Name: ____________________ Student number: ______________

Chemistry 1AA3 **Test 2** **March 10, 2006**

McMaster University **VERSION 1 - ANSWERS**

Instructors: P. Lock, B. McCarry, H. Stover

Duration: 110 minutes

This test contains 24 numbered pages printed on both sides. There are 23 multiple-choice questions appearing on pages numbered 3 to 21. Page 23 includes some useful data and equations. There is a periodic table on page 24. Page 22 may be used for rough work. You may tear off the last page to view the periodic table and to do your rough work.

You must enter your name and student number on the question sheets, as well as on the answer sheet. Your invigilator will be checking your student card for identification.

You are responsible for ensuring that your copy of the question paper is complete. Bring any discrepancy to the attention of your invigilator.

Questions 1 to 16 are each worth 2 marks, questions 17 – 23 are each worth 3 marks; the total marks available are 53. There is **no** additional penalty for incorrect answers.

BE SURE TO ENTER THE CORRECT VERSION OF YOUR TEST (shown near the top of page 1), IN THE SPACE PROVIDED ON THE ANSWER SHEET.

ANSWER ALL QUESTIONS ON THE ANSWER SHEET, IN PENCIL.
Instructions for entering multiple-choice answers are given on page 2.

SELECT ONE AND ONLY ONE ANSWER FOR EACH QUESTION from the answers **(A)** through **(E)**. **No work written on the question sheets will be marked**. The question sheets may be collected and reviewed in cases of suspected academic dishonesty.

Academic dishonesty may include, among other actions, communication of any kind (verbal, visual, *etc.*) between students, sharing of materials between students, copying or looking at other students' work. If you have a problem please ask the invigilator to deal with it for you. Do not make contact with other students directly. Try to keep your eyes on your own paper – looking around the room may be interpreted as an attempt to copy.

Only Casio FX 991 electronic calculators may be used; but they must NOT be transferred between students. Use of periodic tables or any aids, other than those provided, is not allowed.

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Name: ____________________ Student number: ______________

You are writing VERSION 1 of this test. Make sure you have correctly entered your version number ("1") in the correct column on your scan sheet (see p. 2 for details).

Questions 1 through 16 are worth two (2) marks each.

1. For the decomposition of iron(III) oxide, at a certain temperature:

   $Fe_2O_3(s) \rightleftharpoons 2\ Fe(s) + 3/2\ O_2(g)$ $\qquad K_C = 1.12 \times 10^{-5}$

   Which of the following statements is **TRUE**?

(A) Addition of $O_2(g)$ will decrease the value of K_C.

(B) **For this reaction as written, $K_C = K_P(RT)^{-1.5}$.**

(C) The equilibrium constant expression is $K_C = [O_2]^{3/2}[Fe]^2 / [Fe_2O_3]$.

(D) The value of K_C is small, so the forward reaction must be very slow.

(E) Decreasing the size of the reaction vessel will cause the equilibrium to shift to the right.

2. Hydrogen iodide decomposes at 490ºC according to:

   $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$ $\qquad K_P = 2.18 \times 10^{-2}$

   If a vessel contains 1.16 atm of HI, what will be the **percent decomposition of HI when equilibrium is reached**?

(A) 11.4 %

(B) **22.8%**

(C) 45.6%

(D) 77.2%

(E) 88.6%

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3. Find the **pH of the solution that results** when the following solutions are mixed together: (K_a $CH_3COOH = 1.8 \times 10^{-5}$)

100. mL of 0.100 M NaOH(aq)

50.0 mL of 0.200 M HCl(aq)

62.5 mL of 0.160 M CH_3COOH(aq)

(A) 1.33

(B) 2.77

(C) **3.04**

(D) 3.96

(E) 4.74

4. Which of the following reactions could **not be classified** as either a Brønsted-Lowry or Lewis acid-base reaction?

(A) $NaOH(aq) + HCl(aq) \rightarrow H_2O(l) + NaCl(aq)$

(B) $AlCl_3(s) + 6\ H_2O(l) \rightarrow Al(H_2O)_6^{3+}(aq) + 3\ Cl^-(aq)$

(C) $BF_3(g) + NH_3(g) \rightarrow BF_3{\cdot}NH_3(s)$

(D) **$3\ NO_2(g) + H_2O(l) \rightarrow 2\ HNO_3(aq) + NO(g)$**

(E) $BaO(s) + H_2O(l) \rightarrow Ba(OH)_2(aq)$

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5. Which of the following combinations of aqueous solutions **will result in the formation of a buffer solution**? (All stock aqueous solutions are 0.100 M).

(A) 50 mL $HClO_3$ + 25 mL $NaClO_3$

(B) 50 mL $HClO_2$ + 50 mL KOH

(C) 25 mL $HClO_2$ + 50 mL NaOH

(D) 50 mL $HClO_3$ + 50 mL $NaClO_2$

(E) **50 mL $HClO_2$ + 25 mL NaOH**

6. Heat released from the first-order, radioactive decay of plutonium-238 (^{238}Pu) has been proposed as a steady source of heat energy for long-term applications. The half-life of ^{238}Pu is 86 years. What **fraction of the original heat flow** would a ^{238}Pu-powered device be producing when it is retrieved from a remote location 43 years after deployment?

(A) 0.0081

(B) 0.29

(C) 0.35

(D) 0.50

(E) **0.71**

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7. Indicate which of the following rate laws are **second order** overall:

(i) Rate = k $[A]^1$ $[B]^{-1}$ $[C]^2$

(ii) Rate = k $[A]^1$ $[B]^0$ $[C]^1$

(iii) Rate = k $[A]^2$ $[B]^{1.5}$ $[C]^{-0.5}$

(iv) Rate = k $[A]^{1.5}$ $[B]^{-0.5}$

(A) ii, iii

(B) i, iii

(C) ii, iv

(D) **i, ii**

(E) iii, iv

8. Katydids are insects that produce a calling song with 2-4 pulses in each "chirp." On a summer evening (T = 27.4°C) an entymologist (i.e., an insect scientist) determined the average pulse rate to be 2.35 pulses per chirp while on another evening (T = 32.9°C) the average rate was 3.28 pulses per chirp. What is the **activation energy (in kJ mol^{-1})** of the chemical reaction that determines the pulse rate of the katydid's calling song?

(A) 454

(B) 113

(C) 72.8

(D) 57.1

(E) **46.4**

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9. In the stratosphere O_3 is produced and destroyed by light-induced chemical reactions (shown below), resulting in a low but relatively constant level of O_3.

O_3 Production:	O_3 Destruction:
$O_2 \rightarrow O + O$	$O_3 \rightarrow O + O_2$
$O_2 + O \rightarrow 2O_3$	$O_3 + O \rightarrow 2O_2$

NO, arising from man-made combustion emissions, diffuses slowly to the stratosphere where it can react with O_3 by the following reaction mechanism.

NO Reaction Mechanism:

$$O_3 + NO \rightarrow NO_2 + O_2 \quad \text{slow}$$

$$NO_2 + O \rightarrow NO + O_2 \quad \text{fast}$$

Indicate the **TRUE statement(s)** below:

(i) The overall stoichiometric reaction for O_3 destruction is: $2O_3 \rightarrow 3O_2$

(ii) The presence of NO in the stratosphere will result in a net decrease in the level of stratospheric O_3.

(iii) NO_2 is a reactive intermediate in the NO reaction mechanism.

(A) i

(B) i, ii

(C) i, iii

(D) ii, iii

(E) **i, ii, iii**

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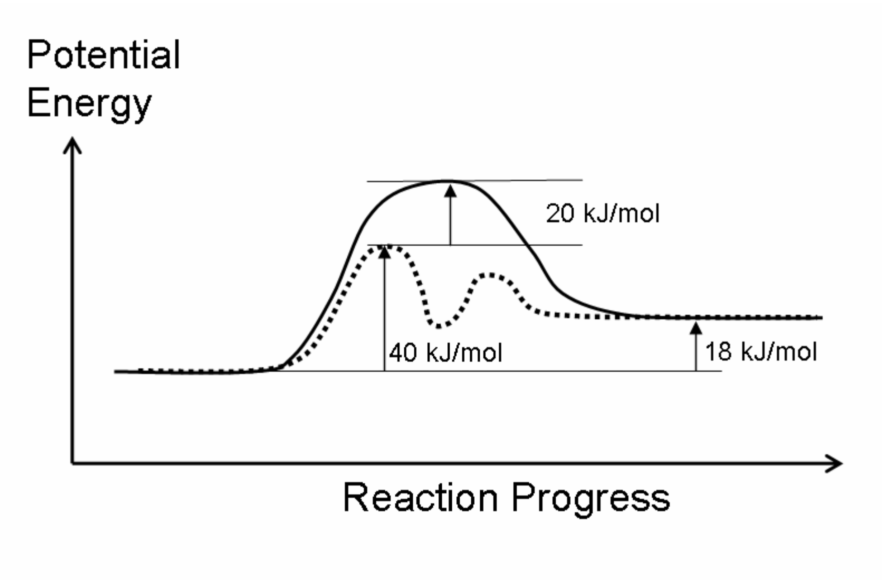
10. Many reactions such as the formation of esters from acids and alcohols can be catalyzed by acid, with significant effects on the reaction energy profile. Indicate the **FALSE statement** for the reaction diagram shown below.



(A) The activation energy for the catalyzed process is 40 kJ mol^{-1}.

(B) **Activation energies depend on the concentration of catalyst.**

(C) The presence of the catalyst will increase the rate of the reverse reaction.

(D) Use of a catalyst gives the reaction access to a different reaction mechanism.

(E) The activation energy for the reverse uncatalyzed reaction is 42 kJ mol^{-1}.

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11. For a reaction having a rate law according to Rate = k $[A]^1$ $[B]^2$ $[C]^0$ indicate which of the following plots will give a **straight line.**

(i) ln[A] vs. time

(ii) 1/[A] vs. time

(iii) [C] vs. time

(iv) ln(k) vs. temperature

(A) **i, iii**

(B) ii, iii

(C) i, iii, iv

(D) i, iv

(E) ii, iv

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12. Indicate the individual reaction orders x, y, z as well as the units for k, for the following reaction:

$$A + B + C \rightarrow E + F \qquad \text{Rate} = k\,[A]^x\,[B]^y\,[C]^z$$

Run#	[A]	[B]	[C]	initial rate [mol L^{-1} s^{-1}]
1	0.1	0.1	0.1	50
2	0.2	0.1	0.1	50
3	0.1	0.2	0.1	100
4	0.1	0.1	0.2	200

	x	**y**	**z**	**units of k**
(A)	**0**	**1**	**2**	**L^2 mol^{-2} s^{-1}**
(B)	0	1	2	L mol^{-1} s^{-1}
(C)	0	2	2	L^2 mol^{-2} s^{-1}
(D)	1	1	2	L^2 mol^{-2} s^{-1}
(E)	1	1	2	L mol^{-1} s^{-1}

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13. In the kinetics lab experiment, the bromination of acetone was monitored by the change in absorbance, A, of bromine, with time, t.

$$(CH_3)_2CO\ (aq) + Br_2(aq) \rightarrow BrCH_2COCH_3(aq) + HBr(aq)$$

The rate law for the reaction was:

$$\text{Rate} = -\,d[Br_2]\,/\,dt \;=\; k\,[(CH_3)_2CO]\,[H^+]$$

Indicate the **TRUE** statements about this process:

(i) The initial concentration of bromine does not affect the rate of the reaction.

(ii) The rate constant for the reaction has the units of L mol^{-1} s^{-1}.

(iii) The absorbance is inversely proportional to the concentration of $Br_2(aq)$.

(iv) The slope for $\Delta A\,/\,\Delta t$ depends on the initial concentration of $Br_2(aq)$.

(A) **i, ii**

(B) ii, iii

(C) ii, iv

(D) i, iii

(E) iii, iv

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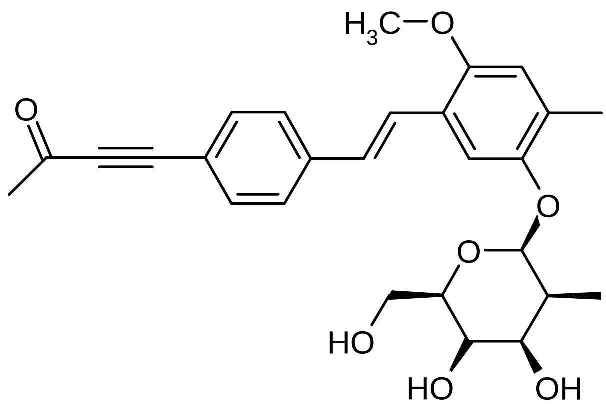
14. The carbohydrate derivative below changes colour upon binding to certain bacteria and viruses. Indicate the **correct number of C-O sigma bonds and C-C pi bonds** in this molecule.



	C-O sigma (σ) bonds	**C-C pi (π) bonds**
(A)	8	8
(B)	10	8
(C)	**10**	**9**
(D)	9	9
(E)	8	9

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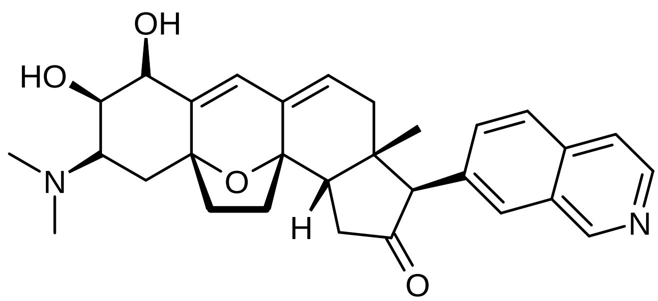
Name: ____________________ Student number: ______________

15. Kobayashi at Osaka University described the isolation of several anti-tumour agents from marine sponges [*J. Am. Chem. Soc.*, published on web 02/17/2006], *e.g.* cortostatin C, shown below. Indicate the **correct number of *sp*^{2} and *sp*^{3} hybridized carbon atoms** in cortostatin C.



	sp^2 C atoms	sp^3 C atoms
(A)	12	14
(B)	13	16
(C)	**14**	**16**
(D)	14	14
(E)	16	20

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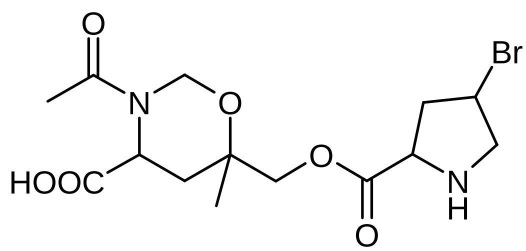
16. The compound below is a potential antibiotic. **Some of the functional groups** it contains, among others, are:



(A) carboxylic acid, 3º amine, ketone, ester

(B) carboxylic acid, ester, ether, 2º alcohol

(C) ketone, 3º amine, ester, 2º bromide

(D) **carboxylic acid, amide, ester, 2º bromide**

(E) carboxylic acid, aldehyde, 2º amine, ester

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Questions 17 through 23 are worth three (3) marks each.

17. A student prepares 1.50 L of a solution that contains 0.862 mol of sodium benzoate (C_6H_5COONa) and sufficient moles of benzoic acid (C_6H_5COOH, $K_a = 6.3 \times 10^{-5}$) to give pH = 4.86. The student wishes to adjust the solution pH to be 5.12. How many **moles of NaOH(s)** must the student add? (Assume no volume change on addition of NaOH(s)).

(A) **0.076 mol**
(B) 0.085 mol
(C) 0.11 mol
(D) 0.19 mol
(E) 0.27 mol

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18. 10.00 mL of 0.101 M acetic acid was diluted with distilled water to 40.00 mL and titrated with 0.100 M NaOH. **Calculate the H_3O^+ concentration at the equivalence point.** (K_a $CH_3COOH = 1.8 \times 10^{-5}$).

(A) 4.22×10^{-9} M

(B) 3.27×10^{-9} M

(C) **2.99×10^{-9} M**

(D) 2.36×10^{-6} M

(E) 3.35×10^{-6} M

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19. A student was given a hypnotic drug at a party and passed out. At midnight doctors withdrew a blood sample, identified the drug and found the concentration in the blood sample to be 126 ng per litre. Patients start to regain consciousness when blood levels of this drug reach 6 ng per litre. If the first-order half-life of the drug in blood is 80 minutes, **approximately when** will the student begin to regain consciousness?

(A) About 1:30 a.m.

(B) About 3:30 a.m.

(C) **About 6:00 a.m.**

(D) About 12:00 noon

(E) About 1:30 p.m.

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20. The activation energy for the uncatalyzed decomposition of H_2O_2 at 25°C is 70.0 kJ mol^{-1} while the activation energy for H_2O_2 decomposition catalyzed by MnO_2 is 61.8 kJ mol^{-1}. **To what temperature (in °C)** would you need to heat H_2O_2 to get an uncatalyzed rate that is equal to the MnO_2-catalyzed reaction at 25°C? (Assume that the pre-exponential term A is constant and that initial concentrations of H_2O_2 are identical.)

$$H_2O_2\ (l) \rightarrow \tfrac{1}{2}O_2\ (g) + H_2O\ (l)$$

(A) 40
(B) **65**
(C) 126
(D) 338
(E) 9640

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21. The hydrolysis of a bromobutane (C_4H_9Br) has been proposed to proceed *via* one of the two mechanisms below:

Mechanism 1:

C_4H_9Br	$\rightarrow$	$C_4H_9^+ + Br^-$	slow
$C_4H_9^+ + H_2O$	$\rightarrow$	$C_4H_9OH_2^+$	fast
$C_4H_9OH_2^+ + H_2O$	$\rightarrow$	$C_4H_9OH + H_3O^+$	fast

Mechanism 2:

C_4H_9Br	$\rightleftarrows$	$C_4H_9^+ + Br^-$	fast equilibrium
$C_4H_9^+ + H_2O$	$\rightarrow$	$C_4H_9OH_2^+$	slow
$C_4H_9OH_2^+ + H_2O$	$\rightarrow$	$C_4H_9OH + H_3O^+$	fast

Indicate the **TRUE** statement(s) below:

(i) Both mechanisms have rate laws: Rate $= k\,[C_4H_9Br]$

(ii) One mechanism has the rate law where: Rate $\propto [Br^-]^{-1}$

(iii) The overall reaction can be written as: $C_4H_9Br + H_2O \rightarrow C_4H_9OH + HBr$

(A) ii

(B) iii

(C) i, ii

(D) i, iii

(E) **ii, iii**

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22. The decomposition of NH_3 to N_2 and H_2 has an activation energy of 335 kJ mol^{-1} and follows the rate law: Rate = k [NH_3]. In the presence of tungsten and osmium metals the activation energies for this reaction are 163 and 197 kJ mol^{-1}, respectively, and the rate law is Rate = k [NH_3] / [H_2].

$$2NH_3\,(g) \rightarrow N_2\,(g) + 3H_2\,(g)$$

Which of the following statements are **TRUE**?

(i) Tungsten and osmium are homogeneous catalysts.
(ii) Tungsten is the more efficient catalyst.
(iii) The inverse dependence on H_2 in the rate law of the catalyzed reaction is most likely the result of the more efficient production of H_2 in the catalyzed reactions, causing some NH_3 to be reformed.
(iv) The inverse dependence on H_2 in the rate law of the catalyzed reaction is most likely the result of adsorption of H_2 to the catalyst surface, leaving less surface area (i.e., fewer active sites) for NH_3 adsorption.

(A) i, iii
(B) i, iv
(C) ii, iii
(D) **ii, iv**
(E) ii, iii, iv

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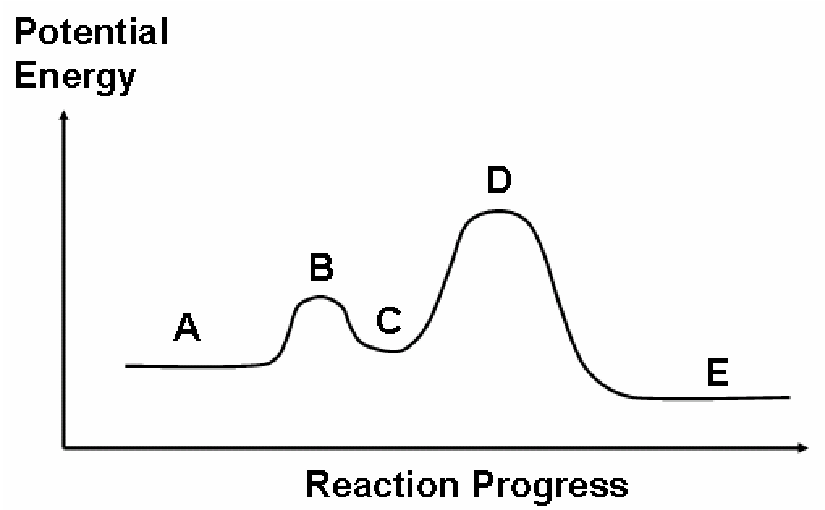
23. Indicate the **TRUE statements** concerning the reaction diagram below:



(i) At the end of the reaction, compounds A, C and E will be present in equal amounts.

(ii) The reaction step with the highest activation energy is the conversion of E to C.

(iii) B and D are reactive intermediates that can be isolated easily.

(iv) The reverse reaction, from E to A, is endothermic.

(v) The rate of the forward reaction depends on the concentration of C and on the activation energy for the elementary reaction step from C to E.

(A) i, v

(B) ii, iv

(C) iii, v

(D) **ii, iv, v**

(E) iv, v

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Name: ____________________ Student number: ______________

DATA PAGE

STP = 273.15 K, 1 atm

$R = 8.3145$ J/K·mol = 0.08206 L·atm/K·mol

$N_A = 6.022 \times 10^{23}\ mol^{-1}$

1 atm = 760 mm Hg = 101.325 kPa

0°C = 273.15 K

$1\ J = 1\ kg\ m^2\ s^{-2} = 1\ kPa\ L = 1\ Pa\ m^3$

$1\ m = 10^9\ nm = 10^{10}$ Å

$1\ cm^3 = 1\ mL$

$1\ g = 10^3\ mg = 10^9\ ng$

1 Hz = 1 cycle/s

$c = 2.9979 \times 10^8$ m/s

$K_W = 1.00 \times 10^{-14}$ at 25°C

$K_a(HClO_2) = 1.12 \times 10^{-2}$

$k = Ae^{-Ea/RT}$

$[A]_t = [A]_o e^{-kt}$

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