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_2O (s) = 2.09 J/g·°C	of H_2O (g) = 2.01 J/g·°C
Heat of vaporization of H_2O = 40.7 kJ/mole	Heat of fusion of H_2O = 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_2O_3 according to the reaction below:

$$2\ Al\ (s) + Fe_2O_3\ (s) \rightarrow 2\ Fe\ (s) + Al_2O_3\ (s) \qquad \Delta H_{rxn} = -850.5\ kJ$$

Lecture Example #2: Find ΔH_{rxn} for the reaction S (s) + 3/2 O_2 (g) → SO_3 (g) given the following:

$$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g) \qquad \Delta H = -296.8\ kJ$$
$$2\ SO_3\ (g) \rightarrow 2\ SO_2\ (g) + O_2\ (g) \qquad \Delta H = 198.4\ kJ$$

Lecture Example #3: Calculate ΔH_{rxn} using standard heats of formation for the balanced equation:

$$CH_4\ (g) + 2\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (l)$$

Given the information in the table below:

CH_4 (g)	$\Delta H_f°$ = -74.6 kJ/mole	H_2O (l)	$\Delta H_f°$ = -285.8 kJ/mole
CO_2 (g)	$\Delta H_f°$ = -393.5 kJ/mole		

1. Calculate ΔE 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.
2. Calculate ΔE for a system that absorbs 726 kJ of energy from its surroundings and does 526 kJ of work on its surroundings.
3. 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?
4. 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?
5. 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?
6. 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?
7. 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:
    a. NH_4NO_3 (s) + H_2O (l) → NH_4NO_3 $\Delta H = +25.7$ kJ
    b. SO_2 (g) + ½ O_2 (g) → SO_3 (g) $\Delta H = -98.9$ 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
ΔH_{vap}	37 kJ/mole	ΔH_{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 Al (s) + 3 Cl_2 (g) → 2 $AlCl_3$ (s) $\Delta H° = -1408.4$ kJ
    How much heat (in kJ) is released on reaction of 5.00 g of Al?
16. How many grams of methane [CH_4(g)] must be combusted to heat 1.00 kg of water from 25.0°C to 90.0°C assuming H_2O(l) as a product and 100% efficiency in heat transfer? The combustion of methane has a $\Delta H_{rxn} = -802.3$ kJ/mole.

Key:

1. -276 kJ
2. +200 kJ
3. 0.71 J/g·°C
5. Au
6. Yes
7. A
8. 57.3°C
9. -244 kJ or 244 kJ removed
10. -47.7°C
11. 3°C
12. ~17 pounds or 2 10-pound bags
15. -131 kJ or 131 kJ released
16. 5.4 g