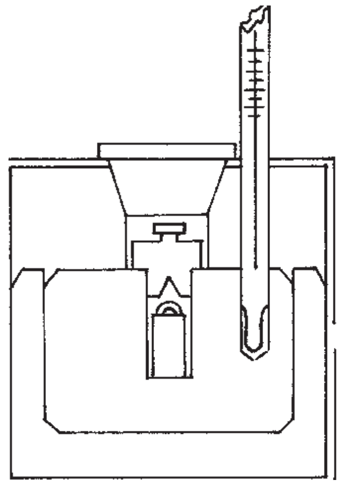
612-1330 (15-120) Aneroid Calorimeter Instructions and Applications

Introduction:

A calorimeter is typically used to determine heat coefficients - specific heat, of fusion and heat of vaporization - in the laboratory. For best results, it is important that the calorimeters themselves lose a little heat as possible.

This aneroid (dry) calorimeter is five times as sensitive as a convention calorimeter with water. Heat loss is minimal; it is safe and easy to store.



Cross section of 15-120 with thermometer

Aneroid Calorimeter *instructions written by Dr. A.Z. M. Ismail, Professor of Physics, Daemen College, Amherst, N.Y.*

Description:

15-120 Aneroid Calorimeter consists of 6 cm aluminum core with 2.5 cm diameter hole into which samples are inserted. An aluminum plug closes the top of cup. A special bore in the aluminum core holds thermometer as shown. The core is surrounded by styrofoam insulation which forms the "outer cup" and is closed by an insulated plug. Entire device is encased in plastic protector.

Additional Materials Needed:

- **612-1332 Specific Heat Specimens** 5 specimens of equal volume designed to fit this Calorimeter's core from Science First®
- **Thermometer** Partial Immersion Mercury thermometer recommended.
- **612-1300 Steam Generator** from Science First®
- **Stopwatch**
- **612-1331 Calorimeter Resistor** from Science First®. *To determine the electrical equivalent of heat.*

Important! We weigh the Calorimeter Core during manufacturing and indicate the weight to the nearest 5 grams (1% accuracy) on Calorimeter housing. If greater accuracy is desired, reweigh the core yourself.

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may containsmall parts that can be choking hazards. Adult su**pervision is required.**

Heat Loss Considerations

The familiar calorimeter has changed little over the last century. Heat losses remain high. They depend upon the cleanliness of their surfaces and can vary threefold in amount.

The Aneroid Calorimeter, however, uses no liquid and has no stirring or evaporation factors to consider. Temperature errors are minimal since the calorimeter core has a water equivalent of about 100 grams compared to about 300 grams in the conventional calorimeter. Heat loss due to radiation and convection are insignificant. Heat loss due to conduction is the only significant factor.

Corrections for heat loss with time are similar for either calorimeter except that temperature changes are slower in the **15-120**. This can be an advantage since the temperature data is recorded more accurately at a leisurely rate of change. The significance of corrections is therefore more readily apparent.

Experimental verification of the **Law of Dulong and Petit** using a conventional calorimeter and con- ventional 60 g specific heat specimen is usually unsatisfactory due to small temperature rise obtained from the high atomic weight metal samples and the attendant experimental error.

[This can be countered by using **612-1332 Specific Heat Specimens**, manufactured by **Science First®**, sized to completely fill the cavity of the core. This results in temperature rises of up to 5° C in the calorimeter.]

Since a mercury in glass laboratory thermometer has graduations of 1° and readings can be estimated to the tenth, it is possible to limit temperature errors to about 2%.

The **15-120** is about the same size and shape as the conventional calorimeter. Although different in construction, it yields similar data and responds to same correction procedures. Its advantages are larger temperature rises and smaller heat losses. Its disadvantage is slower thermal equilibrium.

Since **15-120** uses foam insulation, the cooling process is a combination of conduction and absorption which is less linear than loss due to conduction with radiation. The discrepancy is small compared to other sources of error and the usual correction for heat loss error can be applied with good results.

Thermometer Errors

Thermometers cannot provide exact temperature due to limitations of construction and techniques of use. Where temperatures are gradually changing, thermometers indicate temperatures that are not quite current (not updated.)

The easiest check points are freezing point and boiling point of water. Even here you must take care since both points change with barometric pressure. The freezing point varies less than .001°C with normal air pressure changes, but the boiling point may change up to 1°C in severe weather. Since air pressure is dependent on elevation, this factor must also be considered.

If a thermometer has graduations for each degree, it is easy to read it correctly to within 1° unless the meniscus is nearly midway between graduations. If you improve accuracy by estimating the meniscus position, you may be able to read the thermometer to within 0.1°. Be careful to hold the thermometer perpendicular to the line of sight. You may wish to have a few thermometers in a thermos bottle of tepid water so students can compare their observations.

If you plunge a thermometer in ice water, it will not immediately indicate 0° C. If correct, it will in time do so but in the meantime heat must be removed from the mercury inside the thermometer through the glass to the ice water. The thermometer bulb is made of thin glass which allows rapid heat flow, and the thermometer changes rapidly. The glass stem gradually shrinks upon cooling causing the mercury to rise slightly. All these factors cause the thermometer to respond slowly to change.

Do not accept thermometer readings as accurate unless two or more readings agree. Where temperatures are continually changing, employ special methods to correct the observed value for the errors introduced by temperature changes.

Theory

Heat and Temperature

All matter is made of atoms which may form molecules and be strongly bound together in the form of crystals (solids) or be loosely bound (liquids) or be unbound (gases). Whatever the structure, the constituents are always in one or the other of the three kinds of motion; translational, rotational and vibrational. Such motion imparts kinetic energy to atoms and molecules. Thus atoms and molecules of a substance or object have an average kinetic energy. This average kinetic energy is **heat** energy and is measured in terms of **temperature.** Temperature is, therefore, a measure of the average kinetic energy of atoms and molecules of a substance or object. Heat energy, on the other hand, is the total kinetic energy present in that substance or object. A glass of water will have far less heat energy compared to the water in a lake. But the two may be at the same temperature.

If heat energy be incident on a system from outside, then this energy penetrates down to the individual atoms and molecules of the system and causes the average kinetic energy to increase, raising the temperature of the system. Again, if two substances or assembly of substances, initially at different temperatures be brought together, energy will flow from one at higher temperature to one at lower temperature until both are at the same (equilibrium) temperature. This phenomenon is called **heat flow.** The average kinetic energy of all parts of the system becomes equal; and the common temperature is called **equilibrium temperature.**

Thermal Equilibrium

Being kinetic in nature, heat is energy in motion. It is therefore natural to ask how an object or system can remain at a constant temperature. Being at constant temperature implies that heat energy of the system is constant. This, in turn, implies that heat energy is stagnant i.e. not in motion.

This is not true. Heat energy is always in motion. An object or system is continually receiving heat energy from its neighbors (surroundings) and is continually giving away heat energy to the neighbors. This give and take continues and the average kinetic energy of the system and neighbors becomes equal. The process of heat flow does not end here. The amount of heat energy coming in matches the amount of heat energy going out and an equilibrium condition is reached. Every two or more objects are at the same temperature, heat energy exchange has not stopped; such objects or systems are, in face, in **thermal equilibrium** with one another.

Specific Heat

Two or more objects or systems may be at the same temperature but may not hold the same amount of **total** heat energy. Besides depending on the temperature, the total heat energy content of an object depends on its mass. The greater the mass, the greater the heat energy accommodated in it. In addition, heat energy present in an object also depends on the nature of the substance of which the object is made. A mass of copper will hold more heat energy (in equilibrium with its surroundings) than an equal mass of lead at the same temperature. This shows that copper has holds heat energy better than lead. The capability or capacity of a substance to hold heat energy leads to the property **specific heat.**

Let ‘Q’ be heat energy contents (in joules) of an object. Then:

Q is proportional to m, and
Q is proportional to T
Combining:
Q is proportional to mT

Introducing a constant of proportionality:

Q = mcTc

Here **'c'** is **specific heat** of material of the object. If the temperature of the object changes (on account of influx of heat energy from outside or its exodus to the surroundings) then total heat content of the object will change and so will its temperature. Writing Q and T respectively, we get:

Q = mc △ T

From the above expression we may redefine specific heat as **the amount of heat energy** (in joules) **required to raise the temperature of one kilogram of a substance one degree Celsius.**

The units of c are J/°CKg.

Conservation of Heat Energy

The law of conservation of energy requires that energy in all forms be conserved, provided prerequisites are met. The prerequisite is that the system under investigation be isolated from its surroundings and does not import or export energy. For heat energy, conservation, the prerequisite, will translate into the system being thermally isolated from its neighbors. If different constituents of such a system are at different temperatures then heat redistribution will occur to establish an equilibrium temperature. In the process those constituents of the system at higher temperatures will lose energy to those that were at lower temperature. Heat energy given away by some must equal that received by others. Call the higher temperatures $T_{(hot)}$, lower temperatures $T_{(cold)}$ and the final equilibrium temperature $T_{(eq)}$. Then eat lost or gained is expressed as:

For m and n, constituents of the system losing and gaining heat energy, we shall have, from the law of conservation of energy:

$$Q_{lost} = m_{hot}c_{hot}(T_{hot} - T_{Eq})$$

$$\Delta Q_{gained} = m_{cold}c_{cold}(T_{Eq} - T\ )$$

$$\sum_m \Delta Q_{lost} = \sum_n \Delta Q_{gained}$$

$$\sum m_{hot}c_{hot}(T_{hot} - T_{Eq}) = \sum m_{cold}c_{cold}(T_{Eq} - T\ )$$

Determination of Heat Capacity

Procedure:

1. Find the mass of calorimeter cup and that of the given metal. Call them m (cup) and m (metal).
2. Pour cold water (about 10° C) in a beaker or other suitable container. We suggest you get chilled water from a refrigerator or drinking fountain which has run for about half a minute.
3. Place calorimeter cup in zip-sealed plastic bag and dip in cold water for about 5 minutes.
4. Place the given metal in the water in the boiler and start heating system to boil water.
5. Remove cup from beaker and place in foam jacket. Insert thermometer and wait for it to reach minimum temperature. If thermistor probe is used, let it reach maximum resistance.
6. When temperature does not decrease further and shows signs of rising, start stop watch and record the (minimum) temperature against 'zero' time. Record temperature at intervals of one minute for the next 10 or 15 minutes.
7. Boil water for a couple minutes so that it is in equilibrium with steam, ensuring a temperature of 100° C.
8. Transfer metal to calorimeter cup. Lift it with tongs and, while still in steam, shake it gently and carefully to remove as much water as possible. Record time and temperature of calorimeter cup. Removing lid of cup, transfer metal and replace lid and foam cover.
9. Record temperature every 20 seconds for next 5 minutes; every 30 sec for following 5 minutes; every minute for next 5 -10 minutes. Total duration of recording temperatures should be between 25 and 35 minutes.

10 Turn off boiler after metal has been transferred. Stop watch should be stopped and reset, **since no further temperature measurements are needed.**

Further Suggestions:

In addition to determining the specific heat coefficient as in the above experiment, you can use the Aneroid Calorimeter to determine latent heats of fusion and evaporation.

How To Teach with Aneroid Calorimeter

Concepts: Quantity of heat vs Temperature; specific heat of substances; Determination of sp. heat; Method of Mixtures (calorimetry); Latent heat of fusion; of evaporation. Conservation of energy; Mechanical equivalent of heat; Electrical equivalent of heat; Heat of a chemical reaction.

Curriculum Fit: PS/Energy, Unit: Energy Conservation: Grades 9-10. Unit: Energy Conservation and Phase Change; Grades 9-12. Unit: Energy Transform ations, Grades 11-12.

Related Products and Accessories:

612-1331 Calorimeter Resistor - New! A foolproof way to determine Electrical Equivalent of Heat. Includes 18 ohm resistor; 2 clip leads, instructions, caplug and rubber stopper.

612-1300 Steam Generator - For generating steam to heat specific heat specimens such as 15-060.

612-1332 Specific Heat Specimens - 5 specimens representing all major groups of Periodic Table: cadmium, lead, zinc, aluminum, copper. With machined hooks. Designed to fit in Aneroid Calorimeter Core.

015-0300 Linear Expansion - Determine thermal expansion of 4 different metal rods. Works with warm tap water.

Check out our website at www.sciencefirst.com Download instructions and product information.

Illustration Experiment:

Total weight of calorimeter and cover
= 450 g
Sample material: Aluminum alloy
Heat capacity of this alloy
= 0.214 Cal./g °C
Water equivalent of calorimeter
= (450g)(0.214 cal/g° C)

Determine approximate temperature before adding the sample by extrapolating the temperature reading from 1:10 P.M. forward to 1:21 P.M. (time of sample addition) and 1:45 P.M back to 1:21 P.M. to obtain temperatures 20.3° C and 25.7°C respectively. These are mainly correct.

Next, determine the average of these two temperatures (23.0° C); and from the graph determine the time associated with the temperature (about 1:22 P.M). Extrapolate the initial temperature readings forward to 1:22 P.M. And the later readings back to 1:22 P.M.

This simple correction procedure assumes that all delay in heat flow occurs at the thermometer. This is not strictly correct; were a more precise thermometer employed, a more accurate correction procedure would be justified. The temperature resulting from the extrapolations to 1:22 are 20.3°C and 25.7°C. These readings are as close to correct as you can get considering thermometer limitations.

The heat capacity (C_p) of sample is calculated as:

Cp = (Water equivalent) x (Temp. rise of calorimeter) (Wt. of sample) x (Temperature change of sample)

$$= \frac{110\text{g. Cal/°C } (25.7° \text{ C} - 20.3° \text{ C})}{36.2 \text{ g } \; (99.5° \text{ C} - 25.7°\text{C})}$$

$$= \frac{(110)\ (5.4)\ \text{g° cal}}{(36.2)\ (73.8)\ \text{g° C}}$$

$$= \frac{594}{2671.56} \text{ cal/° C}$$

$$= 0.222 \text{ cal/° C}$$

P/N 24-15120

Analysis

Data obtained in the experiment is plotted as variation of resistance of thermistor with respect to time.

A typical plot shows

(a) a linear temperature variation (with respect to time) before hot metal is transferred to calorimeter cup

(b) nonlinear temperature variation after calorimeter cup and metal have reached an equilibrium temperature. Draw best fit lines.

Let region (b) extend from t_1 to t_2. Select midpoint of range and draw vertical line. Straight lines from regions (a) and (c) are then extrapolated to meet this vertical line at points p_c and p_{eq} respectively.

R_c and R_{eq} are then read off the y-axis against these two points and converted to T_c and T_{eq}.

All masses and temperatures have now been experimentally determined.

Knowing the specific heat of aluminum (0.214 cal/ g°C), one can solve the equation for specific heat of the given metal.

TIME (p.m.)	TEMPERATURE (°C)	OBSERVATIONS/NOTES
1:00	20.2	
1:07	20.2	
1:15	20.3	
1:17	20.3	
1:20	20.3	
1:21	→	Sample added: Temp. 99.5°c
1:22	23.5 (approx)	
1:23	24.5 (approx)	
1:24	25.2	
1:26	25.4	
1:27	25.5	
1:28	25.5	
1:29	25.5	
1:31	25.4	
1:33	25.4	
1:36	25.3	
1:38	25.2	
1:40	25.1	
1:45	25.0	
1:50	24.9