THOMPSON RIVERS UNIVERSITY

KAMLOOPS, BC

TRU Chemistry Contest
Chemistry 12
May 21, 2003 Time: 90 minutes

Last Name ______________ **First name** ____________

School _____________________ **Teacher** _________________

Please follow the instructions below. We will send your teacher a report on your performance. Top performers are eligible for prizes.

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

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, just filling the selected answer box. If you change your answer, be sure to erase completely your previous answer. All questions are of equal value, there is no particular order to the questions and there is no penalty for incorrect answers.

Part B: **(20 points)** Answer in **ink** on the test paper.

<u>**Additional material**</u>**:** 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. You will require a calculator.

Part A: Select one answer on the Scantron Answer Sheet

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

   (a) $Ca(OH)_2(s)$ is added to a $CaCl_2(aq)$ solution
→ **(b) $Ca(OH)_2(s)$ is added to a $NaH_2PO_4(aq)$ solution**
   (c) $Ca(OH)_2(s)$ is added to a solution buffered at pH 10
   (d) $Ca(OH)_2(s)$ is added to a 0.80M $KCl(aq)$ solution

2. What is the pH of a 1.0×10^{-10} M $HNO_3(aq)$ solution?

   (a) 5.00
   (b) 10.00
   (c) 8.00
→ **(d) 7.00**

3. Which two species, when mixed together in aqueous solution, will act as a buffer?

   (a) HNO_3 and $NaNO_3$
   (b) Na_2SO_4 and H_2SO_4
   (c) HCl and NaCl
→ **(d) HNO_2 and $NaNO_2$**

4. Which of the following may affect the rate of a reaction?

   (a) reactant concentration
   (b) addition of a catalyst
   (c) temperature
→ **(d) all of the above**

5. What will happen if 0.500 L of 0.0080M NaCl(aq) is mixed with 0.300L of 0.040M $AgNO_3$(aq) at 25°C?

$$K_{sp}\ AgCl = 1.6 \times 10^{-10} \text{ at } 25°C$$

→ **(a) a precipitate forms**
(b) silver metal is formed
(c) no precipitate forms
(d) a gas is evolved

6. What is the [F^-] when $CaF_{2(s)}$ is in equilibrium with 0.100M $Ca(NO_3)_2$(aq) solution at 25°C?

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

→ **(a) 2.0×10^{-5} M**
(b) 3.9×10^{-5} M
(c) 6.2×10^{-6} M
(d) 4.4×10^{-6} M

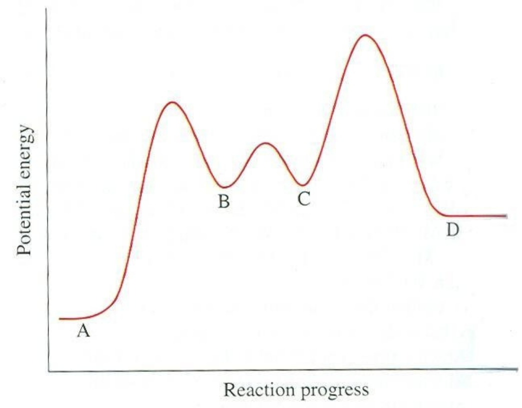
7. The ionization constant, K_w, for pure water at 50°C is 5.3×10^{-14}. What is the pH of pure water at 50°C?

(a) 7.36
→ **(b) 6.64**
(c) 7.00
(d) 5.92

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

(a) $Na_2O(s) + H_2O(\ell) \rightarrow 2NaOH(aq)$
(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) $BaCl_2(aq) + K_2SO_4(aq) \rightarrow BaSO_4(s) + 2KCl(aq)$

9. Which statement about the following plot of reaction progress is correct?



(a) there are 3 transition states and 3 intermediates
(b) there are 2 transition states and 2 intermediates
→ **(c) the fastest step would be B going to C**
(d) the overall reaction is exothermic

10. We have the following information for the two equilibria:

$$Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq) \qquad K_{sp} = 1.8 \times 10^{-11}$$

$$OH^-(aq) + H_3O^+(aq) \rightleftharpoons 2H_2O(\ell) \qquad K = 1/K_w = 1.0 \times 10^{14}$$

What is the equilibrium constant for:

$$Mg(OH)_2(s) + 2H_3O^+(aq) \rightleftharpoons Mg^{2+}(aq) + 4H_2O(\ell)$$

→ **(a) 1.8×10^{17}**
(b) 1.8×10^{3}
(c) 1.0×10^{14}
(d) 4.2×10^{-6}

11. Morphine is a weak base, with a $K_b = 8.0 \times 10^{-7}$. What is the $[OH^-]$ of a 0.067M aqueous morphine solution?

(a) 7.3×10^{-4} M
(b) 8.9×10^{-4} M
→ **(c) 2.3×10^{-4} M**
(d) 5.4×10^{-8} M

12. In the following reaction

$$4BCl_3(g) + 3SF_4(g) \rightarrow 4BF_3(g) + 3\,SCl_2(\ell) + 3Cl_2(g)$$

the reducing agent is:

→ **(a) BCl_3**
(b) SF_4
(c) SCl_2
(d) Cl_2

13. Ephedrine is a base that is used in nasal sprays as a decongestant. It's $K_b = 1.4 \times 10^{-4}$ at 25°C. What is K_a for its conjugate acid at 25°C?

(a) 5.1×10^{-8}
(b) 1.4×10^{-18}
(c) 1.4×10^{3}
→ **(d) 7.1×10^{-11}**

14. $Cl_2(g)$ reacts with $H_2O(\ell)$ as follows

$$Cl_2(g) + 2H_2O(\ell) \rightleftharpoons H_3O^+(aq) + Cl^-(aq) + HOCl(aq)$$

For a planned experiment to succeed, $Cl_2(g)$ must be present and the amount of $Cl^-(aq)$ is solution must be minimized. For this experiment we have planned, should the pH of the solution be:

(a) > 7
→ **(b) < 7**
(c) = 7
(d) the pH is irrelevant

15. A 0.478 g sample of an unknown organic acid is dissolved in water and requires 39.42 mL of a 0.270M sodium hydroxide solution to reach the equivalence point. The unknown acid and NaOH react in a 1:1 mole ratio. What is the molar mass of the unknown acid?

(a) 89.8 g mol^{-1}
(b) 22.5 g mol^{-1}
(c) 0.223 g mol^{-1}
→ **(d) 44.9 g mol^{-1}**

16. The oxidation state of sulfur in the $S_2O_3^{2-}$ ion is:

(a) -2
→ **(b) +2**
(c) +4
(d) +6

17. An acetic acid - sodium acetate buffer solution is prepared at 25°C in which both components are 0.050M. What is the pH of this mixture?

K_a acetic acid = 1.8×10^{-5} at 25°C

→ **(a) 4.74**
(b) 1.30
(c) 9.26
(d) 7.00

18. To one L of the solution in question 17 we then add 25.0 mL of a 2.50M perchloric acid solution. The resulting solution after this addition:

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

19. Predict the magnitude of the equilibrium constant K for the following system:

$$HClO_2(aq) + NO_2^-(aq) \rightleftharpoons HNO_2(aq) + ClO_2^-(aq)$$

given: K_a $HClO_2 = 1.1 \times 10^{-2}$ and K_a $HNO_2 = 4.6 \times 10^{-4}$

→ **(a) K > 1**
(b) K = 1
(c) K < 1
(d) K = 0

20. Which of the following indicators would be best for a titration having pH 9.2 at the stoichiometric point?

	pH range of colour change
phenolphthalein	8.2 – 10.0
thymolphthalein	9.4 – 10.6
bromothymol blue	6.0 – 7.6
thymol blue	8.0 – 9.2

→ **(a) phenolphthalein**
(b) thymolphthalein
(c) bromothymol blue
(d) thymol blue

Part B: Answer in ink on the test paper. Show all yourwork. State any assumptions you made during acalculation. If you need more space, use the back of the page. All written answers must be in complete sentences.

Ammonia has an important use as an agricultural fertilizer, where liquid ammonia is commonly injected directly into the soil. The usual reaction by which ammonia is manufactured is:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \qquad K_c = 0.20 \text{ at } 400^oC$$

6 pts (a) At 400°C in a 5.00L reaction vessel we have a mixture containing 4.0 mol of N_2, 0.50 mol of H_2 and 2.0 mol of NH_3. Is this system at equilibrium? If not, in which direction will the reaction proceed to reach equilibrium at 400°C. **Explain** your answers.

4 pts (b) Once this system has reached equilibrium in this 5.0L reaction vessel, in which direction would the system move if the size of the reaction vessel were to be increased to 10.0L? **Explain** your answer.

4 pts (c) Assume the reaction has reached equilibrium. The reaction as written is exothermic with $\Delta H°_{reaction} = -91.8\ kJ\ mol^{-1}$. **Explain** whether the concentrations of the products will increase or decrease if the temperature is decreased from 400°C to 250°C.

3 pts (d) What will happen to the rate of formation of NH_3 when the temperature is decreased from 400°C to 250°C? **Explain** your answer.

3 pts (e) Gaseous ammonia is a potential air pollutant when applied directly into the soil. If this occurred in a region where acid rain was falling, would the acid rain problem become more serious or less serious? **Explain** your answer.

The End

Periodic Table

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

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
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** 58.93	28 **Ni** 58.69	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.921	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** 102.9	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** 192.2	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)