



THE CANADIAN CHEMISTRY CONTEST 2024
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 online, directly in the TestInvite program.

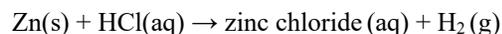
Students may use a scientific calculator. No phones or communication devices are allowed.

- 1) Which of the following symbols is used to label helium tanks?



Use the following information for questions 2 and 3

In an experiment to determine the simplest formula and ratio of zinc to chlorine in zinc chloride, a measured mass of zinc metal reacted with excess of hydrochloric acid. The solid zinc chloride product was isolated by evaporating the unreacted acid.



- 2) If the recovered zinc chloride product were insufficiently dried before weighing, which of the following statements is TRUE?
- A) The calculated number of moles of Cl would be too high
B) The calculated number of moles of Zn would be too low
C) The calculated number of moles of Cl would be unchanged
D) The calculated number of moles of hydrogen gas will be too high
E) The calculated number of moles Cl would be too low
- 3) What would the impact on the calculations be if not all of the zinc metal reacted?
- A) The calculated number of moles of Cl would be unchanged
B) The calculated number of moles of Cl would be too low
C) The calculated number of moles of Zn would be too low
D) The calculated number of moles of hydrogen gas will be too low
E) The calculated number of moles Cl would be too high

- 4) 1.50 g sample of an unknown hydrocarbon is combusted in excess $\text{O}_2(\text{g})$ to produce 4.49 g CO_2 , 2.45 g H_2O and 75.5 kJ of heat. What is the molar heat of combustion for the hydrocarbon (in kJ mol^{-1})?

- A) $-2.22 \times 10^3 \text{ kJ mol}^{-1}$ B) $-2.02 \times 10^3 \text{ kJ mol}^{-1}$
C) $-3.93 \times 10^3 \text{ kJ mol}^{-1}$ D) $-3.63 \times 10^3 \text{ kJ mol}^{-1}$
E) $-2.82 \times 10^3 \text{ kJ mol}^{-1}$

- 5) At STP, 20 mL of gas A reacts with 20 mL of gas B to produce 10 mL of gas A_xB_y . There was an excess of 10 mL of excess gas A. What is the correct empirical formula of the product $\text{A}_x\text{B}_y(\text{g})$?

- A) A_2B B) A_2B_2 C) AB D) AB_2 E) A_2B_3

- 6) Chlorine bleach can be synthesized by bubbling chlorine gas into a solution of sodium hydroxide according to the equation:



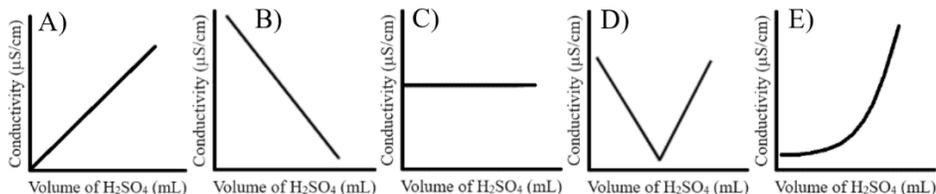
What mass of sodium hypochlorite, NaClO , is produced when $3.45 \times 10^3 \text{ mL}$ of chlorine at 99.5 kPa and 21.0°C is reacted with 250.0 mL of 0.750 mol L^{-1} sodium hydroxide solution?

- A) 10.5 g B) 11.2 g C) 6.98 g D) 27.9 g E) 146 g

- 7) In a reaction, dichromate(VI) ion is reduced to chromium (III) ion in an acidic solution. What is the sum of all the coefficients when this half reaction is balanced?

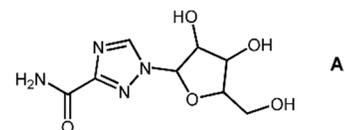
- A) 13 B) 23 C) 24 D) 29 E) 30

- 8) If 20.0 mL of 1.0 mol L⁻¹ sulfuric acid is added dropwise to 40.0 mL of 0.50 mol L⁻¹ barium hydroxide, a precipitate of barium sulfate forms. Which graph represents a plot of conductivity against the volume of acid added?



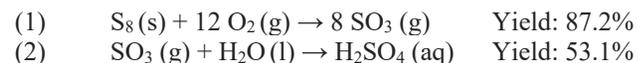
Questions 9 and 10 refer to substance (A) shown below. Molecule (A) is a medication used to treat respiratory syncytial virus, which is prominent in Canada each year from October until the end of winter.

- 9) What is the chemical formula of the substance (A)?



- A) C₇H₁₂N₄O₅ B) C₈H₅N₄O₅ C) C₇H₁₀N₄O₅
 D) C₈H₁₂N₄O₅ E) C₉H₁₂N₄O₅
- 10) Which one of the statements regarding substance (A) is **FALSE**?
- A) A contains both a ketone and an amine functional group
 B) A has 14 lone pairs of electrons
 C) A contains 3 alcohol functional group
 D) A is capable of hydrogen bonding with water molecules
 E) A does not contain any alkene functional groups
- 11) Consider the following equation: Na⁺(g) + e⁻ → Na(g)
 Which statement is **TRUE**?
- A) The energy change for this process is the negative value of the ionization energy of the Na atom
 B) The energy change is equal to the electron affinity of sodium
 C) The energy change for this process is the positive value of the ionization energy of the Na atom
 D) The energy change is greater than Na(g) + e⁻ → Na⁻(g)
 E) Two of the above statements are true

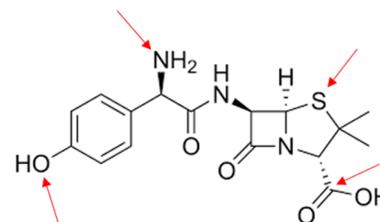
- 12) Sulfuric acid is industrially produced in large quantities. It can be produced in a multistep process from elemental sulfur by first oxidizing the sulfur to sulfur trioxide gas and then bubbling the gas through water.



If 1.25 x 10³ L of 12.0 mol L⁻¹ sulfuric acid is produced using this process, how many kilograms of elemental sulfur was used?

- A) 130 kg B) 1040 kg C) 481 kg D) 223 kg E) 790 kg

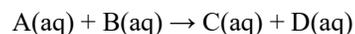
- 13) Amoxicillin, an antibiotic belonging to the penicillin family, is used to treat minor bacterial infections. The structure of amoxicillin is shown below. Which of the following statements is **CORRECT**?



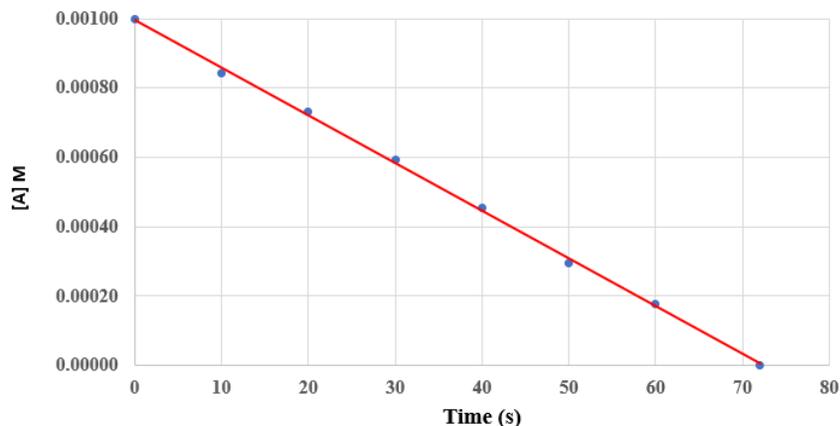
- A) The bonds around the indicated (with an arrow) O atom form a trigonal planar shape and the indicated C atom is sp² hybridized
 B) The bonds around the indicated N atom form a trigonal pyramidal shape and the indicated C atom is sp³ hybridized
 C) The bonds around the indicated O atom form a bent shape and the indicated C atom is sp hybridized
 D) The bonds around the indicated S atom form a bent shape and the indicated C atom is sp³ hybridized
 E) The bonds around the indicated N atom form a trigonal pyramidal shape and the indicated C atom is sp² hybridized
- 14) Which of the following acids has the strongest conjugate base?

- A) HClO₄ B) HNO₃ C) HCl D) HF E) H₂SO₄

- 15) A reacts with an excess of reactant B in aqueous solution:



The concentration of A is found to vary with time as shown in the graph, and the rate constant, k , for the reaction is determined to be $2.78 \times 10^{-5} \text{ s}^{-1}$.



What is the initial concentration of B?

- A) $5.0 \times 10^2 \text{ mol L}^{-1}$ B) 0.48 mol L^{-1}
 C) 5.0 mol L^{-1} D) $1.4 \times 10^{-5} \text{ mol L}^{-1}$
 E) The concentration of B cannot be determined
- 16) For the reaction: $\text{CO}_2(g) + \text{H}_2(g) \rightleftharpoons \text{CO}(g) + \text{H}_2\text{O}(g)$ at equilibrium, the concentrations of reactants and products of the reaction are $[\text{CO}_2] = 0.0500 \text{ mol L}^{-1}$, $[\text{H}_2] = 0.0250 \text{ mol L}^{-1}$, $[\text{CO}] = 0.0200 \text{ mol L}^{-1}$, and $[\text{H}_2\text{O}] = 0.0200 \text{ mol L}^{-1}$. The pressure is increased by adding $\text{Ne}(g)$ to the system, which of the following statements is correct?
- A) $Q > K$ and equilibrium shifts to produce more products.
 B) $Q > K$ and equilibrium shifts to produce more reactants.
 C) $Q < K$ and the equilibrium shifts to produce more products.
 D) $Q < K$ and the equilibrium shifts to produce more reactants.
 E) $Q = K$ and the equilibrium does not shift

- 17) A student added 1.0 L of $0.5 \text{ mol L}^{-1} \text{ AgNO}_3$ solution to 1.0 L of $1.0 \text{ mol L}^{-1} \text{ NaCl}$ solution. A silver chloride precipitate formed, and nearly all the silver ions disappeared from the solution. Which of the following provides the list of ions remaining in solution in order of **increasing** concentration?

- A) $[\text{Ag}^+] < [\text{Na}^+] < [\text{Cl}^-]$ B) $[\text{Cl}^-] < [\text{Ag}^+] < [\text{Na}^+]$
 C) $[\text{Na}^+] < [\text{Ag}^+] < [\text{Cl}^-]$ D) $[\text{Cl}^-] < [\text{Na}^+] < [\text{Ag}^+]$
 E) $[\text{Ag}^+] < [\text{Cl}^-] < [\text{Na}^+]$

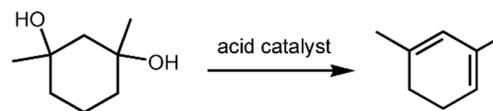
- 18) Monosodium glutamate (MSG) is a food additive known for its umami flavour. It is derived from the triprotic acid, glutamic acid. The equilibrium between glutamic acid (H_3A) and glutamate (H_2A^-) is:



If 50.0 mL of 0.750 mol L^{-1} glutamic acid (pK_a 2.09) reacts with 50.0 mL of $0.25 \text{ mol L}^{-1} \text{ NaOH}$, what is the resulting pH of the solution?

- A) 2.75 B) 2.53 C) 2.34 D) 2.09 E) 1.86

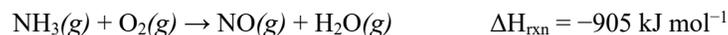
- 19) The reaction below takes place to form a product that contains two new functional groups:



Which two terms can be used to appropriately describe this type of reaction?

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

- 20) At 1000°C, ammonia reacts with oxygen gas to form nitric oxide and water vapour according to the *unbalanced* chemical equation:



Bond	Bond Enthalpy (kJ mol ⁻¹)
N - H	391
N - O	201
N = O	607
O - H	467

Given the data in the table, what is the average O = O bond energy?

- A) 487 kJ mol⁻¹ B) 974 kJ mol⁻¹ C) 381 kJ mol⁻¹
 D) 162 kJ mol⁻¹ E) 458 kJ mol⁻¹
- 21) A student mixes a 0.10 mol L⁻¹ hydrochloric acid solution with an unknown base which has a concentration of 0.25 mol L⁻¹. After adding 100 mL of the hydrochloric acid solution to 200 mL of the unknown base solution, the pH is 10.45. What is the unknown base?
- A) sodium phenolate (NaOC₆H₅) (pK_a = 9.85)
 B) ammonia (NH₃) (pK_a = 9.25)
 C) sodium carbonate (Na₂CO₃) (pK_a = 10.25)
 D) dihydrogen sodium borate (H₂BNaO₃) (pK_a = 10.14)
 E) sodium acetate (NaC₂H₃O₂) (pK_a = 4.76)

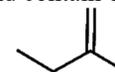
- 22) The Finkelstein reaction is an equilibrium-driven reaction where an alkyl halide and sodium iodide react together in acetone. The product of the reaction is an alkyl iodide and sodium halide, which is precipitates in acetone according to the reaction below:



If the K_{sp} of sodium chloride in acetone is 5.165 × 10⁻¹¹, and the equilibrium constant of the reaction is 0.8, what is the concentration of 1-iodobutane at equilibrium if the initial concentration of 1- chlorobutane is 0.100 M and sodium iodide at 0.110 M?

- A) 0.100 mol L⁻¹ B) 0.0800 mol L⁻¹ C) 0.0719 mol L⁻¹
 D) 0.0472 mol L⁻¹ E) 0.105 mol L⁻¹

- 23) Consider the organic compound below. How many constitutional isomers of this compound contain one ring within their structure?



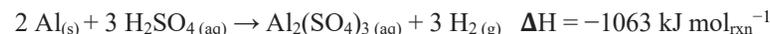
- A) 3 B) 4 C) 5 D) 6 E) 7

- 24) The Fe³⁺ ion typically has a pale-yellow colour in solution. When combined with thiocyanate the resulting FeSCN²⁺ ion has a deep red colour. According to the equilibrium below, which change(s) would result in the solution's colour becoming a deeper red?



- I) Warming the solution
 II) Adding NaSCN to the solution
 III) Precipitating Fe(OH)₃ by adding NaOH
- A) I only B) II only C) III only
 D) I and II only E) I, II, and III

- 25) The reaction of metallic aluminum and sulfuric acid occurs with the given enthalpy of reaction:



If 1.25 g of aluminum reacts inside a calorimeter containing 300.0 mL of 1.0 M sulfuric acid, initially at 21.0 °C, what is the final temperature of the solution? (Assume negligible heat loss, a heat capacity of 4.184 J g⁻¹ °C⁻¹ and density of 1.00 g mL⁻¹ for the solution)

- A) 40.6 °C B) 1.4 °C C) 60.2 °C
 D) 26.9 °C E) 45.6 °C

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