

THE CANADIAN CHEMISTRY CONTEST 2016

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) WHMIS 2015 is the updated labelling system which conforms to the new international standard of classifying hazardous materials. Although all of the compounds below would require some labelling for other characteristics, which compound would **NOT** require the oxidizer label shown to the right?

- A) potassium permanganate B) sodium chlorate
C) ethanol D) nitric acid
 E) hydrogen peroxide



2) A 0.48 g piece of magnesium metal is placed in hydrochloric acid. Assuming the hydrochloric acid is in excess and the magnesium reacts completely, how many grams of hydrogen gas are produced?

- A) 0.010 g **B) 0.040 g** C) 0.080 g
 D) 0.48 g E) 0.96 g

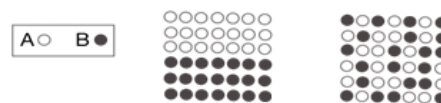
3) If the total pressure increases in each of the reaction mixtures below, for which reaction would the product yield remain unchanged at equilibrium?

- A) $\text{CO (g)} + \text{H}_2\text{O (g)} \rightleftharpoons \text{CO}_2 \text{(g)} + \text{H}_2 \text{(g)}$**
 B) $2 \text{NO (g)} + \text{Cl}_2 \text{(g)} \rightleftharpoons 2 \text{NOCl (g)}$
 C) $2 \text{H}_2\text{S (g)} \rightleftharpoons 2 \text{H}_2 \text{(g)} + \text{S}_2 \text{(g)}$
 D) $2 \text{H}_2 \text{(g)} + \text{O}_2 \text{(g)} \rightleftharpoons 2 \text{H}_2\text{O (g)}$
 E) $3 \text{H}_2 \text{(g)} + \text{CO (g)} \rightleftharpoons \text{CH}_4 \text{(g)} + \text{H}_2\text{O (g)}$

4) Which of the following compounds has the smallest bond angle?

- A) BF_3 B) CF_4 C) NF_3 D) OF_2 **E) ClF_3**

5) After a chemist stirs the contents of a beaker, the rate of a reaction between reactants A and B increases by a factor of four. Use the diagrams below to help you to determine the **main** reason why the rate of reaction increases.



Before stirring After stirring

- A) Reaction surface area increases** B) Activation energy increases
 C) Reactant concentrations increase D) Total kinetic energy increases
 E) Average kinetic energy increases

6) The limit for lead in drinking water is 0.015 ppm according to the Environmental Protection Agency (EPA). A 100.0 mL sample of well water tested for dissolved Pb^{2+} with a saturated potassium iodide solution produced 1.7 mg of yellow lead iodide precipitate. How many times higher than the EPA limit was the concentration of lead in the well water?

- A) 110 times B) 1100 times **C) 510 times** D) 700 times E) 51 times

7) A common method for cleaning up an acid spill is to spread sodium carbonate over the spill to neutralize it. If 50.0 mL of $0.75 \text{ mol L}^{-1} \text{HCl}$ spilled on the countertop, what is the minimum amount of sodium carbonate required to neutralize the spill?

- A) 1.6 g B) 1.9 g **C) 2.0 g** D) 3.1 g E) 4.0 g

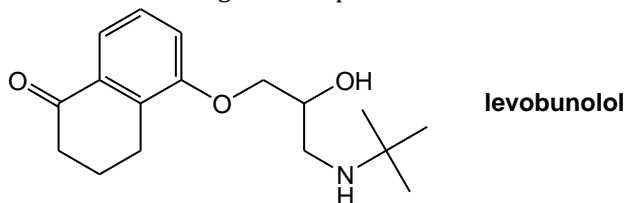
8) Which element would have its highest energy valence electron correspond to the following quantum numbers? $n = 4, \ell = 2$

- A) Sc **B) Y** C) K D) Zn E) Ga

9) The 1st and 3rd ionization energies of aluminum are 577.5 kJ mol⁻¹ and 2744.8 kJ mol⁻¹ respectively. What data best matches the 2nd and 4th ionization energies of aluminum?

| | 2 nd ionization energy (kJ mol ⁻¹) | 4 th ionization energy (kJ mol ⁻¹) |
|-----------|--|--|
| A) | 700 | 3500 |
| B) | 700 | 5000 |
| C) | 700 | 11000 |
| D) | 1800 | 11000 |
| E) | 1800 | 5000 |

10) Levobunolol (structure below) is used topically to treat glaucoma, an eye disorder which causes damage to the optic nerve.



Which of the following functional groups are contained within the structure of levobunolol?

- A) amine, ketone, ether, phenol
 B) amide, ketone, ether, alcohol
 C) amine, ketone, ester, alcohol
D) amine, ketone, ether, alcohol
 E) amine, aldehyde, ether, alcohol

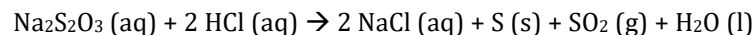
11) Penicillamine is an important organic compound used in the treatment of rheumatoid arthritis. One molecule of penicillamine contains a single sulfur atom and the weight percentage of sulfur in penicillamine is 21.49%. What is the molecular weight of penicillamine in g mol⁻¹?

- A) 85.40 B) 101.3 C) 125.2 D) 137.6 **E) 149.2**

12) For a spontaneous reaction, which relationship below is always true?

- A) $\Delta G^{\circ}_{\text{rxn}} > 0$
 B) $\Delta S_{\text{universe}} > 0$
 C) $\Delta S_{\text{universe}} < 0$
 D) $\Delta H^{\circ}_{\text{rxn}} > 0$
 E) $\Delta H^{\circ}_{\text{rxn}} < 0$

13) A student performs the following reaction to make solid sulfur:



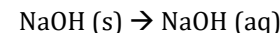
The student records the following data at the start of the reaction:

| | Concentration (mol L ⁻¹) | Volume (mL) |
|--|--------------------------------------|-------------|
| Na ₂ S ₂ O ₃ (aq) | 0.45 | 130 |
| HCl (aq) | 0.15 | 400 |

If the student recovers 0.89 g of solid sulfur from the experiment, what is the % yield of the reaction?

- A) 46% B) 48% C) 75% D) 89% **E) 93%**

14) A student places 0.750 g of solid sodium hydroxide (NaOH) into 20.00 mL of water at 25.0 °C inside a coffee cup calorimeter. The final temperature of the calorimeter contents is 34.6 °C. The density of water is 1.0 g mL⁻¹. Assume the specific heat capacity of the solution approximates that of water at 4.184 J g⁻¹ °C⁻¹ and the calorimeter has 100% efficiency. What is the ΔH_{rxn} for the dissolution reaction below?



- A) -42.8 kJ mol⁻¹ **B) -44.4 kJ mol⁻¹** C) -803 J mol⁻¹
 D) -833 J mol⁻¹ E) -1070 J mol⁻¹

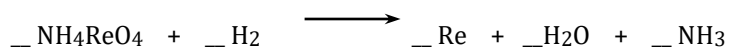
15) Canadian cities began adding fluoride to their drinking water in the mid-1950s, as a means to reducing dental caries (cavities) in children. Sodium fluorosilicate (Na₂SiF₆), a by-product of the industrial processing of phosphate minerals, can be added to drinking water to produce free fluoride ions. A drinking water analysis for a Canadian city revealed the following data:

$$\text{pH} = 7.60 \quad [\text{F}^-] = 3.2 \times 10^{-5} \text{ mol L}^{-1}$$

Given that the pK_a of hydrofluoric acid (HF) is 3.17, determine the concentration of HF in the drinking water of this Canadian city. Assume a water temperature of 25°C.

- A) 5.4 x 10⁻² mol L⁻¹ B) 3.2 x 10⁻⁵ mol L⁻¹ C) 6.4 x 10⁻⁵ mol L⁻¹
 D) 1.9 x 10⁻⁸ mol L⁻¹ **E) 1.2 x 10⁻⁹ mol L⁻¹**

16) The transition metal rhenium (Re), is among the rarest elements in the earth's crust. The precursor to the pure metal, ammonium perrhenate, is produced during the refinement of molybdenum ores. The principal application of rhenium is as an alloy with nickel, used in jet engine components. Consider the unbalanced chemical equation for the hydrogen reduction of ammonium perrhenate:



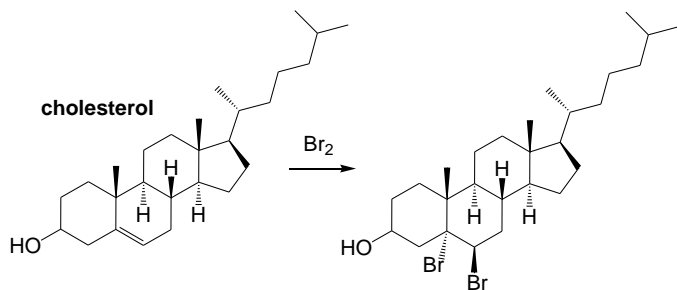
Assume the oxidation number of nitrogen in the reactants and products is unchanged. Determine the **sum** of the smallest integer coefficients for the stoichiometrically balanced chemical equation.

- A) 5 B) 14 C) 18 D) 20 **E) 21**

17) The metric known as *reaction mass efficiency* (RME) provides a way to assess how much reactant material ends up in a desired product at the end of a chemical reaction. One way of expressing RME is as follows:

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

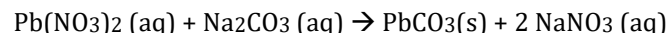
0.115 moles of cholesterol ($\text{C}_{27}\text{H}_{46}\text{O}$) was reacted with 0.365 moles of molecular bromine to form 0.102 moles of dibromocholesterol in an addition reaction (shown below). It was possible to recover and recycle 0.151 moles of molecular bromine from the reaction mixture.



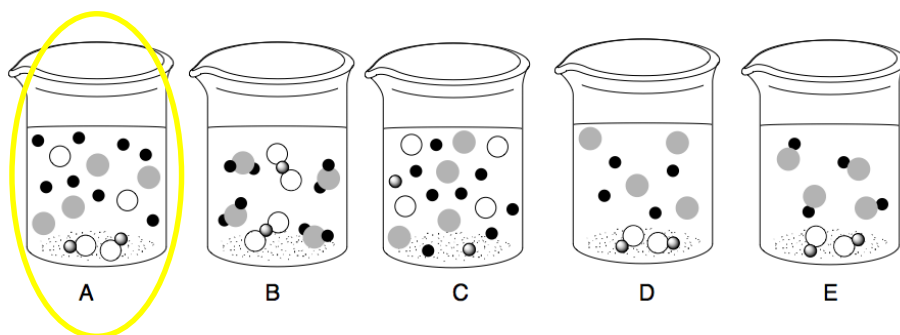
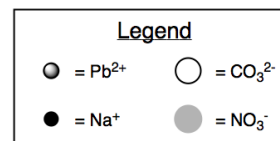
What is the percentage reaction mass efficiency for this process?

- A) 43.3 % B) 54.3 % **C) 70.9 %** D) 84.6 % E) 89.1 %

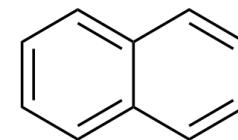
18) Solid lead carbonate precipitate can be formed from mixing aqueous lead nitrate and sodium carbonate:



If 360 mL of 0.15 mol L^{-1} sodium carbonate was combined with 45 mL of 0.60 mol L^{-1} lead nitrate, which of the following diagrams best describes the system once it has gone to completion? **A**



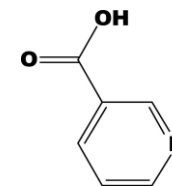
19) Naphthalene is a white crystalline solid, traditionally used as the primary ingredient in mothballs. It has the chemical formula C_{10}H_8 , and its structure is shown to the right. Rank the solubility of naphthalene in the following solvents from most to least soluble.



- I. water II. hexane III. ethanol IV. hexanol

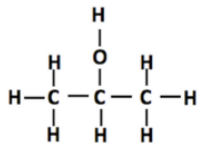
- A) II > IV > III > I** B) IV > II > III > I C) I > III > II > IV
D) II > III > IV > I E) IV > III > II > I

20) Vitamin-B3, or Niacin, is an essential nutrient for humans. Its molecular structure is shown on the right. A $0.0050 \text{ mol L}^{-1}$ solution of Niacin in water has a pH of 3.56. What is the percentage ionization of niacin in water?

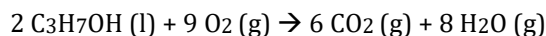


Niacin

- A) 1.4 % B) 2.8 % C) 3.6 % **D) 5.5 %** E) 7.8 %



21) 2-propanol reacts with oxygen as follows:

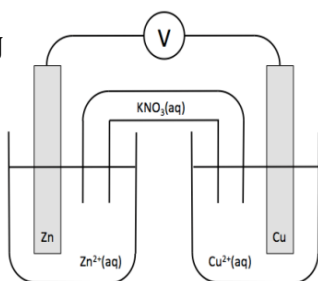
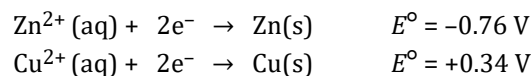


If 0.500 moles of 2-propanol react in the presence of 4.00 moles of oxygen, how many kilojoules of heat would be absorbed or released? A table of average bond energies is given below.

| Bond Type | Bond Energy (kJ mol ⁻¹) | Bond Type | Bond Energy (kJ mol ⁻¹) |
|-----------|-------------------------------------|-----------|-------------------------------------|
| C-H | 413 | O=O | 495 |
| O-H | 467 | C=O | 799 |
| C-O | 358 | C-C | 347 |

- A) - 1890 kJ B) + 1890 kJ C) - 1680 kJ
D) - 946 kJ E) + 473 kJ

22) For the cell depicted, the half-reactions are:



Which of the following is true for the *spontaneous* cell reaction?

- A) Zn is the anode; the electron flow is from anode to cathode; anions migrate through the salt bridge from the Zn/Zn²⁺ to the Cu/Cu²⁺ half-cell and cations migrate in the opposite direction.
 B) Zn is the cathode; the electron flow is from anode to cathode; anions migrate through the salt bridge from the Zn/Zn²⁺ to the Cu/Cu²⁺ half-cell and cations migrate in the opposite direction.
 C) Zn is the anode; the electron flow is from cathode to anode; anions migrate through the salt bridge from the Zn/Zn²⁺ to the Cu/Cu²⁺ half-cell and cations migrate in the opposite direction.
 D) Zn is the cathode; the electron flow is from anode to cathode; cations migrate through the salt bridge from the Zn/Zn²⁺ to the Cu/Cu²⁺ half-cell and anions migrate in the opposite direction.
E) Zn is the anode; the electron flow is from anode to cathode; cations migrate through the salt bridge from the Zn/Zn²⁺ to the Cu/Cu²⁺ half-cell and anions migrate in the opposite direction.

23) A gaseous anesthetic with an unknown molecular formula is 85.63% carbon and 14.37% hydrogen by mass. What is the molecular formula of the unknown if 0.45 L of the compound combusts with excess oxygen at 120.0°C at 72.93 kPa to form 2.70 L of an equimolar mixture of carbon dioxide and water vapour?

- A) C₃H₆** B) C₄H₈ C) C₅H₁₀ D) C₆H₁₂ E) C₇H₁₄

24) Given the following data table for the reaction 2 A + B₂ → 2 AB

| [A] mol L ⁻¹ | [B ₂] mol L ⁻¹ | Rate of Reaction (mol L ⁻¹ s ⁻¹) |
|-------------------------|---------------------------------------|---|
| 0.100 | 0.100 | 0.117 |
| 0.200 | 0.100 | 0.468 |
| 0.200 | 0.200 | 0.936 |

What is the rate of reaction in mol L⁻¹ s⁻¹ if [A] = [B₂] = 0.300 mol L⁻¹?

- A) 1.87 B) 2.81 C) 3.02 **D) 3.16** E) 3.51

25) Flask 1
2.0 g of H₂
gas at 25°C
and P₁



Flask 2
16.0 g of O₂
gas at 25°C
and P₂



Both Flask 1 and Flask 2 have a volume of exactly 2.0 L, KE is the average kinetic energy, and P is pressure. Which statement below is **TRUE**?

- A) P₁ = P₂
 B) the KE of the particles in flask 1 < the KE of the particles in flask 2
C) the number of particles in flask 1 > the number of particles in flask 2
 D) the number of collisions in flask 1 = number of collisions in flask 2
 E) 2 P₁ = P₂

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