# Thermochemistry Unit Check List  Name: _____

## Unit test: Friday, April 28th

| Complete the following assignments in the order given. Place in assignment folder, *in order*, when completed | | | |
|---|---|---|---|
| **Assign #** | **Name** | **Description** | **√ when done!** |
| 1 | Video: Heat vs Temperature | Lecture notes and video<br>Lecture notes must be completed! | |
| 2 | Video: Intro to Thermochemistry | Lecture notes and video<br>Lecture notes must be completed | |
| 3 | Lab Activity: Understanding +q = -q | Activity to determine specific heat of metal<br>All work shown on worksheet<br>***Must be completed April 18th-20th*** | |
| *lab activity (assignment 3) must be turned in for separate grade by mon, apr 24th. It will be returned to you. When you receive it, place it in your folder* | | | |
| 4 | Video: Enthalpy and calorimetry | Lecture notes and video | |
| 5 | Lab Activity: Enthalpy of a reaction | Activity to determine ΔH of baking soda and acetic acid<br>All work shown on worksheet<br>***Must be completed April 19th-21th*** | |
| *lab activity (assignment 5) must be turned in for separate grade by mon, apr 24th. It will be returned to you. When you receive it, place it in your folder* | | | |
| 6 | Calorimetry practice | Homework problems on calorimetry<br>summary of assignments 1-5<br>All work must be shown | |
| 7 | Video: Enthalpy and mole of reaction | Lecture notes and video<br>Lecture notes must be completed | |
| 8 | Mole of reaction practice | homework problems on mole ratios<br>all work must be shown | |
| 9 | Video: Enthalpy and Hess's Law | Lecture notes and video<br>Lecture notes must be completed | |
| 10 | Hess's law practice | Homework problems on hess's law<br>All work must be shown | |
| 11 | Video: Enthalpy and heats of formation | Lecture notes and video<br>Lecture notes must be completed | |
| 12 | Heats of formation practice | Homework problems on heats of formation<br>All work must be shown | |

### Grade for Thermochemistry Unit:

| | |
|---|---|
| Assignment 3: completed April 18-20 and turned in by 4/24 | ____/15 pt |
| Assignment 5: completed April 19-21 and turned in by 4/24 | ____/15 pt |
| Checklist and Assignments 1-12 complete, filled out, and all work shown | ____/20 pt |
| Checklist and Assignments 1-12 in order and in folder | ____/10 pt |
| Unit test | ____/150pt |

# Thermochemistry Unit: Assignment 1

## Lecture notes on Heat vs Temperature Video

**DIRECTIONS:** view "temperature vs heat" video and answer the following questions. Place in project folder when finished.

Define temperature

Define heat

- Please state whether the following statements or true or false.
- Explain your answer using the terms "speed of molecules" and "amount of molecules"

**Statement 1:**

*"Lake Erie and Riverdale high school's swimming pool cannot have the same temperature because there is so much more water in Lake Erie."*

Response:

**Statement 2:**

*"Lake Erie and Riverdale high school's swimming pool cannot have the same total heat energy because there is so much more water in Lake Erie."*

Response:

After completing, place in unit folder

# Thermochemistry Unit: Assignment 2

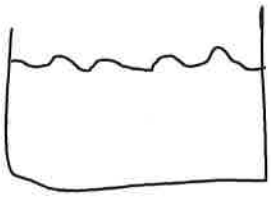
## Lecture notes on "Introduction to Thermochemistry"

**DIRECTIONS:** view "introduction to thermochemistry" video and answer the following questions. Place in project folder when finished.

What is thermochemistry?

How is heat measured?

Review of terms "system" and "environment". Draw the calcium chloride dissolving in water and label the system and environment



What is the 1st law of thermodynamics?

Why is this law important to our understanding of the relationship between the system and the environment?

What is the mathematical relationship between heat and temperature? Define each variable of the equation

What is meant by "specific heat"?

*Continued on next page*

Solve the problem and show your work!

*Calculate the amount of energy required to raise 5.0 grams of water 10 °C. compare this to the amount of energy required to do the same with 5.0 grams of copper. (specific heat of water= 4.18 j/g · °C and the specific heat of copper= .386 j/g · °C.)*

Water:

Copper:

After completing, place in your unit folder.

# Thermochemistry Unit: Assignment 3

## Understanding $q_{environment} = -q_{system}$

**DIRECTIONS:** you will determine the "specific heat" of a metal using the equation $q=mc\Delta T$

Part I: energy absorbed by the water

1. Measure 100 mL of water and place in a coffee cup (remember 1mL=1g of water)
2. Take the initial temp of the water
3. Record the initial temp of the metal by measuring the temp of the hot water the metal was in before the transfer
4. Place the hot metal (either Al, Pb, or Sn) in water (quickly transfer hot metal to water so no energy is lost in the transfer!)
5. Record the highest temp of the water as the final temp of the water and the final temp of the metal
6. Determine the amount of energy absorbed by the water by using $q=mc\Delta T$ for the water.

Work:

Part ii: energy released by the metal

(a) We know that the energy absorbed by the water = energy lost by the metal.

$q_{metal}$ =

(b) Measure the mass of the metal (make sure it is dried off)

$m_{metal}$=

(c) Determining the change in temp of the metal.

$\Delta T_{metal}$=

What principle of thermodynamics allows you to use the temperature of the water as the temperature of the metal?

(d) Determine the specific heat of your metal

| Metal | Specific heat ($J/g \cdot °C$) |
|---|---|
| Copper | .386 |
| Aluminum | .900 |
| Lead | .128 |
| tin | .21 |

How did your value compare to actual values?

After completing, turn in for grade by April 24th. When your graded sheet is returned to you, place in folder

# Thermochemistry Unit: Assignment 4

## Lecture notes on Calorimetry and Enthalpy

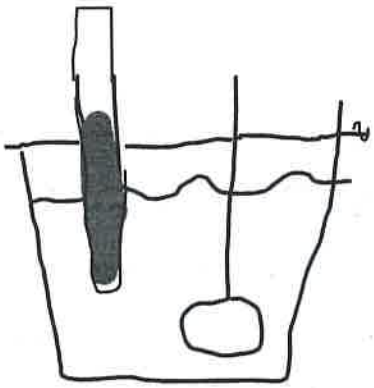
**DIRECTIONS:** view "calorimetry and enthalpy video and answer the following questions. Place in project folder when finished.

Energy of a Chemical Reaction, $\Delta H_{rxn}$

What are the units of enthalpy?

Show a thermochemical equation and explain how it is "read".

Calorimetry—One method of measuring enthalpy. Label the components of a coffee cup calorimeter



How to calculate enthalpy of a reaction using calorimetry

Joe places 5.0 grams of magnesium metal into a coffee cup calorimeter containing 100 mL excess hydrochloric acid at 25°C, After the reaction goes to completion, the temperature is measured at 28.3°C. Determine the enthalpy of the reaction between magnesium and hydrochloric acid.

What do you need to remember in measuring the mass in the equation $q=mc\Delta T$?

How do you convert between q and $\Delta H$?

How do you remember proper sign of reaction?

After completing, place in your unit folder

# Thermochemistry Unit: Assignment 5

## Enthalpy of a reaction

**DIRECTIONS:** you will determine the q and ΔH of a reaction

Start by writing the balanced chemical equation for the reaction between acetic acid and baking soda

Procedure

1. Measure 100 mL of acetic acid and place in a coffee cup (remember 1mL=1g of aqueous solutions)
2. Take the initial temp of the acid
3. Measure approximately 5.00 grams of baking soda ($NaHCO_3$)
4. Place the baking soda all at once into acid, stir with thermometer and record minimum temperature of the water.
5. Determine the amount of energy transferred by this reaction by using $q=mc\Delta T$ .

Work to determine q:

What must I remember for "m"?

What does q represent—specifically if the acid is in excess?

Work to Convert from q to ΔH

What will be the sign of this reaction (Hint: look at temperature change)

After completing, turn in for a grade by April 24th. When your graded sheet is returned to you, place in folder.

# Thermochemistry Unit: Assignment 6

## Calorimetry Practice (summary of assignments 1-5)

**DIRECTIONS:** answer the problems, showing all work. All work includes calculations, equations, and conversions. You may complete on separate piece of paper and staple to this sheet.

1. What is the specific heat of aluminum if the temperature of 28.4 g sample of aluminum is increased by 8.1°C when 207 J of heat is added?

Ans: .899 j/g · °C

2. When 16.9 g sample of NaOH is dissolved in 70.0 g of water in a calorimeter, the temperature rises from 22.C to 86.6°C. calculate the q and ΔH for the process. (specific heat of water: 4.18 J/g · °C)

Ans: -55.4kJ/mol

3. How much heat must be added to a 8.21 g sample of gold to increase its temperature by 6.2°C? the specific heat of gold is 0.13 J/g · °C

Ans: 6.6 J

4. When a 25.7 gram sample of sodium iodide dissolves in 80.0 grams of water in a calorimeter, the temperature rises from 20.5°C to 24.4°C. Calculate q and ΔH for the process

Ans: 9.9 kJ/mol

5. A 2.5 gram sample of zinc is heated to 719°C, then placed in a calorimeter containing 65.0 grams of water. The temperature of the water increases from 20.0°C to 22.5°C. determine the specific heat of the zinc.

Ans: .389 J/ g · °C

6. Nitric acid is neutralized by potassium hydroxide. To determine the heat of the reaction, a student placed 55.0 mL of 1.3 M $HNO_3$ in a coffee cup calorimeter, noted that the temperature was 23.5°C, and added 55.0 mL of 1.3M KOH, also at 23.5°C. the mixture was stirred quickly with a thermometer, and its temperature rose to 31.8°C. write the balanced chemical equation for the reaction. Assume that the specific heats of solution are 4.18 j/g °C and no heat loss to the environment. Calculate q and ΔH (per mole of acid)

Ans: -53.4 kJ/mol

After completing, place in your unit folder

# Thermochemistry Unit: Assignment 7

## Lecture notes on Enthalpy and mole of reaction

**DIRECTIONS:** view "enthalpy and mole of reaction" video and answer the following questions. Place in project folder when finished.

What does "mole of reaction" mean

$3H_2 + N_2 \rightarrow 2NH_3$ +42.3 kJ/mole of reaction

What if we double the coefficients?

What if we halve the coefficients?

$2C_2H_8 + 7O_2 \rightarrow 4CO_2 + 8H_20$ $\Delta H = -342.8$ kJ/mol

What if we double? Halve?

What if we reverse?

What if we reverse and halve the coefficients?

$3H_2 + N_2 \rightarrow 2NH_3$ +42.3 kJ/mole of reaction

How much energy is required to form 15 grams of $NH_3$?

How many grams of nitrogen reacted if 237.8 kJ of energy were used?

Summary thoughts on mole of reaction and the BCE?

After completing, place in your unit folder

# Thermochemistry Unit: Assignment 8

## Mole of reaction Practice (practice from lecture in assignment 7)

**DIRECTIONS:** answer the problems, showing all work. All work includes calculations, equations, and conversions. You may complete on separate piece of paper and staple to this sheet.

$P_4 + 6\ Cl_2 \rightarrow 4\ PCl_3 \quad \Delta H_{rxn} = -1207$ kJ/mol

Using the above thermal chemical equation, determine the $\Delta H_{rxn}$ for each of the following:

1. $2P_4 + 12\ Cl_2 \rightarrow 8\ PCl_3$
2. $\frac{1}{2}\ P_4 + 3\ Cl_2 \rightarrow 2\ PCl_3$
3. $4\ PCl_3 \rightarrow P_4 + 6\ Cl_2$
4. $12\ PCl_3 \rightarrow 3P_4 + 18\ Cl_2$
5. How much energy is released during the formation of 98.7 g of Fe, according to the reaction below?

   $Fe_2O_3 + 2Al \rightarrow Al_2O_3 + 2Fe \quad \Delta H_{rxn} = -852$ kJ

   Ans: 753 kJ

6. Using the following information, what mass of HF must react in order to produce 345 kJ of energy? Assume excess $SiO_2$

   $SiO_2 + 4HF \rightarrow SiF_4 + 2H_2O \quad \Delta H_{rxn} = -184$ kJ

   Ans:150g HF

7. How much energy can be released during the following reaction if 25.6 g $B_2H_6$ and 89.2 g $Cl_2$ are allowed to react?

   $B_2H_6 + 6Cl_2 \rightarrow 2BCl_3 + 6HCl \quad \Delta H_{rxn} = -1396$ kJ/mol

   Ans: -290.8 kJ

8. How many kg of $NH_3$ will be formed during the following reaction, if $3.4 \times 10^5$ kJ energy are used?

   $N_2 + 3H_2 \rightarrow 2NH_3 \quad \Delta H_{rxn} = +42.2$ kJ/mol

   Ans: 274 kJ

After completing, place in your unit folder

# Thermochemistry Unit: Assignment 9

## Lecture notes on Enthalpy and Hess's Law

**DIRECTIONS:** view "Enthalpy and Hess's Law" video and answer the following questions. Place in project folder when finished.

Define Hess's law

What is the application of Hess's law?

Example 1:

Given: $\frac{1}{2}\ N_2(g) + \frac{1}{2}\ O_2(g) \rightarrow NO\ (g)$ $\Delta H = +90.29$ kJ

$\frac{1}{2}\ N_2(g) + O_2(g) \rightarrow NO_2\ (g)$ $\Delta H = +33.2$ kJ

Want: $NO + \frac{1}{2}\ O_2 \rightarrow NO_2$ $\Delta H = ?$

Plan:

- What is the *reactant* that I want? **NO**
- Which equation contains NO? *1st* Is it as a reactant? *No, it is as a product*
- is it the amount I want? *yes*
- What do I need to do to equation 1: *flip it, and change the sign of ΔH*

$NO\ (g) \rightarrow \frac{1}{2}\ N_2(g) + \frac{1}{2}\ O_2(g)$ $\Delta H = -90.29$ kJ

- What is the *product* that I want? $NO_2$
- Which equation contains $NO_2$? *2nd*
- Is it as a product, and the proper amount? *Yes, yes so write equation 2 as it is.*
- Add the equations together, cancelling out what is the same on each side of arrow. Ignore oxygen, as it usually cancels out.

$NO\ (g) \rightarrow \frac{1}{2}\ N_2(g) + \frac{1}{2}\ O_2(g)$ $\Delta H = -90.29$ kJ

$\frac{1}{2}\ N_2(g) + \frac{1}{2}\ O_2(g) \rightarrow NO_2\ (g)$ $\Delta H = +33.2$ kJ

$NO + \frac{1}{2}\ O_2 \rightarrow NO_2$ $\Delta H = -57.09$

Example 2

$C_{graphite} + O_2(g) \rightarrow CO_2\ (g)$ $\Delta H = -393.5$ kJ

$H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$kJ

$C_5H_{12}(g) + 8O_2 \rightarrow 5CO_2(g) + 6H_2O(l)$ $\Delta H = -3535.6$ kJ

$5C + 6H_2 \rightarrow C_5H_{12}$ $\Delta H = ?$

Example 3

$N_2O_5(g) + H_2O(l) \rightarrow 2HNO_3(l)$ $\Delta H = -12$ kJ

$H_2(g) + \frac{1}{2}\ O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$kJ

$\frac{1}{2}\ N_2(g) + 3/2O_2(g) + \frac{1}{2}\ H_2(g) \rightarrow HNO_3\ (l)$ $\Delta H = -174$ kJ

$2N_2(g) + 5O_2(g) \rightarrow 2N_2O_5\ (g)$ $\Delta H = ?$

After completing, place in your unit folder

# Thermochemistry Unit: Assignment 10

## Hess's Law Practice (practice from lecture in assignment 9)

**DIRECTIONS:** answer the problems, showing all work. All work includes calculations, equations, and conversions. You may complete on separate piece of paper and staple to this sheet.

$$S(s) + O_2(g) \rightarrow SO_2(g)$$

Using the following data:

$2S(s) + 3O_2(g) \rightarrow 2SO_3(g)$ $\Delta H = -790.4kJ$

$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $\Delta H = -198.2kJ$

Ans: -296.1 kJ

$$2C_2H_4(g) + H_2O(\ell) \rightarrow C_4H_9OH(\ell)$$

Using:

$2CO_2 + 2H_2O(\ell) \rightarrow C_2H_4(g) + 3O_2(g)$ $\Delta H° = +1411.1\ kJ$

$C_4H_9OH(\ell) + 6O_2(g) \rightarrow 4CO_2 + 5H_2O(\ell)$ $\Delta H° = -1534.7\ kJ$

Ans: -1288 kJ

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$$

Using:

$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta H = -566.0\ kJ$

$N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = 180.6\ kJ$

Ans: -746.6 kJ

**Continue next page**

# Thermochemistry Unit: Assignment 11

## Lecture notes on Enthalpy and Heats of formation

**DIRECTIONS:** view "Enthalpy and Heats of formation" video and answer the following questions. Place in project folder when finished.

Define Heat of Formation

What are standard conditions?

What is NOT a definition of heat of formation?

What is the enthalpy of formation for an element?

Practice writing formation equations

$N_2O_5$

$NH_4Cl$

$SO_3$

*even though we won't require you know: what are the actual allotropes of sulfur and phosphorous at standard conditions?

Write the general equation for the $\Delta H_{rxn}^{\circ}$. define each term

Practice:

$2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$

You try:

$5CO(g) + 11H_2(g) \rightarrow C_5H_{12}(g) + 5H_2O(l)$

After completing, place in your unit folder

$2C(s) + H_2(g) \rightarrow C_2H_2(g)$ $\Delta H° = ???$ kJ

Given the following thermochemical equations:

$C_2H_2(g) + (5/2)O_2(g) \rightarrow 2CO_2(g) + H_2O(\ell)$ $\Delta H° = -1299.5$ kJ

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H° = -393.5$ kJ

$H_2(g) + (1/2)O_2(g) \rightarrow H_2O(\ell)$ $\Delta H° = -285.8$ kJ

Ans: +226.7 kJ

$CS_2(\ell) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$

Given:

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ/mol

$S(s) + O_2(g) \rightarrow SO_2(g)$ $\Delta H = -296.8$ kJ/mol

$C(s) + 2S(s) \rightarrow CS_2(\ell)$ $\Delta H = +87.9$ kJ/mol

Ans: -1075 kJ

After completing, place in your unit folder

# Thermochemistry Unit: Assignment 12

## Heat of formation Practice (practice from lecture in assignment 11)

**DIRECTIONS:** answer the problems, showing all work. All work includes calculations, equations, and conversions. You may complete on separate piece of paper and staple to this sheet.

*Use your table of thermodynamic values to complete this worksheet. $\Delta H_f^o$ included for those not found on your table*

1. Calculate enthalpy of reaction for the following:
   $SO_2Cl_2(g) + 2H_2O(l) \rightarrow 2HCl(g) + H_2SO_4(l)$

   $\Delta H_f^o$ *(kJ/mol)*

   $SO_2Cl_2$ -364
   $H_2SO_4$ -814

   Ans: -62kJ

2. Calculate the enthalpy of reaction for the following:
   $CH_4(g) + 4Cl_2(g) \rightarrow CCl_4(g) + 4HCl(g)$

   $CCl_4$ -96

   Ans: -389 kJ

3. Calculate the enthalpy of reaction for the following:
   $3Fe_3O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g)$

   $Fe_2O_3$ -824
   $Fe_3O_4$ -1118

   Ans: -47kJ

4. Use the $\Delta H_f^o$ *and* $\Delta Hrxn^o$ *to find the* $\Delta H_f^o$ *for IF*

   $IF_7(g) + I_2(g) \rightarrow IF_5(g) + 2\,IF(g)$

   $IF_7(g)$ -941

   $IF_5(g)$ -840

   Ans: -95 kJ

After completing, place in your unit folder

| | $\Delta H_f^\circ$ | $\Delta G_f^\circ$ | $S^\circ$ |
|---|---|---|---|
| **Carbon** | | | |
| C(*s*) (graphite) | 0 | 0 | 6 |
| C(*s*) (diamond) | 2 | 3 | 2 |
| CO(*g*) | -110.5 | -137 | 198 |
| $CO_2$ (*g*) | -393.5 | -394 | 214 |
| $CH_4(g)$ | -75 | -51 | 186 |
| $CH_3OH(g)$ | -201 | -163 | 240 |
| $CH_3OH(l)$ | -239 | -166 | 127 |
| $H_2CO(g)$ | -116 | -110 | 219 |
| HCOOH(*g*) | -363 | -351 | 249 |
| HCN(*g*) | 135.1 | 125 | 202 |
| $C_2H_2(g)$ | 227 | 209 | 201 |
| $C_2H_4(g)$ | 52 | 68 | 219 |
| $CH_3CHO(g)$ | -166 | -129 | 250 |
| $C_2H_5OH(l)$ | -278 | -175 | 161 |
| $C_2H_6(g)$ | -84.7 | -32.9 | 229.5 |
| $C_3H_6(g)$ | 20.9 | 62.7 | 266.9 |
| $C_3H_8(g)$ | -104 | -24 | 270 |
| $C_4H_{10}(g)$ | -125.7 | -15.7 | 310 |
| $C_4H_{10}(l)$ | -147.3 | -15.0 | 231 |
| **Bromine** | | | |
| $Br_2(l)$ | 0 | 0 | 152.231 |
| BrCl(*g*) | 14.64 | -0.96 | 239.99 |
| **Chlorine** | | | |
| $Cl_2(g)$ | 0 | 0 | 223 |
| $Cl_2(aq)$ | -23 | 7 | 121 |
| $Cl^-(aq)$ | -167 | -131 | 57 |
| HCl(*g*) | -92 | -95 | 187 |
| **Fluorine** | | | |
| $F_2(g)$ | 0 | 0 | 203 |
| $F^-(aq)$ | -333 | -279 | -14 |
| HF(*g*) | -271 | -273 | 174 |
| **Hydrogen** | | | |
| $H_2(g)$ | 0 | 0 | 131 |
| H(*g*) | 217 | 203 | 115 |
| $H^+(aq)$ | 0 | 0 | 0 |
| $OH^-(aq)$ | -230 | -157 | -11 |
| $H_2O(s)$ | -292 | | 41 |
| $H_2O(l)$ | -286 | -237 | 70 |
| $H_2O$(g) | -242 | -229 | 189 |
| **Magnesium** | | | |
| Mg(s) | 0 | 0 | 33 |
| Mg(aq) | -492 | -456 | -118 |
| MgO(s) | -601 | -569 | 26.9 |
| **Oxygen** | | | |
| $O_2(g)$ | 0 | 0 | 205 |
| O(*g*) | 249 | 232 | 161 |
| $O_3(g)$ | 143 | 163 | 239 |

| | $\Delta H_f^\circ$ | $\Delta G_f^\circ$ | $S^\circ$ |
|---|---|---|---|
| **Nitrogen** | | | |
| $N_2(g)$ | 0 | 0 | 192 |
| $NCl_3(g)$ | 230 | 271 | |
| $NF_3(g)$ | -125 | -83.6 | 261 |
| $NH_3(g)$ | -46 | -17 | 193 |
| $NH_3(aq)$ | -80 | -27 | 111 |
| $NH_2CONH_2$(aq) | ? | ? | 174 |
| NO(*g*) | 90 | 87 | 211 |
| $NO_2(g)$ | 34 | 52 | 240 |
| $N_2O(g)$ | 82 | 104 | 220 |
| $N_2O_4(g)$ | 10 | 98 | 304 |
| $N_2O_5(g)$ | -42 | 134 | 178 |
| $N_2H_3CH_3(l)$ | 54 | 180 | 166 |
| $HNO_3(aq)$ | -207 | -111 | 146 |
| $HNO_3(g)$ | -134.3 | -73.94 | 266.4 |
| $HNO_3(l)$ | -174 | -81 | 156 |
| $NH_4Cl$(s) | -314 | -201 | 95 |
| $NH_4ClO_4(s)$ | -295 | -89 | 186 |
| $NH_4NO_3(s)$ | -365.6 | -184 | 151.1 |
| **Potassium** | | | |
| $K_2CO_3(s)$ | -1150.2 | -1064.6 | 155 |
| **Silver** | | | |
| Ag(*s*) | 0 | 0 | 42.6 |
| $Ag^+(aq)$ | 105.6 | 77.1 | 72.7 |
| $Ag(S_2O_3)^{3-}(aq)$ | -1285.7 | -- | -- |
| AgBr(s) | -100.4 | -96.9 | 107.1 |
| AgCl(s) | -127.1 | -109.8 | 96.2 |
| **Sodium** | | | |
| NaCl(*aq*) | 407 | -393 | 115.5 |
| NaOH(*aq*) | -470 | -419 | 50 |
| **Sulfur** | | | |
| S(rhombic) | 0 | 0 | 31.8 |
| S(monocl) | 0.3 | 0.1 | 32.6 |
| $SO_2$(g) | -296.8 | -300.2 | 248.8 |
| $SO_3$(g) | -395.7 | -371.1 | 256.3 |
| $H_2S$(g) | -20.17 | -33.0 | 205.6 |
| **Titanium** | | | |
| $TiCl_4(g)$ | -763 | -727 | 355 |
| $TiO_2(s)$ | -945 | -890 | 50 |
| **Aluminum** | | | |
| $AlBr_3(s)$ | -526.3 | -505 | 184 |
| Al(*s*) | 0 | 0 | 28.32 |
| **Barium** | | | |
| $BaCl_2(aq)$ | -872 | -823 | 123 |
| $Ba(OH)_2 \cdot 8H_2O(s)$ | -3342 | -2793 | 427 |
| **Iodine** | | | |
| $I_2(s)$ | 0 | 0 | 116.7 |
| $I_2(g)$ | 62.25 | 19.37 | 260.57 |
| HI(*g*) | 25.94 | 1.30 | 206.3 |

only $\Delta H_f^\circ$ applicable to this unit