Honors chemistry

Spring Examination Study Questions

1. (Chapter 6/Heat Changes) A calorimeter containing water is used to measure the heat produced by a chemical reaction. If the water absorbs 58.5 kJ when the temperature is raised from 21.2°C to 77.2°C, how much water was in the calorimeter? (The specific heat of water is 4.18 J/g °C.)

2. (Chapter 6/Heat Changes) For the reaction between solid iron and water to form iron(III) oxide and hydrogen gas,
   a) write a balanced chemical equation.
   b) use the appropriate table to calculate ΔH for this reaction.
   c) determine whether this reaction is endothermic or exothermic.

3. (Chapter 5/Gases) A sample of gas occupies a volume of 5.60 liters at STP.
   a) What is the pressure of this sample when it is allowed to expand to 18.0 liters at 78°C?
   b) How many moles of gas are in the sample?
   c) If the sample contains 7.50 grams of gas, what is the molar mass of this gas?
   d) The above gas is an alkane. Give its formula, name the alkane, and draw its structure.

4. (Chapter 5/Gases) For the reaction between solid iron and water to form iron(III) oxide and hydrogen gas,
   a) write a balanced chemical equation.
   b) How many liters of hydrogen gas are produced from 29.8 grams of iron at 1.60 atmospheres and 117°C?
   c) What is the density of hydrogen gas in (b)?

5. (Chapter 11/Solutions) You may use the equation below to solve the following problems:
   $$\Delta T_f = -1.86°C \text{ x moles solute particles/kg water}$$
   a) What is the freezing point of a solution containing 117 g NaCl in 500 g of water?
   b) How many moles of a nonelectrolyte in 50 g of water are required for a solution to have a freezing point of −2.79°C?

6. (Chapter 11/Solutions)
   a) How many g of $NaNO_3$ are needed to make 157 ml of a 3.00 M $NaNO_3$ solution?
   b) Describe how you would make the solution in (a).
   c) What is the concentration of $NaNO_3$ in a solution prepared by diluting 240 ml of 0.500 M $NaNO_3$ to 2.00 liters?
   d) The density of a 26.0% solution of $NaNO_3$ is 1.19 g/ml. What is the molarity of the 26.0% solution?

7. (Chapter 12/Reaction Rate) Explain how and why each of the following affect reaction rate:
   a) concentration of reactants
   b) surface area of reactants
   c) temperature
   d) a catalyst

8. (Chapter 13/Equilibrium)
   a) Write a balanced chemical equation for the equilibrium reaction in which bromine gas and chlorine gas combine to form bromine chloride gas.
   b) Write an expression for *K*, the equilibrium constant, for this reaction.
   c) A one-liter flask initially contains 0.70 M bromine and 0.55 M chlorine. When the system reaches equilibrium, the bromine concentration is 0.35 M. Calculate the value for *K* for this system.

9. (Chapter 13/Equilibrium)
   a) For the system at equilibrium,

$$2\ NO_2(g) \rightleftarrows N_2O_4(g) \qquad \Delta H = -58\ kJ,$$

   what affect will each of the following have?
      i) decreasing the volume
      ii) increasing the temperature
      iii) adding a catalyst
      iv) adding more N_2O_4
   b) Write an expression for *K* for this equilibrium. Calculate $[N_2O_4]$ if the $[NO_2] = 0.010$ M when the value for *K* is 10.0.

10. (Chapter 14/pH) Find the pH of each of the following solutions:
   a) 0.0050 M $HClO_4$
   b) 1.0 g NaOH dissolved in 250 ml water
   c) a 0.10 M solution of a weak acid with a K_a of 10^{-7}
   d) 0.00435 M $NaHCO_3$ (K_b for HCO_3^- is 2.3×10^{-8}).

11. (Chapter 15/Buffers)
   a) What is the pH of a buffer made up of 100 mL of 0.10 M HF and 174 mL of 0.10 M NaF?
   b) What ratio of $ClO^-/HClO$ is needed to produce a buffer with a pH of 7.4?

12. (Chapter 15/Titration)
   a) What is the molar mass of an acid, if 0.864 grams of the acid are neutralized by 36.0 ml of 0.400 M NaOH?
   b) What is the molarity of an NH_3 solution if 12.0 liters of the NH_3 solution are neutralized by 360 ml of 4.00 M HCl?

13. (Chapter 16/K_{sp})
   a) The K_{sp} for zinc hydroxide is 4.5×10^{-17}. Find the concentration of zinc hydroxide dissolved in a saturated solution.
   b) What concentration of potassium hydroxide must be added to 0.0040 M zinc chloride to form a precipitate?

14. (Chapter 18/Oxidation-Reduction) For the following oxidation-reduction equation:

$$NO_3^-(aq) + Cu(s) \rightarrow NO(g) + Cu^{2+}(aq)$$

   a) Balance the equation adding H^+ and H_2O as needed.
   b) Use standard reduction potentials to determine E° for the reaction.
   c) Which substance is acting as an oxidizing agent? as a reducing agent?

Answers to Spring Examination Study Questions

1. $Q = C \times m \times \Delta T$; $Q = 58.5$ kJ = 58,500 J; m = ?; $\Delta T = 77.2-21.2 = 56.0°C$; C = 4.18 J/g °C

$$m = \frac{Q}{C \times \Delta T} = \frac{58{,}500\ J}{4.18\ J/g\ {}^{o}C \times 56.0\ {}^{o}C} = 250\ g = 2.50 \times 10^2\ g \quad \text{(3 sig fig)}$$

2. a) $2\,Fe(s) + 3\,H_2O(l) \rightarrow Fe_2O_3(s) + 3\,H_2(g)$
   b) From Table 4.2: $2\,Fe(s) + 1\tfrac{1}{2}\,O_2(g) \rightarrow Fe_2O_3(s)$ $\Delta H = -822.2$ kJ
   $H_2(g) + \tfrac{1}{2}\,O_2(g) \rightarrow H_2O(l)$ $\Delta H = -285.8$ kJ

$2\,Fe(s) + 1\tfrac{1}{2}\,O_2(g) \rightarrow Fe_2O_3(s)$ $\Delta H = -822.2$ kJ
$3\,H_2O(l) \rightarrow 3\,H_2(g) + 1\tfrac{1}{2}\,O_2(g)$ $\Delta H = +3(285.8)$ kJ = +857.4

$2\,Fe(s) + 3\,H_2O(l) \rightarrow Fe_2O_3(s) + 3\,H_2(g)$ $\Delta H = -196.5 + 204.9 =$ **+35.2 kJ**

   c) endothermic

3. a) $V_1 = 5.60$ L; $P_1 = 1$ atm, $T_1 = 273$ K; $P_2 = ?$; $V_2 = 18.0$ L; $T_2 = 78 + 273 = 351$ K.

$$P_2 = P_1 \times \frac{V_1}{V_2} \times \frac{T_2}{T_1} = 1.00\ atm \times \frac{5.60\ L}{18.0\ L} \times \frac{351\ K}{273\ K} = 0.400\ \text{atm}$$

   b) $5.60\ L \times \frac{1\ mol}{22.4\ L} = 0.250\ \text{mol}$; or use $n = \frac{PV}{RT}$ at either T and P.

   c) $\text{molar mass} = \frac{mass}{moles} = \frac{7.50\ g}{0.250\ mol} = 30.0\ \text{g/mol}$

   d) C_2H_6, ethane, $CH_3–CH_3$

4. a) $2\,Fe(s) + 3\,H_2O(l) \rightarrow Fe_2O_3(s) + 3\,H_2(g)$

   b) $29.8\ g\ Fe \times \frac{1\ mol\ Fe}{55.85\ g\ Fe} \times \frac{3\ mol\ H_2}{2\ mol\ Fe} = 0.800\ \text{moles}\ H_2$

$$V = \frac{nRT}{P} = \frac{(0.800\ mol)(0.8206)(390\ K)}{1.60\ atm} = 16.0\ L$$

   c) $mass(H_2) = 0.800\ mol \times \frac{2.016\ g}{1\ mol} = 1.61\ g$; density $= \frac{mass}{volume} = \frac{1.61\ g}{16.0\ L} = 0.101\ g/L$

5. a) moles particles = $117\ g\ NaCl \times \frac{1\ mol\ NaCl}{58.5\ g\ NaCl} \times \frac{2\ mol\ particles}{1\ mol\ NaCl}$ = 4.00 mol particles

$\Delta T_f = 1.86 \times \frac{4.00\ mol\ particles}{0.500\ kg\ H_2O} = 14.9°C$; $T_f = 0 - 14.9°C = -14.9°C$

b) $\Delta T_f = 2.79°C$, moles = ?, 50.0 g = 0.0500 kg H_2O

$\Delta T_f = 1.86 \times \frac{mol\ particles}{kg\ H_2O}$; moles = $\frac{\Delta T_f \times kg\ H_2O}{1.86} = \frac{2.79 \times 0.0500}{1.86} = 0.0750$ mol

6. a) $157\ mL \times \frac{3.00\ mol\ NaNO_3}{1\ L} \times \frac{1\ L}{1000\ mL} \times \frac{85.0\ g\ NaNO_3}{1\ mol\ NaNO_3} = 40.0\ g\ NaNO_3$

b) Review how to prepare a solution from either solid solute or by diluting a concentrated solution: see Procedure from the "Solution Preparation" Experiment.

c) $V_1 \times M_1 = V_2 \times M_2$; V_1 = 240 mL; M_1 = 0.500 M; V_2 = 2.00 L = 2000 mL; M_2 = ?

$M_2 = \frac{V_1 \times M_1}{V_2} = \frac{240\ mL \times 0.500\ M}{2000\ mL} = 0.0600\ M$

d) $\frac{26.0\ g\ NaNO_3}{100\ g\ solution} \times \frac{1.19\ g\ solution}{1\ mL\ solution} \times \frac{1000\ mL}{1\ L} \times \frac{1\ mol\ NaNO_3}{85.0\ g\ NaNO_3} = 3.64\ M$

7. a) **concentration of reactants**: Reaction rate increases as concentration of reactants increases because number of collisions increases, making reaction more likely to occur.
b) **surface area of reactants**: Rate increases as surface area of reactants increases because the greater the area of reactant exposed, the more likely are collisions that will result in product formation.
c) **temperature**: As temperature increases, rate increases because at higher temperature, a greater proportion of reactant molecules have a kinetic energy greater than the activation energy so a greater proportion of collisions result in product formation.
d) **catalyst**: Catalysts increase reaction rate by lowering the activation energy.

8. a) $Br_2(g) + Cl_2(g) \rightleftarrows 2\ BrCl(g)$

b) $K = \frac{[BrCl]^2}{[Br_2][Cl_2]}$

c)

	$Br_2(g)$ +	$Cl_2(g)$	$\rightleftarrows$	$2\ BrCl(g)$
init.	0.70 M	0.55 M		0
Δ	–0.35 M	–0.35 M		+0.70 M
equil.	0.35 M	0.20 M		0.70 M

$K = \frac{[0.70]^2}{[0.35][0.20]} = 7.0$

9. a) i) shift to right (shift to side with fewer moles); ii) shift to the left (shift in endothermic direction to use up heat); iii) no shift; iv) shift to left (use up some of the N_2O_4 added).

b) $K = \frac{[N_2O_4]}{[NO_2]^2}$; $[N_2O_4] = K \times [NO_2]^2 = 10.0\,(0.010)^2 =$ **0.0010 M**

10. a) $HClO_4$ = strong acid, so $[HClO_4] = [H^+] = 0.0050$ M; pH = - log(0.0050) = **2.3**

b) NaOH = strong base, so [NaOH] = $[OH^-] = \frac{1\ g\ NaOH}{0.250\ L} \times \frac{1\ mol\ NaOH}{40.0\ g\ NaOH}$ = 0.10 M NaOH

$[OH^-]$ = 0.10 M = 1×10^{-1} M; $[H^+] = 1 \times 10^{-13}$ M; **pH = 13.0**

c) $K_a = \frac{[H^+][A^-]}{[HA]}$; $[H^+] = [A^-] = x$; $[HA] \approx 0.10$ M; $1.0 \times 10^{-7} = \frac{x^2}{0.10M}$

$x^2 = (1.0 \times 10^{-7})(0.10) = 1.0 \times 10^{-8}$ M; $x = [H^+] = 1.0 \times 10^{-4}$ M; pH = **4.0**

d) $HCO_3^- + H_2O \rightleftarrows H_2CO_3 + OH^-$; $K_b = \frac{[H_2CO_3][OH^-]}{[HCO_3^-]}$; $x = [OH^-] = [H_2CO_3]$

$2.3 \times 10^{-8} = \frac{x^2}{(0.00435)}$; $x^2 = (2.3 \times 10^{-8})(0.00435) = 1.0 \times 10^{-10}$

$x = [OH^-] = (1.0 \times 10^{-10})^{1/2} = 1.0 \times 10^{-5}$ M; pOH = 5.0; **pH = 9.0**

11. a) $pH = pK_a + \log\frac{[F^-]}{[HF]}$; $pK_a(HF) = -\log(7.2 \times 10^{-4}) = 3.14$; $\frac{[F^-]}{[HF]} = \frac{174}{100} = 1.74$

pH = 3.14 + log(1.74) = 3.14 + 0.24 = 3.40; **pH = 3.40**

b) $K_a(HClO) = 3.5 \times 10^{-8}$; $[H^+] = 10^{-7.4}$ M $= 4.0 \times 10^{-8}$ M

$\frac{K_a}{[H^+]} = \frac{[ClO^-]}{[HClO]} = \frac{3.5 \times 10^{-8}}{4.0 \times 10^{-8}} =$ **0.88**

12. a) moles acid = moles base = 0.0360 L $\times \frac{0.400\ mol}{1\ L}$ = 0.0144 moles

molar mass = $\frac{mass}{moles} = \frac{0.864\ g}{0.0144\ mol} =$ **60.0 g/mol**

b) since moles acid = moles base: $V_A \times M_A = V_B \times M_B$

0.360 L x 4.00 M = 12.0 L x M_B; $M_B = \frac{0.360 \times 4.00}{12.0} =$ **0.120 M**

13. a) $Zn(OH)_2(s) \rightleftarrows Zn^{2+}(aq) + 2\ OH^-(aq)$; $K_{sp} = [Zn^{2+}][OH^-]^2$; I$x = [Zn^{2+}]$; $[OH^-] = 2x$

$K_{sp} = x(2x)^2 = 4x^3$; $4.5 \times 10^{-17} = 4x^3$; $x^3 = 1.1 \times 10^{-17}$; $x = 2.2 \times 10^{-6}$ M

b) $K_{sp} = [Zn^{2+}][OH^-]^2$; $x = [KOH]$; $[OH^-] = x$; $[Zn^{2+}] = 0.0040$ M

$4.5 \times 10^{-17} = (0.0040)(x)^2$

$x^2 = (4.5 \times 10^{-17})/(0.0040)$; $x = (1.1 \times 10^{-14})^{1/2} = 1.1 \times 10^{-7}$ M

14. a) oxidation: $Cu(s) \rightarrow Cu^{2+}(aq) + 2\ e^-$; reduction: $3\ e^- + 4\ H^+ + NO_3^-(aq) \rightarrow NO(g) + 2\ H_2O$

overall: $2\ NO_3^-(aq) + 3\ Cu(s) + 8\ H^+(aq) \rightarrow 2\ NO(g) + 3\ Cu^{2+}(aq) + 4\ H_2O$

b) $E° = E°_{ox}(Cu) + E°_{red}(NO_3^-) = -0.34$ v $+ 0.96$ v $= 0.62$ volts

c) NO_3^- is the oxidizing agent (it's reduced); Cu is the reducing agent (it's oxidized).