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CHEMISTRY Olympiads CANADA Olympiades CHIMIE

THE CANADIAN CHEMISTRY CONTEST 2013
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. Bearing in mind the WHMIS symbols associated with each substance, which of the following is/are safe to store next to copper metal?

I) 10.0 mol L^{-1} nitric acid 

II) 12.0 mol L^{-1} hydrochloric acid 

III) 100% Methanol 

A) I only B) II only C) III only D) I and III E) II and III

2. In May 2012, the International Union of Pure and Applied Chemistry (IUPAC) officially approved the names flerovium and livermorium for elements 114 and 116 respectively. The electron configuration of flerovium, element 114 is:

A) [Rn] $7s^2$ $5f^{14}$ $6d^{10}$ $7p^2$ B) [Rn] $7s^2$ $4f^{14}$ $5d^{10}$ $6p^2$
C) [Rn] $7s^2$ $4f^{14}$ $5d^{10}$ $7p^2$ D) [Rn] $7s^2$ $5f^{14}$ $6d^{10}$ $6p^2$
E) [Rn] $7s^2$ $6f^{14}$ $6d^{10}$ $7p^2$

3. The reaction for a homogeneous gas phase reaction of reactants "A_2" and "B_2" and product "AB_3" is given as:

$$A_{2\,(g)} + 3\,B_{2\,(g)} \rightarrow 2\,AB_{3\,(g)}$$

If equal volumes of reactants "A_2" and "B_2" are mixed together in a rigid container at 1.50 x 10^2 atm and a constant temperature of 25°C, what is the partial pressure in atmospheres (atm) of the gaseous product AB_3? Assume the reaction goes to completion.

A) 37.5 B) 50.0 C) 75.0 D) 1.00 x 10^2 E) 1.50 x 10^2

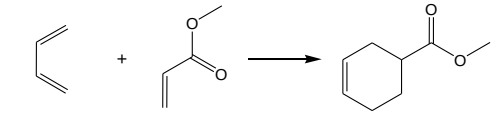
4. The VSEPR theory can be used to predict the geometry of a molecule and whether or not it will have a permanent dipole moment. Which one of the following fluorides will have a non-zero dipole moment?

A) BeF_2 B) NF_3 C) XeF_4 D) PF_5 E) SF_6

5. Which of the following is a Lewis acid but is not a Brønsted acid?

A) H_2O B) BF_3 C) H_3O^+ D) NH_3 E) HF

6. One of the Twelve Principles of Green Chemistry is that "it is better to prevent waste, rather than clean it up". Waste can be created during a chemical process from unreacted starting materials and from the formation of by-products. During the reaction below, 1.26 mol of 1,3-butadiene (formula C_4H_6) was combined with 2.31 mol of methyl acrylate (formula $C_4H_6O_2$) to form the product shown in 86.4% yield.



What is the mass of waste generated during this reaction?
A) 90.4 g B) 1.10 x 10^2 g C) 114 g D) 152 g E) 294 g

7. Dinitrogen pentoxide is a strong oxidizer that is of interest for the preparation of explosives. It decomposes according to the following reaction which has a first order rate law:

$$2\,N_2O_5\,(g) \longrightarrow 4\,NO_2\,(g) + O_2\,(g)$$

If the initial concentration of N_2O_5 is 0.100 mol L^{-1} and the rate is 4.8 x 10^{-5} mol L^{-1} s^{-1}, what is the rate constant for this process?

A) 4.8 x 10^{-4} s^{-1} B) 4.8 x 10^{-6} mol L^{-1} s^{-1} C) 2083 mol L^{-1} s^{-1}
D) 4.8 x 10^{-6} s^{-1} E) 2083 s^{-1}

8. Fluoride salts can be added to municipal water supplies to help reduce tooth decay among the population. Given that the pK_a of hydrofluoric acid, HF(aq), is 3.17 at 25.0°C, calculate the pH of a 0.00500 mol L^{-1} sodium fluoride solution at this temperature.

A) pH = 2.74 B) pH = 3.50 C) pH = 6.57
D) pH = 7.43 E) pH = 10.50

9. Nitrogen gas is pumped into a completely flexible balloon that contains some air at 20°C. The balloon expands against atmospheric pressure. Which of the following graphs most accurately describes the change in conditions inside the balloon over time?

A) $\frac{P_T V_T}{T}$ vs Time (0)
B) P_{O_2} vs Time (0)
C) $\frac{1}{P_T}$ vs Time (0)
D) P_T vs Time (0)
E) P_{N_2} vs Time (0)

10. The hydrocarbon propyne has the following structure: $H_3C–C{\equiv}CH$. The standard enthalpy for the complete combustion of 1 mole of propyne is –1938 kJ mol^{-1}. If the standard enthalpies for the complete combustion of 1 mole of propane and 1 mole of hydrogen are –2220 kJ mol^{-1} and –286 kJ mol^{-1} respectively, the standard enthalpy for the complete hydrogenation of 1 mole of propyne to propane is equal to:

A) – 4730 kJ mol^{-1} B) + 3586 kJ mol^{-1} C) + 4.00 x 10^2 J mol^{-1}
D) + 290 kJ mol^{-1} E) – 290 kJ mol^{-1}

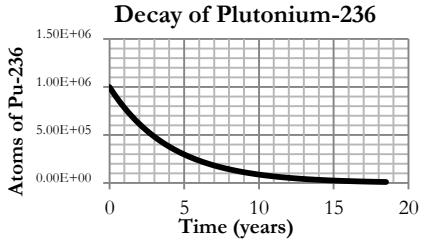
11. Sulfuric acid, nitrogen dioxide gas and water are produced when elemental sulfur (S) is immersed in nitric acid in a laboratory experiment. If 3.00 g of sulfur are mixed with 600.0 mL of 1.00 mol L^{-1} nitric acid, what volume of nitrogen dioxide will be formed at 0°C and 100 kPa?

A) 2.10 L B) 2.23 L C) 8.40 L D) 12.7 L E) 13.4 L

12. A 100.0 mL sample of 0.0875 mol L^{-1} HOCl, a weak monoprotic acid with a K_a= 3.0 x 10^{-8}, reacts with solid sodium hydroxide. If 0.0656 g of solid NaOH are added to the initial sample, calculate the final pH in this neutralization reaction. Assume there are no volume changes in the solution.

A) pH = 4.79 B) pH = 6.89 C) pH =7.00
D) pH = 7.11 E) pH = 8.16

13. The following graph represents the decay of radioactive Plutonium-236.



What is the half-life of Plutonium-236?

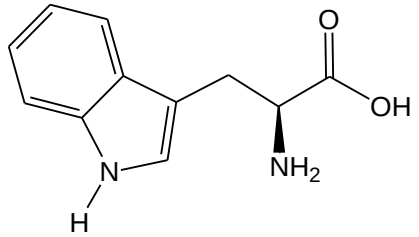
A) 0.500 years B) 2.86 years C) 5.72 years
D) 10.0 years E) 15.0 years

14. The boiling point of chlorine (–35°C) is higher than that of hydrogen chloride (–85°C) because

A) the London dispersion forces between the larger Cl_2 molecules are stronger than the intermolecular forces between the smaller HCl molecules
B) there are hydrogen bonds between the HCl molecules in addition to the London dispersion forces
C) there are dipole-dipole forces between the HCl molecules in addition to the London dispersion forces
D) the covalent bonds in the Cl_2 molecules are stronger than the bonds in the HCl molecules
E) the polar covalent bonds in the HCl molecules are stronger than the bonds in the Cl_2 molecules

Questions 15 and 16 relate to the following information

L-Tryptophan (structure below) is one of the essential amino acids in the human diet. It is a common medical myth that L-tryptophan consumed during a turkey dinner is responsible for the tiredness felt afterwards even though turkey does not contain an especially large proportion of L-tryptophan. Answer the following two questions about this compound.



L-tryptophan

15. How many lone pairs of electrons are there in L-tryptophan?

A) 2 B) 4 C) 6 D) 8 E) 12

16. What is the percentage by mass of oxygen found in L-tryptophan?

A) 5.90 % B) 13.7 % C) 15.7 % D) 22.8 % E) 64.7 %

17. What is the numerical value of the equilibrium constant for the reaction

$$2CO\,(g) + O_2\,(g) \rightleftharpoons 2CO_2\,(g)$$

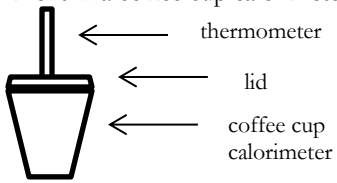
if the equilibrium concentrations are $[CO] = 2.0$ mol L^{-1}, $[O_2] = 1.0$ mol L^{-1}, and $[CO_2] = 8.0$ mol L^{-1}?

A) 1.0 B) 4.0 C) 8.0 D) 16 E) 32

18. Given the solubility product constant (K_{sp}) of silver phosphate (Ag_3PO_4) is 1.8×10^{-18}, the concentration of silver ions (in mol L^{-1}) in a saturated solution of silver phosphate is:

A) 2.6×10^{-10} B) 1.3×10^{-6} C) 1.6×10^{-5}
D) 3.7×10^{-5} E) 4.8×10^{-5}

19. You perform an experiment in a coffee cup calorimeter depicted below



You place 0.500 g of lithium metal in the calorimeter that already contains 75.0 mL of water. The specific heat capacity of water is 4.184 J g^{-1} K^{-1}. You can assume that all of the solutions in the reaction are dilute enough that they have the same density and specific heat capacity as water. Assume that the heat absorbed by the calorimeter is negligible.
You collect the following data:

Mass of lithium (g)	0.500
Mass of water in calorimeter (g)	75.0
Initial temperature of water (°C)	22.0
Final temperature of water (°C)	73.0

The reaction occurring in the calorimeter is

$$2\,Li\,(s) + 2\,H_2O\,(l) \rightarrow 2\,LiOH\,(aq) + H_2\,(g)$$

What is the enthalpy in kJ mol^{-1} for this reaction?

A) – 11.2 B) – 16.1 C) – 112 D) – 222 E) – 16100

20. Carbon tetrachloride reacts with oxygen at high temperatures to produce chlorine and carbonyl chloride

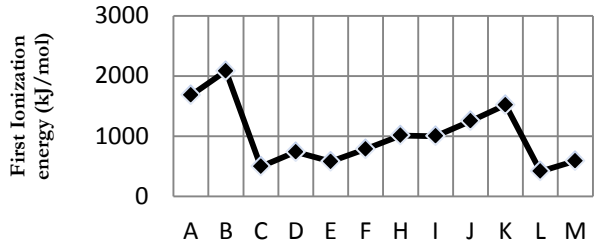
$$2\,CCl_4\,(g) + O_2\,(g) \rightleftharpoons 2COCl_2\,(g) + 2Cl_2\,(g); \quad K_c = 1.9 \times 10^{19}$$

Calculate the K_c for the following reaction:

$$COCl_2\,(g) + Cl_2\,(g) \rightleftharpoons \tfrac{1}{2}\,O_2\,(g) + CCl_4\,(g)$$

A) 5.3×10^{-20} B) -1.9×10^{19} C) -9.5×10^{-20}
D) 9.5×10^{-20} E) 2.3×10^{-10}

21. Below is a selection of unidentified consecutive elements on the periodic table (the atomic number increases by 1 from A to B and so on).



An element that is likely to be a halogen is:

A) A B) B C) C D) H E) M

22. A solution labelled "concentrated sulfuric acid" is found to be a 65.0% solution of H_2SO_4 by mass and has a density of 1.55 g mL^{-1} at 20°C. The pK_b = 4.74 for ammonia (NH_3), and a concentrated solution of ammonia is 28.0 % ammonia by mass and has a density of 0.898 g mL^{-1} at 20°C. What is the maximum volume of the concentrated solution of ammonia that can be completely neutralized by 10.0 mL of the concentrated solution of sulfuric acid?

A) 6.98 mL B) 10.7 mL C) 14.0 mL D) 20.9 mL E) 21.4 mL

23. When an object is silver plated, cyanide ions are added to the electrolyte to keep the silver ions in solution as a soluble silver cyanide complex. The **unbalanced** oxidation and reduction half-reactions are given below:

Oxidation: $CN^-(aq) + Ag(s) \rightarrow Ag(CN)_2^-(aq)$

Reduction: $O_2(g) + 4H^+(aq) \rightarrow 2H_2O(l)$

In acidic solution, the balanced chemical reaction is:

A) $8CN^-(aq) + 4Ag(s) + O_2(g) + 4H^+(aq) \rightarrow 4Ag(CN)_2^-(aq) + 2H_2O(l)$

B) $2CN^-(aq) + Ag(s) + O_2(g) + 4H^+(aq) \rightarrow Ag(CN)_2^-(aq) + 2H_2O(l)$

C) $4CN^-(aq) + 2Ag(s) + O_2(g) + 4H^+(aq) \rightarrow 2Ag(CN)_2^-(aq) + 2H_2O(l)$

D) $2CN^-(aq) + Ag(s) + \frac{1}{2}O_2(g) + 2H^+(aq) \rightarrow Ag(CN)_2^-(aq) + H_2O(l)$

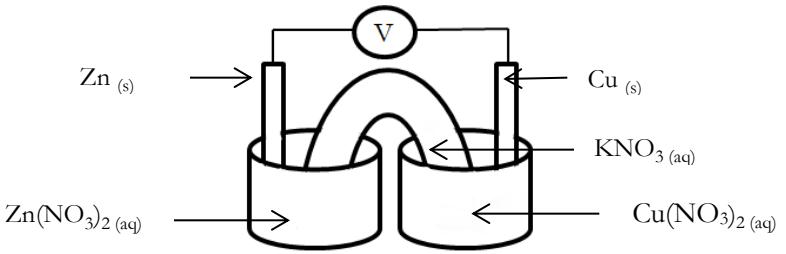
E) $6CN^-(aq) + 3Ag(s) + \frac{1}{2}O_2(g) + 2H^+(aq) \rightarrow 3Ag(CN)_2^-(aq) + H_2O(l)$

Use the following Standard Reduction Potentials for questions 24 and 25

$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	E° = + 1.23 V
$Ag^+ + e^- \rightarrow Ag$	E° = + 0.80 V
$Cu^{2+} + 2e^- \rightarrow Cu$	E° = + 0.34 V
$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2O + H_2SO_3$	E° = + 0.20 V
$Zn^{2+} + 2e^- \rightarrow Zn$	E° = – 0.76 V
$2H_2O + 2e^- \rightarrow H_2 + 2\,OH^-$	E° = – 0.83 V

24. Which of the following statements is true for the following galvanic cell?

I. The copper electrode gains mass
II. The copper electrode is the cathode
III. The direction of electron flow in the wire is from the copper electrode to the zinc electrode



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

25. Electrolysis of a $CuSO_4$ solution with two copper electrodes:

I. Will produce copper at the cathode
II. Will produce hydrogen gas at the anode
III. Will occur if a battery has a potential of 1.5 V

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

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