THE CANADIAN CHEMISTRY CONTEST 2010

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.

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1. What WHMIS symbol(s) would be found on a bottle of methanol?

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 ground state electron configuration of the cation present in potassium chloride?

B. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ **B. $1s^2 2s^2 2p^6 3s^2 3p^6$** C. $1s^2 2s^2 2p^6 3s^2 3p^5$

D. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ E. $1s^2 2s^2 2p^6 3s^2 3p^3$

3. For the ion $^{31}P^{3-}$, the number of protons, neutrons, electrons, the atomic number, and the mass number, respectively, are:

A. 15, 16, 15, 15, 31 **B. 15, 16, 18, 15, 31** C. 31, 31, 3, 15, 30.9737

D. 15, 31, 18, 15, 30.9737 E. 15, 16, 12, 15, 31

4. If the yield for the following reaction is 65.0% by mass, what mass of $KClO_3$ is needed to produce 32.0 g of O_2?

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

A. 53. 1 g B. 81.7 g C. 62.8 g D. 283 g **E. 126 g**

5. Cobalt–60 has practical applications for cancer treatment and in the irradiation of food to kill bacteria such as *E–coli*. In its ground state, the number of unpaired electrons in cobalt is:

A. 0 B. 1 C. 2 **D. 3** E.4

6. The concentration of sulfite ions ($SO_3^{2-}(aq)$) in wastewater from the pulp and paper industry can be analyzed by titration with permanganate ion under acidic conditions. The titration makes use of a redox reaction which may be represented as:

$$\_\_\_SO_3^{2-}(aq) + \_\_\_MnO_4^{-}(aq) \rightarrow \_\_\_SO_4^{2-}(aq) + \_\_\_Mn^{2+}(aq)$$

This is an unbalanced partial equation, showing only the oxidized and reduced species with no stoichiometric coefficients. If the complete balanced equation is considered, how many moles of $KMnO_4$ react with each mole of sulfite ion?

A. 0.2 **B. 0.4** C. 1 D. 2.5 E. 5

7. When the elements Cl, Mg, P, S, and Si, are ranked in order of increasing atomic radius (smallest to largest) the order is:

A. Mg, Si, P, S, Cl B. Si, Mg, P, S, Cl **C. Cl, S, P, Si, Mg**

D. Si, Mg, Cl, S, P E. Cl, Mg, P, S, Si

8. The following thermite reaction is used for welding when space and weight limit the use of conventional welding equipment. Balance the chemical equation given below and determine the mass of Mg needed to produce 15.0 kg of Fe:

$$\_\_\_ Fe_2O_3(s) + \_\_\_ Mg(s) \rightarrow \_\_\_ MgO(s) + \_\_\_ Fe(s)$$

A. 9.80 kg B. 5.20 kg C. 6.50 kg D. 4.40 kg E. 3.40 kg

9. For the following reaction, what volume of aqueous 0.260 mol L^{-1} Na_2S is needed to react with 25.0 mL of 0.315 mol L^{-1} $AgNO_3$?

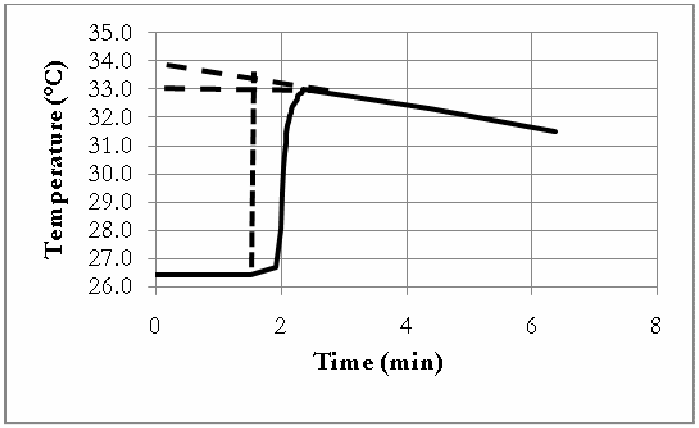
$$Na_2S(aq) + 2AgNO_3(aq) \rightarrow 2NaNO_3(aq) + Ag_2S(s)$$

A. 25.0 mL B. 30.3 mL C. 20.3 mL D. 60.6 mL **E. 15.1 mL**

10. Equimolar amounts of two gases (X and Y) are mixed in a 1.00L container at room temperature and pressure. Gas Y has a molar mass that is twice that of gas X. Which **one** of the following statements is FALSE for the mixture of gases X and Y?

A. On average, molecules of gas X move faster than molecules of gas Y.
B. The kinetic energy distributions of the two gases are identical.
C. Gas X makes less of a contribution to the average density of the mixture than gas Y.
D. Gas X has a smaller partial pressure than gas Y.
E. The mole fractions of gas X and gas Y are identical.

11. The solid line on the following graph represents data collected from a reaction in a constant-pressure coffee cup calorimeter:



Which **one** of the following statements is TRUE?

A. The temperature change for this experiment cannot be measured because of the loss of heat from the calorimeter
B. The maximum temperature used for the ΔT calculation is 33.0°C
C. The faster the reaction, the more precise the data
D. The point at which the reaction begins must be taken into account to correctly measure the change in temperature
E. The rate of heat loss can be measured by extrapolation of the final slope to the y–axis

12. Given K_a values of 1.8×10^{-4} and 6.8×10^{-4} for methanoic acid (HCOOH) and nitrous acid (HNO_2) respectively, calculate the equilibrium constant for the following reaction.

$$NO_2^- + HCOOH \rightleftharpoons HNO_2 + HCOO^-$$

A. 8.6×10^{-4} **B. 0.26** C. 1.2×10^{-7} D. 5.0×10^{4} E. 3.8

13. Fluorine reacts explosively with hydrogen to form hydrogen fluoride, even in the dark. If a 1.00 g sample of fluorine gas reacts completely with excess hydrogen gas and releases 14.27 kJ of heat, the heat of formation of 1 mol of HF(g) is:

A. 813 kJ B. –542 kJ C. 136 kJ D. –1084 kJ **E. –271 kJ**

14. There has been a lot in the news about the shortage of medical isotopes. Technetium–99m is one of the isotopes in short supply because of reactor shutdowns at key production sites, one of which is in Chalk River, Ontario. Tc–99m is favoured in medical applications because it has a relatively short half–life and thus exposes patients to less radiation than some other options. From the data below determine the half–life for the decay of Tc–99m:

Time (min)	[Tc–99m] mol L^{-1}
0	0.891
60	0.794
120	0.708
180	0.630
240	0.562
300	0.501
360	0.446
420	0.398

A. 1 hour B. 3 hours C. 5 hours **D. 6 hours** E. 7 hours

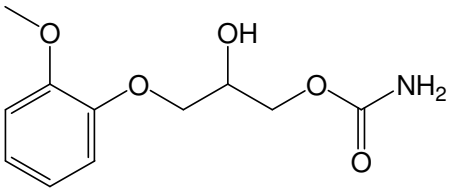
15. For the reaction aA + bB +cC ⇌ dD + eE, the following data are available:

[A] (mol L^{-1})	[B] (mol L^{-1})	[C] (mol L^{-1})	Initial Rate (mol $L^{-1}s^{-1}$)
0.60	0.60	0.60	320
0.30	0.60	0.60	160
0.90	0.15	0.30	30
0.60	0.15	0.60	20

What is the order of reaction with respect to C?

A. Zero B. First C. Second
D. Third E. Cannot be determined

16. The active ingredients in Robaxacet®, an over–the–counter painkiller, are methocarbamol (structure below, molar mass = 241.2 g mol^{-1}) and acetaminophen (formula $C_8H_9NO_2$, molar mass = 151.1 g mol^{-1}). Methocarbamol is a relaxant used to treat muscular spasms.



methocarbamol

Calculate the total percentage of oxygen present by mass in the active ingredients of a Robaxacet® tablet containing 400 mg of methocarbamol and 500 mg of acetaminophen.

A. 21.2% B. 24.3% **C. 26.5%** D. 28.5% E. 33.2%

17. Copper can be electroplated onto a cathode of another metal from a solution of copper (II) nitrate. If the current used for the electrolysis is 1.62 C s^{-1}, how much copper can be deposited on the cathode in one hour?

A. 1.92 g B. 3.79 g C. 3.84 g D. 5.67 g E. 7.68 g

18. What is the pH of a solution at 25°C if the concentration of OH^- ion is 100 times greater than the concentration of H_3O^+ ion?

A. 2 B. 6 **C. 8** D. 12 E. 14

19. Buffer solutions contain a weak acid together with its conjugate base. If the ionization constant (K_a) of acetic acid is 1.8 x 10^{-5}, what mass of sodium acetate ($NaC_2H_3O_2$) must be dissolved in 400 mL of 0.20 mol L^{-1} acetic acid to obtain a buffer with a pH of 5.0?

A. 30 g **B. 12 g** C. 8.6 g D. 3.6 g E. 2.7 g

20. The ionization constant (K_b) of ethylamine ($C_2H_5NH_2$) is 4.3 x 10^{-4}, while that of aniline ($C_6H_5NH_2$) is 7.4 x 10^{-10}. The conjugate acids of these bases are the ethylammonium ion and the anilinium ion. It follows that:

A. Ethylamine is a stronger base than aniline and the ethylammonium ion is a stronger acid than the anilinium ion.
B. Ethylamine is a stronger base than aniline and the anilinium ion is a stronger acid than the ethylammonium ion.
C. The two acids are of equal strength and the two bases are of equal strength.
D. Aniline is a stronger base than ethylamine and the ethylammonium ion is a stronger acid than the anilinium ion.
E. Aniline is a stronger base than ethylamine and the anilinium ion is a stronger acid than the ethylammonium ion.

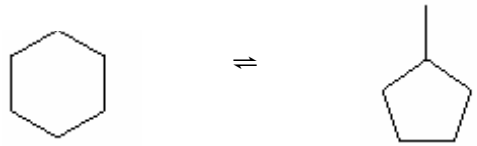
21. For a saturated solution of $Ca(OH)_2$ placed in a drying oven the following data are collected:

Volume of saturated $Ca(OH)_2$ (mL)	25.00
Mass of beaker (g)	20.960
Mass of beaker + dry solid (g)	20.981

What is the molar solubility of $Ca(OH)_2$ per litre of water? Assume the dry solid is $Ca(OH)_2(s)$

A. 0.84 mol L^{-1} B. 2.8 x 10^{-4} mol L^{-1} C. 5.5 x 10^{-6} mol L^{-1}
D. 0.027 mol L^{-1} **E. 0.011 mol L^{-1}**

22. Cyclohexane undergoes a molecular rearrangement in an inert solvent and the presence of $AlCl_3$ to form methylcyclopentane, according to the equation:

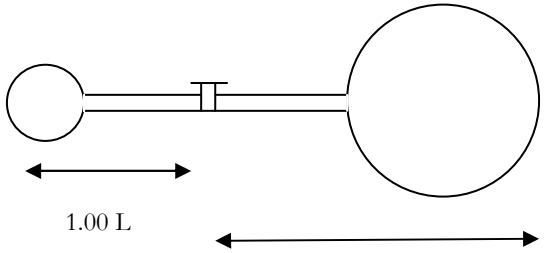


cyclohexane ⇌ methylcyclopentane

If K_c = 0.143 at 25°C for this reaction, find the equilibrium concentrations of cyclohexane and methylcyclopentane if the initial concentrations are 0.200 mol L^{-1} and 0.075 mol L^{-1}, respectively.

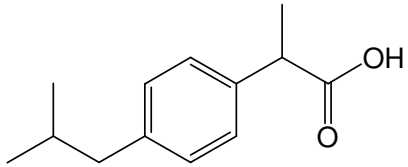
A. [cyclohexane] = 0. 041 mol L^{-1}, [methylcyclopentane] = 0. 234 mol L^{-1}
B. [cyclohexane] = 0. 159 mol L^{-1}, [methylcyclopentane] = 0. 116 mol L^{-1}
C. [cyclohexane] = 0. 241 mol L^{-1}, [methylcyclopentane] = 0. 034 mol L^{-1}
D. [cyclohexane] = 0. 253 mol L^{-1}, [methylcyclopentane] = 0. 022 mol L^{-1}
E. [cyclohexane] = 0. 257 mol L^{-1}, [methylcyclopentane] = 0. 018 mol L^{-1}

23. Given the diagram below of a two bulb system filled with the same gas, the pressure in the 1.00 L bulb is 1.50 atm and the pressure in the 4.00 L bulb is 2.00 atm. If the temperature remains constant and the valve between the two bulbs is opened so that the gas can move freely, what is the final pressure if the total volume of the two bulb system is 5.00 L?



A. 1.75 atm B. 1.80 atm C. 1.85 atm **D. 1.90 atm** E.1.95 atm

24. Ibuprofen (structure below) is a non–steroidal anti–inflammatory drug initially prescribed for treatment of rheumatoid arthritis. It is now marketed in North America as a general painkiller under the trade name Advil®.



ibuprofen

Which **one** of the following statements concerning ibuprofen is **FALSE**?

A. It contains a carboxylic acid functional group.
B. It contains a benzene ring.
C. **It contains twelve carbon atoms.**
D. It can be reacted with a base to form a water–soluble salt.
E. It is classified as an aromatic compound.

25. How many constitutional isomers exist of formula $C_5H_{12}O$ that contain an ether functional group?

A. 3 B. 4 C. 5 **D. 6** E.7

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