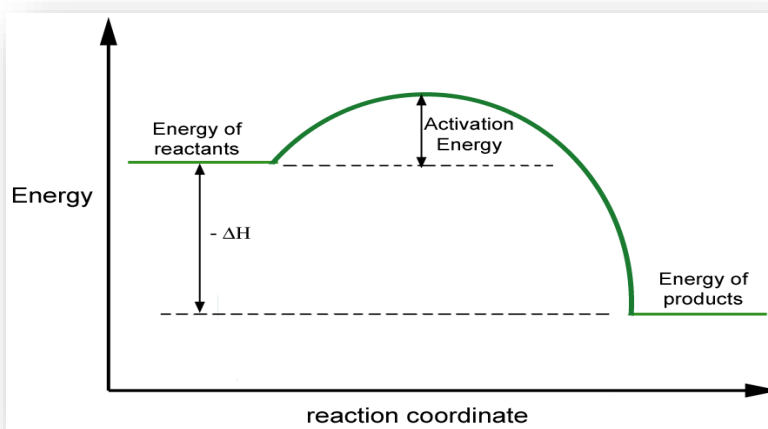


OR



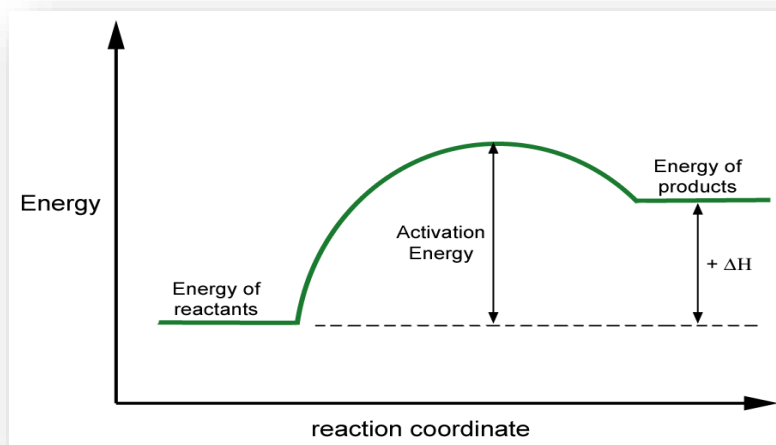
- In EXOTHERMIC rxns heat is given off ($-\Delta H$) so it is written positively on the _____ side.

- **Exothermic Energy Diagram**

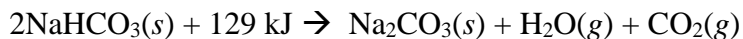


- In ENDOTHERMIC rxns heat is absorbed ($+\Delta H$) so it is written positively on the _____ side.

- **Endothermic Energy Diagram**



- *Practice Problem:* Sodium bicarbonate decomposes when heated...

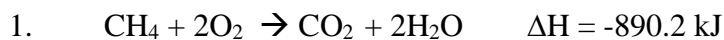


- How much heat (in kJ) is needed to decompose 2.24 moles of sodium bicarbonate?

- *Practice Problem:* When carbon disulfide is formed from its elements, 89.3 kJ heat is absorbed.

- Write the reaction.
- Is the reaction endothermic or exothermic?
- Calculate the amount of heat in kJ that is absorbed with 5.66 g of carbon disulfide is formed.

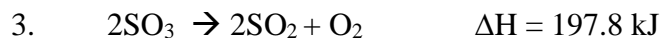
- **Additional Examples**



How much heat is released when 25 g of CH_4 reacts with excess O_2 ?



How much heat is released when 0.75 mol of CO reacts with excess O_2 ?



How many grams of SO_3 react when 575 kJ of heat is absorbed?

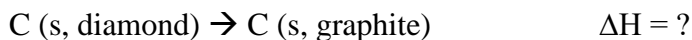


How many kilojoules of heat are produced when 3.40 mol of iron (III) oxide reacts with an excess of carbon monoxide?

HESS'S LAW (Honors Only)

- Provides a way to calculate the _____ of the _____ when it cannot be measured _____.
- If you _____ two or more _____ to give a final equation, then you can also _____ the _____ of the _____ to give the _____ heat of reaction.
- **Examples:**

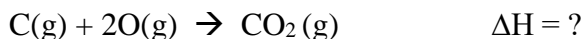
- *Practice 1:* Graphite is more stable than diamond so in time...



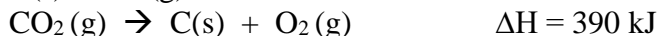
Use the following known thermochemical equations to calculate the heat of reaction for the above equation:



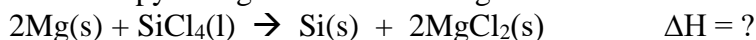
- *Practice 2:* Calculate the enthalpy change for the formation of carbon dioxide from its elements.



Use the following thermochemical equations:



- *Practice 3:* What is the enthalpy change for the following reaction?



Use the following thermochemical equations:

