

## Worksheet 1: Heat Associated with Phase Changes and Reactions

### Helpful constants for this worksheet:

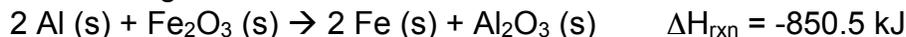
Specific heat capacity of aluminum: 0.903 J/g°C	of iron: 0.449 J/g°C
Specific heat capacity of gold: 0.128 J/g°C	of silver: 0.235 J/g°C
Specific heat capacity of H <sub>2</sub> O (s) = 2.09 J/g°C	of H <sub>2</sub> O (g) = 2.01 J/g°C
Heat of vaporization of H <sub>2</sub> O = 40.7 kJ/mole	Heat of fusion of H <sub>2</sub> O = 6.02 kJ/mole

**Concept questions:** 6.37, 6.39, 6.45, 6.57

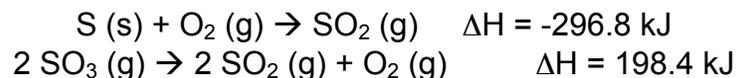
**Simple calculations:** 6.41, 6.43, 6.47, 6.49, 11.79,

**Heat of reactions and phase changes, calorimetry,:** 6.59, 6.61, 6.63, 6.65, 6.67, 6.73, 11.81, 11.83

Lecture Example #1: How much heat is released when 15.0 g of aluminum react with excess Fe<sub>2</sub>O<sub>3</sub> according to the reaction below:



Lecture Example #2: Find  $\Delta H_{\text{rxn}}$  for the reaction  $\text{S (s)} + 3/2 \text{O}_2 \text{ (g)} \rightarrow \text{SO}_3 \text{ (g)}$  given the following:



Lecture Example #3: Calculate  $\Delta H_{\text{rxn}}$  using standard heats of formation for the balanced equation:



Given the information in the table below:

CH <sub>4</sub> (g)	$\Delta H_f^\circ = -74.6 \text{ kJ/mole}$	H <sub>2</sub> O (l)	$\Delta H_f^\circ = -285.8 \text{ kJ/mole}$
CO <sub>2</sub> (g)	$\Delta H_f^\circ = -393.5 \text{ kJ/mole}$		

- Calculate  $\Delta E$  for the combustion of a gas that releases 210 kJ of energy to its surroundings and does 65.5 kJ of work on its surroundings.
- Calculate  $\Delta E$  for a system that absorbs 726 kJ of energy from its surroundings and does 526 kJ of work on its surroundings.
- What is the specific heat of silicon if it takes 192 J to raise the temperature of 45.0 g of Si by 6°C?
- Most automobile engines are cooled by water circulating through them and a radiator. However, the original Volkswagen Beetles had air-cooled engines. Why might car designers choose water cooling over air cooling?
- The same quantity of energy is added to 10.00-g pieces of gold, magnesium, and platinum, all initially at 25°C. The molar heat capacities of these three metals are 25.41 J/mol°C, 24.79 J/mol°C, and 25.95 J/mol°C, respectively. Which piece of metal will have the highest final temperature?
- One hundred grams of water at 30°C absorbs 290 kJ of heat from a mountain climber's stove at an elevation where the boiling point of water is 93°C. Is this amount of energy sufficient to heat the water to its boiling point?
- Two solid objects of equal mass, A and B, are placed in boiling water and allowed to come to temperature there. Each is then lifted out and placed in separate beakers containing 1000 g of water at 10.0°C. Object A increases the water temperature by 3.50°C; B increases the water temperature by 2.60°C. Which object has the larger heat capacity?

8. A 200.0-g piece of aluminum was cooled to 10.0°C in a water bath. The aluminum piece was then dropped into a Styrofoam cup containing 250 mL of water at 65.5°C. What is the final temperature of the water and the aluminum after they come to thermal equilibrium?
9. How much heat is required (added or removed?) to convert 100.0 g of steam at 115°C to liquid water at 65°C?
10. Exactly 10 mL of water at 25°C was added to a hot iron skillet. All of the water was converted into steam at 100°C. If the mass of the pan was 1.20 kg, what was the temperature change of the skillet?
11. CHALLENGE: Your assignment is to prepare freshly brewed iced tea. If you added 250 g of ice that is initially at -18°C to one cup (237 g) of freshly brewed tea initially at 100°C, what would be the final temperature of the tea? Assume that the mixture is in an insulated container, and that 237 g of tea is the same as 237 g of water.
12. CHALLENGE: You are throwing a party and you need to chill your beverages which are 72 aluminum cans each containing 355 mL. Assume an aluminum can is 12.5 g of aluminum. If the temperature of the beverages is 25°C initially, and the temperature of the ice is -8°C, how many 10-pound bags of ice are needed to chill the cans and their contents to an "ice cold" 0°C? Assume heat is only transferred between the ice and cans and not lost to the environment and that the ice melts (or it will take A LOT of ice). 1 pound is 453.6 g.
13. Draw an energy level diagram for the following reactions:
- $\text{NH}_4\text{NO}_3 (\text{s}) + \text{H}_2\text{O} (\text{l}) \rightarrow \text{NH}_4\text{NO}_3$   $\Delta H = +25.7 \text{ kJ}$
  - $\text{SO}_2 (\text{g}) + \frac{1}{2} \text{O}_2 (\text{g}) \rightarrow \text{SO}_3 (\text{g})$   $\Delta H = -98.9 \text{ kJ}$
14. Use the data below to sketch a heating curve for 1 mole of methanol. Start the curve at -100°C and end it at 100°C.

Boiling Point	65°C	Melting point	-94°C
$\Delta H_{\text{vap}}$	37 kJ/mole	$\Delta H_{\text{fus}}$	3.18 kJ/mole
Specific Heat Capacity	2.53 J/g·°C		

15. Aluminum metal reacts with chlorine with a spectacular display of sparks:
- $$2 \text{Al} (\text{s}) + 3 \text{Cl}_2 (\text{g}) \rightarrow 2 \text{AlCl}_3 (\text{s}) \quad \Delta H^\circ = -1408.4 \text{ kJ}$$
- How much heat (in kJ) is released on reaction of 5.00 g of Al?
16. How many grams of methane [ $\text{CH}_4(\text{g})$ ] must be combusted to heat 1.00 kg of water from 25.0°C to 90.0°C assuming  $\text{H}_2\text{O}(\text{l})$  as a product and 100% efficiency in heat transfer? The combustion of methane has a  $\Delta H_{\text{rxn}} = -802.3 \text{ kJ/mole}$ .

Key:

- 276 kJ
- +200 kJ
- 0.71 J/g·°C
- Au
- Yes
- A
- 57.3°C
- 244 kJ or 244 kJ removed
- 47.7°C
- 3°C
- ~17 pounds or 2 10-pound bags
- 131 kJ or 131 kJ released
- 5.4 g