Chem 10113, Exam 2 **Answer Key**

October 24, 2018

1. (10 points) **SHOW ALL WORK.** An average single-family household consumes about 2500 kWh (kilowatt hours) of electrical energy per month (mainly for air-conditioning). Suppose that this energy comes from a power plant that burns coal (i.e., carbon) containing 0.80 % sulfur by mass. Assume that all of the sulfur is converted to SO_2 which then reacts with O_2 and H_2O in the atmosphere to form H_2SO_4. Determine the mass of H_2SO_4 (in kg) that results from this monthly energy consumption. (***Note***: The molar mass of H_2SO_4 = 98.1. The standard heat of formation of $CO_{2(g)}$ = -394 kJ/mole. 1 kWh = 3600 kJ)

   $C + O_2 \longrightarrow CO_2$ $\Delta H° = -394$ kJ (per mole of C)

   (2500 kWh) (3600 kJ / kWh) (1 mole C / 394 kJ) (12.0 g / mole) = 2.741×10^5 g C

   (2.741×10^5 g C) (0.80 g S / 99.20 g C) (1 mole S / 32.0 g S) = 69.08 mole S

   (69.08 mole S) (1 mole H_2SO_4 / mole S) (98.1 g/mole) (1 kg / 10^3 g)

   = 6.78 kg H_2SO_4

2. (9 points) Write a ***balanced chemical equation*** for the process that occurs when each of the following substances are mixed with water. If the substance is a weak electrolyte, indicate that by using the appropriate symbol(s) in your equation.

   (a) $C_4H_4NH + H_2O \rightleftharpoons C_4H_4NH_2^+{}_{(aq)} + OH^-{}_{(aq)}$

   (b) $BaO + H_2O \longrightarrow Ba(OH)_{2(aq)}$

   (c) $HN_3 + H_2O \rightleftharpoons N_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$

3. (4 points) List all *possible* quantum numbers for the *unpaired* electron of indium (In).

   l = 1 m_s = +1/2, -1/2 m_l = -1, 0, +1 n = 5

4. (2 points) Write a specific, ***balanced chemical equation*** for which the ΔH° value is equal to the third ionization energy of calcium.

   $Ca^{2+} \longrightarrow Ca^{3+} + e^-$

5. (3 points) Magnetic experiments show that atoms of molybdenum (Mo) have 6 unpaired electrons. Write the ***valence shell*** electron configuration of Mo that is consistent with this fact.

   Mo $5s^1 4d^5$

6. (8 points) **SHOW ALL WORK.** According to tabulated data in your textbook, the average energy required to break C-H and C-Cl bonds are listed as 414 kJ/mole for C-H and 339 kJ/mole for C-Cl. If a sample of dichloromethane, CH_2Cl_2, is exposed to UV light with a wavelength of 353 nm, determine which bond (C-H or C-Cl) will be broken. (***Note***: $h = 6.626 \times 10^{-34}$ J·sec)

$\lambda = 353 \text{ nm } (10^{-9} \text{ m} / 1 \text{ nm}) = 3.53 \times 10^{-7} \text{ m}$

Energy of one photon:

$E = hc / \lambda = (6.626 \times 10^{-34} \text{ J·sec}) (3.00 \times 10^{8} \text{ m/sec}) / (3.53 \times 10^{-7} \text{ m})$

$E = 5.63 \times 10^{-19} \text{ J} = 5.63 \times 10^{-22} \text{ kJ}$

Bond energy (kJ/mole):

$(5.63 \times 10^{-22} \text{ kJ / photon}) (6.022 \times 10^{23} \text{ photons/mole}) = 339 \text{ kJ/mole}$

∴ C-Cl bond will break

7. (4 points) For each of the following pairs of atoms or ions, circle the one that has the ***smaller*** radius.

Se vs Se^{2-} Cr^{2+} vs Cr^{3+} Rb^{+} vs Br^{-} Br vs Ar

8. In a calorimetry experiment based on the following reaction, 1.25 g of NH_4NO_3 (molar mass = 80.0) was mixed with enough water to make 25.0 mL of solution. Upon mixing, the temperature decreased from 25.8 °C to 21.9 °C.

$$NH_4NO_{3(s)} \longrightarrow NH_4^{+}(aq) + NO_3^{-}(aq)$$

(a) (1 point) Before doing any calculations, indicate whether this reaction is
endothermic or exothermic. (circle one.)

(b) (7 points) **SHOW ALL WORK.** Using the above data, determine ΔH° (in kJ) for the reaction as written. (If necessary, use 1.00 g/mL as the density of the solution and 4.184 J/g·°C as the specific heat.)

For 25 g of solution, the amount of heat absorbed is:

(25 g) (4.18 J/g°C) (25.8 °C - 21.9 °C) = 408 J = 0.408 kJ

ΔH° = heat change for 1 mole of NH_4NO_3 (based on balanced equation)

moles NH_4NO_3 = (1.25 g) (1 mole / 80.0 g) = 0.0156 mole

ΔH° = (0.408 kJ) / (0.0156 mole) = 26.2 kJ/mole

9. (7 points) **SHOW ALL WORK.** You are asked to select a high precision valve that will be used to accurately deliver 1.00 L of uranium hexafluoride (UF_6) gas in 30.0 minutes. For safety and economic reasons, you decide to use nitrogen (N_2) to test the new valve before using it with UF_6. Determine the time required for this valve to deliver 1.00 L of N_2. (molar mass: UF_6 = 352)

$ER_{N_2} / ER_{UF_6} = (FM_{UF_6} / FM_{N_2})^{1/2}$ (Graham's Law of Effusion)

$(1\ L / x) / (1\ L / 30\ min) = (352 / 28.0)^{1/2} = 3.546$

$x = 8.46\ min$

10. (2 points) In aqueous solution, PH_3 reacts with perchlorate ion to produce $Cl^-_{(aq)}$ and phosphate ion. Write the chemical formula for the ***oxidizing agent*** in this process.

ClO_4^-

11. (4 points) Write the oxidation number of nitrogen in each of the following.

N_2O_4 +4 Mg_3N_2 -3 N_2 0 NaN_3 -1/3

12. (8 points) **SHOW ALL WORK.** Given the following thermochemical equations, calculate the ***standard heat of formation*** ($\Delta H°_f$) of thiophene, $C_4H_4S_{(l)}$, in kJ/mole. Your solution method ***must include*** the appropriate chemical equation for the ***formation reaction*** of $C_4H_4S_{(l)}$.

$C_4H_4S_{(l)} + 6\ O_{2(g)} \longrightarrow 4\ CO_{2(g)} + 2\ H_2O_{(l)} + SO_{2(g)}$ $\Delta H° = -2{,}829$ kJ

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\Delta H° = -394$ kJ

$SO_{2(g)} \longrightarrow O_{2(g)} + S_{(s)}$ $\Delta H° = 297$ kJ

$H_2O_{(l)} \longrightarrow H_{2(g)} + 1/2\ O_{2(g)}$ $\Delta H° = 286$ kJ

$4\ CO_{2(g)} + 2\ H_2O_{(l)} + SO_{2(g)} \longrightarrow C_4H_4S_{(l)} + 6\ O_{2(g)}$ $\Delta H° = +2{,}829$ kJ

$4\ C_{(s)} + 4\ O_{2(g)} \longrightarrow 4\ CO_{2(g)}$ $\Delta H° = 4(-394)$ kJ

$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$ $\Delta H° = -297$ kJ

$2\ H_{2(g)} + O_{2(g)} \longrightarrow 2\ H_2O$ $\Delta H° = 2(-286)$ kJ

$4\ C_{(s)} + S_{(s)} + 2\ H_{2(g)} \longrightarrow C_4H_4S_{(l)}$ (formation reaction)

$\Delta H° = \Delta H°_f (C_4H_4S) = +2{,}829 + 4(-394) + (-297) + 2(-286)$

$= 384$ kJ/mole

13. (9 points) In the space below each of the following reactions, clearly write the ***balanced, <u>net</u> <u>ionic</u> <u>equation</u>***. Use subscripts [(s), (aq), (g), etc.] to indicate the phase of each compound or ion.

(a) $NH_4C_2H_3O_{2(aq)}$ + $Ba(OH)_{2(aq)}$ ⟶

$NH_4^+{}_{(aq)}$ + $OH^-{}_{(aq)}$ ⟶ H_2O + $NH_{3(g)}$

(b) $HCO_2H_{(aq)}$ + $KOH_{(aq)}$ ⟶

$HCO_2H_{(aq)}$ + $OH^-{}_{(aq)}$ ⟶ H_2O + $HCO_2^-{}_{(aq)}$

(c) $Na_2CO_{3(aq)}$ + $Fe_2(SO_4)_{3(aq)}$ ⟶

$3\ CO_3^{2-}{}_{(aq)}$ + $2\ Fe^{3+}{}_{(aq)}$ ⟶ $Fe_2(CO_3)_{3(s)}$

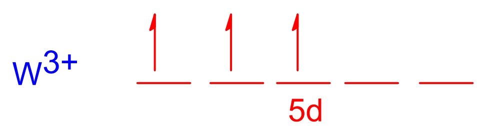
14. (4 points) Write the complete electron configuration for arsenic (As).

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^3$

15. (4 points) Write the ***short-hand*** electron configuration for osmium (Os).

$[Xe]^{54}\ 6s^2\ 4f^{14}\ 5d^6$

16. (4 points) Write the ***valence shell orbital diagram*** of the tungsten(III) ion (W^{3+}).



17. (10 points) **SHOW ALL WORK.** A "copper" penny is mainly zinc coated with a small amount of copper. In a simple lab experiment, a new penny weighing 2.500 g is treated with excess hydrochloric acid in which the zinc reacts as follows (Cu does not react).

$$Zn_{(s)} + 2\ HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$$

The hydrogen gas was collected over water at 20.0 °C in a 1.15 L container and the total pressure was found to be 610.3 torr. Determine the mass percent of Zn in the penny.
(At 20 °C, the vapor pressure of water is 17.6 torr.)

P_{H_2} = 610.3 - 17.6 = 592.7 torr = 0.7799 atm

n_{H_2} = PV / RT = (0.7799 atm) (1.15 L) / (0.0821 L·atm / mole·K) (293 K)

= 0.03728 mole H_2

(0.03728 mole H_2) (1 mole Zn / 1 mole H_2) = 0.03728 mole Zn

(0.03728 mole Zn) (65.38 g/mole) = 2.438 g Zn

(2.438 g / 2.500 g) x 100 % = 97.5 % Zn