AP Chemistry
Unit 5- Homework Problems
Thermodynamics

Specific Heat Problems

1. How many J would it take to raise the temperature of 200. grams of water (C = 4.184 J/g˚C) from 5˚C to 85˚C?
2. How many J would problem number 1 be if it was aluminum (C = 0.897 J/g˚C) instead of water?
3. How many grams of copper (C = 0.385 J/g˚C) could be heated from 20.˚C to 75˚C if 1200. J are applied to it?
4. What is the specific heat capacity of a substance if 750 J caused 100. grams of it to go from 90.˚C to 135˚C?
5. What would the final temperature be if 500. J are applied to 150 grams of ice (C = 2.06 J/g˚C) at -90.˚C?
6. What would the temperature change by if a 90. gram piece of hot iron (C = 0.449 J/g˚C) cooled by losing 200. J?
7. What was the initial temperature if 500. J were applied to 250. g of mercury (C = 0.14 J/g˚C) and the final temperature was 50.˚C?

Phase Change Problems

1. Why can we not use the equation Q = mcΔT for phase changes of a substance (why won't it work)?
2. What is the heat of fusion of a substance?
3. What is the heat of vaporization of a substance?
4. How many J are needed to melt 30. grams of copper (ΔH_{fus} = 13.3 kJ/mol)?
5. How much heat is needed to boil 63 grams of ethanol (ΔH_{vap} = 38.6 kJ/mol)?
6. What is the heat of fusion of carbon dioxide if 1200 J melts 6.3 grams of it?
7. What is the heat of vaporization of carbon dioxide if 50. J boiled 0.14 grams of it?
8. How many grams of copper (ΔH_{fus} = 13.05 kJ/mol) could be melted if 700. J are applied to it?
9. How many grams of water (ΔH_{vap} = 40.7 kJ/mol) could be boiled if 8000. J are applied to it?

Combination Problems

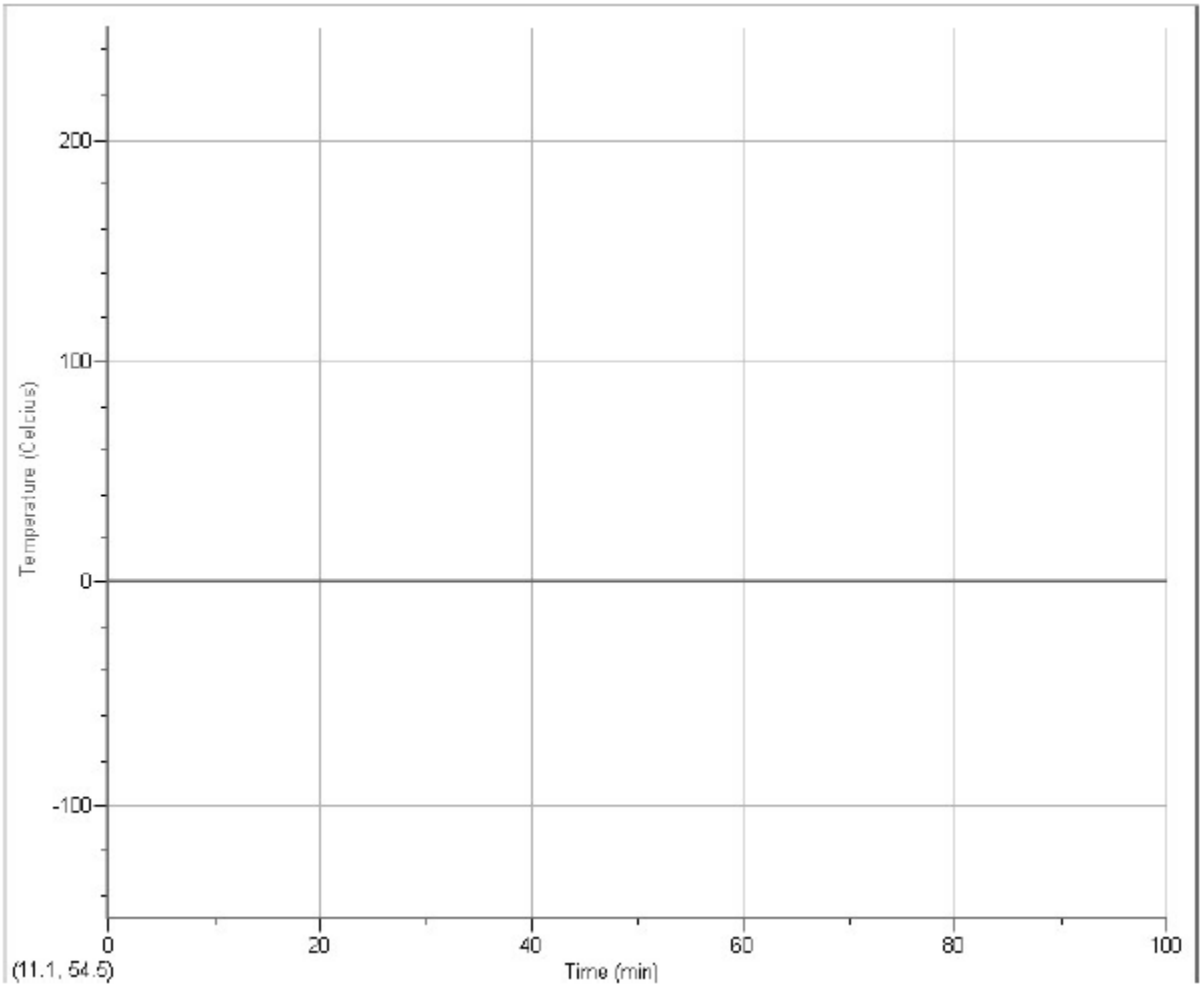
1. How much energy is needed to heat 200. grams of liquid diethyl ether (C_{liquid} = 2.33 J/g˚C, ΔH_{vap} = 357 J/g), $(C_2H_5)_2O$, from 5.0˚C to its boiling point (34.6˚C) and boil it?
2. How much energy is needed to turn 400. grams of liquid benzene, C_6H_6 (C_{liquid} = 1.74 J/g˚C, C_{gas} = 1.06 J/g˚C, ΔH_{vap} = 30.7 kJ/mol, Boiling Point = 80.˚C) , at 20.˚C to gaseous benzene at 150.˚C?
3. How much energy is needed to turn a 75 g block of ice at -40.0˚C to steam at 250.0˚C? (C_{ice} = 2.1 J/g˚C, C_{liq} = 4.184 J/g˚C, C_{steam} = 2.0 J/g˚C, ΔH_{fus} ice = 6.01 kJ/mol, ΔH_{vap} steam = 40.7 kJ/mol)
4. Which part of #3 contributes the most energy to the overall process?

Molar Heat Combination Problems

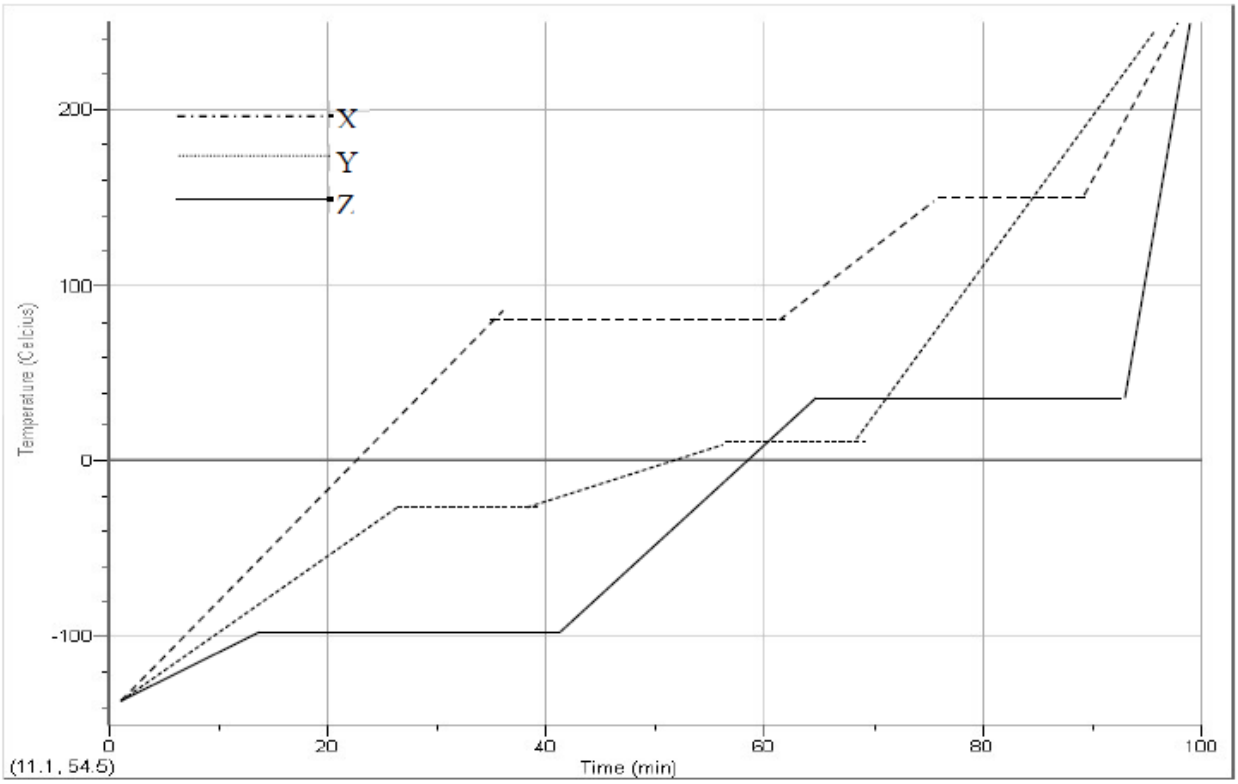
1. Calculate the total energy needed to turn 33.30 grams of ice at 0.00 °C into steam at 150.0 °C. (ΔH_{fus} = 6.01 kJ/mol, C_{liquid} = 4.184 J/g˚C, ΔH_{vap} = 40.7 kJ/mol, C_{gas} = 2.02 J/g˚C)
2. How much heat is released when 105.0 g of steam at 100.0 °C is cooled to ice at -15.0 °C? (ΔH_{vap} = 40.7 kJ/mol, C_{liquid} = 75.4 J/mol˚C, ΔH_{fus} = 6.01 kJ/mol, C_{solid} = 36.4 J/mol˚C)

Heating Curves

1. What do you call each of the following changes of state:
    A. Solid to liquid
    B. Liquid to gas
    C. Gas to solid
    D. Solid to gas
    E. Liquid to solid
    F. Gas to liquid
2. The melting point of a solid is the same as what other point?
3. The condensing point of a gas is the same as what other point?
4. Octane, the major component in gasoline freezes at -57˚C and boils at 125˚C. If gaseous octane was cooled from 200˚C to -100˚C, draw what the graph would look like:



5. The following graph shows three different substances and their phase changes. Answer the following questions about them:
    A. What is the melting point of substance Y?
    B. What is the boiling point of substance Z?
    C. Which substance is still a solid when the other two substances have turned to gases?
    D. Which substance has the lowest boiling point?
    E. Which substance has the lowest freezing point?



6. Water boils at 100˚C. Why are steam burns potentially more dangerous than boiling water burns?

Calorimetry

1. What is the specific heat capacity of water?
2. A piece of ice is placed on the sidewalk on a hot summer day. What happens to the energy content of the piece of ice, does it gain or lose energy? What happens to the air around the ice, does it gain or lose energy?
3. 100. grams of hot water at 80.˚C is combined with 100. grams of cool water at 20.˚C. What is the final temperature of the combined water?
4. 100. grams of hot water at 80.˚C is combined with 50. grams of cool water at 20.˚C. What is the final temperature of the combined water?
5. A 25 gram piece of hot metal at 97˚C is plunged into 35 gram of cool water at 19˚C. The metal gives up its heat to the water until they are both at 22˚C. What is the specific heat capacity of the metal?
6. A 75 gram piece of hot metal at 100.˚C is dropped into 50. gram of cool water at 22˚C. The final temperature of the system is 30.˚C. What is the specific heat capacity of the metal?

7. A 120 gram piece of copper (C = 0.385 J/g˚C) at 75˚C is put into a 20. gram sample of water at 10.˚C. What is the final temperature of the system after the copper releases all its extra heat?
8. 100. g of water at 22˚C was combined with 20. grams of ice at 0˚C. The final temperature of the system was 6˚C. Calculate the heat of fusion of ice based upon this data.
9. 200. g of water at 22˚C was combined with 15 grams of ice at 0˚C. Knowing that the heat of fusion of ice is 333 J/g, calculate the final temperature of the system.
10. Suppose you heat a 50. g piece of silver to 99.8˚C and then drop it onto ice at 0˚C. When the temperature of the metal has dropped to 0˚C, it is found that 3.54 g of ice has melted. What is the specific heat capacity of silver?
11. A 9.36 g piece of Pt is heated to 98.6˚C and then dropped onto a block of ice. When the temperature of the metal has dropped to 0˚C, it is found that 0.37 g of ice melted. What is the specific heat capacity of Pt?
12. Describe each of the reactions below as either endothermic or exothermic. Some are tricky, be careful. Decide whether heat is entering or leaving the system in question:
    A. Exploding fireworks *endothermic* *exothermic*
    B. Melting snow *endothermic* *exothermic*
    C. Lava cooling *endothermic* *exothermic*
    D. Paper burning *endothermic* *exothermic*
    E. An ice cube freezing *endothermic* *exothermic*
    F. Water evaporating *endothermic* *exothermic*

Enthalpy Problems

1. For the equation: $Mg + ½\ CO_2 \rightarrow MgO + ½\ C$
   If 16.7 kJ of heat is given off per 1.0 gram of magnesium reacted, calculate the ΔH_{rxn} in kJ/mol.
2. For the equation: $(NH_4)_2Cr_2O_7 \rightarrow N_2 + 4\ H_2O + Cr_2O_3$
   If 3.0 grams of $(NH_4)_2Cr_2O_7$ gives off 3.57 kJ of energy, calculate the ΔH_{rxn} in kJ/mol.
3. For the equation: $Na + H_2O \rightarrow NaOH + ½\ H_2$
   If 5.0 grams of sodium is placed into 100 grams of water at 20.˚C and the final temperature of the system reaches 27˚C, calculate the ΔH_{rxn} in kJ/mol.
4. For the equation: $Ca + 2\ HCl \rightarrow CaCl_2 + H_2$
   If 2.0 grams of calcium is placed into 75 mL of 2.0 M HCl at 18˚C and the final temperature of the system reaches 23˚C, calculate the ΔH_{rxn} in kJ/mol. (Assume the density of the solution is 1.00 g/mL and the specific heat capacity of the HCl = 4.18 J/g˚C)
5. For the equation: $NaNO_3\ (s) \rightarrow Na^+ + NO_3^-\ (aq)$
   If 20. grams of $NaNO_3$ were placed into 200. grams of water at 22˚C, and the temperature dropped to 12˚C, what is the ΔH_{rxn} in kJ/mol?

Bond Energies

1. Draw the Lewis Dot structures and determine the ΔH_{rxn} for:
   $CO + Cl_2 \rightarrow Cl_2CO$
2. Draw the Lewis Dot structures for and determine the ΔH_{rxn} for:
   $O_2 + 2\ H_2 \rightarrow 2\ H_2O$
3. Draw the Lewis Dot structures for and determine the energy for the O-F bond for:
   $OF_2 + H_2O \rightarrow O_2 + 2\ HF \quad \Delta H_{rxn} = -318$ kJ
4. For the reaction:
   $O_3 + O \rightarrow 2\ O_2 \quad \Delta H_{rxn} = -394$ kJ
   a. Draw the Lewis dot structures for all species
   b. Calculate the O-O bond energy in O_3

c. What is the bond order of the O-O bond in O_3 (remember it is a resonance structure)?
d. Compare the answer you got in part b to the O-O bond energy and the O=O bond energy you can look up. Does your answer make sense? Why or why not?

Hess's Law Problems

1. Given the following equations:

   $2\ H_2 + O_2 \rightarrow 2\ H_2O$ $\quad \Delta H_{rxn} = -572$ kJ

   $N_2O_5 + H_2O \rightarrow 2\ HNO_3$ $\quad \Delta H_{rxn} = -74$ kJ

   $\frac{1}{2}\ N_2 + 3/2\ O_2 + \frac{1}{2}\ H_2 \rightarrow HNO_3$ $\quad \Delta H_{rxn} = -174$ kJ

   Calculate ΔH_{rxn} for:

   $N_2 + 5/2\ O_2 \rightarrow N_2O_5$ $\quad \Delta H_{rxn} =$?????

2. Given the following equations:

   $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ $\quad \Delta H_{rxn} = -92$ kJ

   $4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$ $\quad \Delta H_{rxn} = -906$ kJ

   $H_2 + \frac{1}{2}\ O_2 \rightarrow H_2O$ $\quad \Delta H_{rxn} = -242$ kJ

   Calculate the ΔH_{rxn} for:

   $\frac{1}{2}\ N_2 + \frac{1}{2}\ O_2 \rightarrow NO$ $\quad \Delta H_{rxn} =$?????

3. Given the following equations:

   $Sr + \frac{1}{2}\ O_2 \rightarrow SrO$ $\quad \Delta H_{rxn} = -592$ kJ

   $SrO + CO_2 \rightarrow SrCO_3$ $\quad \Delta H_{rxn} = -234$ kJ

   $C + O_2 \rightarrow CO_2$ $\quad \Delta H_{rxn} = -394$ kJ

   Calculate the ΔH_{rxn} for:

   $Sr + C + 3/2\ O_2 \rightarrow SrCO_3$ $\quad \Delta H_{rxn} =$?????

4. Given the following equations:

   $C + 2\ H_2 \rightarrow CH_4$ $\quad \Delta H_{rxn} = -75$ kJ

   $C + 2\ Cl_2 \rightarrow CCl_4$ $\quad \Delta H_{rxn} = -96$ kJ

   $H_2 + Cl_2 \rightarrow 2\ HCl$ $\quad \Delta H_{rxn} = -92$ kJ

   Calculate the ΔH_{rxn} for:

   $CH_4 + 4\ Cl_2 \rightarrow CCl_4 + 4\ HCl$ $\quad \Delta H_{rxn} =$?????

5. Given the following equations:

   $C_5H_{12} + 8\ O_2 \rightarrow 5\ CO_2 + 6\ H_2O$ $\quad \Delta H_{rxn} = -3506$ kJ

   $C + O_2 \rightarrow CO_2$ $\quad \Delta H_{rxn} = -394$ kJ

   $2\ H_2 + O_2 \rightarrow 2\ H_2O$ $\quad \Delta H_{rxn} = -484$ kJ

   Calculate the ΔH_{rxn} for:

   $5\ C + 6\ H_2 \rightarrow C_5H_{12}$ $\quad \Delta H_{rxn} =$?????

ΔH_f°

1. For each of the substances below, write a balanced equation showing the formation of 1 mole of the compound from its elements in their standard states. Look up the value for ΔH_f° in the appendix in the back of a book or online.
   A. Al_2O_3
   B. $Mg(OH)_2$
   C. $C_{12}H_{22}O_{11}$
   D. $NaHCO_3$

2. For each of the reactions below, calculate ΔH_{rxn}°. (Look up the values for ΔH_f° in the Appendix in the back of a book or online.)
    A. $SO_2\ (g) + ½\ O_2\ (g) \rightarrow SO_3\ (g)$
    B. $4\ NH_3\ (g) + 5\ O_2\ (g) \rightarrow 4\ NO\ (g) + 6\ H_2O\ (g)$
    C. $NH_4NO_3\ (s) \rightarrow N_2O\ (g) + 2\ H_2O\ (g)$
3. Nitroglycerin is a powerful explosive that explodes by the following equation while giving off 4200 kJ of heat.
   $C_3H_5(NO_3)_3 \rightarrow 3/2\ N_2\ (g) + ¼\ O_2\ (g) + 3\ CO_2\ (g) + 5/2\ H_2O\ (g)$
   Calculate the ΔH_f° of nitroglycerin.
4. Oxygen difluoride reacts with water vapor to produce 318 kJ of heat by the following equation:
   $OF_2\ (g) + H_2O\ (g) \rightarrow 2\ HF\ (g) + O_2\ (g)$
   Calculate the ΔH_f° of OF_2
5. Large scale H_2 can be made by the following 3 steps:
   Step 1: $SO_2\ (g) + 2\ H_2O\ (g) + Br_2\ (g) \rightarrow H_2SO_4\ (l) + 2\ HBr\ (g)$
   Step 2: $H_2SO_4\ (l) \rightarrow H_2O\ (g) + SO_2\ (g) + ½\ O_2\ (g)$
   Step 3: $2\ HBr\ (g) \rightarrow H_2\ (g) + Br_2\ (g)$
   Calculate the ΔH_{rxn}° of each step. Calculate the ΔH_{rxn}° of the overall reaction. Is the overall reaction endo or exothermic?