

# 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.

- 1. Print your name here:
- Print your <u>school name</u> and <u>city</u> 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

- 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.
- Now answer the exam questions. Questions are <u>not</u> 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 atom has the most neutrons?
  - **A** <sup>18</sup><sub>9</sub>F
  - \***B** <sup>18</sup><sub>8</sub>O
  - **C**  ${}^{14}_{6}$  C
  - **D**  $^{15}_{7}$ N
  - **E** <sup>11</sup><sub>5</sub>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**  $\alpha$ -particle
  - **B**  $\beta$ -particle
  - **C** electron
  - **D** proton
  - \*E neutron
- 4 The formula of a compound is X<sub>2</sub>O. 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  $\frac{127}{53}$  I?

A State Parties

- **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<sup>2-</sup>, S<sup>2-</sup>, Se<sup>2-</sup>
  - C Mg, Al, Si
  - D Ca<sup>2+</sup>, Fe<sup>3+</sup>, Zn<sup>2+</sup>
  - \*E  $Cl^{-}$ , Ar, K<sup>+</sup>



- 9 Which of the following is an ionic solid?
  - **A** N<sub>2</sub>O
  - B HCI
  - \***C** LiCl
  - $\mathbf{D}$   $CO_2$
  - **E** CH<sub>4</sub>
- 10 What volume of CO<sub>2</sub> is produced when you burn exactly 1.0 litre of gaseous propane (C<sub>3</sub>H<sub>8</sub>) in the presence of excess oxygen in your backyard barbecue? Assume H<sub>2</sub>O and CO<sub>2</sub> 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 (<sup>210</sup>Po) is radioactive, extremely toxic, and it decays according to the chemical equation below. What is the missing product in the equation?

**Δ** <sup>214</sup>Po

- **B** <sup>212</sup>TI
- \***C** <sup>206</sup>Pb
- **D** <sup>214</sup>Rn
- E <sup>210</sup>Po
- 12 The bubbles in boiling water are mostly

<sup>210</sup>Po  $\rightarrow$  ? + <sup>4</sup><sub>2</sub>He

- A He
- \***B** H<sub>2</sub>O
- **C** CO<sub>2</sub>
- $\boldsymbol{D} \quad N_2$
- **E** O<sub>2</sub>

- **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<sub>3</sub>Y
  - **B** XY<sub>3</sub>
  - 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<sup>+</sup>] in your stomach after the meal?
  - \*A 1.66 x 10<sup>-2</sup> mol L<sup>-1</sup>
  - **B** 0.250 mol L<sup>-1</sup>
  - **C** 1.78 mol L<sup>-1</sup>
  - **D** 1.83 x 10<sup>-3</sup> mol L<sup>-1</sup>
  - E 6.03 x 10<sup>-2</sup> mol L<sup>-1</sup>
- **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<sub>2</sub>O, and AlCl<sub>3</sub>. What is the formula of aluminum oxide?
  - A Al<sub>2</sub>O
  - \***B** Al<sub>2</sub>O<sub>3</sub>
  - **C** Al<sub>3</sub>O
  - D AIO
  - E AIO<sub>3</sub>



- 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<sub>8</sub>H<sub>18</sub>), 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 x 10<sup>-4</sup> mol
  - E 1.1 x 10<sup>-3</sup> 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

$1  v   a = 1 \land 10  v  a$

- B 72 mol
- C 44 mol
- **D** 14.1 mol
- \*E 139 mol
- **19** Chlorine has two abundant stable isotopes, <sup>35</sup>Cl and <sup>37</sup>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 <u>not</u> a gas at 298 K?
  - A Ar
  - B He
  - \*C  $Br_2$
  - $\mathbf{D}$   $H_2$
  - **E** O<sub>2</sub>

- **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.

The bond angle is nearest to

- **A** 60°
- **B** 90°
- **C** 105°
- **D** 120°
- \***E** 180°
- **23** What volume of 0.100 mol L<sup>-1</sup> NaOH(*aq*) is required to neutralize 0.245 L of 0.200 mol L<sup>-1</sup> H<sub>3</sub>PO<sub>4</sub>(*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<sub>3</sub>OCH<sub>3</sub>)
  - B methane (CH<sub>4</sub>)
  - **C** hydrogen sulfide (H<sub>2</sub>S)
  - \*D ethanol (CH<sub>3</sub>CH<sub>2</sub>OH)
  - E formaldehyde (H<sub>2</sub>CO)



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

2 Al(s) + 6 HCl(aq)  $\rightarrow$  2 AlCl<sub>3</sub>(aq) + 3 H<sub>2</sub>(g)

How many grams of aluminum (27 g mol<sup>-1</sup>) 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**  $O(g) \rightarrow O^{2+}(g) + 2e^{-1}$
- **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?

Α	$293K+\frac{80.0}{40.0}$	
В	$20^{\circ}C \times \frac{80.0}{40.0}$	
*C	$293\text{K}\times\frac{80.0}{40.0}$	
D	$293\text{K}\times\frac{40.0}{80.0}$	
	40.0	

- **E**  $20^{\circ}C \times \frac{40.0}{80.0}$
- **29** Which drawing shows a pipet correctly filled for delivery?



- **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<sup>-1</sup> Na<sub>2</sub>SO<sub>4</sub>(*aq*)
  - **B** 0.10 mol  $L^{-1}$  NaCl(*aq*)
  - 0.10 mol L<sup>-1</sup> H<sub>2</sub>SO<sub>4</sub>(*aq*) С
  - 0.10 mol L<sup>-1</sup> HNO<sub>3</sub>(aq) D
  - **E** 0.10 mol L<sup>-1</sup> CsCl(*aq*)
- **32** What is the coefficient of O<sub>2</sub> when the following equation is balanced with the smallest whole-number coefficients?

 $Cr_2O_3 + KOH + O_2 \rightarrow K_2CrO_4 + H_2O$ 2 Α \***B** 3 4 С 5 D Е 6

- **33** What is the oxidation state of N in HNO<sub>2</sub>?
  - Α +5
  - \***B** +3
  - С +1
  - D -1
  - Ε -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
  - increases by a factor of  $\sqrt{2}$ Α
  - decreases by a factor of 2 В
  - \*C increases by a factor of 2
  - increases by a factor of 4 D
  - Ε 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?
  - Α group 1
  - В group 3

group 6

- mistakenly given as:
- D group 14

С

- This question was NOT marked. The electron configuration was [Xe] 6s<sup>2</sup> 5f<sup>14</sup> 6d<sup>10</sup> 6p<sup>4</sup>
- \*E group 16
- 36 How many moles of water are there in 1.80 L of H<sub>2</sub>O(I) at 1.00 atm and 298 K? The density of water is 1.00 g/mL at 1.00 atm and 298 K.
  - 1.00 mol Α
  - R 0.0736 mol
  - 55.6 mol С
  - \***D** 1.00 x 10<sup>2</sup> mol
  - Е 13.6 mol
- **37** The reaction  $2 \operatorname{Al}(s) + 6 \operatorname{HCl}(aq) \rightarrow 2 \operatorname{AlCl}_3(aq) + 3 \operatorname{H}_2(g)$ is an example of
  - A a precipitation reaction
  - an acid-base reaction В
  - a decomposition reaction С
  - \*D an oxidation-reduction reaction
  - E an isomerization reaction
- **38** If equal volumes of 0.10 mol L<sup>-1</sup> solutions of NaOH and HCI are mixed, what is the pH of the resulting solution at 298 K?
  - 1 Α
  - В 13
  - \***C** 7
  - D 1.3
  - E 12.7

**39** A calcium chloride solution was prepared by dissolving 11.00 g CaCl<sub>2</sub> in water to make 500 mL of solution. What is the correct way to report the concentration of this solution?

* <b>A</b> 0.1	.2 mol L <sup>-1</sup>	CaCl <sub>2</sub> , 110.98 g mol <sup>-1</sup>	
<b>B</b> 0.	.1982 mol L <sup>-1</sup>		
<ul><li>C 0.</li><li>D 0.</li><li>E 0.</li></ul>	198 mol L <sup>-1</sup> 2000 mol L <sup>-1</sup> 20 mol L <sup>-1</sup>	The number of significa ambiguous (i.e. we dor so we must assume the only to 1 significant figures concentration to 1 sign been recorded as 0.50 concentration as 0.198	ant figures in the volume is n't know if the zeros are significant), e worst: that the volume is known ure. Therefore, we report the ificant figure only. If the volume had 0 L, then we could have given the 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<sub>2</sub>
  - $C CH_3$
  - $\mathbf{D}$  CH<sub>4</sub>
  - $\textbf{E} \quad C_3H_4$

DATA SHEET **AVOGADRO EXAM 2007** 

### DETACH CAREFULLY

1																	18
1A																	8A
1																	2
н	2											13	14	15	16	17	He
1.008	2A	_										3A	4A	5A	6A	7A	4.003
3	4											5	6	7	8	9	10
Li	Be											В	С	Ν	0	F	Ne
6.941	9.012											10.81	12.01	14.01	16.00	19.00	20.18
11	12											13	14	15	16	17	18
Na	Mg	3	4	5	6	7	8	9	10	11	12	AI	Si	Р	S	CI	Ar
22.99	24.31	3B	4B	5B	6B	7B	←	8B	$\rightarrow$	1B	2B	26.98	28.09	30.97	32.07	35.45	39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
κ	Ca	Sc	Ti	v	Cr	Mn	Fe	Со	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
39.10	40.08	44.96	47.88	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.38	69.72	72.59	74.92	78.96	79.90	83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Мо	Тс	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Те	1	Хе
85.47	87.62	88.91	91.22	92.91	95.94	(98)	101.1	102.9	106.4	107.9	112.4	114.8	118.7	121.8	127.6	126.9	131.3
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ва	La	Hf	Та	w	Re	Os	Ir	Pt	Au	Hg	TI	Pb	Bi	Ро	At	Rn
132.9	137.3	138.9	178.5	180.9	183.9	186.2	190.2	192.2	195.1	197.0	200.6	204.4	207.2	209.0	(209)	(210)	(222)
87	88	89	104	105	106	107	108	109	110	111	112	113					
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub	Uut					
(223)	226	227.0															

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Но	Er	Tm	Yb	Lu
140.	140.9	144.2	(145)	150.4	152.00	157.3	158.9	162.5	164.9	167.3	168.9	173.0	175.0
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
232.	) 231.0	238.0	237.0	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(260)

**Conversion factors:** 

0°C = 273.15 K

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

#### **Constants:**

 $N_{\rm A}$  = 6.022 × 10<sup>23</sup> mol<sup>-1</sup>

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

- = 8.3145 kPa L K<sup>-1</sup> mol<sup>-1</sup>
- = 8.3145 J K<sup>-1</sup> mol<sup>-1</sup>

$$K_{\rm w} = 1.0 \times 10^{-14} \text{ (at 298 K)}$$

 $F = 96485 \text{ C mol}^{-1}$ 

**Equations:** PV = nRT  $k t_{1/2} = 0.693$   $pH = pK_a + log ([base]/[acid])$ 

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$