Name: _____ Student number: _____

Chemistry 1A03 **Test 2** **Nov 10, 2017**

McMaster University **VERSION 1**

Instructors: L. Davis, D. Emslie, S. Greenberg, A.P. Hitchcock

Duration: 120 minutes

This test contains 20 numbered pages printed on both sides. There are **28** multiple-choice questions appearing on pages numbered 3 to 16. Pages 17 and 18 are extra space for rough work. Page 19 includes some useful data and equations, and there is a periodic table on page 20. 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 this question sheet, 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 worth 1 mark - the total marks available are 28. There is **no** 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. They must NOT be transferred between students. Use of any aids other than those provided, is not allowed.

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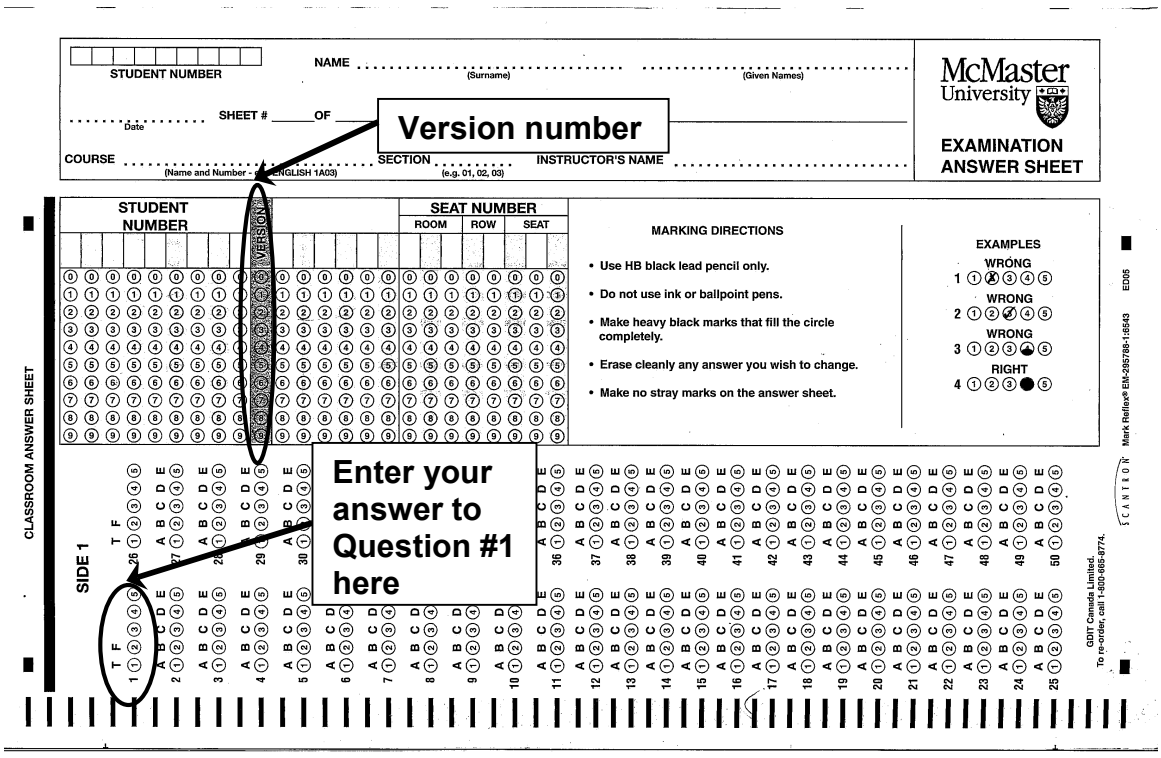
OMR EXAMINATION – STUDENT INSTRUCTIONS

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.
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".



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1. What **volume (in mL)** of a 2.40 mol L^{-1} magnesium bromide solution would contain 3.40 x 10^{23} **bromide** [Br^-(aq)] ions?

   A) 118
   B) 12.3
   C) 543
   D) 58.9
   E) 74.6

2. The human eye contains a molecule called 11-*cis*-retinal that changes shape when struck with light of sufficient energy, which results in an electrical signal being sent to the brain. The minimum energy required to change the conformation of 11-*cis*-retinal within the eye is 164 kJ/mol. Calculate the **longest wavelength (in nm) visible to the human eye.**

   A) 729
   B) 752
   C) 196
   D) 121
   E) 247

3. Which species would **fall in the middle** when the following species are ranked from smallest to largest radius ?

   Al, Al^{3+}, S^{2-}, P, Cl^{-}

   A) Al
   B) Al^{3+}
   C) S^{2-}
   D) P
   E) Cl^{-}

4. Which one of the following statements is **FALSE** ?

   A) The magnitude of the electron affinity of C is larger than that of N.
   B) The first ionization energy of Li is larger than that of Na.
   C) The radius of F^{-} is larger than that of F.
   D) The first ionization energy of Mg is smaller than that of Al.
   E) The effective nuclear charge, Z_{eff}, is higher for Mg than for Na.

5. What is the **<u>electron pair</u> geometry** for the AsF_4^- anion ?

   A) See-saw
   B) Square planar
   C) Trigonal bipyramidal
   D) Octahedaral
   E) Square pyramidal

6. Which one of the following statements about **BCl_3** is **FALSE** ?

   A) The B atom does not obey the octet rule.
   B) The B−Cl bonds are polar.
   C) The BCl_3 molecule has a permanent dipole moment.
   D) The Cl-B-Cl bond angles are 120°.
   E) The formal charge on boron is zero.

7. How many unique, **polar isomers** could exist for AsF_2Cl_3 ?

   A) 1
   B) 2
   C) 3
   D) 4
   E) 5

8. Four chemical species are shown below. Based on the principles of the VSEPR theory, how many of these molecules are **unlikely to exist** (i.e. there are fundamental reasons why these molecules would not be stable) ? In each case **the central atom is singly bonded to each of the halogen atoms**.

   NF_5 BeI_2 CF_4 CCl_2

   A) 0
   B) 1
   C) 2
   D) 3
   E) 4

9. A stable, non-paramagnetic molecule, **EF_5**, has a **square pyramidal** molecular geometry. Which one of the following is a possible **identity for the element E** ?

   A) Xe
   B) F
   C) Te
   D) P
   E) Cl

10. Which one of the following statements is **FALSE** ?

   A) Arsenic (As) has less metallic character than thallium (Tl).
   B) The bonds in $SnCl_4$ have more ionic character than those in SCl_2.
   C) VSEPR would predict the bond angles in H_2S to be larger than those in a BH_2^- anion.
   D) The oxidation state of tin in $SnCl_4$ is 4+.
   E) There are two lone pairs in H_2S.

11. When strontium nitrate and sodium sulfate are mixed, the **net ionic equation** is:

A) $Sr(NO_3)_2\ (aq) + Na_2SO_4\ (aq) \rightarrow 2\ NaNO_3\ (aq) + SrSO_4\ (s)$
B) $Sr^{2+}\ (aq) + SO_4^{2-}\ (aq) \rightarrow SrSO_4\ (s)$
C) $2\ SrNO_3\ (aq) + NaSO_3\ (aq) \rightarrow Sr_2SO_3\ (s)$
D) $2\ Sr^{+}\ (aq) + SO_4^{2-}\ (aq) \rightarrow Sr_2SO_4\ (s)$
E) $Na^{+}\ (aq) + NO_3^{-}\ (aq) \rightarrow NaNO_3\ (s)$

12. A chemical reaction has an equilibrium constant, *K*, with a value of X. If the stoichiometric coefficients of all reactants and products are doubled, what is the **new value of *K*** ?

A) X
B) 2X
C) X^2
D) X/2
E) X^{-1}

13. Determine the one **FALSE** statement.

A) Pure water is a strong electrolyte.
B) At equal concentrations, $MgCl_2$ is a stronger electrolyte than NaCl.
C) $CaSO_4$ is insoluble in water.
D) The oxidation state of vanadium in VO_4^{3-} is +5.
E) Adding 1.0 M Na_2CO_3 (aq) to a 1.0 M solution of $Ca(ClO_4)_2$ (aq) will precipitate $CaCO_3$ (s).

14. Consider the following gas phase equilibrium.

$A\ (g) + B\ (g) \rightleftharpoons 2\ C\ (g) \qquad K = 36.0$

Initially 2.00 bar of A and 2.00 bar of B were mixed in a sealed vessel, and equilibrium was established. Then 0.50 bar of C was added. After the final equilibrium is established, what is the **partial pressure of C (in bar)** in the reaction vessel ?

A) 4.55
B) 4.50
C) 3.00
D) 3.38
E) 3.50

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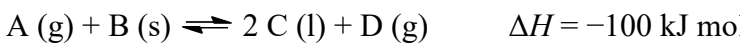
15. Considering the chemical equilibrium below, which of the following changes will cause the equilibrium **amount of D to increase** ?

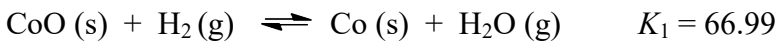


$$A\,(g) + B\,(s) \rightleftharpoons 2\,C\,(l) + D\,(g) \qquad \Delta H = -100\ \text{kJ mol}^{-1}$$

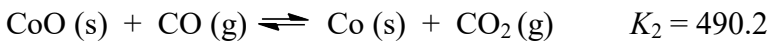
i. Increasing the volume of the vessel.
ii. Decreasing the temperature.
iii. Adding B.
iv. Removing C.
v. Adding A.

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

16. From the following information :

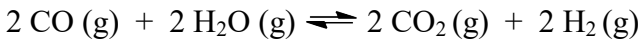


$$CoO\,(s) + H_2\,(g) \rightleftharpoons Co\,(s) + H_2O\,(g) \qquad K_1 = 66.99$$



$$CoO\,(s) + CO\,(g) \rightleftharpoons Co\,(s) + CO_2\,(g) \qquad K_2 = 490.2$$

determine ***K*** for the reaction shown below.



$$2\,CO\,(g) + 2\,H_2O\,(g) \rightleftharpoons 2\,CO_2\,(g) + 2\,H_2\,(g)$$

A) 53.55
B) 1.212×10^{-4}
C) 9.385×10^{3}
D) 7.303×10^{-3}
E) 13.56

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17. Recall that K_{ow} relates to the following equilibrium S (aq) $\rightleftharpoons$ S (org) where S is a substance which is partially soluble in both aqueous and organic phases. A certain POP (persistent organic pollutant) was stored as a 1.00 M solution in octanol. S has **log K_{ow} = 3.10**. If a large spill of the POP occurred into a pond (pond and spill each have a volume of 15,500 L), what would be the **total number of POP molecules in the aqueous phase of the pond** ?

A) 7.41×10^{24}
B) 9.31×10^{23}
C) 8.62×10^{22}
D) 1.13×10^{25}
E) 4.08×10^{23}

18. In the **forward** reaction below, which species is behaving as a **Bronsted-Lowry acid** ?

$K^+ (aq) + HCO_3^- (aq) + H_2O (l) \rightleftharpoons H_3O^+ (aq) + K^+ (aq) + CO_3^{2-} (aq)$

A) HCO_3^-
B) H_2O
C) H_3O^+
D) CO_3^{2-}
E) K^+

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19. The shells of corals and other marine organisms contain calcium carbonate, $CaCO_3$. In the presence of acid, the shell dissolves according to the following balanced equation:

$$CaCO_3\,(s) + H_3O^+\,(aq) \rightleftharpoons Ca^{2+}\,(aq) + HCO_3^-\,(aq) + H_2O\,(l)$$

At greater water depths, the pressure increases, and the dissociation constant of water (K_w) also increases.

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

(i) Shallow water has a greater concentration of H_3O^+ than deep water.
(ii) Deep water has a greater concentration of H_3O^+ than shallow water.
(iii) Sea shells dissolve to a greater extent in shallow water compared to deep water.
(iv) Sea shells dissolve to a greater extent in deep water compared to shallow water.

A) (i) and (iii)
B) (ii) and (iii)
C) (ii) and (iv)
D) (i) and (iv)
E) None of these statements are true.

20. Determine the **pH** at 25 ^oC of a 0.0162 mol/L solution of **calcium hydroxide**.

A) 1.790
B) 12.210
C) 1.489
D) 12.511
E) 13.489

21. Rank the following polyprotic oxyacids **from most acidic to least acidic** for the first dissociation in water.

H_3AsO_3 H_3PO_4 H_3PO_3

A) $H_3PO_4 > H_3PO_3 > H_3AsO_3$
B) $H_3AsO_3 > H_3PO_3 > H_3PO_4$
C) $H_3PO_3 > H_3PO_4 > H_3AsO_3$
D) $H_3AsO_3 > H_3PO_4 > H_3PO_3$
E) $H_3PO_3 > H_3AsO_3 > H_3PO_4$

22. Codeine, a painkiller, is a weak base that can accept only one proton. A 0.0600 mol L^{-1} solution of codeine at 25 °C has a pH of 10.36. What is the K_b **of codeine** ?

A) 2.3×10^{-4}
B) 8.8×10^{-7}
C) 4.3×10^{-11}
D) 1.6×10^{-6}
E) 3.7×10^{-3}

23. Acetylsalicylic acid is the active ingredient of aspirin. It is a weak acid with $K_a = 3.0 \times 10^{-4}$. What **concentration of acetylsalicylic acid (in mol/L)** will result in a solution with pH = 2.00 at 25 °C ?

A) 2.0
B) 3.0×10^{-4}
C) 1.0×10^{-2}
D) 1.6
E) 3.4×10^{-1}

24. When placed in distilled water, how **many** of the following salts have a **neutral pH** at 25 °C ?

NH_4Br NaBr Na_2CO_3 CaO $KClO_4$

A) 1
B) 2
C) 3
D) 4
E) 5

25. From the following list of reactions, **how many** demonstrate **work being done *by* the system *on* the surroundings** ?

$2\ SO_2\,(g) + O_2\,(g) \rightarrow 2\ SO_3\,(g)$

$C_6H_6\,(l) + 15/2\ O_2\,(g) \rightarrow 6\ CO_2\,(g) + 3\ H_2O\,(l)$

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

$Zn\,(s) + 2\ HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$

$PC1_5\,(g) \rightarrow PCl_3\,(g) + Cl_2\,(g)$

A) 5
B) 4
C) 3
D) 2
E) 1

26. When a particular gas is compressed with a constant external pressure of 3.50 atm, the volume decreases by 7.95 L. During this transformation the gas also releases 900. J of heat. What is the energy change, ΔU **(in kJ)**, for the gas ?

A) +3.02
B) +1.92
C) −1.92
D) +3.72
E) −2.02

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27. During experiment 2, Cycles of Copper, a student obtains a percent yield/recovery that is less than 100%. Which of the following observations is **NOT a plausible cause of reduced yield** for this experiment?

    A) After adding the Zn, the solution was still faintly blue before the copper product was rinsed and dried.
    B) Despite the addition of the H_2SO_4, some black precipitate was present when Zn(s) was added to the reaction beaker.
    C) Small amounts of CuO(s) were lost during the decanting step.
    D) The final product was slightly damp and smelled of acetone when its mass was recorded.
    E) The actual mass of Cu(s) reacted was 0.2013 g, but the student accidentally used a value of 0.2031 g in their calculations.

28. A student is titrating NaOH against HCl to determine the unknown concentration of NaOH. The student accidentally uses a 20.00 mL volumetric pipette to transfer the 0.1351 M HCl thinking they used a 10.00 mL volumetric pipette. The student determines the concentration of NaOH to be 0.1071 M. What is the **actual concentration (in M) of NaOH** ?

    A) 0.05355
    B) 0.2142
    C) 0.06755
    D) 0.1351
    E) 0.1071

Name: _____ Student number: _____

Extra space for rough work

Name: _____ Student number: _____

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.**

STP = 273.15 K, 1 atm
$N_A = 6.022 \times 10^{23}$ mol^{-1}
$h = 6.6256 \times 10^{-34}$ Js
density(H_2O, l) = 1.00g/mL
F = 96485 C/mol
$c = 2.9979 \times 10^{8}$ m/s
$m_e = 9.109 \times 10^{-31}$ kg
$\Delta H^{o}_{vap}[H_2O] = 44.0$ kJ mol^{-1}
Specific heat of water = 4.184 J / g·°C
$R = 8.3145$ J K^{-1} mol^{-1} = 0.08206 L atm K^{-1} mol^{-1} = 0.083145 L bar K^{-1} mol^{-1}

1 bar = 100.00 kPa = 750.06 mm Hg = 0.98692 atm
1 J = 1 kg m^2 s^{-2} = 1 kPa L = 1 Pa m^3
1 cm^3 = 1 mL
1 Hz = 1 cycle/s
0°C = 273.15 K
1 m = 10^6 μm = 10^9 nm = 10^{10} Å
1 g = 10^3 mg

De Broglie wavelength:
$\lambda = h / mu = h / p$

Hydrogen atom energy levels:
$E_n = -R_H / n^2 = -2.179 \times 10^{-18}$ J / n^2
$KE = ½mu^2$

Nernst Equation:

$$E = E° - \frac{RT}{zF}\ln Q \quad = E° - \frac{0.0257\ \text{V}}{z}\ln Q \quad = E° - \frac{0.0592\ \text{V}}{z}\log_{10} Q$$

Entropy change: $\Delta S = \frac{q_{rev}}{T}$

Solubility Guidelines for Common Ionic Solids

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations and the NH_4^+ cation are soluble . Except LiF and Li_2CO_3 which are insoluble.
2. Nitrates, acetates, bicarbonates, and perchlorates are soluble.
3. Salts of silver, lead and mercury (I) are insoluble. Except AgF which is soluble.
4. Fluorides, chlorides, bromides, and iodides are soluble. Except Group 2 fluorides which are insoluble
5. Carbonates, phosphates, chromates, sulfides, oxides, and hydroxides are insoluble. Except Group 2 sulfides and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} which are soluble.).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

Name: ____________________ Student number: ______________

PERIODIC TABLE OF THE ELEMENTS

ALDRICH®

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]												

Transition Metals: groups 3–12

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