1. Chemical Energetics

You are a rare coin collector. A coin dealer offered you a good buy on a rare coin that you know was minted in either gold ($C_p = 25.21$ J/mol K) or platinum ($C_p = 25.36$ J/mol K). The dealer heated the coin, which weighed 16.1 g to 100°C in boiling water and then dropped the hot coin into 21.5 g of water at T = 16°C in a coffee-cup calorimeter. The temperature of the water rose to 22°C. Should you report the dealer to the police? Why or why not? (35 points)

(1) $\Delta H_{H_2O} = q_{H_2O} = n C_{p\,H_2O} \Delta T$

$= \left(\frac{21.5\text{ g } H_2O}{18.02\text{ g/mole } H_2O}\right)\left(\frac{75.291\text{ J}}{\text{mol K}}\right)(22-16\text{K}) = \boxed{539\text{ J}}$

(2) $\Delta H_{coin} = q_{coin} = n C_{p\,coin} \Delta T$

$= (15.5\text{ g/mw})(C_{p\,coin})(22-100\text{K})$

$-539\text{ J} = -1209\text{ (C@/mw)}_{\text{g.K}}$

$C_{@/mw} = \boxed{0.446\text{ J/g.K}}$

(3) For Gold $\frac{C_p}{mw} = \frac{25.21\text{ J/mole.K}}{197.0\text{ g/mole}} = \boxed{0.127\text{ J/g.K}}$

For Pt $\frac{C_p}{mw} = \frac{25.36\text{ J/mole.K}}{195.1\text{ g/mole}} = \boxed{0.130\text{ J/g.K}}$

(4) You should report the dealer to the police. The coin is fake

2. Principles of Reactivity

Predict the products of the following reactions and state if they are precipitation (PR), gas-forming (GF), acid-base (AB), no reaction (NR), and/or oxidation-reduction (redox) reactions. Balance the equations. (8 points each, 40 total)

a. $(NH_4)_2S_{(aq)} + Hg(NO_3)_{2(aq)} \longrightarrow HgS(s) + 2NH_4NO_3(aq)$

PR

b. $H_3PO_{4(aq)} + 3KOH_{(aq)} \longrightarrow 3H_2O(l) + K_3PO_4(aq)$

AB

c. $K_2CO_{3(aq)} + 2HClO_{4(aq)} \longrightarrow 2KClO_4(aq) + CO_2(g) + H_2O(l)$

GF

a. $Ca(OH)_{2(s)} + 2HCl_{(aq)} \longrightarrow CaCl_2(aq) + 2H_2O(l)$

AB

b. $(NH_4)_2S_{(aq)} + Hg(NO_3)_{2(aq)} \longrightarrow HgS(s) + 2NH_4NO_3(aq)$

PR

3. The Composition of Molecules

The FBI confiscates a packet of white powder, which they believe contains heroin (molecular weight about 370 g/mol). Purification by a forensic chemist gave a 38.7 mg sample for combustion analysis. This sample gave 97.46 mg CO_2, and 20.81 mg H_2O. A second sample was analyzed for it nitrogen content, which was 3.8%. Show by calculations whether or not these data are consistent with the formula for heroin, $C_{21}H_{23}O_5N$. Determine the molecular formula of heroin. (35 points)

$$C_x H_y O_z N_A + O_2 \rightarrow CO_2 + H_2O$$

38.7 mg → 97.46 mg, 20.81 mg

(1) For C: $(97.46\text{ mg } CO_2)\left(\frac{1\text{ mol } CO_2}{44.0\text{ g } CO_2}\right)\left(\frac{1\text{ mol C}}{1\text{ mol } CO_2}\right)\left(\frac{12.0\text{ g C}}{1\text{ mol C}}\right)$

$= 0.02658\text{ g C}$

For H: $(20.81\text{ mg } H_2O)\left(\frac{1\text{ mol } H_2O}{18.0\text{ g } H_2O}\right)\left(\frac{2\text{ mol H}}{1\text{ mol } H_2O}\right)\left(\frac{1.00\text{ g H}}{1\text{ mol H}}\right)$

$= 0.002335\text{ g H}$

(2) Given 3.8% N

$\%\text{ C} = \left(\frac{0.02658\text{ g C}}{0.0387\text{ g}}\right)(100\%) = 68.68\%\text{ C}$

$\%\text{ H} = \left(\frac{0.002335\text{ g H}}{0.0387\text{ g}}\right)(100\%) = 6.034\%\text{ H}$

$100\text{ g} - 3.8\text{ g N} - 68.68\text{ g C} - 6.034\text{ g H} = 21.08\text{ O}$

(3) $\frac{3.8\text{ g N}}{14.0\text{ g/mol N}} = 0.27\text{ mol N}$ $\quad \frac{68.68\text{ g C}}{12.0\text{ g/mol C}} = 5.723\text{ mol C}$

$\frac{6.034\text{ g H}}{1.00\text{ g/mol H}} = 6.034\text{ mol H}$ $\quad \frac{21.0\text{ g O}}{15.9997\text{ g/mol O}} = 1.343\text{ mol O}$

$$CHON = C_{5.723}H_{6.034}O_{1.343}N_{0.27}$$

$$\frac{\times 4}{\sim C_{21}H_{23}O_5N}$$

4. Chemical Reactions and Stoichiometry

You are asked to determine the amount of inert impurities in a contaminated sample of oxalic acid ($H_2C_2O_4 \cdot 2H_2O$; two acidic hydrogens). You first prepare a standard solution of NaOH by diluting 50.00 mL of a 1.632 M solution to 1.000 L in a volumetric flask. This solution was used to titrate a 0.2500 g sample of the contaminated oxalic acid dissolved in 75 mL of water. The titration required 40.00 mL of base to reach the stoichiometric point. Find the percent purity of the oxalic acid sample. (40 points)

(1) $\left(\frac{1.632 \text{ mole NaOH}}{1 \text{ L}}\right)(0.05 \text{ L})\left(\frac{1}{1.00 \text{ L}}\right)(0.040000 \text{ L})$

$\left(\frac{1 \text{ mole } C_2H_2O_4 \cdot 2H_2O}{2 \text{ mole NaOH}}\right)\left(\frac{126.1 \text{ g } C_2H_2O_4 \cdot 2H_2O}{1 \text{ mole}}\right)$

$= 0.2058 \text{ g } C_2H_2O_4 \cdot 2H_2O$

(2) % purity $= (0.2058 \text{ g})/0.25000 \text{ g} \times 100\% = 82.3\%$