Experiment #13

Heat Transfer

OBJECT:

EQUIPMENT:

- Thermometers
- Beakers
- Heat Source
- Styrofoam Cups
- Tin Can
- Aluminum Can
- Plastic Cup
- Lids
- Specific Heat Capacity Samples
- Stopwatch

RECOMMENDED ITEMS TO BRING:

- Kitchen Mittens (to protect your hand)
- Electric pot (to heat water)

General Directions:

A: Newton's cooling law

Before the actual lab, **create a prediction section next to the procedure**. Also, predict as a group which cup has the highest "k", and discuss why the group thinks so.

1. Measure the room temperature.
2. Heat water to almost boiling.
3. Pour water into a Styrofoam cup, a plastic cup, an aluminum cup, and a tin cup and put lids on them.
4. Measure the water temperatures when t = 0 sec.
5. Measure the water temperatures every 10 minutes for one hour.
6. Using Newton's cooling law, calculate theoretical temperatures.
7. Graph both actual and theoretical values on a temperature vs. time graph for each sample.
8. Discuss how cooling rates differ for different samples including the group prediction and the result. If they are not the same, why they are different.
9. Calculate % errors and discuss why there may be differences.

B: Mixing of two different water volumes & temperatures

1. Collect two sets of water with different volumes and temperatures in beakers, and record their volumes and temperatures.

2. Pour the both beakers of water into a doubled Styrofoam cup and put a lid on it.

3. Measure the equilibrium temperature and record it.

4. Calculate the theoretical temperature of the mix.

5. Calculate the % error, and discuss possible causes of errors.

C: Mixing of water and other materials

1. Measure densities of the specific heat capacity samples, and determine the metals from their densities (http://www.reade.com/Particle_Briefings/spec_gra.html is a big help).

Use the following numbers as Metal ID:

1: Gold color
2: Silver color
3: Rusted color
4: Dull silver color

2. Heat up water. When the water is hot, lower the specific heat capacity samples into the water (DO NOT DROP THEM!). Record the water temperature (you will have to wait for a while until the samples become the same temperature as the hot water.)

3. Pick up one sample from the hot water and submerge it into the water of known volume and temperature in a doubled Styrofoam cup. Put a lid over it.

4. When the system reaches thermal equilibrium, record the temperature.

5. Repeat 2 – 4 for other samples.

6. Calculate the specific heat capacity of the sample from the data, and determine the samples.

7. Discuss the results including possible causes of errors.

Note: Since the silver color metal is pure silver and the gold color metal is pure gold, please do not take them home with you. They are very expensive and our department is poor as you know.

Specific Gravity Table For Ceramics, Metals & Minerals

Substance / Specific Gravity

Alumina	**~ 3.4 - 3.6**
Aluminum, cast-hammered	**2.55 - 2.80**
Antimony	**6.68**
Baryte / Barite	**4.25**
Barium	**3.62**
Barium sulfate	**4.5**
Bentonite	**2.4**
Beryllium	**1.848**
Bismuth	**9.79**
Boron	**2.34**
Brass, cast-rolled	**8.4 - 8.7**
Bronze, aluminum	**7.7**
Bronze, 7.9 - 14% Sn	**7.4 - 8.9**
Bronze, phosphor	**8.88**
Calcium carbonate	**2.7**
Carbon	**2.26**
Cement	**3.0**
Cerium	**6.77**
Cesium	**1.873**
Chromium	**7.19**
Chromium dioxide (Cr203)	**5.22**
Chromium oxide (Cr02)	**4900 kg m^{-3}**
Clays	**2.6**
Coal slag	**2.7**
Cobalt	**8.92**
Copper, cast-rolled	**8.8 - 8.95**
Copper ore, pyrites	**4.1 - 4.3**
Diamond	**2.26**
Dolomite	**2.9**
Dysprosium	**8.55**
Erbium	**9.066**
Europium	**5.244**
Ferrosilicon- 15%	**6.7-7.1**

Flint stones/ pebbles	**2.4 - 2.6**
Gadolinium	**7.9**
Gallium	**5.91**
Germanium	**5.32**
German silver	**8.58**
Glass beads	**2.5**
Gold, cast-hammered	**19.25 - 19.35**
Gold coin (U.S.)	**17.18 - 17.2**
Gold, pure	**19.32**
Gypsum	**2.3**
Hafnium	**13.31**
Hematite, specular	***5.4***
Holmium	***8.795***
Ilmenite	**4.5- 5.0**
Indium	**7.31**
Iodine	**4.93**
Iridium	**21.78 - 22.65**
Iron carbonate	**3.9+**
Iron, gray cast	**7.03 - 7.13**
Iron, cast, pig	**7.2**
Iron, wrought	**7.6 - 7.9**
Iron, spiegeleisen	**7.5**
Iron, ferrosilicon	**6.7-7.3**
Iron ore, hematite	**5.2**
Iron, ore, limonite	**3.6 - 4.0**
Iron ore, magnetite	**4.9 - 5.2**
Iron ore, specular	**5.4**
Iron slag	**2.5 - 3.0**
Lanthanum	**6.17**
Lead	**11.34**
Lead ore, galena	**7.3 - 7.6**
Lead oxide (yellow)	**9.5 - 9.9**
Limestone	**2.8**
Lithium	**0.53**
Lutetium	**9.84**
Magnesium	**1.738**
Manganese	**7.35**
Manganese ore, pyrolusite	**3.7 - 4.6**

Mercury	**13.534**
Molybdenum	**10.22**
Monel metal, rolled	**8.97**
Mullite beads	**2.8**
Neodymium	**7.00**
Nickel	**8.9**
Niobium	**8.57**
Osmium	**22.61**
Palladium	**12.02**
Phosphorus	**2.34**
Platinum	**21.5**
Potassium	**0.856**
Praseodymium	**6.77**
Quartz sand	**7.00**
Rhenium	**21.02**
Rhodium	**12.41**
Rubidium	**1.532**
Ruthenium	**12.45**
Salt	**2.2**
Samarium	**7.52**
Sand, silica	**2.6**
Sand, Quartz	**7.0**
Scandium	**2.989**
Selenium	**4.28**
Sialon	**3.26**
Silicon	**2.33**
Silicon carbide	**3.1**
Silicon nitride	**3.2**
Silver, pure	**10.4 - 10.6**
Sodium	**0.968**
Steatite beads	**2.6 - 2.7**
Steel, carbon	**7.8**
Steel, chrome	**7.8**
Steel, cold-drawn	**7.83**
Steel, machine	**7.80**
Steel, 440C stainless	**7.7**
Steel, tool	**7.70 - 7.73**
Strontium	**2.64**

Sulfur	**2.07**
Tantalum	**16.69**
Tellurium	**6.24**
Terbium	**8.27**
Thallium	**11.85**
Thulium	**9.32**
Tin, pure	**7.2 - 7.5**
Tin ore, cassiterite	**6.4 - 7.0**
Titanium	**4.506**
Titanium dioxide, Anatase	**3.77**
Tin, 100% Pure	***7.29***
90 Sn & 10 Pb	***7.54***
63 Sn & 37 Pb	***8.42***
60 Sn & 40 Pb	***8.52***
50 Sn & 50 Pb	***8.89***
10 Sn & 90 Pb	***10.50***
5 Sn & 95 Pb	***11.00***
Tungsten	**19.25**
Tungsten carbide	**14.29**
Uranium	**18.7**
Vanadium	**6.11**
Water, fresh	**1.0**
Ytterbium	**6.97**
Yttrium	**4.47**
Zinc, cast-rolled	**6.9 - 7.2**
Zinc, ore, blend	**3.9-4.2**
Zirconia, stabilized (MgO)	**5.4**
Zirconia, stabilized (REO)	**6.1**
Zirconia, stabilized (Y203)	**6.0**
Zirconium	**6.506**
Zirconium silicate	**3.85**
Zinc, cast-rolled	**6.9 - 7.2**

Substance	c/J kg^{-1} K^{-1}	Substance	c/J kg^{-1} K^{-1}
Aluminium	900	Ice	2100
Iron/steel	450	Wood	1700
Copper	390	Nylon	1700
Brass	380	Rubber	1700
Zinc	380	Marble	880
Silver	230	Concrete	850
Mercury	140	Granite	840
Tungsten	135	Sand	800
Platinum	130	Glass	670
Lead	130	Carbon	500
Hydrogen	14000	Ethanol	2400
Air	718	Paraffin	2100
Nitrogen	1040	Water	4186
Steam	2000	Sea water	3900

TABLE 12.1

Densities of Common Substances (kg/m^3)

(For density in g/cm^3, divide by 1000)

Solids	Density
Iridium	22,650
Osmium	22,610
Platinum	21,090
Gold	19,300
Uranium	19,050
Lead	11,340
Silver	10,490
Copper	8,920
Brass	8,600
Iron	7,874
Tin	7,310
Aluminum	2,700
Concrete	2,300
Ice	919
Liquids	
Mercury	13,600
Glycerin	1,260
Seawater	1,025
Water at 4°C	1,000
Ethyl alcohol	785
Gasoline	680

SPECIFIC HEAT OF THE ELEMENTS AT 25°C

C_p = cal g^{-1} °K^{-1}

Element	Kelly: Bureau of Mines Bulletin 592 (1961)	Hultgren: Selected values of Thermodynamic properties of Metals and Alloys (1963)	N.B.S. Circular #500 Part 1 (1952)
Aluminum	0.215	0.215	0.2154
Antimony	0.049	0.0495	0.0501
Argon	0.124	......	0.124
Arsenic	0.0785	......	0.0796
Barium	0.046	0.0362	0.0458
Beryllium	0.436	0.436	0.4733
Bismuth	0.0296	0.0238	0.0292
Boron	0.245	......	0.2463
Bromine (Br_2)	0.113	0.0537	
Cadmium	0.0555	0.0552	0.0554
Calcium	0.156	0.155	0.1566
Carbon (Diamond)	0.124	......	0.120
" (Graphite)	0.170	......	0.172
Cerium	0.049	0.0459	0.0442
Cesium	0.057	0.0575	0.0558
Chlorine (Cl_2)	0.114	......	0.114
Chromium	......	0.107	0.1073
Cobalt	0.109	0.107	0.1037
Columbium		See Niobium	
Copper	0.092	0.0924	0.0920
Dysprosium	0.0414	0.0414	
Erbium	0.0401	0.0401	
Europium	0.0421	0.0326	
Fluorine (F_2)	0.197	0.197	
Gadolinium	0.055	0.056	
Gallium	0.089	0.088	0.0911
Germanium	0.077		
Gold	0.0308	0.0308	0.0305
Hafnium	0.035	0.028	0.0344
Helium	1.24	......	1.242
Holmium	0.0393	0.0394	
Hydrogen (H_2)	3.41	......	3.42
Indium	0.056	0.0556	0.0570
Iodine (I_2)	0.102	......	0.034
Iridium	0.0317	0.0312	0.0305
Iron (α)	0.106	0.1075	0.1078
Krypton	0.059	......	0.059
Lanthanum	0.047	0.0479	0.0475
Lead	0.038	0.0305	0.0308
Lithium	0.85	0.834	0.814
Lutetium	0.037	0.0285	
Magnesium	0.243	0.245	0.235
Manganese (α)	0.114	0.114	0.1147
" (β)	0.119	......	0.1120
Mercury	0.0331	0.0333	0.0331
Molybdenum	0.0599	0.0597	0.0584
Neodymium	0.049	0.0453	0.0499
Neon	0.246	......	0.246
Nickel	0.106	0.1061	0.1057
Niobium	0.064	0.0633	
Nitrogen (N_2)	0.249	......	0.249
Osmium	0.03127	0.0310	0.0310
Oxygen (O_2)	0.219	0.219	
Palladium	0.0584	0.0583	0.0590