

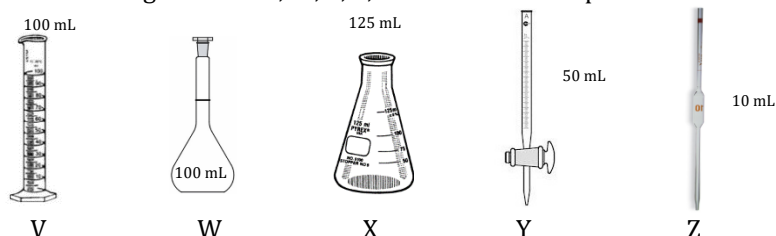


THE CANADIAN CHEMISTRY CONTEST 2018  
PART A – MULTIPLE CHOICE QUESTIONS (60 minutes)

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) Sodium hydroxide (NaOH) is commonly used in high school labs. NaOH is a WHMIS category 1 health hazard causing severe eye, skin and respiratory tract effects. NaOH is hygroscopic and readily absorbs moisture from the air. Any prepared solution of NaOH should be standardized to determine its precise concentration. You have the glassware V, W, X, Y, Z below and solid pellets of NaOH.



Which of the choices provides the safest, most efficient method of preparing exactly 100.0 mL NaOH of approximately 1M before standardizing the solution with 0.500 M oxalic acid ( $C_2O_4H_2$ )? Assume the NaOH solution is mixed thoroughly once prepared.

- A) Filling V with approximately 50 mL water, adding 4.0 g NaOH, diluting to precisely 100 mL in V.  
B) Filling W with approximately 50 mL water, adding 4.0 g NaOH and diluting to 100 mL in W.  
C) Placing 4.0 g NaOH in X then adding 100 mL of water to X using Y.  
D) Placing 4.0 g NaOH in W then adding 100 mL of water to W using Z.  
E) Filling X with precisely 50 mL of water using Z, adding 4.0 g of NaOH and adding an additional 50 mL of water using Z.
- 2) Vitamin C ( $C_6H_8O_6$ ) supplements often come in 500 mg tablets. If a person consumes one 500 mg tablet of Vitamin C, how many moles of Vitamin C would they be consuming?
- A)  $2.84 \times 10^{-3}$     B)  $8.81 \times 10^{-2}$     C) 1.00  
D) 2.84    E) 88.1

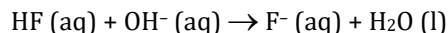
- 3) What is the mole percent of a solution of ethanol ( $C_2H_5OH$ ) which consists of 71.0 g of ethanol for every 12.8 g of water present?
- A) 2.17 %    B) 12.3 %    C) 31.6 %  
D) 68.4 %    E) 84.7 %
- 4) A 2.0 L balloon initially holds 3.0 mol of helium. When 3.0 mol of helium are added, the volume of the balloon increases to 4.0 L and the temperature remains unchanged. Which expression correctly describes the final pressure of the system in terms of the initial pressure, P? Assume Ideal Gas behaviour.
- A) P    B) 2P    C) 3P    D) 4P    E) 6P
- 5) A compound is composed of element X and hydrogen. Analysis shows the compound to be 79.89 % X by mass, with three times as many hydrogen atoms as X atoms per molecule. Which element is element X?
- A) He    B) C    C) N    D) P    E) S
- 6) To increase strength and hardness when forging knives and blades, hot steel can be quenched by rapidly cooling in water. A 454 g steel blade is heated to a uniform temperature, and then quenched in 2000 mL of 25.0 °C water. If the steel blade loses 173.7 kJ of heat during the quenching process, what is the final temperature of the water? The specific heat capacity of water is  $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$ . Assume no water evaporates during the quenching process.
- A) 16.9 °C    B) 20.7 °C    C) 41.9 °C    D) 45.8 °C    E) 91.5 °C

7) Table 1: Successive Ionization Energies of 3<sup>rd</sup> Period Elements

Element	IE <sub>1</sub> (kJ <sup>-1</sup> mol <sup>-1</sup> )	IE <sub>2</sub> (kJ <sup>-1</sup> mol <sup>-1</sup> )	IE <sub>3</sub> (kJ <sup>-1</sup> mol <sup>-1</sup> )	IE <sub>4</sub> (kJ <sup>-1</sup> mol <sup>-1</sup> )	IE <sub>5</sub> (kJ <sup>-1</sup> mol <sup>-1</sup> )
V	787	1577	3231	4356	16091
W	738	1451	7733	10540	13630
X	1251	2297	3822	5158	6540
Y	496	4562	6912	9543	13353
Z	578	1817	2745	11575	14830

Based on this information, which of the following statements is **FALSE**?

- A) Y is sodium  
 B) X has the smallest radius  
 C) W is an alkaline earth metal  
 D) Z forms the largest cation  
 E) V is a semi-metal
- 8) Hydrofluoric acid reacts with potassium hydroxide according to the net ionic equation:



If 5.0 mL of 1.0 M KOH are added to 25.0 mL of 2.0 M HF, what is the pH of the resulting solution? The  $K_a$  of HF is  $7.2 \times 10^{-4}$ .

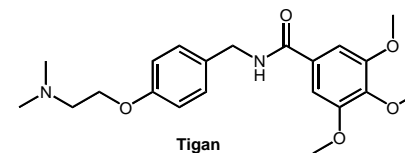
- A) 1.42      B) 1.48      C) 1.66      D) 2.19      E) 2.84
- 9) For a reaction  $A + B \rightarrow \text{Products}$ , the rate law is:  $\text{rate} = k[A][B]^2$ . For containers with the same volume, which mixture would have the highest rate of reaction according to this rate law? The legend indicates which molecule is A and which is B.

**Legend**    ● A

A)      B)      C)      D)      E)

○ B

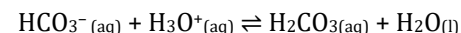
- 10) Tigan (structure below) is an antiemetic drug used to prevent nausea and vomiting. It is often prescribed for patients with gastroenteritis, medication-induced nausea, and other illnesses.



Which of the following functional groups are present within Tigan?

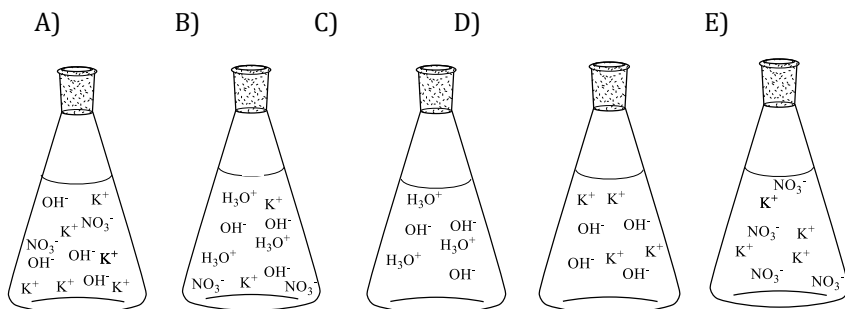
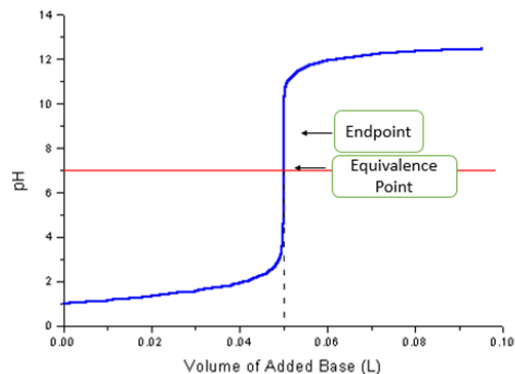
- A) amine, ether, amide      B) amine, ketone, ether, alcohol  
 C) ether, aldehyde, amine      D) alcohol, amine, ether, amide  
 E) ketone, amine, ether
- 11) How many carbon (C) and hydrogen (H) atoms are present in a molecule of Tigan?
- A) 21 C and 28 H atoms      B) 21 C and 27 H atoms  
 C) 16 C and 28 H atoms      D) 20 C and 28 H atoms  
 E) 21 C and 29 H atoms

- 12) Which of the following would increase the  $K_{eq}$  of the reaction below?



- A) Increasing the pH      B) Decreasing the pH      C) Adding water  
 D) Adding  $\text{H}_2\text{CO}_3$       E) None of the options provided
- 13) In 1962, at the University of British Columbia, Neil Bartlett shattered conventional chemistry wisdom and synthesized xenon tetrafluoride, the first binary compound of a noble gas. Which of the following statements is/are true about a molecule of xenon tetrafluoride?
- I) The molecule has no lone pairs on the central atom  
 II) The molecule has a tetrahedral geometry  
 III) The molecule has no net molecular dipole
- A) I only      B) II only      C) III only      D) II and III      E) I, II and III

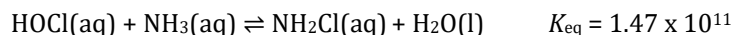
- 14) For the titration of  $\text{HNO}_3$  with  $\text{KOH}$ , which of the following receiving flasks best depicts the ions present at the **endpoint** as indicated on this titration curve?



- 15) What is the pH of a solution created by mixing 1000.0 mL of 0.120 M  $\text{HNO}_3$  (aq) with 250.0 mL of 0.750 M  $\text{HBr}$  (aq)?

A) 1.268    B) 0.000    C) 0.060    D) 0.512    E) 0.609

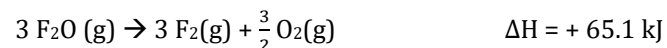
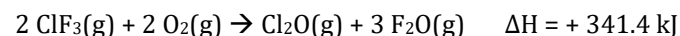
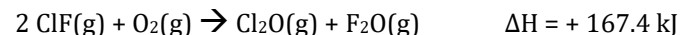
- 16) The smell often associated with public swimming pools comes from chloramines. The reaction of hypochlorous acid with ammonia from human urine will produce monochloramine ( $\text{NH}_2\text{Cl}$ ) as follows:



One part per million (ppm) is a  $\text{mg L}^{-1}$ . A typical public swimming pool volume (750,000 L) contains 75.0 L of urine. The concentration of ammonia in 1 L of urine is 0.200 M. If the concentration of hypochlorous acid in pool water is 1.00 ppm, determine the concentration (in ppm) of monochloramine ( $\text{NH}_2\text{Cl}$ ) in a typical public swimming pool. Assume the mass of 1 L of pool water is 1 kg.

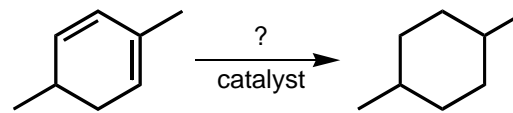
A) 1.91    B) 1.64    C) 1.03    D) 1.00    E) 0.98

- 17) Use the information provided below to calculate the enthalpy of reaction when one mole of chlorine trifluoride gas decomposes into one mole of chlorine monofluoride gas and one mole of gaseous fluorine.



A) -217.4 kJ    B) +25.0 kJ    C) +68.4 kJ    D) +108.7 kJ    E) 573.9 kJ

- 18) Consider the following reaction, where the starting compound is treated with an unknown reagent over a catalytic surface to form the product:



Which two terms can be used to describe this process?

A) hydrogenation, elimination    B) hydration, addition  
C) hydrogenation, substitution    D) hydrogenation, addition  
E) hydration, substitution

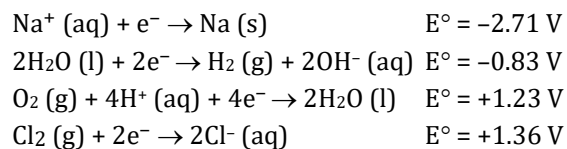
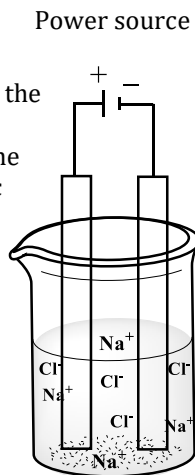
- 19) A quantity of solid material weighing 6.445 g was obtained from a hazardous waste facility. A 1.545 g sample of this material was analyzed for barium content by dissolving in water and then adding sodium sulfate. The insoluble barium sulfate precipitate was dried, and a total of 73.8 mg of  $\text{BaSO}_4$  was collected. What percentage by mass of the sample is barium?

A) 0.281 %    B) 0.674 %    C) 2.81 %    D) 4.02 %    E) 6.74 %

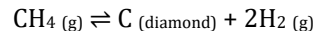
- 20) Which of the following accurately represents a trend in atomic radius?

A)  $\text{F} > \text{Cl} > \text{Br}$     B)  $\text{F} > \text{O} > \text{N}$     C)  $\text{Cl}^- > \text{Na}^+ > \text{Mg}^{2+}$   
D)  $\text{Ca}^{2+} > \text{K}^+ > \text{Ca}$     E)  $\text{O}^{2-} > \text{S}^{2-} > \text{Cl}$

- 21) 96.5% of water available on Earth is sea water. Desalination of seawater could provide a solution to the global fresh water crisis. There are many challenges that chemists face in achieving desalination. Given the half reactions below and the setup of the electrolytic cell to the right, what would happen with an applied potential difference from the power source?



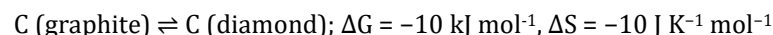
- A) With 1.35 V, the cell produces Na at the cathode and Cl<sub>2</sub> at the anode  
 B) With 1.35 V, the cell produces Na at the anode and Cl<sub>2</sub> at the cathode  
 C) With 4.07 V, the cell produces Na at the cathode and Cl<sub>2</sub> at the anode  
 D) With 2.06 V, the cell produces H<sub>2</sub> at the anode and H<sub>2</sub>O at the cathode  
 E) With 2.06 V, the cell produces H<sub>2</sub> at the cathode and O<sub>2</sub> at the anode
- 22) The market for lab-made diamonds is growing. Chemists can create diamonds identical to mined diamonds by using chemical vapour deposition in which methane decomposes in the presence of a hydrogen catalyst and plasma. If this methane decomposition reaction were possible at 298 K, what would be the Gibbs Free Energy ( $\Delta G^\circ$ ) of the lab-made diamond synthesis process indicated below (in kJ mol<sup>-1</sup>)?



Compound	CH <sub>4</sub> (g)	C (diamond)	H <sub>2</sub> (g)
$\Delta H^\circ_f$ (kJ mol <sup>-1</sup> )	-74.87	1.897	0
$S^\circ$ (J K <sup>-1</sup> mol <sup>-1</sup> )	186.1	2.377	130.6

- A) -23.0    B) 23.0    C) 53.7    D) -53.7    E) 92.6

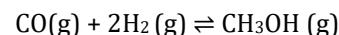
- 23) Another way to make diamonds in the lab is by converting graphite to diamond. At 2000 K and 200 000 atm:



Which of the following is a good approximation of the equilibrium temperature for the reaction at 200 000 atm if enthalpy and entropy are assumed to be temperature independent?

- A) T<sub>eq</sub> = 2000 K    B) T<sub>eq</sub> = 3000 K    C) T<sub>eq</sub> = 1000 K  
 D) T<sub>eq</sub> = 4000 K    E) T<sub>eq</sub> = 100 K

- 24) Over 80% of global methanol (CH<sub>3</sub>OH) production is converted into further synthetic chemicals. Consequently, methanol is an economically significant chemical compound. *Methanex*, a Vancouver-based company, is the world's largest producer and distributor of methanol. Methanol is produced according to the following balanced chemical reaction:

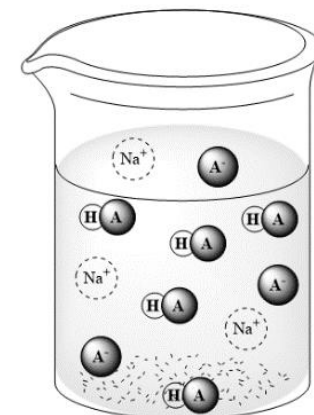


Given initial partial pressures of  $P_{\text{CO}} = 26$  bar and  $P_{\text{H}_2} = 65$  bar, and an equilibrium partial pressure of  $P_{\text{CH}_3\text{OH}} = 16$  bar, determine  $K_p$ . Assume constant container volume and ideal gas behaviour.

- A)  $1.5 \times 10^{-4}$     B)  $6.7 \times 10^{-4}$     C)  $1.5 \times 10^{-3}$   
 D)  $3.3 \times 10^{-2}$     E)  $4.8 \times 10^{-2}$

- 25) A chemist creates one litre of buffer solution by mixing unequal volumes of 1.0 M acetic acid ( $K_a = 1.74 \times 10^{-5}$ ) and 1.0 M sodium hydroxide to obtain a solution with the ratio of solution particles in the diagram to the right. What is the pH of the buffer solution?

- A) 4.33    B) 4.54    C) 4.76  
 D) 4.98    E) 5.19



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

HA = acetic acid  
 A<sup>-</sup> = acetate anion  
 Na<sup>+</sup> = sodium cation