University of Waterloo

AVOGADRO EXAM 2009

UNIVERSITY OF WATERLOO
DEPARTMENT OF CHEMISTRY

21 MAY 2009 **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 The "lead" of a pencil is mostly

A lead, Pb

B carbon, C

C silicon dioxide, SiO_2

D silicon, Si

E calcium carbonate, $CaCO_3$

2 How many protons, neutrons and electrons are there in a single atom of $^{209}_{84}Po$?

A 84 protons, 84 neutrons, 209 electrons

B 84 protons, 209 neutrons, 84 electrons

C 209 protons, 125 neutrons, 209 electrons

D 125 protons, 84 neutrons, 125 electrons

E 84 protons, 125 neutrons, 84 electrons

3 The mass of one atom of ^{12}C is exactly 12 atomic mass units. With the assumption that a proton and a neutron are equally massive, what is the total number of protons and neutrons in the body of a 75-kg person? (You may neglect the mass of an electron is negligible compared to that of a proton or neutron.)

A 2.2×10^{27}

B 4.5×10^{28}

C 8.0×10^{21}

D 3.8×10^{23}

E 8.0×10^{24}

4 Mercury, Hg(*l*), has a density of 13.6 g mL^{-1} at 25 °C. What is the volume of 4.25 grams of Hg(*l*) at 25 °C?

A 0.0173 mL

B 3.20 mL

C 0.0562 mL

D 0.313 mL

E 0.0735 mL

5 Which of the following molecules has the same number of electrons as a water molecule?

A HF

B BH_3

C CO

D H_2S

E F_2

6 Which of the following elements is a liquid at room temperature and atmospheric pressure?

A chlorine

B phosphorus

C sulfur

D bromine

E iodine

7 What is the formula of the binary compound formed between Mg and P?

A MgP

B Mg_2P

C MgP_2

D Mg_2P_3

E Mg_3P_2

8 Which of the following elements has no known stable compounds?

A neon, Ne

B xenon, Xe

C gold, Au

D platinum, Pt

E uranium, U

9 Which of the following elements is believed to be the most abundant in the earth's crust?

A hydrogen

B oxygen

C carbon

D nitrogen

E silicon

10 Which of the following has the highest concentration at equilibrium when one mole of HCl is dissolved in 1.0 L of water at 25 °C?

A Cl^-

B Cl^+

C Cl_2

D H_2

E HCl

11 What is the symbol for the atom or ion that results from the addition of two protons to a single atom of $^{42}_{20}Ca$?

A $^{42}_{22}Ca^{2+}$

B $^{44}_{22}Ca^{2+}$

C $^{42}_{22}Ti$

D $^{44}_{22}Ti^{2+}$

E $^{44}_{20}Ti^{2+}$

12 In a mixture of N_2 and O_2 gases, all the N_2 molecules and the O_2 molecules have the same

A average speed

B average kinetic energy

C partial pressure

D average molecular mass

E average momentum

13 When ethanol, CH_3CH_2OH, is burned in excess oxygen, carbon dioxide and water are the only products. What is the coefficient of O_2 when the chemical equation representing the combustion reaction is balanced **using the smallest whole number coefficients**?

A 1

B 2

C 3

D 7

E none of the above

14 In an experiment, 16 g of methane and 32 g of oxygen react to produce 11 g of carbon dioxide. A balanced chemical equation for the reaction is given below.

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$$

What is the percentage yield of carbon dioxide in this experiment?

A 10%

B 25%

C 50%

D 67%

E 75%

15 If an oxide of nitrogen contains 25.9% by mass of nitrogen, what is its empirical formula?

A NO

B N_2O

C NO_2

D N_2O_4

E N_2O_5

16 What is the percentage by mass of sodium in a mixture containing 1.00 mol NaCl and 1.00 mol NaF?

A 39.3%

B 45.8%

C 47.1%

D 50.0%

E 54.8%

17 When the hydrides of the group 16 elements are arranged in order of increasing boiling point, the order is

A H_2S H_2Se H_2Te H_2O

B H_2O H_2S H_2Se H_2Te

C H_2Te H_2Se H_2S H_2O

D H_2O H_2Te H_2Se H_2S

E H_2S H_2O H_2Se H_2Te

18 How many unpaired electrons are there in a ground state Mn^{2+} ion?

A zero

B one

C two

D three

E more than three

19 What is the pressure (in mmHg) of the gas inside the apparatus below if P_{atm} = 750 mmHg, Δh_1 = 40 mm and Δh_2 = 30 mm?

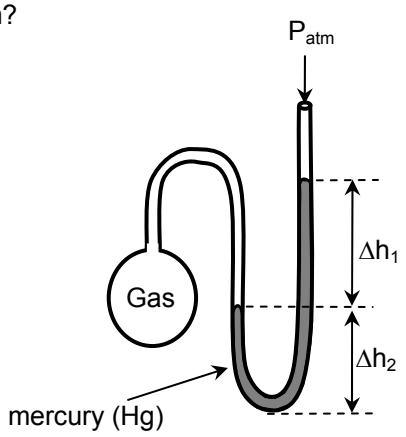
A 710 mmHg

B 790 mmHg

C 720 mmHg

D 780 mmHg

E 820 mmHg



20 What is the HCH bond angle in a formaldehyde (H_2CO) molecule? Choose the closest value.

A 45^o

B 90^o

C 109^o

D 120^o

E 180^o

21 Which of the following diatomic molecules has the strongest bond?

A N_2

B O_2

C F_2

D Cl_2

E Br_2

22 Which of the following molecules or ions is planar? (The central atom is underlined and all other atoms are bonded to it.)

A $\underline{N}H_3$

B $\underline{N}H_4^+$

C $\underline{S}F_4$

D $\underline{S}O_3^{2-}$

E $\underline{S}O_3$

23 What is the formula of iron(II) sulfate?

A Fe_2S

B FeS_2

C $FeSO_4$

D $FeSO_3$

E $Fe_2(SO_4)_3$

24 The pH of lemon juice is about 2.3. What is $[H^+]$ in lemon juice?

A 0.36 mol L^{-1}

B 0.83 mol L^{-1}

C 0.10 mol L^{-1}

D 5.0×10^{-3} mol L^{-1}

E 0.071 mol L^{-1}

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

$$2\ Al(s) + 6\ HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2(g)$$

A reaction mixture contains 0.500 mol HCl and 0.400 mol Al. Assuming the reaction goes to completion, how many moles of the excess reactant remain?

A 0.000 mol

B 0.100 mol

C 0.167 mol

D 0.233 mol

E 0.400 mol

26 What volume does 11 kg of carbon dioxide occupy at 0 °C and 101.3 kPa?

A 246 m^3

B 5.6×10^3 L

C 11 L

D 0.25 L

E 0.22 m^3

27 What is the ground state electron configuration of an isolated sulfur (S) atom?

A $1s^2\ 2s^2\ 2p^2\ 3s^2\ 3p^2\ 4s^2\ 3d^2\ 4p^2$

B $1s^2\ 2s^2\ 2p^6\ 3s^1\ 3p^3\ 3d^5$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

E $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3d^6$

28 What volume of 0.123 mol/L aqueous H_2SO_4 is needed to neutralize 40.0 mL of 0.175 mol/L aqueous NaOH? A balanced chemical equation for the reaction is given below.

$H_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(l)$

A 28.5 mL

B 56.9 mL

C 114 mL

D 80.0 mL

E 40.0 mL

29 Three successive elements, in order of increasing atomic number, have these first ionization energies:

1680 2080 494 kJ/mol

Which of following sets represents the three elements?

A N O F

B O F N

C Ne Na Mg

D F Ne Na

E Na Mg Al

30 Which of the following gases does not burn, does not support combustion, and has no effect on lime water, $Ca(OH)_2(aq)$?

A hydrogen, H_2

B oxygen, O_2

C carbon monoxide, CO

D nitrogen, N_2

E carbon dioxide, CO_2

31 Which of the following elements would you expect to be the most similar in chemical properties to element 20?

A element 19

B element 21

C element 18

D element 4

E element 38

32 A weather balloon filled with helium gas, He(*g*), has a volume of 2.00×10^3 m^3 at ground level where the atmospheric pressure is 1.000 atm and the temperature is 27 °C. After the balloon rises high above the earth to a point where the atmospheric pressure is 0.400 atm, its volume increases to 4.00×10^3 m^3. What is the temperature of the atmosphere at this altitude?

A −33 °C

B −22 °C

C −73 °C

D 22 °C

E 240 °C

33 In which of these compounds is the oxidation state of O the highest (i.e., the most positive)?

A F_2O

B O_2

C O_3

D H_2O_2

E H_2SO_4

34 The molar volumes of $C_2H_6(g)$ and $H_2(g)$, measured at 300 K and 10.0 atm, are 2.30 L and 2.51 L, respectively. Which of the following statements accounts for the observation that the molar volume of $C_2H_6(g)$ is smaller than that of $H_2(g)$?

A C_2H_6 molecules are larger than H_2 molecules.CO_2

B The intermolecular attractions in $C_2H_6(g)$ are weaker than they are in $H_2(g)$.

C The intermolecular attractions in $C_2H_6(g)$ are stronger than they are in $H_2(g)$.

D The average kinetic energy of H_2 molecules is greater than that of C_2H_6 molecules.

E The average kinetic energy of H_2 molecules is less than that of C_2H_6 molecules.

35 When aqueous sodium carbonate, Na_2CO_3, is treated with dilute hydrochloric acid, HCl, the products are sodium chloride, water and carbon dioxide gas. What is the **net ionic equation** for this reaction?

A $Na_2CO_3(aq) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + CO_2(g) + H_2O(l)$

B $CO_3^{2-}(aq) + 2\ HCl(aq) \rightarrow H_2O(l) + CO_2(g) + 2\ Cl^-(aq)$

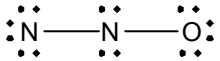
C $CO_3^{2-}(aq) + 2\ H^+(aq) \rightarrow H_2O(l) + CO_2(g)$

D $Na_2CO_3(s) + 2\ H^+(aq) \rightarrow 2\ Na^+(aq) + CO_2(g) + H_2O(l)$

E $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

36 Which of the following is the best Lewis structure (i.e., the best electron dot structure) for the N_2O molecule?

A



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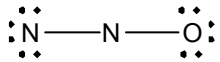

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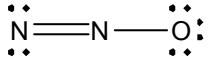

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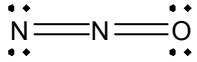
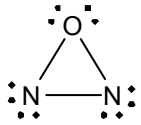


E



37 A 2.4917-g sample of a hydrate of cobalt (II) fluoride, $CoF_2 \cdot x\,H_2O$, was heated to drive off all of the water of hydration. The remaining solid weighed 1.4290 g. What is the formula of the hydrate?

A $CoF_2 \cdot H_2O$

B $CoF_2 \cdot 2H_2O$

C $CoF_2 \cdot 3H_2O$

D $CoF_2 \cdot 4H_2O$

E $CoF_2 \cdot 5H_2O$

38 How many isomers are there for C_4H_8? Consider both structural (i.e. constitutional) isomers and stereoisomers.

A one

B two

C three

D four

E more than four

39 Which of the following combinations reagents react to form an insoluble precipitate?

A $HNO_3(aq)$ and $Ca(OH)_2(aq)$

B $Zn(s)$ and $HCl(aq)$

C $Zn(s)$ and $Cu(NO_3)_2(aq)$

D $NaHCO_3(aq)$ and $NaOH(aq)$

E $Na_2CO_3(aq)$ and $CaCl_2(aq)$

40 Which of the following will occur if a 0.10 mol L^{-1} solution of acetic acid (CH_3COOH) is diluted to 0.010 mol L^{-1} at constant temperature?

A the pH will decrease

B the dissociation constant of CH_3COOH will increase

C the dissociation constant of CH_3COOH will decrease

D the hydrogen ion concentration will decrease to 0.010 mol L^{-1}

E the percentage ionization of CH_3COOH will increase

DATA SHEET
AVOGADRO EXAM 2009

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