Thermochemistry Concepts

Calorimetry

1. State the "**First Law of Thermodynamics**". What equation is used to represent this law?

2. When solid sodium hydroxide pellets dissolve in a beaker of water, the water warms up considerably.

   a. Is this reaction **endothermic** or **exothermic**? Explain.

   b. What is the sign for the **enthalpy change**, **ΔH**, for this reaction?

3. State if each **phase change** below is endothermic or exothermic. Indicate the sign of ΔH for the process.

Phase Change	Endothermic or Exothermic	Sign of ΔH
Melting		
Boiling		
Freezing		
Sublimation		
Condensation		

4. **Enthalpy** (**H**) is not an intuitive concept. But it can be shown that under constant pressure conditions, **enthalpy change, ΔH, is equal to heat (q)**. Why are most chemical and physical changes considered to be under "constant pressure"? Describe a lab situation where pressure would NOT be constant.

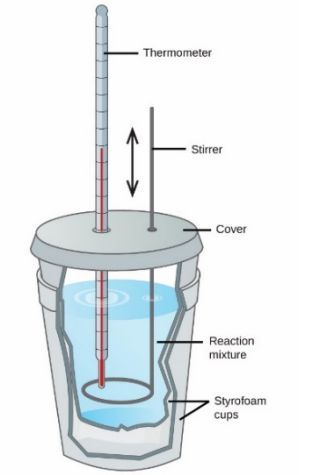
5. Define **specific heat capacity**, C.

Specific Heats of Common Materials

MATERIAL	SPECIFIC HEAT (Joules/gram • °C)
Liquid water	4.18
Solid water (ice)	2.11
Water vapor	2.00
Dry air	1.01
Basalt	0.84
Granite	0.79
Iron	0.45
Copper	0.38
Lead	0.13

6. The specific heat capacities of common materials are shown above. When exposed to the same heat source, which would warm up *fastest*?

Coffee Cup Calorimeter



7. A student placed a hot 25.0-g piece of copper metal into a coffee cup calorimeter that had 20.0 mL of water at 18.4°C. The final temperature inside the calorimeter was 36.1°C. Calculate the initial temperature of the hot copper metal.

8. A 20.0-g sample of metal was heated to 100.0°C and then added to a coffee cup calorimeter. The calorimeter held 50.0 g of water at 21.2°C. If the temperature rose to 24.4°C, calculate the specific heat capacity of the metal.

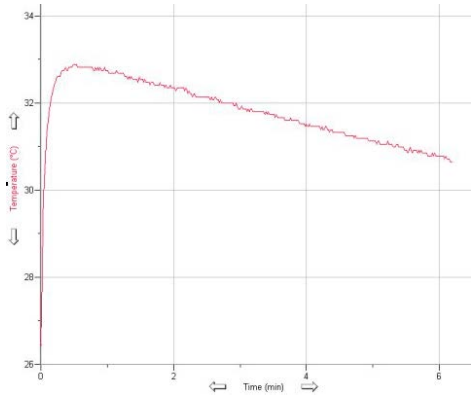
9. A 52.6-g sample of granite, initially at 125°C, was added to a coffee cup calorimeter. The calorimeter held 100.0 mL of water at 20.0°C. What will be the final temperature in the calorimeter?

10. A student mixed 500.0 mL of boiling water with 2.00 L of ice water. What will be the final temperature of the mixture?

11. In each of the questions you've done involving calorimetry, what assumption was being made about the calorimeter?

12. What is the definition of **calorimetry**?

Temperature Change for Dissolving NaOH



13. A student did a calorimetry experiment to determine the **enthalpy of dissolution** for sodium hydroxide. She used a sensor to measure the temperature change in a **calorimeter** while dissolving a sample of NaOH in distilled water. Use her data below and the graph above to find **$\Delta H_{solution}$ for NaOH**, expressed as "**kJ/mol rxn**".

$$NaOH_{(s)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$$

Data: Heat of Dissolution of NaOH

Mass of Empty Calorimeter	52.56 g
Mass of Calorimeter with Water	72.05 g
Mass of NaOH	0.62 g
Initial Water Temperature	25.4°C

a. Estimate the final temperature after the sodium hydroxide dissolved.

b. Is the dissolving of NaOH **endothermic** or **exothermic**? Justify your choice.

c. Calculate the heat, q, for the dissolving of NaOH in this experiment.

d. Calculate $\Delta H_{solution}$ expressed as "kJ/mol rxn".

e. The graph shows evidence of a source of error in this calorimetry experiment. Explain.

14. A coffee-cup calorimeter is used to find the heat of neutralization for the reaction below. A student added 20.0 mL of 0.625-M NaOH at 21.40°C to 30.0 mL of 0.500-M CH_3COOH already in the calorimeter at the same temperature. The final temperature is measured to be 24.35°C. Assume the specific heat capacity of the mixture is the same as that of water, and that the **density** of the mixture is 1.02 g/mL.

$$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow NaCH_3COO_{(aq)} + H_2O_{(l)}$$

a. Calculate the heat in the neutralization reaction.

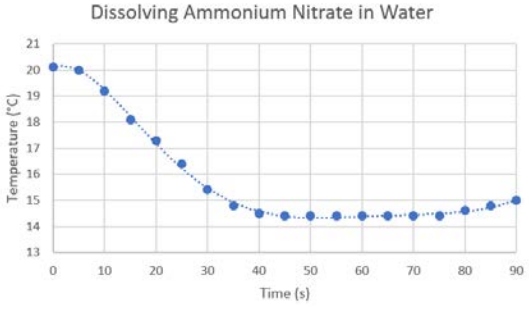
b. Determine $\Delta H_{neutralization}$ for the reaction, expressed as "kJ/mol rxn".

15. A student was asked to determine the heat of reaction for the precipitation of lead(II) iodide, by the reaction shown below. He mixed in a coffee cup calorimeter 50.0 g of a solution containing 6.62 g of $Pb(NO_3)_2$ with a 50.0 g of a solution containing 6.00 g of NaI. The initial temperature in both solutions was 21.2°C. The final temperature after the precipitation reaction is 24.4°C. Assume the specific heat capacity of the mixture is the same as that of water.

$Pb(NO_3)_{2(aq)} + 2\ NaI_{(aq)} \rightarrow PbI_{2(s)} + 2\ NaNO_{3(aq)}$

a. Calculate the heat evolved in the reaction.

b. Calculate the ΔH for the reaction, expressed as "kJ/mol rxn".



16. A student designed an experiment to measure the heat of solution for ammonium nitrate – a common ingredient in cold packs. She added solid NH_4NO_3 to water in a coffee cup calorimeter that was placed on a magnetic stirrer to mix the contents. She used a sensor to measure the temperature change and obtained the graph shown above.

$NH_4NO_{3(s)} \rightarrow NH_4^{+}{}_{(aq)} + NO_3^{-}{}_{(aq)}$

Data: Heat of Solution for NH_4NO_3

Mass of Empty Coffee Cup	63.71 g
Mass of Cup with Water	88.73 g
Mass of NH_4NO_3 dissolved	2.00 g

a. From the graph, estimate ΔT for the experiment.

b. Is the dissolving of ammonium nitrate exothermic or endothermic? Explain.

c. Calculate the heat during this experiment.

d. Calculate the molar heat of solution for NH_4NO_3, expressed as "kJ/mol rxn".