THE CANADIAN CHEMISTRY CONTEST 2009
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 required, but no other data may be given. Answers should be marked on the Answer Grid provided.

1. You have been asked to insert a thermometer through a rubber stopper. There is resistance upon your first try. Which of the following actions should you take (in the correct order)?

   (i) Try to put the thermometer through again
   (ii) Wrap the thermometer with rubber tubing or paper towel
   (iii) Lubricate the bulb of the thermometer with water or glycerin
   (iv) Get a friend to hold the stopper while you push in the thermometer

   A. i   B. ii, i   C. iii, i   D. iii, iv   E. iii, ii, i

2. Which one of the following molecules contains a pair of atoms that share six electrons?

   A. CO_2 B. C_2H_2 C. C_2H_4 D. C_2H_6 E. C_6H_6

3. In which of the following substances does the bonding have the most ionic character?

   A. K   B. KBr   C. Br_2 D. HBr   E. H_2

4. When analysing water, each mole of dissolved oxygen (O_2) liberates two moles of iodine (I_2) through a series of complex redox reactions involving manganese and iodine. The amount of dissolved iodine is then accurately determined by titration with standard sodium thiosulfate solution. The balanced equation representing the titration is:

$$2\,Na_2S_2O_3 + I_2 \rightarrow 2\,NaI + Na_2S_4O_6$$
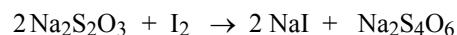
A 25.00-mL water sample required 18.64 mL of a 0.00113 mol L^{-1} sodium thiosulfate solution to titrate the amount of iodine present after the original treatment. What is the concentration of dissolved oxygen in this sample (in mg O_2 per litre of water)?

A. 0.211 mg O_2/L   B. 3.37 mg O_2/L   C. 6.74 mg O_2/L

D. 13.48 mg O_2/L   E. 18.64 mg O_2/L

5. In which one of the following molecules are the atoms NOT all in one plane?

A. C_2H_2 B. C_2H_4 C. C_2H_6 D. C_6H_6 E. CH_2O

6. The following graph shows the logarithm of successive ionization energies (log I.E. in kJ mol^{-1}) as the first 14 electrons are removed from atoms of one particular element.
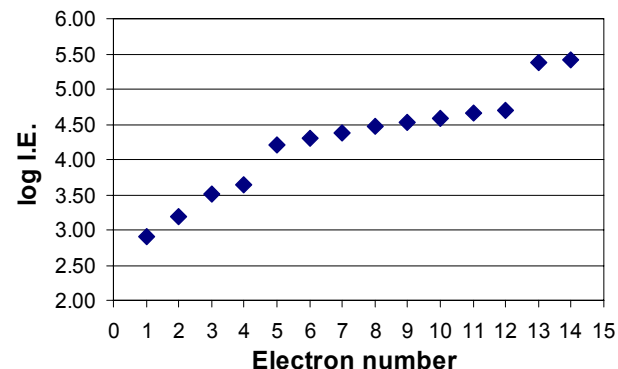
Which one of the following elements could this be?

A. Ca   B. Mg   C. S   D. Sn   E. Si

7. A student reported that in the synthesis of an iodide of tin, 0.500 g of tin and 2.00 g of iodine were completely consumed in the reaction. From these data, you can conclude that the formula of the tin iodide is:

A. SnI_2, with an experimental error of more than 10%
B. SnI_2, with an experimental error of less than 10%
C. SnI_4, with no appreciable experimental error
D. SnI_4, with an experimental error of more than 10%
E. SnI_4, with an experimental error of less than 10%

8. Given the following data:

Hydrogen halide	HF	HCl	HBr	HI
Boiling point, K	293	188	206	238

Which one of the following statements about the hydrogen halides can be deduced from these data?

A. HF has the strongest intramolecular bonding
B. HF has the strongest intermolecular bonding
C. HCl has the strongest intramolecular bonding
D. HCl has the strongest intermolecular bonding
E. HI has the strongest intramolecular bonding

9. Aluminium reacts with oxygen to produce aluminium oxide. If 6.00 g of aluminium is reacted with 6.00 g of oxygen gas, what is the maximum mass of aluminium oxide that can be produced?

A. 8.25 g Al_2O_3 B. 9.40 g Al_2O_3 C. 11.3 g Al_2O_3

D. 12.7 g Al_2O_3 E. 19.2 g Al_2O_3

10. A 2.0 cm length of magnesium ribbon was added to 100 mL of 2.0 mol L^{-1} hydrochloric acid. All the magnesium reacted and the temperature of the acid increased by $20^{\circ}C$.

What volume of 2.0 mol L^{-1} hydrochloric acid would produce a temperature rise of $10^{\circ}C$ with a 1 cm length of magnesium ribbon?

A. 20 mL   B. 25 mL   C. 50 mL   D. 100 mL   E. 200 mL

11. A sample of baking soda of total mass 0.364 g is composed of sodium hydrogen carbonate, $NaHCO_3$, mixed with a non-volatile impurity. When heated, the sodium hydrogen carbonate decomposes to sodium carbonate, Na_2CO_3, and there is a loss in mass of 0.112 g. The purity of the $NaHCO_3$ mixture was:

A. 30.8%   B. 50.0%   C. 69.2%   D. 83.3%   E. 90.3%

12. In an experiment to determine the percentage of water in a mixture of water and propanone (acetone), a 9.95-mL sample of a liquid mixture of propanone and water was weighed:

Experimental data: Mass of flask and sample = 103.639 g
                   Mass of flask alone   = 94.604 g
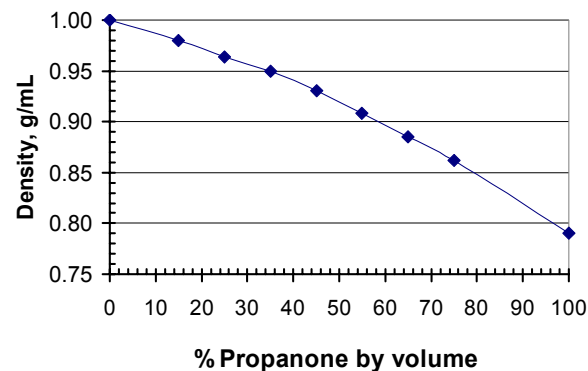
From the experimental data and the calibration graph shown above, what was the percentage of water by volume in the mixture?

A. 32%   B. 42%   C. 58%   D. 68%   E. 75%
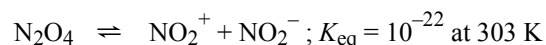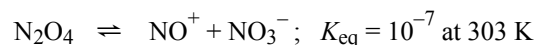
13. Which of the following aqueous solutions has the highest numerical value of pH?

A. Pure water   B. 0.01 M KBr   C. 0.01 M HBr

D. 0.01 M NH_4Br E. 0.01 M CH_3COOK

14. Zinc hydroxide is used in surgical dressings. Given that its solubility product constant, K_{SP} ($Zn(OH)_2$) = 4.15 x 10^{-17}, what is the concentration of hydroxide ions in a saturated solution of zinc hydroxide?

A. 2.2 x 10^{-6} mol L^{-1} B. 1.5 x 10^{-6} mol L^{-1} C. 3.5 x 10^{-6} mol L^{-1}

D. 4.4 x 10^{-6} mol L^{-1} E. 6.9 x 10^{-6} mol L^{-1}

15. Dinitrogen tetroxide is often a component in smog: it is corrosive, highly toxic and oxidising. It undergoes three different types of self dissociation according to the following equations:

$$N_2O_4 \rightleftharpoons 2\,NO_2 ; \qquad K_{eq} = 10^{-2} \text{ at 303 K}$$

$$N_2O_4 \rightleftharpoons NO^+ + NO_3^- ; \quad K_{eq} = 10^{-7} \text{ at 303 K}$$

$$N_2O_4 \rightleftharpoons NO_2^+ + NO_2^- ; \, K_{eq} = 10^{-22} \text{ at 303 K}$$

Assuming that no other reactions are taking place, which one of the following species will be present in the greatest concentration at 303K?

A. NO^+ B. NO_2^+ C. NO_2^- D. NO_3^- E. N_2O_4

16. The polymer sodium poly(aspartate) (used as an anti-scaling agent) is manufactured by initially heating the amino acid known as aspartic acid at 180°C, causing a condensation polymerization to occur. This is followed by reaction with sodium hydroxide to form the final polymer, which has two repeating units (structure below).

sodium poly(aspartate)
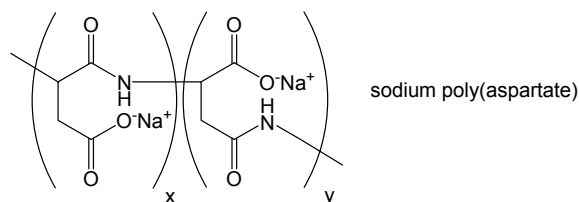
What type of polymer is sodium poly(aspartate)?

A. a polyamide   B. a polyester   C. a rubber

D. polynucleotide   E. a polysaccharide

17. In one type of breathalyser used to detect alcohol in a driver's breath, an orange solution of potassium dichromate ($K_2Cr_2O_7$) in dilute sulfuric acid reacts with alcohol (if present) to form green $Cr_2(SO_4)_3$, and the intensity of the green colour is measured. In this reaction, what is the change in the oxidation number of each chromium atom?

A. --6   B. --3   C. 0   D. +3   E. +6

18. In aqueous solution the Fe^{3+} ion is bound to six water molecules and forms the hydrated ion $Fe(H_2O)_6^{3+}$. Many salts of this ion form acidic solutions, for example in red iron-containing soils. The cause of this acidity is that the hydrated ion

A. can add a water molecule to form $Fe(H_2O)_7^{3+}$

B. can lose a water molecule to form $Fe(H_2O)_5^{3+}$

C. can lose a hydroxide ion from a water molecule to form $FeH(H_2O)_5^{4+}$

D. can lose a proton from a water molecule to form $FeOH(H_2O)_5^{2+}$

E. can lose a proton from the iron nucleus to form $Mn(H_2O)_6^{2+}$

19. Pyrrolidine is a weak base found in carrot leaves, with formula C_4H_9N and structure as shown below.
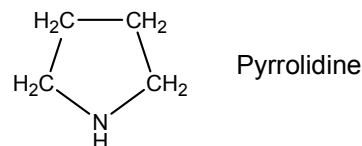
Pyrrolidine

The pH of a 1.00×10^{-3} mol/L solution of pyrrolidine in water is measured to be 10.82. The value of the ionization constant K_b of this base is

A. 1.3×10^{-3} B. 4.4×10^{-4} C. 2.3×10^{-19} D. 6.7×10^{-19} E. 1.9


20. A test for hydrogen iodide (a colourless gas) is to insert a hot platinum rod into the gas, which will then turn purple due to the formation of iodine gas according to the following equation:
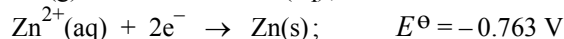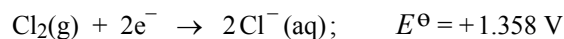
$$2\,HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

Based on this information, which combination of the following statements about the forward reaction is correct:

	Type of reaction	Enthalpy
A.	Endothermic	Decreases
B.	Endothermic	Increases
C.	Exothermic	Decreases
D.	Exothermic	Increases
E.	Neither exothermic nor endothermic	Does not change

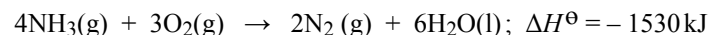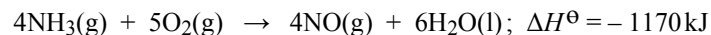21. A possible battery system for electric cars is the zinc-chlorine battery, in which the overall reaction is:

$$Zn(s) + Cl_2(g) \rightarrow ZnCl_2(aq)$$
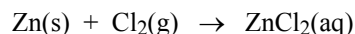
What is the overall voltage of each battery cell under standard conditions, given the following reduction potentials:

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq); \quad E^\ominus = +1.358 \text{ V}$$
$$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s); \quad E^\ominus = -0.763 \text{ V}$$

A. 0.168 V   B. 0.595 V   C. 1.943 V   D. 2.121 V   E. 3.469 V

22. The standard enthalpy change of formation of nitric oxide, $\Delta H^\ominus_f(NO)$, cannot be determined directly from the elements but it can be calculated using the following thermodynamic equations:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l); \quad \Delta H^\ominus = -1170 \text{ kJ}$$
$$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l); \quad \Delta H^\ominus = -1530 \text{ kJ}$$

What is the value of $\Delta H^\ominus_f(NO)$ as found from these equations?

A. $+90 \text{ kJ mol}^{-1}$ B. -90 kJ mol^{-1} C. $+360 \text{ kJ mol}^{-1}$
D. -360 kJ mol^{-1} E. $+2700 \text{ kJ mol}^{-1}$

23. Halomon (structure below) is a polyhalogenated hydrocarbon initially isolated from *Portieria hornemannii*, a red algae. This substance has cytotoxic properties and has important potential as an anti-cancer drug.
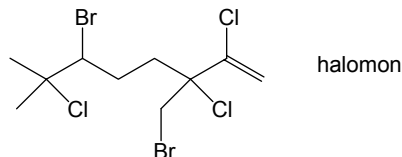

halomon

Which of the following represents the correct IUPAC name of halomon?

A. 6-bromo-3-(bromomethyl)-2,3,7-trichloro-7-methyloct-1-ene

B. 3-bromo-6-(bromomethyl)-2,6,7-trichloro-2-methyloct-7-ene

C. 6-bromo-3-(bromomethyl)-7-methyl-2,3,7-trichlorooct-1-ene

D. 6-bromo-3-(bromoethyl)-2,3,7-trichloro-7-methyloct-1-ene

E. 3,6-dibromo-2,6,7-trichloro-2-methyloct-7-ene

24. Each of the following organic substances has the chemical formula $C_5H_{12}O_2$ and is a liquid at room temperature and pressure. Which one has the highest boiling point?

A.   B.   C.

D.   E.
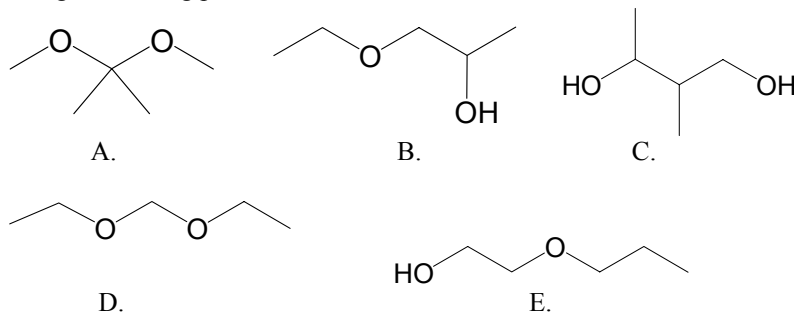
25. Farnesol (structure below) is an organic substance used in perfumery to emphasise the odours of floral fragrances, and is a natural pesticide for mites. How many different stereoisomeric (geometric) structures of farnesol are possible?

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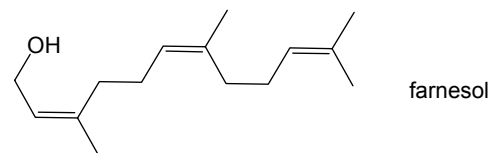
A. 2   B. 3   C. 4   D. 6   E. 8

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