Name: _____ Student number: _____

Chemistry 1E03/1A03	**Test 2**	**June 5, 2018**
McMaster University	**VERSION 1**	**13:30 – 15:00**
Instructors: Drs. R.S. Dumont and L. Davis		Duration: 120 minutes

This test contains 19 numbered pages printed on both sides. There are **25** multiple-choice questions appearing on pages numbered 3 to 15. Page 16 and 17 are extra space for rough work. Page 18 includes some useful data and equations. There is a periodic table on page 19. You may tear off the last page to view the periodic table and the data provided.

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.

All questions are each worth 2 mark; the total marks available are 50. 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. 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.

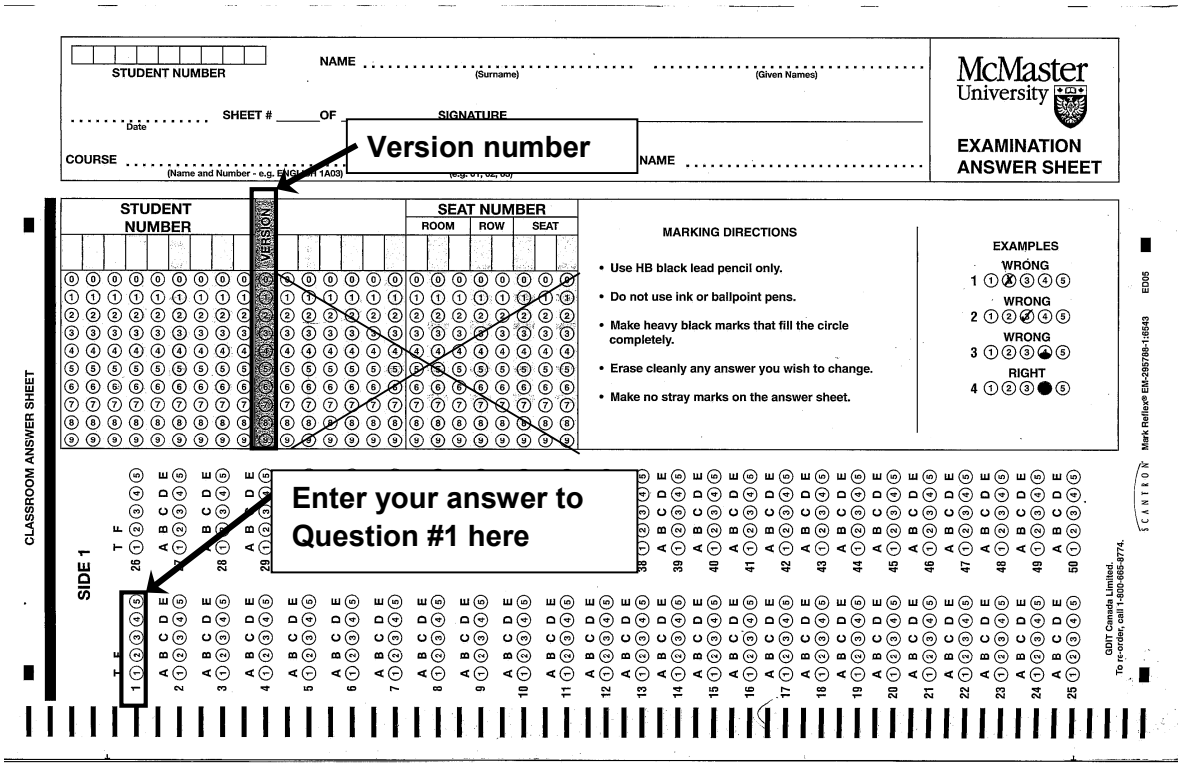
Name: _____ Student number: _____

OMR EXAMINATION – STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUR EXAMINATION RESULT DEPENDS UPON PROPER ATTENTION TO THESE INSTRUCTIONS.

The scanner, which reads the sheets, senses the bubble shaded areas by their non-reflection of light. A heavy mark must be made, completely filling the circular bubble, with an HB pencil. Marks made with a pen will **NOT** be sensed. Erasures must be thorough or the scanner will still sense a mark. Do **NOT** use correction fluid on the sheets. Do **NOT** put any unnecessary marks or writing on the sheet.

1. On SIDE 1 (**red side**) of the form, in the top box, *in pen*, print your student number, name, course name, and the date in the spaces provided. Then you **MUST** write your signature, in the space marked SIGNATURE. **ONLY USE THE RED SIDE OF THE OMR FORM.**
2. In the second box, *with a pencil*, mark your **student number** in the space provided. If your student number does **NOT** begin with a 4, put "00" before your student number. Then fill in the corresponding bubble numbers underneath.
3. Do NOT put in a leading zero when bubbling in your **exam version number**.
4. Answers: mark only **ONE** choice from the alternatives (A,B,C,D,E) provided for each question. The question number is to the left of the bubbles. Make sure that the number of the question on the scan sheet is the same as the number on the test paper.
5. Pay particular attention to the marking directions on the form.
6. Begin answering the question using the first set of bubbles, marked "1".



Name: _____ Student number: _____

1. Which of the following statements is(are) **TRUE**?

(i) $TeCl_2$ is a bent molecule.
(ii) All of the atoms of $TeCl_3^+$ are in the same plane.
(iii) $TeCl_4$ has one nonbonding pair of electrons on tellurium.

A) iii
B) i
C) i, iii
D) ii
E) i, ii

2. Choose the **FALSE** statement about the Lewis structure of the peroxide anion, O_2^{2-}:
.

A) Two resonance forms are required to describe bonding in this anion.
B) The oxygen-oxygen bond is a single bond.
C) Each oxygen atom has 3 nonbonding electron pairs.
D) Each oxygen atom carries a formal charge of -1.
E) Each oxygen atom obeys the octet rule.

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

   (i) Br atoms are smaller than As atoms.
   (ii) O has a higher first ionization energy than N.
   (iii) Li has a higher magnitude of electron affinity than O.
   (iv) Ba is easier to ionize than Sr.
   (v) Cl^- is a larger ion than Ca^{2+}.

   .

A) i, iii, v
B) all
C) i, iv, v
D) ii, iii, v
E) i, ii, iv

4. The O–H bond enthalpy in water is approximately 467 kJ mol^{-1}. What is the **wavelength** of the photon with just enough energy to break one O–H bond?

   .

A) 23.7 nm
B) 4130 nm
C) 467 nm
D) 256 nm
E) 213 nm

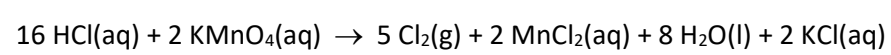
5. Identify the **incorrect** combination of quantum numbers (n,ℓ,m_ℓ) for the given atomic orbitals:
.

A) 4s (4, 0, 0)
B) 2p (2, 1, 0)
C) 2p (2, 1, –1)
D) 3s (3, 0, 1)
E) 3d (3, 2, –2)

6. During experiment 2, Cycles of Copper, a student obtains a percent yield of 108%. What is the most likely source of error?
.

A) Copper oxide was lost during the decanting step.
B) 108% is a valid yield as the atomic weight of copper at the end of the experiment is higher than at the start.
C) There was residual solvent left within the copper precipitate at the end of the experiment.
D) Not all of the zinc reacted with the Cu^{2+} (aq) to yield Cu(s).
E) The student accidently added too much nitric acid in the first step.

7. Identify the **oxidizing agent** in the following reaction.

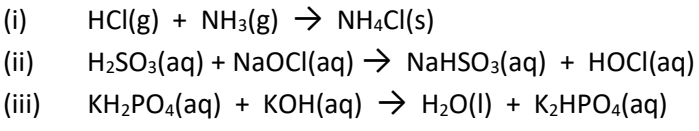


$$16\ HCl(aq) + 2\ KMnO_4(aq) \rightarrow 5\ Cl_2(g) + 2\ MnCl_2(aq) + 8\ H_2O(l) + 2\ KCl(aq)$$

.

A) $MnCl_2(aq)$
B) $K^+(aq)$
C) $H^+(aq)$
D) $Cl^-(aq)$
E) $MnO_4^-(aq)$

8. Which statement is **FALSE** regarding the following three product-favored reactions?



(i) $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$
(ii) $H_2SO_3(aq) + NaOCl(aq) \rightarrow NaHSO_3(aq) + HOCl(aq)$
(iii) $KH_2PO_4(aq) + KOH(aq) \rightarrow H_2O(l) + K_2HPO_4(aq)$

.

A) All of these reactions are Brønsted-Lowry acid-base reactions.
B) In reaction (ii), H_2SO_3 is acting as a Brønsted-Lowry acid.
C) NH_4^+ is the conjugate acid of NH_3.
D) HOCl is the conjugate acid of OCl^-.
E) HOCl is a stronger acid than H_2SO_3.

9. Dichromate ions, $Cr_2O_7^{2-}(aq)$, react with zinc metal in acid solution to produce $Cr^{3+}(aq)$ and $Zn^{2+}(aq)$ ions. When the reaction is balanced, such that the smallest possible integers appear as stoichiometric coefficients, what is the **coefficient** of Zn^{2+}?

.

A) 2
B) 6
C) 4
D) 1
E) 3

10. Which statement is **TRUE** regarding the following three reactions?

(i) $Cd(s) + NiO_2(s) + 2\ H_2O(l) \rightarrow Cd(OH)_2(s) + Ni(OH)_2(s)$

(ii) $2\ MnO_4^-(aq) + 5\ H_2SO_3(aq) \rightarrow 2\ Mn^{2+} + 5\ SO_4^{2-}(aq) + 4\ H^+(aq) + 3\ H_2O(l)$

(iii) $KH_2PO_4(aq) + KOH(aq) \rightarrow H_2O(l) + K_2HPO_4(aq)$

.

A) In reaction (iii), HPO_4^{2-} is the conjugate acid of $H_2PO_4^-$.
B) In reaction (i), NiO_2 is the reducing agent.
C) In reaction (i), Cd(s) is oxidized.
D) In reaction (ii), sulfur is reduced.
E) In reaction (iii), $H_2PO_4^-$ is acting as a Brønsted-Lowry base.

11. An unknown aqueous solution contains either KNO_3 or K_3PO_4. Addition of which **one** of the following aqueous solutions provides a simple visual test that identifies the unknown?
.
A) $CaBr_2$
B) Na_2SO_4
C) RbOH
D) LiBr
E) NaCl

12. Select the one **false** statement concerning the equilibrium,

$$MgCO_3(s) \rightleftharpoons MgO(s) + CO_2(g)$$

for which $\Delta H° = 100.6$ kJ.
.
A) Adding MgO(s) does not change the amount of $MgCO_3(s)$.
B) Removing $CO_2(g)$ increases the amount of MgO(s).
C) Doubling the amount of all three species (with the volume of the reaction vessel fixed) has no effect on the equilibrium.
D) Halving the size of the reaction vessel increases the amount of $MgCO_3(s)$.
E) Increasing the temperature increases the amount of MgO(s).

13. For the heterogeneous reaction,

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g),$$

the equilibrium constant at 112°C is $K_p = 0.220$. If the partial pressure of $CO_2(g)$ is 0.50 bar at this same temperature, which one of the following statements is **TRUE**?

.

A) $Q > K$, the reaction will proceed to the right.
B) $Q < K$, the reaction will proceed to the left.
C) $Q < K$, the reaction will proceed to the right.
D) $Q = K$, the system is at equilibrium.
E) $Q > K$, the reaction will proceed to the left.

14. 1.41 bar of $PCl_5(g)$, 7.95 bar of $PCl_3(g)$ and 7.95 bar of $Cl_2(g)$ are at equilibrium in a reaction vessel. Calculate the **equilibrium constant** K_p for

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

at the temperature of the equilibrium mixture.

.

A) 9.71
B) –1.30
C) 28.6
D) 51.8
E) 44.8

15. The equilibrium constant K_p for

$$C(s) + CO_2(g) \rightleftharpoons 2\ CO(g)$$

is 1.52 at 700°C. If the partial pressure of CO in an equilibrium mixture at 700°C is 1.30 bar, what is the **partial pressure** of CO_2 (in bar)?

.

A) 1.30
B) 1.11
C) 0.900
D) 0.860
E) 1.17

16. A student creates a calibration curve relating the absorbance of $FeSCN^{2+}(aq)$ to the concentration of $FeSCN^{2+}(aq)$. The slope of this plot is 1.68. If a student mixes 10.0 mL of 0.20 M $Fe^{3+}(aq)$ with 10.0 mL of 0.40 M $SCN^{-}(aq)$ an absorbance of 0.084 is observed. What is the **equilibrium constant** for the reaction?

.

A) 3.2
B) 6.7
C) 12
D) 120
E) 44

17. Heroin, a derivative of morphine, is a powerful analgesic and a powerful narcotic agent. **Calculate K_b** for heroin if the pH of a 1.7×10^{-3} M solution was found to be 9.60.
.
A) 9.5×10^{-7}
B) 2.3×10^{-2}
C) 8.3×10^{-7}
D) 1.5×10^{-7}
E) 3.7×10^{-7}

18. Your stomach (volume = 2.5 L) has a pH of 1.00 because of the presence of HCl. **How many grams of $Mg(OH)_2$** (58.3 g mol^{-1}) do you need to add to completely neutralize the acid in your stomach?
.
A) 7.3 g
B) 15 g
C) 21 g
D) 2.9 g
E) 5.8 g

19. A 2.60 g sample of propanoic acid (CH_3CH_2COOH, molar mass = 74.1 g mol^{-1}, K_a = 1.40 x 10^{-5}) was dissolved in water and made up to a final volume of 100. mL in water. **What is the pH** of this solution?

.

A) 2.66
B) 4.85
C) 3.26
D) 2.32
E) 1.82

20. Order the following species according to **increasing acid dissociation constant**, K_a:

CH_3COOH, CF_3COOH, CH_2FCOOH, CH_3CH_2OH

.

A) $CH_3COOH < CF_3COOH < CH_2FCOOH < CH_3CH_2OH$
B) $CH_3COOH < CH_2FCOOH < CF_3COOH < CH_3CH_2OH$
C) $CH_3CH_2OH < CF_3COOH < CH_2FCOOH < CH_3COOH$
D) $CH_3CH_2OH < CH_3COOH < CH_2FCOOH < CF_3COOH$
E) $CF_3COOH < CH_2FCOOH < CH_3CH_2OH < CH_3COOH$

21. Dissolving 4.24 g of CaF_2 in 50.0 mL of pure water at 20.00°C results in a solution with temperature 16.79°C. What is the **enthalpy of dissolution of CaF_2 (in kJ mol^{-1})?** Assume that the specific heat of the solution equals 4.18 J K^{-1} g^{-1}.

.

A) +13.4
B) +1.05
C) –1.05
D) –13.4
E) –671

22. A chemical reaction with an enthalpy change $\Delta H°$ = –400 kJ is carried out in a calorimeter containing 1500 cm^3 of pure water initially at 25.0°C. What is the **final temperature** (in °C) of the water?

.

A) 67.5
B) –28.7
C) 336.7
D) 69.3
E) 88.8

23. $PCl_5(s)$ can be prepared by the reaction,

$$PCl_3(l) + Cl_2(g) \rightarrow PCl_5(s).$$

Calculate the **enthalpy change** (in kJ) that accompanies the production of 100.0 g of $PCl_5(s)$ by the above reaction, given the following data.

$P_4(s) + 6\ Cl_2(g) \rightarrow 4\ PCl_3(l)$ $\quad \Delta H° = -1280\ kJ\ mol^{-1}$

$P_4(s) + 10\ Cl_2(g) \rightarrow 4\ PCl_5(s)$ $\quad \Delta H° = -1774\ kJ\ mol^{-1}$

.

A) +124.7
B) –258.1
C) +59.31
D) –124.7
E) –59.31

24. Determine the **enthalpy of formation** (in kJ mol^{-1}) of hydrogen chloride gas using the following bond enthalpy data:

Cl-Cl	243 kJ mol^{-1}
H-H	436 kJ mol^{-1}
H-Cl	431 kJ mol^{-1}

.

A) 17.1
B) –91.5
C) 91.5
D) –17.1
E) –53.4

25. Considering the reaction

$2\ B(s) + 3\ F_2(g) \rightarrow 2\ BF_3(g)$

and the data below, identify the **FALSE** statement(s).
enthalpy of formation of B(g) = 563 kJ mol^{-1}
bond enthalpy of F-F bond = 159 kJ mol^{-1}
bond enthalpy of B-F bond = 646 kJ mol^{-1}

(i) The reaction is a redox reaction.
(ii) The reaction of boron and fluorine is endothermic.
(iii) The sublimation of boron is an endothermic process.
(iv) $F_2(g)$ is a highly reactive species.
.

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

Extra space for rough work.

Extra space for rough work.

Name: _____ Student number: _____

Some general data are provided on this page.

A Periodic Table with atomic weights is provided on the next page.

$R = 8.3145\ \text{J K}^{-1}\ \text{mol}^{-1} = 0.08314\ \text{L bar K}^{-1}\ \text{mol}^{-1}$

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

$c = 2.9979 \times 10^{8}\ \text{m s}^{-1}$

$h = 6.6256 \times 10^{-34}\ \text{Js}$

$m_e = 9.10 \times 10^{-31}\ \text{kg}$

1 bar = 100.0 kPa

0°C = 273.15 K

1 J = 1 kg $\text{m}^2\ \text{s}^{-2}$ = 0.01 L bar = 1 Pa m^3

1 m = 10^9 nm = 10^{10} Å

1 cm^3 = 1 mL

1 g = 10^3 mg

1 Hz = 1 cycle/s

De Broglie wavelength:

$\lambda = h / mv = h / p$

Hydrogen atom energy levels:

$E_n = -R_E / n^2 = -2.180 \times 10^{-18}\ \text{J} / n^2$

Density of water:

1.00 g mL^{-1}

Specific heat capacity of water:

4.18 J K^{-1} g^{-1}

Solubility Guidelines for Common Ionic Solids

1. Alkali metal and ammonium salts are *soluble*.
2. Nitrate, chlorate, perchlorate, hydrogen carbonate and ethanoate salts are *soluble*.
3. Sulfate salts are *soluble*, *except* for the calcium, strontium, barium and lead salts which are *insoluble*.
4. Chloride, bromide and iodide salts are *soluble*, *except* for the silver, lead and mercury I salts which are *insoluble*.
5. Silver, lead and mercury I salts are *insoluble*, unless deemed soluble by rule 2 or 3.
6. Sulfide salts are *insoluble*, *except* for the alkali metal, ammonium, and alkaline earth salts which are *soluble*.
7. Oxide and hydroxide salts are *insoluble*, *except* for the alkali metal, ammonium, calcium, strontium and barium salts which are soluble.
8. Carbonate and phosphate are *insoluble*, *except* for the alkali metal and ammonium salts.

Name: ______________________ Student number: __________________

PERIODIC TABLE OF THE ELEMENTS

ALDRICH®

Transition Metals (groups 3–12)

I 1	II 2	3	4	5	6	7	8	9	10	11	12	III 13	IV 14	V 15	VI 16	VII 17	VIII 18
1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	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 69.723	32 Ge 72.61	33 As 74.922	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 105.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	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 Unq [261]	105 Unp [262]	106 Unh [263]												

Atomic weights are based on $^{12}C = 12$ and conform to the 1987 IUPAC report values rounded to 5 significant digits.
Numbers in [ ] indicate the most stable isotope.

* Lanthanides	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.97	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
** Actinides	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 [262]

END OF EXAM