Name: _____ **Student number:** _____

Chemistry 1E03 **Term Test** **Oct. 2, 2015**

McMaster University ***SOLUTIONS***

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Duration: 120 minutes

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1. Identify the **incorrect** chemical name from among the following:

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A) $KClO_3$ potassium perchlorate
B) $Ca(NO_2)_2$ calcium nitrite
C) NaH_2PO_4, sodium dihydrogenphosphate
D) AlN, aluminum nitride
E) $FeSO_4$, iron(II) sulfate

$KClO_3$ is potassium chlorate. $KClO_4$ would be potassium perchlorate.

2. What is the correct **chemical formula** for calcium nitrate?

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A) Ca_2NO_2
B) $Ca(NO_3)_2$
C) Ca_2NO_3
D) $CaNO_3$
E) $Ca(NO_2)_2$

Calcium has 2 positive charges, nitrate has 1 negative charge, so this is the right proportion for neutrality.

3. How many **moles of Na_2O (s)** are produced when 56 grams of nitrogen gas are produced in the reaction below?

$5\ NaN_3\ (s) + \ NaNO_3\ (aq) \longrightarrow \ 3\ Na_2O\ (s) \ + \ 8\ N_2\ (g)$

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A) 0.75
B) 1.5
C) 0.63
D) 8.0
E) 0.38

N has an atomic mass of 14 g/mol, so N_2 is 28 g/mol and 56 grams correspond to 2 moles of nitrogen gas. To maintain the proportions, there has to be 3/4 moles of Na_2O.

4. What **volume** (in mL) of a 0.0850 M $Ba(OH)_2$ solution, when diluted to 250.0 mL with water, will give a solution that is 0.0400 M in hydroxide ions (*i.e.* $[OH^-]$ = 0.0400 M)?

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A) 58.8
B) 27.4
C) 76.2
D) 14.7
E) 118

250.0 ml of a 0.0400 M solution will have 0.0100 moles of hydroxide in them. A 0.0850 M $Ba(OH)_2$ solution will be 0.1700 M in hydroxide, so 1/17 L of it will have the right amount of hydroxide.

5. The empirical formula of a compound is CH. At 200 °C, 0.145 g of this compound in the gas phase occupies a volume of 97.2 mL at a pressure of 0.75 bar. What is the **molecular formula** of the compound?

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A) C_5H_5
B) C_6H_6
C) C_8H_8
D) C_2H_2
E) C_7H_7

From the ideal gas law, $pV = nRT$, we can calculate $n = 0.0972\ L * 0.75\ bar / (R * \{200 + 273.15\ K) = 0.001878\ mol$, so its molar mass is 0.145 g / 0.001878 mol = 77.2 g/mol, which comes closest to the molecular weight of C_6H_6.

6. How many **grams** of Na_2CO_3 are required for complete neutralization of 50.0 mL of 0.155 M HNO_3? The products are sodium nitrate, carbon dioxide and water.

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A) 0.922
B) 0.206
C) 0.411
D) 0.00388
E) 0.00776

Na_2CO_3 + 2 HNO_3 -> 2 $NaNO_3$ + CO_2 + H_2O
Hence we need 0.0725 moles of Na_2CO_3 @ a molecular weight of (2 23 + 12 + 3 * 16) g/mol = 106 g/mol to neutralize 1 L of 0.155 M HNO_3, or 1/20 of that amount for 50.0 mL of HNO_3.*
*0.05 * 0.0775 * 106 g = 0.411 g*

7. The anion $^{33}S^-$ contains

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A) 33 neutrons, 16 protons, 17 electrons
B) 17 neutrons, 17 protons, 16 electrons
C) 33 neutrons, 17 protons, 18 electrons
D) 16 neutrons, 17 protons, 18 electrons
E) 17 neutrons, 16 protons, 17 electrons

Sulfur is element 16, i.e. 16 protons and 16 electrons. Due to the single negative charge the number of electrons increases to 17. 33 is the atomic mass, so there have to be 33 – 16 = 17 neutrons in the nucleus.

8. If light with a wavelength of 400. nm falls on the surface of cesium metal, electrons with a kinetic energy of 1.60×10^{-19} J are ejected. The **minimum frequency** of light required to eject an electron from cesium is (in Hz):

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A) 3.20×10^{8}
B) 7.10×10^{14}
C) 5.63×10^{-19}
D) 5.08×10^{14}
E) 3.46×10^{-19}

*$E = h\,c\,/\,\lambda$, hence $E = 6.6256 \times 10^{-34}$ Js * 2.9979×10^{8} m s^{-1} / 4 x 10^{-7} m = 4.966 x 10^{-19} J, from that goes the kinetic energy, leaving a work function of 3.366 x 10^{-19} J. Use $E = h\,\nu$, or $\nu = E\,/h$ to get the frequency from that.*

9. Which atom has the **greatest number of *unpaired* electrons** in its ground-state electron configuration?
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A) N
B) Mn
C) Be
D) Ni
E) S

The electron configuration of Mn is [Ar]$3d^5 4s^2$, i.e. 5 unpaired d electrons. This beats N (3 unpaired), Be (0 unpaired), Ni (2 unpaired) and S (2 unpaired).

10. What is the wavelength of an electron travelling with a velocity of 1000 m s^{-1}? :
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A) 40.0 nm
B) 145 nm
C) 400 mm
D) 72.7 mm
E) 727 nm

The deBroglie relation states $\lambda = h / p$, where $p = m_e v$. Using v = 1000 m/s, Planck's constant and the mass of the electron from the back of the exam, we directly get the result as 7.27 x 10^{-7} m, which we now just have to properly convert into nm.

11. Which of the following statements regarding quantum mechanics are **FALSE**?
(i) The energy of a photon is proportional to its frequency.
(ii) In a hydrogen atom, the electron is at a fixed distance from the nucleus.
(iii) As the velocity of a given particle gets larger, its wavelength gets shorter.
(iv) The size of atomic orbitals is mainly determined by the magnetic quantum number.
(v) For a given shell of a many-electron atom, d orbitals have higher energy than s orbitals.

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

E = h v, so (i) is indeed correct, with Planck's constant as the proportionality factor.
(ii) was an assumption in the Bohr model, but the orbital shapes we discussed from modern quantum mechanics contradict this.
(iii) Higher velocity is higher energy, and wavelength is indeed inversely proportional to energy.
(iv) The size is mainly determined by the principal quantum number, although the orbital angular momentum quantum number also impacts the shape quite a bit.
(v) True for many-electron atoms, although for one-electron atoms this does not hold.

12. Which of the following is/are believed to be **TRUE** for **all** atoms?
(i) Electrons move in circular orbits around the nucleus.
(ii) The energy of the electrons is restricted to specific, discrete values.
(iii) The energy of each electron depends only on its principal quantum number, *n*.
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A) i, ii
B) ii
C) i
D) i, ii, iii
E) ii, iii

We know that the orbitals are not shaped like circles, so (i) is not true. Modern quantum mechanics still holds true that the electron energies are restricted to certain values. (iii) is only true for one-electron atoms, so mostly hydrogen or certain unlikely-to-occur cations. The entire rest of the periodic table does NOT follow this rule, in spite of what Bohr might have thought at the time.

13. Which electron configuration(s) correspond(s) to an **excited state** of a **non-metallic** atom?
(i) [Ne] $3s^2\ 4p^1$
(ii) [Ar] $4s^2\ 3d^{10}\ 4p^5$
(iii) [Ne] $3s^2\ 3p^3\ 4s^1$
(iv) [Ar] $4s^1\ 3d^5$
(v) [Ar] $4s^2\ 3d^{10}\ 4p^5\ 4d^1$
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A) iii, v
B) iv, v
C) i, ii, iii
D) i, iii, iv
E) ii, v

The (i) could be an excited state of Al (metal); (ii) is the ground state of Br (not a metal); (iii) could be an excited state of S (not a metal); (iv) is the ground state of Cr (metal); (v) could be the exited state of Kr (not a metal).

14. From the O=O bond dissociation energy (499 kJ/mol), compute the **maximum wavelength** (in nm) of light capable of dissociating the O_2 molecule into O atoms.
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A) 699
B) 3.98×10^{-22}
C) 240
D) 2.18×10^{6}
E) 213

$E = 499\ kJ/mol\ /\ 6.022 \times 10^{23}\ mol^{-1} = 8.286 \times 10^{-19}\ J = h\ c\ /\ \lambda$. So we can solve for λ.

15. Which one of the following statements is **false**?
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A) Light is emitted when electrons are promoted to higher energy levels.
B) As the quantum number ***n*** of an orbital increases, so does the average distance between nucleus and electron.
C) When the quantum number $\ell = 2$, the possible values of m_ℓ are -2, -1, 0, 1, or 2.
D) As the wavelength of light increases, the energy decreases.
E) The photoelectric effect occurs when light strikes the surface of a metal and electrons are ejected.

Statement (A) because in order to promote an electron to a higher energy level we need to add energy (e.g. by absorbing light), not remove energy, as would be the case for light emission. All other statements are true.

16. An element is a molecular solid at room temperature. It burns to form a solid oxide, which is acidic when dissolved in water. The element's first ionization energy is higher than either of its neighbouring elements (to the left and right) in the periodic table. **Which element is this**?
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A) Cl
B) P
C) Al
D) Si
E) S

Cl is not even a solid at room temperature. Al has an ionization energy smaller than both neighbors, so does S. Si does have a larger ionization than one of its neighbors (Al), but smaller then the other neighbor (P). The ionization energy of phosphorous is larger than that of both Si and S, because of the stability of its half-filled 3p-shell.

17. Which one of the following is the **correct** size sequence?

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A) $Cl^- > Rb^+ > Ca^{2+} > K+$
B) $Rb^+ > K^+ > Cl^- > Ca^{2+}$
C) $Rb^+ > Cl^- > K^+ > Ca^{2+}$
D) $Ca^{2+} > Cl^- > K^+ > Rb^+$
E) $Rb^+ > Ca^{2+} > K^+ > Cl^-$

Rubidium is near the bottom of the periodic table, far below the other elements, so going by the trends in the periodic table it will be the biggest. Cl^-, K^+, and Ca^{2+} all have the same number of electrons, but Cl has the lowest nuclear charge, K is in the middle and Ca has the highest nuclear charge, with the result that Cl^- will be largest and Ca^{2+} will be smallest.

18. Which of the following statements about periodic trends are **TRUE**?

(i) The ions Na^+ and F^- have the same ionic radius because they are isoelectronic.
(ii) The bonds in a phosphorus trichloride molecule are polar covalent.
(iii) The metallic character of Group 15 elements increases with increasing atomic mass.
(iv) The energy required for removing an electron from an atom in the gas phase is called the atom's electron affinity.

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

Statement (i) is wrong because they have different nuclear charges, resulting in different Coulomb attraction forces.
Statement (ii)is correct, because the electronegativities of 2.19 for P and 3.16 for Cl put them apart enough to make the bond polar, but not far enough apart for ionic bonding.
Statement (iii) is correct, because as you go down the periodic table, it is indeed the trend for the metallic character to increase.
Statement (iv) is not correct, because removal of an electron is referred to as ionization, so the corresponding energy is the ionization energy. Electron affinity measures the willingness to accept an additional electron.

19. Which ONE of the following choices lists the species in order of **increasing** size?
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A) $F^- < Cl^- < Cl$
B) $I^- < I < Br$
C) $F^- < F < Cl$
D) $Cl^+ < Cl^- < Cl$
E) $F < F^- < Cl^-$

F^- has an additional charge in the valence electron shell, increasing electron-electron repulsion and making it larger than F. Cl^- is larger than F^- because it is below F^- in the periodic table and has additional shells in its electron configuration. The radii are 60 pm < 133 pm < 181 pm.

20. Put the following elements in order of **increasing atomic radius.**
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A) As < S < F <Ne
B) As < S < Ne < F
C) Ne < F < S < As
D) F < Ne < S < As
E) F < Ne < As < S

Ne (62 pm) ≈ F (60 pm) < S (104 pm) < As (120 pm)

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

$R = 8.3145\ \text{J K}^{-1}\ \text{mol}^{-1} = 0.08206\ \text{L atm K}^{-1}\ \text{mol}^{-1}$

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

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

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

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

1 bar = 100.0 kPa

$0^\circ\text{C} = 273.15\ \text{K}$

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

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

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

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

1 Hz = 1 cycle/s

De Broglie wavelength:

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

Hydrogen atom energy levels:

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