THE CANADIAN CHEMISTRY CONTEST 2015
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. Through the Workplace Hazardous Materials Information System (WHMIS), labs use eight labels to identify the dangers chemists encounter from the six classes of hazardous materials. Using your knowledge of the properties of chemical substances, identify the list below which contains three chemicals that should ALL be identified with the flammable materials label?

   A) Copper wire, sodium chloride and helium
   B) Hydrogen, magnesium wire, ethanol
   C) Platinum wire, iron (III) oxide, carbon dioxide
   D) Neon, potassium iodide, silver wire
   E) Liquid mercury, calcium bromide, nitrogen

2. What is the correctly balanced form of the chemical reaction depicted in the figure below?
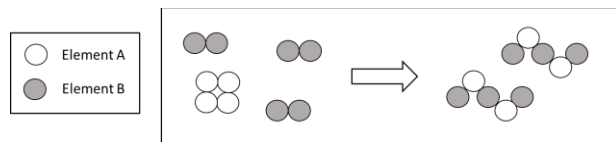
   A) $4\,A + 6\,B \rightarrow A_4B_6$
   B) $A_4 + B_6 \rightarrow A_4B_6$
   C) $A_4 + 3\,B_2 \rightarrow 2\,A_2 + 2\,B_3$
   D) $A_4 + 3\,B_2 \rightarrow 2\,A_2B_3$
   E) $4\,A + 3\,B_2 \rightarrow 2\,A_2B_3$

3. One component of gastric (stomach) fluid is hydrochloric acid (HCl). Baking soda ($NaHCO_3$) will neutralize HCl according to the reaction:
   $$NaHCO_3\ (aq) + HCl\ (aq) \rightarrow NaCl\ (aq) + H_2O\ (l) + CO_2\ (g)$$

   How many grams of CO_2 are produced when 300 mL of 1.22 mol L^{-1} HCl react with 175 mL of 1.55 mol L^{-1} $NaHCO_3$?

   A) 9.89 g   B) 10.5 g   C) 11.9 g   D) 14.4 g   E) 16.1 g

4. When dissolved in aqueous solution, Al^{3+} forms a six coordinate complex with water that can undergo dissociation according to the following equation:

   $$Al(OH_2)_6{}^{3+}(aq) + H_2O\ (l) \rightleftharpoons Al(OH_2)_5(OH)^{2+}(aq) + H_3O^+(aq)\quad K_a = 1.0 \times 10^{-5}$$
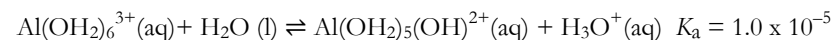
   If the initial concentration of $Al(OH_2)_6{}^{3+}$ is 0.10 mol L^{-1}, what is the approximate pH of the solution?

   A) 1.00   B) 3.00   C) 4.00   D) 5.00   E) 7.00

5. Dapsone is the active ingredient in Aczone™ gel, a treatment for adult acne. Each gram of Aczone gel contains 50 mg of dapsone (molecular weight 248.3 g mol^{-1}). The dapsone content of a 10.0 g sample of Aczone was analyzed and found to be composed of 290.3 mg carbon, 64.5 mg sulphur, 56.4 mg nitrogen and 24.4 mg hydrogen with the remaining mass being oxygen. What is the molecular formula of dapsone?

   A) $C_{12}H_{10}NOS_2$ B) $C_{10}H_8N_4O_2S$ C) $C_{11}H_8N_2O_3S$
   D) $C_{13}H_{14}NO_2S$ E) $C_{12}H_{12}N_2O_2S$

6. Given a fixed mass of gas in a closed, expandable container at constant pressure, which graph shows the variation in the volume of gas (y-axis) versus the temperature in degrees Kelvin (x-axis)?

   A)   B)   C)

   D)   E)
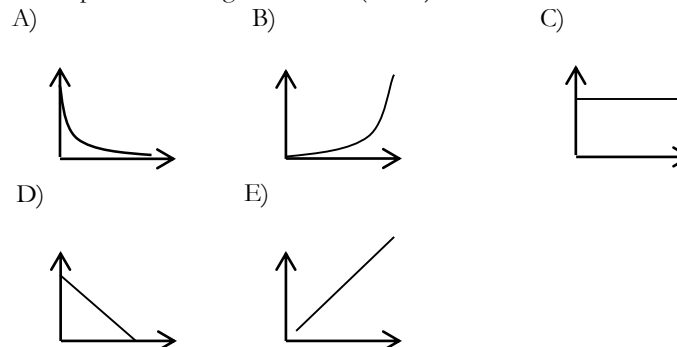
7. Assuming the oxidation number of chlorine is -1, the oxidation numbers of iodine and antimony in the compound $[ICl_2]^+[SbCl_6]^-$ are respectively

   A) +2 and +6   B) +2 and +5   C) +1 and +7
   D) +3 and +5   E) +3 and +7

8. Water and carbon tetrachloride (CCl_4) are immiscible liquids. If a student adds solid iodine to a beaker containing water and carbon tetrachloride, stirs vigorously to dissolve the iodine and allows the mixture to settle, which particulate diagram best describes the physical change that occurs?
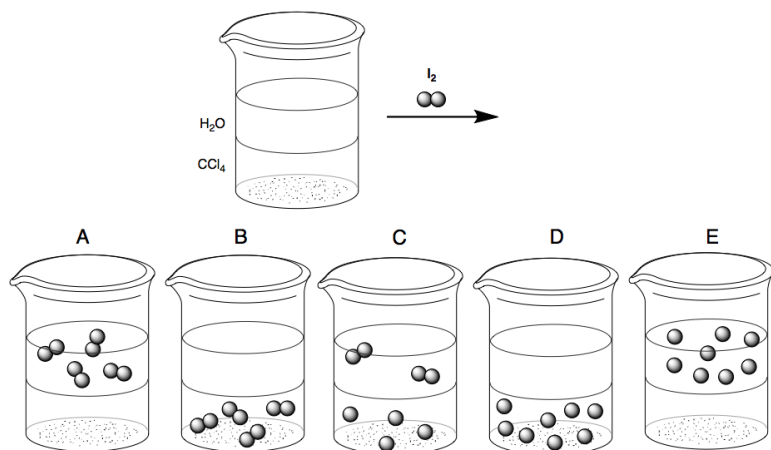
9. Potassium iodate, KIO_3, has applications as both source of dietary iodine in table salt and as protection against the accumulation of radioactive iodine in the human thyroid gland. The following reaction produces potassium iodate:

   $2KClO_3(s) \ + \ I_2(s) \ \rightarrow 2KIO_3(s) \ + \ Cl_2(g)$

   What is the theoretical yield of KIO_3 if the limiting reactant is 51.0 g I_2?

   A) 43.0 g   B) 46.2 g   C) 86.0 g   D) 172 g   E) 185 g

10. The first ionization energy of phosphorus is lower than that of:

   A) chlorine   B) silicon   C) sodium   D) barium   E) bismuth

11. In which of the following four compounds is intermolecular hydrogen-bonding present?
    (I)   2-propanol, $(CH_3)_2CHOH$
    (II)   triethylamine, $(C_2H_5)_3N$
    (III)   dimethyl ether, $(CH_3)_2O$
    (IV)   n-butylamine, $CH_3CH_2CH_2CH_2NH_2$

    A) (I), (III) and (IV)   B) (I) and (III)   C) (II) and (IV)
    D) (I) only   E) (I) and (IV)

12. A student sets up two 1.00 L gas bulbs at 25.0 °C connected by a glass tube. The combined volume of one bulb and half of the tube is 1.00 L. The student opens the valve and allows 0.0400 moles of A_2 (g) and 0.0400 moles of B (g) to mix. The reaction forms AB (g). What is the final pressure (kPa) in the 2.00 L system if the reaction proceeds to completion and the temperature remains constant?

    A_2 (g) + 2B (g) → 2AB (g)
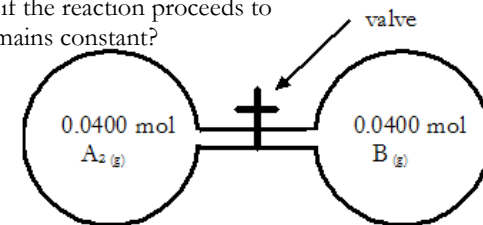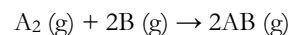
    A) 198 kPa   B) 149 kPa   C) 99.1 kPa   D) 74.3 kPa   E) 49.6 kPa

13. The combustion of acetylene, C_2H_2, provides the hottest flame temperature of all commercially available fuels. The average bond energy (ΔH) data table and the balanced chemical equation are below.
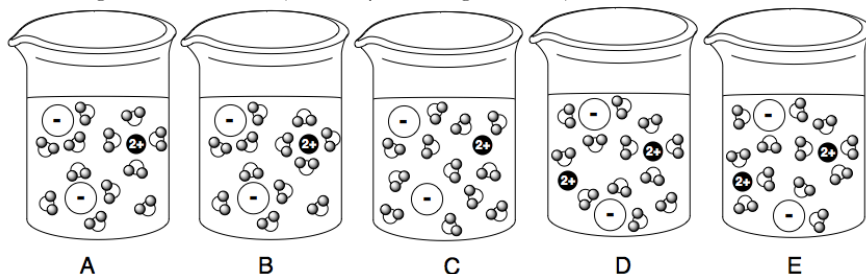
    $2 \ C_2H_2 \ (g) + 5 \ O_2 \ (g) \rightarrow 4 \ CO_2 \ (g) + 2 \ H_2O \ (g)$
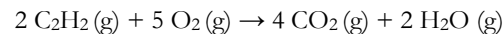
Bond type	ΔH (kJ mol^{-1})	Bond type	ΔH (kJ mol^{-1})
C–H	+411	C=O	+799
C–C	+346	O=O	+494
C≡C	+835	O–H	+459

    What is the enthalpy of combustion for **1 mole** of acetylene?

    A) + 3422 kJ mol^{-1} B) + 2444 kJ mol^{-1} C) – 611 kJ mol^{-1}
    D) – 1222 kJ mol^{-1} E) – 3422 kJ mol^{-1}

14. Which particulate diagram best represents a dilute aqueous solution of magnesium chloride (solubility = 59.2 g/100 mL).

A   B   C   D   E

15. Assuming all orbitals in a given sublevel have equivalent energy, in which type of orbital(s) would the highest energy electron(s) in the Sc^{3+} be found? The neutral element scandium has an atomic number of 21.

(i)   (ii)   (iii)   (iv)   (v)

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

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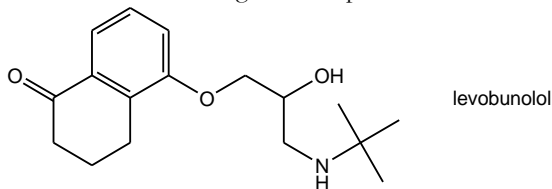
levobunolol

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, aldehyde, ether, alcohol
E)   amine, ketone, ether, alcohol

17. What is the smallest F—Xe—F bond angle in XeF_4?

A)   <90°   B) 90°   C) 104.5°   D) 109.5°   E) 120°

18. A student titrated aqueous ethanoic acid with sodium hydroxide and recorded the change in pH on the graph below. Using the curve, estimate the pH at the equivalence point for this titration.
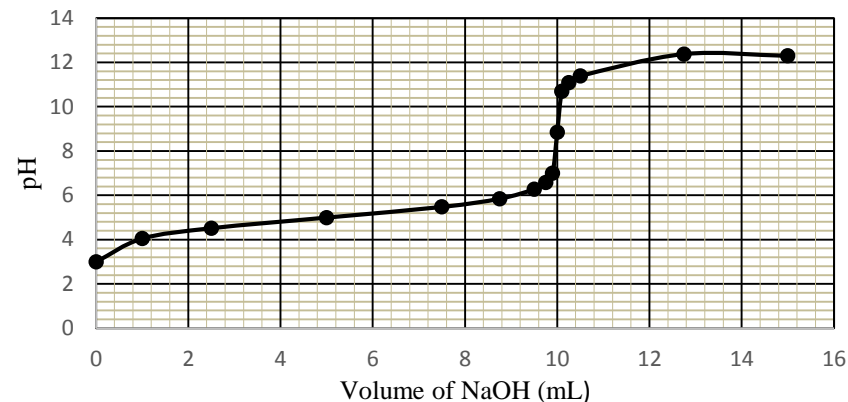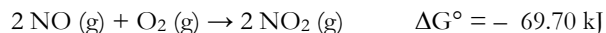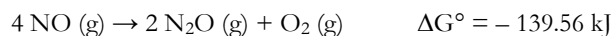
A)   3.0   B) 7.0   C) 8.8   D) 11.0   E) 12.5

19. At a lab at the University of Toronto in 1929, Dr. Velyen Henderson and Dr. George Lucas were the first to discover the use of cyclopropane as a general anesthetic. Cyclopropane undergoes slow molecular rearrangement to propene. From the data below, determine the rate law for the reaction:

Initial concentration of cyclopropane (mol L^{-1})	Rate of formation of propene (mol $L^{-1}s^{-1}$)
0.050	2.95×10^{-5}
0.100	5.90×10^{-5}
0.150	8.85×10^{-5}

A)   Rate = 5.9×10^{-4} s^{-1} × [cyclopropane]
B)   Rate = 1.2×10^{-2} L mol^{-1} s^{-1} × [cyclopropane]^2
C)   Rate = 2.4×10^2 mol L^{-1} s^{-1} × [cyclopropane]^2
D)   Rate = 1.7×10^3 s^{-1} × [cyclopropane]
E)   Rate = 2.4×10^{-1} mol L^{-1} s^{-1} × [cyclopropane]^2

20. Joseph Priestley discovered sweet-smelling, colourless laughing gas, nitrous oxide (N_2O), in 1763. N_2O has been widely used as an anesthetic for medical and dental applications. Nitrogen dioxide (NO_2) is a toxic reddish brown gas that is the major component of smog. Nitrogen oxide (NO) is a colourless, non-toxic gas that readily oxidizes to nitrogen dioxide in the presence of oxygen. Using the reactions:

$4\ NO\ (g) \rightarrow 2\ N_2O\ (g) + O_2\ (g)$ $\Delta G° = -139.56\ kJ$

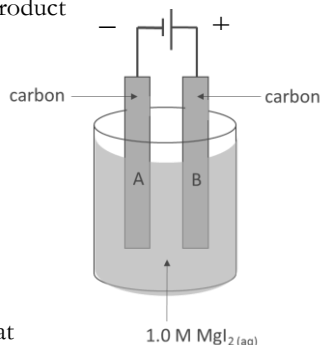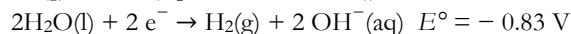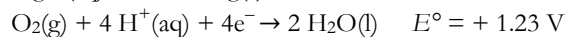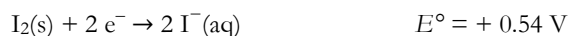$2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$ $\Delta G° = -69.70\ kJ$

calculate the Gibbs Free Energy released or required when 2 moles of nitrous oxide combine with three moles of oxygen to produce four moles of nitrogen dioxide.

A) $-209.26\ kJ$ B) $-139.86\ kJ$ C) $-69.86\ kJ$
D) $+0.16\ kJ$ E) $+139.72\ kJ$

21. Which of the following statements about the electrolysis of a solution of magnesium iodide, as depicted in the diagram, is **false**?
A) If the negative and positive terminals of the cell are reversed, magnesium would begin to plate on electrode B.
B) The reaction is non-spontaneous without an applied power source.
C) An acid-base indicator could be used to detect a product formed at electrode A.
D) I_2 forms at the anode.
E) A gas is formed at the cathode.

$I_2(s) + 2\ e^- \rightarrow 2\ I^-(aq)$ $E° = +0.54\ V$
$Mg^{2+}(aq) + 2\ e^- \rightarrow Mg(s)$ $E° = -2.37\ V$
$O_2(g) + 4\ H^+(aq) + 4e^- \rightarrow 2\ H_2O(l)$ $E° = +1.23\ V$
$2H_2O(l) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-(aq)$ $E° = -0.83\ V$

carbon ——— carbon
A   B
1.0 M $MgI_{2\ (aq)}$

22. Milk of magnesia is sold at drugstores in Canada to treat indigestion or mild constipation. The active ingredient in milk of magnesia is magnesium hydroxide, $Mg(OH)_2$. The solubility of $Mg(OH)_2$ is 7.05×10^{-3} g L^{-1}. What is the K_{sp} of magnesium hydroxide?

A) 1.99×10^{-4} B) 1.40×10^{-6} C) 3.50×10^{-7}
D) 1.46×10^{-8} E) 7.06×10^{-12}

23. Consider the following half-cell reactions in aqueous, acid conditions:

$Cl_2(aq) + 2e^- \rightleftharpoons 2Cl^-(aq)$ $E° = +1.36\ V$

$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$ $E° = +1.49\ V$
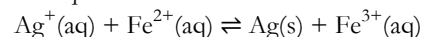
Assuming correct stoichiometric ratios of reactants, which of the following represents the *products* from the *spontaneous* cell reaction? (H^+ *and* H_2O *have been omitted for clarity*)

Legend: Mn ◯   O ◯   Cl ●

A   B   C   D   E
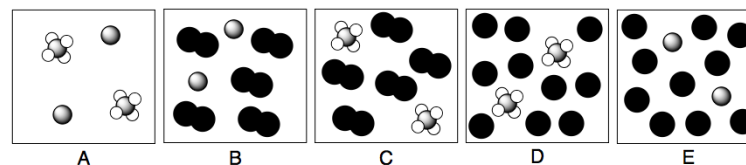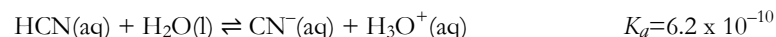
24. Which of the following would cause the precipitation of more silver in the equilibrium which is exothermic in the forward direction.
$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$

A) Increasing the temperature
B) Increasing the volume of water
C) Removing some of the solid silver precipitate
D) Increasing the concentration of Fe^{3+} ions
E) Increasing the concentration of Fe^{2+} ions

25. Given the following equilibria,

$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ $K_b = 1.8 \times 10^{-5}$
$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$ $K_a = 1.8 \times 10^{-5}$
$HCN(aq) + H_2O(l) \rightleftharpoons CN^-(aq) + H_3O^+(aq)$ $K_a = 6.2 \times 10^{-10}$

Which salt is the most **alkaline** from among the options below?

A) NaCN   B) $NaCH_3COO$ C) NH_4Cl D) NH_4CH_3COO E) NH_4CN

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