University of
# Waterloo

# AVOGADRO EXAM 2008
## UNIVERSITY OF WATERLOO
## DEPARTMENT OF CHEMISTRY

**15 MAY 2008**                                            **TIME:  75 MINUTES**

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*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.*

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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.

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

# AVOGADRO EXAM 2008 - Answers

**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** $\alpha$-particle

    **B** $\beta$-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.

$$^{131}I \rightarrow \boxed{\text{?}} + {}^{0}_{-1}e$$

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** $1.58 \times 10^{24}$ g

   **B** $6.02 \times 10^{23}$ g

   **C** $6.36 \times 10^{23}$ g

   **D** 63.6 g

   **E** $1.58 \times 10^{23}$ g

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

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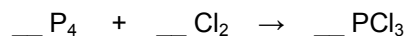
   **A** 12

   **\*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  $90^{\circ}$

B  $45^{\circ}$

C  $120^{\circ}$

*D  $109^{\circ}$

E  $180^{\circ}$

**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 $L^{-1}$ $H_2SO_4(aq)$ 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.

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

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  $NH_4Cl$

   *C  $K_2CO_3$

   D  $NaNO_3$

   E  $CuBr_2$

**30** Which of the following describes the process that produces $Fe(s)$ from $Fe_2O_3(s)$?

   A  combustion

   B  precipitation

   C  hydrolysis

   *D  reduction

   E  oxidation

**31** Which one of the following solutions will be the worst electrical conductor at $25^\circ$C?

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

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

C   $0.10$ mol $L^{-1}$ $CaSO_4$(aq)

*D   $0.10$ mol $L^{-1}$ $CH_3OH$(aq)

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

$$HSO_4^- + HCO_3^- \rightleftharpoons SO_4^{2-} + H_2CO_3$$

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°C = 273.15 K

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