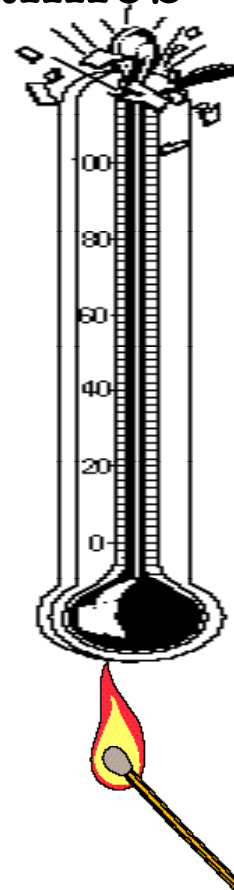
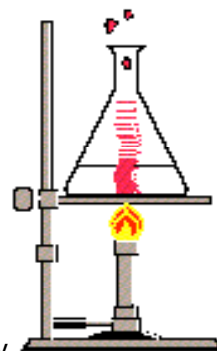


<u>Due Date</u>	<u>Assignment</u>
Thur 1/6	___ Read <u>Calorimetry Lab</u>
Fri 1/7	___ Do <u>WS 7.1</u> ___ Do <u>Calorimetry Lab ?'s</u>
Mon 1/10	___ Do <u>WS 7.2</u>
Tue 1/11	___ Do <u>WS 7.3 #1-12</u>
Wed 1/12	___ Do <u>WS 7.3 #13-17</u> ___ Read <u>Hess's Law Lab</u>
Thur 1/13	___ Do <u>Hess's Law Lab ?'s</u> ___ Read <u>Heats of Combustion Lab</u>
Fri 1/14	___ Do <u>Heats of Combustion Lab ?'s</u>
Tue 1/18	___ Do Lab Write-Up (mass using calorimetry,

# + Packet 7: Thermodynamics

$$q = m c \Delta T$$



--- *the return of Dr. Don Showalter* ---

Thur 1/20 \_\_\_ Do WS 7.4

... Mustard Day ...

$$\Delta G = \Delta H - T\Delta S$$

**free energy**

Fri 1/21 \_\_\_ Do WS 7.5

\_\_\_ Do WS 7.6

\*\*\* Quiz Today \*\*\*

\_\_\_ Come to class with packets ready to be turned in at beginning of class, with the above underlined assignments in order, in your folder, with this page as the cover page.

- For 1/2 point, be sure this packet is inside a **pocket folder**. (no torn folders or 3-ring binders)
- For 1/2 point, be sure **not** to turn in material from **1st semester**

packet order:  
- assignment sheet  
- WS 7.1 ~ 7.6

calorimetry:  
 $q_{hot} = q_{cold}$

*Some things to think about...*

How is it possible to add heat to something without changing its temperature?

Could a substance exist that has a **negative** specific heat?

**+ WS 7.1 Specific Heat & Calorimetry**

Show all work neatly.....

$$q = m c \Delta T$$

Specific Heats	
substance	c (J/g°C)
water	4.184
ethanol	2.452
graphite	0.720
diamond	0.502
iron	0.444
copper	0.385
silver	0.237
gold	0.129
ice	2.092

1. How much heat is required to raise the temp of 654 g of water from 34.5°C to 89.7°C?

Ans \_\_\_\_\_

2. How much heat is required to raise the temp of 654 g of silver from 34.5°C to 89.7°C?

Ans \_\_\_\_\_

3. If 7350 J were added to 152 g of ethanol, its temp would go up by how much?

Ans \_\_\_\_\_

4. 16.25 g of water at 54.0°C releases 402.7 J. What will be its final temp?

hint: it's cooling down, so the final temperature will be *less than* 54.0°C

Ans \_\_\_\_\_

5. 697 J are added to a 36.8 g of kerosene and the temp increases from 22.5°C to 34.7°C. Determine kerosene's specific heat.

Ans \_\_\_\_\_

6. 25 copper pennies (each weighing 3.12 g) are placed in 36.0 g of ethanol at room temp (22.1°C). How much heat will it take to raise the temperature up to 65.8°C?

hint: Calculate  $q$  for the copper &  $q$  for the ethanol separately. Then add your 2 answers together

Ans \_\_\_\_\_

---

7. What mass of 54.0°C water must be added to 468 g of 21.0°C water to make the final temp of both come out to be 29.0°C?

Ans \_\_\_\_\_

8. What mass of 54.0°C gold must be added to 468 g of 21.0°C water to make the final temp of both come out to be 29.0°C?

Ans \_\_\_\_\_

9. A 325 g brass rod at 100.0°C is placed in a cup containing 162 g of 24.3°C water. The final temp comes out to be 37.4°C. Determine brass's specific heat.

Ans \_\_\_\_\_

10. 100.0 g of water at 20.0°C are mixed with 200.0 g of copper at 40.0°C. What will the final temp come out to be?

Ans \_\_\_\_\_

**+ WS 7.2 Phase Changes & Heat** (*"life of an ice cube..."*)  
*Show all work neatly...*

1. How much heat is required to change...  
 a) 32.6 g of ice at 0.0°C into water at 0.0°C?  
 b) 32.6 g of water at 100.0°C into steam at 100°C?

<b>Specific Heats</b>	
<u>substance</u>	<u>c</u> (cal/g°C)
water	1.00
ethanol	0.58
ice	0.50
steam	0.48

for water:  
 mp = 0.0°C    bp = 100.0°C  
 H<sub>f</sub> = 80.0 cal/g    H<sub>v</sub> = 540. cal/g

a: \_\_\_\_\_ b: \_\_\_\_\_

2. How much heat is required to change 45.4 g of ice at 0.0°C into water and then raise the water temp to 23.0°C?

Ans: \_\_\_\_\_

3. How much heat is given off when 18.5 g of water at 35.0°C freezes to ice at -5.00°C?

Ans: \_\_\_\_\_

4. Find how much heat is needed to change 10.0 g of substance "X" from -16.0°C to 150.0°C.  
*Substance "X" is not water, so you'll have to use this table of physical properties:*

<b>Substance "X"</b>	
<u>phase</u>	<u>specific heat</u>
solid	.200 cal/g°C
liquid	.300 cal/g°C
gas	.150 cal/g°C
m.p.= 20.0°C	b.p.= 85.0°C
H <sub>f</sub> = 12.0 cal/g	H <sub>v</sub> = 95.0 cal/g

Ans: \_\_\_\_\_

5. What mass of water at room temp (22.0°C) can be turned to steam at 100.0°C with the addition of 5720 cal?

Ans: \_\_\_\_\_

6. When 2.54 g of steam condense to water and then cool off to 35.0°C, 1625 cal are released. How hot must the steam have been originally?

(more on back...)

Ans: \_\_\_\_\_

7. Pretend you don't know that water has a heat of fusion ( $H_f$ ) of 80.0 cal/g, and you do the following experiment to determine what it is: You add 1589 cal of heat to 17.4 g of ice at  $-6.0^\circ\text{C}$ . The ice melts & the water is warmed to  $12.4^\circ\text{C}$ . What does this give for  $H_f$ ?

hint: when you set-up your equation, leave  $H_f$  as your variable

Ans: \_\_\_\_\_

8. A 42.0 g chunk of cobalt at  $385.0^\circ\text{C}$  is added to 5.00 g of ice at  $-10.0^\circ\text{C}$  and the two come to a final temp of  $18.4^\circ\text{C}$ . Determine the specific heat of cobalt.

hint: this is a calorimetry problem, but the cold side is also going through a phase change. Your set-up may look like this:

$$(m)(x)(\Delta T) = (m)(c)(\Delta T) + (m)(H_f) + (m)(c)(\Delta T)$$

(cobalt)                      (water)

Ans: \_\_\_\_\_

9. **Bartending question**: How many grams of  $-12.0^\circ\text{C}$  ice should be added to 125 g of ethanol (drinking alcohol) to cool it from  $25.0^\circ\text{C}$  to precisely  $14.2^\circ\text{C}$ ?

hint: this is a calorimetry problem, but the COLD side is also going through a *phase change*!

Ans: \_\_\_\_\_

---

**Ans** (IRO+2): 0.0336    7.8    9.26    75.9    172    473    1430    2170    2610    4680    7520    17,600  
**Units** (IRO): cal    cal    cal    cal    g    g    cal/g    cal/g $^\circ\text{C}$      $^\circ\text{C}$

### + WS 7.3 Heat of Reaction / Hess's Law

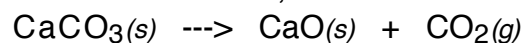
1. What is meant by *enthalpy*?
2. What is the general equation to calculate enthalpy change?
3.  $\Delta H$  will always be positive for an (endothermic/exothermic) reaction,  
and  $\Delta H$  will always be negative for an (endothermic/exothermic) reaction.
4. What is meant by *heat of formation*?
5. How many kJ are released when 1 mole of  $\text{Pb}(\text{NO}_3)_2$  is formed from its elements?  
(see reference sheet):
6. Given the following reaction:  $\text{Si}(s) + \text{O}_2(g) \rightarrow \text{SiO}_2(s) \quad \Delta H_f = -910.7 \text{ kJ/mol}$   
Calculate  $\Delta H_f$  for 2 moles of  $\text{SiO}_2$ : \_\_\_\_\_ Calculate  $\Delta H_f$  for 0.5 moles of  $\text{SiO}_2$ : \_\_\_\_\_
7. What is  $\Delta H_f$  for this reaction?  $2 \text{P}(s) + 5/2 \text{O}_2(g) \rightarrow \text{P}_2\text{O}_5(s)$  \_\_\_\_\_
8. What is  $\Delta H_f$  for this reaction?  $4 \text{P}(s) + 5 \text{O}_2(g) \rightarrow 2 \text{P}_2\text{O}_5(s)$  \_\_\_\_\_
9. How many kJ are released when 1 mole of beer alcohol ( $\text{C}_2\text{H}_5\text{OH}$ ) is burned? \_\_\_\_\_  
(see table of "heats of combustion")
10. Octane (in gasoline) is quite flammable. Change this sentence into a **balanced equation**:  
"When 1 mole of octane is burned, \_\_\_\_\_ kJ of heat energy is released."  
(hint: use fractions to balance the equation, and see reference sheet for values)
11. What is the value for  $\Delta H_c$  when 249.2 g of sugar (sucrose) is burned?  
(hint: change grams to moles, and see reference sheet for values)
12. What is meant by *Hess's Law*? (see wikipedia)
13. Using Hess's Law and the reference sheet, calculate  $\Delta H_f$  for butane ( $\text{C}_4\text{H}_{10}$ ).  
(hint: you'll need to combine 3 'given' equations from the reference sheets to solve)

(circle  
correct  
term)

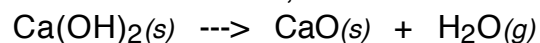
**Ans (IRO+1):** -6019.8, -5470.5, -4110 -3009.9, -2014.1, -1821.4, -1366.8, -455.4, -125.4, 451.9  
**Units:** kJ/mol (for all)

WS 7.3 (continued)

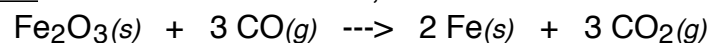
15. Using Hess's Law and the reference sheet, calculate  $\Delta H$  for:



16. Using Hess's Law and the reference sheet, calculate  $\Delta H$  for:



17. Using Hess's Law and the reference sheet, calculate  $\Delta H$  for:

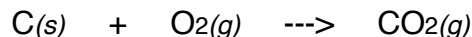


Ans (IRO)+3: -23.5 106.5 179.2 241.1 309.4 440.2

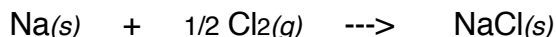
Units: kJ/mol (for all)

## + WS 7.4 Entropy & Free Energy

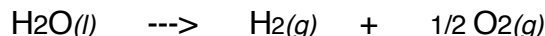
1. What is *entropy* (S) a measure of? \_\_\_\_\_
2. What is the entropy of a solid at  $-273\text{ }^{\circ}\text{C}$ ? \_\_\_\_\_
3. In general, entropy is highest for which state of matter? ( solid / liquid / gas )
4. The driving force in nature is towards ( increasing / decreasing ) **enthalpy** and ( increasing / decreasing ) **entropy**.
5. For a given chemical reaction... (circle correct response)
  - if  $\Delta H$  is exothermic and  $\Delta S$  is (+), the reaction will ( always / sometimes / never ) proceed.
  - if  $\Delta H$  is endothermic and  $\Delta S$  is (-), the reaction will ( always / sometimes / never ) proceed.
  - if  $\Delta H$  is exothermic and  $\Delta S$  is (-), the reaction will ( always / sometimes / never ) proceed.
  - if  $\Delta H$  is endothermic and  $\Delta S$  is (+), the reaction will ( always / sometimes / never ) proceed.
6. Determine if the following reaction will occur at room temperature ( $298\text{ K}$ ) by calculating  $\Delta G$ :



7. Determine if the following reaction will occur at room temperature ( $298\text{ K}$ ) by calculating  $\Delta G$ :

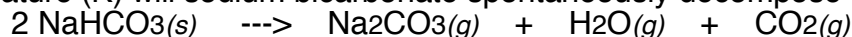


8. Determine if the following reaction will occur at room temperature ( $298\text{ K}$ ) by calculating  $\Delta G$ :  
(*hint*- look-up  $H_f$ , and change its sign to 'reverse' the reaction)



9. Above what temperature (K) would reaction #8 occur spontaneously?  
(*hint*- let  $\Delta G$  be zero, and solve for T)

10. At what temperature (K) will sodium bicarbonate spontaneously decompose to these products?



( $\Delta H = +129.274\text{ kJ/mol}$ , calculate  $\Delta S$  from chart)

Ans (IRO):    0        -358.8 (yes)        383 K        +237.2 (no)        1751 K        -394.4 (yes)

## + WS 7.5 - Thermodynamics Concepts & Vocab

### Specific Heat

Specific heat is a \_\_\_\_\_ property which is a measurement of the amount of \_\_\_\_\_ energy (in calories or joules) required to raise one \_\_\_\_\_ of a substance by 1°C. Some materials, such as copper, have a \_\_\_\_\_ specific heat. This means that it doesn't require much heat for that material to change its \_\_\_\_\_. In fact, this is why copper is often used in \_\_\_\_\_ - it heats up quickly & \_\_\_\_\_ heat to the food quickly. Other materials, such as \_\_\_\_\_, have a high specific \_\_\_\_\_. This means that they resist \_\_\_\_\_ in temperature. A whopping 2.1 joules of heat are \_\_\_\_\_ to warm 1 gram of \_\_\_\_\_ by 1°C, making it an ideal material for protecting the \_\_\_\_\_ during reentry.. Water has a \_\_\_\_\_ high specific heat. 4.2 \_\_\_\_\_. This is why water takes so long to undergo \_\_\_\_\_ changes. Ever wonder how \_\_\_\_\_ can stay cool in the \_\_\_\_\_? ...why lakes take so long to \_\_\_\_\_ in the \_\_\_\_\_? It's all due to water's ability to \_\_\_\_\_ changes in temperature.

### **Answers, in alphabetical order + 1 extra (IAO +)**

**\*\* cross them off as you go! \*\***

ceramic, ceramic, changes, cookware, freeze, gram, heat, J/g°C, low, phase, physical, required, resist, space shuttle, summer, swimming pools, temperature, temperature, thermal, transfers, very, winter

---

### Calorimetry

In the \_\_\_\_\_ lab, you were able to calculate the specific heat of \_\_\_\_\_ by heating it in a test tube, mixing it with cool \_\_\_\_\_, and measuring the \_\_\_\_\_ change. The aluminum had a large temperature change (partly due to its \_\_\_\_\_ specific heat) and the water had a \_\_\_\_\_ temperature change (partly due to its high specific heat). According to the 1st Law of \_\_\_\_\_, which states that energy is \_\_\_\_\_, the heat lost by the aluminum was \_\_\_\_\_ to the heat gained by the water. This is a valid assumption, since we did the mixing in a well-insulated \_\_\_\_\_ cup. Remember, a calorimeter measures *heat*.. not to be confused with a thermometer, which measures \_\_\_\_\_.

### **Answers, in alphabetical order + 1 extra (IAO +)**

**\*\* cross them off as you go! \*\***

aluminum, calorimetry, conserved, energy, equal, low, small, styrofoam, temperature, temperature, thermodynamics, water

---

### Phase Changes

When \_\_\_\_\_ the energy during a \_\_\_\_\_ change, we use the \_\_\_\_\_  $q=mc\Delta T$ . However, if a phase \_\_\_\_\_ lies between the two temperatures, we must calculate these \_\_\_\_\_. For example, to go from 0°C \_\_\_\_\_ to 0°C water, it requires 80.0 cal/g of energy (this is known as the heat of \_\_\_\_\_). Likewise, to go from 100°C water to 100°C \_\_\_\_\_, it requires \_\_\_\_\_ cal/g of energy (this is known as the \_\_\_\_\_ of vaporization). We cannot use \_\_\_\_\_ during these phase changes, since the change in temperature is equal to \_\_\_\_\_. Instead, we use  $q=m\cdot H_f$  for \_\_\_\_\_, and  $q=m\cdot H_v$  for \_\_\_\_\_.

### **Answers, in alphabetical order + 1 extra (IAO +)**

**\*\* cross them off as you go! \*\***

540., boiling, calculating, change, equation, fusion, heat, ice, melting,  $q=mc\Delta T$ , peanut-butter glue, separately, steam, temperature, zero

---

### Enthalpy, Entropy, and Free Energy

One way to determine if a \_\_\_\_\_ is spontaneous or not is to calculate the change in \_\_\_\_\_ (also known as  $\Delta G$ ). This takes into consideration the change in enthalpy (which is a measure of change of \_\_\_\_\_ between reactants and products), as well as \_\_\_\_\_ (in Kelvin) of the reaction, and the change in \_\_\_\_\_ of the reaction. Reactions which produce heat are also called \_\_\_\_\_ and have a negative value for  $\Delta H$ . Reactions which create disorder tend to have a positive change in \_\_\_\_\_, which is predicted by the \_\_\_\_\_ law of thermodynamics. An endothermic reaction ( $\Delta H$  is \_\_\_\_\_) with a negative  $\Delta S$  will never be \_\_\_\_\_.

### **Answers, in alphabetical order + 0 extra (IAO +)**

**\*\* cross them off as you go! \*\***

2nd, entropy, entropy, exothermic, free-energy, heat, positive, reaction, spontaneous, temperature

### + WS 7.6 Review

1. How much heat (in joules) is required to raise the temp of 205 g of water from 15.2°C to 16.2°C?

Ans \_\_\_\_\_

2. What mass of 67.5°C iron must be added to 235 g of 5.00°C water to make the final temp of both come out to be 15.0°C?

Ans \_\_\_\_\_

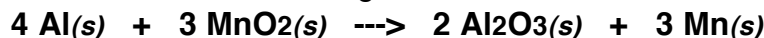
3. How many kJ are released when 205 L of propane gas (C<sub>3</sub>H<sub>8</sub>) is burned at STP conditions?

(remember, at STP, 1 mole = 22.4 L)

Ans \_\_\_\_\_

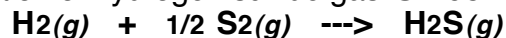
4. Use Hess's Law to calculate ΔH for the following reaction:

(ΔH<sub>f</sub> Al<sub>2</sub>O<sub>3</sub>(s) = -1676 kJ/mol)



5. Calculate ΔG for the following set of values: [ ΔH= -288 kJ/mol, ΔS= 125 J/mol·K, T= 700. K ]  
Would this reaction occur spontaneously? \_\_\_\_\_

6. Calculate ΔG for the composition of hydrogen sulfide gas @ 298 K:



7. Above what temperature (K) would reaction #6 occur spontaneously?

8. What minimum temperature (°C) is required for silver chloride (AgCl) to spontaneously decompose?

9. 1.05 g of methane (CH<sub>4</sub>) is heated 175.0 g of water by 82.0°C. Calculate the experimental H<sub>c</sub> value in kJ/mol.

Ans (IRO): -1792   -376   -915   -12.3   422   612   860   1913   20300   yes  
Units (IRO): g   J   kJ   kJ   kJ/mol   kJ/mol   K   °C

TABLE A-5 HEAT OF COMBUSTION

Substance	Formula	State	$\Delta H_c$
hydrogen	H <sub>2</sub>	g	-285.8
graphite	C	s	-393.5
carbon monoxide	CO	g	-283.0
methane	CH <sub>4</sub>	g	-890.8
ethane	C <sub>2</sub> H <sub>6</sub>	g	-1560.7
propane	C <sub>3</sub> H <sub>8</sub>	g	-2219.2
butane	C <sub>4</sub> H <sub>10</sub>	g	-2877.6
pentane	C <sub>5</sub> H <sub>12</sub>	g	-3535.6
hexane	C <sub>6</sub> H <sub>14</sub>	l	-4163.2
heptane	C <sub>7</sub> H <sub>16</sub>	l	-4817.0
octane	C <sub>8</sub> H <sub>18</sub>	l	-5470.5
ethene (ethylene)	C <sub>2</sub> H <sub>4</sub>	g	-1411.2
propene (propylene)	C <sub>3</sub> H <sub>6</sub>	g	-2058.0

Substance	Formula	State	$\Delta H_c$
benzene	C <sub>6</sub> H <sub>6</sub>	l	-3267.6
toluene	C <sub>7</sub> H <sub>8</sub>	l	-3910.3
naphthalene	C <sub>10</sub> H <sub>8</sub>	s	-5156.3
anthracene	C <sub>14</sub> H <sub>10</sub>	s	-7076.5
methanol	CH <sub>3</sub> OH	l	-726.1
ethanol	C <sub>2</sub> H <sub>5</sub> OH	l	-1366.8
ether	(C <sub>2</sub> H <sub>5</sub> ) <sub>2</sub> O	l	-2751.1
formaldehyde	CH <sub>2</sub> O	g	-570.7
glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	s	-2803.0
sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	s	-5640.9

$\Delta H_c$  = heat of combustion of the given substance. All values of  $\Delta H_c$  are expressed as kJ/mol of substance oxidized to H<sub>2</sub>O(l) and/or CO<sub>2</sub>(g) at constant pressure and 25°C.

Substance	State	$\Delta H_f$	Substance	State	$\Delta H_f$
ammonia	g	-45.9	lead(IV) oxide	s	-274.5
ammonium chloride	s	-314.4	lead(II) nitrate	s	-451.9
ammonium sulfate	s	-1180.9	lead(I) sulfate	s	-919.94
barium chloride	s	-858.6	lithium chloride	s	-408.6
barium nitrate	s	-992.1	lithium nitrate	s	-483.1
barium sulfate	s	-1473.2	magnesium chloride	s	-641.5
benzene	g	+82.88	magnesium oxide	s	-601.6
benzene	l	+49.080	magnesium sulfate	s	-1284.9
calcium carbonate	s	-1207.6	manganese(IV) oxide	s	-520.0
calcium chloride	s	-795.4	manganese(II) sulfate	s	-1065.3
calcium hydroxide	s	-983.2	mercury(I) chloride	s	-264.2
calcium nitrate	s	-938.2	mercury(II) chloride	s	-230.0
calcium oxide	s	-634.9	mercury(II) oxide (red)	s	-90.8
calcium sulfate	s	-1434.5	methane	g	-74.9
carbon (diamond)	s	+1.9	nitrogen dioxide	g	+33.2
carbon (graphite)	s	0.00	nitrogen monoxide	g	+90.29
carbon dioxide	g	-393.5	dinitrogen monoxide	g	+82.1
carbon monoxide	g	-110.5	dinitrogen tetroxide	g	+9.2
copper(II) nitrate	s	-302.9	oxygen (O <sub>2</sub> )	g	0.00
copper(II) oxide	s	-157.3	ozone (O <sub>3</sub> )	g	+142.7
copper(II) sulfate	s	-771.4	diphosphorus pentoxide	s	-3009.9
ethane	g	-83.8	potassium bromide	s	-393.8
ethyne (acetylene)	g	+228.2	potassium chloride	s	-436.49
hydrogen (H <sub>2</sub> )	g	0.00	potassium hydroxide	s	-424.58
hydrogen bromide	g	-36.29	potassium nitrate	s	-494.6
hydrogen chloride	g	-92.3	potassium sulfate	s	-1437.8
hydrogen fluoride	g	-273.3	silicon dioxide (quartz)	s	-910.7
hydrogen iodide	g	+26.5	silver chloride	s	-127.01 = 0.5
hydrogen oxide (water)	g	-241.8	silver nitrate	s	-120.5
hydrogen oxide (water)	l	-285.8	silver sulfide	s	-32.59
hydrogen peroxide	g	-136.3	sodium bromide	s	-361.8
hydrogen peroxide	l	-187.8	sodium chloride	s	-385.9
hydrogen sulfide	g	-23.9	sodium hydroxide	s	-425.9
iodine (I <sub>2</sub> )	s	0.00	sodium nitrate	s	-467.9
iodine (I <sub>2</sub> )	g	+62.4	sodium sulfate	l	-1387.1
iron(II) chloride	s	-399.4	sulfur dioxide	g	-296.8
iron(III) oxide	s	-825.5	sulfur trioxide	g	-395.7
iron(III) oxide	s	-825.5	tin(IV) chloride	l	-511.3
iron(II) sulfate	s	-928.4	zinc nitrate	s	-483.7
iron(II) sulfide	s	-100.0	zinc oxide	s	-350.5
lead(II) oxide	s	-217.3	zinc sulfate	s	-980.14

$\Delta H_f$  is heat of formation of the given substance from its elements. All values of  $\Delta H_f$  are expressed as kJ/mol at 25°C. Negative values of  $\Delta H_f$  indicate exothermic reactions. s = solid, l = liquid, g = gas

Table 18.1 Standard Entropies (at 25°C)

Formula	S°, J/(mol · K)	Formula	S°, J/(mol · K)	Formula	S°, J/(mol · K)
<b>Hydrogen</b>					
H <sup>+</sup> (aq)	0	<b>Carbon (continued)</b>		S <sub>2</sub> (g)	228.1
H <sub>2</sub> (g)	130.6	CS <sub>2</sub> (l)	151.0	S(rhombic)	31.9
<b>Sodium</b>					
Na <sup>+</sup> (aq)	60.2	HCN(g)	201.7	S(monoclinic)	32.6
Na(s)	51.4	HCN(l)	112.8	SO <sub>2</sub> (g)	248.1
NaCl(s)	72.1	CCl <sub>4</sub> (g)	309.7	H <sub>2</sub> S(g)	205.6
NaHCO <sub>3</sub> (s)	102	CCl <sub>4</sub> (l)	214.4	<b>Fluorine</b>	
Na <sub>2</sub> CO <sub>3</sub> (s)	139	CH <sub>3</sub> CHO(g)	266	F <sup>-</sup> (aq)	-9.6
<b>Calcium</b>					
Ca <sup>2+</sup> (aq)	-55.2	C <sub>2</sub> H <sub>5</sub> OH(l)	161	F <sub>2</sub> (g)	202.7
Ca(s)	41.6	<b>Silicon</b>		HF(g)	173.7
CaO(s)	38.2	Si(s)	18.0	<b>Chlorine</b>	
CaCO <sub>3</sub> (s)	92.9	SiO <sub>2</sub> (s)	41.5	Cl <sup>-</sup> (aq)	55.1
<b>Carbon</b>					
C(graphite)	5.7	SiF <sub>4</sub> (g)	285	Cl <sub>2</sub> (g)	223.0
C(diamond)	2.4	<b>Lead</b>		HCl(g)	186.8
CO(g)	197.5	Pb(s)	64.8	<b>Bromine</b>	
CO <sub>2</sub> (g)	213.7	PbO(s)	66.3	Br <sup>-</sup> (aq)	80.7
HCO <sub>3</sub> <sup>-</sup> (aq)	95.0	PbS(s)	91.3	Br <sub>2</sub> (l)	152.2
CH <sub>4</sub> (g)	186.1	<b>Nitrogen</b>		<b>Iodine</b>	
C <sub>2</sub> H <sub>4</sub> (g)	219.2	N <sub>2</sub> (g)	191.5	I <sup>-</sup> (aq)	109.4
C <sub>2</sub> H <sub>6</sub> (g)	229.5	CO <sub>2</sub> (g)	193	I <sub>2</sub> (s)	116.1
C <sub>6</sub> H <sub>6</sub> (l)	172.8	NO(g)	210.6	<b>Silver</b>	
HCHO(g)	219	NO <sub>2</sub> (g)	239.9	Ag <sup>+</sup> (aq)	73.9
CH <sub>3</sub> OH(l)	127	HNO <sub>3</sub> (aq)	146	Ag(s)	42.7
CS <sub>2</sub> (g)	237.8	<b>Oxygen</b>		AgF(s)	84
		O <sub>2</sub> (g)	205.0	AgCl(s)	96.1
		O <sub>3</sub> (g)	238.8	AgBr(s)	107.1
		OH <sup>-</sup> (aq)	-10.5	AgI(s)	114
		H <sub>2</sub> O(g)	188.7		
		H <sub>2</sub> O(l)	69.9		

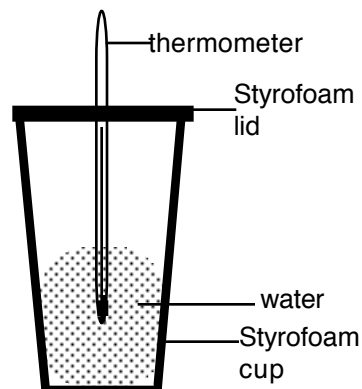
# Calorimetry Lab

Name \_\_\_\_\_

A calorimeter is a device used to measure heat flow. It is a container with insulating walls, made so that essentially no heat is exchanged between the contents of the calorimeter and the surroundings. The purpose of this experiment is to determine the specific heat (*c*) of aluminum. This will be accomplished by heating the aluminum to a certain temperature, adding the aluminum to the water inside the calorimeter, and measuring the rise in water temperature.

## Procedure

- Record the mass of about 12 aluminum pellets. Insert Al pellets into a large test tube, and place test tube in hot water bath. Heat for about 7 minutes.
- Add (and weigh) about 50 mL of water in the calorimeter cup. Record mass of water in data table. Assemble the calorimeter as shown, making sure the thermometer is submerged. Record the temperature of the water to the 0.1's place (initial temp)
- Take the test tube out of the hot water, and pour the metal into the water in the calorimeter. Be careful that no water adhering to the outside of the test tube runs into the calorimeter! Replace the calorimeter cover and agitate the water by shaking.
- Record the temperature of the water every 30 seconds until the temperature remains constant for two consecutive readings.



Date Table	Trial 1	Trial 2
mass of aluminum		
temp of aluminum	95.0 °C	95.0 °C
mass water		

time (min)	water temperature, °C	
	Trial 1	Trial 2
<i>initial T</i> 0		
0.5		
1.0		
1.5		
<i>final T</i> 2.0		

## Calculations

- Using the equation  $m \cdot c \cdot \Delta T = m \cdot c \cdot \Delta T$ , calculate *c* for the aluminum for *trial 1* and then again for *trial 2*. (Use 4.184 J/g°C for the specific heat of water). For 1/2 point, don't forget units!!

Ans (trial 1) \_\_\_\_\_

Ans (trial 2) \_\_\_\_\_

Average \_\_\_\_\_

- What is the **actual value** for the specific heat of aluminum, as given to you by Mr. A? \_\_\_\_\_ J/g°C

- Calculate the percent error from your average specific heat.

$$\% \text{ error} = \frac{(\text{actual value} - \text{experimental value})}{\text{actual value}} \times 100$$

% error = \_\_\_\_\_

**(questions on back side)...**

Questions

1. Which component (the aluminum or water) experienced a greater change in temperature ( $\Delta T$ )?
2. Give two possible explanations for your observations in question #1:

3. Consider each of the following potential error sources.

thinker  
question!

***Answer...***

..."H" if it would have caused your experimental value for aluminum to come out too high,

..."L" if it would have caused it to come out too low, or

..."N" if it would have had no effect at all on your value

\_\_\_\_\_ You forgot to subtract the mass of the empty cup

\_\_\_\_\_ After weighing the aluminum pellets, a few of them unknowingly fell to the floor

\_\_\_\_\_ You measured the temperature using the Kelvin scale

\_\_\_\_\_ You used a metal can (which conducts heat away) instead of styrofoam (which insulates)

\_\_\_\_\_ You unknowingly used ethanol (specific heat =  $2.452 \text{ J/g}^\circ\text{C}$ ) instead of water

\_\_\_\_\_ Someone drank some of your calorimeter water after you weighed it

\_\_\_\_\_ Instead of using water you used ethanol, and used ethanol's specific heat in the equation

**Answer Bank (prob #3): IRO:**

L L N N H H H

## Heat of Combustion Lab

Name: \_\_\_\_\_

In this lab, you will measure the heat of combustion ( $H_c$ ) for paraffin (candle) wax, butane, and Cheetos. You will use a simple aluminum can style calorimeter, remembering the 1st law of thermodynamics: the heat lost by the fuel equals the heat gained by the water to which the heat is transferred.

### Procedure

part 1,  $H_c$  for paraffin: Assemble soda can calorimeter as was shown in class. Weigh ca. 100 mL of cold water, pour into calorimeter. Record mass of candle. Place candle directly under calorimeter. Record initial temp. of water. Light candle & allow to burn for about 5 minutes. Carefully extinguish candle. Record highest temp. reached by the water. Wait for candle to cool, and record its final mass.

part 2,  $H_c$  for butane: Reset calorimeter with ~50 mL cool water. Record mass of a butane lighter. Use lighter to warm the water for about 1 minute. Record highest temp. reached by the water. Record final mass of lighter.

part 3,  $H_c$  for Cheetos: Reset calorimeter with ~50 mL cool water. Impale a Cheeto on the nail mounted to the wooden block. Record this mass. Ignite Cheeto with a bunsen burner & place under calorimeter (\* if Cheeto goes out, relight it w/ the bunsen burner). Record highest temp. reached by the water. Record final mass of Cheeto/nail/block assembly.

### Data/Calculations

part 1

mass of water: \_\_\_\_\_  
specific heat of water ( $J/g^{\circ}C$ ) 4.184  
initial T of water: \_\_\_\_\_  
final T of water: \_\_\_\_\_  
 $\Delta T$  of water: \_\_\_\_\_  
q gained by water (J): \_\_\_\_\_  
  
initial mass of candle: \_\_\_\_\_  
final mass of candle: \_\_\_\_\_  
mass of paraffin burned: \_\_\_\_\_  
 $H_c$  of paraffin ( $kJ/g$ ): \_\_\_\_\_

part 2

mass of water: \_\_\_\_\_  
specific heat of water ( $J/g^{\circ}C$ ) 4.184  
initial T of water: \_\_\_\_\_  
final T of water: \_\_\_\_\_  
 $\Delta T$  of water: \_\_\_\_\_  
q gained by water (J): \_\_\_\_\_  
  
initial mass of lighter: \_\_\_\_\_  
final mass of lighter: \_\_\_\_\_  
mass of butane burned: \_\_\_\_\_  
 $H_c$  of butane ( $kJ/g$ ): \_\_\_\_\_

part 3

mass of water: \_\_\_\_\_  
specific heat of water ( $J/g^{\circ}C$ ) 4.184  
initial T of water: \_\_\_\_\_  
final T of water: \_\_\_\_\_  
 $\Delta T$  of water: \_\_\_\_\_  
q gained by water (J): \_\_\_\_\_  
  
initial mass of set-up: \_\_\_\_\_  
final mass of set-up: \_\_\_\_\_  
mass of Cheeto burned: \_\_\_\_\_  
 $H_c$  of Cheeto ( $kJ/g$ ): \_\_\_\_\_

### Analysis

Part 1. The actual  $H_c$  for paraffin is  $-41.5 \text{ kJ/g}$ . Calculate your % error.

Part 2. The actual  $H_c$  for butane is on the table printed on your reference sheet, in units of **kJ/mol**. Recalculate your  $H_c$  for part 2 to match these units (butane =  $C_4H_{10}$ ). Then, calculate your % error.

Part 3. The actual  $H_c$  for Cheetos is printed on the bag, in units of **Cal/g**. Recalculate your  $H_c$  for part 3 to match these units. Then, calculate your % error.

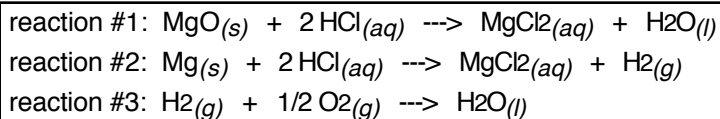
List several sources of experimental error:

## Heat of Formation using Hess's Law Lab

Name: \_\_\_\_\_

In this lab, you will determine the  $H_f$  for magnesium:  $Mg(s) + 1/2 O_2(g) \rightarrow MgO(s)$  (reaction #4)

Since this would be difficult to measure directly, we will instead use the following 3 reactions & combine them using Hess's Law:



**Pre-Lab Exercise:** below, combine reaction 1, 2, & 3 to obtain the desired reaction (#4):

#1 \_\_\_\_\_

#2 \_\_\_\_\_

#3 \_\_\_\_\_

+  
#4 \_\_\_\_\_

### Procedure:

reaction #1:

1. Weigh ca. 100 g of HCl solution into styrofoam calorimeter. Record the mass of HCl solution used.
2. Weigh ca. 1 g of MgO on weighing paper. Record the mass of MgO used.
3. Take the initial temperature of the solution.
4. Add the MgO to the calorimeter & mix. Record the maximum temp. reached. Discard the solution down the sink.

reaction #2: Repeat the steps above, but use the piece of Mg ribbon provided by Mr. A instead of the MgO. Be sure to record the mass of the ribbon.

reaction #3: simply look-up the  $H_f$  values on your reference sheet in your packet.

### Data / Calculations:

reaction #1

mass of solution \_\_\_\_\_

specific heat of solution (J/g°C): 4.184

initial T of solution: \_\_\_\_\_

final T of solution: \_\_\_\_\_

$\Delta T$  of solution: \_\_\_\_\_

q gained by solution (J): \_\_\_\_\_

mass of MgO used: \_\_\_\_\_

moles of MgO used: \_\_\_\_\_

$H_f$  for reaction #1 (kJ/mol): \_\_\_\_\_

reaction #2

mass of solution \_\_\_\_\_

specific heat of solution (J/g°C): 4.184

initial T of solution: \_\_\_\_\_

final T of solution: \_\_\_\_\_

$\Delta T$  of solution: \_\_\_\_\_

q gained by solution (J): \_\_\_\_\_

mass of Mg used: \_\_\_\_\_

moles of Mg used: \_\_\_\_\_

$H_f$  for reaction #2 (kJ/mol): \_\_\_\_\_

**Calculate  $H_f$  for reaction #4:**

Refer to your reference table for the actual value for  $H_f(MgO)$ : \_\_\_\_\_

Calculate your % error: