Experiment 25 – Calorimetry (Enthalpies and Specific Heats)

Pre-Lab Hints

1. Explain how the temperature of the metal and the water bath become equalized, and how that final equalized temperature is measured.
2. Heat loss causes a lower T_f. Examine Figure 25.5 and read the label over the line to see the overall effect on T_f. Consider how that heat loss affects ΔT_{H2O} ($T_f - 21\ ^oC$) and ΔT_M ($T_f - 100\ ^oC$) in problem 4. Then, determine how those changes affect the result for s in equation 25.5.
3. Note that all three trials used at least as much acid as base, so that the total moles reacted in each trial is the same as the initial moles of base. Therefore, all three reactions will create the same amount of heat (q). Find the combined mass, based on the total water volume, for each of the three trials, then refer to equation 25.8.
4. Line 1 Use equation 25.6 with $T_f = 24.6\ ^oC$.
   Line 2 Use equation 25.2 with s = 4.18 J/g•°C for water.
   Line 3 Use equation 25.6 with $T_f = 24.6\ ^oC$. The result is negative.
   Line 4 Use equation 25.5 along with the result from Line 2.
   The result is positive and less than 1.
5. Line 2 Divide mass of salt by the molar mass of KBr to get the moles.
   Line 1 Use values provided in Part 2 (line 7 minus line 6). The result is negative.
   Line 2 Use equation 25.2 with s = 4.18 J/g•°C for water. The result is negative.
   Line 3 Use equation 25.2 with the value provided for the specific heat (s).
   Use the mass of salt provided in Part 2.
   ΔT is the same (negative value) for both the salt and the water.
   Line 4 Ignore equation 25.11. Find the sum of heat changes in Line 2 and Line 3.
   Line 5 Divide Line 4 by moles of salt from Part 2. See equation 25.12.
   The result is negative.

Procedure Notes

- Copy unknown number for part A. The number will have either one or three digits.
- Use a hot plate, not a Bunsen burner, for part A.
- Tap water is acceptable for part A.
- After each trial, dry the metal, and then either reuse it or put it back in its container.
- Graphing is not necessary. Use the highest temperature recorded for all T_{max} values.
- Skip the acid's temperature measurement in step B1. Use the base's temperature from step B2 for both temperatures in lines B2 and B4 of your report sheet.
- Clean and dry the thermometers after the experiment.
  Then, return them to the supply bench.
- Rinse the used coffee cups and place them in dirty glassware bins after the experiment.
- Pour the water from part A down the drain.
- Place the reaction mixture from part B in the waste container.
- Skip part C entirely.

Calculations

- In the part A, $\Delta T_{water} = T_F - 21\ ^oC$ (positive) and $\Delta T_{metal} = T_F - 100\ ^oC$ (negative).
- Note that the sign change in equation 25.5 will make your specific heat positive.
- In part B, use equation 25.8 with combined solution mass to determine the heat evolved.
- OH^{-1} moles are found by multiplying NaOH volume (in L) times its molarity (mol/L).
- Use equation 25.7 for the amount of water formed (two time OH^{-1} moles).
- ΔH value in kJ per mole of water is negative and is equal to the heat evolved divided by moles of water formed.
- Please provide calculations for all trials on a separate sheet of paper. Include all units and conversion factors.

Lab Questions

1. Suppose that your metal sample in part A gets wet while heating it, and this water from the hot water bath is added to your calorimeter along with the hot metal. Explain how this water affects your final temperature.

2. Suppose that your metal sample contains an impurity that increases its specific heat. Refer to equation 25.5. How does this change ΔT_{H2O}? How does this change the magnitude of ΔT_M? What happens to your final temperature (T_F)?

3. Suppose that you use HNO_2 (nitrous acid), a weak acid, instead of HCl in part B. The net ionic equation is different from equation 25.7 because a weak acid does not fully dissociate. So, $HNO_{2(aq)}$ is written as a molecule on the reactant side of the net ionic equation. Write this net ionic equation. Explain why the acid-base reaction of HNO_2 with NaOH and the reaction of HCl with NaOH would have different enthalpies and temperature changes.

4. The coffee cup calorimeter is not a perfect insulator as it can (slowly) absorb heat. Suppose your acid-base reaction in part B increases the temperature of both the solution and the styrofoam from 21.0 ^oC to 30.5 ^oC, and that the styrofoam has a mass of 3.00 g, and a specific heat of 1.34 J/g·^oC. Use q = smΔT to calculate the heat absorbed by the styrofoam calorimeter and show all units in your equation. Also, explain how the absorption of heat by the calorimeter affects the final temperature.

5. The 1.00 M NaOH solution is the limiting reagent in part B. Determine the moles of NaOH used in one trial. Then, calculate the volume of 1.10 M HCl that is actually needed to neutralize the NaOH. Explain what would happen to the heat evolved and to the final temperature if more than that amount of HCl solution was used.