AVOGADRO EXAM 2008
UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

15 MAY 2008   **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. The names of the top 200 students will be published in the September issue of Chem 13 News.

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.

1 Which of the following elements is **not** a metal?

*A Se

B Sn

C Sr

D Sc

E Cs

2 A colourless, odourless gas is thought to be oxygen. Which of the following experimental results would support this conclusion?

A Burning the gas in air produces only water.

B The gas extinguishes a flame.

C The gas turns a $Ca(OH)_2$ solution milky.

*D A glowing piece of wood bursts into flames in the gas.

E The gas tarnishes silver.

3 Which of the following particles is the most massive?

*A α-particle

B β-particle

C electron

D proton

E neutron

4 What volume of 5.0 mol L^{-1} $H_2SO_4(aq)$ must be diluted with water to make 1.00 L of 0.45 mol L^{-1} $H_2SO_4(aq)$?

*A 0.090 L

B 0.44 L

C 0.090 mL

D 0.045 L

E 2.22 mL

5 How many neutrons are there in the nucleus of ^{131}I?

A 44

B 53

*C 78

D 131

E 184

6 Which group of elements contains no metals or metalloids?

A group 13

B group 14

C group 15

D group 16

*E group 17

7 Which of these chloride salts is least likely to exist?

A NaCl

B CuCl

C $CaCl_2$

D $FeCl_3$

*E MgCl

8 When a sample of atomic hydrogen gas is heated, it emits violet, blue, green and red light. Which of the following statements best explains this observation?

*A The energy of the electron in a hydrogen atom is restricted to certain values.

B The energy of the electron in a hydrogen atom is not restricted in any way.

C The electron in a hydrogen atom is restricted to one of only four possible circular orbits.

D The distance between the electron and the nucleus in a hydrogen atom is restricted to certain values.

E none of the above

9 Which of the following is **not** a mixture?

    A seawater

    *B table sugar

    C brass

    D cement

    E smoke

10 Radioactive ^{131}I is used to treat thyroid cancer. An incomplete chemical equation for the radioactive decay of ^{131}I is given below.

$$^{131}I \ \rightarrow \ \boxed{?} \ + \ _{-1}^{\ 0}e$$
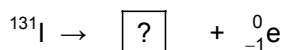
What is the missing product in the equation above?

    A ^{130}I

    B ^{129}I

    *C ^{131}Xe

    D ^{131}Te

    E $^{131}I^+$

11 Which of the following has the highest concentration in air at STP?

    A He

    B H_2O

    C CO_2

    *D N_2

    E O_2

12 The average mass of a solid copper penny is 2.63 g. What is the mass of one mole of pennies?

    *A 1.58×10^{24} g

    B 6.02×10^{23} g

    C 6.36×10^{23} g

    D 63.6 g

    E 1.58×10^{23} g

13 What is the sum of the coefficients when the following equation is balanced using the smallest whole number coefficients?

$$\_\_ P_4 \ + \ \_\_ Cl_2 \ \rightarrow \ \_\_ PCl_3$$
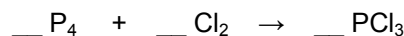
    A 12

    *B 11

    C 6

    D 5

    E 3

14 How many litres of gaseous methane (CH_4) must be burned in oxygen to produce enough H_2O and CO_2 to fill a 3.0-L balloon? Assume that H_2O and CO_2 are the only combustion products and that the temperature and pressure remain constant.

    *A 1.0 L

    B 1.5 L

    C 2.0 L

    D 2.5 L

    E 3.0 L

15 A compound that contains only Fe and O is 69.9% Fe by mass. What is the empirical formula of this compound?

    A FeO

    B FeO_2

    *C Fe_2O_3

    D Fe_2O

    E Fe_3O_4

16 If 17.0 grams of sodium chloride are dissolved in water to make 0.5 L of solution, then what is the final concentration of the solution? Give your answer with the correct number of significant figures.

*A 0.6 mol L^{-1}

B   0.58 mol L^{-1}

C   0.581 mol L^{-1}

D   0.3 mol L^{-1}

E   0.291 mol L^{-1}

17 What is the effect of adding a catalyst to a reaction mixture?

A   It increases the equilibrium concentrations of the products.

B   It decreases the enthalpy change of the reaction.

*C It reduces the activation energy of the reaction.

D   It increases the value of the equilibrium constant for the reaction.

E   It increases the time it takes for the reaction to reach equilibrium.

18 How many valence electrons are there in one Al^{3+} ion?

A   2

B   4

C   6

*D 8

E   10

19 What volume of He(g) contains the same number of moles of gas as 1.00 L of N_2(g) at the same temperature and pressure?

A   7.00 L

*B 1.00 L

C   0.143 L

D   35.7 mL

E   4.00 L

20 What is the HNH bond angle in an ammonia (NH_3) molecule? Choose the closest value.

A 90°

B 45°

C 120°

*D 109°

E 180°

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

*A radio waves

B   ultraviolet radiation

C   infrared radiation

D   x-rays

E   purple laser light

22 An **incomplete** Lewis structure (i.e. electron dot structure) for the O_3 molecule is given below.

$$O \text{——} O \text{——} O$$

How many lone pairs of electrons are there in the completed structure?

A   two

B   four

C   five

*D six

E   eight

23 Which of the following is **not** a common oxide of nitrogen?

A   NO

B NO_2

C N_2O_4

D N_2O

*E NO_3

24 In an experiment, 0.12 L of 0.10 mol L^{-1} H$_2$SO$_4$(aq) and 0.20 L of 0.10 mol L^{-1} NaOH(aq) are combined. Which of the following statements is **true**?

*A The pH of the resulting solution is less than 7.

B The pH of the resulting solution is greater than 7.

C The pH of the resulting solution is close to 7.

D The pH of the resulting solution is exactly 7.

E None of the statements above are true.

25 Solid aluminum dissolves in hydrochloric acid solution according to the following chemical equation.

2 Al(s) + 6 HCl(aq) → 2 AlCl$_3$(aq) + 3 H$_2$(g)

How many moles of H$_2$ are produced if 17.5 moles of Al are added to a solution containing 24.8 moles of HCl?

A 26.3 mol

*B 12.4 mol

C 7.30 mol

D 17.5 mol

E 24.8 mol

26 Which of the following choices does **not** involve a chemical change?

A evaporation and neutralization

B neutralization and sublimation

C oxidation and sublimation

*D evaporation and sublimation

E neutralization and oxidation

27 Which of the following atoms or ions has the electron configuration 1s^2 2s^2 2p^6 3s^1 in its ground electronic state?

A Na$^-$

*B Mg$^+$

C K

D Ca$^+$

E Al^{3+}

28 Which of the following is a brittle solid and an electrical insulator at room temperature, but an excellent electrical conductor in its liquid form?

A sulphur

*B sodium chloride

C aluminum

D mercury

E carbon

29 Which of the following salts produces a basic solution when it is dissolved in water?

A KCl

B NH$_4$Cl

*C K$_2$CO$_3$

D NaNO$_3$

E CuBr$_2$

30 Which of the following describes the process that produces Fe(s) from Fe$_2$O$_3$(s)?

A combustion

B precipitation

C hydrolysis

*D reduction

E oxidation

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

A $0.10 \text{ mol L}^{-1} \text{ Na}_2\text{SO}_4 \text{ (aq)}$

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

C $0.10 \text{ mol L}^{-1} \text{ CaSO}_4(aq)$

*D $0.10 \text{ mol L}^{-1} \text{ CH}_3\text{OH}(aq)$

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

32 Which of the following atoms is **not** present in large numbers in biological molecules?

A   C

*B   F

C   O

D   N

E   H

33 In which of these compounds is the oxidation state of Cl the highest?

A HClO_2

B ClO_2

C Cl_2O_5

D Cl_2O

*E HClO_4

34 Which of the gases most closely resembles an ideal gas at standard temperature and pressure?

A CO_2

B NH_3

C HI

*D H_2

E H_2O

35 Which of the following have ground state electron configurations of the type $ns^2 np^2$?

A   group 2 atoms

B   group 4 atoms

C   group 6 atoms

*D   group 14 atoms

E   group 16 atoms

36 Which of the species in the reaction below are Brønsted-Lowry acids?

$$\text{HSO}_4^- + \text{HCO}_3^- \rightleftharpoons \text{SO}_4^{2-} + \text{H}_2\text{CO}_3$$
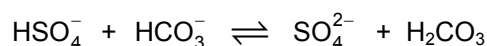
A HSO_4^- and HCO_3^-

*B HSO_4^- and H_2CO_3

C HCO_3^- and SO_4^{2-}

D SO_4^{2-} and H_2CO_3

*E HSO_4^- and SO_4^{2-}

37 Which of the following is **not** an alkane?

*A C_2H_4

B C_3H_8

C C_4H_{10}

D C_5H_{12}

E C_6H_{14}

38 What happens when a solution of lithium chloride (LiCl) and a solution of ammonium nitrate (NH_4NO_3) are mixed?

   A   A precipitate forms.

   B   A new salt is formed.

   C   A gas is evolved.

   D   A metal is formed.

   *****E**   No reaction occurs.

39 An average person expends approximately 100 kJ to walk 1 km. How far will the average car travel by the time it expends the same amount of energy (i.e. 100 kJ) as a person who walked 1 km? Use the data given below to determine the answer. Choose the closest answer.

   A   2 km

   B   0.2 km

   *****C**   0.02 km

   D   20 km

   E   200 km

| Fuel consumption of an average car, 8 km L^{-1} |
| Heat of combustion of gasoline, 50 kJ g^{-1} |
| Density of gasoline, 0.7 g mL^{-1} |

40 How many structural isomers are there for C_5H_{12}?

   A   less than three

   *****B**   three

   C   four

   D   five

   E   more than five

DATA SHEET
AVOGADRO EXAM 2008

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:

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

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

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

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

$K_w \ = \ 1.0 \times 10^{-14} \ (at \ 298 \ K)$

$F \ = \ 96 \ 485 \ C \ mol^{-1}$

Conversion factors:

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

$0^oC = 273.15 \ K$

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