Calorimetry practice problems   KEY

1) Two aqueous solutions at room temperature are mixed in a coffee cup calorimeter. The reaction causes the temperature of the resulting solution to fall below room temperature. Which of the following statements is TRUE? 1) ________

A) This type of experiment directly yields ΔE_{rxn}.
B) Energy is leaving the system during reaction.
C) The products have a lower potential energy than the reactants.
D) The mixing is endothermic.
E) The solution has special properties that enable it to violate the first and second law of thermodynamics.

2) Lead, water, sulfur, and arsenic have specific heats of 0.128, 4.18, 0.706, and 0.329 J/g°C, respectively. Which of these would require the smallest amount of heat to increase its temperature by 10 °C (assume all samples have the same mass)? 2) ________

LEAD ⇒ LOWEST HEAT CAPACITY

3) When power was turned off to a 30.0 gal. water heater, the temperature of the water dropped from 75.0 °C to 22.5 °C. How much heat was lost to the surroundings? 3) ________

$30.0\,gal \times \frac{3.7854\,L}{gal} \times \frac{mL}{10^{-3}\,L} \times \frac{1.00\,g}{mL} = 113562\,g$

HEAT LOST = $-q$ (ANSWER WILL BE POSITIVE)

$q = -(mC\Delta T) = 2.49 \times 10^4\,kJ$

4) How much heat is needed to raise the temperature of 5.28 gal of water from 25.0 °C to 88.0 °C (1 gal = 3.785 L)? 4) ________

$5.28\,gal \times \frac{3.7854\,L}{gal} \times \frac{mL}{10^{-3}\,L} \times \frac{1.00\,g}{mL} = 19987\,g$

$q = mC\Delta T$

$q = 5270\,kJ$

5) 14.0 g of metal at 24.0 °C has 250 joules of heat added to it. The metal's specific heat is 0.105 J/g °C. What is its final temperature? 5) ________

$q = mC(T_f - T_i) \Rightarrow \left(\frac{q}{mC}\right) + T_i = T_f \Rightarrow \left[\frac{(250\,J)}{(14.0\,g)(4.184\,\frac{J}{g°C})}\right] + 24.0°C = 28.3°C$

6) 1219 joules of heat raise the temperature of 250 g of metal by 64 °C. What is the specific heat in J/g °C? 6) ________

$q = mC\Delta T \Rightarrow C = \frac{q}{m\Delta T} = \frac{1219\,J}{(250\,g)(64\,°C)} = 0.076\,\frac{J}{g°C}$

7) 1674 J of heat are absorbed by 25.0 mL of NaOH (d = 1.10 g/mL, specific heat = 4.10 J/g °C). The temperature of the NaOH goes up how many degrees? 7) ________

$25.0\,mL \times \frac{1.10\,g}{mL} = 27.5\,g$

$q = mC\Delta T$

$\Delta T = \frac{q}{mC} = \frac{1674\,J}{(27.5\,g)(4.10\,\frac{J}{g°C})} = 14.8°C$

8) What is the final temperature when 150.0 mL of water at 90.0 °C is added to 100.0 mL of water at 30.0 °C? 8) ________

66.1 °C SEE ATTACHED WORK

9) 50.0 g of iron (C=0.449 J/g°C) that has an initial temperature of 225 °C and 50.0 g of gold (C=0.128 J/g°C) that has an initial temperature of 25.0 °C are brought into contact with one another. Assuming no heat is lost to the surroundings, what will be the temperature when the two metals reach thermal equilibrium? 9) ________

1.80×10^2 °C

10) A 12-inch diameter ball of pure cobalt metal at 225 °C was placed in 10.0 gal. of water at 15.0 °C. What is the final temperature of the water? Assume no heat is lost to the surroundings. (specific heat for cobalt is 0.421 J/g °C, density of cobalt = 8.862/cm^3, 1 gal. = 3.785 L, 1 in = 2.54 cm, V(sphere) = 4/3 πr^3) 10) ________

69.25 °C

11) 100.0 g of nickel at 150 °C was placed in 1.00 L of water at 25.0 °C. The final temperature of the nickel-water mixture was 26.3 °C. What is the specific heat of the nickel? 11) ________

0.440 $\frac{J}{g°C}$

12) A piece of iron (mass = 25.0 g) at 398 K is placed in a styrofoam coffee cup containing 25.0 mL of water at 298 K. Assuming that no heat is lost to the cup or the surroundings, what will the final temperature of the water be? The specific heat capacity of iron = 0.449 J/g°C and water = 4.18 J/g°C. 12) ________

34.6 °C

13) A 100.0 mL sample of 0.300 M NaOH is mixed with a 100.0 mL sample of 0.300 M HNO_3 in a coffee cup calorimeter. If both solutions were initially at 35.0°C and the temperature of the resulting solution was recorded as 37.0°C, determine the $\Delta H°_{rxn}$ (in units of kJ/mol NaOH) for the neutralization reaction between aqueous NaOH and HNO_3. Assume that no heat is lost to the calorimeter or the surroundings, and that the density and the heat capacity of the resulting solution are the same as water. 13) ________

-55.7 kJ/mol

14) A 35.6 g sample of ethanol (C_2H_5OH) is burned in a bomb calorimeter, according to the following reaction. If the temperature rose from 35.0 to 76.0°C and the heat capacity of the calorimeter is 23.3 kJ/°C, what is the value of $\Delta H°_{rxn}$? The molar mass of ethanol is 46.07 g/mol. 14) ____________

$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$ $\Delta H°_{rxn}$ = ? −1240 kJ/mol

15) A 21.8 g sample of ethanol (C_2H_5OH) is burned in a bomb calorimeter, according to the following reaction. If the temperature rises from 25.0 to 62.3°C, determine the heat capacity of the calorimeter. The molar mass of ethanol is 46.07 g/mol. 15) ____________

$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$ $\Delta H°_{rxn}$ = −1235 kJ 15.7 kJ/°C

16) A 12.8 g sample of ethanol (C_2H_5OH) is burned in a bomb calorimeter with a heat capacity of 5.65 kJ/°C. Using the information below, determine the final temperature of the calorimeter if the initial temperature is 25.0°C. The molar mass of ethanol is 46.07 g/mol. 16) ____________

$C_2H_5OH(l) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(g)$ $\Delta H°_{rxn}$ = −1235 kJ 86 °C

17) A student is preparing to perform a series of calorimetry experiments. She first wishes to determine the heat capacity of the calorimeter (C_{cal}) for her coffee cup calorimeter. She pours a 50.0 mL sample of water at 345 K into the calorimeter containing a 50.0 mL sample of water at 298 K. She carefully records the final temperature of the water as 317 K. What is the value of C_{cal} for the calorimeter? 17) ____________

99 J/°C

18) Two solutions, initially at 24.60°C, are mixed in a coffee cup calorimeter (C_{cal} = 15.5 J/°C). When a 100.0 mL volume of 0.100 M $AgNO_3$ solution is mixed with a 100.0 mL sample of 0.200 M NaCl solution, the temperature in the calorimeter rises to 25.30°C. Determine the $\Delta H°_{rxn}$ for the reaction as written below. Assume that the density and heat capacity of the solutions is the same as that of water. 18) ____________

$NaCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + NaNO_3(aq)$ $\Delta H°_{rxn}$ = ?

−59.6 kJ/mol

8) $-q_{HOT} = q_{COLD}$

$-(mC\Delta T)_H = mC\Delta T_C$

$(-150.0g)(4.184\frac{J}{g°C})(T_F - 90.0°C) = (100.0g)(4.184\frac{J}{g°C})(T_F - 30.0°C)$ } DISTRIBUTE

$-627.6\frac{J}{°C}(T_F) + 56500\,J = 418.4\frac{J}{°C}(T_F) - 12600\,J$ } COMBINE LIKE TERMS

$1046\frac{J}{°C}(T_F) = 69100\,J$

$T_F = 66.1\,°C$

9) $-q_{Fe} = q_{AU}$

$-M_{Fe}C_{Fe}\Delta T_{Fe} = M_{AU}C_{AU}\Delta T_{AU}$

$(-50.0g)(0.449\frac{J}{g°C})(T_F - 225°C) = (50.0g)(0.128\frac{J}{g°C})(T_F - 25.0°C)$

$-22.5\frac{J}{°C}(T_F) + 5050\,J = 6.40\frac{J}{°C}(T_F) - 1.60\times10^2\,J$

$5210\,J = 28.9\frac{J}{°C}(T_F)$

$T_F = 1.80\times10^2\,°C$

10) 6 in. RADIUS ⇒ $6\,in. \times \frac{2.54\,cm}{in.} = 15.24\,cm$

$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(15.24\,cm)^3 = 14827\,cm^3$ ← VOLUME OF SPHERE

$14827\,cm^3 \times \frac{8.862\,g}{cm^3} = 1.314\times10^5\,g$ ← MASS OF SPHERE

$10.0\,gal \times \frac{3.7845\,L}{gal} \times \frac{mL}{10^{-3}L} \times \frac{1.00\,g}{mL} = 3.78\times10^4\,g$ ← MASS OF H_2O

} USE TO GET T_F

10) CONTINUED

$$-q_{Co} = q_{H_2O}$$

$$-m_{Co} C_{Co} \Delta T_{Co} = m_{H_2O} C_{H_2O} \Delta T_{H_2O}$$

$$(-1.314\times10^5 g)(0.421 \tfrac{J}{g\cdot°C})(T_F - 225°C) = (3.78\times10^4 g)(4.184 \tfrac{J}{g°C})(T_F - 15.0°C)$$

$$-55300 \tfrac{J}{°C}(T_F) + 1.24\times10^7 J = 158000 \tfrac{J}{°C}(T_F) - 2.37\times10^6 J$$

$$213300 \tfrac{J}{°C}(T_F) = 1.477\times10^7 J$$

$$T_F = 69.25°C$$

11) $$-q_{Ni} = q_{H_2O}$$

$$-m_{Ni} C_{Ni} \Delta T_{Ni} = m_{H_2O} C_{H_2O} \Delta T_{H_2O}$$

$$C_{Ni} = \frac{m_{H_2O} C_{H_2O} \Delta T_{H_2O}}{-m_{Ni} \Delta T_{Ni}} = \frac{(1000.0g)(4.184 \tfrac{J}{g°C})(26.3°C - 25.0°C)}{(-100.0g)(26.3°C - 150.0°C)}$$

$$C_{Ni} = 0.440 \tfrac{J}{g°C}$$

12) $$-q_{Fe} = q_{H_2O}$$

$$(-25.0g)(0.449 \tfrac{J}{g°C})(T_F - 125°C) = (25.0g)(4.184 \tfrac{J}{g°C})(T_F - 25.0°C)$$

$$-11.2 \tfrac{J}{°C}(T_F) + 1.40\times10^3 J = 105 \tfrac{J}{°C}(T_F) - 2620 J$$

$$T_F = 34.6°C$$

13) $-q_{rxn} = q_{SOLN}$

↑

TEMP OF SOLUTION INCREASED

$q_{rxN} = -q_{SOLN} = -m_{SOLN} \, C_{SOLN} \, \Delta T_{SOLN}$

$q_{rxN} = (-200.0\,g)(4.184\,\frac{J}{g\,°C})(37.0°C - 35.0°C)$

$q_{rxn} = -1670\ J = -1.67\ kJ$ ⟵ WE NEED IN kJ/mol NaOH

MOLES NaOH:

$100.0\ mL \times \frac{10^{-3}\ L}{mL} \times \frac{0.300\ mol\ NaOH}{L} = 0.0300\ mol\ NaOH$

$\frac{-1.67\ kJ}{0.0300\ mol} = -55.7\ kJ/mol$

14) $-q_{rxn} = q_{cal}$

$q_{rxn} = -(23300\,\frac{J}{°C})(76.0°C - 35.0°C) = -955\ kJ$

$35.6\ g \times \frac{mol\ CH_3CH_2OH}{46.07\ g} = 0.773\ mol\ CH_3CH_2OH$

$\Delta H°_{rxn} = \frac{-955\ kJ}{0.773\ mol} = -1240\ kJ/mol$

15) $21.8\,g \times \frac{mol\ CH_3CH_2OH}{46.07\,g} \times \frac{1235\,kJ}{mol\ CH_3CH_2OH} \times \frac{10^3\,J}{kJ} = 5.84 \times 10^5\,J$

$\uparrow$

$-q_{rxn} = 5.84 \times 10^5\,J$

$-q_{rxn} = q_{CAL}$

$\downarrow$

$-q_{rxn} = C_{cal}\,\Delta T_{cal} \Rightarrow C_{cal} = \frac{-q_{rxn}}{\Delta T_{cal}} = \frac{5.84 \times 10^5\,J}{(62.3°C - 25.0°C)}$

$C_{cal} = 15.7\,kJ/°C$

16) $12.8\,g \times \frac{mol\ CH_3CH_2OH}{46.07\,g} \times \frac{1235\,kJ}{mol\ CH_3CH_2OH} = 343\,kJ$

$-q_{rxn} = q_{cal} = C_{cal}\,\Delta T_{cal}$

$-q_{rxn} = C_{cal}(T_F - T_i)$

$T_F = \left[\frac{-q_{rxn}}{C_{cal}}\right] + T_i = \frac{343\,kJ}{5.6\,kJ/°C} + 25.0°C = 86°C$

17) $-q_{HOT} = q_{cold} + q_{cal}$

$-m_{HOT}\,C_{H_2O}\,\Delta T_{HOT} = m_{cold}\,C_{H_2O}\,\Delta T_{cold} + C_{cal}\,\Delta T_{cal}$

$(-50.0\,g)(4.184\,\frac{J}{gK})(317K - 345K) = (50.0\,g)(4.184\,\frac{J}{gK})(317K - 298K) + C_{cal}(317K - 298K)$

$C_{cal} = 99\,\frac{J}{K}$ OR $99\,\frac{J}{°C}$

18) $-q_{rxn} = q_{SOLN} + q_{cal}$

$$-q_{rxn} = (200.0\,g)\left(4.184\,\frac{J}{g\,°C}\right)(25.30°C - 24.60°C) + \left(15.5\,\frac{J}{°C}\right)(25.30°C - 24.60°C)$$

$$q_{rxn} = -596\,J$$

$$100.0\,mL \times \frac{10^{-3}\,L}{mL} \times \frac{0.100\,mol\,AgNO_3}{L} = 0.0100\,mol$$ ← $AgNO_3$ IS LIMITING

$$q_{rxn} = \frac{-596\,J}{0.0100\,mol} = -59.6\,kJ/mol$$