

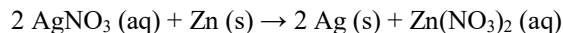


THE CANADIAN CHEMISTRY CONTEST 2020  
PART A – MULTIPLE CHOICE QUESTIONS (60 minutes)

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. Students may use a scientific calculator. No phones or communication devices are allowed.

- 1) 15 mL of 0.25 mol L<sup>-1</sup> aqueous silver nitrate reacts with 0.10 g of zinc as follows:



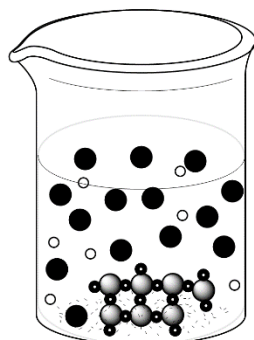
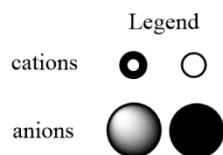
What mass of silver metal should the reaction produce?

- A) 0.16 g    B) 0.20 g    **C) 0.33 g**    D) 0.40 g    E) 0.81 g
- 2) Two elements X and Y form a covalent compound. X has six valence electrons and Y has seven valence electrons. Which of the options (I-IV) given below, represent possible formulae and shapes of covalent compounds of X and Y based on VSEPR theory and Lewis structures?

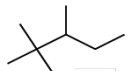
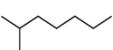
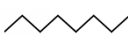
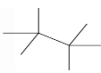
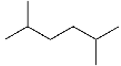
I) XY <sub>4</sub>	II) XY <sub>6</sub>	III) bent	IV) see-saw (or distorted tetrahedral)
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- A) I and III only                      B) II and IV only                      C) I and IV only  
D) I, II and III only                      **E) I, II, III and IV**
- 3) A student combines 100 mL of two clear, equimolar, colourless solutions and observes a solid white precipitate form at the bottom of the beaker. A representation of the resultant particles in the beaker is in the diagram below. Which combination of reactants would best align with the information provided and diagram of resultant particles in the beaker?

- A) lead (II) nitrate (aq) + potassium chloride (aq)  
B) zinc nitrate (aq) + sodium phosphate (aq)  
C) nickel (II) nitrate (aq) + lithium bromide (aq)  
D) copper (II) nitrate (aq) + sodium hydroxide (aq)  
**E) silver nitrate (aq) + magnesium sulfate (aq)**



- 4) A student drew structural diagrams for some of the isomers of a molecule and wrote down each isomer's boiling point (b.p.). There is an error in the student's work. For which structure did the student **incorrectly** record the boiling point?

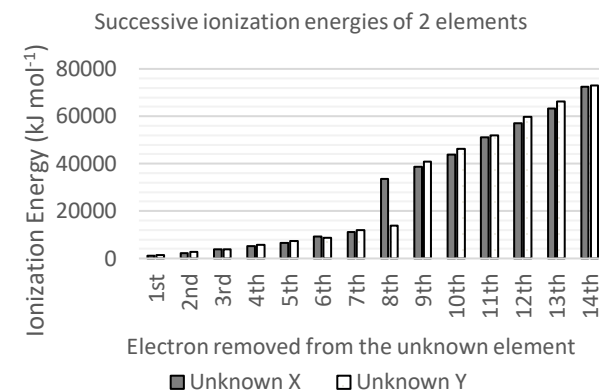
- A)**  b.p. 129°C    B)  b.p. 116°C  
C)  b.p. 126°C    D)  b.p. 106°C  
E)  b.p. 109°C

- 5) In which of the following substances does sulfur have the lowest oxidation state?

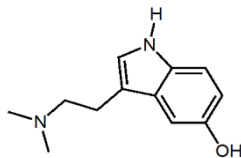
- A) S<sub>8</sub>    B) Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>    C) Na<sub>2</sub>SO<sub>4</sub>    **D) H<sub>2</sub>S**    E) SO<sub>2</sub>

- 6) Given the graph of the successive ionization energies for two unknown atoms, which combination provides the most likely identity of X and Y?

Unknown:	X	Y
A)	Al	Si
B)	Kr	Rb
<b>C)</b>	<b>Cl</b>	<b>Ar</b>
D)	Se	Br
E)	Rb	Sr



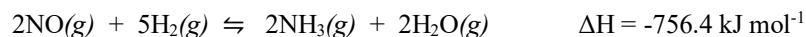
- 7) The structure below is a substance found in the skin of certain species of amphibians. In large quantities, the substance can have a psychoactive effect on humans, changing brain function and altering behaviour. What is the correct molecular formula of the substance?



- A) **C<sub>12</sub>H<sub>16</sub>N<sub>2</sub>O**      B) C<sub>10</sub>H<sub>12</sub>N<sub>2</sub>O      C) C<sub>11</sub>H<sub>14</sub>N<sub>2</sub>O  
 C) C<sub>12</sub>H<sub>18</sub>NO      E) C<sub>12</sub>H<sub>14</sub>N<sub>2</sub>O
- 8) How many constitutional isomers and how many stereoisomers does the organic molecule with the formula C<sub>3</sub>H<sub>9</sub>N have?

	constitutional isomers	stereoisomers		constitutional isomers	stereoisomers
A)	2	2	<b>D)</b>	<b>4</b>	<b>0</b>
B)	3	2	E)	3	0
C)	4	2			

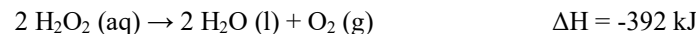
- 9) Consider the following equilibrium in a sealed container



Which of the following changes would most likely shift the equilibrium position towards reactants?

- A) **Increasing the temperature**      D) Adding nitrogen monoxide gas  
 B) Adding argon gas      E) Removing ammonia  
 C) Decreasing the volume of the sealed container
- 10) When a sample of an unknown compound with a formula of C<sub>x</sub>H<sub>y</sub> combusts with an excess amount of oxygen, the reaction produces 132.001 g of carbon dioxide and 72.064 g of water. Based on the information given, this unknown compound is:
- A) methane    B) ethane    **C) propane**    D) butane    E) octane

- 11) Hydrogen peroxide decomposes to form oxygen gas and water via the following chemical equation:



The density of 30% hydrogen peroxide is 1.11 g mL<sup>-1</sup>. If 50.0 mL of a 30% by mass hydrogen peroxide solution decomposes, what is the accompanying change in energy?

- A) **96 kJ released**      B) 117 kJ absorbed      C) 173 kJ released  
 D) 192 kJ released      E) 392 kJ absorbed
- 12) A mixture of ethanol and nitric acid, called nital, is an industrial etching agent. A student prepared a 20.0 mL solution of nital using 0.70 mL of nitric acid of unknown concentration and 19.3 mL of 98% ethanol. The student determined by titration that the final concentration of nitric acid in the nital etching agent was 4.0 % by mass. The density of 98% ethanol was 0.79 g mL<sup>-1</sup> and the density of the unknown concentration of aqueous HNO<sub>3</sub> was 1.4 g mL<sup>-1</sup>. What was the **original** concentration of HNO<sub>3</sub>, in w/w, in the 0.70 mL reagent the student used for the nital solution preparation?

- A) 63%      **B) 66%**      C) 70%      D) 73%      E) 93%

- 13) A student placed 3 identical metal cubes into an oven and heated them to the same final temperature. The student entirely submerged each of the 3 cubes in separate beakers as shown in the diagram below. All solutions had approximately the same density and all were at room temperature before adding the metal cubes. The maximum temperature compared as follows:

$$T_{\text{max}} \text{ beaker B} > T_{\text{max}} \text{ beaker A} > T_{\text{max}} \text{ beaker C.}$$

Which of the following is true about the relationship of the specific heat capacities of solutions A, B and C?

- A) c<sub>A</sub> > c<sub>C</sub> > c<sub>B</sub>  
 B) c<sub>C</sub> > c<sub>B</sub> > c<sub>A</sub>  
**C) c<sub>C</sub> > c<sub>A</sub> > c<sub>B</sub>**  
 D) c<sub>B</sub> > c<sub>A</sub> > c<sub>C</sub>  
 E) c<sub>B</sub> > c<sub>C</sub> > c<sub>A</sub>



100 mL of solution A

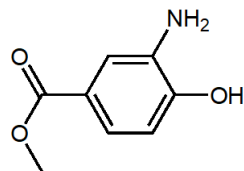


100 mL of solution B

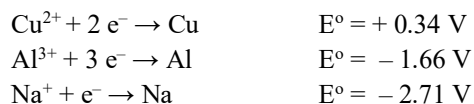


50 mL of solution C

- 14) The organic compound below is a local anesthetic developed over one hundred years ago to treat pain. What is the correct IUPAC name of the compound?



- A) methyl 4-hydroxy-5-aminobenzoate  
 B) methyl 3-hydroxy-4-aminobenzoate  
 C) methyl 3-aminophenolate  
 D) methyl 3-amino-4-hydroxybenzoic acid  
 E) methyl 3-amino-4-hydroxybenzoate
- 15) Given the following standard reduction potentials.



Which of the following statement(s) is/are true?

- I. Na is the most easily oxidized  
 II. Cu is the best reducing agent.  
 III.  $\text{Cu}^{2+}$  cannot be spontaneously reduced by Al  
 IV.  $\text{Na}^{+}$  has a greater attraction for electrons than  $\text{Al}^{3+}$
- A) I only      B) I and II only      C) I, II and III only  
 D) II and IV only      E) II, III, and IV only
- 16) Which of the following should have the same electron arrangement as  $\text{BF}_4^{-}$  around the central atom?
- A)  $\text{IF}_4^{-}$       B)  $\text{XeCl}_4$       C)  $\text{ClF}_4^{+}$       D)  $\text{SF}_4$       E)  $\text{CCl}_4$

- 17) A student adds two moles of liquid water initially at 273 K to three moles of liquid water at 363 K in a perfectly insulated container. The total volume of water remains constant. Assume that the molar heat capacity of liquid water is constant and independent of temperature. What is the final equilibrium temperature of the water?

A) 298 K      B) 309 K      C) 318 K      D) 327 K      E) 358 K

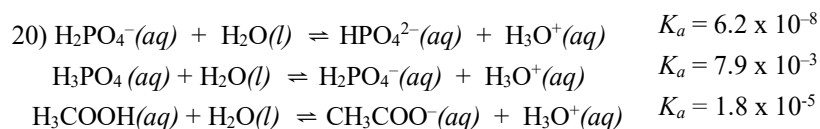
- 18) One mole of uranium-238 decays slowly. If uranium-238 decays according to first order kinetics, after how many half-lives is there likely only one atom of uranium-238 left?

A) 85      B) 10      C) 238      D) 41      E) 79

- 19) Consider the structures and associated  $\text{pK}_a$  values in the table below. Which statement below the table best explains the  $\text{pK}_a$  values observed?

acetic acid	chloroacetic acid	dichloroacetic acid	trichloroacetic acid
$\text{pK}_a = 4.76$	$\text{pK}_a = 2.85$	$\text{pK}_a = 1.35$	$\text{pK}_a = 0.66$

- A) The electron density on the ionizable proton is diminished by induction, which increases the strength of the acid  
 B) The presence of electron-donating alkyl groups increases the stability of the conjugate base, increasing the strength of the acid  
 C) Resonance stabilization of the conjugate base increases the strength of the acid  
 D) The presence of electronegative atoms decreases the stability of the conjugate base, decreasing the strength of the acid  
 E) Resonance stabilization of the conjugate base decreases the strength of the acid



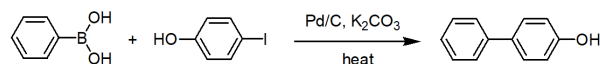
Using the equilibria below, determine which of the following combinations of solutions will generate a buffer with a pH of approximately 5?

- A) 50 mL of 0.10 mol L<sup>-1</sup> Na<sub>2</sub>HPO<sub>4</sub> + 100 mL of 0.10 mol L<sup>-1</sup> NaH<sub>2</sub>PO<sub>4</sub>  
 B) 100 mL of 0.10 mol L<sup>-1</sup> NaCH<sub>3</sub>COO + 100 mL of 0.10 mol L<sup>-1</sup> NaOH  
 C) 100 mL of 0.10 mol L<sup>-1</sup> NaH<sub>2</sub>PO<sub>4</sub> + 100 mL of 0.10 mol L<sup>-1</sup> HCl  
 D) 100 mL of 0.10 mol L<sup>-1</sup> NaH<sub>2</sub>PO<sub>4</sub> + 100 mL of 0.10 mol L<sup>-1</sup> NaOH  
**E) 100 mL of 0.10 mol L<sup>-1</sup> CH<sub>3</sub>COOH + 50 mL of 0.10 mol L<sup>-1</sup> NaOH**

- 21) The *reaction mass efficiency* (RME) helps a student determine how much reactant material a product contains at the end of a chemical reaction. RME is calculated as follows:

$$\text{reaction mass efficiency} = \frac{\text{mass of desired product}}{\text{(total input mass - mass of recycled material)}} \times 100\%$$

0.205 moles of phenylboronic acid (C<sub>6</sub>H<sub>7</sub>BO<sub>2</sub>) was reacted with 0.205 moles of 4-iodophenol (C<sub>6</sub>H<sub>5</sub>IO) and 0.615 moles of potassium carbonate to form 0.185 moles of 4-phenylphenol (shown below). 300 mg of catalytic palladium on carbon was used and completely recycled.



- A) 18.4 %    **B) 20.3 %**    C) 24.2 %    D) 25.5%    E) 35.1 %

- 22) The crossover temperature for a reaction is the temperature at which a chemical reaction changes from occurring spontaneously to being non-spontaneous. For a particular chemical reaction, the entropy change is -157 J mol<sup>-1</sup>·K<sup>-1</sup> and the enthalpy change is -82 kJ mol<sup>-1</sup>. What is the crossover temperature for the reaction?

- A) 0 K    B) 75K    C) 239 K    **D) 522K**    E) There is no crossover temperature for this reaction

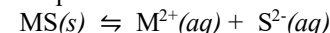
- 23) One source of oxygen in chemical oxygen generators for emergencies in submarines and aircraft is potassium perchlorate, which decomposes as follows:



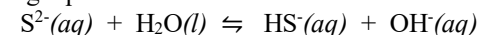
Assume ideal gas behaviour for the reaction, a temperature of 25.0°C and a pressure of 1.00 bar. If 138.5 grams of potassium perchlorate decompose inside an oxygen generator, what volume of oxygen does the reaction generate if there is a 78.0% yield?

- A) 9.65 L    B) 19.3 L    C) 24.8 L    **D) 38.6 L**    E) 49.6 L

- 24) Metal sulfides have considerable applications in industry, including their use as components of semiconducting materials. Consider the following equilibrium, where M represents a transition metal:



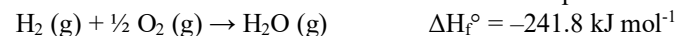
S<sup>2-</sup> ions liberated in solution readily react and form HS<sup>-</sup> and OH<sup>-</sup> according to the following equilibrium:



Which of the following will increase the solubility of the metal sulfide?

- A) Increasing the concentration of OH<sup>-</sup> by adding a strong base  
**B) Adding a strong acid**  
 C) Increasing the amount of the metal sulfide present  
 D) Diluting the solution present  
 E) Adding MCl<sub>2</sub>

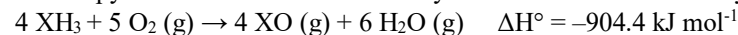
- 25) The thermochemical reaction for the formation of water vapour is:



The thermochemical reaction of diatomic element X with oxygen is:



If the enthalpy of the reaction of the tri-hydride of element X with oxygen is:



What is the enthalpy (in kJ) of the synthesis of 2 mols of the tri-hydride of element X from the reaction of X<sub>2</sub>(g) and hydrogen gas?

- A) -996.8    B) -391.2    C) -513.2    **D) -92.4**    E) -964.4

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