Answers to Extra Credit

(1)

a) $2\ C_7H_6O_2 + 15\ O_2 \rightarrow 14\ CO_2 + 6\ H_2O$

b) $$\left(\frac{35.61\ \text{kJ}}{1.350\ \text{g benzoic acid}}\right)\left(\frac{122.12\ \text{g benzoic acid}}{1\ \text{mol benzoic acid}}\right) = 3221\ \text{kJ / mol benzoic acid}$$

c) $$\left(\frac{3221\ \text{kJ}}{\text{mol benzoic acid}}\right)\left(\frac{2\ \text{mol benzoic acid}}{15\ \text{mol } O_2}\right) = 429.5\ \text{kJ / mol } O_2$$

(2)

a) $(NH_2)_2CO_{(s)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + N_{2(g)} + 2\ H_2O_{(l)}$

or $2\ (NH_2)_2CO_{(s)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 2\ N_{2(g)} + 4\ H_2O_{(l)}$

b) $$\frac{-632.2\ \text{kJ}}{\text{mol } (NH_2)_2CO} \times \frac{2\ \text{mol } (NH_2)_2CO}{4\ \text{mol } H_2O} = -316.1\ \text{kJ / mol } H_2O$$

c) $\Delta H_{rxn} = -\ 632.2\ \text{kJ}$

$= [\Delta H_f^\circ(CO_2) + \Delta H_f^\circ(N_2) + 2\ \Delta H_f^\circ(H_2O)] - [(\Delta H_f^\circ((NH_2)_2CO) + 3/2\ \Delta H_f^\circ(O_2)]$

$$= \left[(1\ \text{mol } CO_2)\left(\frac{-393.5\ \text{kJ}}{\text{mol } CO_2}\right) + (1\ \text{mol } N_2)\left(\frac{0\ \text{kJ}}{\text{mol } N_2}\right) + (2\ \text{mol } H_2O)\left(\frac{-285.8\ \text{kJ}}{\text{mol } H_2O}\right)\right]$$

$-[(1\ \text{mol } (NH_2)_2CO)\ \Delta H_f^\circ (NH_2)_2CO + (3/2\ \text{mol } O_2)(0\ \text{kJ/mol } O_2)]$

$= [-393.5\ \text{kJ} - 571.6\ \text{kJ}] - [(1\ \text{mol } (NH_2)_2CO)(\Delta H_f^\circ (NH_2)_2CO)]$

$(1\ \text{mol } (NH_2)_2CO)\ \Delta H_f^\circ (NH_2)_2CO = -393.5\ \text{kJ} - 571.6\ \text{kJ} + 632.2\ \text{kJ} = -\ 332.9\ \text{kJ}$

$\Delta H_f^\circ (NH_2)_2CO = -332.9\ \text{kJ/mol } (NH_2)_2CO$

(3)

$\Delta T = 296.36\ \text{K} - 298.00 = -1.64\ \text{K}$

$$\frac{1.00\ KClO_3}{122.55\ \text{g } KClO_3 / \text{mol}} = 8.16 \times 10^{-3}\ \text{mol} \qquad \frac{50.0\ \text{g } H_2O}{18.02\ \text{g } H_2O / \text{mol}} = 2.7747\ \text{mol}$$

$q_{H_2O} = (n_{H_2O})(C_{p,H_2O})(\Delta T)$

$= (2.7747\ \text{mol})(75.291\ \text{J/mol K})(-1.64\ \text{K}) = -342.6\ \text{J}$

$q_{salt} + q_{H_2O} = 0$

$q_{salt} = (n_{salt})(\Delta H_{soln}) = -q_{H_2O} = -(-342.6\ \text{J})$

$$\Delta H_{soln} = \frac{q_{salt}}{n_{salt}} = \frac{342.6\ \text{J}}{8.16 \times 10^{-3}\ \text{mol}} = 4.20 \times 10^4\ \text{J / mol} = 42.0\ \text{kJ / mol}$$

(14)

Any living organism will die if made into an isolated thermodynamic system. Even before dying, its performance will change from the normal.

(5) Prefer classification as physical change. The process can be reversed by a physical process; that is, the water can be allowed to evaporate (or be boiled off) to recover the original substance, $NaCl_{(s)}$.

(6) Let T = the final temperature of the system.

$q_{H_2O} = -q_{Cu}$

$nC_{p,H_2O}\Delta T_{H_2O} = -nC_{p,Cu}\Delta T_{Cu}$

$$(200\ \text{mL})\left(\frac{1.00\ \text{g}}{\text{mL}}\right)\left(\frac{\text{mol H}_2\text{O}}{18.02\ \text{g H}_2\text{O}}\right)\left(\frac{75.291\ \text{J}}{\text{mol K}}\right)(T - 278\ \text{K})$$

$$= -(9.50\ \text{g})\left(\frac{\text{mol Cu}}{63.55\ \text{g Cu}}\right)\left(\frac{24.435\ \text{J}}{\text{mol K}}\right)(T - 473\ \text{K})$$

$(835.6\ \text{J} + 3.653\ \text{J})\ T = 1728\ \text{J K} + 232{,}300\ \text{J K}$

$(839.3\ \text{J})\ T = 2.340 \times 10^5\ \text{J K}$

$T = 278.8\ \text{K} = 5.7°\text{C}$

(7) Let T = final temperature $\qquad q_{spoon} = -\ q_{coffee}$

$nC_{p,spoon}\Delta T = -\ nC_{pH_2O}\Delta T$

$$\left(\frac{99\ \text{g Ag}}{107.9\ \text{Ag / mol}}\right)\left(\frac{25.351\ \text{J}}{\text{mol K}}\right)(T - 280\ \text{K})$$

$$= -(200\ \text{mL H}_2\text{O})\left(\frac{1.00\ \text{g}}{\text{mL}}\right)\left(\frac{1\ \text{mol}}{18.02\ \text{g H}_2\text{O}}\right)\left(\frac{75.291\ \text{J}}{\text{mol K}}\right)(T - 350\ \text{K})$$

$(23.26\ \text{J/K})\ T - 6512.8\ \text{J} = -\ (835.64\ \text{J/K})\ T + 292473.4\ \text{J}$

$2.98986 \times 10^5\ \text{J} = (858.9\ \text{J/K})\ T$

$T = 348.1\ \text{K}$

An aluminum spoon of the same mass (99 g) would be (99 g/27 g mol^{-1}) 3.7 moles while the silver spoon would be (99 g/107.9 g mol^{-1}) 0.92 moles. C_p times number of moles yields:

For Ag: (25.351 J/mol K)(0.92 mol) = 23 J/K

For Al: (24.35 J/mol K)(3.7 mol) = 90 J/K

Therefore, the final temperature of the coffee would be lower for the aluminum spoon.

(8) $\Delta H_{H_2O} = q_{H_2O} = nC_{p,H_2O}\Delta T =$

$$\left(\frac{21.5\ \text{g H}_2\text{O}}{18.02\ \text{g H}_2\text{O / mol}}\right)\left(\frac{75.291\ \text{J}}{\text{mol K}}\right)(21.5°\text{C} - 15.5°\text{C})\left(\frac{\text{K}}{°\text{C}}\right) = 539\ \text{J}$$

$\Delta H_{coin} = q_{coin} = nC_{p,coin}\Delta T = (15.5\ \text{g/MM})(C_{p,coin})(21.5°\text{C} - 100°\text{C})(\text{K/°C})$

$\Delta H_{coin} = -\ 539\ \text{J} = -\ 1216.75\ (C_p/\text{MM})\text{g K}$

$C_p/\text{MM} = 0.443\ \text{J/g K}$

for silver: $\frac{C_p}{\text{MM}} = \frac{25.351\ \text{J / mol K}}{107.9\ \text{g / mol}} = 0.235\ \text{J / g K}$

for nickel: $\frac{C_p}{\text{MM}} = \frac{26.07\ \text{J / mol K}}{58.70\ \text{g / mol}} = 0.444\ \text{J / g K}$

The coin is a counterfeit nickel copy.

(9)

$\Delta H_{H_2O} = -\Delta H_{metal}$

$n_{H_2O} C_{p,\,H_2O}\,\Delta T_{H_2O} = -n_{metal} C_{p,\,metal}\,\Delta T_{metal}$ where C_p is per gram

$$(80.0\text{ g } H_2O\left(\frac{4.184\text{ J}}{(\text{g } H_2O)\text{ K}}\right)(28.4°C - 24.8C)\left(\frac{K}{°C}\right)$$

$$= -(44.0\text{ g metal})\left(C_{p,\,metal}\right)(28.4C - 100.0°C)\left(\frac{K}{°C}\right)$$

$1205\text{ J} = (+\,3150.4\text{ g K})\,C_{p,\,metal}$

$C_{p,\,metal} = (0.382\text{ J/g K})$

The metal was Cu (0.385 J/g K).

(10)

$2\,N_2H_{4(l)} + N_2O_{4(g)} \rightarrow 3\,N_{2(g)} + 4\,H_2O_{(g)}$

a) $\Delta H_{rxn} = [3\ \Delta H_f^\circ(N_2) + 4\ \Delta H_f^\circ(H_2O_{(g)})] - [2\ \Delta H_f^\circ(N_2H_4) + \Delta H_f^\circ(N_2O_4)]$

$$= \left[(3\text{ mol } N_2)\left(\frac{0\text{ kJ}}{\text{mol } N_2}\right) + (4\text{ mol } H_2O)\left(\frac{-241.8\text{ kJ}}{\text{mol } H_2O}\right)\right]$$

$$-\left[(2\text{ mol } N_2H_4)\left(\frac{50.6\text{ kJ}}{\text{mol } N_2H_4}\right) + (1\text{ mol } N_2O_4)\left(\frac{9.16\text{ kJ}}{\text{mol } N_2O_4}\right)\right]$$

$= [0\text{ kJ} + (-967.2\text{ kJ})] - [101.2\text{ kJ} + 9.16\text{ kJ}] = -1077.6\text{ kJ}$

$(\Delta H_{rxn})/2\text{ mol } N_2H_4 = -538.8\text{ kJ mol}^{-1}$

b) $N_2H_{4(l)} + O_{2(g)} \rightarrow N_{2(g)} + 2\,H_2O_{(g)}$

$\Delta H_{rxn} = [\,\Delta H_f^\circ(N_2) + 2\ \Delta H_f^\circ(H_2O_{(g)})] - [\,\Delta H_f^\circ(N_2H_4) + \Delta H_f^\circ(O_2)]$

$$= \left[(1\text{ mol } N_2)\left(\frac{0\text{ kJ}}{\text{mol } N_2}\right) + (2\text{ mol } H_2O)\left(\frac{-241.8\text{ kJ}}{\text{mol } H_2O}\right)\right]$$

$$-\left[(1\text{ mol } N_2H_4)\left(\frac{50.6\text{ kJ}}{\text{mol } N_2H_4}\right) + (1\text{ mol } O_2)\left(\frac{0\text{ kJ}}{\text{mol } O_2}\right)\right]$$

$= [\,0\text{ kJ} + (-483.6\text{ kJ})] - [50.6\text{ kJ} + 0\text{ kJ}] = -534.2\text{ kJ mol}^{-1}$

The reaction with O_2 gives off less heat per mole of hydrazine because the hydrazine reaction with dinitrogentetroxide results in the formation of more (1.5 moles vs. 1.0 moles) of the highly stable N_2.