THOMPSON RIVERS UNIVERSITY

KAMLOOPS, BC

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TRU Chemistry Contest
Chemistry 12 Answers
May 16, 2007 Time: 90 minutes

Last Name ____________________ **First name** _____________

School _______________________ **Teacher** ___________________

Please follow the instructions below. We will send your teacher a summary of your results. Top performers are eligible for prizes.

Part A: Please answer on the Scantron answer sheet. In the **top right hand corner** of the answer sheet, please **clearly print** the following:
(20 points)

Your name (last name, first name), your school, your teacher

On the answer sheet, mark one choice beside the question number with a firm pencil mark, to fill the selected answer box. If you change your answer, completely erase your previous answer. All questions are of equal value, there is no particular order and there is no penalty for incorrect answers.

Part B: Please answer in **ink** on the Contest paper.
(20 points)

Additional material: The last page of the test contains a Periodic Table and the value for K_w at 25°C. Any other useful information is included in the question.

Programmable calculators are not permitted

Part A: Select one answer on the Scantron Answer Sheet

1. For which of the following situations will the solubility of $Fe(OH)_2(s)$ be greater than the solubility of $Fe(OH)_2(s)$ in pure water?

   (a) $Fe(OH)_2(s)$ is added to a $FeCl_{2(aq)}$ solution
→ **(b) $Fe(OH)_2(s)$ is added to a $NaHSO_4(aq)$ solution**
   (c) $Fe(OH)_2(s)$ is added to a solution buffered at pH 8
   (d) $Fe(OH)_2(s)$ is added to a 0.80 M $KCl(aq)$ solution

2. As the temperature of a reaction is decreased, the rate of the reaction:

   (a) decreases because the reactant molecules collide more frequently
   (b) decreases due to a lower activation energy
   (c) increases because reactant molecules collide less frequently but with more energy per collision
→ **(d) decreases because reactant molecules collide with less energy per collision**

3. An ammonia - ammonium chloride buffer solution is prepared by making an aqueous solution that is 0.050 M in NH_3 and 0.050 M in NH_4Cl. If 0.0010 moles of hydrobromic acid, $HBr(aq)$ are added to 250.0 mL of this buffer solution, the resulting solution will:

→ **(a) be only slightly more acidic than the original buffer**
   (b) no longer be a buffer solution
   (c) be only slightly more basic than the original buffer
   (d) have the same pH as the original buffer

4. In the following reaction

$$2Bi(OH)_3 + 3SnO_2^{2-} \rightarrow 2Bi + 3H_2O + 3SnO_3^{2-}$$

   The reducing agent is:

   (a) $Bi(OH)_3$
→ **(b) SnO_2^{2-}**
   (c) SnO_3^{2-}
   (d) Bi

5. A 0.523 g sample of an unknown organic base is dissolved in water and requires 32.82 mL of a 0.370 M hydrochloric acid solution to reach the equivalence point. The unknown base and HCl(aq) react in a 1:2 mole ratio. What is the molar mass of the unknown base?

(a) 43.22 g/mol
(b) 172.9 g/mol
(c) 8.722 g/mol
→ **(d) 86.14 g/**mol

6. The oxidation state of molybdenum in the $Mo_2O_7^{2-}$ ion is:

(a) +7
(b) +2
(c) +14
→ **(d) +6**

7. What is the pH of a 1.0 x 10^{-12} M KOH(aq) solution?

→ **(a) 7.00**
(b) 5.00
(c) 8.00
(d) 12.00

8. The pH of a 0.30 M solution of the monoprotic acid ascorbic acid is 2.31. What is the K_a value for ascorbic acid?

(a) 1.2 x 10^{4}
(b) 1.6 x 10^{-2}
(c) 1.8 x 10^{-5}
→ **(d) 8.0 x 10^{-5}**

9. Ephedrine is a base that is used in nasal sprays as a decongestant. It has a K_b = 1.4 x 10^{-4}. What is the value of pK_a for its conjugate acid?

(a) 3.85
→ **(b) 10.15**
(c) 1.4 x 10^{-4}
(d) 7.0 x 10^{-11}

10. What will happen if 0.500 L of 0.0080 M NaF(aq) is mixed with 0.250 L of 0.050 M $CaCl_2$(aq) at 25ºC?

$$K_{sp}\ CaF_2 = 3.9 \times 10^{-11} \text{ at } 25ºC$$

(a) a precipitate of $CaCl_2$ forms
(b) no precipitate forms
→ **(c) a precipitate of CaF_2 forms**
(d) fluorine gas is evolved

11. The K_{sp} for $Cd(OH)_2$ is 2.5 x 10^{-14}. What is the [Cd^{2+}] in a saturated $Cd(OH)_2$ buffered at pH 8.5?

(a) 1.0 x 10^{-11} M
(b) 3.2 x 10^{-9} M
(c) 2.8 x 10^{-7} M
→ **(d) 2.4 x 10^{-3} M**

12. Br_2(g) reacts with H_2O(ℓ) as follows

$$Br_2(g) + 2H_2O(\ell) \rightleftharpoons H_3O^+(aq) + Br^-(aq) + HOBr(aq)$$

This reaction can be encouraged to have the equilibrium favor the products by adjusting the pH of the reaction mixture so that it is constantly kept:

→ **(a) greater than 7**
(b) less than 7
(c) at 7
(d) approximately 2

13. The ionization constant for pure water, K_w, at 10°C is 0.29 x 10^{-14}. The pH of pure water at 10 °C is:

→ **(a) 7.27**
(b) 5.40
(c) 7.00
(d) 13.5

14. A sealed 1.00 L flask contains 6.00 mol of $I_2(g)$ and 0.700 mol of $Cl_2(g)$. The Following reaction ensues:

$$I_{2(g)} + Cl_{2(g)} \rightleftharpoons 2\,ICl_{(g)}$$

When the contents of the flask reach equilibrium, it contains 0.840 mol of ICl(g). The value of K_{eq} is:

(a) 0.538
(b) 1.86
→ **(c) 0.452**
(d) 2.21

15. When $SO_2(g)$ is dissolved in water it forms $H_2SO_3(aq)$. The solution of $H_2SO_3(aq)$ is used in industry to make $H_2SO_4(aq)$ by oxidation with $H_2O_2(aq)$. The elementary steps of the mechanism for formation of $H_2SO_4(aq)$ by this method are shown below

$$H_2SO_{3(aq)} + H_2O_{2(aq)} \rightleftharpoons SO_2OOH^-(aq) + H_3O^+{}_{(aq)}$$

$$SO_2OOH^-(aq) + H_3O^+{}_{(aq)} \rightleftharpoons H_2SO_{4(aq)} + H_2O_{(\ell)}$$

and it involves the unusual compound peroxymonosulfurous acid (SO_2OOH^-). According to this mechanism, the SO_2OOH^- is:

→ **(a) an intermediate**
(b) a catalyst
(c) an activated complex
(d) part of a transition state

16. Hydrogen cyanide is a weak acid, with a K_a of 4.9×10^{-10}. What is the $[OH^-]$ of a 0.082 M aqueous hydrogen cyanide solution?

(a) 5.20
(b) 6.3×10^{-6}
→ **(c) 1.6×10^{-9}**
(d) 8.80

17. Which one of the following reactions is an oxidation-reduction reaction?

(a) $MgO(s) + H_2O(\ell) \rightarrow Mg(OH)_2(aq)$
(b) $CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(\ell) + CO_2(g)$
→ **(c) $N_2O_4(g) + KCl(s) \rightarrow NOCl(g) + KNO_3(s)$**
(d) $BaCl_2(aq) + K_2CO_3(aq) \rightarrow BaCO_3(s) + 2KCl(aq)$

18. Which one of the following indicators would be best for a titration having a pH of 5.0 at the stoichiometric point?

		pH range of colour change
	(a) phenolphthalein	8.0 - 10.0
→	**(b) methyl red**	**4.3 - 6.0**
	(c) bromocresol purple	5.0 - 6.6
	(d) alizarin	5.6 - 7.2

19. An acetic acid - sodium acetate buffer solution is prepared at 25ºC by mixing 60.0 mL of 0.300 M acetic acid and 45.0 mL of 0.400 M sodium acetate solutions. The K_a for acetic acid is 1.8×10^{-5} at 25ºC. What is the pH of this buffer solution?

→ **(a) 4.74**
(b) 4.86
(c) 4.62
(d) 6.07

20. We have the following information for the two equilibria shown here:

$$SnO_2(s) + 2CO(g) \rightleftharpoons Sn(s) + 2CO_2(g \qquad K_{eq} = 14$$
$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad K_{eq} = 1.3$$

What is the equilibrium constant K_{eq} for the following reaction:

$$SnO_2(s) + 2H_2(g) \rightleftharpoons Sn(s) + 2H_2O(g)$$

(a) 24
→ **(b) 8.3**
(c) 11
(d) 15

Part B: Answer in ink on the Contest paper. Show all your work. If you need more space, use the back of the page. All written answers must be in complete sentences.

1. There is great potential to use molecular hydrogen, H_2, as a fuel. Its exothermic combustion reaction with O_2 to produce $H_2O(g)$ has a high fuel value of 142 kJ/g. Hydrogen is a reactive element and is always found naturally combined with another element; e.g. with oxygen in water. Consequently, we must find a method of synthesizing $H_2(g)$.

5 points (a) One method involves the reaction of steam with solid carbon (or coal) to produce a mixture of CO(g) and $H_2(g)$, known as synthesis gas or syngas:

$$C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g) \qquad \Delta H = 131 \text{ kJ}$$

The equilibrium constant for this system at 600 ºC is 0.0210. If we add 512 g of $H_2O(g)$ to a 11.0 L container along with lots of coal at 600 ºC, how many moles of $H_2(g)$ would be produced at equilibrium at 600 ºC?

2 points (b) How much heat would we be able to produce from the combustion of all the $H_2(g)$ produced in the above equilibrium?

3 points (c) From an environmental point of view, should we use the products of the above equilibrium directly as a fuel or should we separate the CO and H_2? Explain your choice using chemical equations as part of your explanation.

4 points (d) If we added a catalyst **<u>and</u>** used a temperature lower than 600 °C would we expect more or less $H_2(g)$ produced? Explain your choice.

2 points 2. Hydrogen is also an important component of acids. The K_a values for acetic acid and nitrous acids are 1.8×10^{-5} and 7.1×10^{-4}, respectively. Which is the stronger acid? Explain your choice.

4 points 3. Not all acid-base titrations have an equivalence point at pH 7.00; the equivalence point pH can be greater than or less than 7.00 depending on the strengths of the acids and bases involved. For example, a titration of ammonia with $HCl(aq)$ has an equivalence point at a pH of about 4.9. Explain why this equivalence point has a pH < 7. Use chemical equations as part of your explanation.

The End

Data Page

$K_w = 1.0 \text{ x } 10^{-14}$ at 25°C

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A	**2A**	**3A**	**4A**	**5A**	**6A**	**7A**	**8A**			**1B**	**2B**	**3B**	**4B**	**5B**	**6B**	**7B**	**8B**
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.011	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.179
11 **Na** 22.99	12 **Mg** 24.305											13 **Al** 26.982	14 **Si** 28.086	15 **P** 30.974	16 **S** 32.066	17 **Cl** 35.453	18 **Ar** 39.948
19 **K** 39.098	20 **Ca** 40.078	21 **Sc** 44.956	22 **Ti** 47.88	23 **V** 50.942	24 **Cr** 51.996	25 **Mn** 54.938	26 **Fe** 55.847	27 **Co** 58.933	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.468	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.224	41 **Nb** 92.906	42 **Mo** 95.94	43 Tc (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 **La*** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.03	89 **Ac**** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)									

*	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 Pm (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
**	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)