Calorimetry and Change of State Energy

Read from **Lesson 1 in** the **Chemistry Tutorial Section, Chapter 12** of **The Physics Classroom**:
Part d: Calorimetry Part e: Energy and Changes of State

Part 1: Calorimetry

Calorimetry is the study of heat transfer during physical and chemical processes. To calculate the heat gained or lost during a chemical reaction using a coffee cup calorimeter, chemistry students use the Q equation:

$$Q = m \cdot C \cdot \Delta T$$

- **Q** represents the quantity or amount of heat gained or lost by the sample
- **m** represents the mass of the sample
- **C** represents the specific heat capacity of the material. **The specific heat of a substance**: the amount of heat required to raise the temperature of 1.00 gram of a substance by 1.00 °C. (*see table to the right*)
- **ΔT** represents the temperature change of the sample

Substance	Specific Heat Capacity (J/g/°C)
Aluminum	0.89
Copper	0.385
Iron	0.450
Lead	0.129
Lithium	3.58
Mercury	0.14
Sodium	1.228
Water	4.184
Ice	2.09
Steam	2.03

Calorimetry Questions

1. A 25.0 g piece of lead is heated from 25.0°C to 85.0°C. What is the amount of heat energy absorbed by the lead?

2. A cup of coffee (160 grams) cools from 88.0°C down to 25.0°C. How much energy does it release into the surroundings? (*Assume that coffee is mostly water and use the specific heat for water in your calculation.*)

3. A 4.50 g copper coin released 139 J of energy as it cooled to 30.2°C. What was its initial temperature?

4. A 4.50 g sample of peanut is burned in a bomb calorimeter, causing the temperature of 500.0 g of water to increase from 25.0°C to 38.0°C. What is the energy content (in Joules per gram) of the peanut?

Thermochemistry

5. A 47.0 g piece of an unknown metal is heated to 100.0°C. It is then placed into 150.0 g of water which is 20.0°C. The final temperature of the metal-water system is 25.0°C. Determine the specific heat capacity of the unknown metal. What is the identity of the unknown metal?

6. Molly Cule is conducting a calorimetry experiment to determine the specific heat capacity of an unknown liquid. She has three metals to choose from—copper, iron, and aluminum—each with a mass of 5.00 g. Her goal is to transfer energy from the metal to the liquid, increasing its temperature by at least 10°C. Which metal can absorb and transfer the most energy? Justify your answer with clear reasoning or calculations.

Part 2: Energy in Changes of State

Heat of Fusion and Heat of Vaporization

When substances change state—like ice melting into water or water boiling into steam—energy is either absorbed or released. **Heat of fusion** is the amount of energy needed to change a substance from a solid to a liquid at its melting point. **Heat of vaporization** is the energy required to change a substance from a liquid to a gas at its boiling point.

To calculate the energy (Q) involved in a phase change, use the other Q formula: **$Q = n \cdot \Delta H$ or $m \cdot \Delta H$**

Q = heat energy, **n** = moles of the substance or **m** = mass of the substance, and **ΔH** = heat of fusion or heat of vaporization

Heat of fusion of water ΔH_f = 334 J/g   Heat of vaporization of water ΔH_v = 2,260 J/g

No temperature change occurs during a phase change—only the phase changes!

Energy Questions

1. How much heat is required to melt 45 g of ice at 0°C?

2. How much heat is released when 2.00 moles of steam condense at 100.0°C?

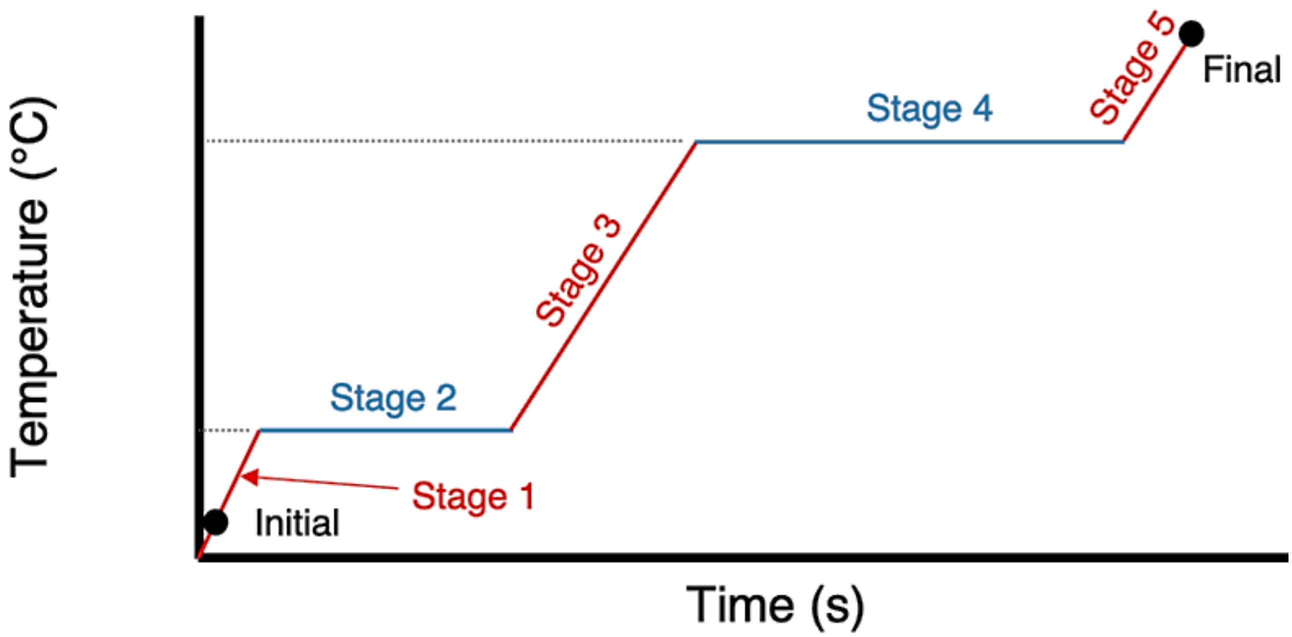
Thermochemistry

Heating Curve Analysis

3. Acetone (C_3H_6O) is a colorless and volatile flammable liquid and is commonly used as a solvent. Acetone has a melting point of -95°C and a boiling point of 56°C.
A sample of acetone is carefully heated from -122°C to 155°C. The mass of the sample is 49.7 grams.

Fill in the missing information on the heating curve for acetone.

- Label the initial and final temperature.
- Label the melting and vaporization points for acetone.
- Label which stages are solid, liquid, and gas as well as label where melting and vaporization occur.



4. Use the following information to calculate the amount of heat needed to heat the 49.7 grams of acetone -122°C to 155°C.
The specific heat capacity of acetone in solid, liquid, and gas phases are solid (1.65 J/g·°C), liquid (2.15 J/g·°C), and gas (1.29 J/g·°C).
ΔH_f for acetone is 5.77 kJ/mol and **ΔH_v** for acetone is 31.3 kJ/mol.

Calculate the energy for each stage. Write the formula (one of the Q formulas) to be used on Line 1. Line 2 is for the values and units for each variable in the formula. Line 3 is for the answer in kilojoules.

Follow this example for calculating how much energy is needed to raise the temperature of 37.0 g of H_2O from 12.5°C to 65.5°C.

Line 1: $\underline{Q = m \bullet C \bullet \Delta T}$ Line 2: $\underline{Q = (37.0g)(4.184\ J/g\cdot°C)\ (65.5°C - 12.5°C)}$ Line 3: $\underline{8204\ J = 8.20\ kJ}$

Thermochemistry

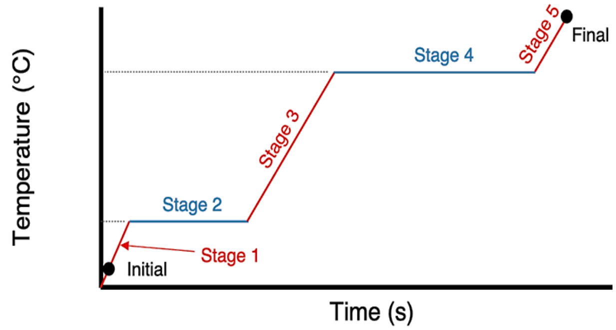
A sample of acetone is carefully heated from -122°C to 155°C. The mass of the sample is 49.7 grams.

Acetone has a melting point of -95°C and a boiling point of 56°C.

The specific heats of acetone are: solid (1.65 J/g·°C), liquid (2.15 J/g·°C), and gas (1.29 J/g·°C).

ΔH_f for acetone is 5.77 kJ/mol
ΔH_v for acetone is 31.3 kJ/mol

The molar mass of acetone is 58.08 g/mol.



Stage 1 **Line 1:** ______________________________

Line 2: ______________________________

Line 3: ______________________________

Stage 2 **Line 1:** ______________________________

Line 2: ______________________________

Line 3: ______________________________

Stage 3 **Line 1:** ______________________________

Line 2: ______________________________

Line 3: ______________________________

Stage 4 **Line 1:** ______________________________

Line 2: ______________________________

Line 3: ______________________________

Stage 5 **Line 1:** ______________________________

Line 2: ______________________________

Line 3: ______________________________

Total Energy (add all of the Line 3s) ______________________________