AVOGADRO EXAM 2007
UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

17 MAY 2007   **TIME: 75 MINUTES**

This exam is being written by several thousand students. Please be sure that you follow the instructions below.
We'll send you a report on your performance. Top performers are eligible for a prize.

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1. Print your **name** here:

2. Print your **school name** and **city** on your STUDENT RESPONSE sheet.

3. Select, and enter on the STUDENT RESPONSE sheet, one of the following CODE numbers:

Code 1   **Ontario**, now studying Grade 11 Chemistry in a nonsemestered school

Code 2   **Ontario**, now studying Grade 11 Chemistry in a semestered school

Code 3   **Ontario**, Grade 11 Chemistry already completed

Code 4   Any **other Ontario** student

Code 5   **Manitoba or Saskatchewan** high school student

Code 6   **Québec** high school student

Code 7   **not used**

Code 8   **Alberta or British Columbia** high school student

Code 9   **New Brunswick, Newfoundland, Nova Scotia, or Prince Edward Island** high school student

Code 10   **Northwest Territories, Nunavut, or Yukon** high school student

Code 11   High school student **outside Canada**

Code 12   **Teacher**

4. **Print** your name (last name, first name and optional middle initial) **on the STUDENT RESPONSE sheet**. Also fill in the corresponding circles below your printed name.

5. **Carefully detach the last page.** It is the datasheet.

6. Now answer the exam questions. Questions are **not** in order of difficulty. Indicate your choice on the STUDENT RESPONSE sheet by marking one letter beside the question number.

    • Mark only one answer for each question.

    • Questions are all of the same value.

    • **There is a penalty** (1/4 off) for each incorrect answer, but no penalty if you do not answer.

7. Take care that you make firm, **black** pencil marks, just filling the oval.

    Be careful that any erasures are complete—make the sheet white again.


Carefully detach the last page.
It is the Data Sheet.

AVOGADRO EXAM 2007 - Answers

1 Which atom has the most neutrons?

   A $^{18}_{9}F$

   *B $^{18}_{8}O$

   C $^{14}_{6}C$

   D $^{15}_{7}N$

   E $^{11}_{5}B$

2 Which of the following pairs of atomic symbols and elements is incorrect?

   A   Fe, iron

   B   Mg, magnesium

   C   Ca, calcium

   *D Br, boron

   E   Mn, manganese

3 Which of the following particles is not a charged particle?

   A α-particle

   B β-particle

   C   electron

   D   proton

   *E neutron

4 The formula of a compound is X_2O. Which of the following is X <u>least</u> likely to be?

   *A barium (Ba)

   B   sodium (Na)

   C   cesium (Cs)

   D   hydrogen (H)

   E   copper (Cu)

5 How many protons are there in the nucleus of $^{127}_{53}I$?

   A   7

   *B 53

   C   74

   D   127

   E   180

6 Which group of elements has the greatest electron affinity?

   A   group 14

   B   group 15

   C   group 16

   *D group 17

   E   group 18

7 The difference between deuterium, $^{2}_{1}H$, and the more common form hydrogen is that deuterium

   A   does not occur naturally.

   B   is radioactive.

   C   has one more atom per molecule.

   D   has one more proton in the nucleus.

   *E has one more neutron in the nucleus.

8 Which group of atoms and ions contain the same number of electrons?

   A   F, Ne, Na

   B O^{2-}, S^{2-}, Se^{2-}

   C   Mg, Al, Si

   D Ca^{2+}, Fe^{3+}, Zn^{2+}

   *E Cl^-, Ar, K^+

9 Which of the following is an ionic solid?

A N_2O

B HCl

*C LiCl

D CO_2

E CH_4

10 What volume of CO_2 is produced when you burn exactly 1.0 litre of gaseous propane (C_3H_8) in the presence of excess oxygen in your backyard barbecue?   Assume H_2O and CO_2 are the only combustion products and that the pressure and temperature remain constant.

A 1.0

B 1.5

C 2.0

D 2.5

*E 3.0

11 Polonium-210 (^{210}Po) is radioactive, extremely toxic, and it decays according to the chemical equation below. What is the missing product in the equation?

$$^{210}Po \rightarrow \boxed{?} + \, ^{4}_{2}He$$

A ^{214}Po

B ^{212}Tl

*C ^{206}Pb

D ^{214}Rn

E ^{210}Po

12 The bubbles in boiling water are mostly

A He

*B H_2O

C CO_2

D N_2

E O_2

13 An element, X, from group 1 of the periodic table, combines to form a stable compound with an element, Y, from group 16. The formula of that compound is most likely to be

A X_3Y

B XY_3

C XY

*D X_2Y

E XY_2

14 After a large meal the pH of your stomach drops to 1.78. What is [H^+] in your stomach after the meal?

*A 1.66×10^{-2} mol L^{-1}

B 0.250 mol L^{-1}

C 1.78 mol L^{-1}

D 1.83×10^{-3} mol L^{-1}

E 6.03×10^{-2} mol L^{-1}

15 The chemical formula of barium perrhenate is $Ba(ReO_4)_2$. What is the charge on the perrhenate ion?

A +2

B +1

C 0

*D -1

E -2

16 These three compounds have been isolated: NaCl, Na_2O, and $AlCl_3$. What is the formula of aluminum oxide?

A Al_2O

*B Al_2O_3

C Al_3O

D AlO

E AlO_3

17 The average car in Canada uses 0.93 L of gasoline to go 100 km. If it is assumed that gasoline is pure octane (C_8H_{18}), with a density of 0.70 g/mL and a molar mass of 114.2 g/mol, then how many moles of octane are consumed by driving 100 km?

A 0.93 mol

*B 5.7 mol

C 11 mol

D 5.7×10^{-4} mol

E 1.1×10^{-3} mol

18 How many moles of gas are present in a 15.0-L scuba tank, if the pressure in the tank is 23.0 MPa and the temperature is 298 K? Assume the gas behaves ideally.

A 23 mol

$1 \text{ MPa} = 1 \times 10^3 \text{ kPa}$

B 72 mol

C 44 mol

D 14.1 mol

*E 139 mol

19 Chlorine has two abundant stable isotopes, ^{35}Cl and ^{37}Cl, with atomic masses of 34.97 amu and 36.96 amu respectively. What is the percent abundance of the heavier isotope?

A 78%

*B 24%

C 64%

D 50%

E 36%

20 Which of the following is not a gas at 298 K?

A Ar

B He

*C Br_2

D H_2

E O_2

21 Which of the following types of radiation has the highest energy per photon?

A radio waves

B ultraviolet radiation

C infrared radiation

*D x-rays

E purple laser light

22 The Lewis structure (i.e. electron dot) structure for the HCN molecule is given below.

$$H \!-\!\!-\! C \equiv N \colon$$

The bond angle is nearest to

A 60°

B 90°

C 105°

D 120°

*E 180°

23 What volume of 0.100 mol L^{-1} NaOH(aq) is required to neutralize 0.245 L of 0.200 mol L^{-1} H_3PO_4(aq)?

A 0.490 L

B 0.500 L

*C 1.47 L

D 2.30 L

E 1.47 mL

24 Which of the following molecules forms hydrogen bonds amongst themselves?

A dimethyl ether (CH_3OCH_3)

B methane (CH_4)

C hydrogen sulfide (H_2S)

*D ethanol (CH_3CH_2OH)

E formaldehyde (H_2CO)

25 Aluminum dissolves in acidic solution according to the chemical equation below.

$$2\ Al(s) + 6\ HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2(g)$$
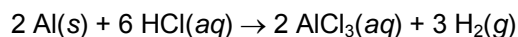
How many grams of aluminum (27 g mol^{-1}) are required to produce 0.50 mol H_2?

A 20 g

*B 9.0 g

C 14 g

D 27 g

E 0.24 g

26 For which of the following reactions is the change in energy equal to the first ionization energy of oxygen?

A $O^-(g) + e^- \rightarrow O^{2-}(g)$

B $O(g) + 2e^- \rightarrow O^{2-}(g)$

*C $O(g) \rightarrow O^+(g) + e^-$

D $O(g) + e^- \rightarrow O^-(g)$

E $O(g) \rightarrow O^{2+}(g) + 2e^-$

27 How does the pH of a solution change as HCl is added to a solution of NaOH?

*A The pH decreases and may go below 7.

B The pH will not change.

C The pH decreases until it reaches a value of 7 and then stops.

D The pH increases until it reaches a value of 7 and then stops.

E The pH increases and may go above 7.

28 The volume of a gas, initially at 1 atm and 20°C, is increased from 40.0 mL to 80.0 mL. If the pressure remains constant, what is the final temperature of the gas?

A $293\,K + \dfrac{80.0}{40.0}$

B $20\,°C \times \dfrac{80.0}{40.0}$

*C $293\,K \times \dfrac{80.0}{40.0}$

D $293\,K \times \dfrac{40.0}{80.0}$

E $20\,°C \times \dfrac{40.0}{80.0}$

29 Which drawing shows a pipet correctly filled for delivery?
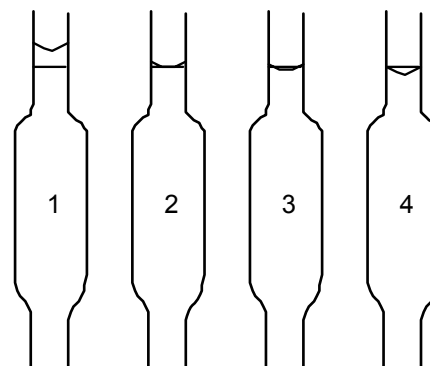
A 1

*B 2

C 3

D 4

E none of the above

30 What is the mass percentage of copper in $CuCl_2$?

A 12.1%

B 64.2%

C 91.2%

D 25.2%

*E 47.3%

31 Which one of the following solutions will be the best electrical conductor at 25°C?

*A 0.10 mol L^{-1} $Na_2SO_4(aq)$

B 0.10 mol L^{-1} $NaCl(aq)$

C 0.10 mol L^{-1} $H_2SO_4(aq)$

D 0.10 mol L^{-1} $HNO_3(aq)$

E 0.10 mol L^{-1} $CsCl(aq)$

32 What is the coefficient of O_2 when the following equation is balanced with the smallest whole-number coefficients?

___Cr_2O_3 + ___ KOH + ___O_2 → ___K_2CrO_4 + ___H_2O

A   2

*B 3

C   4

D   5

E   6

33 What is the oxidation state of N in HNO_2?

A   +5

*B +3

C   +1

D   −1

E   −3

34 If the Kelvin temperature of a sample of ideal gas doubles (e.g. from 200 K to 400 K), then the average kinetic energy of the molecules in the sample

A   increases by a factor of $\sqrt{2}$

B   decreases by a factor of 2

*C increases by a factor of 2

D   increases by a factor of 4

E   remains the same

35 The ground state electronic configuration of a certain neutral atom is [Xe] $6s^2$ $4f^{14}$ $5d^{10}$ $6p^4$. To which group of the periodic table does this atom belong?

A   group 1

B   group 3

C   group 6

D   group 14

*E group 16

> This question was NOT marked. The electron configuration was mistakenly given as:
> [Xe] $6s^2$ $5f^{14}$ $6d^{10}$ $6p^4$

36 How many moles of water are there in 1.80 L of $H_2O(l)$ at 1.00 atm and 298 K? The density of water is 1.00 g/mL at 1.00 atm and 298 K.

A   1.00 mol

B   0.0736 mol

C   55.6 mol

*D 1.00×10^2 mol

E   13.6 mol

37 The reaction $2\,Al(s) + 6\,HCl(aq) \rightarrow 2\,AlCl_3(aq) + 3\,H_2(g)$ is an example of

A   a precipitation reaction

B   an acid-base reaction

C   a decomposition reaction

*D an oxidation-reduction reaction

E   an isomerization reaction

38 If equal volumes of 0.10 mol L^{-1} solutions of NaOH and HCl are mixed, what is the pH of the resulting solution at 298 K?

A   1

B   13

*C 7

D   1.3

E   12.7

39 A calcium chloride solution was prepared by dissolving 11.00 g $CaCl_2$ in water to make 500 mL of solution. What is the correct way to report the concentration of this solution?

*A 0.2 mol L^{-1}

| $CaCl_2$, 110.98 g mol^{-1} |

B 0.1982 mol L^{-1}

C 0.198 mol L^{-1}

D 0.2000 mol L^{-1}

E 0.20 mol L^{-1}

The number of significant figures in the volume is ambiguous (i.e. we don't know if the zeros are significant), so we must assume the worst: that the volume is known only to 1 significant figure. Therefore, we report the concentration to 1 significant figure only. If the volume had been recorded as 0.500 L, then we could have given the concentration as 0.198 mol L^{-1}.

40 A compound of carbon and hydrogen is found to be 85.6 % carbon, by mass, and 14.38% hydrogen. What is the simplest formula of the compound?

A CH

*B CH_2

C CH_3

D CH_4

E C_3H_4

DATA SHEET
AVOGADRO EXAM 2007

DETACH CAREFULLY

1 1A																	18 8A
1 **H** 1.008	2 **2A**											13 **3A**	14 **4A**	15 **5A**	16 **6A**	17 **7A**	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	3 **3B**	4 **4B**	5 **5B**	6 **6B**	7 **7B**	8 ←	9 **8B**	10 →	11 **1B**	12 **2B**	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** 47.88	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** 72.59	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** 95.94	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** 227.0	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Uun**	111 **Uuu**	112 **Uub**	113 **Uut**					

58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.00	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** 237.0	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** (260)

Constants:

$N_A = 6.022 \times 10^{23}$ mol^{-1}

R = 0.082058 atm L K^{-1} mol^{-1}

= 8.3145 kPa L K^{-1} mol^{-1}

= 8.3145 J K^{-1} mol^{-1}

K_w = 1.0×10^{-14} (at 298 K)

F = 96 485 C mol^{-1}

Conversion factors:

1 atm = 101.325 kPa = 760 torr = 760 mm Hg

0°C = 273.15 K

Equations: $PV = nRT$ $k\, t_{1/2} = 0.693$ $pH = pK_a + \log\left([base]/[acid]\right)$ $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$