THE CANADIAN CHEMISTRY CONTEST 2011

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. Copper (II) sulfate pentahydrate is a compound commonly used in high school laboratories. The MSDS label classifies this compound as a moderate health hazard (Level 2). Which of the following symbol(s) should appear on a WHMIS label of solid copper(II) sulfate pentahydrate?

I.  II.  III. 

A. I only B. II only C. III only

D. II and III only E. I, II and III

2. What is the electron configuration of the cation in $NiCl_2 \cdot 6\ H_2O$?

A. [Ar] $4s^2 3d^6$ **B. [Ar] $3d^8$** C. [Ar] $4s^2 3d^8$

D. [Ar] $4s^2 3d^5$ E. [Ar] $3d^7$

3. Given the following table of **fifth** ionization energies in kJ mol^{-1} for successive elements in the same period of the periodic table:

Fifth ionization energy (kJ mol^{-1})	16,100	6,270	6,950	6,560
Element	A	B	C	D

Element A is most likely in group:

A. 14 B. 15 C. 16 D. 17 E. 18

4. Nitric oxide is made from the oxidation of ammonia at high temperatures and in the presence of a platinum catalyst according to the **unbalanced** equation:

$$\_\_\_\ NH_3\ (g) + \_\_\_\ O_2\ (g) \rightarrow \_\_\_NO\ (g) + \_\_\_H_2O\ (g)$$

Assuming the reactants and the products are at the same temperature and pressure and excess ammonia reacts with 13.96 L of oxygen gas to produce 8.96 L of nitric oxide, what is the percent yield of the reaction?

A. 19.8 % B. 51.3 % C. 64.2 % **D. 80.2 %** E. 95.4 %

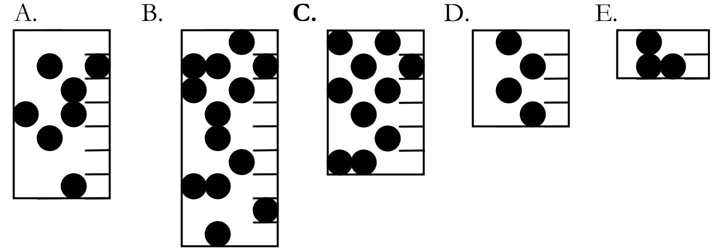
5. When the elements S, Al, Ar, Cl, Ga are ranked in order of increasing magnitude (smallest to largest) exothermic electron affinity, the order is:

A. Al, Ga, S, Cl, Ar B. Ga, Al, S, Cl, Ar C. Ar, Cl, S, Al, Ga

D. Cl, S, Ga, Al, Ar **E. Ar, Ga, Al, S, Cl**

6. Each of the following represents a cylinder at 25°C with molecules of a theoretical gas W whose relative number of particles is represented by the black circles. The cylinder containing the gas at the highest pressure is:

A. B. **C.** D. E.



7. A cold pack used for first aid contains solid ammonium nitrate that dissolves in water when the pack is activated. This entropy-driven reaction rapidly cools the pack. Given the data in the table below, what is the standard molar Gibbs free energy change, $\Delta G^{\ominus}$, for the reaction taking place in the cold pack? ($\Delta G = \Delta H - T\Delta S$)

Ammonium nitrate	Standard molar values at 25°C	
	Enthalpy change of formation ($\Delta H_f^{\ominus}$) kJ mol^{-1}	Entropy, ($S^{\ominus}$) J mol^{-1} K^{-1}
Crystalline solid	–365.6	151.1
Aqueous solution	–339.9	259.8

A. – 32.4 kJ mol^{-1} B. – 25.7 kJ mol^{-1} **C. – 6.7 kJ mol^{-1}**

D. + 25.7 kJ mol^{-1} E. + 108.7 kJ mol^{-1}

8. What is the pH of a solution in which 35.0 mL of 0.067 mol L^{-1} of $Ba(OH)_2$ is mixed with 50.0 mL of 0.050 mol L^{-1} HBr?

A. 1.59 B. 1.89 C. 7.00 D. 12.11 **E. 12.41**

9. At 100°C, the ionic product K_w for water is 5.13×10^{-13}. Which statement best describes pure water at its boiling point?

A. pH = 7.0; the water is neither basic nor acidic.
B. pH = 6.14; the water is neither basic nor acidic.
C. pH = 6.14; the water is acidic.
D. pH = 6.14; the water is basic.
E. the value of K_w decreases when water temperature increases.

10. A saturated solution of BaF_2 is obtained when 6.3×10^{-3} moles of BaF_2 are dissolved in 1 litre of water. What is the K_{sp} of barium fluoride?

$$BaF_2\ (s) \rightleftharpoons Ba^{2+}\ (aq) + 2F^-\ (aq)$$

A. 6.3×10^{-3} B. 2.5×10^{-5} C. 4.0×10^{-5} **D. 1.0×10^{-6}** E. 2.5×10^{-7}

11. Acetylene (ethyne), which is used in welding, produces a very hot flame when burned in oxygen according to the following equation:

$$H{-}C{\equiv}C{-}H\ (g) + 2\tfrac{1}{2}\ O_2\ (g) \rightarrow 2CO_2\ (g) + H_2O\ (g)$$

Propyne, $H{-}C{\equiv}C{-}CH_3$ (g), can be more easily stored and is used in preference to acetylene as a rocket fuel. The average molar bond energies (BE) are given in the table below:

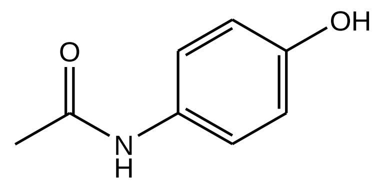
Bond	C–C	C–H	O=O	C=O	O–H	C≡C
BE (kJ mol^{-1})	346	411	494	745	459	835

How much more energy is released when one mole of propyne is completely burned in oxygen compared with one mole of ethyne (under standard conditions)?

A. 499 kJ mol^{-1} B. 845 kJ mol^{-1} C. 1006 kJ mol^{-1}

D. 1505 kJ mol^{-1} E. 2408 kJ mol^{-1}

12. Acetaminophen (structure below) is marketed in North America as an analgesic (to relieve pain) and an antipyretic (to reduce fever) under the tradename Tylenol®.



acetaminophen

Which of the following statements concerning acetaminophen is **TRUE**?

A. It is not classed as an aromatic compound.
B. It has an amide functional group.
C. Its chemical formula is $C_7H_9NO_2$.
D. It has a ketone functional group.
E. It does not contain any polar covalent bonds.

13. For the general reaction L + M $\rightarrow$ LM the initial rate data are given in the table below:

[L] (mol L^{-1})	[M] (mol L^{-1})	Rate (mol L^{-1} s^{-1})
0.10	0.10	0.050
0.20	0.10	0.20
0.30	0.30	0.45

The rate law for this reaction is:

A. Rate = $[L]^1[M]^2$ B. Rate = $[L]^2[M]^1$ C. Rate = $[L]^2[M]^2$

D. Rate = $[L]^2$ E. Rate = $[L]^1[M]^1$

14. A mixed oxide has the formula X_7O_8. If element X exists as both X^{2+} and X^{3+} in the compound, what is the ratio of X^{2+}/X^{3+}?

A. 0.438 B. 0.875 C. 1.14 D. 2.29 **E. 2.50**

15. In the following reaction, which are the Brønsted-Lowry acids?

$$HCO_3^- (aq) + H_2O (l) \rightleftharpoons H_3O^+ (aq) + CO_3^{2-} (aq)$$

A. HCO_3^- (aq) and H_3O^+(aq)
B. HCO_3^- (aq) and CO_3^{2-}(aq)
C. H_2O(l) and H_3O^+(aq)
D. H_2O(l) and CO_3^{2-} (aq)
E. HCO_3^- (aq) and H_2O(l)

16. Valeric (pentanoic) acid, $C_5H_{10}O_2$, is found naturally in the perennial flowering plant *Valeriana officinalis*, from which it gets its name. Including valeric acid itself, how many five-carbon compounds exist that contain a carboxylic acid functional group and are constitutional isomers of one another?

A. 2   B. 3   **C. 4**   D. 5   E. 6

17. Oxalic acid, $C_2H_2O_4$, reacts with the permanganate ion according to the equation:

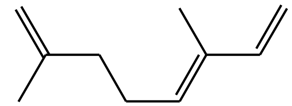
$$5\ C_2H_2O_4\ (aq) + 2\ MnO_4^-\ (aq) + 6\ H^+\ (aq) \rightarrow 2\ Mn^{2+}\ (aq) + 10\ CO_2\ (g) + 8\ H_2O\ (l)$$

If 25.0 mL of 0.0150 mol L^{-1} $KMnO_4$ reacts with 25.0 mL of 0.0208 mol L^{-1} $C_2H_2O_4$, how many moles of carbon dioxide gas will be produced?

A. 3.75×10^{-4} mol   B. 5.20×10^{-4} mol   C. 8.95×10^{-4} mol

D. 1.04×10^{-3} mol   E. 1.88×10^{-3} mol

18. α-Ocimene (structure below) is a monoterpene substance found within a variety of flowers and fruits. It has a characteristic citrus scent and can exist as geometric isomers.



α-ocimene

Ignoring any isomerism, which of the following represents the correct IUPAC name of α-ocimene?

A. 2,6-dimethylocta-2,6,8-triene

B. 3,7-dimethylocta-2,4,8-triene

C. 2-methylene-6-methylocta-5,7-diene

D. 2,6-dimethylocta-1,5,7-triene

E. 3,7-dimethylocta-1,3,7-triene

19. PETN was the explosive used by the Christmas Day bomber on Northwest Airline flight 253 to Detroit in 2009. The portability of PETN is one of the reasons that security on airlines in North America are so much more stringent today than they were 10 years ago. A sample of 0.2000 mol of PETN weighs 63.23 g and has the following percent composition by mass:

carbon	hydrogen	nitrogen	oxygen
18.99%	2.56%	17.72%	60.73%

The molecular formula of PETN is:

A. CH_5NO_2 B. $C_5H_2N_7O_{12}$ C. $C_6H_4N_4O_{11}$

D. $CH_8N_7O_{15}$ **E. $C_5H_8N_4O_{12}$**

20. Given the following standard electrode potentials

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ $\quad E° = +0.80$ V

$Cu^{2+}(aq) + 2e^{-} \rightarrow Cu(s)$ $\quad E° = +0.34$ V

Which of the following statements is/are TRUE for the standard electrochemical cell below?

$$Cu(s)|Cu^{2+}(aq)\ ||\ Ag^{+}(aq)|Ag(s)$$

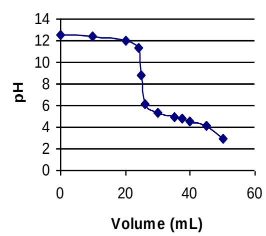
I the cathode reaction is $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^{-}$
II the cell potential is 1.14 V
III the silver electrode will increase in mass when the cell operates

A. I only B. II only **C. III only**

D. I and II E. II and III

21. The following graph shows the titration curve of:

A. a dilute strong base titrated with a strong acid
B. a concentrated weak base with a strong acid
C. a concentrated strong base with a weak acid
D. a dilute weak base with a weak acid
E. a dilute strong base with a weak acid



22. An equilibrium is established when one mole of hydrogen gas reacts with one mole of solid iodine and 51.8 kJ of energy (heat) are supplied. The product of the reaction is gaseous hydrogen iodide. The correct equilibrium constant expression for this reaction is:

A. $\dfrac{[H_2]\,[I_2]}{[HI]}$ B. $\dfrac{[H_2]\,[I_2]}{[HI]^2}$ C. $[H_2]\,[I_2]$

D. $\dfrac{[HI]^2}{[H_2]\,[I_2]}$ **E.** $\dfrac{[HI]^2}{[H_2]}$

23. The average human contains about 125 grams of potassium which is a mixture of 3 isotopes: K-39, K-40 and K-41. Only potassium 40 is radioactive and its relative abundance in a sample of potassium is 0.012%. If the half life of K-40 is 1.28 x 10^{9} years, how many K-40 atoms of the original 125 g will be present after 5.12 x 10^{9} years?

A. 1.41 x 10^{19} B. 2.26 x 10^{20} C. 1.13 x 10^{20}

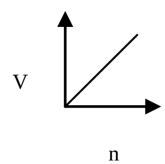
D. 5.65 x 10^{19} E. 2.83 x 10^{19}

24. Which **ONE** of the following species has a dipole moment?

A. XeF_4 B. SO_4^{2-} C. CCl_4

D. SeF_4 E. $PbCl_4$

25. Which one of the following graphs does NOT correctly describe the Ideal Gas Law?

A.


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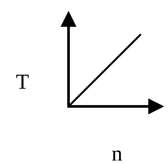
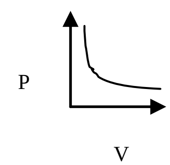
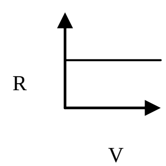
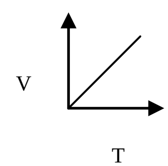


C.


D.


E.


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