Topic D Problems

1) What is the sign of q for each of the following processes, assuming that the water is the system? You do not need to calculate the numerical values of q.
   a) 50 g of ice melts.
   b) 50 L of steam condenses.
   c) 50 mL of water cools down from 20˚C to 10˚C.

2) A student puts a hot rock into some cold water and waits until the temperature of the rock and the water are no longer changing.
   a) The student writes the following equation: final T_{rock} = final T_{water}. Is this a true statement? If not, how should it be modified to make it true?
   b) The student then writes the following equation: $q_{rock} = q_{water}$. Is this a true statement? If not, how should it be modified to make it true? *(Assume that the rock and water are in an insulated container, so no energy can enter or leave.)*

3) Use the following properties of bromine (Br_2) to answer parts a through g below.
   Specific heat capacity of $Br_2(l)$ = 0.473 J/g·˚C
   Heat of fusion of Br_2 = 33.1 J/g
   Heat of vaporization of Br_2 = 96.6 J/g
   Melting point of Br_2 = -7.2˚C
   Boiling point of Br_2 = 58.9˚C
   a) How much heat is needed to raise the temperature of 40.0 g of liquid bromine from -5.8˚C to 11.9˚C?
   b) How much heat is needed to boil 40.0 g of liquid bromine?
   c) How much heat is needed to melt 40.0 g of solid bromine?
   d) A 25.0 g sample of liquid bromine is at 10.0˚C. If you add 125 J of heat to the bromine, what will its final temperature be?
   e) A 25.0 g sample of liquid bromine is at its boiling point. If you add 1.500 kJ of heat to the bromine, how much of it will boil?
   f) How much heat is needed to convert 10.0 g of solid bromine at -7.2˚C into gaseous bromine at 58.9˚C?

4) A 34.82 g piece of beryllium at 61.9ºC is placed into 41.33 g of water at 16.1ºC. What will the temperature be after the water and the beryllium have reached thermal equilibrium, assuming that no heat is lost to the surroundings? The specific heat capacity of beryllium is 1.82 J/g·ºC, and that of water is 4.18 J/g·ºC.

5) A chemist puts an unknown mass of aluminum at 68.0ºC and 67.3 g of chromium at 75.0˚C into 125.0 g of water at 8.2ºC. When the mixture reaches thermal equilibrium, the temperature is 16.4ºC. Using this information, and assuming that no heat is lost to the surroundings, calculate the mass of the piece of aluminum. The relevant specific heat capacities are:
   aluminum = 0.902 J/g·ºC, chromium = 0.448 J/g·ºC, water = 4.18 J/g·ºC.

6) A 46.51 g piece of copper at 71.2˚C is put into 51.32 g of liquid ethanol (C_2H_5OH) at 4.9˚C. When the mixture reaches thermal equilibrium, the temperature is 13.2˚C. The specific heat capacity of copper is 0.385 J/g·˚C. Calculate the specific heat capacity of liquid ethanol.

7) The melting point of gallium (Ga) is 29.8˚C; this is also the temperature at which liquid gallium freezes. A chemist pours 54.72 g of liquid gallium at 29.8˚C into 67.09 g of water at 5.2˚C. When the mixture reaches thermal equilibrium, the gallium has solidified and the temperature is 21.4˚C. The specific heat of gallium is 0.371 J/g·ºC and the specific heat of water is 4.18 J/g·ºC. Use this information to calculate the heat of fusion of gallium. Give your answer in J/g and in kJ/mol.

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8) Consider the following two facts about the reaction of HCl with NaOH

   Fact #1: ΔE is a negative number for this reaction, which means that the energy of the chemicals <u>decreases</u>.

   Fact #2: When HCl and NaOH are mixed, the mixture becomes hotter, which means that the energy of the chemicals <u>increases</u>.

   Explain how both of these statements can be true at the same time.

9) When aqueous HCl reacts with solid $NaHCO_3$, the mixture becomes colder.
   a) Does the kinetic energy of the chemicals increase, decrease, or remain the same during the reaction?
   b) Does the potential energy of the chemical increase, decrease, or remain the same during the reaction?
   c) What is the sign of ΔE for this reaction?

10) For the reaction $2\ Al(s) + 6\ H^+(aq) \rightarrow 2\ Al^{3+}(aq) + 3\ H_2(g)$, ΔE = -1057 kJ
   a) How much energy is given off when 2.822 g of Al reacts with hydrogen ions, assuming the hydrogen ions are in excess?
   b) How much energy is given off when 1.413 g of Al is added to 23.0 mL of a solution that contains 5.89 M H^+?
   c) If you want to obtain 50.0 kJ of energy from this reaction, how many grams of aluminum and how many mL of 3.00 M HCl must you use?
   d) If this reaction produces 13.3 L of $H_2(g)$ at 25.0˚C and 1.014 atm, how much energy does it give off?

11) When 4.00 g of Br_2 reacts with excess Al to form $AlBr_3$, 8.80 kJ of energy is given off. Calculate ΔE for the reaction $2\ Al(s) + 3\ Br_2(s) \rightarrow 2\ AlBr_3(s)$.

12) A chemist burns 0.5177 g of liquid hexane (C_6H_{14}) in a bomb calorimeter that has a heat capacity of 4287 J/ºC. The temperature of the calorimeter rises from 21.382ºC to 27.170ºC during the reaction. Calculate ΔE for the following reaction:

$$2\ C_6H_{14}(l) + 19\ O_2(g) \rightarrow 12\ CO_2(g) + 14\ H_2O(l)$$

13) Explain why some reactions give off different amounts of heat when they are carried out at constant pressure versus constant volume.

14) A reaction has $\Delta E = -50$ kJ.
   a) If this reaction occurs, will the reaction mixture become hotter, or colder?
   b) Is this an exothermic reaction, or is it an endothermic reaction?
   c) After this reaction has occurred, will the potential energy of the chemical mixture be higher than, lower than, or the same as it was before the reaction?
   d) After this reaction has occurred, will the kinetic energy of the universe be higher than, lower than, or the same as it was before the reaction (assuming no other reaction has occurred)?

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15) A reaction has $\Delta E = 10$ kJ, and it converts a solid into a gas.
   a) If this reaction occurs in a closed, rigid container, will the amount of heat that is absorbed be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
   b) If this reaction occurs in an open container, will the amount of heat that is absorbed be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
   c) Will PV work be done in either part a or part b? If so, which part(s)?
   d) What is the sign of the PV work when PV work occurs?

16) A reaction has $\Delta E = -10$ kJ, and it converts a gas into a liquid.
   a) If this reaction occurs in a closed, rigid container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
   b) If this reaction occurs in an open container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
   c) Will PV work be done in either part a or part b? If so, which part(s)?
   d) What is the sign of the PV work when PV work occurs?

17) A reaction has $\Delta E = -10$ kJ, and it converts a liquid into a gas.
   a) If this reaction occurs in a closed, rigid container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
   b) If this reaction occurs in an open container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
   c) Will PV work be done in either part a or part b? If so, which part(s)?
   d) What is the sign of the PV work when PV work occurs?

18) a) What is the PV work when 3.00 moles of liquid water boils at 100˚C at constant pressure? Give your answer in kJ, and include the correct sign.
   b) What is the PV work when 3.00 moles of steam condenses at 100˚C at constant pressure? Give your answer in kJ, and include the correct sign.

19) Consider the following reaction:

$$4\ C_3H_9N(l) + 21\ O_2(g) \rightarrow 12\ CO_2(g) + 18\ H_2O(l) + 2\ N_2(g) \quad \Delta E = -9667\ kJ$$

The following questions (parts a through j) refer to this reaction.

a) Calculate ΔH for this reaction at 25˚C.
b) How much heat will be given off if 8.250 g of C_3H_9N reacts with excess O_2 in a closed, rigid container at 25˚C?
c) How much heat will be given off if 8.250g of C_3H_9N reacts with excess O_2 in an open container at 25˚C?
d) Calculate the PV work in part b. Include the correct sign.
e) Calculate the PV work in part c. Include the correct sign.
f) If you want to obtain 200.0 kJ of heat by reacting C_3H_9N with O_2 in an open container, what mass of C_3H_9N must you use?
g) How much heat is produced when 2.199 g of liquid C_3H_9N reacts with 5.738 g of gaseous O_2 in an open container?
h) If you burn enough liquid C_3H_9N to produce 841.2 kJ of heat in an open container, what volume of gaseous N_2 will you form at 25.0˚C and 752 torr?
i) If this reaction is carried out in a closed, rigid container and produces 31.74 g of liquid H_2O, how much heat does it produce?

20) When 2.810 g of solid Al reacts with excess gaseous F_2 in an open container at 25˚C, 157.3 kJ of heat is produced.

a) Calculate ΔH and ΔE for the following reaction at 25˚C:

$$2\ Al(s) + 3\ F_2(g) \rightarrow 2\ AlF_3(s)$$

b) How much heat will be produced if 8.493 g of solid Al reacts with 16.610 g of gaseous F_2 in a closed, rigid container at 25˚C? Use your answer from part a to solve this problem.

21) A chemist burns 1.628 g of liquid isopropyl alcohol (C_3H_8O) in a bomb calorimeter that has a heat capacity of 3927 J/˚C. The temperature of the calorimeter rises from 19.085˚C to 31.683˚C during the reaction. Calculate ΔH and ΔE for the following reaction at 25˚C:

$$2\ C_3H_8O(l) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(l)$$

22) For the reaction $2\ C(s) + O_2(g) \rightarrow 2\ CO(g)$, $\Delta E = -219$ kJ. When will ΔH also be -219 kJ?

a) When the reaction is carried out in an open container.
b) When the reaction is carried out in a closed, rigid container.
c) ΔH will always equal ΔE.
d) ΔH will never equal ΔE.

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23) Using the enthalpies of formation in **T1: Standard Thermodynamic Quantities** of your online textbook, calculate the amount of heat that will be released when 5.00 g of solid $NaNO_3$ reacts with excess graphite in an open container. The chemical equation for this reaction is:

$$4\ NaNO_3(s) + 5\ C(s, graphite) \rightarrow 2\ Na_2O(s) + 2\ N_2(g) + 5\ CO_2(g)$$

24) Pyrrole (C_4H_5N) is a liquid that reacts with oxygen as follows:

$$4\ C_4H_5N(l) + 21\ O_2(g) \rightarrow 16\ CO_2(g) + 10\ H_2O(l) + 2\ N_2(g) \qquad \Delta H = -9407\ kJ$$

Using this information and the enthalpies of formation in **T1: Standard Thermodynamic Quantities** of your online textbook, calculate the enthalpy of formation (ΔH_f°) of $C_4H_5N(l)$.

25) For the reaction $4\ K(s) + O_2(g) \rightarrow 2\ K_2O(s)$, $\Delta H = -722$ kJ. Using this information, calculate ΔH for each of the following three reactions.

a) $12\ K(s) + 3\ O_2(g) \rightarrow 6\ K_2O(s)$
b) $K(s) + {}^1/_4\ O_2(g) \rightarrow {}^1/_2\ K_2O(s)$
c) $12\ K_2O(s) \rightarrow 24\ K(s) + 6\ O_2(g)$

26) Given the following chemical reactions and ΔH values:

$3\ Ag^+(aq) + PO_4^{3-}(aq) \rightarrow Ag_3PO_4(s)$ $\qquad \Delta H = -32.7$ kJ
$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl\ (s)$ $\qquad \Delta H = -65.5$ kJ

Calculate ΔH for the chemical reaction below:

$Ag_3PO_4(s) + 3\ Cl^- \rightarrow 3\ AgCl(s) + PO_4^{3-}(aq)$

27) Given the following chemical reactions and ΔH values:

$As_2O_5(s) + 3\ H_2O(l) \rightarrow 2\ H_3AsO_4(s)$ $\qquad \Delta H = -30.2$ kJ
$H_3AsO_4(s) + 3\ KOH(s) \rightarrow K_3AsO_4(s) + 3\ H_2O(l)$ $\qquad \Delta H = -31.6$ kJ
$2\ KOH(s) \rightarrow K_2O(s) + H_2O(l)$ $\qquad \Delta H = 202.0$ kJ

Calculate ΔH for the chemical reaction below:

$As_2O_5(s) + 3\ K_2O(s) \rightarrow 2\ K_3AsO_4(s)$

28) The enthalpy of formation (ΔH_f°) of solid $AgNO_3$ is -124 kJ/mol.

a) Based on this information, write a balanced chemical equation for which $\Delta H = -124$ kJ. Include the state of each substance in your equation.
b) Write a balanced chemical equation for which $\Delta H = 124$ kJ.
c) Write a balanced chemical equation for which $\Delta H = -62$ kJ. *Hint: 124 = 2 × 62.*

29) The enthalpy of formation of solid AgBr is -100.4 kJ. Based on this information, can you calculate ΔH for the reaction $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$? Explain why or why not.

30) Calculate the volume of gaseous C_4H_{10} (butane) at 25.00˚C and 785.0 torr that must be burned in a closed, rigid container if you want to obtain enough heat to convert 15.50 g of ice at 0.00˚C into steam at 100.00˚C. Use the following information:

ΔH_f° of $C_4H_{10}(g) = -149.1$ kJ/mol
ΔH_f° of $H_2O(l) = -285.8$ kJ/mol
ΔH_f° of $CO_2(g) = -393.5$ kJ/mol
ΔH_{fusion} of ice = 6.009 kJ/mol
$\Delta H_{vaporization}$ of water = 40.67 kJ/mol at 100˚C.
Average specific heat capacity of liquid water in the range 0˚C to 100˚C = 4.174 J/g·˚C

(Do not look up any other thermochemical information.)