Chemical Institute of Canada | *For Our Future*
Institut de chimie du Canada | *Pour notre avenir*

CHEMISTRY Olympiads CANADA Olympiades CHIMIE

THE CANADIAN CHEMISTRY CONTEST 2019
MULTIPLE CHOICE QUESTIONS (60 minutes)

The only reference material allowed is the CIC/CCO Periodic Table provided. You must complete answers on the Scantron Sheet provided. A scientific calculator is allowed. No phones or any devices that can be used for communication are allowed.

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1) A solution is 0.0240 mol L^{-1} KI and 0.0146 mol L^{-1} MgI_2. What volume of water should be added to 100.0 mL of this solution to produce a solution with [I^-] concentration of 0.0500 mol L^{-1}?

A) 106.4 mL B) 53.2 mL C) 26.6 mL D) 13.3 mL E) 6.4 mL

2) The boiling points of the compounds acetic acid (CH_3COOH), 1-pentanol ($C_5H_{11}OH$), dibutyl ether ($C_8H_{18}O$) and dodecane ($C_{12}H_{26}$) increase in that order. Which of the following statements provides the best explanation for this increase?

A) The London dispersion forces increase
B) The hydrogen bonding increases
C) The dipole-dipole forces increase
D) The chemical reactivity increases
E) The number of carbon atoms increases

3) Health Canada recommends that women between the ages of 12 and 45 consume 400 micrograms of folic acid ($C_{19}H_{19}N_7O_6$) per day, which reduces the risk of neural tube defects during pregnancy. How many moles of folic acid are equivalent to 400 micrograms?

A) 1.10 mmol B) 0.177 mol C) 0.906 mol
D) 0.906 mmol E) 9.06 x 10^{-7} mol

4) An unknown amino acid contains 9.5 % nitrogen by mass as determined by elemental analysis. Which of the following could be the unknown amino acid?

A) arginine $C_6H_{14}N_4O_2$ B) cysteine $C_3H_7NO_2S$
C) histidine $C_6H_9N_3O_2$ D) glutamic acid $C_5H_9NO_4$
E) glycine $C_2H_5NO_2$

5) The melting point of CaS is higher than that of KCl. Explanations for this observation include which of the following?

I. Ca^{2+} is more positively charged than K^+.
II. S^{2-} is more negatively charged than Cl^-.
III. The K^+ ion is smaller than the Ca^{2+} ion.

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

6) Fluorine is the most electronegative element on the periodic table. As a result it always forms polar bonds with other non-metals. Despite this, which of the following fluorine containing compounds would be a non-polar molecule?

A) SF_4 B) PF_3 C) IF_5 D) BrF_3 E) XeF_4

7) Ronald James Gillespie, who developed Valence Shell Electron Pair Repulsion (VSEPR) theory, isolated the superacid fluorosulfuric acid (HSO_3F) when he combined fluorinated compounds with concentrated sulfuric acid, creating brightly coloured solutions. Which of the following best describes the molecular shape of fluorosulfuric acid, as predicted by VSEPR theory?

A) See saw B) Trigonal bipyramidal C) Tetrahedral
D) Square planar E) Trigonal pyramidal

8) Vinegar used as a cooking ingredient, or in pickling, is a solution of 5% acetic acid (CH_3COOH) by mass in solution with water. The pKa= 4.76 for acetic acid at 25°C. Evaluate the **pH** of vinegar at 25 °C.

A) 4.80 B) 4.15 C) 2.92 D) 2.42 E) 2.24

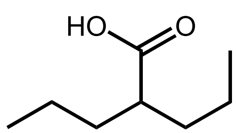
9) The ionization energies for period 3 element *X* are listed in the table below.

Ionization Energies for element *X* (kJ mol^{-1})				
First	Second	Third	Fourth	Fifth
580	1,815	2,740	11,600	14,800

Based on the data, which statement about element X is **FALSE**?

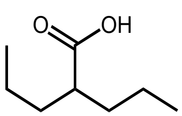
A) Its most common oxidation state is +3
B) It is displaced from aqueous solution by copper metal
C) It is the most abundant metal in the Earth's crust
D) Its oxide is insoluble in water
E) It is a lustrous metal

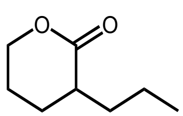
10) Stavzor (structure below) is a medication primarily used to treat epilepsy and bipolar disorder.

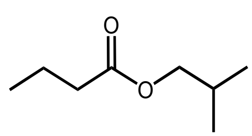


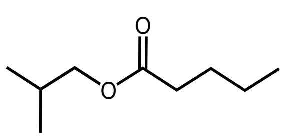
Stavzor

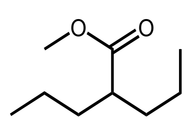
A well-known substance with a characteristic odour of bananas (**A**) is a constitutional isomer of Stavzor. Which of the following is a possible structure for **A**?

(a) 

(b) 

(c) 

(d) 

(e) 

11) Given the following electrochemical cell data:

Cell 1 Cd(s) | Cd^{2+} (1.0M) || Cu^{2+} (1.0M) | Cu(s) E^o = +0.74 V
Cell 2 Zn(s) | Zn^{2+} (1.0 M) || Cu^{2+} (1.0 M) | Cu(s) E^o = +1.10 V
Cell 3 Zn(s) | Zn^{2+} (1.0 M) || Cd^{2+} (1.0 M) | Cd(s)

Determine the standard cell potential for Cell 3.

A) – 0.36 V B) 0.36 V C) –1.84 V
D) –0.18 V E) 0.18 V

12) Lead (II) sulfate can decompose into lead (II) sulfite and oxygen gas when heated. If the reaction generates 2.25 g of oxygen gas, what mass of lead (II) sulfate reacted? Assume 100% yield in this reaction.

A) 42.6 g B) 21.3 g C) 20.2 g D) 10.7 g E) 4.50 g

13) A student combines 75 mL of 0.500 mol L^{-1} hydrochloric acid with 55 mL of 0.125 M KOH. What is the pH of the resulting solution?

A) 0.30 B) 0.39 C) 0.63 D) 1.51 E) 7.00

14) A system undergoes a reversible cyclic process and proceeds through a series of thermodynamic processes, exchanging heat and work with its surroundings and ultimately returning to its original state. Which one of the following statements is true? Assume that the surroundings are much larger than the system.

A) $\Delta S_{surroundings} > 0$ B) $q > 0$ C) $q < 0$ D) $q = w = 0$ E) $\Delta S > 0$

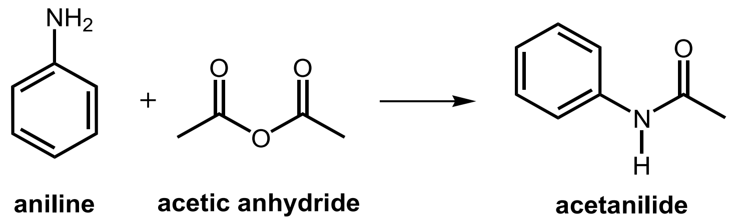
15) The thermite reaction is the reaction of aluminum metal and iron (III) oxide:

$$2\ Al\ (s) + Fe_2O_3\ (s) \rightarrow Al_2O_3\ (s) + 2\ Fe\ (s) \qquad \Delta H = -852\ kJ$$

A teacher does a demonstration with 1.00 mol of iron (III) oxide and 2.00 mol of aluminum metal both initially at 25.0 °C. If the combined specific heat of the products is 0.800 J g^{-1} $°C^{-1}$ over a wide range of temperatures, what is the final temperature of the products?

A) 3550°C B) 4960 °C C) 5010 °C D) 6470 °C E) 6500°C

16) The compound acetanilide is important in the industrial synthesis of several dyes. Acetanilide (mol. wt. = 135.16) can be made in the laboratory by a reaction between aniline and excess acetic anhydride which has a yield of 61.5%:



Aniline and acetic anhydride are both liquids which have densities of 1.219 g mL^{-1} and 1.082 g mL^{-1} respectively.

What volume of aniline was used in this reaction if the recorded mass of acetanilide product was 7.14 g?

A) 4.03 mL B) 9.75 mL C) 4.92 mL
D) 5.99 mL E) 6.56 mL

17) One of the Twelve Principles of Green Chemistry is that "synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product". One way to consider this is to calculate the *atom economy* (AE) of a chemical reaction where AE is defined as follows:

$$atom\ economy = \frac{molecular\ mass\ of\ desired\ product}{molecular\ mass\ of\ all\ reactants} \times 100\%$$

The atom economy of the reaction in the previous question (#16) is:

A) 61.5% B) 69.2% C) 100% D) 68.9% E) 74.4%

18) Given the following set of equilibria and their respective constants

$NH_4^+ \rightleftharpoons H^+ + NH_3$ $K_a = 5.6 \times 10^{-10}$
$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ $K_{a1} = 4.2 \times 10^{-7}$
$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$ $K_{a2} = 2.4 \times 10^{-8}$

what would the equilibrium constant be for the reaction below?

$H_2CO_3 + 2\ NH_3 \rightleftharpoons (NH_4)_2CO_3$ K = ?

A) 1.8×10^{-5} B) 4.4×10^{-7} C) 9.0×10^{-6}
D) 3.2×10^{4} E) 3.1×10^{-5}

19) The subshell filling order used for the quantum mechanical model of the atom is an approximation of the relative subshell energies, which assumes the energies remain fixed. However, there are exceptions to the Aufbau Principle. Which of the following is the correct ground state configuration of an element found on the periodic table?

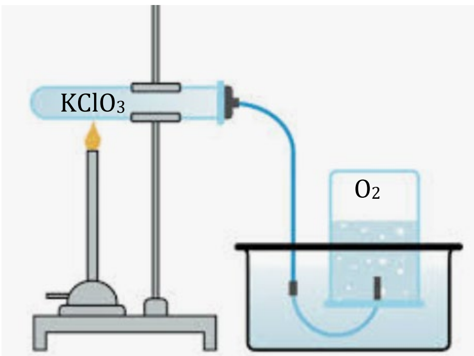
A) [Ar] $4s^1\ 3d^5$ B) [Ar] $4s^2\ 3d^4$ C) [Ar] $4s^2\ 4d^4$
D) [Ar] $4s^2\ 4p^4$ E) [Ar] $4s^1\ 4p^5$

20) A vessel contains 2.50 mol of O_2 gas, 0.50 mol of N_2 gas and 1.00 mol of CO_2 gas. The total pressure is 200 kPa. The partial pressure exerted by the O_2 in the mixture is:

A) 25 kPa B) 50 kPa C) 100 kPa D) 125 kPa E) 150 kPa

21) The O_2 (g) produced in the decomposition of 3.275 g mixture of potassium chlorate and potassium chloride which is 65.82% $KClO_3$ by mass is collected over water at 21.0 °C. Assume ideal gas conditions. If atmospheric pressure is 753.5 mmHg, water vapour pressure at 21.0°C is 18.7 mmHg, once the pressure in the gas collection vessel was equalized with atmospheric pressure, how many milliliters of O_2 gas would be produced according to the reaction:

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



A) 130 mL B) 439 mL C) 563 mL
D) 658 mL E) 1320 mL

22) The equilibrium $CO\ (g) + NO_2\ (g) \rightleftharpoons CO_2(g) + NO\ (g)$ is established in four different, but identical containers. Each container started with a different composition as follows:

Container	CO (mol)	NO_2 (mol)	CO_2 (mol)	NO (mol)
1	1	1	0	0
2	1	0	1	1
3	1	1	1	0
4	0	1	1	1
5	1	1	1	1

After equilibrium is established, which container would have the largest concentration of CO (g)

A) 1 B) 2 C) 3 D) 4 E) 5

23) For the reaction $H_2\ (g) + I_2\ (g) \rightleftharpoons 2\ HI\ (g)$ $\Delta H° = +52.96$ kJ.
Which of the following statement(s) is/are correct?

I. The heat of formation of 1 mol of HI is +26.48 kJ
II. As the temperature increases, the reaction will proceed to the right
III. As the pressure increases, the reaction will proceed to the right

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

24) Calculate $\Delta G°$ at 25 °C for the reaction given the data below

$4\ HCl\ (g) + O_2\ (g) \rightarrow 2\ Cl_2\ (g) + 2\ H_2O\ (g)$ $\Delta H° = -114.4$ kJ

$S^o_{Cl_2}$= 223.0 J mol^{-1} K^{-1} $S^o_{H_2O}$= 188.7 J mol^{-1} K^{-1},
$S^o_{O_2}$= 205.0 J mol^{-1} K^{-1} S^o_{HCl}= 186.8 J mol^{-1} K^{-1}

A) + 14.4 kJ B) −111.18 kJ C) + 3105.6 kJ
D) + 38 kJ E)– 76.0 kJ

25) For the reaction $2\ NO\ (g) + Cl_2\ (g) \rightarrow 2\ NOCl\ (g)$ the table below provides experimental data for 3 different reactions.

Experiment	[NO] (mol L^{-1})	[Cl_2] (mol L^{-1})	Initial Rate (mol L^{-1}s^{-1})
1	0.0125	0.0128	1.14 x 10^{-5}
2	0.0125	0.0511	4.55 x 10^{-5}
3	0.0250	0.0255	9.08 x 10^{-5}

What is the rate constant for the reaction?

A) 140 L mol^{-1} s^{-1} B) 0.0714 L mol^{-1} s^{-1} C) 5.70 L^2 mol^{-2} s^{-1}
D) 0.562 L mol^{-1} s^{-1} E) 1.39 L^2 mol^{-2} s^{-1}

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Data Sheet
Fiche de données

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Relative Atomic Masses (2012, IUPAC)
***For the radioactive elements the atomic mass of an important isotope is given**

Masses Atomiques Relatives (UICPA, 2012)
***Dans le cas des éléments radioactifs, la masse atomique fournie est celle d'un isotope important**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.008																	2 **He** 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (269)	111 **Rg** (272)	112 **Cn** (285)	113 **Nh** (284)	114 **Fl** (289)	115 **Mc** (288)	116 **Lv** (292)	117 **Ts** (294)	118 **Og** (294)

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
90 **Th** 232.0	91 **Pa** (231.0	92 **U** (238.0)	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

	Symbol **Symbole**	**Value** **Quantité numérique**	
Atomic mass unit	*amu*	1.66054×10^{-27} kg	Unité de masse atomique
Avogadro's number	N_A	6.022×10^{23}	Nombre d'Avogadro
Charge of an electron	*e*	1.60218×10^{-19} C	Charge d'un électron
Dissociation constant (H_2O)	K_w	1.00×10^{-14} (25ºC)	Constante de dissociation de l'eau (H_2O)
Faraday's constant	*F*	96 485 C mol^{-1}	Constante de Faraday
Gas constant	*R*	8.31451 J K^{-1} mol^{-1} 0.08206 L atm K^{-1} mol^{-1}	Constante des gaz
Mass of an electron	m_e	9.10939×10^{-31} kg	Masse d'un électron
Mass of a neutron	m_n	1.67493×10^{-27} kg	Masse d'un neutron
Mass of a proton	m_p	1.67262×10^{-27} kg	Masse d'un proton
Planck's constant	*h*	6.62608×10^{-34} J s	Constante de Planck
Speed of light	*c*	2.997925×10^{8} m s^{-1}	Vitesse de la lumière
Rydberg constant	R_H	1.096×10^{7} m^{-1}	Constante de Rydberg

1 Å = 1×10^{-10} m
1 atm = 101.325 kPa
1 bar = 1×10^{5} Pa

STP/TPN	**SATP/TPAN**
273.15 K	298 K
100 kPa	100 kPa

Scratch Paper