Name: _____ **Student number: _____**

Chemistry 1E03 **Test 1** **Sep. 29, 2017**

McMaster University ***VERSION 1***

Instructors: Drs. R.S. Dumont, P. Kruse & L. Davis

Duration: 90 minutes

This test contains 14 numbered pages printed on both sides. There are **20** multiple-choice questions appearing on pages numbered 3 to 10. Pages 11 and 12 provide extra space for rough work. Page 13 includes some useful data and equations, and there is a periodic table on page 14. You may tear off the last pages 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 20. There is **no** additional penalty for incorrect answers.

BE SURE TO ENTER THE CORRECT VERSION NUMBER 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.

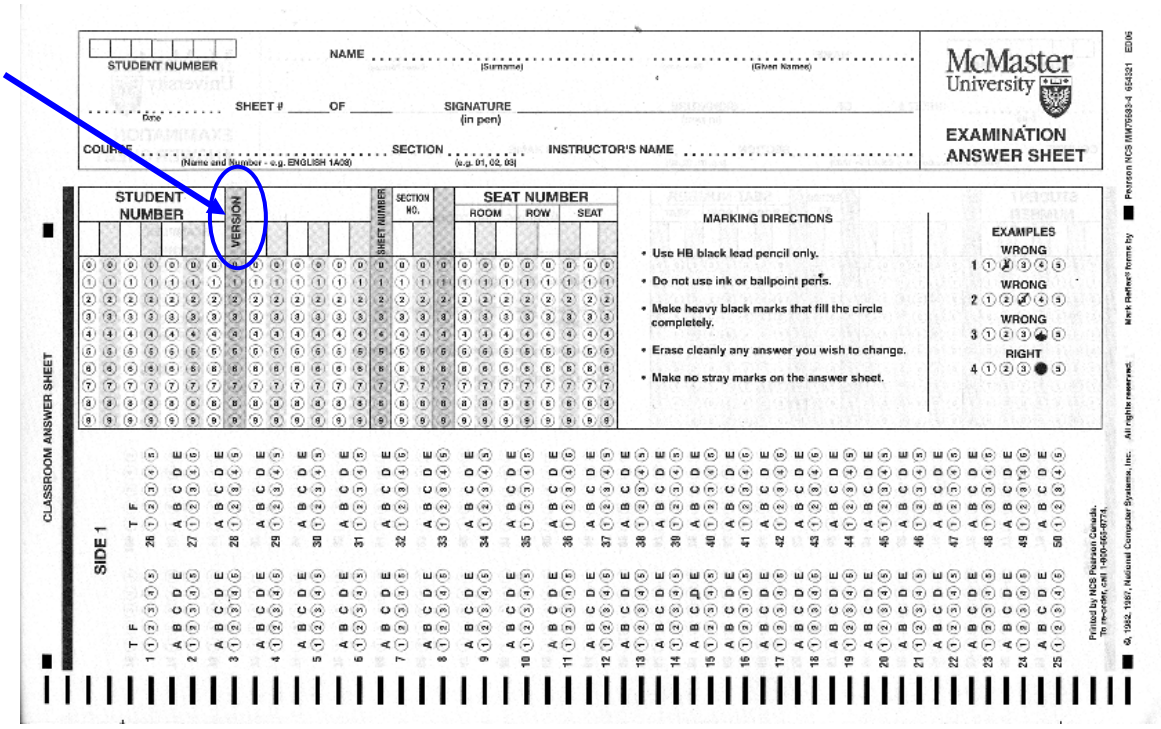
Name: _____ Student number: _____

OMR EXAMINATION – STUDENT INSTRUCTIONS

NOTE: IT IS YOUR RESPONSIBILITY TO ENSURE THAT THE ANSWER SHEET IS PROPERLY COMPLETED: YOUT EXAMINIATION 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, **exam version number** in the space provided and <u>fill in the corresponding bubble numbers underneath</u>.
3. 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.
4. Pay particular attention to the Marking+ Directions on the form.
5. Begin answering the question using the first set of bubbles, marked “1”.



1. Suppose we start with 40.0 L of an ideal gas at 300. K and 2.00 bar pressure. What is the **final volume** (in L), if both temperature and pressure of the gas are doubled?
   .

A) 160.
B) 10.0
C) 20.0
D) 40.0
E) 80.0

Ideal gas law: $P\,V = n\,R\,T$ or $V = n\,R\,T / P$
Doubling pressure and temperature introduces a factor of 2 in both numerator and denominator. They cancel. Consequently, the final volume is the same as the initial volume.

2. A hydrocarbon gas (C_xH_y) sample weighing 0.5653 g is completely burned in excess oxygen. The resulting gas mixture is cooled until all the water produced, in the reaction, is condensed and weighed. The result is 1.016 g of water. What is the formula of the **hydrocarbon gas**?
   .

A) C_3H_8
B) C_2H_6
C) CH_4
D) CH
E) C_2H_4

$C_xH_y + (2x + y/2)\ O_2 \rightarrow x\ CO_2 + (y/2)\ H_2O$
1.016 g of water => 0.05640 mol of water
=> 0.1128 mol H atoms => 0.1137 g of H atoms (these come from C_xH_y sample)
Sample has mass 0.5653 g. Therefore, the mass of carbon atoms in sample is
0.5653 - 0.1137 g = 0.4516 g
Moles of H in sample = 0.1128
Moles of C in sample = 0.4516 g / (12.011 g/mol) = 0.03760 mol
Ratio of (moles) H to C = 0.1128 / 0.03760 = 3
Only C_2H_6 has this molar ratio.

3. Hydrogen cyanide, HCN, is a poisonous gas that is also important in industrial chemical synthesis. It is produced from methane, ammonia and oxygen according to

$$2\ CH_4(g) + 2\ NH_3(g) + 3\ O_2(g) \rightarrow 2\ HCN(g) + 6\ H_2O(g)$$

What mass of **oxygen** (in kg) is required to produce 300. kg of hydrogen cyanide?

.

A) 533
B) 611
C) 164
D) 427
E) 398

300. kg of HCN => 3.00×10^5 g / (27.0259 g/mol) = 1.11×10^4 mol
This requires $3 \times 1.11 \times 10^4$ mol / 2 = 1.67×10^4 mol of O_2
or 1.67×10^4 mol x 29.998 g/mol = 5.33×10^5 g = 533 kg of O_2

4. What is the **empirical formula** of the most likely compound formed by gallium and sulfur?

.

A) Ga_2S
B) GaS_3
C) Ga_3S_2
D) GaS
E) Ga_2S_3

Ga is in group 13. It commonly forms Ga^{3+} - i.e., upon losing its 3 valence electrons.
S is in group 16. It commonly (when forming compounds with metals) forms S^{2-} - upon gaining 2 electrons to complete its octet.
A neutral compound corresponds to 2 Ga^{3+} for every 3 S^{2-}.

5. Which of the following statements regarding lab safety is **FALSE**?
.

A) Students are permitted to wear lab gloves in the hallways outside ABB 122 and ABB 217.
B) Students must wear lab safety goggles, rather than safety glasses, when conducting an experiment.
C) Students must wear long pants, or a long skirt, and shoes covering their entire foot - when in the lab.
D) Broken glass must be discarded in designated glass-waste containers, in the lab.
E) Students should never pour chemical waste into the sink. It must be poured into designated waste containers.

Students must remove gloves before leaving the lab.

6. A 3.00 L flask contains 2.88 g of a gas at 50.0°C and 0.586 bar pressure. What is the **molar mass** of the gas (in g mol^{-1})?
.

A) 27.9
B) 65.7
C) 49.1
D) 30.0
E) 44.0

$P\,V = n\,R\,T$ or $n = P\,V / R\,T$ = 0.586 bar x 3.00 L / (0.08314 L bar K^{-1} mol^{-1} x 323.15 K)
= 0.0654 mol
Molar mass = 2.88 g / 0.0654 mol = 44.0 g mol^{-1}

7. What is the name of the element with **atomic number** equal to 13?
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A) Bromine
B) Aluminum
C) Berylium
D) Chlorine
E) Antimony

8. Identify the **TRUE** statements from among the following:

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(i) A 3s orbital has a higher energy than a 2s orbital.
(ii) The red emission line in the hydrogen spectrum corresponds to an electron transition from the level n = 2 to the level n = 1.
(iii) A photon with an energy of 1.988 x 10^{-15} J has a wavelength shorter than 1 nm.
(iv) An electron with a velocity of 7.274 x 10^{4} m s^{-1} has a wavelength longer than 1 nm.
(v) The yellow coloration of a flame by sodium chloride is due to electronic transitions in the chlorine atoms.

.

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

(i) True. Higher principle quantum number means higher energy
(ii) False. Emissions ending in n = 1 are in the UV part of the electromagnetic spectrum.
(iii) True. $\lambda = c / \nu$ where $\nu = E / h$.
So, λ = 2.9979 x 10^{8} m s^{-1} / (1.988 x 10^{-15} J / 6.626 x 10^{-34} J s)
= 9.992 x 10^{-11} m < 1 nm = 1 x 10^{-9} m
(iv) True. $\lambda_{electron} = h / m\,u$ = 6.626 x 10^{-34} J s / (9.11 x 10^{-31} kg x 7.274 x 10^{4} m s^{-1})
= 6.626 x 10^{-34} kg m^{2} s^{-1} / (9.11 x 10^{-31} kg x 7.274 x 10^{4} m s^{-1})
= 1.00 x 10^{-8} m > 1 nm = 1 x 10^{-9} m
(v) False. The visible color of a flame due to a salt is associated with electronic transitions of the metal atoms in the flame – not the non-metal (here, chlorine)

9. The *emission* spectrum of atomic hydrogen can be divided into several well-separated series of lines, associated with particular transitions. Calculate the **longest wavelength** observed in series in the near infrared that contains all transitions ending at n = 3.

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A) 1.10 µm
B) 1.29 µm
C) 1.88 µm
D) 91.6 nm
E) 656 nm

The longest wavelength of transitions ending at n = 3 corresponds to the transition with the lowest energy difference – i.e., n = 4 to n = 3.

ΔE = -2.178 $\times$ 10^{-18} J (1/ 4^{2} - 1/ 3^{2}) = 2.178 $\times$ 10^{-18} J (1/9 - 1/16) = 1.059 $\times$ 10^{-19} J
$\lambda = c / \nu$ where $\nu = \Delta E / h$
λ = 2.9979 x 10^{8} m s^{-1} / (1.059 x 10^{-19} J / 6.626 x 10^{-34} J s) = 1.876 x 10^{-6} m

10. The minimum frequency of light needed for the photoelectric effect of a particular metal is 4.00×10^{14} Hz (1 Hz = 1 s^{-1}). What is the minimum energy (in J) needed to eject one electron from this metal?

.

A) 1.98×10^{-15}
B) 4.00×10^{14}
C) 2.65×10^{-19}
D) 4.89×10^{-19}
E) 2.34×10^{-15}

$E = h\nu = 6.626 \times 10^{-34}$ J s $\times 4.00 \times 10^{14}$ $s^{-1} = 2.65 \times 10^{-19}$

11. An electron traveling inside an electron microscope has an associated wavelength of 0.040 Å. Calculate its velocity.

.

A) 1.8 km/s
B) 18×10^{6} m/s
C) 1.8×10^{8} m/s
D) 0.90×10^{8} km/s
E) 0.90×10^{8} m/s

$\lambda_{electron} = h / m u$

So, $u = h / m \lambda_{electron} = 6.626 \times 10^{-34}$ J s / (9.11×10^{-31} kg $\times 0.040 \times 10^{-10}$ m)

$= 6.626 \times 10^{-34}$ kg m^2 s^{-1} / (9.11×10^{-31} kg $\times 0.040 \times 10^{-10}$ m)

$= 1.82 \times 10^{8}$ m s^{-1}

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

    .

    (i) (2, 1, 0) corresponds to a 2p orbital
    (ii) (1, 2, 0) corresponds to a 2p orbital
    (iii) (2, 1, −1) corresponds to a 2p orbital
    (iv) (3, 0, 1) corresponds to a 3s orbital
    (v) (3, 2, −2) corresponds to a 3d orbital
    (vi) (3, 1, −2) corresponds to a 3p orbital

    .

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

(ii) ℓ = 2 corresponds to a d orbital (not allowed for n = 1, in any case)
(iv) m_ℓ cannot be greater than ℓ (= 0 here)
(vi) $|m_\ell|$ cannot be greater than ℓ (= 1 here)

13. Which one of the following atoms will **not** accommodate **more** than 8 electrons in its valence shell?

    .

A) Kr
B) S
C) Br
D) P
E) C

C is in period two. Its valence shell (n=2) cannot accommodate more than 8 electrons.

14. What is the **maximum number of electrons** that can occupy an energy level described by principal quantum number, n.

    .

A) $2n^2$
B) n
C) $n + 1$
D) n^2
E) $2n$

There are n^2 orbitals per shell, and each orbital can accommodate two electrons.

15. Choose the **correct** statements from the following:

(i) Sodium has a larger first ionization energy than potassium.
(ii) Sodium has a larger atomic size than chlorine.
(iii) Calcium has a larger first ionization energy than fluorine.
(iv) Sulfur has a larger electronegativity than chlorine.
.

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

(i) True – follows general trend
(ii) True – follows general trend
(iii) False. Calcium ionization energy is less than that of bromine, which is less than that of fluorine (these observations follow general trends).
(iv) False – violates general trend.

16. Select the two most electronegative atoms from the following list: Cl, Na, Br, O, Be
.

A) Cl and Na
B) Na and Be
C) Br and O
D) O and Cl
E) Be and Br

General trend.

17. Select the **correct** sequence of the elements Al, K, Mg and N in order of **decreasing atomic size**:
.

A) K > Mg > Al > N
B) K > Al > N > Mg
C) K > N > Mg > Al
D) K > Al > Mg > N
E) Al > Mg > K > N

General trend.

18. Identify the **TRUE** statement(s):

.

(i) Be has a larger atomic radius than B.
(ii) Overall, electronegativity decreases from left to right across a period.
(iii) F^- has a smaller ionic radius than Na^+.
(iv) Rb has a lower first ionization energy than Na.
(v) All period 2 elements form acidic oxides.

.

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

(i) True
(ii) False
(iii) False
(iv) True
(v) False. Period 2 includes lithium whose oxide is basic.

19. Which atomic property decreases **down** a group?

.

A) metallic character
B) core charge
C) ionic radius
D) atomic radius
E) first ionization energy

Metallic character, ionic and atomic radii increase down a group. Core charge is the same for all elements in a group.

20. Select the **correct** sequence of the elements Al, K, Mg and N in order of **increasing first ionization energy**:

.

A) K < Al < N < Mg
B) Al < Mg < K < N
C) K < N < Mg < Al
D) K < Al < Mg < N
E) K < Mg < Al < N

General trend, except that Al < Mg (filled subshell effect).

Name: _____ Student number: _____

- **Some general data are provided on this page.**
- **A Periodic Table with atomic weights is provided on the next page.**

$R = 8.3145\ \text{J K}^{-1}\ \text{mol}^{-1} = 0.083145\ \text{L bar K}^{-1}\ \text{mol}^{-1}$

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

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

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

$m_e = 9.11 \times 10^{-31}\ \text{kg}$

1 bar = 100.0 kPa

0°C = 273.15 K

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

$1\ \text{m} = 10^9\ \text{nm} = 10^{10}\ \text{Å}$

$1\ \text{cm}^3 = 1\ \text{mL}$

$1\ \mu\text{m} = 10^{-6}\ \text{m}$

1 Hz = 1 cycle/s

$1\ \text{g} = 10^3\ \text{mg}$

De Broglie wavelength:

$\lambda = h / mu = h / p$

Hydrogen atom energy levels:

$E_n = -2.178 \times 10^{-18}\ \text{J} / n^2$