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CHEMISTRY Olympiads CANADA Olympiades CHIMIE

THE CANADIAN CHEMISTRY CONTEST 2017

PART A – MULTIPLE CHOICE QUESTIONS (60 minutes)

All contestants should attempt this part of the contest before proceeding to Part B and/or Part C

The only reference material allowed is the CIC/CCO Periodic Table provided. You must complete answers on the Scantron Sheet provided. A scientific calculator is allowed. No phones or any devices that can be used for communication are allowed.

1) Which of the following metals should be labelled with the WHMIS symbol for flammable substances  ?

A) Al B) Ni C) Mg D) Pb E) Hg

2) A reaction AB + C, undergoes a single displacement reaction. Which of the following would be a product of the reaction if A is a group 2 metal and C is a group 1 metal?

A) CA_2 B) B C) CB D) A_2 E) C_2B

3) In which of the following situations could hydrogen bonding occur between H_2O and the solute?

A) ammonia gas dissolved in water
B) hydrogen gas dissolved in water
C) carbon dioxide gas in water
D) methane gas dissolved in water
E) hydrogen sulfide gas dissolved in water

4) The exothermic thermite reaction between iron (III) oxide and aluminum metal occurs as follows:

$$Fe_2O_3\,(s) + 2Al\,(s) \rightarrow 2Fe\,(s) + Al_2O_3\,(s)$$

If 8.0 g of iron (III) oxide is combined with 5.4 g of aluminum metal, what mass of iron metal will be produced?

A) 2.8 g B) 5.6 g C) 8.0 g D) 11 g E) 14 g

5) Which of the following molecules has a molecular dipole?

A) XeF_4 B) SeF_4 C) CF_4 D) SiF_4 E) KrF_2

6) Given the following heats of formation, what is the enthalpy of combustion for toluene shown in the following equation?

$$C_7H_8\,(l) + 9\,O_2\,(g) \rightarrow 7\,CO_2\,(g) + 4\,H_2O\,(l)$$

Substance	ΔH_f (kJ mol^{-1})	**Substance**	ΔH_f (kJ mol^{-1})
C_7H_8 (l)	+12.0	H_2O (l)	-286
CO_2 (g)	-394	O_2 (g)	0

A) 680 kJ mol^{-1} B) 692 kJ mol^{-1} C) –692 kJ mol^{-1}
D) –3890 kJ mol^{-1} E) –3914 kJ mol^{-1}

7) Artificial photosynthesis involves splitting water with solar energy. This clean energy reaction is: $2\,H_2O\,(l) \rightarrow 2\,H_2\,(g) + O_2\,(g)$

Which of the following statements about the splitting of water is **incorrect**:
A) The oxidation state of hydrogen in water is +1
B) The oxidation state of hydrogen gas is 0
C) Water is the oxidizing and reducing agent
D) The oxidation state of oxygen in water is – 1
E) The oxygen atoms are oxidized in this process

8) Cows are one of the most significant sources of methane (CH_4) emitted into the atmosphere. The average cow produces 259 grams of methane per day. The lower explosive limit (LEL) is the lowest concentration at which there is a risk of an explosion. For methane, the LEL at SATP is 5.0% v/v. Assuming a constant rate of methane emission from cows, how long would it be safe to keep an average cow in a 10.0 m^3 enclosed space at 25°C and 100 kPa before there is a risk of explosion? The molar volume of a gas at SATP is 24.8 L.

A) 30 hours B) 60 hours C) 90 hours D) 600 hours E) 900 hours

9) Predict the conditions maximizing the rate of hydrogen gas production in the steam methane reforming reaction:

$CH_4\,(g) + H_2O\,(g) \rightleftharpoons CO(g) + 3H_2\,(g)$ $\Delta H = +206$ kJ mol^{-1}

A) Low temperature, high pressure and a catalyst
B) Low temperature, low pressure and a catalyst
C) Low temperature, high pressure and no catalyst
D) High temperature, high pressure and a catalyst
E) High temperature, low pressure and a catalyst

10) The *molality (m)* of a solution is defined as the number of moles of solute per kilogram of solvent. Lauryl alcohol ($C_{12}H_{26}O$) is prepared from coconut oil and is used to make sodium lauryl sulfate, a synthetic detergent. What is the molality of a solution of 17.1 g lauryl alcohol dissolved in 3.21 moles of ethanol (C_2H_6O)?

A) 0.310 *m* B) 0.621 *m* C) 0.842 *m* D) 1.41 *m* E) 2.52 *m*

11) The following data were taken for the addition of solid barium fluoride to enough water to make 100.0 mL of solution. What is the K_{sp} of barium fluoride:

$BaF_2\,(s) \rightleftharpoons Ba^{2+}(aq) + 2\,F^{-}(aq)$?

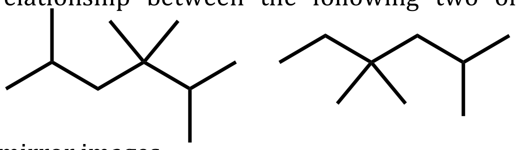
Mass of solid added (g)	**Mass of solid dissolved (g)**	**Mass of solid undissolved (g)**
0.100	0.100	0
0.200	0.200	0
0.300	0.300	0
0.400	0.319	0.081

A) 1.30×10^{-1} B) 3.25×10^{-2} C) 2.41×10^{-5}
D) 6.03×10^{-6} E) 6.03×10^{-9}

12) The electron configuration $1s^22s^22p^63s^23p^64s^23d^8$ corresponds to which of the following?

A) Ni B) Ni^{2+} C) Fe D) Fe^{2+} E) Zn^{2+}

13) What is the correct relationship between the following two organic substances?



A) non-superimposable mirror images
B) identical
C) Structural, non-geometric isomers
D) hydrocarbons with different molecular formulae
E) geometric isomers

14) Canada is a world-leader in the production of radionuclides such as technetium-99m (^{99m}Tc), which is used to diagnose bone diseases. ^{99m}Tc has a relative atomic mass of 98.91 amu and exhibits first-order radioactive decay with a half-life of 6.00 hours. If 8.62×10^{-12} mol of sodium pertechnetate ($Na^{99m}TcO_4$) is injected into a 75 kg adult patient, what mass of ^{99m}Tc would remain after 24 hours?

A) 1.46×10^{-9} g B) 2.13×10^{-10} g C) 3.66×10^{-11} g
D) 5.33×10^{-11} g E) 9.15×10^{-11} g

15) The first electron affinity (EA) for any element X is represented by the equation: $X\,(g) + e^{-} \rightarrow X^{-}\,(g) + EA_1$. Negative values for electron affinity indicate that energy is released when an atom gains an electron. Most highschool textbooks teach the trend that electron affinity increases across a period. According to the table below, which of the following statement(s) is/are true?

Element	Li	Be	B	C	N	O	F	Ne
EA (kJ mol^{-1})	−59.6	0	−26.7	−153.9	−7	−141	−328	0

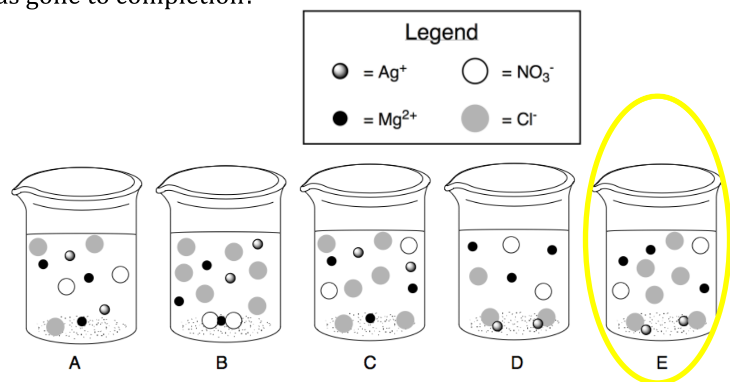
I. The absolute value of the energy released when an atom gains an electron is always lower for metals than non-metals
II. Metals cannot form anions
III. Neutral atoms with complete subshells do not release energy during anion formation

A) I only B) II only C) III only
D) I and II only E) I and III only

16) When aqueous magnesium chloride is added to a solution of silver nitrate, silver chloride is precipitated according to the following **unbalanced** chemical equation:

$$AgNO_3\ (aq) + MgCl_2\ (aq) \rightarrow AgCl\ (s) + Mg(NO_3)_2\ (aq)$$

If excess magnesium chloride is added to the silver nitrate solution, which of the following diagrams best depicts the balanced chemical reaction after it has gone to completion?



17) The *process mass intensity* (PMI) allows chemists to calculate how much material is used when generating a target amount of product in a chemical reaction. PMI is expressed as follows:

PMI = [(mass of all input materials) / (mass of desired product)]

To synthesize moclobemide, an anti-depressant pharmaceutical, 0.00381 moles of 4-(2-aminoethyl)morpholine ($C_6H_{14}N_2O$) is dissolved in 20.0 mL of triethylamine (density: 0.726 g mL^{-1}) and 0.00384 moles of 4-chlorobenzoyl chloride ($C_7H_4Cl_2O$) is added. After rapid stirring for 30 minutes, 10.0 mL (density: 1.00 g mL^{-1}) of water is added followed by 10.0 mL of dichloromethane (density: 1.325 g mL^{-1}) and then the mixture transferred to a separatory funnel. After extraction, the dichloromethane is dried with 5.0 g of magnesium sulfate. At the end of the process, 0.826 g of pure moclobemide is recovered.

The PMI for this reaction is:

A) 43.8 B) 47.1 C) 49.3 D) 53.2 E) 55.9

18) A closed 600.0 mL flask contains solid mercuric oxide and air initially at 21.0°C and 101.3 kPa. When heated, mercuric oxide decomposes completely according to the reaction:

$$2\ HgO\ (s) \rightarrow 2\ Hg\ (s) + O_2\ (g)$$

After heating, the flask is at a temperature of 75.2°C and has a pressure of 205.5 kPa. What mass of mercury metal is in the flask when the reaction is complete?

A) 7.11 g B) 4.33 g C) 3.56 g D) 17.1 g E) 8.66 g

19) When you do extreme exercise, your body converts glucose to lactic acid ($HCH_3H_5O_3$). Lactic acid has a K_a= 1.38 x 10^{-4}. Buffer systems maintain the pH of your blood at 7.4 during exercise. Without buffers, what would your blood pH range be at equilibrium if 4.00 x 10^{-3} mol L^{-1} of lactic acid dissociated according to the equation:

$$HCH_3H_5O_3\ (aq) + H_2O(l) \rightleftharpoons CH_3H_5O_3^-(aq) + H_3O^+(aq)$$

A) 2<pH<3 B) 3<pH<4 C) 4<pH<5 D) 5<pH<6 E) 6<pH<7

20) Molecular hydrogen is an essential feedstock for the industrial production of ammonia. Due to the impracticality of transporting molecular hydrogen, it is produced at the site of ammonia production through *steam methane reforming*, as follows:

$$H_2O\ (g) + CH_4\ (g) \rightleftharpoons CO\ (g) + 3\ H_2\ (g)$$

Given a starting steam (H_2O) to methane (CH_4) mole ratio of 2.5:1.0, an initial pressure of 28 atm, no starting carbon monoxide or molecular hydrogen, determine the K_p if 62.5% of the initial methane is converted to products. Assume *ideal gas* behaviour.

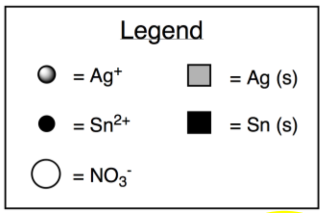
A) 1.7 x 10^0 B) 1.4 x 10^1 C) 2.1 x 10^2
D) 3.8 x 10^2 E) 5.6 x 10^3

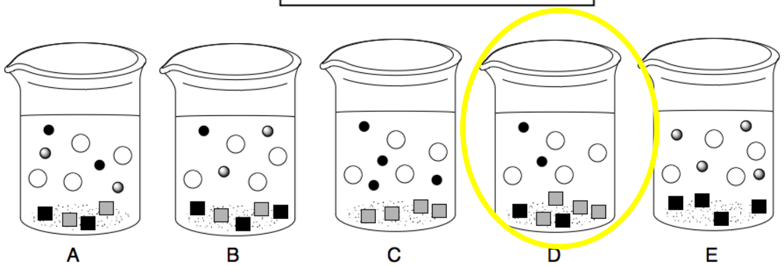
21) If the rate law for an equation A + B + C → ABC is Rate= k $[A]^0[B][C]^2$ and the reactant concentration of all of the reactants doubles, by what factor does the rate of reaction increase?

A) 3　　B) 4　　C) 6　　D) 8　　E) 10

22) When solid tin is added to a solution of silver nitrate, a single displacement reaction occurs to generate silver metal.

If 1.2 g of tin is added to 50 mL of 0.20 M silver nitrate solution, which of the following diagrams best describes the reaction once it has gone to completion?



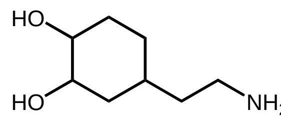


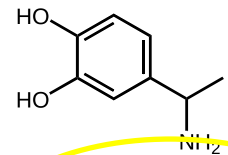
23) *Hypophosphatemia* is a condition of abnormally low phosphate concentration in the human blood stream, occurring in 2% of hospitalized patients. The treatment includes administration of intravenous phosphate buffer to increase blood phosphate concentration. However, since phosphoric acid is a weak acid, care needs to be taken to maintain blood pH at 7.4. Given the data below, and assuming similar concentrations of both species of the acid-base conjugate pair, determine the most effective buffer combination to achieve a pH of 7.4.

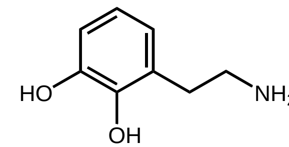
$H_3PO_4^-$; $K_a = 7.2 \times 10^{-3}$　　$H_2PO_4^-$; $K_a = 6.3 \times 10^{-8}$　　HPO_4^{2-}; $K_a = 4.2 \times 10^{-13}$

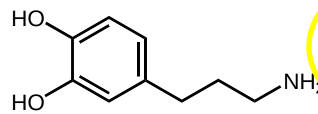
A) H_3PO_4 and $H_2PO_4^-$　　B) H_3PO_4 and HPO_4^{2-}　　C) $H_2PO_4^-$ and HPO_4^{2-}
D) $H_2PO_4^-$ and PO_4^{3-}　　E) HPO_4^{2-} and PO_4

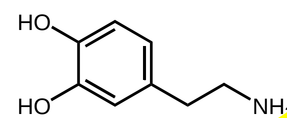
24) Dopamine is a neurotransmitter found in the human brain that is involved in motor control. The IUPAC name for dopamine is 4-(2-aminoethyl)benzene-1,2-diol. Which of the following structures represents a molecule of dopamine?

A) 

B) 

C) 

D) 

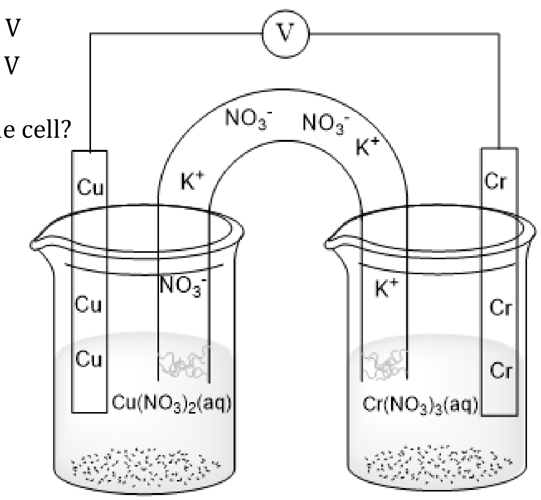
E) 

25) Given the following half reactions and galvanic cell diagram

$K^+ (aq) + e^- \rightarrow K (s)$　　E° = −2.93 V
$Cu^{2+} (aq) + 2e^- \rightarrow Cu (s)$　　E° = +0.34 V
$Cr^{3+} (aq) + 3e^- \rightarrow Cr (s)$　　E° = −0.74 V

what is the theoretical potential of the cell?

A) 0.40 V　　B) 1.08 V
C) 1.85 V　　D) 2.19 V
E) 2.50 V



End of Part A of the contest
Go back and check your work