Name: _____ **Student number:** _____

Chemistry 1E03 **Term Test** **Oct. 24, 2014**

McMaster University ***VERSION 1 SOLUTIONS***

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Duration: 120 minutes

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1. For the following pure substances, identify the one **incorrect** chemical name from among the following:

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   A) Li_2CO_3, lithium carbonate
   B) Fe_2O_3, iron(III) oxide
   C) HF, hydrogen fluoride
   D) $Ca(H_2PO_4)_2$, calcium dihydrogen phosphate
   E) NH_4ClO_2, ammonium chlorate

NH_4ClO_2 is the formula for ammonium chlorite.

2. The cation $^{27}\mathbf{Al^{3+}}$ contains

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   A) 13 neutrons, 14 protons, 11 electrons
   B) 17 neutrons, 10 protons, 13 electrons
   C) 14 neutrons, 13 protons, 10 electrons
   D) 13 neutrons, 13 protons, 13 electrons
   E) 27 neutrons, 13 protons, 12 electrons

Aluminum is element 13. It has 13 protons. ^{27}Al has 27 protons and neutrons – in total. It has 14 neutrons. A cation with charge, 3+, has three fewer electrons than protons. $^{27}Al^{3+}$ has 10 electrons.

3. The percentage by mass of hydrogen carbonate in a certain antacid is 35.0 %. Calculate the **volume** of carbon dioxide gas (in mL) generated at 37°C and 1.00 bar pressure, when a person ingests a 3.30 g tablet. The reaction in the stomach is:

$$HCO_3^-(aq) + H^+(aq) \rightarrow H_2O(l) + CO_2(g)$$

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   A) 623
   B) 21.6
   C) 972
   D) 79.1
   E) 488

Mass of hydrogen carbonate = 0.35 × 3.30 g = 1.155 g (carry 1 extra digit)
Moles of hydrogen carbonate = 1.155 g / 61.02 g mol^{-1} = 0.01893 mol.
Moles of $CO_2(g)$ = 0.01893 mol (1:1 stoichiometry)
Volume of $CO_2(g)$ = 0.01893 mol × 0.08314 L bar K^{-1} mol^{-1} × 310.15 K / 1.00 bar = 0.488 L

= 488 mL

4. Aluminum displaces platinum from a platinum chloride compound. The *unbalanced* reaction is $Al(s) + PtCl_x(aq) \rightarrow AlCl_3(aq) + Pt(s)$. A 1.02 g sample of platinum chloride is dissolved in water and reacted with an excess of aluminum to give 0.59 g of platinum metal (atomic number 78). What is the **empirical formula** of the platinum chloride?

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   A) $PtCl$
   B) $PtCl_2$
   C) $PtCl_4$
   D) $PtCl_5$
   E) $PtCl_3$

Moles of platinum = 0.59 g / 195.1 g mol^{-1} = 0.00302 mol.
Moles of $PtCl_x$ = 0.00302 mol (each Pt atom came from one $PtCl_x$ unit)
Molar mass of $PtCl_x$ = 1.02 g / 0.00302 mol = 337.3 g mol^{-1}
= 195.1 + x × 35.45 g mol^{-1}
Therefore, x = (337.3 – 195.1) / 35.45 = 4.0
i.e., we have $PtCl_4$

5. Choose the one **false** statement from the following:

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   A) The volume of an ideal gas, at a given temperature and pressure, is directly proportional to the number of moles of the gas.
   B) The density of an ideal gas is proportional to its molar mass.
   C) Pressure is defined as force per unit area.
   D) The pressure of a fixed volume of an ideal gas is directly proportional to the temperature of the gas.
   E) All ideal gases have the same density.

All ideal gases have the same number of moles per volume. However, density is mass per volume. The density of an ideal gas is proportional to the molar mass.

6. Which one of the following atoms has **more** than one **unpaired** electron in its **ground-state** electron configuration?

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   A) Al
   B) P
   C) Xe
   D) Sr
   E) F

Ground state electron configurations:
Al: [Ne] $3s^2\ 3p^1$ one unpaired electron
P: [Ne] $3s^2\ 3p^3$ three unpaired electrons > 1

Xe: [Kr] $5s^2\ 4d^{10}\ 5p^6$ no unpaired electrons
Sr: [Kr] $5s^2$ no unpaired electrons
F: [He] $2s^2\ 2p^6$ no unpaired electrons

7. 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 **kinetic energy** (in J) of an electron ejected by a photon with frequency, 12.00×10^{14} Hz?

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   A) 4.00×10^{14}
   B) 1.98×10^{-18}
   C) 2.34×10^{-19}
   D) 4.89×10^{-18}
   E) 5.30×10^{-19}

The minimum frequency, ν_{thres} needed for the photoelectric effect satisfies

$h\,\nu_{thres} = \varphi$

A photon of energy, $h\,\nu > \varphi$, ejects an electron with kinetic energy,

$E_{kin} = h\,\nu - \varphi = h\,(\nu - \nu_{thres}) = 6.626\times10^{-34}\ \text{J s} \times (12.00 \times 10^{14} - 4.00 \times 10^{14})\ s^{-1}$
$= 5.30 \times 10^{-19}\ \text{J}$

8. An arsenic atom ($Z = 33$) is in its **ground state**. Which one of the following sets of quantum numbers (n, l, m_l, m_s) could **not** possibly describe one of its electrons?

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   A) 4, 2, 2, -1/2
   B) 2, 1, -1, ½
   C) 3, 0, 0, -1/2
   D) 3, 2, -2, ½
   E) 4, 1, 0, ½

None of the above quantum number sets violates the rules of possible quantum numbers. So, we must consider the ground state electron configuration of As: [Ar] $4s^2\ 3d^{10}\ 4p^6$. Quantum numbers, (4, 2, 2, -1/2), correspond to a 4d electron, not presetn in the ground state electron configuration of As.

9. A sample of hydrogen atoms have their electrons excited to various energy levels. This is followed by emission of light. Which one of the following emission transitions produces a photon with the **shortest wavelength**?

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A) $n = 7 \rightarrow n = 6$
B) $n = 7 \rightarrow n = 1$
C) $n = 3 \rightarrow n = 2$
D) $n = 2 \rightarrow n = 1$
E) $n = 5 \rightarrow n = 2$

Shortest wavelength corresponds to largest frequency and largest energy difference. The largest energy difference is associated with the smallest final n value – the lower energy level spacings are much greater than the spacings between higher n levels. Therefore, the answer is either B or D, both with final n value 1. It is B because the initial n value is higher in this case (7 versus 2).

10. Which one of the following electron configurations is **not** a **ground-state** configuration of any neutral atom?

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A) $[Kr]4d^{10}5s^2$
B) $[Ar]4s^1$
C) $[Ne]3s^23p^4$
D) $[Ne]3s^23p^63d^2$
E) $[Ar]3d^24s^2$

The Aufbau principle tells us that 4s is filled before 3d. $[Ne]3s^23p^63d^2$ is an excited state electron configuration.

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

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

The periodic table trend for atomic size (radius): Smallest in the upper right, and largest in the lower left.

Relative positions in periodic table:

N
Mg Al
K

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

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

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

(i) True. Br is right of As in period 4.
(ii) False. N is to the right of C in period 2 (and it has the relatively stable half-filled p subshell)
(iii) False. O is to the right of Li.
(iv) True.

13. Which one of the following atoms has the **largest** first ionization energy? (Hint: consider the ground state electron configurations for these atoms.)

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A) S
B) P
C) K
D) Si
E) Al

Using the general trend, we would pick S and then P. However, P has a higher first ionization energy than S because it has the favorable half-filled 3p subshell, whereas S is easier to ionize (than otherwise expected) because it achieves the half-filled 3p subshell subsequent to ionization.

14. Identify the **FALSE** statement(s):

(i) Lithium fluoride contains larger ions than potassium iodide.
(ii) Magnesium has a larger atomic radius than sodium.
(iii) For some elements, the 2nd ionization energy ($M^+ \rightarrow M^{2+} + e^-$) is smaller than the 1st ionization energy ($M \rightarrow M^+ + e^-$).

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

(i) False. Li^+ ions are smaller than K^+ ions, and F^- ions are smaller than I^- ions.

(ii) False. Mg is to the right of Na.
(iii) False. The 2nd ionization energy is always larger than the 1st ionization energy.

15. Which is the **correct** ordering of electronegativities for the atoms Mg, Ba, O, P?

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A) Mg < Ba < P < O
B) Ba < P < O < Mg
C) O< Mg < Ba < P
D) Ba < Mg < P < O
E) P < O < Mg < Ba

Electronegativity increases up and to the right in the periodic table.

16. For the species NO^+, NO_2^-, NO_3^-, what is the correct order of **decreasing** N-O **bond length**?

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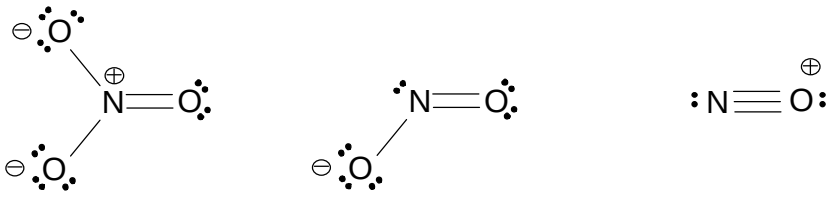
A) $NO_2^- > NO_3^- > NO^+$
B) $NO_3^- > NO^+ > NO_2^-$
C) $NO_3^- > NO_2^- > NO^+$
D) $NO^+ > NO_2^- > NO_3^-$
E) $NO_2^- > NO^+ > NO_3^-$

Draw the Lewis structures to get the bond orders:

NO_3^- NO_2^- NO^+



Bond orders: 4/3 < 3/2 < 3

Bond length decreases with increasing bond order.

17. Rank the molecules PF_5, PF_3 and PH_3, in order of **increasing molecular dipole moment**? (Electronegativity values: P = 2.1; H = 2.2; F = 4.0)

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A) $PH_3 < PF_5 < PF_3$
B) $PF_3 < PF_5 < PH_3$
C) $PF_5 < PH_3 < PF_3$
D) $PF_5 < PF_3 < PH_3$
E) $PH_3 < PF_3 < PF_5$

P-F bonds have the largest bond dipole. In PF_5 they cancel. PF_5 is trigonal bipyramidal – the bond dipoles cancel. PF_3 is trigonal pyramidal, which is asymmetrical – there is a net molecular dipole. PH_3 has a smaller net dipole.

18. Choose the **true** statement concerning nitrosyl chloride, ONCl (N is the central atom):

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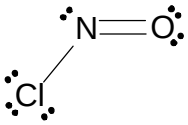
A) The molecule contains 5 nonbonding electron pairs.
B) The molecule is linear.
C) All formal charges can be minimized to zero.
D) The molecule contains 4 bonding electron pairs.
E) None of the above statements are true.

NOCl



There are six nonbonding electron pairs. The molecule is AX_2E, and is therefore bent. All formal charges can be minimized to zero.

19. What is the average **bond order** of the iodine-oxygen bond in IO_3^-?

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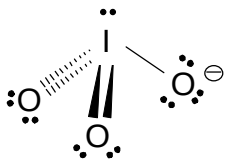
A) 1
B) 5/3
C) 2
D) 3/2
E) 4/3



20. What is the geometry around the carbon atom of the formate anion, HCO_2^- (H is bonded to the central atom, carbon)?

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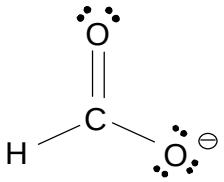
A) T-shaped
B) tetrahedral
C) triangular pyramidal
D) triangular planar
E) linear



AX_3 - trigonal planar – also known as triangular planar.

21. 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?

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A) Na_2SO_4
B) LiBr
C) NaCl
D) RbOH
E) $CaBr_2$

$Ca_3(PO_4)_2$ is insoluble, and precipitates when $CaBr_2$ solution is mixed with K_3PO_4 solution – but not KNO_3 solution.

22. Identify the reducing agent in the following reaction.

$$5\ Fe^{2+}(aq) + MnO_4^-(aq) + 8\ H^+(aq) \rightarrow 5\ Fe^{3+}(aq) + Mn^{2+}(aq) + 4\ H_2O(l)$$

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A) MnO_4^-
B) H^+
C) Fe^{3+}
D) Fe^{2+}
E) Mn^{2+}

Fe^{2+} loses an electron (to MnO_4^-), and is therefore the reducing agent.

23. Select the **TRUE** statement, below, 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) $KH_2PO_4(aq) + KOH(aq) \rightarrow H_2O(l) + K_2HPO_4$

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

In reaction (iii), OH^- is the Brønsted base. In reaction (ii), sulfurous acid is oxidized. In reaction (i), NiO_2 is the oxidizing agent.

24. Regarding the chemical reactions (i,ii,iii), identify the **false** statement below.

(i) $LiOH(s) + HOCl(aq) \rightarrow LiOCl(aq) + H_2O(l)$
(ii) $C(s) + O_2(g) \rightarrow CO_2(g)$
(iii) $KHSO_4(aq) + NaCH_3COO(aq) \rightarrow KNaSO_4(aq) + CH_3COOH(aq)$

A) $SO_4^{2-}(aq)$ is a spectator ion in reaction (iii).
B) CH_3COO^- acts as a base in reaction (iii).
C) HOCl acts as an acid in reaction (i).
D) Four electrons are transferred in reaction (ii).
E) Reaction (ii) is an oxidation reduction.

$SO_4^{2-}(aq)$ is the product in (acid-base) reaction (iii).

25. Complete and balance the following redox equation in acidic solution. What is the **coefficient of S,** when the reaction is balanced with smallest whole number coefficients.

$$H_2S + HNO_3 \rightarrow S + NO$$

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

$$H_2S + HNO_3 \rightarrow S + NO$$

Oxidation numbers: +1 –2 +1 +5 –2 0 +2 –2

N gains 3 electrons, while S loses 2. This gives

$3\ H_2S\ +\ 2\ HNO_3\ \rightarrow\ 3\ S\ +\ 2\ NO$

This is not balanced with respect to H and O. However, that is unnecessary here, since only the coefficient of S is requested. If you did balance the equation completely (in acid, since there is nitric and hydrosulfuric acid present), you would get

$3\ H_2S\ +\ 2\ HNO_3\ \rightarrow\ 3\ S\ +\ 2\ NO\ +\ 4\ H_2O$

26. In the event of an uncontrollable fire in the lab, the **safest** course of action for a student is:

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A) Find the Laboratory Coordinator
B) Exit the lab and wait in the hallway until safe to return
C) Exit the laboratory and building, pulling the fire alarm while exiting the building
D) Collect all personal items and exit the building
E) Attempt to extinguish the fire

27. Determine the **equilibrium constant** for the formation of ozone,

$$O_2(g) + O(g) \rightleftharpoons O_3(g),$$

from the following data:

$$NO_2(g) \rightleftharpoons NO(g) + O(g) \qquad K_1 = 6.8\times10^{-49}$$
$$O_3(g) + NO(g) \rightleftharpoons NO_2(g) + O_2(g) \qquad K_2 = 5.8\times10^{-34}$$

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A) 5.6×10^{83}
B) 8.1×10^{-81}
C) 3.7×10^{-82}
D) 2.5×10^{81}
E) 1.9×10^{82}

The target reaction is – Rxn 1 – Rxn 2. Therefore, $K = 1/(K_1 K_2) = 2.5\times10^{81}$.

28. The equilibrium constant for the reaction $N_2(g) + O_2(g) \rightarrow 2\ NO(g)$ is 1.7×10^{-1} at an elevated temperature. A reaction vessel at this temperature contains $N_2(g)$ at a partial pressure of 0.25 bar, $O_2(g)$ at a partial pressure of 0.25 bar, and NO(g) at a partial pressure of 4.2×10^{-1} bar. Select the one **true** statement for this system.

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A) The reaction quotient *Q* is smaller than *K*, and there is net forward reaction.
B) The reaction quotient *Q* is smaller than *K*, and there is net reverse reaction.
C) The reaction quotient *Q* is larger than *K*, and there is net forward reaction.
D) The reaction quotient *Q* is larger than *K*, and there is net reverse reaction.
E) The system is at equilibrium.

$$Q = \frac{P_{NO}^2}{P_{O_2} P_{N_2}} = \frac{0.42}{0.25 \times 0.25} = 6.72 > K = 0.17$$

$Q > K$ means net reverse reaction.

29. In the cycles of copper lab, a student obtains a yield of 105% copper in the final step. Which of the following provide **possible explanations** for this result?

(i) There is unreacted metallic zinc mixed in with the copper.
(ii) The copper product is not completely dry.
(iii) The student added too much HCl(aq).

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A) None. There is nothing unusual about a yield of 105%
B) i, ii and iii
C) i and ii
D) i and iii
E) ii and iii

The measured mass of copper is too high. Unreacted (in the reaction with HCl) zinc would give an anomalously high copper mass. Also, water present (i.e., the copper is not completely dry) would also do this. Adding too much HCl would not cause this result. Rather it would ensure all the zinc reacted. Excess HCl is removed in the drying step.

30. Select the one **false** statement concerning the equilibrium,
$MgCO_3(s) \rightleftharpoons MgO(s) + CO_2(g)$ for which $\Delta H° = 100.6$ kJ mol^{-1}.

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

$CO_2(g)$ is a product gas. Removing it causes net forward reaction which increases the amount of MgO(s). Halving the size of the reaction vessel doubles the pressure of the $CO_2(g)$ (the only gas). Net reverse reaction ensues to counter the increased product partial pressure. This increases the amount of $MgCO_3(s)$, a reactant. Adding MgO(s) has no effect on the equilbrium - MgO(s) is a pure solid. Doubling the amount of all three species (with the volume of the reaction vessel fixed) does affect on the equilibrium. The double amount of $MgCO_3(s)$ and MgO(s) has no effect. However, doubling $CO_2(g)$ with fixed volume doubles its partial pressure and causes net reverse reaction.