Chemistry 2720 Fall 2005 Quiz 1 Solution

There are lots of ways to go about this. Here are two:

1. We can use an experiment similar to the one used in class for a solid sample:

   (a) Get a test tube with a tight-fitting stopper which is impermeable to water *and* to the sample. (Hopefully, you've been told *something* about the chemical nature of the sample. Otherwise, it's very difficult to devise a safe experiment.)

   (b) Weigh the dry test tube and stopper.

   (c) Fill the test tube $\frac{2}{3}$ full with water and stopper it. Weigh the tube to determine the mass of water.

   (d) Warm the test tube to a known temperature (e.g. in a constant temperature water bath). I would suggest that 40°C would be a good temperature for this experiment. At much higher temperatures, the vapor pressure of water might blow our stopper off!

   (e) While the test tube is warming, weigh out a volume of water into an adiabatic container (e.g. a styrofoam container) which is sufficient to almost completely immerse the tube. Start monitoring the temperature of the water in the adiabatic enclosure.

   (f) Clamp the tube in the calorimeter up to (but not over) its neck. Monitor the temperature to measure the temperature change.

   (g) Using the data collected, we can determine the heat capacity of the test tube. (In practice, the number we calculate will include contributions from the clamp, etc. The point is to do the experiment as similarly as possible both times so that these systematic errors cancel out. Furthermore, we would try to use materials like plastic which have smallish heat capacities relative to the test tube to minimize systematic errors.) The calculation is based on the equation

   $$C_{P(\text{tube})}(T_f - T_b) + m_{\text{H}_2\text{O sample}}\tilde{C}_{P(\text{H}_2\text{O})}(T_f - T_b) + m_{\text{H}_2\text{O cal}}\tilde{C}_{P(\text{H}_2\text{O})}(T_f - T_i),$$

   where T_f is the final temperature, T_b is the bath temperature, and T_i is the initial temperature of the water in the calorimeter (adiabatic enclosure).

   (h) Now empty and dry the test tube. Fill it $\frac{2}{3}$ full with the sample liquid, weigh it, and repeat the above procedure. The data will now be sufficient to determine the heat capacity of the liquid. Our equation is now

   $$C_{P(\text{tube})}(T_f - T_b) + m_{\text{sample}}\tilde{C}_{P(\text{sample})}(T_f - T_b) + m_{\text{H}_2\text{O cal}}\tilde{C}_{P(\text{H}_2\text{O})}(T_f - T_i).$$

   The only unknown in this equation is now the specific heat capacity of the sample.

   This is pretty crude, and if we wanted accurate results, we would surely have to take several additional factors into account, but this would give you a decent figure provided your calorimeter has a negligible heat capacity (i.e. it's made from foam or light plastic).

2. If the liquid isn't too volatile or flammable or explosive, there is a slightly simpler experiment:

   (a) Measure the resistance of a sealed electric heating element.

   (b) Put a weighed amount of the sample into an insulated container. There should be enough sample to completely cover the heating element.

   (c) Install a thermometer in the container.

   (d) Start a timer.

   (e) Apply a constant (known or measured) voltage to the heating element. Record the temperature vs heating time.

   (f) Since the electric power is $P = V^2/R$, the total electrical work done is $w = Pt = V^2t/R$. This is completely converted to heat, q. Thus the calculation becomes as simple as $\tilde{C}_P = q/(m\Delta T) = V^2t/(mR\Delta T)$.

   If you needed to worry about the heat capacity of the container, which you would if your container were made of, e.g., glass, then you could carry out the above procedure with a known amount of water, work out the heat capacity of the container from that experiment, and then work that into your calculation for the heat capacity of the unknown. I leave you to work out the details of such a procedure as an exercise.