



THE CANADIAN CHEMISTRY CONTEST 2012

for high school and CEGEP students

PART A – MULTIPLE CHOICE QUESTIONS (60 minutes)

All contestants should attempt this part of the contest before proceeding to Part B (the CIC section) and/or Part C (the CCO section).

A CIC/CCO Periodic Table is provided, but no other data may be given. Answers should be marked on the Answer Grid provided.

1. Each of the following acids might be found in a typical high school laboratory acid storage cupboard. Which of them should be stored in a separate compartment within the acid storage cupboard? The WHMIS symbols for each acid are indicated.

I. 10 mol L⁻¹ HNO₃



II. 12 mol L⁻¹ HCl



III. 18 mol L⁻¹ H₂SO₄



- A. I only B. II only C. III only
D. II and III E. All of them should be stored separately

2. Which of the following atoms has the greatest number of unpaired electrons in its ground state?

- A. strontium (Sr) B. bismuth (Bi) C. zirconium (Zr)
D. uranium (U) E. gadolinium (Gd)

3. Which of the following molecules has the smallest angle between two neighbouring covalent bonds?

- A. BeH₂ B. BF₃ C. CCl₄ D. NH₃ E. OH₂

4. A volatile alkane (C_xH_{2x+2}) is analyzed by the Dumas method to determine its molar mass. A 0.01613 g sample of the compound is injected under vacuum into a 100.00 mL flask at 25.0°C. The pressure of the sample is 13.33 kPa. What is the molecular formula of the alkane?

- A. CH₄ B. C₂H₆ C. C₃H₈ D. C₄H₁₀ E. C₅H₁₂

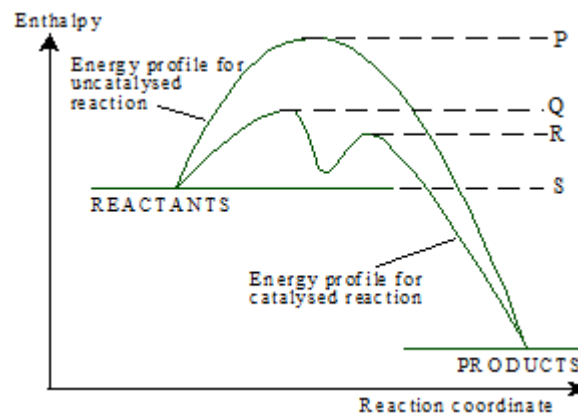
5. A teenager requires about 8 200 kJ of body energy from food per day.

Calculate the mass of glucose, C₆H₁₂O₆(s), required to provide this energy if it is generated by the metabolism of glucose with oxygen to produce water and carbon dioxide.

Compound	Standard enthalpy of formation ΔH_f° (kJ mol ⁻¹)
C ₆ H ₁₂ O ₆ (s)	-1273
CO ₂ (g)	-394
H ₂ O(l)	-286

- A. 2.92 g B. 276 g C. 526 g D. 757 g E. 2.49 kg

6. For the potential energy (or enthalpy) diagram below, what is the minimum activation energy required for the CATALYSED reaction to occur?

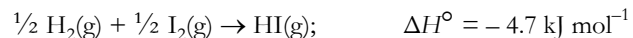


- A. (P – Q) B. (P – S) C. (Q – S) D. (R – S) E. (Q – R)

7. During a lab experiment, 0.250 g of copper metal is recovered, and is left overnight to ensure that it is totally dry. The following day, the copper product is greeny-blue in colour and has a mass of 0.490 g. Assuming only one copper product is produced from the original copper metal, that product is likely:

- A. CuO B. Cu₂O C. CuCO₃ D. Cu₂CO₃ E. Cu₃N₂

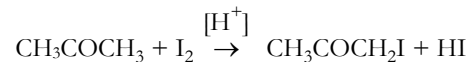
8. Calculate the bond energy of $I_2(g)$ given the following standard enthalpy of reaction:



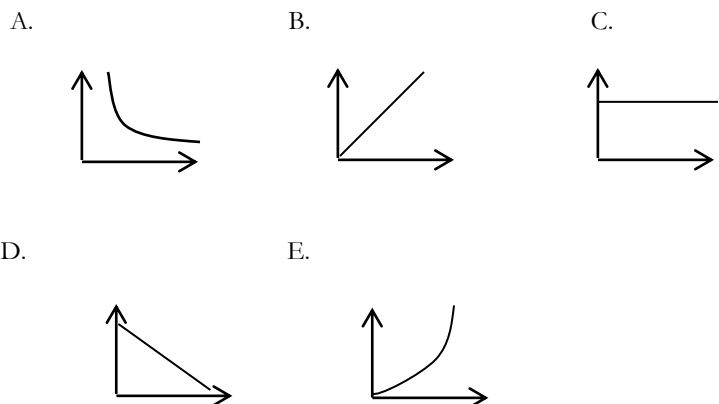
Compound	Bond Energy (kJ mol ⁻¹)
H ₂ (g)	436
HI (g)	298

- A. -138 kJ mol⁻¹ B. -80 kJ mol⁻¹ C. +80 kJ mol⁻¹
 D. -151 kJ mol⁻¹ E. +151 kJ mol⁻¹

9. The acid-catalysed iodination of propanone represented by the equation



is first order with respect to hydrogen ions and to propanone and zero order with respect to iodine. Given this information which of the unlabelled graphs below is a correct representation of rate of reaction versus time for this reaction?



10. To how many isomers does the molecular formula C_3H_8O correspond?

- A. 4 constitutional (structural) isomers including one which has 2 stereoisomers
 B. 4 constitutional isomers and no stereoisomers
 C. 3 constitutional isomers including one which has 2 stereoisomers
 D. 3 constitutional isomers and no stereoisomers
 E. 2 constitutional isomers and no stereoisomers

11. Given the following data on carbon monoxide (CO) and nitrogen (N₂) molecules, which is the best evaluation of the intermolecular forces in CO?

Compound	Melting point(°C)	Boiling point (°C)	Density at STP (g L ⁻¹)
Nitrogen	-210	-196	1.251
Carbon monoxide	-205	-191.5	1.250

- I. London dispersion forces are the dominant intermolecular forces in carbon monoxide
 II. Dipole-dipole interactions are the dominant intermolecular forces in carbon monoxide
 III. Carbon monoxide has a dipole moment which contributes significantly to the strength of its intermolecular forces

- A. I only B. II only C. III only
 D. II and III E. I and III

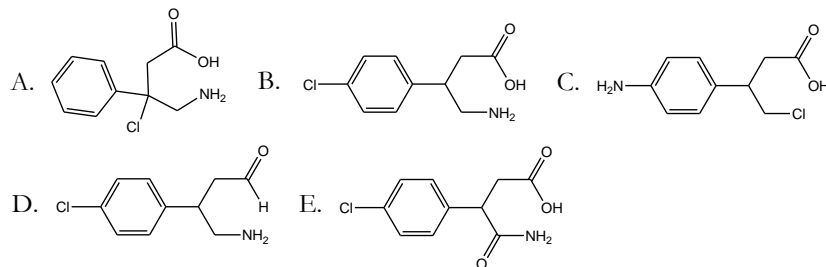
12. Which of the following statements is true for a 0.010 mol L⁻¹ aqueous solution of the weak base ethylamine (C₂H₅NH₂) if the $K_a = 1.78 \times 10^{-11}$ for the conjugate acid?

- A. The pH is equal to 2 B. The pH is between 2 and 7
 C. The pH is equal to 7 D. The pH is between 7 and 12
 E. The pH is equal to 12

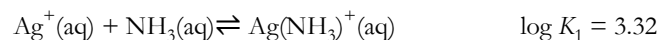
13. The sour taste of vinegar is due to acetic acid, CH₃COOH. When aqueous acetic acid reacts with aqueous sodium hydroxide in a titration, the products of the net ionic equation are:

- A. CH₃COOH₂⁺, Na₂O
 B. CH₃COOH, H₂O, Na⁺
 C. CH₃COO⁻, Na⁺
 D. CH₃COO⁻, H₂O
 E. CH₃COOH, NaOH

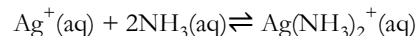
14. Baclofen is a muscle relaxant which is also effective in the treatment of alcohol dependence and withdrawal. The IUPAC name of baclofen is 4-amino-3-(4-chlorophenyl)butanoic acid. Which of the following structures correctly represents this molecule?



15. Silver ions are more soluble in aqueous ammonia solution than in water due to the formation of complexes. Information about the sequential equilibria involved at 298K is as follows:



What is the equilibrium constant, K_C , for the following process?



- A. 7.02 B. 7.24 C. 13.01 D. 1.04×10^7 E. 1.74×10^7

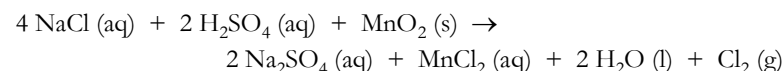
16. At a temperature of 25.0°C , a reaction has an enthalpy change of $-26.9 \text{ kJ mol}^{-1}$ and an entropy change of $-11.3 \text{ J mol}^{-1} \text{ K}^{-1}$. Which of the following statements is true if the temperature is lowered to -25.0°C ?

- A. The reaction is spontaneous at both temperatures
 B. The reaction is non-spontaneous at both temperatures
 C. The reaction is spontaneous at $+25.0^\circ\text{C}$ and non-spontaneous at -25.0°C
 D. The reaction is non-spontaneous at $+25.0^\circ\text{C}$ and spontaneous at -25.0°C
 E. The reaction is non-spontaneous at $+25.0^\circ\text{C}$ and at equilibrium at -25.0°C

17. A forensic laboratory analyzed a white powder. Tests indicated that the powder is a known drug mixed with sodium chloride. An elemental analysis gave the following results: 60.58% C, 6.282% H, 4.158% N. Assume the white powder is only a mixture of the pure drug and NaCl. Which drug is in the white powder and what is the **percent by mass** content of sodium chloride in it?

- A. Cocaine ($\text{C}_{17}\text{H}_{21}\text{NO}_4$); contains 20% NaCl by mass
 B. Morphine ($\text{C}_{17}\text{H}_{19}\text{NO}_3$); contains 20% NaCl by mass
 C. Cocaine ($\text{C}_{17}\text{H}_{21}\text{NO}_4$); contains 10% NaCl by mass
 D. Morphine ($\text{C}_{17}\text{H}_{19}\text{NO}_3$); contains 10% NaCl by mass
 E. Cocaine ($\text{C}_{17}\text{H}_{21}\text{NO}_4$); contains 15% NaCl by mass

18. In 1774, Swedish chemist Carl Wilhelm Scheele produced molecular chlorine gas from the reaction between sodium chloride, sulfuric acid, and manganese(IV) oxide shown below:



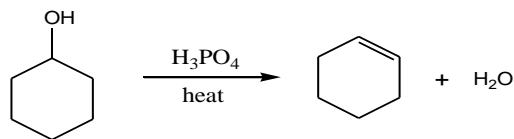
To reproduce Scheele's experiment, 50.0 mL of 2.00 mol L^{-1} NaCl is mixed with 25.0 mL of 6.00 mol L^{-1} H_2SO_4 , and 4.35 g of MnO_2 . What volume of Cl_2 gas will be produced at 101.325 kPa of pressure and 25.0°C of temperature?

- A. 0.611 L $\text{Cl}_2(\text{g})$ B. 1.22 L $\text{Cl}_2(\text{g})$ C. 1.83 L $\text{Cl}_2(\text{g})$
 D. 2.44 L $\text{Cl}_2(\text{g})$ E. 3.67 L $\text{Cl}_2(\text{g})$

19. If the standard reduction potentials of $\text{Al}^{3+}|\text{Al}$ and $\text{Sn}^{2+}|\text{Sn}$ electrodes are -1.676 V and -0.137 V respectively, and both metal cations in the electrochemical cell have concentrations of 1.0 mol L^{-1} , which of the following is true?

- A. Al is oxidized at one electrode and Sn is oxidized at the other
 B. Al is oxidized at one electrode and Sn is reduced at the other
 C. Al is reduced at one electrode and Sn is oxidized at the other
 D. Al is reduced at one electrode and Sn is reduced at the other
 E. Al is oxidized and Sn is reduced at both electrodes

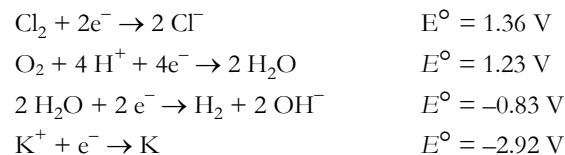
20. Consider the following reaction, where cyclohexanol reacts with concentrated phosphoric acid to form cyclohexene. Cyclohexene is a precursor to adipic acid, one of the important compounds used in the industrial preparation of nylon.



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

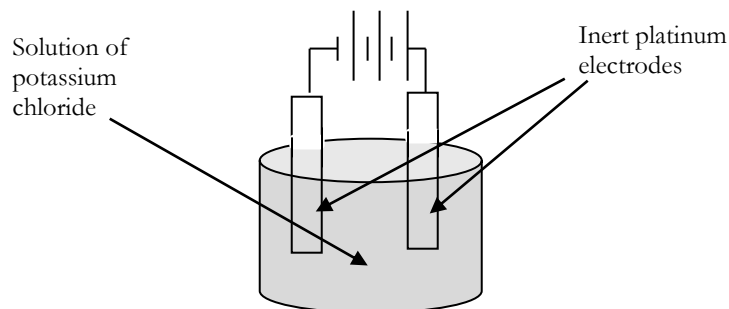
- A. addition, dehydration B. elimination, hydration
 C. substitution, dehydration D. elimination, dehydration
 E. substitution, hydration
21. The thiosulfate ion $S_2O_3^{2-}$ has a structure in which a central sulfur atom forms four single bonds to one terminal S atom and three O atoms. The two non-equivalent S atoms have two different oxidation states. The oxidation state of the central S atom is:
- A. +6 B. +5 C. +4 D. +2 E. -2
22. What is the result of an increase in the temperature of a system at equilibrium?
- A. The endothermic reaction is favoured and the rate of this reaction decreases.
 B. The exothermic reaction is favoured and the rate of this reaction decreases.
 C. The endothermic reaction is favoured and the rate of this reaction increases.
 D. The exothermic reaction is favoured and the rate of this reaction increases.
 E. The activation energy for the forward reaction becomes smaller.
23. 25.0 mL of 0.100 mol L^{-1} NaOH are added to 50.0 mL of a 0.100 mol L^{-1} solution of acetic acid ($K_a = 1.8 \times 10^{-5}$) at 25°C . Select the pH value that most closely describes the pH after the addition has taken place.
- A. 7.00 B. 4.75 C. 2.89 D. 3.12 E. 8.72

24. The cell depicted below is powered by three 1.5 V batteries and has platinum electrodes in an aqueous solution of potassium chloride. The following standard reduction potentials are provided as a reference.



What is the product at the cathode?

- A. O_2 B. Cl_2 C. K D. H_2 E. H_2O



25. Car batteries consist of lead/lead(IV) oxide plates suspended in sulfuric acid. Lead(II) sulfate gradually forms during the discharge process. If an equilibrated mixture of lead(II) sulfate in water is filtered, and 50.0 mL of the filtrate is added to 50.0 mL of sodium sulfate solution (1.0 mol L^{-1}), some lead(II) sulfate precipitates out. What is the concentration of lead(II) ions remaining in solution? ($K_{sp}(\text{PbSO}_4) = 1.6 \times 10^{-8}$, values are at 25°C .)
- A. $8.0 \times 10^{-9} \text{ mol L}^{-1}$ B. $1.6 \times 10^{-8} \text{ mol L}^{-1}$ C. $3.2 \times 10^{-8} \text{ mol L}^{-1}$
 D. $1.3 \times 10^{-4} \text{ mol L}^{-1}$ E. $2.2 \times 10^{-3} \text{ mol L}^{-1}$

End of Part A of the contest.
Now go back and check your work.