HEATS OF REACTION: CALORIMETRY

SPECIFIC HEAT CAPACITY (c)

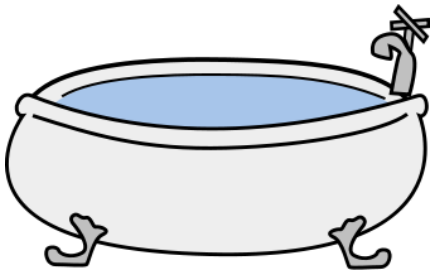
- energy needed to raise temperature of 1 gram of a substance by 1°C
- See Table 5.2 on last page
- units -- J/g·°C

Examples: iron -- 0.444 J/g·°C

water -- 4.184 J/g·°C

wood -- 1.76 J/g·°C

HEAT CAPACITY



- depends on mass of substance
- units ignore the mass -- kJ/°C
- the 2 samples of water have the same **specific heat capacity**
- water in the tub has a larger **heat capacity** than water in the cup

1. $Q = mc\,\Delta T$ -- used for water surroundings

where Q = heat or energy (J)

m = mass (g)

c = constant specific heat cap.

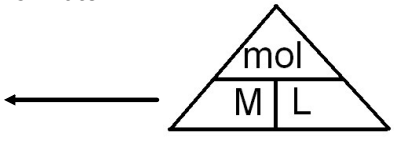
ΔT = change in temperature = $T_f - T_i$ (°C)

2. $Q_{reaction} = -Q_{insulated\ surroundings}$ (use for energy released by the reaction)

- **heat released** (exothermic reaction) = **- heat gained** (surroundings)
- chemical reaction is balanced
- insulated surroundings are usually the water

1 mL of water (or dilute solution) -- 1 gram of water

3. $\Delta H = \dfrac{Q_{reaction}}{n_{reactant}}$



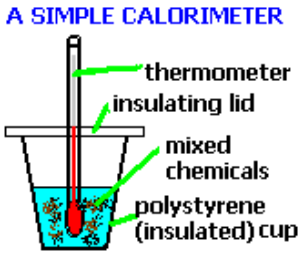
ONLY for aqueous solutions (Not for gases)

- usually have to convert grams of reactant to moles (using molar mass)
- based on number of moles of of a reactant
- units expressed in kJ/mol
- also may need to convert concentrations to moles if reactants are solutions

EXAMPLE 1: How much heat is required to warm 0.100 kg of ethanol from 20.0°C to 60.0°C?

EXAMPLE 2: What is the final temperature if 0.200 kg of water at 30°C when 12 600 J of heat is released from it?

COFFEE CALORIMETRY



EXAMPLE 3:

100 mL of water is placed in a coffee cup calorimeter. The temperature of the water is 14.4°C. A mass of 0.412 g of calcium metal is placed in the calorimeter. When the reaction is complete, the temperature of the solution is 24.6°C. Calculate the enthalpy change (in kJ/mol) for this reaction:

$$Ca_{(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(s)} + H_{2(g)}$$

V of H_2O =

T_i =

T_f =

m_{Ca} =

Energy Lost by Ca = Energy Gained by water

EXAMPLE 4: $CuSO_{4(aq)} + 2NaOH_{(aq)} \longrightarrow Cu(OH)_{2(s)} + Na_2SO_{4(aq)}$

50.0 mL of 0.300 mol/L $CuSO_4$ solution is mixed with an equal volume of 0.600 mol/L NaOH. The initial temperature of both solutions is 21.4°C. After mixing the solutions in a coffee-cup calorimeter, the highest temperature reached is 24.6°C. Determine the enthalpy change and write the thermochemical equation.

EXAMPLE 5: 50.0 mL of 0.100 M H_2SO_4 reacts with 75.0 mL of 0.050 M NaOH in a coffee cup calorimeter. If the temperature increased by 14.3°C, determine the enthalpy change.

EXAMPLE 6: 0.500 g of iron metal was heated to 80.0°C, then dropped into 100.0 mL water (at 22.0°C). What is the final temperature?

Table 5.2 Specific Heat Capacities of Selected Substances

Substance	Specific heat capacity (J/g • °C at 25°C)
Element	
aluminum	0.900
carbon (graphite)	0.711
hydrogen	14.267
iron	0.444
Compound	
ammonia (liquid)	4.70
ethanol	2.46
ethylene glycol	2.42
water (liquid)	4.184
Other material	
air	1.02
concrete	0.88
glass	0.84
wood	1.76

Practice Problems

5. A sample of ethylene glycol, used in car radiators, has a mass of 34.8 g. The sample liberates 783 J of heat. The initial temperature of the sample is 22.1°C. What is the final temperature?
6. A sample of ethanol, C_2H_5OH, absorbs 23.4 kJ of energy. The temperature of the sample increases from 5.6°C to 19.8°C. What is the mass of the ethanol sample? The specific heat capacity of ethanol is 2.46 J/g • °C.
7. A child's swimming pool contains 1000 L of water. When the water is warmed by solar energy, its temperature increases from 15.3°C to 21.8°C. How much heat does the water absorb?
8. What temperature change results from the loss of 255 kJ from a 10.0 kg sample of water?

Practice Problems

9. A chemist wants to determine the enthalpy of neutralization for the following reaction.

   $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(\ell)}$

   The chemist uses a coffee-cup calorimeter to neutralize completely 61.1 mL of 0.543 mol/L $HCl_{(aq)}$ with 42.6 mL of $NaOH_{(aq)}$. The initial temperature of both solutions is 17.8°C. After neutralization, the highest recorded temperature is 21.6°C. Calculate the enthalpy of neutralization, in units of kJ/mol of HCl. Assume that the density of both solutions is 1.00 g/mL. Also assume that the specific heat capacity of both solutions is the same as the specific heat capacity of water.

11. Nitric acid is neutralized with potassium hydroxide in the following reaction.

$HNO_{3(aq)} + KOH_{(aq)} \rightarrow KNO_{3(aq)} + H_2O_{(\ell)} \quad \Delta H = -53.4$ kJ/mol

55.0 mL of 1.30 mol/L solutions of both reactants, at 21.4°C, are mixed in a calorimeter. What is the final temperature of the mixture? Assume that the density of both solutions is 1.00 g/mL. Also assume that the specific heat capacity of both solutions is the same as the specific heat capacity of water. No heat is lost to the calorimeter itself.

12. A student uses a coffee-cup calorimeter to determine the enthalpy of reaction for hydrobromic acid and potassium hydroxide. The student mixes 100.0 mL of 0.50 mol/L $HBr_{(aq)}$ at 21.0°C with 100.0 mL of 0.50 mol/L $KOH_{(aq)}$, also at 21.0°C. The highest temperature that is reached is 24.4°C. Write a thermochemical equation for the reaction.