# THE CANADIAN CHEMISTRY CONTEST 2008
for high school and CEGEP students
(formerly the National High School Chemistry Examination)
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 required, but no other data may be given. Answers should be marked on the Answer Grid provided.

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1. Sodium metal is kept under oil because it reacts violently with water, and more slowly with air. Which one of the following WHMIS symbols best informs you that a susbtance might react violently with air and/or water?

A.   B.   C.

D.   E.
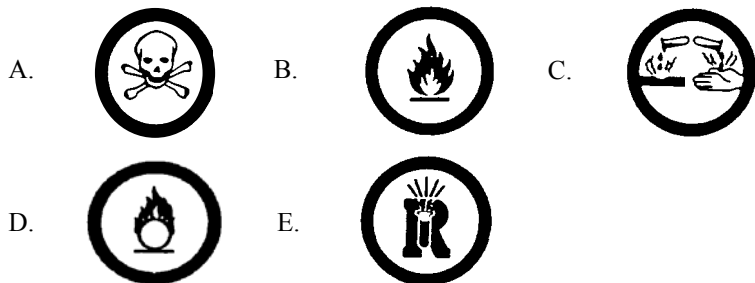
2. The number of neutrons in ^{121}Sb is:
A. −3   B. 51   C. 70   D. 121   E. 121.75

3. Isotopes are:

   A. Two elements in the same group of the periodic table
   B. Two elements in the same period of the periodic table
   C. Two molecules with the same formula but different arrangements of atoms
   D. Two atoms with the same number of neutrons but different numbers of protons
   E. Two atoms with the same number of protons but different numbers of neutrons

4. Which one of the following series of compounds is written in order of increasing oxidation state of chlorine:

   A. $NaClO_4 < NaClO_3 < NaClO_2 < NaClO$
   B. $NaClO_4 < NaClO < NaClO_3 < NaClO_2$
   C. $NaClO_3 < NaClO_2 < NaClO < NaClO_4$
   D. $NaClO < NaClO_2 < NaClO_3 < NaClO_4$
   E. $NaClO < NaClO_3 < NaClO_2 < NaClO_4$

5. The number of lone pairs of electrons on the central atom in the Lewis structures of CO_2, PF_3, $BrCl_3$, NH_2^-, NH_4^+ are, in order,

A. 0, 1, 1, 1, 0   B. 0, 1, 2, 2, 0   C. 0, 1, 2, 2, 1

D. 2, 1, 1, 1, 0   E. 2, 1, 1, 1, 1

6. Three electrons are removed from an iron atom. What is the electronic configuration of the resulting ion in its ground state?

   A. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$
   B. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
   C. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$
   D. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
   E. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$

7. The following chart shows the melting points of **oxides of consecutive elements** in the periodic table.
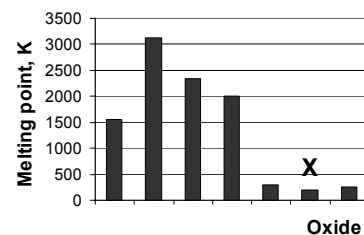
Which one of the following is a correct description of oxide X? It is:

   A. A covalent network substance that does not dissolve in water
   B. An ionic substance that dissolves in water to give an acidic solution
   C. An ionic substance that dissolves in water to give an alkaline solution
   D. A covalent molecular substance that dissolves in water to give an acidic solution
   E. A covalent molecular substance that dissolves in water to give an alkaline solution

8. At low temperatures ammonia is a liquid that boils at $-33°C$. This liquid is used as a solvent for some chemical reactions and can autoionize in a manner analogous to liquid water. In liquid ammonia the conjugate base of NH_3 is:

A. NH_2^- B. NH_3 C. NH_4^+ D. OH^- E. H_2O

9. Adipic acid, $HOOC(CH_2)_4COOH$, is an important chemical product used primarily to manufacture nylon. It is a diprotic acid with $K_{a1} = 3.9 \times 10^{-5}$ and $K_{a2} = 3.9 \times 10^{-6}$. If a saturated solution (approx. 0.1 mol L^{-1}) of adipic acid is titrated with 0.1 mol L^{-1} NaOH, which of the following values is closest to the pH when 1.5 mole NaOH have been added for each mole of adipic acid?

A. 4.4   B. 4.9   C. 5.4   D. 7.0   E. 12.3

10. Which of the following derivatives of benzene is the most acidic?

A.

B.

C.

D.

E.
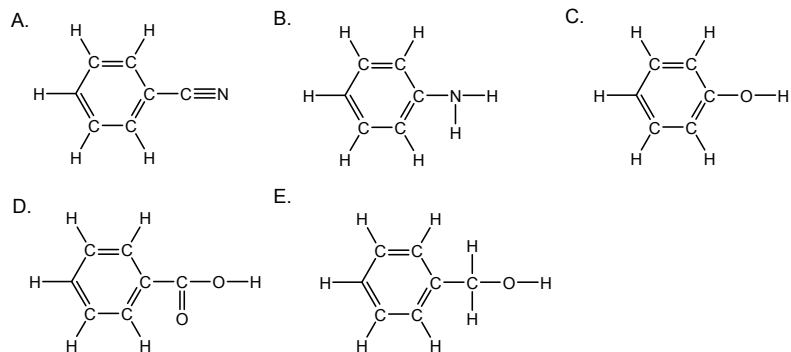
11. The reaction between manganese dioxide and hydrochloric acid may be written:

$$MnO_2(s) + 4H^+(aq) + 2Cl^-(aq) \rightarrow Mn^{2+}(aq) + 2H_2O(s) + Cl_2(g)$$
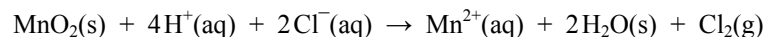
In this reaction
   A. Chlorine is oxidized and manganese is reduced
   B. Chlorine is reduced and manganese is oxidized
   C. Chlorine is reduced and hydrogen is oxidized
   D. Hydrogen is oxidized and manganese is reduced
   E. Oxidation and reduction do not occur

12. During the commercial electrolysis of brine by the membrane process, a concentrated solution containing approximately equal masses of sodium chloride and sodium hydroxide is partly evaporated at $100°C$ to give a mixture containing a solid and a solution. Using the solubility curves given below, determine which one of the statements about the mixture is correct:
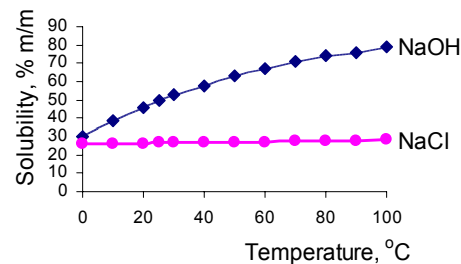
A. The solid contains mainly NaCl
B. The solid contains mainly NaOH
C. The solid contains equal masses of NaCl and NaOH
D. The solution contains equal masses of NaCl and NaOH
E. The solid and the solution each contain equal masses of NaCl and NaOH

13. Cryolite, Na_3AlF_6, is a mineral used in the Hall-Héroult process for producing aluminum. Cryolite can be synthesized by the following reaction:

$$6HF + Al(OH)_3 + 3NaOH \rightarrow Na_3AlF_6 + 6H_2O$$

How many kilograms of cryolite are produced if the reaction has a 94.3% yield and a limiting reagent of 27.8 kilograms of HF?

A. 15.0   B. 15.9   C. 45.9   D. 48.6   E. 275

14. In the titration of 25.00 mL of vinegar to find the concentration of ethanoic acid ($Mr = 60.1$) in a commercial sample, a student needed 22.50 mL of 0.0944 mol L^{-1} sodium hydroxide to reach the end point colour change. What is the concentration of ethanoic acid in the sample being analyzed? (The density of the solution is 1.00 g mL^{-1} at $25°C$.)

A. 0.0650 mol L^{-1} B. 0.0850 mol L^{-1} C. 0.1049 mol L^{-1}

D. 4.50 %   E. 5.00 %

15. Which of the following atoms has the largest atomic radius?

A. Ca   B. F   C. O   D. P   E. Si

16. Propenenitrile (acrylonitrile) is used in the manufacture of synthetic fibres and nitrile rubber. It can be made from propene using the following gas phase reaction:

$$CH_2=CH–CH_3 + NH_3 + 3/2 O_2 \rightarrow CH_2=CH–CN + 3 H_2O$$
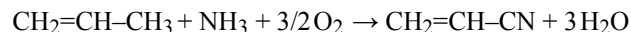
Which one of the following values corresponds to the correct standard enthalpy change for this reaction? Assume that the combustion of both reactants and products yields CO_2, H_2O and N_2, and that the enthalpy changes of combustion are $\Delta H_c^\ominus [CH_2=CH–CH_3] = – 2058.0 \text{ kJ mol}^{-1}$, $\Delta H_c^\ominus [NH_3] = – 382.8 \text{ kJ mol}^{-1}$, $\Delta H_c^\ominus [CH_2=CH–CN] = – 1756.4 \text{ kJ mol}^{-1}$.

A. $– 4197.2 \text{ kJ mol}^{-1}$ B. $– 684.4 \text{ kJ mol}^{-1}$ C. $– 41.0 \text{ kJ mol}^{-1}$
D. $+ 41.0 \text{ kJ mol}^{-1}$ E. $+ 684.4 \text{ kJ mol}^{-1}$

17. Some students are going to determine the rate of the following reaction:

$$2 MnO_4^-(aq) + 16 H^+(aq) + 5 C_2O_4^{2-}(aq) \rightarrow 2 Mn^{2+}(aq) + 10 CO_2(g) + 8 H_2O(l)$$
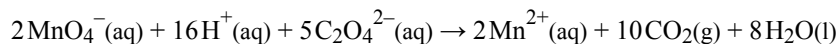
Which one of the following methods of monitoring the rate would NOT be possible? Measuring the change in the:

     A. pH of the solution
     B. mass of the solution
     C. volume of gas produced
     D. amount of precipitate produced
   E. intensity of the purple colour of the solution

18. In benzene solution, benzoic acid forms an equilibrium mixture with its dimer (double molecule), as shown in the following equation:

$$2 C_6H_5COOH \rightleftharpoons (C_6H_5COOH)_2$$
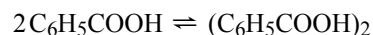
If the concentration of benzoic acid in the initial solution is 0.1 mol L^{-1}, and the concentration of dimer in the equilibrium solution is x mol L^{-1}, then which of the following expressions for the equilibrium constant is correct?

A. $x/(0.1 – x)^2$ B. $x/(0.2 – x)^2$ C. $x/2(0.1 – x)^2$
D. $x/(0.1 – x)$ E. $x/(0.1 – 2x)^2$

19. The following graph shows the relationship between the number of molecules with a particular kinetic energy (on the y axis) and the kinetic energy of these molecules (on the x axis), in a gas at a particular temperature. The gas is about to take part in a reaction for which the activation energy is E_a.

Number of molecules

Kinetic energy

X
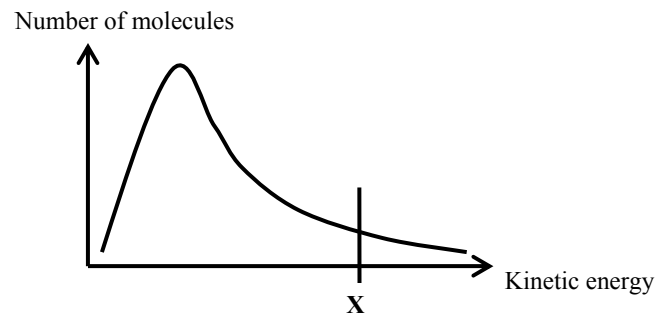
Which one of the following statements is always true?

A. X indicates the activation energy for any reaction
B. There are always some molecules with zero energy
C. The value of the activation energy depends on the temperature
D. The value of the activation energy depends on the reaction about to take place
E. The area under the curve represents the number of molecules that have enough energy to react

20. In the aluminum-air battery, an aluminum anode is oxidized in alkaline solution:

$$Al(s) + 4 OH^-(aq) \rightarrow Al(OH)_4^-(aq) + 3 e^-$$
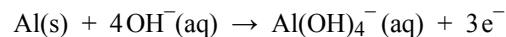
At the carbon-air cathode, oxygen is reduced by the half-reaction:

$$O_2(g) + 2 H_2O(l) + 4 e^- \rightarrow 4 OH^-(aq)$$
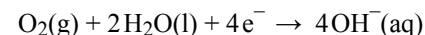
for which the standard reduction potential $E^\ominus (O_2, OH^-) = +0.40$ V. The standard voltage of the cell $E^\ominus_{cell} = 2.71$ V. We may conclude that the standard reduction potential at the anode, $E^\ominus (Al^{3+}, Al)$, is:

A. +3.11 V   B. +2.31 V   C. 0.00 V   D. –2.31 V   E. –3.11 V

21. Propyl ethanoate (below) is an organic substance with a characteristic odour of pears. How many constitutional isomers of propyl ethanoate exist that contain an ester functional group (not counting the one shown)?
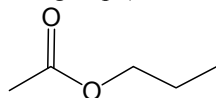
propyl ethanoate

A. 2   B. 3   C. 4   D. 6   E. 8

22. Modafinil (shown below) is an anti-narcoleptic drug that will reportedly suppress the need for sleep for up to 40 hours.
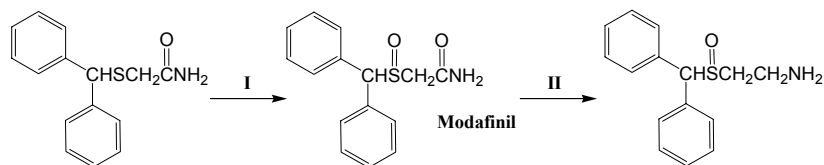

Modafinil

Identify which type of reaction is taking place during **I** and **II** and the nature of the nitrogen-containing functional group in modafinil.

|	I	II	Functional Group
A.	Reduction	Oxidation	Amide
B.	Oxidation	Reduction	Amide
C.	Oxidation	Substitution	Amide
D.	Oxidation	Elimination	Amine
E.	Oxidation	Reduction	Amine

23. Isoprene is an important hydrocarbon, containing two alkene functional groups, that is used to produce a synthetic version of natural rubber. When isoprene was treated with an excess of molecular bromine in dichloromethane solvent, compound **Q** was formed. Elemental analysis of **Q** showed it to be composed of 2.08% hydrogen and 82.43% bromine. What is the percentage of carbon present in isoprene?

A. 15.49%   B. 30.98%   C. 85.63%   D. 88.16%   E. 90.12%

24. Lyrica® is marketed by the pharmaceutical company Pfizer as an anticonvulsant drug used to treat generalised anxiety disorder. Lyrica® is also known by the chemical name 3-(aminomethyl)-5-methylhexanoic acid. Which of the following represents a molecule of Lyrica®?
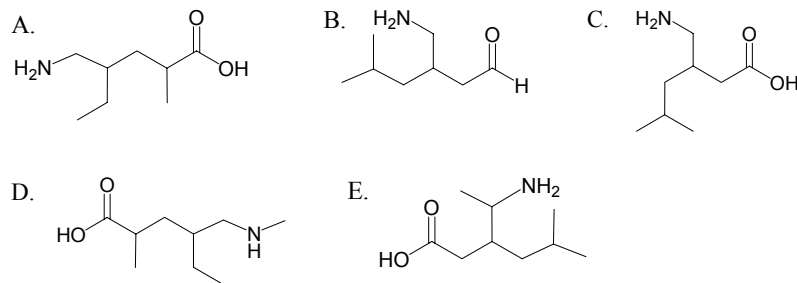
25. The In Situ Resource Utilization research for Mars has been evaluating a reaction between CO_2 (found in the Martian atmosphere) and H_2 (brought from Earth). This reaction produces water that can be electrolysed to give O_2 for use in the propellant needed for returning a rocket to Earth. The essential reaction is:

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$
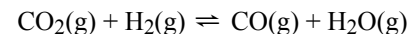
The reaction is performed at $400^{o}C$ with Fe/Cr as catalyst. If equimolar amounts of CO_2 and H_2 are mixed in a closed container, what is the approximate molar percentage of water in the mixture at equilibrium? (Keq ≈ 0.5 at $400^{o}C$)

A. 16%   B. 20%   C. 25%   D. 33%   E. 50%

**This is the end of Part A of the contest.
Now go back and check your work.**